Chapter 8
Ten Top Things to Know About Small Satellites and Space Debris

Because of the substantial advantages that small satellites can offer to educational programs on limited budgets, to those deploying global constellations in low Earth orbit, and to those who can meet specific space-related tasks with miniaturized payloads, it seems likely that there will continue to be an exponential increase in launch of small satellites and consequently, in the number of associated debris in orbit. In order to reduce space debris, national regulatory and technical solutions would need to be developed and implemented. In light of the fear of a future avalanche of space debris that can cascade out of control, there are many steps that are being taken to mitigate space debris and a number of these steps prescribe better ways to proceed with small satellite missions and experiments.

The following represent our top ten thoughts about how the small satellite enterprise might move forward in a positive way without making the already serious space debris problem even worse.

1. **There are many new and promising technologies that should be supported with targeted R&D to aid better small satellite design and operation. Consolidated "mega cube" satellite systems and kits that include de-orbit capabilities would be of value and could streamline registration procedures.**

   Enormous progress has been made in the past decade to develop amazing new technologies. The new technologies related to micro thrusters, high speed processing, end-of-life de-orbit systems, on-board storage, and standardized kits have combined to allow better small satellite design, lower cost, higher performance at lower cost with higher reliability and longer life. Yet there is much more that can still be done to develop better miniaturized components (i.e., microprocessors and storage units), improved power systems (i.e., quantum dot solar power systems, improved batteries), lower cost and more compact de-orbit systems, improved antenna systems (i.e., phased-array feed systems, inflatable antennas), and lower cost thrusters and launch systems. In addition to the development of new satellite and launch technologies, there can also be improved technology transfer systems that allow developments related to larger-scale spacecraft to be applied to smaller-scale systems.

R.S. Jakhu and J.N. Pelton, *Small Satellites and Their Regulation*, SpringerBriefs in Space Development, DOI 10.1007/978-1-4614-9423-2_8,

2. **De-orbit and pointing and positioning systems for small satellites should be considered a priority. Again consolidated free-flyers might be a cost-effective way to accomplish this goal.**

   One of the large differences between early types of small satellites and many that are being designed and deployed today is that the latter can be equipped with active thrusters for positioning and de-orbiting capabilities. There are many new technologies that might be considered useful for small satellite missions, but the development of new mechanisms that provide reliable and low cost positioning capabilities and especially systems that can aid removal from orbit at end-of life should be considered the top priority in terms of new development programs. These could be a combination of "active" programs, such as small scale and low level thrusters, or "passive" in terms of inflatable balloons or wings that increase atmospheric drag and assist eventual removal from orbit. Elements such as inflatable antennas could add to small satellite capabilities in the first phase of operation and then assist with removal from orbit at end-of-life.
3. **"Consolidation" for many types of small satellite projects or examination of a "hosted payload" approach to meeting mission needs should be considered a prime objective and implemented whenever possible.**

   Many small-scale space projects should be examined at the earliest stages to see whether multiple mission objectives could be achieved through "effective consolidation." Often, such consolidation can reduce costs and risks and also minimize problems associated with orbital debris. There are many options now available in this respect. One increasingly attractive alternative is the use of hosted payloads. This approach can be used for one-of-a-kind experiments where a package can be hosted on a geosynchronous satellite. In other instances where global coverage is required, various types of packages might be hosted on low Earth orbit constellations when numerous subsystem packages need to fly.

   Yet another option is for small educational space projects to use the Nanoracks capability that permits experiments to fly on the International Space Station. In this case the costs are low and astronauts can start and stop experiments while also providing dynamic control over them. Further, by running the experiments on the International Space Station there is no problem of de-orbiting nano satellites at the end-of-life. As private space stations are deployed such as the Bigelow Aerospace Company intends to do, the range of options for flying a wide variety of experiments and educational packages that are small, medium, or large will multiply. The idea that small, nano, pico, or femto satellites must be free flyers in space really has no particular advantage other than some sort of assumed "national or personal prestige." Combining and consolidating small satellite missions as "packages" that can share power and fly into space as an integrated effort has many advantages. This consolidated approach can cut launch, satellite mission-design, and operational costs. It can also extend experimental times in orbit, reduce potential liabilities, insure access to reliable power, aid capabilities in such areas as pointing accuracy, positioning, and stability. Finally it could ease the difficulty of meeting registration requirements.

