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Critical issues related to registration of space objects and transparency of space activities

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A B S T R A C T

The main purpose of the 1975 Registration Convention is to achieve transparency in space activities and this objective is motivated by the belief that a mandatory registration system would assist in the identification of space objects launched into outer space. This would also consequently contribute to the application and development of international law governing the exploration and use of outer space. States Parties to the Convention furnish the required information to the United Nations' Register of Space Objects. However, the furnished information is often so general that it may not be as helpful in creating transparency as had been hoped by the drafters of the Convention. While registration of civil satellites has been furnished with some general details, till today, none of the Parties have described the objects as having military functions despite the fact that a large number of such objects do perform military functions as well. In some cases, the best they have done is to indicate that the space objects are for their defense establishments. Moreover, the number of registrations of space objects is declining. This paper addresses the challenges posed by the non-registration of space objects. Particularly, the paper provides some data about the registration and non-registration of satellites and the States that have and have not complied with their legal obligations. It also analyses the specific requirements of the Convention, the reasons for non-registration, new challenges posed by the registration of small satellites and the on-orbit transfer of satellites. Finally, the paper provides some recommendations on how to enhance the registration of space objects, on the monitoring of the implementation of the Registration Convention and consequently how to achieve maximum transparency in space activities.

1. Introduction

The Convention on Registration of Objects Launched into Outer Space (the Convention) [1] was the fourth international space treaty that was drafted by the United Nations Committee on Peaceful Uses of Outer Space (UNCOPUOS). This treaty was adopted by consensus by the United Nations (UN) General Assembly as Resolution 3235 (XXIX) on 12 November 1974. As of early 2017, 63 States have ratified the Convention, while 4 States have signed and 3 international organizations have made declarations accepting the rights and obligations under the Convention [2].

The Registration Convention is an elaboration of two provisions of the 1967 Outer Space Treaty [3], which is the foundational and most adhered to international agreement that laid down fundamental principles for global governance of outer space and space activities. Firstly, Article V of the Outer Space Treaty requires States Parties to safely and promptly return astronauts in distress during an emergency landing to the State of registry of their space vehicle [4]. Secondly, Article VIII entitles and requires the State of registry of an object launched into outer space to "retain jurisdiction and control over such object, and over any personnel thereof" [5]. If such objects or their component parts are found beyond the limits of the State of registry, they must be returned to that State [6]. However, the Outer Space Treaty does not provide a detailed procedure and requirements for registration of space objects. Those lacunae were filled by the Registration Convention.

After 41 years of entry into force of the Registration Convention, it seems appropriate to objectively assess the efficacy of this international instrument which is important for global space governance, particularly from the perspective of its effectiveness in rapidly expanding space activities and space players. This paper examines the achievements of the objectives of the Convention since its coming into force. For this purpose, the paper provides some important and relevant data about the registration and non-registration of satellites and the States that have and have not complied with their legal obligations. It also analyses the specific requirements of the Convention, the reasons for non-registration, new challenges posed by the registration of small satellites and by the on-orbit transfer of satellites. Finally, it provides some recommendations on how to enhance the registration of space objects, on the monitoring of

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the implementation of the Registration Convention, and consequently how to achieve maximum transparency in space activities.

2. International obligations relating to the registration of space objects

2.1. Obligations pursuant the UN General Assembly resolution 1721 B (XVI)

It may be recalled that the requirement of the registration of space objects was actually initiated as early as 1961 by the UN General Assembly, in its unanimously adopted Resolution 1721 B (XVI) [7]. This Resolution calls upon States to "promptly" furnish information for the registration of their launchings of objects into orbit or beyond to the UN Secretary-General [8]. It also requires the Secretary-General to maintain a public registry of the information furnished by States [9]. The nature and scope of the required information are not specified. This requirement is applicable to all States, though has been superseded by the detailed obligations imposed by the Registration Convention upon the States Parties to the Convention. The rationale for the registration of space objects is not mentioned in the Resolution. However, given the global geopolitical tension during the Cold War, it can logically be assumed that the need for transparency of space activities would have been the main reason for international registration of space objects.

It is interesting to note that States have been frequently registering their space objects pursuant to this Resolution. The data collected by the beginning of 2017 show that since 1962 (a year after the adoption of the Resolution) 23 States (14 that have subsequently become parties to the Registration Convention and 9 still remain non-parties) [10] have sent on voluntary basis their registration notifications to the UN regarding their respective space objects launched [11]. The United Nations Office for Outer Space Affairs (UNOOSA) has, as of 1 April 2016, registered "nearly 6000 functional and non-functional space objects" under Resolution 1721B (XVI) [12]. Though the Resolution requires States that are launching objects into orbit or beyond to furnish information only for the registration of launchings, some States have been providing data about their space objects that had decayed and those that did not reach their orbits.

The information sent under Resolution 1721 B (XVI) is archived in the UN A/AC.105/INF document series rather than the ST/SG/SER.E series, which is used for States with registries.

In 1962, recognizing that the "establishment of [the UN] registry marks another step forward in the direction of open and orderly conduct of outer space activities" [13], the United States (US) became the first country to submit information regarding its 72 space objects under the UN Resolution [14]. It expressed the hope "that comparable information will be made available by others in accordance with resolution 1721 B (XVI), as the value of the registry will depend largely on the co-operation of all concerned" [15]. For the period from 1962 to 1976, the US habitually continued its practice as it forwarded information not only about 4000 launched space objects but also about 1200 objects that had decayed and brief mentions of about 50 objects that did not reach orbits [16]. This initiative and example of the US has been followed by, as noted above, other launching States (as well as those that procured the launches), like the Soviet Union/Russian Federation [17], France, Japan, India, Nigeria, Saudi Arabia, the United Kingdom, Venezuela, and so on. An important example, in this regard, is that of Luxembourg (which is not a Party to the Registration Convention), as it has registered its 116 space objects under the UN Resolution [18]. It is believed that there has been a consistent State practice of registration of space objects pursuant to the UN Resolution 1721 B (XVI), and the States have been doing so believing that it is their legal obligation to comply with the Resolution (*opinio juris*). Therefore, it is believed that the legal obligation to register space objects in accordance with the Resolution has evolved to become a part of customary international law, which ought to be respected by all space-faring States, irrespective of whether or not they are Parties to the Registration Convention.

2.2. Compliance with obligations under the Registration Convention

2.2.1. Objective and scope of the Registration Convention

The principal objective of the Registration Convention, as stated in its Preamble, is to establish and maintain a publicly accessible and mandatory central register of space objects by the Secretary-General of the United Nations in order to assist in the identification of space objects and to contribute to the application and development of international law governing the exploration and use of outer space [19]. In other words, the Convention aims at achieving transparency in space activities and fosters the effective application of international space law agreements, particularly the Outer Space Treaty, the Rescue and Return Agreement [20] and the Liability Convention [21]. The Registration Convention plays a crucial role in the international space governance, including the maintenance of peace and security. Therefore, full and comprehensive compliance with the Registration Convention by space-faring States is significant.

If a space object is not launched 'into earth orbit or beyond' it would not be required to be registered; e.g. an object sent only on a sub-orbital flight.

Article I of the Convention delineate its scope and application. The Convention requires the registration of a "space object", which is not fully defined in the Convention, except that it "includes component parts of a space object as well as its launch vehicle and parts thereof" [22]. The term is very broad. However, from the perspective of the Registration Convention it should be understood to mean any tangible human-made material or physical object or device, irrespective of its size, shape, composition and purpose (e.g. like a payload or satellite, a launch vehicle or rocket, an astronaut suit, oxygen tank and other life support equipment, etc.) that has been launched into Earth orbit or beyond. The term "space object" is broader in scope than ""satellites". All space objects, including their component parts as well as their launch vehicles and their parts, must be registered irrespective of their ownership, application or purposes, which could be scientific, technical, commercial, military or humanitarian. In practice, it may pose difficulty in determining which component part ought to be registered or otherwise.

Some States (such as the US and France) have interpreted "space object" to include non-functional objects, such as discarded rocket stages and debris, while others (e.g. Russia) consider only payloads. The language also does not make clear whether the verb "launched" includes additional objects created by separation or fragmentation at a later time. For the purpose of international transparency and security of space activities, it would seem that at least inert rocket stages should be registered so that they are not confused with dormant (and potentially hostile) payloads.

