68th International Astronautical Congress (IAC), Adelaide, Australia, 25-29 September 2017.

IAC-17-A6.10-B4.10.1

Norms of Behavior for Small Satellite Operators – Basic Principles

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Abstract

Recognizing the rapid expansion in space activity and increasing complexity of the operational environment, both government and industry leadership have called for the private sector to take the lead in identifying norms for safe and responsible space operations in order to help maintain the accessibility of the space environment to all actors (and the derived societal and economic benefits thereof). A key driver in this conversation has been the emergence, and increasing utility, of small satellite driven technical and business approaches.

Drawing from both existing literature published space industry and government sources (e.g. the Satellite Industry Association and the UNCOPUOS Working Group on the Long-term Sustainability of Outer Space Activities), and from a series of recent workshops on industry norms and best practices hosted by the authors' organization, this will paper will describe the basic principles that could provide the baseline for industry-led development of norms for safe and sustainable small satellite operations. These basic principles include description of potential elements topics that might be fruitfully addressed through industry-led norms, and a proposed approach for moving that dialogue forward over the next several years. It will also draw distinction between the roles of operational norms vs. technical standards.

The paper will begin by establishing the business rationale for the discussion: the market technical factors that have driven the emergence of small satellites, high-level operational challenges, and the link to the long-term sustainability of the business model. The analysis will then review existing literature focused on norms of operations for small satellites. The literature review will focus on identifying what topics and challenges have been suggested as areas of focus for discussion of norms, and what are gaps in existing conversation and practices. The paper will also discuss initial high-level findings from a series of workshops convened by the authors over 2016 and 2017, which have covered such topics as: best practices for smallsat orbit determination and conjunction assessment; norms for rendezvous and proximity operations; and best practices for smallsat launch deployment and tracking. The analysis will conclude by suggesting a forward work path for further development of norms for smallsat operations.

Keywords: norms of behavior, best practices, small satellites, cubesats

Acronyms/Abbreviations

ADR – Active Debris Removal
CONFERS – Consortium For Execution of Rendezvous and Servicing Operations
COPUOS – United Nations Committee on the Peaceful Uses of Outer Space
DARPA – Defense Advanced Research Projects Agency
GVF – Global VSAT Foundation
IADC – Inter-Agency Space Debris Coordination Committee
IHL – International Humanitarian Law (IHL)
LOAC – The Law of Armed Conflict (LOAC),
LTS – Long-term Sustainability
MILAMOS – Manual on International Law Applicable to Military Uses of Outer Space
OOS – On-Orbit Servicing
PMD – Post Mission Disposal
RPO – Rendezvous and Proximity Operations
SIA – Satellite Industry Association
SSA – Space Situational Awareness
SWF – Secure World Foundation

1. Introduction

There has recently been a notable amount of conversation in the space community about the potential need or opportunity to establish norms of behavior for the safe and responsible use of space [1]. This conversation has emerged as space becomes increasingly globalized, commercial, transparent, and interdependent. These trends will result in increased benefits from space on Earth, but also several significant challenges that will need to be overcome. This paper seeks to provide a baseline discussion of what norms are, why there is a need for the further development of norms in the space sector, what initiatives are currently ongoing, and suggest some key topic areas for further work.

2. Norms in Space Governance

2.1 The Changing Context of Space Activities

Change is the operative word in the space sector today, as uses and users of space diversify. New actors, technologies, and applications are changing the way in which society interacts with, operates in, and benefits from the space environment. Since the beginning of the space age in the late 1950's, space has gradually shifted from a domain dominated by two superpowers, then broadened through civil, security, and scientific utilization, to a now multi-user environment with commercial, academic, civil, and security benefit. As the former U.S. Deputy Assistant Secretary of Defense for Space Policy, Douglas Loverro, writes in a recent edition of The Space Review:

> *…[S]pace has moved from being solely the means by which two superpowers warned of, guarded against, and executed nuclear war, to an internationally vibrant and expanding economic nexus, a means for conducting routine national security and military missions, and an interconnected infrastructure that literally empowers the way of life of the earthbound citizenry who depend upon it. [2]*

This change has accelerated in recent years and will continue to do so. Driven by reductions in cost, commoditization of electronics, increases in computing power, and mass market uptake of information and communications technologies, the commercial use of space is increasing – and doing so in innovative ways that challenge traditional approaches to operations.