4. **All spacefaring nations and enterprises that launch satellites should agree to binding arrangements for orbital debris mitigation and active debris removal.**

   Significant progress has been made through the IADC collaborations and the U.N.'s COPUOS to move to agreement on voluntary procedures to prevent the creation of new orbital debris and to remove objects at end-of life. These procedures, however, need to be strengthened and made mandatory in nature. They need to be transformed into binding international law backed by sanctions (and or rewards) to help enforce them. Today, many small satellites are not being registered and they are thus, in a way, "flying under the radar" when it comes to careful monitoring and concerted efforts to avoid their possible contribution to the orbital debris problem.

   The problem of orbital debris is, of course, not just the result of satellite deployment but also debris that is created by upper stage launch vehicles and such things as exploding fuel tanks. All types of activities that contribute to orbital debris need to be considered and mandatory procedures developed to mitigate this problem. Many that are new to space activities or have limited resources or wish to use small satellites for experiments might tend to feel that they are being discriminated against because they have not created the problem of space debris, but they are being singled out for some of the most restrictive measures. In this regard, larger spacefaring nations with assets in space that allow small scale space experiments (i.e. the owners and operators of the International Space Station) might wish to give consideration to incentives such as permitting educational experiments and projects from countries new to space use to be consolidated on experimental facilities like Nanoracks. In so doing, large spacefaring nations stand to benefit in the long run by avoiding the proliferation of free-flyers that contribute to the space debris problem.

5. **New economic arrangements and insurance provisions should be put into place for all satellite launches, including small satellites.**

   As discussed above, new regulations may not only forestall the creation of new debris but could also require each new launch contribute to a fund to support active debris removal. Today, as most commercial launches into orbit take place, there is a launch insurance policy in place that provides various types of coverage. Some of the coverage is for liability in the event that a major accident should occur and the mission should fly off course and land in a populated area. Some of the coverage is for the mission itself and offers financial protection in the event that the objectives of the mission fail to be achieved. This coverage would serve to pay for a new launch and a new satellite. There are other types of insurance coverage to protect against a satellite collision and the destruction of the satellite.

   There is no reason that insurance mechanisms and a related orbital debris fund could not be fashioned to cope with the problem of space debris. This new type of economic arrangement and insurance coverage would apply to all launches (commercial, civilian, government, and defense) and all types and classes of satellites – large, medium, and small. The need for insurance (particularly with regard to liability and protection against orbital debris) could be, in effect, eliminated for these individual efforts if small space missions were carried out as consolidated projects launched as combined packages. A consolidated mission would also simplify registration notifications since there could be only one registration rather than four if that many projects were indeed consolidated This type of insurance arrangement would thus act as both a "carrot" and a "stick" (i.e., reward and/or sanction) in that the cost of a small "free flyer" would be more, but the cost of a "consolidated" mission would be reduced.

6. **New liability arrangements for space objects as well as incentives for removal of space debris need to be put in place.**

   The current Liability Convention is not well suited to fully addressing orbital debris issues. Currently, a nation only pays for damage from a space object if it occurs and liability is clearly established. There is no particular reward or incentive to actively work to prevent debris from occurring and to minimize the risk in the first place. A positive step would be to amend the Liability Convention so that countries and commercial organizations have active incentives to reduce space debris in the first place and have legal and economic processes that would help to minimize risk and reduce future potential liability from the outset.