2.2.2. The obligation and responsibility to register a space object

The obligation and responsibility to register a space object, domestically and internationally, are placed only on the "launching State" of that space object. The Registration Convention, in line with the provisions of the Outer Space Treaty and the Liability Convention, defines the term "launching State" to mean: (i) a State which launches or procures the launching of a space object; and (ii) a State from whose territory or facility a space object is launched [23]. Obviously, there is a possibility of four launching States with respect to one space object, though in practice the number of concerned launching States could be higher than four. That might create problems in precisely determining which State(s) ought to register a particular space object.

All space activities of private companies are, from the international space law perspective, considered to be those of their States [24]. Therefore, to ensure that the State has knowledge of and oversight over all space activities, States are responsible for registering the space objects belonging to (procured or launched for or by) their non-governmental entities (private companies). The State under such responsibility could be determined on the basis of the generally accepted principle of international law, i.e. the State of incorporation of a private company [25]. Private companies are not entitled to directly register their space objects with the UN Secretary-General. In order to do so, they have to rely upon their respective State(s).

The international legal status of a launching State is determined through the application of appropriate treaties (e.g. the Outer Space Treaty, the Registration Convention, and the Liability Convention) and cannot be renounced unilaterally because of international obligations that flow from such a status. Unilateral renunciation of a State's international obligation might be considered "an internationally wrongful act" on the part of that State, which is obliged to fulfill its international obligations in good faith [26]. On the other hand, there seems to be no prohibition on the unilateral assumption of the status of a launching State, if not successfully contested by other State(s). A launching State, on whose registry a space object is carried, is considered to be the 'State of registry' for that space object [27]. Since a State can undertake to be a launching State, it can also eventually become the State of registry of a space object once that object is purchased by a public entity or private company of the State.

Since it is desired that there should be maximum transparency in space activities, Article VII of the Registration Convention makes provision for its possible application by any international intergovernmental organization (IGO), which conducts space activities. Normally, only States are considered to be subjects of international law, but recognition of intergovernmental organizations as important players at international level, including the space field, has emerged especially after the Second World War. Such organizations possess international personality, different from that of their constituent Member States, and can be entitled to rights and subject to obligations as specified under applicable treaties [28]. In order to become a party to the Registration Convention, an intergovernmental organization must make a declaration accepting the rights and obligations provided for in this Convention [29]. Secondly, this declaration can be made only if a majority of the States members of the organization are States Parties to the Registration Convention and to the Outer Space Treaty, and it is the obligation of such States to ensure that the organization makes such a declaration [30]. Having made the required declarations, the European Organization for the Exploitation of Meteorological Satellites, the European Space Agency and the European Telecommunications Satellite Organization are obliged to set up their respective registries of space objects and to inform the UN about their space objects launched into Earth orbit and beyond.

It should be noted that obligation to register space objects is imposed only on the IGO that has made a declaration of acceptance of rights and obligations under the Registration Convention and States Parties to the Registration Convention are obligated to ensure the issuance of such declaration only if they form a majority of States Parties both to the Registration Convention and to the Outer Space Treaty. However, what happens if the IGO does not make the required declaration? The implication, presumably, is that the IGO is not considered a "State of registry" for the purposes of the Convention. If the members of the IGO form a majority of States Parties both to the Registration Convention and to the Outer Space Treaty, they would be considered in violation of their obligation under article VII(2) of the Registration Convention. What actually happens is that the other States involved in the organization wash their hands of the matter. Notably, 28 satellites from the former international organization INTELSAT launched between 1981 and 1998 are unregistered. INTELSAT did not establish a registry under Articles VII since it never made a declaration of acceptance of rights and obligations under the Registration Convention, and so Articles I, II and VII of the Registration Convention would suggest to some that the organization's host country - the United States - was and is responsible for registering at least 15 of these satellites and coordinating with France to register the remaining 13 satellites launched by Ariane, a French entity. The US appears to read the Convention to mean that as an IGO, INTELSAT had the sole responsibility and it is not the responsibility of no one else. INTELSAT's initial operations were carried out by the US company COMSAT, and prior to 1981 all INTELSAT satellites were indeed registered by the US. The successor organization to INTELSAT is Intelsat Ltd., the satellites of which are currently being registered by the US, so it is difficult to see who else is retrospectively responsible. Most of the satellites in question are now defunct, but all remain in orbit.

A similar situation exists with the London-based INMARSAT, which was also later privatized. In 2002, the UK denied that it was the launching State or State of registry for INMARSAT satellites [31]. Since INMARSAT had no registry, that leaves the launch vehicle providers (US, Russia and France) as the only potential launching States for the 9 INMARSAT satellites launched between 1990 and 1998. The UK's denial of being a launching State and State of registry is questionable as the private INMARSAT is a British company, headquartered in London, UK, which should be assumed to have 'procured' the INMARSAT satellites from the now dissolved international organization INMARSAT. Both under the Outer Space Treaty and the Liability Convention, the general rule is - 'once a launching State is always a launching State'. ESA and EUMETSAT both have active registries. Unfortunately, when the Meteosat satellites were transferred from ESA to EUMETSAT, registration of a launch (Meteosat-6) which occurred during the transition was omitted.

2.2.3. Obligation to establish national registry of space objects, to register domestically, and to inform the UN

With respect to national registration of space objects, Article II of the Registration Convention imposes three obligations on each State Party that is a launching State, i.e. it undertakes:

(a) to establish and maintain an appropriate national registry of space objects;
(b) to record in the registry its space objects that have been launched into Earth orbit or beyond; and
(c) to inform the UN Secretary-General of the establishment of such a registry [32].

Such national action is presumed to be taken in accordance with the applicable national laws, policies and administrative procedures. They also establish requirements and procedures for private companies to supply the concerned governmental office (keeper of the national registry) with the required information about their launched space objects. Such requirements and procedures are generally imposed through applicable licensing processes. The nature and scope of the information to be entered as well as the timing of recording in the national registry are left to the discretion of each State, though it would be logical that they coincide, as a bare minimum, with the requirements for international registration under Article IV of the Registration Convention.

In the years since adoption of the Registration Convention, many spacefaring States have provided at least some data under its provisions with respect to the setting up of national registries of space objects. While Canada was the first State to send its notification of its national registry [33], the most recent notification is of Austria [34]. However, compliance with the Convention has not been uniform. As of early 2017, 33 States [35] and two international organizations (ESA and EUMETSAT) have sent such notifications [36]. Establishment of these registries, when they occur, often comes long after the first space launch of that State or organization, and the formal notification can be even later. For example, the People's Republic of China, a launching State at the time of the 1975 Convention, declared that it established its registry in 2001 but notified the UN only in 2005 [37]. Similarly, Austria notified the UN on 30 January 2017 that it has established its national registry of objects launched into outer space on 25 August 2015 [38], while it had already sent its notification in accordance with article IV of the Registration Convention on 13 May 2013 concerning its space objects BRITE-A TUGSAT-1 which was launched on 25 February 2013 [39]. The United Kingdom started sending information referring to its registry and to Article II in 1985 [40] but only remembered to send a formal Article II notification of the registry itself in 2015 [41]. Sweden's Article II notification came as a trailing paragraph to an Article IV submission in a document furnished for information of registration of space objects on 4 June 1986 [42], however is not found on the UNOOSA's list of notification documents.

Although in recent years, notifications have included specific contact addresses, the content of these national registries is rarely directly accessible to outsiders. Belgium is to be commended for providing a web link to theirs [43], the Netherlands also has a web-accessible registry [44], and a version of the US registry is available at the website of the US State Department [45], although it is not clear if its URL was notified to the UN.

Even States which have not established national registries under Article II(1) have often nevertheless sent registration information on their satellites to the UN. There are a total of 45 States Parties to the Registration that have sent their Article IV notifications, while only Article II - notified registries have been submitted by 33 States. It is estimated that about half of the notifying States sent their first registration information 4 or more years prior to the notification of the registry under Article II(1).

2.2.4. *Joint responsibility to register*

There is a possibility of multiple launching States with respect to a single space object. In the case when there are two or more launching States, they are jointly obliged to determine which one of them should register such an object [46]. In making such a determination, all the concerned States should bear in mind the provisions of Article VIII of the Outer Space Treaty, according to which the State of registry of a launched space object has the right and is obliged to "retain jurisdiction and control over such object". All the concerned launching States may conclude appropriate agreements related to jurisdiction and control over the space object [47]. This flexibility is particularly important in cases of the on-orbit transfer of space objects. As noted earlier, the concerned launching States may agree to determine which one of them would be a State of registry, and consequently, would retain jurisdiction and control over the transferred space object. However, no one can renounce their status a launching State.

