Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C., 20554

In the matter of	)	
	)	
Mitigation of Orbital Debris in the New	)	IB Docket 18-313
Space Age	)	

COMMENTS OF:

ASTROSCALE HOLDINGS
ALTIUS SPACE MACHINES, INC
NANORACKS LLC
ORBITFAB, INC
ROCCOR, LLC
SPACEBRIDGE LOGISTICS, INC
SPACE EXPLORATION ENGINEERING, LLC
SPACENAV, LLC

"GLOBAL NEWSPACE OPERATORS"

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"GLOBAL NEWSPACE OPERATORS"
APRIL 5, 2019

Upon release of the FCC NPRM on "Mitigation of Orbital Debris in a New Space Age"[1] (the "NPRM"), this group decided to provide a joint comment into this critical and timely issue. Comprised of emerging orbital operators, spaceflight safety experts, manufacturing and suppliers, and engineering services, we all have a stake in furthering spaceflight safety by mitigating the creation of orbital debris. Throughout this comment, we will refer to the group as "Global NewSpace Operators".

The Global NewSpace Operators would like to thank the FCC for the opportunity to submit comments towards this NPRM. While we provide comments on specific segments of interest in the NPRM, we would like to point out that any omissions do not indicate endorsement.

[1] FCC NPRM IB Docket 18-313

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INTRODUCTION

The Global NewSpace Operators are comprised of emerging orbital operators, spaceflight safety experts, manufacturers and suppliers, and providers of engineering services. Our missions are to deploy technology that supports the safe and efficient deorbit of defunct satellites, repair and upgrade functional satellites, and provide safety of flight services through the navigation of satellites through congested space.

We urge the Commission to consider a balanced approach that avoids over-regulation and encourages responsible actions in space. This means focus should be given to *behaviors* that sustain the environment vice mandating complex deconfliction solutions that are difficult to enforce nor are internationally recognized. We see the role of the FCC as a regulator that encourages those under its jurisdiction to conform to industry best practices and acknowledges novel solutions to remediate the orbital debris environment, such as passive or active debris removal concepts.

We also have expectations of ourselves and the satellite community. By entering the orbital environment, we believe satellite operators, whether new or established, large or small, experimental or fully operational, have a duty of care obligation, and as part of a space-based social contract, should operate spacecraft with reasonable care to avoid interfering with or harming other spacecraft operations. There should be no room for ignorance of the debris problem from launch to operations to end-of-life. As a manner of speaking, satellites do not operate in a vacuum; there is a large and growing community of space actors that could be affected by the negligent actions of one operator. Core to responsible space operations is transparency of operations and orbital data, ensuring your satellite is trackable and identifiable, and making sure you have not just a deorbit plan that considers a healthy satellite, but one that plans for deorbit with a satellite that is no longer functional.

THE NEED FOR A PARADIGM CHANGE

Just a decade ago, the type and number of commercial operations in space were markedly different from today. Accessibility to launch and proliferation of satellite technology has allowed growth in the space industry, and by extension, has provided greater benefit to citizens on Earth. However, with increased congestion and risk of collision, it is no longer sustainable to operate satellites with rules designed for a different era. There will be unexpected timelines for the refresh of constellations numbering in the hundreds to thousands, greater activity in orbits above 650 km where objects will not naturally decay within approximately today's guide of 25 years, and an increased impact on satellite operators requiring frequent maneuvering to steer out of the way of debris or other active space objects. These are just a few of the new "normals" to come.

There is currently very little economic incentive to take advantage of solutions that are coming to market which assist in the mitigation of orbital debris due to the low-probability/high-impact nature of satellite operations. And, current guidelines encourage operators to achieve the minimum in spaceflight safety, including the "25-year rule". Industry best practices are emerging, but not quickly enough nor are they enforceable.

The Commission seeks to update rules for the mitigation of orbital debris and address this new paradigm in the NPRM. What is not evident within is to what extent is the Commission is prepared to monitor and enforce the rules it is developing. We urge the Commission to develop rules that support positive changes of behavior in space, but also do not inhibit technological solutions that can mitigate future collisions in space.

RESPONSES TO ITEMS WITHIN THE NPRM

A. Control of Debris Released During Normal Operations

The Commission proposes to require disclosure by applicants if deployment devices are used to deploy their spacecraft, as well as a specific justification for their use, and that such disclosure include information regarding the planned orbital debris mitigation measure specific to the deployment device. The Commission specifically references the Special Temporary Authority granted to the spacecraft SHERPA.

Generally, SHERPA and any other propulsive or powered release mechanisms should be treated as any other satellite and be subject to the same mitigation requirements. The Commission should clarify what the metrics for any special justification for use would be and what the metrics would accomplish. There should be harmonization of orbital debris mitigation efforts between this NPRM and other Government efforts, however if the required orbital debris mitigation measures overlap with informational requirements of other agencies, then the applicant should provide a reference to the authorization of the other agency.

B. Safe flight profiles

Quantifying collision risk

Consistent with Global NewSpace Operators balanced approach to these rules, we agree that to the extent an applicant can quantify the risk of collision with a large object during its life, then the applicant should perform the analysis. We assert that small, amateur and experimental operators may have insufficient resources to produce an extremely high-quality report. We agree with the definition that if an object is cataloged, then it is a large object. Our team also recognizes that as it relates to orbital lifetime, the accuracy of the analysis is fraught with uncertainty, and the Commission should recognize this uncertainty as well. And, we agree that if the debris mitigation plan includes maneuvering to avoid collision, the risk is greatly reduced as it relates to the applicant's plan, but we understand maneuvering alone could induce some amount of risk.