   Unfortunately, this does not seem likely to occur in the relative near term. Thus, it might be necessary for the members of the IADC to discuss this issue and see if there might be some sort of formula that spacefaring nations might agree to – including the creation of a multi-lateral space object liability fund that would cover a first round of liability claims in the event of a space debris-related accident. Such an arrangement might serve as a basis for addressing this issue and establish a possible transfer of liability exposure from one space actor to another with the fund serving as possible form of "insurer" against an undesirable outcome. It would seem that some such mechanism could reduce the overall risk and create incentives to reduce the risk of space collisions as well as the creation of more space debris in the future. In short, we need space agreements and mechanisms to allow solutions to be pursued actively, rather than just hoping that space accidents do not occur. If these types of economic arrangements cannot be devised, then perhaps mandatory arbitration procedures could be set up as yet another way to approach this problem.

   If such liability reforms cannot be done through the mechanism of COPUOS and other U.N. processes, then perhaps other options may be possible. New types of liability insurance arrangements and new ways to pay to actively reduce orbit debris risks might be discussed and agreed through the IADC, or perhaps even more likely through the space insurance business. What seems necessary is some new types of governmentally sanctioned or commercially agreed arrangements. These arrangements need to be backed up by sanctions, financial bonds, or some form of insurance or mandatory arbitration arrangements.

7. **De-orbit provisions should be lowered from 25 years to 20 years and be made mandatory.**

   Currently, the IADC guidelines recommend that satellites be designed so that they will de-orbit within 25 years. With the increasing rate of launch of cube-sats, nano satellites, pico satellites, and even femto satellites many view these provisions as no longer being adequate. The addition of inflatables or other de-orbit mechanisms should make such new guidelines feasible without undue complexity and expense. To the extent that addition of de-orbit capabilities is seen as an undue burden, the possibility of moving to consolidated experimentation on the International Space Station (i.e., via Nanoracks) or on commercial space stations such as Bigelow Aerospace is planning to deploy can offer longer cost-saving options. The change, however, needs to include mandatory registration of small satellites and de-orbit provisions that are backed by some form of reward or sanction process. This would entail agreement by all spacefaring nations to not launch any small satellite unless suitable arrangements are made for de-orbit within 20 years or to migrate the small satellite mission to a consolidated mission on a space station or a hosted payload so that the return of the small satellite to Earth would be implemented on a guaranteed basis.

8. **Part of the longer term solution of orbit debris and space safety would seem to require some form of space traffic management and control that is achieved through the International Civil Aviation Organization (ICAO) and/or national and regional air and space traffic agencies.**

   The systematic study of space traffic management and control is now in its earliest stages. Preliminary steps have included the publishing of books on this issue such as *The Need for an Integrated Regulatory Regime for Aviation and Space: An ICAO for Space?* Edited by Ram S. Jakhu, Tommaso Sgobba, and Paul S. Dempsey. Discussions are now underway to create a study process within the International Association for the Advancement of Space Safety (IAASS) in cooperation with ICAO and national or regional air traffic control agencies.

   The initial focus of these new processes will give top priority to the safety of airline passengers as the most significant risk factor to mitigate. As the number of private space activities such as suborbital space adventure flights, commercial launches to space, private space stations, and especially hypersonic transportation tests increases, the range of issues to be explored and new regulatory capabilities to be devised will also increase. As these regulatory efforts increase over time it is important for the range of issues to also expand to cover environmental, frequency management, as well as other issues and concerns that arise from space transportation and flights that involve so-called sub-space or the "protozone" operations in altitudes that range between 21 and 100 km – the normally accepted definition of outer space.[1] These activities may eventually involve the amendment of the 1944 Convention on International Civil Aviation (Chicago Convention), under which ICAO operates, and formal designation of responsibilities to U.N., agencies such as the World Meteorological Organization (WMO), the U.N. Environmental Program (UNEP), and the International Telecommunication Union (ITU).