Article II (2) provides that if one State launches another State's satellite, they should sort out amongst themselves which of the two States should register the satellite as the 'launching State' to be the State of registry for that satellite. In practice, it is almost always the owner rather than the launch vehicle provider which registers the satellite. However, often confusion reigns and either both parties register the satellite or neither party takes responsibility and the satellite remains unregistered. The essential role of the rocket in getting the satellite to orbit suggests that in the event of dispute, the launch vehicle provider should have responsibility, but the Convention makes no such provision.

Some case studies of the confusion that has or will ensue(d):

(a) Protostar 1 was launched in 2008 by France and was owned by the US subsidiary of a Bermuda-based company. Of the three States, none has registered the satellite.
(b) Ariane launched the BSAT-2b satellite into the wrong orbit in 2001; BSAT-2b was to be a Japanese satellite but the contract was for on-orbit delivery, and it remained the property of the US manufacturer - but US registration officials appear not to have received the memo.
(c) The unregistered Astra 1K satellite was launched by Russia in 2002 into an incorrect orbit; the satellite was to be owned by the Luxembourg-based SES telecommunications company, however, depending on the terms of the launch contract, the satellite may still be under the responsibility of the French-based manufacturer.
(d) The Article IV registration documents from the Russian Federation typically add information about payloads launched for foreign customers in footnotes, and such footnotes are not generally understood to constitute registration of the satellite. Zarya, the US-owned module of the International Space Station launched in 1998, was Russian-built and -launched, and was noted by Russia as under "American registration", however it is omitted from the relevant US documents.
(e) The US registers most of its orbiting rocket stages and debris, but does not mention the foreign payloads. Thus, for launch 2006-012, a Centaur rocket is registered but there is no mention of the Luxembourg-registered payload. For Sea Launch missions, however, neither Russia (the launch vehicle integrator) nor the US (the launch services provider) noted the launches. The unregistered Telstar 18 satellite, owned by the US company Loral, was orbited by a 2004 Sea Launch mission and fell through the cracks in the process.

2.2.5. *Obligation to inform the UN for international registration*

The need for international transparency is being met by obliging the State of registry to furnish, to the Secretary-General of the United Nations, the following information concerning each of its space object:

(a) Name of launching State or States;
(b) An appropriate designator of the space object or its registration number;
(c) Date and territory or location of launch;
(d) Basic orbital parameters, including:
   (i) Nodal period,
   (ii) Inclination,
   (iii) Apogee,
   (iv) Perigee;
(e) General function of the space object [48].

It may be noted that nature and scope of the above required information have essentially been based on the practice of several States that provided space object data to the UN under Resolution 1721 B (XVI).

The required information needs to be submitted only *post facto*, but "as soon as practicable" which appears to be different from the requirement under Resolution 1721 B (XVI). Under the Resolution, information should be "promptly" communicated to the UN [49]. As we discuss below, some States have used the wording "as soon as practicable" to delay the required communications by years. The wording "as soon as practicable" appears to be based on the communication and monitoring technologies as well as administrative procedures of the 1970s. Given the enormous expansion of and profound increase in the efficiency of technologies and procedures in the 21st Century, this wording should be understood to mean either "promptly" or "as soon as possible". The traditional understanding of "as soon as practicable" will create problems in the case of registering small satellites, especially those that will be in orbit for a very limited period of time.

When submitting information about the launched space object, the State of registry is obliged to communicate the marked designator or registration number of the space object [50]. Each State of registry is further obliged to notify the UN Secretary-General about their already registered space objects that are no longer in Earth orbit (i.e. decayed) [51]. However, such information needs to be transmitted only "to the greatest extent feasible and as soon as practicable" [52]. No such information is required about the space objects that have gone beyond the Earth orbit and decayed. Each State of registry may voluntarily, when it likes, submit to the UN Secretary-General with additional information concerning its nationally registered space object(s) [53].

Article IV (1), the core of the Convention, also includes the phrase "as soon as practicable". If a satellite is registered at all, this is usually done within one to two years of launch, although some 140 have been registered after a 10 year or longer delay. Many of these late registrations have occurred since around 2003, following successful efforts by the UN and Member States to improve the process.

The most recent available submission from the United States is dated as having been submitted 7 months after the last launch date included in it. For Russian Federation, April 2014 data were submitted in July and published by the UN in November, but their data for previously missing months in 2011 were only submitted in August 2014. Most other States are at least as bad. The combination of late and infrequent submission, and long delays within the UN system before public accessibility, must be seen as seriously compromising the effectiveness of the Convention. In the era of the Internet, "as soon as practicable" should be a matter of hours or days, not months or years.

By comparing the US space surveillance catalogue with published information and astronomical observations of satellites, a high quality historical list of satellite payloads launched between October 1957 and December 2014 has been assembled. As of July 2017 the UNOOSA public pages do not include sufficient registration documents for a useful analysis of the 2015–2017 launches; of 226 payloads launched in 2015, 221 payloads in 2016, and 151 payloads to date in 2017, only 35%, 15% and 0% respectively for these years had been registered.

Because of this, rather different results emerge using different time-spans. For example:

With a December 2014 cutoff, there were:
7113 payloads
6728 payloads registered by Jul 2017
94.6% registered by Jul 2017
However, if we adopt an April 2016 cutoff, we get slightly different figures; i.e.
7413 payloads (functional space objects)
6774 registered by Apr 2016 (91%)
6812 registered by Jul 2017 (92%)

The reason we chose the December 2014 cutoff is exactly because of this issue of delay in registering space objects. The difference between 92% and 94.6% is that many States are dilatory. Therefore, in our list of unregistered satellites we only project ones' that are more than 2 years late. If we move the goalpost to 2016 of course there are several hundred more space objects that haven't been registered yet, but we can hope that they will be registered by 2018. We distinguish between the usual slow registration by many States and those space objects that don't get registered ever (or take perhaps a decade to do so), and in this paper, we focus on the latter.

Comparison of the 7113 payloads in the 2014 list with 6728 payloads registered with the UN shows that 94.6% of the payloads have been registered. Of the 385 unregistered payloads, 59 were launched in 2014 and illustrate the slow pace of compliance rather than lack of it. We have assigned probable launching States to the remaining 326 unregistered payloads based on satellite ownership. 114 of these satellites are owned by the United States, 34 by China, and 27 by Russia (including the former Soviet Union). For these 326 payloads, we have also attempted to assign a probable reason for the lack of registration, grouped together with cases identified by a two-letter code as shown in Table 1. This paper has already made available the full dataset of the 326 payloads with the case code assigned to each [54]. Fig. 1 shows the launch rate of satellites per decade for the US, the USSR/Russia and other nations, indicating registered and unregistered satellites.

[Note added in proof: As of Dec 2017 the UN OOSA added up-to-date US,Russian and Chinese registration data to their public database. Unfortunately this does not yet include the actual registration documents with the orbital information, but we can update the fraction of registrations. For 7575 payloads launched to end 2016, 7106 (93.8 percent) have now been registered, leaving 469 unregistered payloads (60 of which are from 2016 launches). Registration patterns have not greatly changed, except that many (31 so far) of the small satellites now being launched by China are unregistered.]

Article IV(1) also specifies mandatory information to be supplied including the "general function of the space object" and some orbital parameters (apogee, perigee, inclination) which are sufficient to define the shape of the orbit but not to predict the exact location of the satellite.

Table 1
Reasons for lack of registration (Satellites launched to end 2014 as of early 2017).