A key element of this change is the increasing use - and utility - of small satellites (and cubesats) for commercial, civil, and academic missions. Smallsats and cubesats contribute to the increase in the number and type of actors accessing space technology - including many actors who may not be familiar with traditional operating approaches and best practices. These systems also enable new concepts of operations that both drive new benefits and challenge exists paradigms of behavior [3]. In particular, the use of cubesat and smallsat systems in constellation architectures has significantly increased in recent years, and is forecast to continue to do so [4]. Based on currently announced plans, more than 16,000 private-sector satellites are planned for launch in the next decade – dwarfing the approximately 1,500 satellites that are currently operating. Over the next decade the commercial sector will become the dominant player in the space environment [4].

2.2 Why Norms

This wave of commercial development has been supported – indeed enabled – by a mostly predictable and stable international space governance regime supported by international norms and principles. However, the increasingly commercial character of the space domain presents the need to develop norms of behavior that reflect that character and that might inform changes to space governance frameworks. As national efforts - and international discussions - focused on creating or updating regulatory frameworks for non-traditional commercial space activities proceed, norms are a way to shape the development of a system that protects multiple interests and provides stability to most actors. Norms may be established "because formal regulatory instruments many not be timely enough for rapidly-developing activities. Instead, norms can emerge from all actors in a bottom-up fashion, subject to iterations and corrections, as a way in which to create some sort of stability for the new situation that has gotten ahead of formal laws on the matter [5]."

3. Conceptual Foundation for Norms and Their Role in Space Governance

3.1 Conceptual Foundation for Norms

The concept of norms of behavior is simultaneously very familiar and a bit foreign. Most people practice normative behavior on a daily basis, sometimes without being consciously aware of it because the norms are so ingrained in our social interactions. Yet in the realm of public policy, and in particular space policy, the conceptual foundations of norms are often not well known or misunderstood, and the term is often used in a vague manner.

The conceptual foundations of norms of behavior can be found in in the field of sociology. Social norms are informal understandings that govern the behavior of members of society [7]. Social norms often evolve in an unplanned manner out of interactions between members of a society. Their main function is usually to increase the efficiency of transactions and improve overall social welfare. Social norms are often tied to beliefs, which can add a moral context to both an individual's willingness to follow social norms and their perceptions of other's lack of compliance. Whether or not an individual complies with a given norm involves a complex set of interactions between their empirical expectation of how many people follow the norm, a normative expectation that others expect one to comply with it as well, and the possibility of sanctions or rewards being imposed [8]. Norms often begin within a small group, and over time evolve towards broader acceptance within a population, although the exact mechanism is not well understood.

Norms of behavior have also found their way into international relations theory as a potential tool to help explain the behavior of nation states. One of the biggest questions in international relations is why states choose to follow, or not follow, international law. Generally, there are three broad schools of thought on the answer: those who believe state behavior is determined by national interests, those who believe it is determined by domestic politics, and those who believe it is determined by international norms and institutions [9]. The relative strength of each school has varied over time, correlated with broader geopolitical trends. The national interest school held sway during the latter part of the Cold War, while the international norm school saw a resurgence after the end of the Cold War in the mid-1990s [10]. Yet in the mid-2000s, the national interest school began to rise again, with renewed efforts to develop a formal model for state behavior [11].

Norms of behavior can be seen to play three main roles in governance. The first is by moderating or influencing behavior in the absence of laws and regulations on a specific activity. This is the most common use of norms, and includes many of the social norms we follow every day, often unconsciously. The second major role for norms is as the basis for laws or regulation. In some cases, a voluntary norm may be deemed important or pervasive enough to codify into law. The motivation for doing so may be safety related, such as codifying which side of the road automobiles drive on [12], or reflect a moral imperative, such the treaties prohibiting the death penalty for juveniles [13]. The third major role for norms is to help enforce compliance with laws and regulations. For example, both federal local municipalities are finding that informing individuals of their neighbors paying their taxes [14] or refraining from watering lawns during droughts [15] can increase compliance rates.

4. Current International Initiatives Related to the Development of Norms of Behavior in Space

There are a number of efforts linked to the development of norms of behavior in space underway within multilateral institutions, national governments, civil society, and industry associations. While this paper does not aim to provide an exhaustive review of these initiatives, brief discussion of some is illustrative of the overall scope of interest in developing norms of behavior for space activities.

4.1 International Space Debris Mitigation Guidelines

One of the most successful recent normative efforts was the developing of international guidelines for mitigating the creation of new space debris. The effort began in the 1980s with scientists at NASA and the European Space Agency who became increasingly concerned about the growth in human-generated space debris orbiting the Earth and the collision risk it posed to space activities [16]. In the mid-1990s, several major national space agencies created the Inter-Agency Space Debris Coordination Committee (IADC) to coordinate research on space debris. In 2007, the IADC published the first consensus technical space debris mitigation guidelines, which were endorsed by the United Nations in 2008.