[1] Joseph N. Pelton, "Beyond the Protozone: A New Global Regulatory Regime for Air and Space" American Bar Association Forum on Air and Space Law, Washington, D.C. June 6, 2013.

9. **New international regulations and guidelines should be put into place with regard to toxic rocket and thruster fuels and power systems, etc.**

   Again, these concerns are not specifically related to small satellites since issues involving toxic rocket and thruster fuels and hazardous power systems relate first and foremost to larger and medium-sized satellite deployment. As more environmental friendly fuels and power systems are developed, they will need to be applied to all types of satellites – including small satellites. Since owners and operators of small satellite missions are extremely cost conscious, there will be a particular concern to make sure that new regulations in these areas, as well as restrictions related to de-orbiting systems, positioning, etc., do not create undue financial difficulties or create overly difficult regulatory processes for those engaged in small satellite-related activities. Currently, there are particularly difficult issues to be addressed in that some of the safest and lowest cost rocket systems that have been developed by commercial launch systems involve the burning of solid fuel (i.e., neoprene) which is particularly challenging in terms of damaging particulate emissions and environmental concerns.

10. **It is imperative to undertake active debris removal activities pursuant to an international operational and regulatory framework that should establish an inter-governmental organization incorporating public-private partnerships.**[2]

   There is a massive amount of debris already in existence in Earth orbit that now exceeds 6,300 metric tons. In order to avoid the generation of new debris that results in a catastrophic type Kessler syndrome, active debris removal of *existing* debris seems more and more essential in addition to the mitigation and prevention efforts. Various technical means and debris removal capabilities are being developed. However, the removal of space objects faces numerous challenges, both technical and regulatory.

   The state on whose registry an object launched into outer space is carried holds jurisdiction and control over even a non-functional space object (i.e., space debris). If a state, or a state-licensed actor, wishes to remove a space object, it can only legally do so if it has legal jurisdiction and control over that space object (i.e., space debris) or with prior permission from the state of registry. Regulatory mechanisms must be sought to facilitate the seeking and granting of permission and to establish rules respecting both the jurisdiction and control issue and consent. There should be a standard and legally acceptable definition of what constitutes space debris in order to permit the conduct of active debris removal activities. Moreover, active debris removal technologies and activities have strategic and military implications since they may be used as anti-satellite weapons (ASAT). In order to minimize military, diplomatic, and

[2] For details, see "Active Debris Removal – An Essential Mechanism for Ensuring the Safety and Sustainability of Outer Space: A Report of the International Interdisciplinary Congress on Space Debris Remediation and On-Orbit Satellite Servicing," UN Document: A/AC.105/C.1/2012/CRP.16 of 27 January 2012.

political concerns in relation to debris removal or changing the orbit of any space object, it is believed that debris removal activities need to be monitored and coordinated at both the national and international levels, and should be undertaken pursuant to an international operational and regulatory framework. This might be accomplished via commercial arrangements or perhaps even require the establishment of an inter-governmental organization (IGO) to foster the development of the technologies for active debris removal and subsequently to perform, "license," or coordinate the removal operations on a commercial basis. The international agreement establishing such an organization should have (a) a clear definition of space debris, and (b) a provision under which the participating states authorize the removal or servicing of those pieces of space debris for which they are the states of registration. All these considerations are complicated by the fact that there are a host of other space-related issues that also need to be addressed, such as space traffic management, environmental protection, and regulation of the "protozone." New international arrangements in these areas may or may not overlap with arrangements involving space debris.

The bottom line is that space activities will become more and more of a political, economic, legal, ethical, and commercial interest to all people and nations. It is time – indeed it is past the time – for comprehensive thought and action to be given to the best ways for dealing with such problems. We hope that the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) and the Inter-Agency Space Debris Coordinating (IADC) Committee, along with other relevant international agencies, will start to seriously address space-related issues that now face us and seek new solutions before they become even more difficult to solve.