7 Potential Innovations in Space Regulatory Systems and Standards

Introduction

The advent of small satellites has been a source of innovative technology, new entrepreneurial business initiatives, new economic models for space ventures, and many other changes. As noted in Chapter 6 this has not surprisingly given rise to a host of new issues and perceived needs for new standards of operations, codes of behavior, and perhaps new regulatory actions at the national and international level to keep space activities safe, harmonious, and operationally effective. Truly small satellites, of the cubesat and smaller category, have given rise to one set of concerns, while large-scale satellite constellations, sometimes called megaLEO systems, have given rise to other types of concerns.

This chapter addresses possible solutions to the various issues raised in Chapter 6. It thus considers what new standards, codes of conduct, and other soft law instruments, such as transparency and confidence building measures, can provide improved global space governance in these areas of concern. In addition, some possible international regulatory reforms are also proposed.

The U. N. Committee on the Peaceful Uses of Outer Space (COPUOS) at its UNISPACE + 50 event scheduled for Vienna, Austria, in June 2018 had the mission to develop an effective 12-year agenda to support the U. N. General Assembly's 17 Sustainable Development Goals for 2030. One of the pillars of this process is the consideration of how to effectively apply new global space governance to support these goals in terms of possible new rules, regulations, and guidelines. Since the use of smallsats to support the Sustainable Development Goals represents one part of this process, the analysis that follows is hoped to be both timely and useful to this twelve-year process. Further it is hoped that some of the concepts might also prove useful to the discussions within the COPUOS Working Group on the Long Term Sustainability of Outer Space Activities.

Aanalyses of issues and related possible actions that might be considered and implemented at the global, regional,

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or national level are addressed one by one throughout this chapter. The discussion starts with those issues that relate to the International Telecommunication Union (ITU), which has perhaps the most potential for developing new procedures, processes, or regulations that address small satellite related issues. Next there will be a discussion of matters that fall within the purview of UN COPUOS, and finally there will be consideration of how international, regional, or national actors individually might be able to assist with enhancing collectively the governance and related issues raised by smallsats.

Assessing the ITU's Potential to Assist with Regulatory Reform

The ITU is the world's oldest intergovernmental organization. It began as the International Telegraph Board and was first headquartered in Bern, Switzerland. The initial mission was to coordinate telegraph usage and allow international connection of telegraph systems. In the earliest days of telegraph service, international messages were decoded and walked across international boundaries and then sent along their way again. We have certainly come a long way from this historical situation to today's Internet, which has allowed us to become a globally interconnected world. Today the ITU, which is now headquartered in Geneva, Switzerland, provides standards and assists with the coordination of international communications and networking services of all types. These include texting, facsimile, radio and television broadcasting, telephone, videoconference, high-definition television, digital video/motion picture distribution, unlicensed industrial, scientific, and medical wireless services, and indeed all forms of digital and analog networking, broadcasting, multi-casting, and distribution services. The ITU addresses and agrees on global transmission standards for all types of media and transmission services whether via wire, coaxial cable, optical transmission systems, radio frequency and infrared transmission, or wireless mobile telecommunications systems of all types including cellular telephone, radio communications services (including specialized commercial, medical, and emergency services), satellite services of all types, and even links to UAVs and High-Altitude Platforms. It is, in short, responsible for all types of wire and wireless communications and maintains a master frequency registration file associated with all satellites among other wireless services. Fig. 7.1 shows the ITU headquarters in Switzerland.

The complexity of the frequency allocation plan that is put forth by the members of the ITU is enormous. There are problems with exceptions to this process in that countries can add a footnote to indicate that they are not agreeing to a particular frequency allocation inside their borders. In the case of satellite communications there are many technical coordination issues. For instance, an RF spectrum allocation for one type of service can be closely adjacent to another. The frequency band used for mobile satellite services is adjacent to the frequency spectrum critical to radio astronomy surveys that are particularly sensitive to interference. Further, because of the significant demand for RF spectrum in lower frequencies, the ITU can assign a primary

Fig. 7.1 The International Telecommunication Union (ITU) headquarter facilities in Geneva, Switzerland. (Graphic courtesy of the ITU)

allocation, a secondary allocation, and even a tertiary (or third level of priority) for some types of services. Because of the reserved right of countries to exclude certain frequency allocations within their national borders, and also because the ITU is divided into three different regions (Region One [North and South America and Caribbean countries], Region Two [Europe, Middle East, and Africa], and Region Three [Asia and Australasia]), every country's frequency allocation chart is different. Nevertheless, there is still a good deal of commonality for most allocations.