Global NewSpace Operators assert the FCC should apply the rule on an aggregate, system-wide basis if the orbital characteristics across the constellation are consistent, but should not include multiple systems, especially if the orbital characteristics between systems are not consistent (e.g., different altitudes or orbital regimes). We believe operators are generally attempting to be responsible and not trying to evade the rules but limiting the analysis to a single system-wide aggregate analysis simplifies the FCC's review and consideration, especially if the constellations maintain separate business plans, schedules, and probability to move forward. Simply put, the FCC should consider each system separately.

If the definition of a large object is an object that is cataloged, then quantifying the probability of collision with a small, uncatalogued objects may be too burdensome for any operator. We suggest that to maintain consistency from satellite to satellite, constellation to constellation, while considering the risk profiles are different from one orbital regime to another, the U.S. Government[2] should conduct this analysis itself and communicate the results to the applicant. Additionally, the FCC should be clear within the rule of its expectations should a satellite or system does not meet the limits of less than 0.01 for small objects[3].

Global NewSpace Operators suggests the FCC provide clear guidance within the rules as it relates to collision risk with other, specifically-identified satellite operators. We agree the applicant should disclose and include the analysis of potential risk of collision with the other system, disclose whether the applicant is currently coordinating or will coordinate with the other system, and that the applicant will specify the measures it has taken to date and plans to take in the future. Additionally, instead of confusing the applicant with regards to what orbital regime this rule applies, extend the rule to all applicants, regardless of orbital regime.

Orbit Selection

The Commission proposes two informational requirements in this section. First, for NGSO satellites planned for deployment above the International Space Station (ISS) that will transit the ISS orbit, the Commission proposes that the applicant provide information about any operational constraints to the ISS or other inhabitable spacecraft and strategies to avoid collision with *crewed*[4] spacecraft.

It is unclear to this group how the FCC intends to apply the information it proposes to collect in this circumstance. It is also unclear how the FCC is defining "transit the ISS orbit." If this means satellites being deployed at the same inclination and in the same plane, then the necessary coordination with NASA is required. Currently only ISS resupply vehicles are deploying satellites above the ISS in the same inclination and plane, and NASA has completed extensive analysis to demonstrate a minimum safe altitude for deployment of spacecraft above the ISS that results in an acceptable level of risk of having to conduct debris avoidance maneuvers. More clarity on these two points could lead to more substantive feedback.

Generally, being prescriptive regarding orbital regimes should not outweigh the consideration of safe practice and behaviors in space, such as, but not limited to, in-orbit maneuverability, active deorbit plans, and backup deorbit plans. We agree that there should be some requirement for maneuvering capability above crewed spacecraft, but that this requirement

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[2] NASA is likely to be the appropriate agency here.

[3] Per the NPRM, "The NASA Standard provides that for each spacecraft, the NASA program or project demonstrate that during the mission of the spacecraft, the probability of accidental collision with orbital debris and meteoroids sufficient to prevent compliance with the applicable postmission disposal requirements is less than 0.01".

[4] See NASA Style Guide, *Gender-specific language.* https://history.nasa.gov/styleguide.html

should be technology neutral and allow for operators to meet a safety objective based on realistic standards that do not preclude smaller operators from performing technology demonstrations, and built upon a dialogue between the satellite community and the human spaceflight community, which includes NASA and future private space habitat operators.

Next, the Commission proposes that the applicants provide justification or rationales for choosing particular orbits based upon altitude (above 650 km), mission lifetime to orbital lifetime ratio, and density of orbit.

This group appreciates the intent here as there is a greater risk of orbital debris being created for operators that choose an altitude above 650 km simply because it will be in orbit for a longer period of time, however this requirement could prove problematic. Operators choose orbits for a variety of reasons to include both mission performance and launch accessibility. Each applicant should understand the environment in which they are operating and should make a showing that they understand and outline the risks to the FCC in a detailed post mission plan. If applicants are required to describe the debris environment, the FCC should point to a standard model, such as software already provided by NASA.

Similarly, requiring justification of the orbit selected for satellite operators that will remain in orbit for a period of time longer than their mission lifetime could prove complex if not effectively monitored or enforced, and it is unclear that it will bring any benefit in the end. In fact, it could have the effect of pushing satellite operators out of the United States to jurisdictions that do not have burdensome and seemingly arbitrary requirements for justification of a deorbit time based upon the mission lifetime. It would be better to ensure deorbit and backup deorbit capabilities based upon a guidepost, rather than a complicated scheme impractical to enforce.

This would also apply to any proposed requirement for justification for selection of a crowded orbit. Applicants should be asked to show how they plan to mitigate risks, but not to justify the selection of the orbit. It is still unclear based on the wording of the proposals how the FCC would determine an applicant has sufficiently justified their choice of orbit. What threshold of congestion would be considered too risky?

The Commission also asks if they should require all NGSO satellites planning to operate above a particular orbit to include propulsion capabilities, and if so what altitude. This is a broad question without a public interest justification. It is unwise to mandate a specific technology, because there are other non-propulsive technologies that could affect deorbit maneuvers that are not considered in that proposal, and could, again, drive business out of the U.S. to other jurisdictions.

Tracking and Data Sharing

The Commission proposes to require a statement from applicants regarding the ability to track proposed satellites. We generally agree with this approach and point out that there are current and emerging commercial space surveillance capabilities that are improving the trackability of space objects. However, the Commission may not be able to verify the technical capability of these space situational awareness (SSA) data and services. The Commission, therefore, should provide further detail of what information they are looking for in such a statement (for example, to what accuracy and how often should tracking occur?), and whether or not they require verification from the SSA provider that they can indeed track the proposed satellites.

While the ability to track satellites is an important element for safe space operations, so is the identification of satellites. For some deployments, dozens of satellites are released within a close time period in the same orbit making it difficult to distinguish which satellite belongs to which owner. For example, the SSO-A satellite deployment from December 2018 released 66 objects[5]. As of March 4th, 2019, four have yet to be identified, according the SpaceFlight Industries[6]. To help remedy situations such as this, we believe the Commission should take into consideration in the application the use of radio-frequency transponder tags, such as those being currently researched under several ongoing DARPA TTO SBIR Phase II research grants[7], or other unique telemetry markers that can support identification of objects that may not have positive communication once in orbit.