A	**Considered out of scope by launching state**		71
AA	US satellites reentered prior to Res.1721B (Early USSR satellites were retroactively registered)	32	
AB	Instrument packages or subsatellites not considered as full payloads	39	
B	**Probable deliberate omission:**		17
BA	Soviet unacknowledged planetary launch failures in Earth orbit.	6	
BB	Soviet space weapons tests (1966)	2	
BC	Shanghai-built payloads omitted from Chinese retrospective registration	6	
BD	Rumoured highly secret US satellite deliberately uncataloged (PROWLER 1990-097E) (Molczan T, http://www.satobs.org/prowler.html)	1	
BE	Chinese military satellite (Kuaizhou-1)	1	
BF	US classified maneuvering spacecraft deliberately cataloged as debris (2012-048P) and not registered. 4 others in same series registered, but only as debris.	1	
C	**Accidental omission:**		71
CA	Satellites failed soon after launch, overlooked by launching state	6	
CB	Deep space objects overlooked (US, Japan, ESA)	8	
CC	Omitted/lost Soviet registration document (Jul–Aug 1970)	11	
CD	US satellite launched on foreign rocket, omitted in error (Iridium 33)	1	
CE	NATO satellites omitted in error - 6 of 8 were registered by US, 2 not	2	
CF	US military satellites omitted in error? (1983-60C, Nova 2, ODERACS 2F, ORSES)	4	
CG	Short-lived satellites omitted in error (STS-44, SEDS-1, STS-66)	3	
CH	Chinese small satellites (NX1, BX-1, ZP, FN, XY, TT-1)	6	
CJ	Chinese large satellites omitted in error (Zhongwei-1, SJ8, Shenzhou 9, 10)	4	
CK	US satellite launched on Sea Launch, omitted in error (Telstar 18)	1	
CL	Miscellaneous satellites omitted in error for unknown reasons US (Nanosail-D2, Fastrac-2), Germany (AMSAT OSCAR 13), Saudi Arabia (Badr 4), Spain (Spainsat), Anik G1 (Canada), Turkey (ITUPSat-1, Turksat-3USat), Indonesia (Palapa D, Telkom 3), South Korea (OSSI)	11	
CM	US forgot to register all Sep 2013 launches	8	
CN	ESA forgot to register all 2011–2012 launches	6	
D	**Turf wars:**		51
DA	IGO (INTELSAT and INMARSAT) satellites ignored by US and UK.	36	
DB	lost in transition between 2 IGOs (Meteosat-6, ESA/EUMETSAT)	1	
DC	lost in Hong Kong transition between UK and China (Asiasat 3)	1	
DD	Joint ownership by multiple government space agencies (SARAL)	1	
DE	globalization confusion (LMI-1 owned by Lockheed subsids in US, UK; Latinsat owned by US company and not its Argentine subsidiary; MBSAT jointly owned by Japanese and S Korean companies; Protostar, SES-3, IS-23)	8	
DF	remained property of manufacturer after launch failure? (BSAT-2b, Arabsat 4A)	2	
DG	New Skies satellites ownership transfer from US to Netherlands upon successful launch by France.	2	
E	**Non participation in convention:**		55
EA	Launched after Res. 1721B but prior to state beginning registrations	22	
EB	State has not registered any of its satellites (Taiwan, Vietnam, Singapore, Iran, Mauritius, Switzerland, Portugal, Morroco, Columbia, Romania, Ecuador, Estonia)	33	
F	**Intermittent participation - no known reason for omission:**		22
FA	Italy 7, Canada 3, Denmark 3, Netherlands 4, Brazil 2 (Dove-1, SCD-2), Argentina 2 (Pehuensat, LO-74), Israel 1 (Ofeq-2)	22	
G	**Dilatory registration - no recent submission from launching state:**		36
GA	Israel - last sub in 1995 (registered 2 sats in 1998 and 1995, no others)	12	
	Egypt - last sub in 2008	1	
	Saudi Arabia - last sub in 2009	4	
	Spain - last sub in 2010	5	
	South Africa - last sub in 2013	1	
	USA - last sub in 2014 for 2013 data	13	

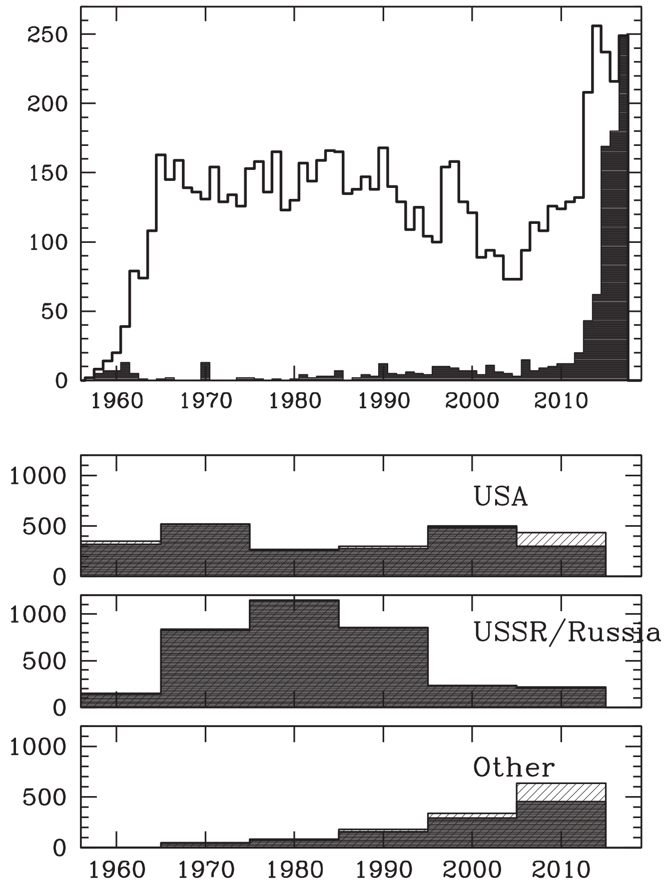


Fig. 1. (a) Total satellites launched each year. Black line: satellites registered prior to Apr 2016. Shaded: satellites which had not been registered by Apr 2016. (b) Satellites launched each decade by USA, USSR/Russia, and other States. Shaded areas indicate satellites not registered by early 2017.

The "general function" requirement is the most abused aspect of the Convention, as military and intelligence satellites are rarely acknowledged as such. In particular, military satellites are inadequately reported or, more often than not, they are not reported at all. For example, a US military photographic reconnaissance satellite launched on 28 August 2013 was reported to the UN with the inadequate description of its function as "[s]pacecraft engaged in practical applications and uses of space technology such as weather or communications" [55].

The Soviet Union used the phrase "Investigation of the upper atmosphere and outer space" for its military satellites, although the Russian Federation has moved to the more honest description as - "Intended for assignments on behalf of the Ministry of Defense of the Russian Federation", albeit without further details. For example, in 2011 Russia informed the UN that its Meridian satellite (launched on 2 November 2010) is "[i]ntended for assignments on behalf of the Ministry of Defence of the Russian Federation" [56].

This is unlike China, which has described its military reconnaissance satellite, Yaogan 19 (launched on 20 November 2013), just as "remote sensing" satellite without any details [57]. The United States describes its intelligence-gathering satellites with the bare-faced prevarication "Spacecraft engaged in practical applications of space technology such as weather or communications". In contrast, France openly reported its Elisa electronic intelligence satellites as "Microsatellite d'ecoute" [58]. Exceptionally, a series of five United States secret satellites which have been observed to maneuver have been misleadingly catalogued as debris [59]; one of the five (2012-048P) was not registered with the UN, and one (2005-004C) did not have its orbital parameters registered. The opposite error occurred with 2004-025B, which was inadvertently registered with the name Celestis 4 [60]. In fact, the object was an inert rocket stage (correctly given as the stated purpose) and the intended attached Celestis payload had been removed before launch.

The orbital parameters of the satellite are very helpful in confirming that the object described is indeed the one being tracked. From the point of view of international transparency it also gives some indication of the suitability of the satellite for various missions and the probability that it will pose a collision risk for other spacecraft. In fact, orbits are omitted for some short-lived United States payloads (civilian and military) which re-entered during the reporting period, which does not seem consistent with the Convention. Many States omit the specified data for geostationary satellites where the approximate parameters are understood and only a longitude is provided instead. Nevertheless, orbital parameters were provided as required for 92% (6,041) of the 6586 registered satellites. Of the remaining 545 satellites, 156 were in hyperbolic (escape) or deep space orbits; 81 were non-US and non-Russian satellites in geostationary orbit; 237 are US satellites, 45 are Russian/Soviet-owned, and 26 satellites from other nations had their orbital data omitted for no known reason (see Fig. 2).

Fig. 3 shows the distribution of orbital heights (average of apogee and perigee) for all satellites. Data are from the registration documents where provided, otherwise from public US tracking data or observations by amateur astronomers.