Each country, however, has its own frequency allocation plan. In the area of satellite services, especially for amateur satellite communications and smallsats, these are generally common. For purposes of illustration, Fig. 7.2 shows the U. S. frequency allocation and illustrates the enormous complexity that is involved. As one moves from the lowest frequencies to the higher frequencies, which provide wider and wider spectrum ranges, the complexity of the allocations still tend to remain but with fewer intricacies. Thus, although the VHF and UHF bands are the most intricate, the microwave and millimeter spectrum ranges still contain complexity as to the types of assigned services.

The ITU Registration and Notification Processes for Satellites

The first step in getting a license to operate a satellite in most countries is to file for the use of the intended frequency with the national radio licensing organization. Each country spells out the type

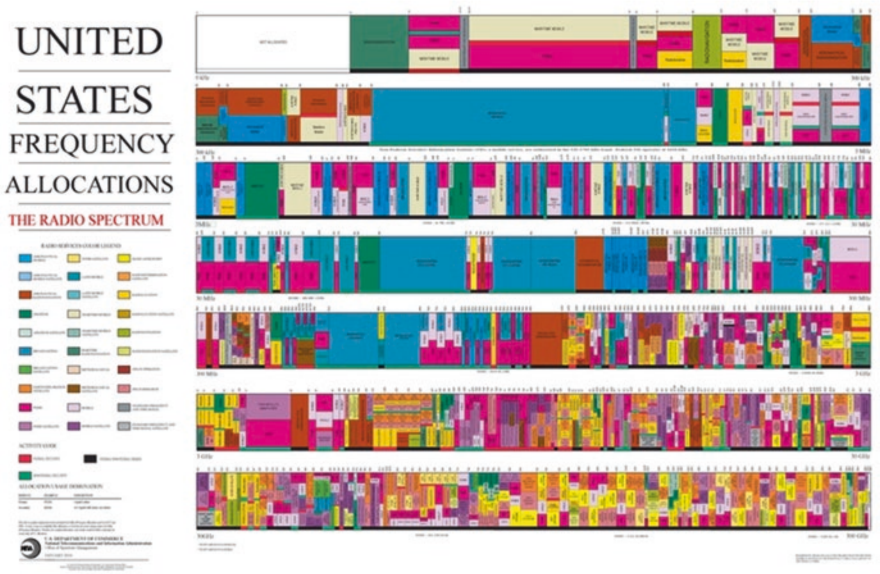

Fig. 7.2 A frequency allocation chart illustrating complexity in frequency allocation processes as typically found in each country – especially for VHF and UHF bands. (This chart is provided for illustrative purposes only. A higher-resolution version may be seen at https://en.wikipedia.org/wiki/Frequency_allocation)

of information that they require in order to provide a license for satellites for which they are considered to be a "launching state" under the Outer Space Treaty and the Registration Convention. In the case of a cubesat experimental project using typical VHF satellite frequencies for data relay and TT&C services this can be a fairly straightforward process. As noted later in this chapter, there have been efforts to streamline the registration, notification, and intersystem coordination processes for experimental cubesat launches.

In the cases where the project is a commercial undertaking intending to deploy one or more satellites to provide fixed satellite services (FSS), broadcast satellite services (BSS), or mobile satellite services (MSS), the national licensing agency will also require much more information. This type of requirement for national licensing information would typically be for the number and size of the satellites and many details of their technical characteristics, plus business plans for the services to be provided, the builder of the satellite and related contractual details, the financial details as to financing, contractors to build and launch the satellite, specific details as to mitigation procedures to lessen the possibility of creating orbital debris, etc. The licensing agency will then determine if this is a legitimate project, and not a so-called "paper filing" and then ultimately determine if the entire system will be licensed. This process in some countries can take some considerable length of time – even years. Once this national licensing decision is made, it is then up to the national administration that is the official member of the ITU to notify the ITU, so that this satellite system can be coordinated with other countries of the world via the official ITU administrative procedures for technical coordination with the satellite systems of other countries.