Overall, it may be more practical to have the applicant state the ability, from launch to end-of-life, to obtain or generate precise orbit determination and identification for its satellite(s). How this is achieved can be outlined in the application, available for evaluation and comment by the Commission. A variety of methodologies, both active and passive, could be listed to support the plan for precision and frequency in the operator's satellite tracking and identification.

With regards to an operational rule requiring NGSO satellite operators to provide certain information to the 18th Space Control Squadron (18SPCS) or any successor civilian entity, we consider this type of data sharing to be good practice but stop short of agreeing to mandate it for delivery under regulation to the 18SPCS. A civilian entity is a more desirable option for the handling of SSA data stemming from commercial satellite operators and provision of government-based space traffic management services. As such, we support the establishment of a civilian agency whose authority will include space situational awareness (SSA) and space traffic management (STM) specifically for civil and commercial space users.

Finally, the Commission proposes that applicants for NGSO systems certify that the operator will take certain steps to assess and mitigate a collision risk upon receipt of a conjunction

[5] https://www.spaceflightindustries.com/2019/03/04/sso-a-deployment-status/

[6] However, there are observers that state 13 SSO-A objects were still not identified by March 4th: https://twitter.com/planet4589/status/1102740681515253761 whereas the 18SPCS has still not identified the owner/operators of 19 of those objects: https://www.theverge.com/2019/4/2/18277344/space-situational-awareness-air-force-tracking-sso-a-spaceflight-cubesats.

[7] Multiple Phase I and Phase II contracts were funded under DARPA 2017 SBIR Topic Number SB171-015.

notice. We agree that operators should share as much information as is practical to avoid a collision but that industry best practices should decide further specifics as to what information needs to be shared in the event of a conjunction notice. We recommend the Commission simply require the applicant to have an operational procedure and process for a conjunction warning, whether the satellite is maneuverable or not.

Maneuverability

NewSpace Global Operators agrees that it is beneficial for satellite operators to understand other satellite's/system's maneuvering capabilities, but only to the extent that disclosure does not reveal proprietary information about the applicant's system. It goes without saying that this knowledge and subsequent communication is paramount as it relates to a collision avoidance maneuver plan. We strongly encourage this disclosure as a best practice, however, we fall short of suggesting such practice is mandatory.

While we agree that the Commission should not mandate a satellite to have maneuvering capability, we believe it is a good practice and sound system design, especially if the analysis during the application process reveals significant risk.

Regarding emerging technologies that include differential drag, our team is well-versed in the concept, and believe with advanced warning and with the ability to plan, it can be an effective approach for debris mitigation in general. However, with certain scenarios, this type of an approach may not be practical to reduce the risk or avoid collision at all. For example, implementing a drag maneuver within hours of a close approach may not be effective. Global NewSpace Operators supports disclosure of such systems, if no other constraint exists that would preclude the applicant from disclosing (i.e., proprietary reasons).

Multi-Satellite Deployment

The Commission seeks comment on whether they should include additional informational requirements regarding launches with a single deployment of multiple satellites or use of a free-flying deployment device, what mitigation measures are commonly used, and whether the Commission should adopt any of them as requirements.

This is certainly an area for the launch community to comment on, and to provide input on whether there is any overlap with Federal Aviation Administration (FAA) regulations[8]. Multiple techniques are used to mitigate the risk of collision on such launches. These include phased deployment (i.e. NASA requires 1.5 hours between deployments) and the release of

[8] For example, the FAA has released a draft Notice of Proposed Rulemaking regarding Streamlined Launch and Reentry Licensing Requirements which includes elements of a debris analysis: https://www.faa.gov/news/updates/media/SLR2_NPRM.pdf

satellites at different angles. The goal here should not be to prescribe any one method, but to evaluate them on a case by case basis depending on the mission parameters.

C. Post-Mission Disposal

Probability of Success Disposal Method

Multiple NASA and ESA studies in recent years, including several referenced in the NPRM, have shown that the *achieved* reliability of post-mission disposal operations is one of the most critical factors in the growth of the LEO debris environment. Based on the NASA Orbital Debris Program Office (ODPO) study referenced in the NPRM[9], for large constellations, the *achieved* post-mission disposal reliability needs to be in the >95-99% reliability region to avoid a massive increase in the quantity of debris in LEO. It should be noted that the achieved post-mission disposal reliability to-date since the establishment of the existing orbital debris mitigation guidelines is well below 90%[10], so achieving this much higher rate of post-mission disposal reliability will almost certainly require a different approach than what has been used to-date.

Specifically, we believe that it is unlikely that a 99% post-mission disposal reliability is achievable solely through trying to make the satellite designs more reliable. Achieving these levels of reliability will almost certainly require a "defense in depth" approach that includes not just design and fabrication reliability, but also one or more of incorporation of backup disposal systems, capture interfaces for enabling cooperative disposal tug services, servicing interfaces to enable repairing failed but repairable satellites, and potentially other means of ensuring reliable post-mission disposal even if the satellite itself has completely failed.

In some ways this is analogous to the current approach to human spaceflight launch safety -- even the best current rockets are typically 95-98% reliable, which is inadequate reliability for crewed missions, but if you combine a reliable rocket with a reliable launch escape system, it is possible to achieve a much higher overall probability of avoiding crew casualties. A 90% reliable rocket with a 90% reliable launch escape system can provide a 99% probability of not losing the crew. Likewise, because of diminishing returns it is much more likely to be able to achieve a 99% post-mission disposal reliability by combining a 90% reliable satellite design and a 90% reliable backup post-mission disposal technique/system than trying to design a satellite with 99% reliability.

