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Mitigation of Orbital Debris in the New Space Age	))	IB Docket No. 18-313
Streamlining Licensing Procedures for Small Satellites	))	IB Docket No. 18-86

Comments of University Small-Satellite Researchers

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Summary

Building on previous comments submitted to the Commission's *Streamlining Licensing Procedures for Small Satellites* docket, university small satellite researchers urge the Commission to adopt debris mitigation policies that promote the environmental sustainability of space while allowing for universities to meaningfully engage in satellite research. Several topics raised in this proceeding may disproportionately impact university researchers, including propulsion and maneuverability requirements, end-of-life disposal requirements, imposing quantitative risk assessments without adequate guidance on compliance, and other possibly burdensome pre-license informational requirements.

We are specifically concerned with the Commission's proposals regarding propulsion and trackability. The Commission should not impose propulsion or maneuverability requirements that effectively prevent university researchers from occupying orbital locations that are especially useful to them. If the Commission requires onboard propulsion for NGSO operators, it should only do so for operational altitudes of 600km or greater. Moreover, any trackability requirements should be clear and unambiguous to ensure seamless compliance.

In light of today's diverse space operations, the Commission should also modernize its one-size-fits all 25-year disposal guideline to a proportional-to-lifetime standard, but do so in a way that preserves flexibility for academic research. University small satellite research missions typically have tight budgets and are short in duration. Although university researchers are cognizant of the impact of non-functioning satellites that take multiple years to deorbit on the overall space environment, we urge the Commission to allow for flexible proportionality standards that do not unduly constrain academic research.

Moreover, the Commission should not implement quantitative informational disclosures, such as collision risk assessments or design reliability requirements, without clear guidance on how applicants can guarantee their compliance. The Commission's failure to establish clear compliance criteria for quantitative assessments risks increasing regulatory burden without yielding practical benefits. In each case where the Commission requires satellite operators to complete quantitative

informational disclosures as part of their applications, it should provide a safe harbor method of compliance.

Next, the Commission should avoid a totality of pre-license informational disclosures that have the effect of significantly delaying the average design-to-deployment timeline for university missions. A large number of strict informational requirements may specifically impact university researchers because of their unique mission timelines and the fact that university operators often do not know specific characteristics of their orbits until a launch has been secured. The Commission should structure its informational disclosures in a way that gives the Commission an accurate window into a particular mission's operational characteristics while allowing university operators flexibility in launch shopping and orbital selection.

Finally, the Commission should proceed with its plans to adopt a streamlined application process for small satellites and should avoid adopting a set of orbital debris policies that detracts from the utility of this streamlined application process. The Commission should proceed with its plans to update its 2004 orbital debris rules, striking a balance between safeguarding the sustainability of the space environment while allowing universities and other players in the New Space age to continue innovating.

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Discussion

The above-listed academic researchers in the areas of aerospace engineering, space sciences, and other related fields respectfully comment on the Commission's Notice of Proposed Rulemaking concerning Orbital Debris Mitigation.[1] Our comments specifically concern debris mitigation policy as it relates to university satellite research, and build on our previously filed comments[2] in the Commission's *Small Satellite* proceeding.[3]

Universities and non-profit research institutes have been launching satellite missions for more than three decades and are vital contributors to innovation in the New Space Age. University small satellite missions are instrumental to the technological diversity and development of this "turning point in the history of space development."[4] In its introduction to the *Orbital Debris NPRM*, the Commission specifically notes that CubeSats have "demonstrated their utility and capabilities across a wide range of satellite services."[5]

Institutions including California Polytechnic State University–San Luis Obispo and Stanford University created the CubeSat standard and continue to drive innovation in small satellite system designs and operations. CubeSat programs have allowed dozens of U.S. universities to produce graduates with invaluable experiences in space systems development, integration and testing and space mission operations who have already contributed significantly to the U.S. space and defense workforce. The above-referenced researchers include principals at the following laboratories:

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[1] *Mitigation of Orbital Debris in the New Space Age*, Notice of Proposed Rulemaking, IB Docket No. 18-313 (Nov. 19, 2018) ("*Orbital Debris NPRM*"), available at https://docs.fcc.gov/public/attachments/FCC-18-159A1.pdf.