Some countries have in the past accelerated (and abused) the national review process to file so-called "paper satellites" with certain technical characteristics with the ITU simply to take advantage of the ITU's "first come, first served" principle. Needless to say, such practices undermine the principle of equitable access to spectrum resources. The ITU now has created charges for satellite filing and other milestone procedures to limit such "paper filings."

The filing process is different in the case of GSO (also called GEO) satellite networks. This is because it is necessary to seek specific orbital locations in the GEO belt and to identify slots that might be available that are not occupied by existing satellite networks. In the case of non-GSO satellites that are intended to be deployed in constellations, either in low Earth orbit or medium Earth orbit, the filings with the ITU must spell out the number of operational satellites and spare satellites to deployed, whether or not there are to be inter-satellite links (ISLs) among adjacent satellites, and the specific frequency bands that are to be utilized as well as the specific orbits and orbital patterns to be used by the intended system.

In the case of the first commercial small satellite constellations, known as the Iridium and Globalstar satellite systems for mobile communications, as well as the Orbcom system for mobile satellite data relay, the U. S. Federal Communications Commission (FCC) required information as to the ability of these systems to remove these satellites from orbit at the end of life. Further, the FCC halted the launch of some of the Orbcom launches and requested changes to better ensure that the Orbcom system deployment would not add to orbital debris. This topic of orbital debris mitigation procedures will be discussed later in this chapter.

The Teledesic satellite system, which would have been the first so-called megaLEO system with nearly a thousand satellites, was licensed by the FCC and referred to the ITU for intersystem coordination in official filings by the United States two decades ago, but this system declared bankruptcy and was never launched. Thus this was not a true precedent. The current conditions with regard to the proposals for the deployment of so-called megaLEO small satellite constellations is an unprecedented situation with regard to the actual deployment of a large number of satellites subject to licensing and intersystem coordination processes under the ITU global procedures.

The FCC has, as of the end of 2017, licensed two of the large-scale LEO constellations, namely the OneWeb network (up to 1,000 satellites including spares) and the Telesat (120 satellites plus spares). A number of others are pending, as shown in Table 6.1, which lists the various large-scale networks currently under consideration and their various levels of development. Since these systems are all in a state of flux one should consult the official websites of the ITU or those entities associated with the various systems to seek current information.

This leads to a quite pertinent and difficult issue. Currently there are established procedures for reviewing applications for new satellite systems and licensing their services, but there are no national or global regulatory procedures to decide just how many of these new megaLEO systems can be plausibly deployed, or which frequency plans, RF transmission power levels, or constellation orbital deployment locations are reasonable in terms of approving these systems for launch. As indicated in the Table in 6.1, there could be in the range of 20,000 such satellites launched in the coming decade, in addition to those already deployed in LEO orbits.

No one has established what are acceptable or agreed levels for intersystem coordination in terms of reasonable levels of interference between and among LEO or MEO constellations and particularly levels of interference with regard to "protected" GSO/GEO satellite networks. A further concern is also how many of these new megaLEO constellations can be deployed without posing too great a risk to the future safety of all space operations in the context of orbital crowding and space debris.

The deployment of all of the currently proposed small satellite megaLEO systems could lead to an excessive potential buildup of orbital debris. Increasing the number of objects in low Earth object by tens of thousands of objects without verifiable systems to deorbit these satellites with a high degree of certainty is thought, at least by some, likely to cross the threshold that leads to the so-called Kessler syndrome. This Kessler syndrome means that there could then possibly be a runaway increase in debris elements that in time would become a dangerous and deadly avalanche of "space junk." This specific issue has been addressed earlier and will again be addressed later in this chapter.

It seems urgent to seek reasonable new procedures with regard to the process for licensing, frequency registration, coordination, and deployment of such systems. Such procedures are needed at the national level and also new procedures are needed within the ITU. Some analysts feel that that there should be a moratorium on the deployment of any of these megaLEO systems until a reasonable global decision-making process can be established with regard to how many megaLEO systems can be reasonably deployed and how authorization of systems can be fairly prioritized among various countries. It is becoming urgent for countries with pending proposals for such megaLEO systems, the Inter-Agency space Debris Committee (IADC), the ITU, and the U. N. Office of Outer Space Affairs (OOSA) to create a new coordination and notification process to deal with these new type satellite systems.