Since then, several countries have adopted some or all of the IADC guidelines into national law, and are enforcing them for government and private sector space activities alike. This is an example of a voluntary norm becoming codified in hard law. However, there are concerns that the actual rate of compliance with the guidelines remains low, and there is not yet evidence of a growing trend towards increased compliance [17]. Still, the space debris mitigation initiative is generally regarded as a successful "bottom up" initiative that could be a model for future governance initiatives. There is also growing discussion of among satellite operators of the need for more positive and negative signaling to help encourage compliance.

4.2 Long-Term Sustainability Guidelines

Since 2010 a working group under the auspices of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) has been working to develop a set of long-term sustainability (LTS) guidelines, which aim to publish a set of voluntary "best practices" for space sustainability [18]. The LTS guidelines "reflect

existing best practices used by states and will exist as non-binding norms [19]." COPUOS is working to finalize the LTS guidelines, and efforts will be need to be made to ensure that they remain up to date as new norms and best practices developed as novel activities and technologies are fielded [20].

4.3 Manual on International Law Applicable to Military Uses of Outer Space

The Manual on International Law Applicable to Military Uses of Outer Space (MILAMOS) is an effort led by McGill University in Canada and the University of Adelaide in Australia to clarify how international law applies to military activities in space [21]. The motivation for MILAMOS is the growing concern about armed conflict on Earth extending into space, which may include attacks against satellites and space capabilities. An existing body of international law, known as International Humanitarian Law (IHL) or the Law of Armed Conflict (LOAC), defines the circumstances by which states may use armed force, and limits the effects caused by armed conflict. The MILAMOS Project is an attempt to develop guidance for military lawyers on the application of IHL/LOAC for the space domain in a similar fashion to existing manuals for the maritime, air, and cyber domains. While not binding agreements, the manuals have nonetheless had an impact on how militaries conduct activities in peacetime, periods of tension, and armed conflict.

The MILAMOS Project is expected to run over several years. It involves a group of more than thirty international lawyers, both academics and practitioners, and technical experts. It also includes experts in both IHL/LOAC and space law. An initial kick-off meeting was held in Montreal, Canada, in September 2016. Following the kick-off, the experts are working electronically and meeting in-person at workshops held three times per year in geographically diverse locations. In 2017, the first workshop was held in February in Adelaide, Australia, and the second workshop was held in June in New Delhi, India. The third workshop is scheduled to be held in Colorado Springs, the United States, in October 2017.

4.4 Consortium For Execution of Rendezvous and Servicing Operations

The U.S. Defense Advanced Research Projects Agency (DARPA) is the process of standing up the Consortium For Execution of Rendezvous and Servicing Operations (CONFERS). CONFERS aims to establish an international, industry-led, forum and body to leverage best practices from government and industry to research, develop, and publish non-binding, consensus-derived technical and safety standards for on-orbit servicing operations. In doing so, the program would provide a clear technical basis for definitions and expectations of responsible behavior in outer space [22]."

4.5 Private Sector Statements

Industry trade associations have published consensus statements on best practices in some areas – such as the Satellite Industry Association's (SIA) 2015 White Paper on Responsible Space Operations and the 2016 joint statement of SIA and the Global VSAT Foundation (GVF) on Core Principles for Cybersecurity – which might provide the basis for further development.[23] Some industry actors have suggested the development of self-regulatory organizations (SROs) in key areas of small satellite operations [24].

5. Areas of Opportunity for Smallsat Operations Norms of Behavior

During 2016 and 2017 the Secure World Foundation (SWF) has held a series workshops discussing best practices in several areas related to smallsat and cubesat operation. Topics addressed at these workshops have included: satellite operator best practices for minimizing collisions; space situational awareness (SSA) and smallsats; cubesat launch and deployment best practices; cubesat post-mission disposal best practices; and principles for safe and responsible active debris removal. Discussions at these workshops have identified or raised a number of considerations that should be included in space industry efforts to develop norms of behavior.

5.1 Rendezvous and Proximity Operations

A range of commercial and government development efforts are underway to deploy services that that include close physical approach and operations between multiple space objects, such as active debris removal (ADR) and on-orbit servicing (OOS). In 2012 and 2013 SWF organized a series of international workshops to foster dialogue within the international space community regarding sustainable on-orbit satellite servicing. In April 2017, SWF held a workshop - as a side event to the 7th European Space Debris Conference in Darmstadt Germany - to discuss the basic principles, key issues, and opportunities which need to be addressed in order to ensure that ADR activities develop in a safe, responsible, and transparent matter [25].

As the development of ADR technology progresses and initial demonstration missions are being considered, there is need to facilitate discussion of initial principles

for transparency in operations and approaches. Workshop participants included representatives from several space agencies, commercial satellite end-of-life service providers, spacecraft manufacturers, and industry and academic representatives involved in space debris modelling and tracking activities. Participation included operators of ADR demonstration missions scheduled to occur in the next years.