As such, Global NewSpace Operators agrees with the Commission's recommendation that satellite operator applicants should provide information concerning the expected reliability of their post-mission disposal measures, and how those reliability estimates were derived. While the FCC should not be prescriptive in how applicants meet post-mission disposal reliability

[9] NASA Orbital Debris Quarterly News, Aug 2018, Large Constellation Study (J.-C. Liou, M. Matney, A. Vavrin, A. Manis, and D. Gates)

[10] European Space Agency. "ESA's Annual Space Environment Report," April 27, 2017, https://www.sdo.esoc.esa.int/environment_report/Environment_Report_I1R2_20170427.pdf

requirements -- we want the FCC to encourage innovative approaches to how this problem is solved -- it is appropriate to ask applicants how to factor in a primary disposal plan and also describe what their backup plans are in case one or more satellites in their fleet fail prior to completion of their own deorbit maneuvers. We believe, based on the current NASA and ESA research, large constellations (>100 satellites or >10,000kg of aggregate constellation mass) may need to be held to a much higher target of >95-99% post-mission disposal reliability than small constellations or applicants proposing individual satellites, where a 90-95% estimated post-mission disposal reliability target might be acceptable.

Factoring in Deorbit Tug Services Into Post-Mission Disposal Reliability Assessments

Another consideration in assessing post-mission disposal reliability estimates is how to quantitatively factor in the use of deorbit tugs for backup post-mission disposal into estimates of post-mission disposal reliability. Because commercial deorbit tug services are not yet proven and commercially available, there is some level of uncertainty whether such service will be available when needed. However, nearly every study on orbital debris issues known to our group has concluded that the ability to actively remove debris objects will be required for long-term sustainability of the LEO environment. We believe the Commission should follow the progress of such back-up methods for disposal and look favorably on applicants with back-up deorbit plans should their satellite(s) suffer a malfunction in orbit. While such deorbit tug solutions are still in development, we believe the Commission should provide some favorable weighting for applicants who take active measures to design their satellites with capture interface for deorbit tugs, and a more favorable weighting for applicants willing to either contract with or purchase an insurance policy covering such disposal tug services.

Design Requirement

Regarding the Commission's request for comment on the idea of requiring a design and fabrication reliability requirement, of for example 0.999 per spacecraft, the Global NewSpace Operators agree that ensuring high design and fabrication reliability is a necessary and very important part of a comprehensive post-mission disposal plan, but we are not sure that requiring operators to prove some specific level of theoretical design reliability will always be sufficient to achieve the desired post mission disposal reliability targets by itself. As stated earlier, we feel the best approach is to have the applicants describe their overall approach to achieving the required level of post-mission disposal reliability, of which design and fabrication reliability are only one of several tools for solving the problem, which also includes backup means of achieving successful post-mission disposal.

Overall, larger constellations and constellations operating at higher altitudes (>650km), or the corresponding altitude if the allowable deorbit period is reduced from the current 25yr guidelines, should be held to a higher standard than individual satellites, small constellations, or satellites operating at lower altitudes, such as those that operate below most valuable commercial and national assets such as the ISS.

Other Requirements for satellites with planned operations in LEO

With regards to the proposal to have satellite operators confirm full functionality of a satellite below 650 km before maneuvering to a higher orbit, there are several items to consider. While checkout at a lower altitude may result in a defunct satellite that can naturally deorbit within the 25 year guideline, it may be preferred to conduct a checkout in the operational orbit so long as a backup deorbit mechanism is placed on the satellite, or there is sufficient reliable backup deorbit propulsion that will deliver an alternative means to a safe and timely deorbit. Additionally, satellite performance can be better determined in the operational orbit for which it was designed. Because spacecraft anomalies can occur at the beginning, middle and end of a satellite's operational life, an initial orbit below 650 km does not guarantee the satellite will not malfunction in a higher orbit. Therefore, while we encourage the practice of checkout prior to arriving at a higher orbit, we do not recommend regulating this checkout at a specific altitude, rather, propose the Commission ensures the license applicant has a pathway to deorbit should their satellite(s) malfunction, regardless of altitude.

With regards to testing the operational capabilities of a certain number of satellites in a lower orbit for a number of years before deploying the full constellation, in theory, such action would be a recommended practice in order to discover design failures that manifest after launch. However, requiring "years" of testing in-orbit would not be a viable option due to the economic challenges it presents for the operator as it would drive long iteration cycles and add time to market in an industry that iterates on a much faster level than before. We recommend operators set their own timelines for in-orbit testing of new technology, allowing them to lean forward in business objectives while mitigating any risk from widespread design issues. The Commission will not have the technical insight to know how long is enough for testing of various satellite technologies in-orbit and thus, industry should lead in determining the right parameters to ensure its satellite technology is truly functional.

The Commission proposes that applicants provide a statement that spacecraft disposal will be automatically initiated in the event of loss of power or contact with the spacecraft. We would like to point out that many constellations will be using low-thrust propulsion systems that can require multiple months of continuous operations and control in order to move from an operational orbit to a safe orbit. Therefore, an automatic initiated disposal is not practical in this case. The Commission also asks if there should be a requirement in the design for automatic disposal by deorbiting device. Automatic deorbit devices become progressively less effective as operating altitude increases. Below approximately 800 km, there are options for automatically deployed deorbit devices, such as drag sails. Above 1000 km, where a large number of satellites are planned to operate, most passive deorbit systems become impractically large to achieve a 25-year disposal timeline. We recommend that the Commission and satellite operators consider practicality of solutions for deorbiting a satellite without power or communications, whether the method is passive or active.