Article IV(1) does not specify the epoch at which the orbital parameters should apply and this provides a loophole for evasion of responsibilities. For satellites 2007-054A and B (USA 197 and its Delta 4 rocket stage) an orbit of 918 × 36,319 km is given in a US registration document [61]. The Delta 4 vehicle was indeed briefly in this orbit, with the USA 197 satellite still attached, but by the time when it deployed the satellite a few hours later and they became two separate objects and were in a quite different orbit. Representing the elliptical ascent orbit as the orbit of the USA 197 payload for the purposes of the Registration Convention is misleading, but this has been done as of standard practice for classified US payloads. The secret US military satellite USA 72 was registered with a 24 year delay and without the required orbital data. Other States do not seem to have tricked the system in this way.

For most registered satellites, the orbital parameters provided in the registration agree very well with published US tracking data and with data in other sources. There are occasional outright mistakes in the orbital parameters – the values for several US military satellites, (e.g. 1978-93A) [62] appear to be in nautical miles instead of the claimed kilometres, or (e.g. 1978-38A) [63], the compilers have forgotten to subtract the radius of the Earth. These appear to be due to carelessness in combining data from a different (classified) source with the information for unclassified satellites.

The requirement of furnishing information about the "general function of the space object" is not an approval for States to conceal the real,

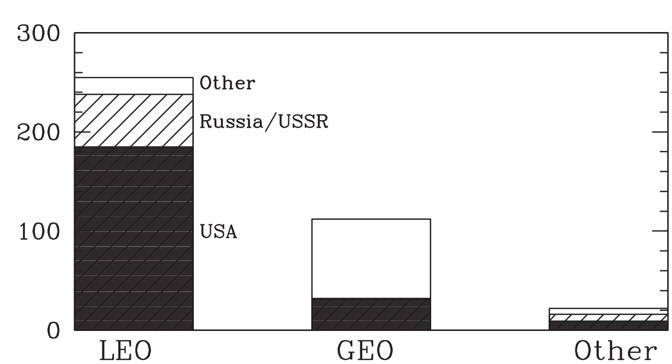


Fig. 2. Registered satellites with specified orbital parameters not provided, versus orbit type (Low Earth Orbit: LEO; Geostationary Earth Orbit: GEO; and other, mostly elliptical orbit). US figures in solid black, Russia/USSR shaded, and other in white.Note the large number of non-US/Russian GEO satellites with no orbit parameters. As mentioned in the text, this is not as significant as for LEO satellites since there is not much variation in GEO orbit parameters.

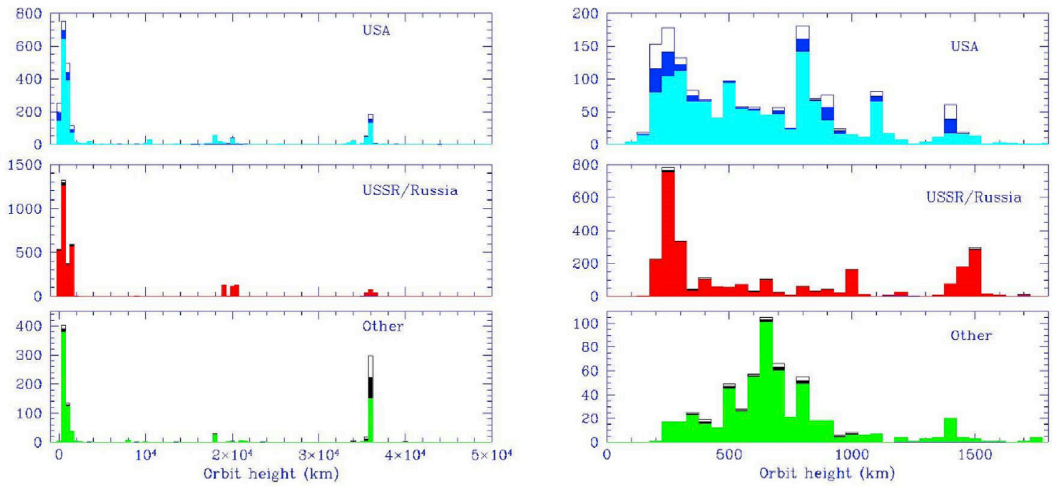


Fig. 3. Number of satellites versus orbital average height. Registered satellites in Low Earth Orbit (LEO) with specified orbital parameters provided (light color); registered but orbit not provided (dark color); unregistered (white). Left figure gives orbital range from Earth surface to above GEO; right figure gives details of distribution at low (LEO) altitudes. Note different y axis scales for each panel; also note relatively high proportion of lowest- orbit US satellites without orbital parameters. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

actual, or main purpose and function of the space object. States have often provided very vague or sometimes misleading information, which may conceal or obfuscate the real, actual or main purpose of the space object. The determination of "general function" must not be left to a State's subjective judgement and should be based upon objective international standards and criteria.

The function or responsibility of the UN Secretary-General appears simply to maintain (create and update) an international register of space objects by recording the information as furnished by the notifying State(s) in accordance with Article IV. In addition, the Secretary-General is required to ensure "full and open access to the information in this Register" [64]. These functions seem to be purely administrative and bureaucratic in nature and scope, and do not suggest any discretionary authority of the UN to examine the accuracy or question the inaccuracy of the information supplied by the State Parties to the Registration Convention. For example, the Democratic People's Republic of Korea acceded to the Registration Convention on 10 March 2009, and on 22 January 2013 it informed the UN about its space object (KWANG-MYONGSONG 3-2, an Earth-observation satellite) which it launched on 12 December 2012 from its Sohae Space Centre "for surveying crops, forest resources and natural disasters" [65]. The UN Secretary-General seems to have registered the information as supplied by the Democratic People's Republic of Korea (DPRK) without any further inquiry. Could the validity of such registration be questioned by the Republic of Korea (or any other States) alleging that the launch of 12 December 2012 was in violation of the UN Security Council Resolutions 1718 (2006) and 1874 (2009)? [66].

It is doubtful. There is no question that a satellite was indeed orbited by the DPRK, and in the interest of transparency it should therefore be registered. The requirement to register does not imply that the act of registration is a sufficient condition for the launch to be a legal act. However, registration-related disputes in the future cannot be ruled out as space commercialization expands and on-orbit transfers of space objects increase. It may be noted here that there is no provision in the Registration Convention for settling registration-related disputes. Even so, several generally available peaceful means for dispute resolution can be relied upon. One of the recent space related dispute settlement mechanisms is the Optional Rules for Arbitration of Disputes Relating to Outer Space Activities adopted in 2011 by the Permanent Court of Arbitration based in The Hague [67]. Though these Rules have not yet been used by anyone, yet both the States and private companies do have the option of employing them for settling their space-related activities, including the registration of space objects.

2.2.6. On-orbit transfers and responsibility to register

In case of a change in the ownership of a satellite system, its international registration would also be needed to be changed by subsequently notifying the UN under the Registration Convention. The UK effected such a change when it notified the UN that AsiaSat 1, Apstar 1, and Apstar 1A satellites were transferred from the UK register to that of China (the PRC) as sovereignty over Hong Kong returned to China. The UK informed the UN to amend the Register of Space Objects. The notification stated:

> With effect from 1 July 1997, the space objects mentioned (i.e. AsiaSat 1, Apstar 1, and Apstar 1A) above ceased to be carried on the Register of Space Objects of the United Kingdom. Therefore, on that date the United Kingdom ceased to be the State of registry of those space objects for the purposes of the Registration Convention and Article VIII of the [Outer Space Treaty]. Please amend accordingly the Register of Space Objects maintained by the Secretary General in accordance with article III of the Registration Convention [68].

Using similar wording, the PRC has notified to the UN for registration of these three satellites in its name [69]. It may be noted that China was a launching State of these satellites.

There have been several other examples of such on-orbit transfers, including the 1996 on-orbit sale of the BSB-1A. The satellite was launched from Cape Canaveral, US, in 1989 by its owner/operator the British Satellite Broadcasting Ltd. (UK), and ownership was later transferred to a company of Sweden, which was not a launching State of this satellite [70]. Under the Registration Convention, only a launching State can register a space object [71]. Thus in this case, Sweden may be assumed to have taken-up the status of the launching State of the satellite acquired from the UK.

Due to the expanding globalization of space commerce and changing demand and supply patterns for space services globally, on-orbit sales of space objects can be expected to increase. Consequential change in international registrations with the UN might go hassle-free, though there remains a possibility of difficulties and disputes over the issue of the responsibility for re-registration with the UN.