This process also needs to address the further issues of excessive interference and excessive orbital debris buildup. The trouble is that this would require an ITU resolution at an upcoming World Radio Conference, or an action by the U. N. Security Council or the General Assembly. None of these actions seems at all likely at this time in that there is no consensus view on any of the key matters. So it is likely that this problem and related concerns will continue to build as more and more megaLEO systems are filed for licensing at the national level and are referred to the ITU for intersystem coordination. When the limits of intersystem coordination appear to be reached, this issue of "too many satellites" in too many non-GSO networks

Fig. 7.3 The OneWeb megaLEO system that will involve nearly 1,000 smallsats orbiting in 800 to 950 km orbits. (Graphic courtesy of OneWeb)

may finally be address seriously [1]. Fig. 7.3 shows the large number of satellites (nearly 1,000) that would exist in the OneWeb constellation alone. The latest systems planned by SpaceX contemplate eight times more satellites than that of the OneWeb system.

Separate from the issue of large-scale commercial satellite constellations, there are also issues related to cubesats and smaller satellites that are being deployed for student experiments and often by developing countries just starting space programs. Here the concern relates to issues such as whether the registration and notification procedures of the ITU might be too stringent and exacting for these non-GSO satellites with short mission lives. This concern led to the adoption of Resolution 757 WRC-12 at the ITU World Radio Conference Twelve, which stated that there were clear distinguishing factors between small satellites (i.e., in this case truly small femto, pico, and nano satellites, or cubesats and below) and the quite different characteristics of larger satellites that were more massive, had longer development and operational lifetimes, and typically used different frequencies and were deployed in different orbits and with fewer orbital controls [2].

This ITU resolution indicated that these differences should be noted in the registration process. The resolution "invited the development of regulatory procedures aimed at facilitating deployment and operation of small satellites and making them successful and timely ….The nature of this category of satellites should be considered, when revising current provisions of the ITU Radio Regulations for the purposes of coordination and notification of satellites" [3].

To date, no such revisions to the ITU Radio Regulations have actually been adopted. At the ITU World Radio Conference (WRC-15), however, the Radio Section of the ITU (ITU-R) was mandated in Resolution 659 to study: "the spectrum requirements for telemetry, tracking and command (TT&C) in the space operation service for the growing number of non-GSO satellites with short duration missions" [4]. The issues related to facilitating the truly small satellites as set forth in Resolution 757-12 have yet to be seriously addressed. In light of the problems and concerns associated with the deployment of the megaLEO systems it seems likely that the streamlining of registration and notification procedures for cubesats will also be delayed [5].

ITU Regulations with Regard to LEO/GEO Interference, Jamming, and Related Concerns

The ITU radio regulations confer on satellites in the geosynchronous/geostationary (GEO/GSO) orbit protection from satellites in non-GSO orbits. This is because these satellites for many years were the almost completely dominant form of space communications and because low Earth orbit (LEO) and medium Earth orbit (MEO) satellites cross the GSO/GEO orbital plane twice with each orbit. This creates the possibility of significant interference to satellites in GSO that are high above the LEO and MEO satellites. Since GSO satellites are typically some 40 times further out from Earth than LEO orbiting satellites there is on the order of 1,600 (40^2) times more path loss than is the case with the satellites orbiting much closer to Earth. This means GSO satellites require more protection against interference from LEO and MEO satellites.

Designers of LEO constellations have had many ideas about how to operate their satellites and meet the protective standards against interference protections and priorities provided to GSO satellites. Some operators have thought of deploying LEO satellites configured with each one having a "chaser" satellite so that the first satellite goes "quiet" as it passes through the GEO plane, and traffic is switched to the chaser satellite and so on around the constellation orbits. Another concept is of an antenna system that swings away from transmitting in the same arc that is used by GSO satellites during the time that they cross the GEO orbital plane. OneWeb and the Telesat constellation have plans to test two trial satellites in orbit before their full constellations are deployed. This form of trial confirmation of non-interference is not currently required under ITU regulations, but it would seem prudent to confirm acceptable levels of non-interference for all current and planned megaLEO systems that operate or will operate in the FSS, MSS, and BSS satellite communications bands.