The Commission asks if there are other technologies that can be used to ensure that satellite disposal is completed in the event of a major anomaly, and should the Commission require their use during operations in particular regions. There are several technologies that could be considered for disposal of a satellite with a major anomaly. The goal is to achieve a PMD rate such that orbits remain usable and that debris-making events are minimized. This PMD rate has been proposed as 99% by NASA and can be much harder to achieve in altitudes above 650 km due to the inability to have a naturally decaying orbit within 25 years. We ask the Commission to consider applicants favorably that have backup deorbit devices so long as it is effective in removal within 25 years or lower. At lower altitudes, backup deorbit drag and propulsion kits that automatically trigger on failure of the satellite can potentially be an effective solution, but a capture interface that permits attachment to the satellite combined with a deorbit tug may be a more practical way to guarantee PMD reliability at higher altitudes.

The Commission proposes in-orbit testing and automatic deorbit capability apply to satellites above 650 km and below 2000 km. This proposal does not take into account the impact from the spread of debris should a collision occur. In-space collisions, including those resulting from defunct satellites, can send debris into orbits with perigees and apogees as much as 300-500 km different from the colliding objects. Therefore, collisions at lower altitudes than 650 km can still endanger satellites at higher altitudes. For larger constellations below 650 km (>100 satellites), some backup means of disposal (either capture interface, drag kit, or deorbit propulsive system, etc.) should be encouraged.

Means of LEO Spacecraft disposal

In addition to the typical primary deorbit plan for most satellites including a deorbit propulsion system and reserving sufficient propellant for deorbit at end of life, there are several backup means of achieving post-mission disposal that could make sense as part of an applicant's post-mission disposal reliability plan. Two main categories of backup disposal methodologies include pre-installed backup deorbit systems, and the use of deorbit tugs.

Several companies have proposed a wide range of backup deorbit systems that can be preinstalled into a spacecraft before launch. These include deployable drag sails[11], inflatable drag balloons[12], electrodynamic tethers[13], plasma brakes, backup deorbit rockets[14], and potentially others. These systems have the benefit of being preinstalled, triggered in case the spacecraft fails prematurely, and do not require complicated rendezvous and capture operations, but may not be suited as the operating altitude of the spacecraft increases; most drag based systems stop being practical around 900-1000km altitude.

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[11] Davis, B. et al "Planning for End-of-Life Satellite Disposal; The Story of a High Strain Composite Tip-Rolled De-Orbit Sail" 32nd Annual AIAA/USU Conference on Small Satellites, https://roccor.com/wp-content/uploads/2018/07/Davis-SSC18-XII-06-SmallSat-Paper-FINAL.pdf

[12] http://gaerospace.com/projects/GOLD/index.html

[13] http://tethers.com/TT.html

[14] https://www.deorbitaldevices.com/wp-content/uploads/2016/06/D3-Technical-Sheet.pdf

There is significant development and on-orbit demonstration activity with respect to deployable drag sails. Aerodynamic drag works by changing the projected surface area of the spacecraft on-orbit, which directly interacts with fast-moving atoms in the ionosphere to provide increased drag. Numerous deployable drag sails have been developed having a primary architecture consisting of a thin sail membrane that deploys via structural booms. Flight heritage of this type of sail include NASA's NanoSail-D2 in 2010 (note, this was actually a solar sail, but similar concept to a drag sail), and the University of Surrey, Surrey Space Center's InflateSAIL in 2017. Several other designs are in development by various entities, including Roccor[15], with imminent flight demonstrations planned.

The other class of solution for backup disposal is the use of deorbit tugs. Again, several companies are developing deorbit tug vehicles designed to rendezvous with, grapple, and then maneuver a failed spacecraft into a safe disposal orbit. One key difference between these commercial deorbit tug services and past active debris removal efforts is the focus on having clients pre-install capture interfaces and other lightweight, low-cost cooperative servicing aids, to reduce the risk, cost, and complexity of rendezvous and capture. While such cooperative deorbit services are still somewhat complex and risky, they are in a different risk/cost profile from active debris removal systems for legacy space debris objects. These solutions are more operationally complex than pre-installing a deorbit kit and will generally be more expensive on a per-deorbit basis but can operate at a wider range of client satellite operating altitudes where the up-front costs can be minimized and where deorbit services are procured only for failed satellites.

Two of the members of this comment team, Altius and Astroscale, are actively developing capture interfaces that incorporate a thin ferrous gripping target that can allow for magnetic capture of the client vehicle and are in talks with several NGSO constellations about incorporating such capture into their vehicles. Due to the ability of magnetic capture systems to attract the interface even at a non-zero distance, these passive magnetic capture interfaces can provide a way to simplify the capturing of even tumbling targets without risking the creation of secondary debris from the use of harpoons or nets. By including capture interfaces into a design, and publishing the interface, the operator now has a way to enable disposal of failed satellites.

Additionally, DARPA is funding SBIR contracts with several companies to develop low-cost transponders that can be placed on satellites[16]. Some of these rely on passive RFID technology, others are self-powered, but all of them provide a backup means of tracking even a failed satellite, and in some cases can provide additional state data such as tumble rates. The combination of capture interfaces and transponder beacons can both increase the reliability of deorbit services and provide improved ways to track failed satellites at very low up-front cost to constellation operators.

[15] https://roccor.com/
[16] These were funded under DARPA 2017 SBIR Topic Number SB171-015

Because the required post-mission disposal reliability to obtain long-term sustainability of orbit is high, we urge the FCC to consider appropriate ways to encourage applicants to evaluate and incorporate backup deorbit systems, capture interfaces and other cooperative servicing aids, and transponder beacons into their spacecraft or constellation's post-mission disposal plans, instead of relying solely on the assumption that their spacecraft will never fail on orbit.

Disposal of NGSO satellites in orbits above LEO

With regards to the disposal of NGSO satellites in orbits above LEO, we would like to echo the comments made by the Aerospace Corporation[17] to take into consideration orbital eccentricity and inclination in assessing the impact of disposal above LEO. In general, we ask the Commission to ensure such technical assessment is detailed and robust for orbits above LEO and to encourage satellite operators to have a backup deorbit mechanism or deorbit tug capture interface on the satellite should there be an affordable and effective method to remove the satellite from orbit.