For example, two satellites, NSS6 and NSS7, which were launched from French territory, were delivered-in-orbit on April 2002 and December 2002 to New Skies Satellites, which is incorporated in Netherlands. The Netherlands acknowledged responsibility for the operation of certain satellites (NSS6 and NSS7) under Article VI of the Outer Space Treaty [72] but denied that it had any responsibility to register the satellites under the Registration Convention, since the satellites were delivered on orbit to the Dutch-based company which bought them. Several years later, the Netherlands reported the satellites as being under its national registry under Article XI of the Outer Space Treaty [73] however made a point of noting that the satellite was not registered with the UN [74]. The fact of the matter is that Netherlands-based New Skies Satellites N.V. procured the satellites and their launch from Lockheed Martin and Arianespace, and subsequently issued press releases at the launch describing the satellite as theirs. Regardless of the delivery terms of the contract, this fact, as Lee pointed out, would seem to make the Netherlands one of the launching States under Article I of the Registration Convention [75].

Both the US and the UK have without comment omitted to register the SES-3 satellite launched in 2011. At the time of launch, the satellite was owned by a UK-based subsidiary of SES, and once in operation it was transferred to a US-based subsidiary of the same company.

There is currently no requirement for a State acquiring on-orbit assets from another State to verify that those assets have been registered, and no requirement for reporting the change of ownership of an operating space object from one State to another. In light of this, the concept of the 'Launching State' was reviewed by the UN in 2002 [76], and in 2005 the UN General Assembly adopted a resolution [77] which underscores the challenges of on-orbit sales but does not make specific changes to the registration process.

2.3. Obligation to assist in the identification of a space object

Presumably to help identification in the case of re-entry (or on-orbit inspection), States are expected to mark their space objects with the designators or registration numbers and to inform them to the UN [78]. The Member States of the UN that negotiated the Registration Convention recognized the necessity of identification of any space object that would cause damage or which might be of a "hazardous or deleterious nature" [79]. It was understood that numerous States might not have the technical capability to identify such a space object and the application of the provisions of this Convention might not be helpful in this regard either. Therefore, an important provision was added in the Registration Convention that imposes additional obligation on States Parties, including in particular States possessing space monitoring and tracking facilities, to assist the injured State in the identification of the object that caused the injury [80]. However, the requested assistance is to be provided under "equitable and reasonable conditions" and subject to agreement between the States Parties concerned.

2.4. Challenge of the registration of small satellites

There has been a significant increase in the launch of small satellites (micro-, nano-, pico-, cube-, PocketQub, and femto sats), which are as small as 5 cm in size and weigh as little as 0.2 kg. There is no internationally agreed upon specific definition of 'small satellite.' This term undoubtedly indicates a space object as understood within the scope of the Registration Convention, which applies to small satellites in the same way as it does to big satellites. Small satellites have been or are being designed for research and technological development. More importantly, their operational use is expected to increase exponentially for several commercial purposes (e.g. Earth observation, communications, high-speed data connectivity, education, etc.) and military applications. Several governments, private companies and educational institutions around the world are actively planning the construction and launch of various types of small satellites. There have been several estimates about the number and the economic value of such satellites. For example, While SpaceWorks believes that "as many as 3000 nano/microsatellites will require a launch from 2016 through 2022," [81] Euroconsult forecasts the launch of more than 3600 smallsats by 2026 with their total market value of approximately $22 billion [82]. In addition to the serious issue of the availability of appropriate radio frequencies and their registration with the International Telecommunication Union, small satellites will pose a significant challenge for their registration with the UN [83], particularly because some of them will be in orbit for a limited period of time. They might possibly not even be registered in the respective national registries, especially in those States which do not have appropriate regulatory and administrative provisions for this purpose. This challenge has been recognized both by the UNOOSA and the International Telecommunication Union, which have produced a "guidance document to assist small satellite developers and operators with space object registration and frequency management" [84] without making or proposing any changes in the procedures required for registration with these two international institutions.

2.5. Objective of full international transparency

Article III of the Registration Convention promises the UN register would to be "full and open access" source. However, there is no mention of the timeliness or transparency of process, and no commitment that adequate resources will be made available satisfy the requirements of this article. For many years access to a UN repository library was the only avenue to inspect the data. An internal database was created by the UN in the early 1990s, leading to a review of the registrations by R. Wickramatunga [85], who reached some of the same conclusions and recommendations we find here.

Recently, the UNOOSA has created a web-based *Online Index of Objects Launched into Outer Space,* which contains information obtained from non-official sources, particularly about those space objects that have not been notified by States. This source of information would certainly prove to be an excellent means for transparency, especially if it is regularly updated, and would possibly encourage States to send their notifications more promptly.

In October 1994, an online tabulation and analysis of the registration documents were made public [86]. The introduction of an online database, including PDF scans of the registration documents, on the UNOOSA website in the 2000s was a major step forward in allowing public access. Progress has been made in processing the backlog of data from previous years. However, two Russian registration documents [87] covering the May to July 2014 period had been held back for about a year despite a subset of their information having been included in the online database.

3. Need for verification of compliance with the registration Convention

3.1. Rationale for verification

It has been long known that there are numerous types of spacecraft orbiting in near and far Earth orbits performing various military functions that include intelligence gathering, early-warning, communications, navigation, meteorology and weather forecasting. Capabilities of many of these are still closely guarded secrets. In this regard, the US has not been the only one— Russia (the former Soviet Union) has also been very active, and now China, Japan and Europe have also entered the field and no doubt others will follow.

The Registration Convention obliges States to furnish the United Nations with details about their space objects, their basic orbital parameters, and the general function of the space objects. However, the Convention does not contain any provisions to verify the compliance of the States Parties with the provisions of the Convention. In the previous section, it was demonstrated that the States Parties, by and large, do not comply with the terms of the Convention. In this section, it will be proposed how this situation might be improved by suggesting a verification regime. Some of the verification technologies that can be used by such a regime are also considered.

The Union of Concerned Scientists in the United States has been publishing a satellite database, containing considerable amount of details, on all satellites in Earth orbits [88]. Not all what is tracked is published in the open literature, particularly as much of the activities of the US, Russia and China remain classified. The US Satellite Catalogue that is largely maintained by the United States Strategic Command (USSTRATCOM), by and large, does not contain information on military satellites of some States. The catalog includes for each satellite the two line orbital elements (TLE), which consist of detailed orbital parameters enabling one to compute the position of a satellite in its orbit and its movements, and thus possibly predict its functions.

A further complication is when a State is tempted to use its non-operational spacecraft in orbit as targets for the development of its anti-satellite (ASAT) weapons. This was demonstrated by the Chinese and the US ASAT tests on 11 January 2007 and on 21 February 2008 respectively. As the weapons were ground-based, they were not required to be reported to the UN but the US reported that its target satellite was no longer in orbit without giving any reason for this event. It also reported some debris from this event. While China had registered its target satellite, it did not report that the satellite was no longer in orbit or that there has been debris belonging to the satellite FY-1C, which was recorded as a meteorological satellite [89].

From these examples above, it is clear that there is a need for the UN and the international community to be better informed on the launches of satellites in Earth orbits. This could be achieved by establishing an international verification system, which could use some of the readily available technologies and capabilities.

3.2. Some verification technologies and capabilities

Essentially there are three types of sensor systems used to monitor near (< 200 km) and far (Geostationary ~ 35,000 km) Earth orbits. These are ground-based optical and radar systems, and space-based optical sensors. Very extensive space surveillance is being carried out by the US followed by Russia, China, Europe and, to a very limited extent, by India. These sensors detect, track and identify all artificial objects in Earth orbits. A surveillance sensor observes a very large area of the sky at one time, whereas a tracking sensor usually has a very narrow field of view so that a more precise location of the object can be determined. Some of the surveillance systems are capable of detecting objects of some 75 cm in diameter at a distance of up to 30,000 km [90] or 9 cm–13 cm at a distance of 1932 km [91].

As most of the sensors within the USSTRATCOM network are located in the Northern Hemisphere (see Fig. 4) should the returning spacecraft be located outside the sensor coverage continuous observation would be impossible.