Currently the ITU procedures with regard to interference are to notify the national administration of the launching nation of an interference problem and request elimination or reduction of the interference to acceptable levels. This process does typically achieve a reasonable level of success in that most interference problems are the result of inadvertent transmissions and are resolved without great difficulty. The ITU has no legal enforcement powers, though, and there are no "ITU police" to hand out fines to offenders. This is a particular problem when the interference is, in fact, intentional jamming.

Some countries engage in intentional jamming as a form of national protection against unwanted transmissions into their country. In these instances there is currently no particular legal or regulatory recourse available. At this time countries are reluctant to give up any more of their sovereignty to international intergovernmental organizations such as the ITU. Yet, given trends of integrative technology, global patterns of economics and trade, and international online employment, the need for regulatory "teeth" for international intergovernmental organizations will perhaps be recognized. The World Trade Organization (WTO) is the only international organization that has the ability to impose fines on nations that engage in trade infractions. Today the ITU has standards and recommended practices that are based on consensus, but it has no specific enforcement power behind these measures. In light of the tremendous importance of the global Internet, corporate intranets, global communications systems and mobile networks, and satellite networks of the world, there should be serious consideration given to strengthening of the ITU Convention to provide greater enforcement powers to this international institution so key to the future sustainability of outer space activities.

ITU Processes for Intersystem Coordination

The ITU has a well-established process for receiving formal notifications of satellite networks filed by member administrations and sharing them with all members of the ITU to determine if there are concerns about interference. The process is for the administrations that have concerns to notify the ITU of perceived possibilities of interference. The administrations that are concerned have the possibility to meet and find ways to minimize interference. If these coordination meetings are successful then the results are formally filed with the ITU. If these discussions are not successful, then ITU officials can meet with the administrations concerned (and with the owners and operators of the satellite systems and their contractors if the administrations are not directly involved with the satellite networks) to resolve the interference issues.

This process has historically led to resolution of the interference problems. There have nevertheless been concerns about the process and particularly with the process that favors those that have deployed satellite networks and have the priority that comes from the "first come, first served" principle. In one instance an orbital location in GSO was optimum for providing service for the Indian Ocean region that provided satellite connectivity between the United Kingdom to the western end of this service region and to Australia at the eastern extreme of this service area. This same GSO orbital location from the perspective of India would also represent the best position to get the optimum power footprint to cover the Indian subcontinent with an Indian satellite and thus minimize the size of ground systems. Since Intelsat had precedence for this location, India had to move their satellite to a less desirable location, and this required them to deploy higher gain ground stations at higher cost.

As a result of this experience, India petitioned the ITU at the next WRC meeting to remove the higher priority accorded to existing satellite network operators. This started a completely new discussion as to how networks are coordinated and priorities are assigned to countries receiving assignments in the orbital arc. Currently there are no procedures with regard to the priorities that might be assigned to satellite constellations in low Earth orbit. The only key regulation that is in effect is that GSO satellites have protected status against non-GSO satellites.

The U. N. COPUOS and the Office for Outer Space Affairs

Liability Convention Concerns

The provisions of the Liability Convention state in Article II that "A launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the Earth or to aircraft in flight" [6]. The convention also specifies in Article I that this liability includes attempted launches and launch failures. This means that a country that launches or procures the launch of even a cubesat would absolutely be liable for any such damages. Under Article III of the convention it specifies that: "In the event of damage being caused elsewhere than on the surface of the Earth to a space object of one launching State or to persons or property on board such a space object by a space object of another launching State, the latter shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible" [7]. Any country that considers sponsoring the launch of a cubesat must thus consider the potential liability that it is exposed to in doing so.

When the Liability Convention was negotiated and agreed to in the early 1970s only the United States and the U.S.S.R. were launching satellites into orbit. The concept of smallsats, and especially of cubesats and even smaller satellites, was entirely unknown. No one thought that in the future someone might create a very tiny satellite and then launch it along with a larger satellite, and what this would imply from the standpoint of this convention.

Today the situation in space has changed in many ways. Hundreds of cubesats are being launched, and if a launch failure with a rocket carrying a number of cubesats from many different countries end up landing in a major city, causing potentially billions of dollars of damages, it is unclear how damages and apportioned liability would be decided.