Post-mission lifetime

We are supportive of shortening post-mission time to deorbit from 25 to 5 years or less, particularly for large commercial constellations in congested orbits. However, a passive deorbit approach (i.e. drag sail) utilizing up to the full 25 year deorbit window should be allowed in some cases. Examples of this satellite class include non-profit entities such as university cubesats, science focused payloads or one-time demonstration missions.

For all deorbit mitigation techniques, a standard evaluation of deorbit time needs to be established. For example, a standardized tool taking into account the solar cycle, atmospheric density fluctuations and calculation of the spacecraft's ballistic coefficients is key to accurately predicting de-orbit times. This also ensures fairness and consistency among the spacecraft community.

We note that large constellations at altitudes that deorbit naturally within a 25-year timeframe (or even 5 years) may not be sufficient in itself to negate the need for a back-up deorbit solution, particularly when traversing through zones with crewed spacecraft or lower orbits that are congested. Post-mission disposal reliability is still a critical element of orbital debris mitigation. Both shortening time in orbit after operations have ended and ensuring post-mission disposal reliability together yield an ideal solution for orbital debris mitigation. Rigorous means should be employed to establish on-orbit verification defining the performance of the deorbit system. In the case where the spacecraft is non-responsive, the deorbit system should be capable of becoming triggered via a ground command, timer or

[17] 9 Dec 2018, In the Matters of Mitigation of Orbital Debris in a New Space Age, Comments of the Aerospace Corporation, page 16, "Probability of Success of Disposal Method, paragraph 55-57"

fault identifier, similar to a 'kill-switch' currently employed on launch vehicles. Deorbit performance is ultimately identified via ground-based tracking of the debris. The reliability of a specific deorbit technology should be assessed and considered for subsequent missions.

D. Proximity Operations

The Commission proposes that applicants be required to disclose whether the spacecraft is capable of, or will be, performing space rendezvous or proximity operations (RPO). Our response is that this capability should be evident in the application, but we seek to understand the intent of a specific disclosure or what details the Commission requires with regards to such a disclosure. The Commission should also apply the need for communicating maneuvers in general to RPO activities.

With regards to a proposed notification requirement and more specific information to be provided to the 18SPCS, we believe it a good practice for operators to share as much detail as practical, within the limits of export control or proprietary information, with whichever U.S. agency is responsible for SSA and/or STM. During some RPO activities, SSA sensors will detect two single objects merging into one object. Providing information to the 18SPCS or other civil agency on the identification of these objects throughout the operation will help to maintain accurate space situational awareness.

Further, we refer the Commission to industry best practices and standards being developed on an ongoing basis by the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS). CONFERS members are stakeholders in rendezvous, proximity operations, and on-orbit servicing activities and have developed both guiding principles[18] and recommended design and operational practices[19].

E. Operational Rules

Orbit Raising

The Global NewSpace Operators agree that the frequency of orbit raising at NGSO will continue to increase and the Commission should ensure rules are adapted that balance orbital safety without overburdening the small operator; however, we have a few clarifying comments and suggestions. The referenced existing rule 47 CFR 25.283 appears to regulate GSO operations in general, whereas, the rules we are reviewing have a specific purpose to mitigate orbital debris. Therefore, the rules concerning orbit raising should, likewise, focus on encouraging safe operations with the intended result to reduce orbital debris. This does not suggest this team disagrees with TT&C/RFI coordination, but we believe the Commission

[18] *Guiding Principles for Commercial Rendezvous and Proximity Operations (RPO) and On-Orbit Servicing (OOS)*, CONFERS. https://www.satelliteconfers.org/wp-content/uploads/2018/11/CONFERS-Guiding-Principles_7Nov18.pdf

[19] *CONFERS Recommended Design and Operational Practices*, CONFERS https://www.satelliteconfers.org/wp-content/uploads/2019/02/CONFERS-Operating-Practices-Approved-1-Feb-2019-003.pdf

should clarify its intent to implement orbit raising rules as it relates to mitigating orbital debris.

Additionally, orbit raising at GSO has unique implications, whether the purpose is end-of-life or repositioning in general, as coordinating conjunctions (and RFI) with other GSO operators are somewhat predictable, and relatively “slow-moving” events; however, NGSO orbit raising is relatively much faster as it relates to other NGSO satellites, with conjunctions from an RFI perspective occurring many times an orbit and, in fact, a specific RFI event may occur without impacting operations due to the short duration. We suggest that the Commission clarify its position, considering the difference in orbital characteristics between GSO and NGSO, as it relates to RFI and focus the rule on encouraging operators to coordinate orbit raising, as it should for any maneuver type, with the purpose to mitigate orbital debris.

Maintaining Ephemeris Data

The Commission proposes that NGSO operators be required to maintain ephemeris data for each satellite they operate and share that data with specific operators or U.S. Government entities. Two potential issues could arise from this requirement. First, some operators rely on Department of Defense produced Two-Line Element sets (TLEs) and therefore would not have ephemeris to share. Further, ephemeris that is provided may not be of adequate quality. The Commission could ask the applicant for details of how they will maintain ephemeris in their application. All satellite operators, including those with amateur and experimental licenses, should follow the same recommendations. Finally, we believe the sharing of ephemeris amongst satellite operators should be encouraged, should such ephemeris be available.