As an example of electro-optical devices, the US Air Force Space Command uses ground-based telescopes in tracking (particularly deep space objects) and analyzing the results using its Ground-Based Electro-Optical Deep Space Surveillance facility. Radars use beams of electromagnetic energy transmitted towards an object to track that object in outer space. Previously, the US operated a "space fence", which is a very high frequency radar network located across sites in the Southern United States to track objects in space. However, with the retirement of that outdated tracking system, individual conventional and phased-array radars across the world are now being relied on. The information generated is collected to form a catalogue which is used by several States, space agencies and research individuals. Space-based sensors also exist which have the capability to detect and track space objects day and night without interference from clouds. The sensors consist of optical or infrared sensors that either scan or quickly focus between targets without having to spend time and additional fuel to reposition the entire spacecraft.

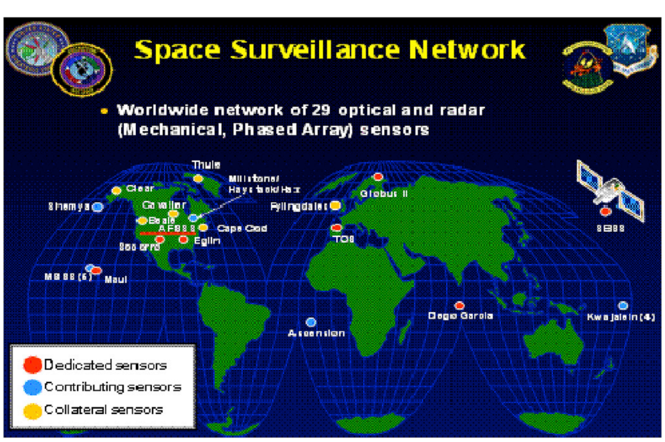


Fig. 4. US space surveillance network.
Source: http://www.stratcom.mil/Media/Factsheets/Factsheet-View/Article/976414/usstratcom-space-control-and-space-surveillance/.

Apart from the US, the European Space Agency also has, under its near-Earth object and space debris tracking activities, the Space Situational Awareness Program (see Fig. 5) [92]. Other than this, recently five European States have signed a space surveillance and tracking agreement [93]. This initiative is expected to provide the European Union with an independent capability of monitoring the space environment. Such collaboration might be extended to include Japan and India, with the latter reported to have reasonably extensive ground-based tracking capabilities [94].

Russia has the Krona Space Object Recognition Station and the Krona-N telescope- and radar-based space surveillance sites. In addition, Russia also has Okno and Okno-S telescope-based surveillance facilities. The Main Space Intelligence Centre headquarters are its military space surveillance network (Fig. 6) [95].

3.3. A possible new surveillance system

Information needed under the Registration Convention is generally provided by a State well after a launch has taken place. Today, there are global state-of-the-art-technologies that are not used but could help the detection of the preparation and the launch of a satellite. The technique is divided into space-based and ground-based systems.

It is suggested that civil observation satellites might be used to monitor the preparation and launches of satellites. Two types of accessible observation satellites that might be used are those in low Earth orbits (LEO), such as the IRS, Ikonos, QuickBird, SPOT and WorldView-1 and those in the geostationary orbits (GSO) such as the US GOES and European Meteosat. For this, two characteristics are important: the spatial resolution i.e. the size of the spot on the ground "seen" by one particular point in the image or seen by a scanning sensor at the instant of observation; and the temporal resolution i.e. how frequently a satellite comes back to a particular point on the Earth's surface. Clearly in the first instance, a number of satellites would be required both in LEO and in GSO to observe launches of satellites effectively. The revisit time for a single satellite in the LEO is too long. This is illustrated by the following four WorldView 1 images (see Fig. 7) acquired at different times using Google Maps web site over the North Korean missile launch site.

While it is possible to detect the preparations of the launch of a satellite, it is important to observe the launch sites more frequently for timely detection of the launch. In other words, one needs a higher temporal resolution. In practice, a temporal resolution of few minutes would be needed. This could be achieved in two ways: one is to use several satellites launched by a single State in the LEO, which may not be feasible. The other is to use satellites in the LEO launched by several States to improve the temporal resolution. This is illustrated in Fig. 8 in which the orbits of number satellites are plotted using software from Analytical Graphics, Inc. (AGI). It can be seen that there are number of satellites operated by different countries in very similar orbits, and if used cooperatively, they could improve the temporal resolution. However, this would require cooperation between the space-faring nations.

More useful satellites are in GSO from where plumes of a launcher could be detected. There are essentially three sources of radiation:

Fig. 5. Global space surveillance sites.
Source: http://news.bbc.co.uk/1/hi/sci/tech/7916582.stm.

combustion gases and particles in the exhaust plume; heated parts of the engine, exhaust nozzle, missile skin surface due to aerodynamic heating and internal heat sources; and reflected radiation from ambient sky, ground and the Sun [96]. Generally, the strongest of these is the radiation from the exhaust plume during the boost phase. The radiation emitted is mainly in the mid infrared (IR) portion of the electromagnetic spectrum at wavelengths between 2 μm and 5 μm. The spectrum from the exhaust of a tactical ballistic missile with liquid propellant in the boost phase has been calculated using NATO InfraRed Air TArget Model (NIRATAM) when the missile has reached an altitude of 10 km.

Both the US and the former Soviet Union deployed the so-called early-warning satellites that detect the launches of missiles, space launchers and nuclear detonations in outer space and in the Earth's atmosphere. However, the data from these spacecraft are highly classified and therefore are not in the public domain. Such satellites have IR sensors on board. Therefore, there may be a possibility of using some meteorological satellites to detect launches of satellites as they deploy electro-optical sensors that are sensitive in the IR region of the electromagnetic spectrum. Thus, it is worth examining the types of sensors on board civil meteorological satellites and see whether they can be used for early warning application.

Basically two types of orbits are used for such weather satellites: polar orbiting satellites fly at relatively low altitudes of around 800 km above the Earth, and can provide information based on a relatively high spatial resolution. However, a disadvantage is that when only one polar satellite is deployed, the same spot on the Earth is visited only two times a day requiring more than one polar satellite with different equatorial crossing times in order to increase the temporal resolution. Satellites in the GSO record observations of the Earth every 15 min or so, thus making a single satellite less useful. However, if additional satellites are used with observations made at different times, temporal resolution could be improved. This could be achieved by either a single State orbiting several satellites or by using data from a number of existing satellites or those operated by a number of State. In either case, cooperation needs to be established so that data could be shared. This could be achieved under a Multilateral Technical Means (MTM) [97] regime and the establishment of an International Data Centre to facilitate the sharing of information.

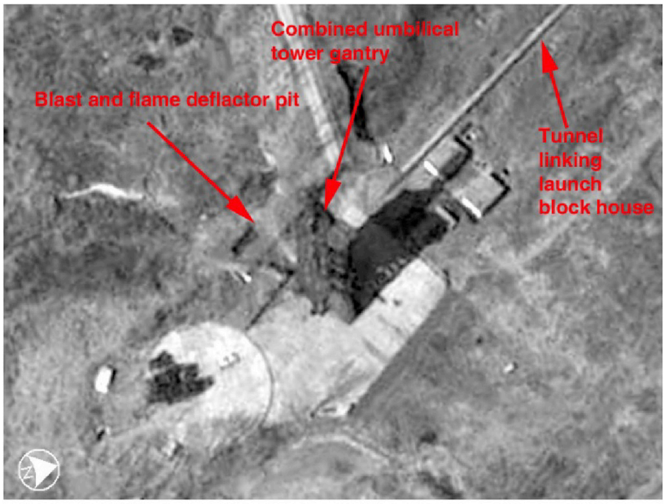
At present, two Earth Observation Satellites (EOS), Terra (EOS AM-1) and Aqua (EOS PM-2), are operational. The main sensor on board the Moderate Resolution Imaging Spectroradiometer (MODIS), which has 36 spectral channels with high radiometric (12 bit) and moderate spatial (1000, 500 and 250 m) resolutions (see Table 2).

The second is the GSO in which satellites are in the equatorial plane at an altitude of some 36,000 km above the Earth. These have an orbital period similar to that of the Earth's rotation on its axis so that the satellite always views the same area. A disadvantage is the relatively high altitude limiting spatial resolution.

Fig. 6. Russian space surveillance sites as of June 2017.
Source: https://en.wikipedia.org/wiki/Main_Space_Intelligence_Centre.