Recognizing that ADR activities will necessarily involve rendezvous and proximity operations between space objects, raising concerns about both dual-use implications and of the potential to create additional debris through operations, participants were asked to discuss what measures ADR providers or operators could take to provide transparency in their operations. Responses focused on five initial tenants [26]:

1. Provide a clear declaration of intent: the ADR operator/provider should state which object(s) they intend to approach and remove, and their purpose in doing so.
2. If possible, the ADR provider should identify the owner of the target object(s) and establish a relationship with that owner if one doesn't already exist; so that clear ownership and permission aspects are established.
3. Share top level description of the technology (e.g. harpoon, net, tether, etc.) to be used for ADR operations, at a minimum with the owner of the target object, ideally in a public media.
4. Share a public high level concept of operations, with steps and timing of operations, and as operations proceed, provide status updates.
5. Prior to ADR operations, the owner of the target object (and other sources) should share previous observations on the current state of the object with the ADR provider.

5.2 Smallsat/Cubesat Operations

SWF has been involved in facilitating dialogue around industry best-practices for cubesat operations in several areas, including space situational awareness and tracking; launch deployment, and post-mission disposal. In 2016, SWF organized discussions among small satellite operators and space situational awareness (SSA) providers on how to improve detection, tracking, and collision avoidance practices [27]. The discussions highlighted the challenges posed by the growing numbers of small satellites, particularly cubesats that are launched in large numbers. Participants emphasized the need to raise awareness of existing best practices among new satellite operators, and to develop a more comprehensive approach to bringing to market the technology for satellite-mounted devices that can improve the detecting, tracking, and identification of small satellites.

Most recently an SWF-organized side event at the 2017 Small Satellite Conference in Logan, Utah discussed post-mission disposal (PMD) practices for cubesat operators. In a moderated small group workshop format, this discussion with satellite operators (including commercial and academic), satellite manufacturers, and de-orbit and launch service providers focused on actions for increasing confidence in, and understanding of, those practices [28].

This workshop identified several areas or actions through understanding of cubesat PMD compliance practices might be further developed or addressed within the space community. These include [29]:

- Increasing communication on cubesat PMD guideline compliance at industry events, and increasing interaction with the space debris modeling and tracking community to better understand where there is non-compliance.
- Working to build better information sharing links with the policy and regulatory community.
- Leveraging cubesat developer and operator community events to begin to build dialogue on best practices for end of life operations, beyond the de-orbit guidelines.

This last point identifies an area where norms of behavior could be further developed - starting from broadening the conversation around of end of mission best practices and PMD for cubesat operators beyond just de-orbiting. Participants at the workshop expressed a need for the operator community to develop a better shared understanding over how "end of mission" or "end of spacecraft life" is defined. This might include developing best practices for end of life spacecraft passivation and configuration for end of mission, covering topics such as: battery discharge, shutting down transmit functions, and safing of other spacecraft systems [30].

5.3 Large Constellation Operations

Current commercial sector plans to field multiple large constellations to provide remote sensing and communications services offer the potential to greatly expand space-based applications and benefits to society. At the same time, these new constellations, and the possible interactions between them, have raised concerns in the community about their possible impacts on the long-term sustainability of the space environment. Several operators have made public

statements providing a commitment to responsible practices in managing these constellations [31].

As the deployment and operations phases for these large constellations approach, there is an opportunity to further develop these commitments through the creation of shared industry operations principles, norms, and best practices. Speaking at a July 2017 panel session, OneWeb's Director of Mission Systems Engineering stated: "We truly believe that new environmental safeguards and responsible norms of behavior need to be established now in order to ensure the sustainability of future space activities for everybody [32]."

Potential topics that might be considered include:

- De-orbit & decommission commitments & practices
- Orbital plane and altitude separations
- Launch vehicle deployment & satellite check-out practices
- Inter-operator coordination practices
- Satellite tracking, orbital position sharing, and maneuver notification/coordination

6. Conclusion

Normative efforts are a common – and useful approach in multilateral forums where consensus based approach and multi-stakeholder interests make achieving more formally binding measures difficult. Norms are also found in private-sector and industry contexts in which industry actors seek to establish commonly accepted frameworks for interaction and behavior, while simultaneously informing the regulatory environment. In the rapidly innovating and diversifying commercial space sector there is an emerging need for collective action to develop norms of behavior, in complement to efforts underway the multilateral government level. Research conducted by the authors' organization, and others, have identified a number of promising areas where industry norms of behavior might be developed. Some of those areas have been described in this paper.

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