Telemetry, Tracking, and Command Encryption

The Global NewSpace Operators have multiple suggestions to the Operational Rule to require TT&C encryption. First, we want to ensure the Commission is aware of a satellite industry cyber security statement jointly prepared by the Satellite Industry Association (SIA) and the Global VSAT Forum (GVF)[20]. The statement encourages industry participants to adopt industry and Government cyber security best practices to protect all aspects of space systems. The Commission may elect to adopt some of the language within this rule; however, the statement is rather broad, covering cyber security across the entire space system which can be burdensome to implement for a small satellite operator. Therefore, we suggest the Commission be specific about the risk it is attempting to mitigate and why. For example, instead of implying a risk, the Commission should state, as an example, its desire to mitigate the risk of inadvertent or malicious commanding of a satellite’s propulsion system, maneuvering the satellite into an unknown and potentially catastrophic orbit. Furthermore, it

[20] *Joint Statement on the Satellite Industry’s Commitment to Cybersecurity,* Nov 2016. https://www.sia.org/wp-content/uploads/2016/11/SIA-GVF-Joint-Cybersecurity-Policy-Statement-FINAL-v.1-Nov-2016.pdf

is not clear what the Commission means by the phrase "for example, delta velocity capability" (delta-V for orbital velocity, delta-h for attitude only thrust maneuvers, or both?). A solution could be to quantify a total thrust capability that might clarify the criteria for encryption and the risk. Additionally, we do not advocate to enforce any specific mitigation approach. Perhaps other mechanisms or operational procedures would satisfy the intent for the Commission. For example, specific command sequences, command structures, or two-factor authentication.

We also found that the scenario outlined in the NPRM regarding radio frequency interference (RFI) confused the primary objective to mitigate orbital debris. Although our team recognizes RFI as an issue, we are unclear regarding the intent of the following phrase: "recognizing that other possible harm, such as radio-frequency interference, could result from such scenarios?" It is not clear to what scenarios the Commission is referring. We suggest a statement that the Commission encourages operators to employ a mitigation approach to prevent inadvertent or malicious commanding of their satellites, with the primary objective being debris mitigation, with the additional benefit to prevent, for example, turning on the TT&C system which could cause RFI. Our team recognizes the list of negative effects to a satellite, neighboring satellites, and the surrounding environment is lengthy as it relates to unauthorized access to a satellite.

Liability Issues and Economic Incentives

The Commission is seeking comment on how insurance might serve as an economic incentive by incentivizing operators to adopt debris mitigation strategies that reduce risk and lower insurance premiums. Currently, only 5% of low-Earth orbiting satellites possess insurance[21]. This is due to operators deciding they do not need insurance, are unable to secure insurance, or cannot afford insurance. The Global NewSpace Operators agree that debris mitigation strategies would ideally reduce insurance premiums but at the moment, collision risk is not adequately priced into third party liability insurance.

We see the insurance market needing to evolve in two ways before debris mitigation strategies become incentivized through premiums. First, new insurance products need to be developed that encompass new orbital activities, such as end-of-life deorbit services. Second, the premium pricing model will need to be updated to match the collision risk. For example, while the UK Space Agency requires third party insurance before a license is granted, there are no incentives in place to ensure the insurance companies update those premiums to reflect collision risk. The U.S. insurance market could indeed remain competitive by offering new products for a new era of space activity matched with premiums that can be updated to reflect collision risk.

The Commission also asks whether there are any distinctions that might be made between different types of operations that are higher or lower in risk. Here, a space sustainability

[21] XL Catlin/AXA XL. *Space Insurance Update*, Jan 2019.

rating could prove valuable. The World Economic Forum Global Future Council on Space Technologies is helping to steer such a Space Sustainability Rating project[22]. The results could be used by insurers as a market standard to assess risks posed by the operator to the orbital environment.

F. Scope of Rules

Amateur and Experimental

The Global NewSpace Operators encourage amateur and experimental operations and we also agree these operators need to operate responsibly. Given the complexity and cost to develop comprehensive debris mitigation plans, we suggest the FCC establish a balanced approach by publishing guidance and requiring any operator to follow rules. The FCC must understand that the plan from these operators may not be as comprehensive as plans from commercial operators, therefore, the FCC must be prepared to support these operators with follow up guidance. Contrary, our team does not believe amateur and experimental operators should be allowed to carry out a plan that imparts undue risk to other operators or the space environment in general.

Furthermore, consistent with our comment to the ephemeris topic earlier in our comments, small operators may not have the resources to provide ephemeris and rely on Government provided TLEs for operation. We suggest the FCC encourage generating and sharing ephemeris, but do not suggest mandating this rule to amateur and experimental operators.

Non-U.S. Licensed Satellites

The Global NewSpace Operators agree the NPRM rules should apply to non-U.S.-licensed operators seeking access to the U.S. market. We also agree that the degree of activity is not a factor and that transmission and reception on a limited basis, such as telemetry, tracking and commanding, still constitutes a commercial reason and the operators should be held to the same rules as U.S.-licensed operators. Recognizing an operator received a license from non-U.S. administration amounts to reciprocity, and our team encourages this practice as long as the administration in question also encourages or otherwise mandates responsible space operations. We agree a case by case policy is the correct approach.

G. Regulatory Impact Analysis

Prioritizing Approaches to Reducing Debris in Orbit

The Commission seeks comment on six approaches to reducing debris in orbit. The Global NewSpace Operators agree that a blend of approaches are necessary to sustain operations in Earth orbit but the Commission may not be the appropriate entity to apply rules in some or all

[22] https://www.weforum.org/communities/the-future-of-space-technologies

of these approaches. For example, the Commission cites adopting rules that reduce the overall number of satellites launched. Such rules would severely impact the health of the U.S. space industry, stifling innovation and ceding leadership. It also usurps the authority of the Department of Transportation, Federal Aviation Administration to encourage, facilitate, and promote commercial space launch and reentry.