4. Conclusions and way forward

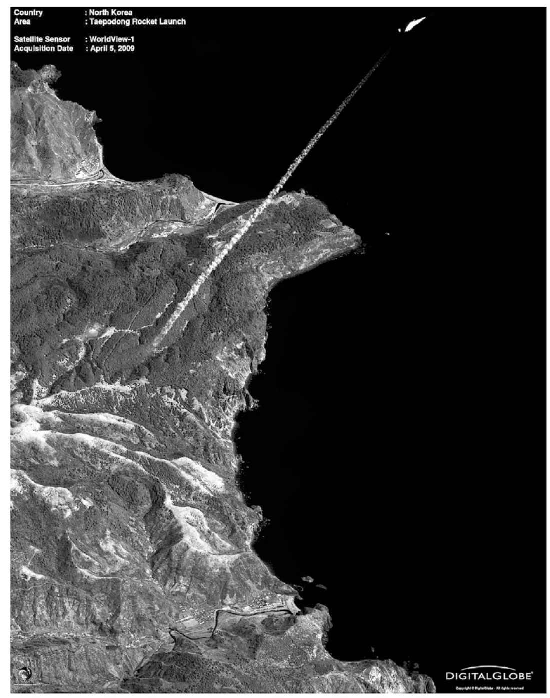
UN Resolution 1721 B (XVI), though *per se* non-binding, seems to have evolved into a norm of customary international law requiring all States that launch objects into orbit or beyond to *promptly* furnish information to the UN about their launchings for registration. However, the nature and scope of the information to be supplied are matters of discretion of the notifying State. On the other hand, the Registration Convention, which is currently binding on 62 States and 3 intergovernmental organizations, has created a mandatory system for the registration of the launched space objects in order to achieve transparency in space activities and to assist in the implementation of international space law agreements. The Convention imposes on States Parties positive obligations (as opposed to negative duties, i.e. prohibitions) that ought to be respected in good faith [98], irrespective of whether their non-compliance results in any injury or damage. Non-fulfilment of international obligations is “an internationally wrongful act” which entails international responsibility [99]. The Registration Convention imposes no sanctions on the violators of its provisions. However, the weight of



24 March 2009

2 April 2009

5 April 2009 the day the missile was launched



Rocket detected as it emerges above the clouds on 5 April 2009.

Fig. 7. The North Korean missile launch site observed at least on four occasions by the US WorldView 1 satellite.
Source: http://maps.google.com/maps.

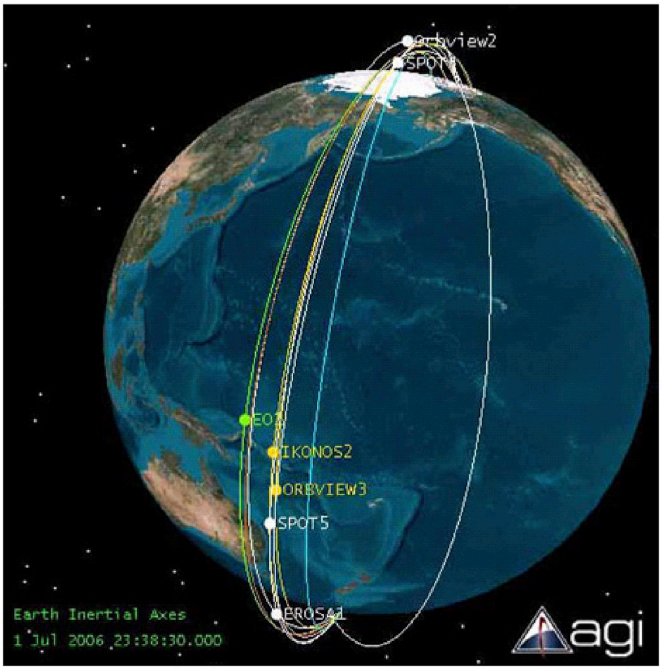


Fig. 8. Orbits of a number of satellites are plotted using the AGI software to illustrate the improvement in the temporal resolution.

Table 2
Some of the potentially useful meteorological satellites for monitoring launches of missiles and satellite launchers.

Launcher State	Name of satellite	Date of launch	Sensors	Position in GSO
GSO				
USA	GOES-12	23072001	MODIS	75°W
	GOES-14	07072009	MODIS	89.5°W
European/ESA	Meteosat-8/ MSG-1	29012004	SEVIRI	3.5°W
	Meteosat-9/ MSG-1	21122005	SEVIRI	0° over Atlantic Ocean
Polar orbit				
Multinational/ NASA	Terra	18121999	MODIS	
	Aqua (EOS-PM-1)	04052002	MODIS	

public opinion (both within and outside of international official fora), and in particular the possibility of being "named and shamed" particularly through some publicly available information provided by a neutral and international verification system, acts as a good deterrent against violations of, as well encourage compliance with, the Convention. Perhaps more unlikely, there exists a possibility that a State may initiate a formal process to compel another State to fulfill its obligations under the Registration Convention [100].

The Registration Convention has been moderately successful in creating an atmosphere of international transparency in the use of space, with a good faith effort on the part of most actors to provide relevant information. However, ambiguities in the requirements and poor feedback and quality control in the system have led to significant flaws in the registry which allow cover for the small number of deliberate abuses. We itemize below some specific improvements which would promote more complete registration (the letter codes from Table 1 are used to indicate which specific problems the improvements would address):

a) requiring retrospective registration, even for satellites which were launched prior to the State joining the Convention, or for satellites which have already re-entered, to ensure a complete register (AA, EA);
b) requiring the registration of all objects, except for fragmentation debris, and requiring that it be noted whether the objects were inert or actively operating; this removes any ambiguity about whether small satellites or packages attached to rocket stages should be registered (AB, CH), or whether satellites that failed soon after reaching orbit should be included (CA);
c) putting in place an improved system for alerting States to oversee registrations, perhaps including a mechanism for public or expert input to the UNOOSA on the matter, so that inadvertent omissions of satellites (CJ, CL) or entire registration documents (CC, CM, CN) can be fixed in a timely manner;
d) clarifying the rules for Article II(2), perhaps, by putting the primary responsibility on the launch vehicle operator, and ensuring that satellites are registered even when multiple launching States are involved (DA to DG). Further, cases where there may be disagreement on the State responsible for the launch vehicle itself when the launch occurs in international waters or airspace (cf. the case of Sea Launch) must be considered;
e) providing a web page on the UN website to consolidate links to all the various online national registries;
f) continuing discussions with new space States, or States with only occasional space activity, to see what process simplifications (document templates, etc.) might improve compliance and participation (FA, EB);
g) establishing expectations for the timely submission of registrations (GA) and ensuring that UN staff have sufficient resources to make the data quickly public, perhaps in a provisional manner;
h) re-emphasizing the requirement for the standard orbital parameters;
i) requiring that the parameters apply to an epoch after the space object has become a separate satellite (so that it is not still attached to its rocket stage) and, if only one set of parameters is given, the data should represent the operational orbit;
j) requiring that orbital data should be given for deep space objects (lunar, planetary and heliocentric), for example heliocentric ecliptic orbital elements. In addition, for such objects which spend even a brief period in Earth parking orbit, the corresponding Earth orbit parameters should be given; and
k) encouraging States to provide additional information on controlled (deorbiting) re-entries.

Due to the need for enhanced transparency in space activities, a serious commitment to full adherence to the Registration Convention and monitoring compliance with this treaty are essential. A number of space-related conventions can be verified by ground- and space-based assets. An important element of this process is the adequate notification of outer space activities, such as the pre-notification of launches, possible potential break-ups in orbits or the premature re-entry of space objects that may cause potential harm to the Earth's atmosphere and on the ground.

The early warning satellites deployed in the past by the US and the Soviet Union provided those countries with data which were useful in building confidence but their data are highly classified and therefore accessible to very few? There is a possibility of using some civilian meteorological satellites with IR sensors to detect launches of missiles and satellites. It is worth examining the types of sensors on board civil meteorological satellites and see whether they can be used for the early-warning and detection of launches of spacecraft and missile applications.

Clearly, the above suggested mechanisms indicate the possibilities of using such open sources of information provided by civil meteorological satellites in order to verify the compliance with the obligations and provisions of the UN Registration Convention and also some possible future treaties limiting missiles and their testing.

It is proposed that Multi-lateral Technical Means (MTM) of verification should now be recognized as a viable and measure to detect and oversee space-related activities. It has also been proposed that an

International Data Centre (IDC) is established in support of the MTM. With the level of technical capabilities of most space faring nations, an MTM is now possible. Thus, MTM and IDC should be recognized not only in all the existing space-related treaties, conventions and Codes of Conduct but also in any other future measures for enhancing global space governance.

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