As things stand, each country that registers a smallsat with the U. N. Office of Outer Space Affairs office could be held "absolutely" liable for damages, particularly if there were a catastrophic launch failure accident involving people on the ground or in aircraft. In light of the small size of cubesats they fortunately would in virtually all conceivable circumstances burn up before they might hit an aircraft or fall to the ground. (*Note:* See Appendix 4 in this book for the detailed language contained in this convention.)

Registration Convention Improvements

The other most relevant convention involving smallsats is the Registration Convention. As noted earlier at the ITU WRC-12 Resolution 757 was adopted that addressed the issue as to whether the notification language concerning a new satellite network for the purposes of intersystem coordination under the ITU regulations might be changed to streamline the provisions and processes related to smallsats (i.e., cubesats and below). There is a parallel but different provision in the U. N. Registration Convention that requires launching states to provide information with regard to all satellites launched into Earth orbit. This information is, in part to establish potential liability in the case of collisions in space or accidents involving space objects on the ground. It has been suggested that the registration procedures to provide information to the U. N. Office of Outer Space Affairs (OOSA) might be simplified for cubesats and even smaller satellites as well. Again, as in the case of the Liability Convention, the drafters of the Registration Convention did not anticipate that there might be such a development as smallsats that would need to be registered with OOSA in the future.

Currently most smallsats – although not necessarily all – are duly registered. At the start of this process there were only a small number of smallsats. Today over 100 cubesats were deployed in a single launch. And going forward there might be thousands of commercial small satellites that although they might be considered small are indeed of significant size, i.e., in the 150 to 500 kg. If nothing else, this will create a significant new workload for OOSA to register this many satellites.

The main point here is that the Registration Convention does not serve the operational needs of space traffic management, especially for very short-lived cubesat missions, where the orbital lifetime may exceed the time for the registration process to be concluded, as per the convention. And then, there would be the problem of the international U. N. register of space objects being "polluted" with hundreds, if not thousands, of entries for space objects no longer in orbit. Keeping the register up-to-date would be a mammoth task. From an operational perspective, space situational awareness systems are of much more practical use than the space object register. Currently the U. S. Space Command seeks to track all satellites in orbit and orbital debris as well. With the deployment of the S-band radar space fence it will literally be able to track over 100,000 space objects in LEO, MEO, and GEO orbits. The key issue here, of course, is today not the registration of all space objects in Earth orbit to be able to assess liability. Rather the key issue is that of orbital space debris.

Orbital Space Debris

The U. N. Committee on the Peaceful Uses of Outer Space has established a Working Group on the Long Term Sustainability of Outer Space Activities. This working group has been tasked with identifying areas of concern for the long-term sustainability of outer space activities, proposing measures that could enhance sustainability and producing voluntary guidelines to reduce risks to the long-term sustainability of space activities. The working group has addressed thematic areas including sustainable space utilization supporting development on Earth; space debris, space operations and tools to support collaborative space situational awareness; space weather; and regulatory regimes and guidance for actors in the space arena [8].

Despite the UN COPUOS space debris Mitigation Guidelines and the more detailed IADC Mitigation Guidelines (see Appendix 2 and 5 in this book, respectively) the problems of space debris continue to mount. The deployment of conventional and now large-scale LEO constellations to provide remote sensing, fixed and mobile telecommunications, and data-relay services, has tended to raise levels of concern to much higher levels.

In view of the lack of appetite by UN COPUOS to amend the U. N. Outer Space Treaty and its four subsidiary conventions and international agreements, it is unlikely that there will be a new international agreement to address the problem of space debris and its mitigation and containment. The solution may well lie in the establishment of agreed international norms (such as voluntary guidelines) that may be implemented at the national level to impose strict controls related to space debris in various ways. The French government, under the French Space Operations Act, has enacted legislation to impose significant fines on any French space system that does not meet the conditions of the deorbiting of all satellites within 25 years of their operational end of life. The U. S. administrative regulations have similar provisions to enforce due diligence to prevent orbital space debris prior to any launch.

Another approach would be to have an international code of conduct for outer space that would establish clear, albeit not explicitly enforceable, guidelines that would cover space safety concerns including those that relate to improved space situational awareness and mitigation of orbital debris. Some of the concepts that could be considered for a global code of conduct for outer space might include the following:

Deploy LEO Cubesats and Other Smallsats at an Altitude of 300 km or Lower: This guideline would urge the deploying of experimental cubesats or smallsats of developing countries in very low, short-lived orbits in order to seek to minimize the problem of orbital debris. The 300-km altitude is suggested to be below the orbit of the ISS, but this is, of course, not a magic number, and it might be moved higher to altitudes such as 350 or 400 km. The key is to set an altitude so that the 25-year guideline would always be met [9].