Therefore, we are providing our perspective on prioritizing the regulatory approaches to reducing debris in orbit for a wider whole-of-government audience. We do not recommend mandating in regulation specific satellite design concepts or active collision avoidance, rather prefer that these elements emerge as industry best practices with the most effective and innovative solutions available. The government certainly has a role to play in incentivizing industry to become more active in preserving Earth orbit. We believe the U.S. government should adopt policies that support research and development, and commercial operations that mitigate and remediate orbital debris. This would include the removal of U.S. government derelict objects in space, such as upper stage rocket bodies.

We agree that there is a business imperative to remove defunct satellites from orbit but requiring satellite operators to engage in active debris removal at this time, especially as the costs of such services are not yet well established, would likely have unintended negative consequences of operators seeking licenses elsewhere. The use of such services should be encouraged; however the most practical, cost-neutral, and immediate regulatory actions can come from requiring changes in operations and disposal procedures. This echoes our above comments supporting several proposals within the NPRM that would result in a change in satellite operator behavior to achieve a maximum post-mission disposal rate (above 95%).

Role of the FCC with Multiple U.S. Government Stakeholders

In the NPRM, the Commission asks how it can ensure an appropriate, coordinated approach that avoids duplication of efforts within the U.S. Government. The Global NewSpace Operators recognize the role of the FCC in integrating debris mitigation guidelines into regulation since its 2004 Orbital Debris rulemaking[23]. There are benefits that have resulted from this role. First, the license application process is very transparent, allowing the public to better understand the debris mitigation and deorbit plans of satellite operators. Second, the Commission has a global reach, able to request the same debris mitigation information from foreign companies looking for U.S. market access.

At the same time, we have several concerns with the Commission's role in orbital debris mitigation as a regulator. First, we are concerned there is not enough in-house expertise specific to orbital debris matters at the FCC, especially as the issue is growing in importance. To mitigate this issue, we recommend the Commission collaborate with experts in the debris mitigation plan review process while ensuring not to add on to the complexity or time required towards a license. The Commission should also consider establishing an advisory

[23] *In the Matter of Mitigation of Orbital Debris,* IB Docket 02-54, released June 21, 2004.

committee made up of academic, non-governmental, and industry experts in order to access expertise and advice regarding orbital debris mitigation, analogous to other government Federal Advisory Committees, such as the FAA's Commercial Space Transportation Advisory Committee (COMSTAC). We are also concerned that there is inadequate monitoring and enforcement of debris mitigation rules. We urge the Commission to outline how it intends to monitor licensee activities in space for adherence to the rules and specify methods of enforcement.

Third, while we refrain from commenting on statutory authorizations of the FCC, we recognize there is concern within the satellite community whether the Commission has the proper jurisdiction to lead on orbital debris mitigation regulation. Space Policy Directive-3 (SPD-3) gives direction to develop space traffic standards and best practices including "technical guidelines, minimum safety standards, behavioral norms, and orbital conjunction prevention protocols related to pre-launch risk assessment and on-orbit collision avoidance support services". Orbital debris matters require an inter-agency dialogue and thus we urge the Commission to develop or update rules in a manner that ensures harmonization with other department and agency efforts per SPD-3. This will ensure clarity and predictability of regulations with regards to orbital debris mitigation.

We also recognize that orbital debris affects all stakeholders in space, not just one nation. There needs to be international consensus on what constitutes safe and responsible behavior in space otherwise such rulemaking efforts will not be as effective, and industry will be tempted to gain license approval outside the United States where such detailed consideration of orbital debris mitigation is lacking. We recognize the efforts of the U.S. State Department here, having supported the development of 21 long-term sustainability guidelines at the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS). We also recognize NASA's efforts within the Inter-agency Debris Committee, where debris mitigation guidelines were first developed within this multi-lateral body. We encourage the Commission to collaborate with the Department of State and NASA to promulgate similar orbital debris mitigation actions outside the United States, specifically for engagement on the issue at the ITU.

H. Other Considerations

The Global NewSpace Operators would like to offer for discussion two additional items. First, it is important to understand how current or pending license approvals are affected by this NPRM. For operators already on-orbit, it is not practical to apply new debris mitigation requirements retroactively. However, there may be a need to selectively apply updated debris mitigation rules to large constellations yet to be launched, such as any changes to end-of-life deorbit timelines.

Additionally, we feel it is time to start a discussion on how any debris mitigation rules should apply to lunar orbit. This is not a far-fetched scenario. By 2021, there could be as many as half a dozen commercial spacecraft in lunar orbit or requiring access to the surface of the Moon. In fact, a conjunction has already occured in lunar orbit; the NASA Lunar Atmosphere and Dust Environment Explorer (LADEE) mission was forced to postpone a station-keeping maneuver in lunar orbit in 2014 to avoid a conjunction with the Lunar Reconnaissance Orbiter (LRO)[24]. There are different orbital properties of lunar orbit versus Earth orbit (the lack of a natural decay driven by atmospheric drag for example) that stakeholders should start to consider in order to maintain the sustainability of lunar orbit. In addition, there is no organization independently tracking all lunar spacecraft, so proper and accurate ephemeris sharing must but addressed.

In conclusion, a mix of industry best practices, updated standards and regulations, and economic incentives will ultimately be needed in order to adapt to the reality of new and growing activities in space, and to mitigate the creation of orbital debris. This is not the sole responsibility of the FCC; whole-of-government, international, and industry efforts are underway that must also be taken accounted for. We believe focusing on post-mission disposal reliability is an important element towards the long-term sustainability of space. To quote the Boys Scouts of America, we urge all satellite operators to “leave no trace”. We thank the FCC for establishing this NPRM and the opportunity to provide comments towards this critical issue.

[24] M. D'Ortenzio, J. Bresina, A. Crocker, R. Elphic, A. Hawkins, R. Hunt, B. Owens, L. Plice, L. Policastri, "Operating LADEE: Mission Architecture Challenges Anomalies and Successes", 2015 IEEE Aerospace Conference Proceedings, DOI: 10.1109/AERO.2015.7118961, March 7-14, 2015.

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