This policy could be further refined to urge consideration of such projects being sent up and down via the International space station (ISS) or on platforms equipped to accommodate a large number of cubesats. Such a platform that could consolidate smallsat launches could also provide power, TT&C and communications services, as well as most importantly, critical deorbit services. In the case of using a multi-satellite platform with deorbit capabilities, higher altitude orbits with longer lifetimes could be accommodated [10].

Failing that, all such launches would be deployed in space so as to operate at a sufficiently low altitude so that natural gravitational effects and solar wind pressure would hasten their reentry into Earth's atmosphere. What is critical to note is that in the case of a collision at these altitudes, the resulting debris would also decay in a reasonably short period and thus would not pose a risk to other operational satellites or to launch operations.

Regulatory Systems and Funds for Cleaning Up Orbital Debris : Ultimately all of these strategies are still not going to be able to remove all orbital debris from Earth orbit to guarantee true long-term sustainability of the LEO environment. There will need to be some method of active debris removal (ADR). The possibilities in this respect were discussed in Chapter 6 and illustrated in Figs. 6.1, 6.2, and 6.3. The question is under what sort of regulatory framework and under what type of financial or insurance mechanisms might such ADR activities take place?

Scientists and engineers will of course tend to focus on what might be an effective technological approach. It is, however, just as important to develop a suitable economic and regulatory process that is internationally agreed on and viable. There have been a wide range of proposals made in this regard, including the idea of creating a new international approach based on a model such as the original Intelsat organization.

Others have suggested that the funding to support such an active orbital debris removal activity might be structured so that it would work much more like a sort of launch insurance policy. Under this approach all future commercial and governmental launches would be required to pay into this fund. This might be structured so that there could be at least a partial refund after the satellites in question were successfully deorbited or sent beyond Earth orbit cleanly. Such a fund would not restrict active debris removal to a single entity. Instead it would allow for a variety of different technical approaches to be pursued and proven on a competitive basis. It would also allow for commercial entities that removed debris successfully to be compensated by the global debris removal insurance fund. It is also key that this fund could be shut down or phased out if over time debris removal systems became sufficiently successful that this type of operation were thankfully no longer needed [11]. In keeping with the provisions of the Outer Space Treaty, this fund concept could be implemented and managed at a national level. States without the technical capabilities to execute ADR measures could use their national debris removal insurance fund to contract entities in other States with such capabilities to perform the necessary ADR operations on space objects under their jurisdiction and control.

Conclusions

The advent of small satellites, as well as large commercial smallsat constellations, has given rise to a wide range of new concerns and questions as to whether new standards, regulations, or guidelines should be developed and agreed, either globally or at a national level. A number of these issues and possible regulatory solutions or standards have been addressed in this chapter.

Under the ITU regulations and associated processes it might be appropriate to change the notification procedures, to change ITU processes with regard to intersystem interference and jamming, to strengthen ITU regulatory enforcement powers, and to change the processes and requirements with regard to intersystem coordination.

Under the U. N. Committee on the Peaceful Uses of Outer Space and its Subcommittees certain other matters appear necessary to consider. These include: (i) changes to registration processes under the Registration Convention with regard to various types of smallsats and smallsat constellations; (ii) consideration of pragmatic guidelines to establish a common registration practice of States for short-lived smallsats under the Registration Convention, and how the Liability Convention might be interpreted so as to better facilitate active debris removal; (iii) actions that would encourage or enable action at the commercial, the national, and the international level to allow improved space situational awareness; and (iv) new incentives or regulation to prevent the future buildup of orbital debris, initiatives to create new mechanisms such as orbital debris funds, insurance arrangements, or entities to encourage or enable active space debris removal; or (v) better regulations, mechanisms, and technology to help to ensure removal of satellites from orbit at end of life.

At the national level the creation of new mechanisms, regulations, laws, and other measures to aid in the effective registration, intersystem coordination, operation, and removal of small satellites from orbit after their operational end-of-life.

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