[2] Comments of Dr. Scott Palo, et al., Docket No. 18-86 (June 22, 2018) ("*Researchers FY 2018 Comments*"), available at https://www.fcc.gov/ecfs/filing/1062172793709, Comments of Dr. Scott Palo, et al., IB Docket No. 18-86 (July 9, 2018) ("*SmallSat Researcher Comments*"), available at https://www.fcc.gov/ecfs/filing/107091398724499.

[3] *See Streamlining Licensing Procedures for Small Satellites*, Notice of Proposed Rulemaking, IB Docket No. 18-86, 33 FCC Rcd. 4152 (April 17, 2018) ("*SmallSat NPRM*"), https://docs.fcc.gov/public/attachments/FCC-18-44A1.pdf.

[4] *Orbital Debris NPRM* ¶ 1.

[5] *Id.*

- The Colorado Center for Astrodynamics Research (CCAR) at the University of Colorado is dedicated to the study of astrodynamics and the application of satellites to science, navigation, and remote sensing of the Earth and planets.
- The Precision Space Systems Lab at the University of Florida relies heavily on nanosatellite missions to demonstrate new technologies for future space navigation, time transfer, communications and astrophysics observations.
- The Center for Space Engineering at Utah State University is a multi-disciplinary group with expertise in space technology, systems engineering, and space science. The center brings together academics, industry, and government to advance the state of the art and train the next generation of space professionals. USU has hosted the annual Small Satellite Conference for over 30 years, providing a focal point for innovation in the New Space community.
- The Space Systems Group at the University of Florida conducts and facilitates research that addresses the technological challenges associated with the development of next generation high performance pico- and nano-class satellites for addressing socio-economic problems.
- The Space Systems Design Laboratory (SSDL) at Georgia Tech's Guggenheim School of Aerospace Engineering centers on identification and assessment of new technologies and approaches for robotic and human space and planetary exploration.
- The Space Telecommunications, Astronomy, and Radiation Laboratory at MIT develops technology demonstration payloads and novel nanosatellite system capabilities, with an emphasis on weather sensing, optical communications, and astrophysical applications.
- The Haystack Observatory is an interdisciplinary research center of the Massachusetts Institute of Technology (MIT) engaged in radio astronomy, geodesy, upper atmospheric physics, and radar applications. Its missions include study of the structure of our galaxy and the larger universe, advancement of scientific knowledge of our planet and its atmosphere, and advancement of technology and applications of radio science and radar sensing.
- The CubeSat Research Lab at California Polytechnic State University is instrumental in the success CubeSats enjoy today. The lab maintains the CubeSat Design Specification and has

facilitated the launch of over 160 CubeSats via its Poly-Picosatellite Orbital Deployer. It is actively engaged in educating the broader CubeSat community in both applicable regulations and best practices. The lab has launched ten CubeSats since inception and provided flight mission experience to hundreds of undergraduate students across most of the engineering disciplines at Cal Poly.

- The Space Science and Engineering Laboratory at Montana State University performs fundamental studies of the space environment, while engaging students in Space Physics research and in the design and development of small satellites with enhanced technical capabilities to further these research objectives.
- The Hawaii Space Flight Laboratory (HSFL) at the University of Hawaii at Manoa (UHM) is a research and development center for small satellites and launch vehicles. It is also an Aerospace workforce development program for the State of Hawaii to train the next generation of Space Engineers and Scientists.
- The Space Science Center at Morehead State University focuses on the development and operation of small satellites. The Center provides Telemetry, Tracking, and Command (TT&C) services for LEO missions using its 21-meter Antenna, and provides TT&C and Ranging services for inner solar system interplanetary small satellite missions.

The Commission has enabled this legacy of university satellite research through a balanced regulatory approach concerning the informational disclosures and operational requirements required of license applicants. As it considers significant changes to its debris mitigation policy, we urge the Commission to be mindful of how policy changes will affect university satellite research. The Commission should ensure that rules for mitigation of orbital debris are not overly cumbersome considering their practical impacts. An optimal regulatory balance will safeguard orbital sustainability in the long term while maintaining orbital accessibility for educational small satellites and New Space industries at large.

It is also important to bear in mind that under fair regulations, educational missions possess equal capacity to make major contributions to industry and science as their commercial counterparts.

Efforts to accommodate educational small satellites will stimulate the economic development of the small satellite industry and help maintain the U.S.'s leadership in technological innovation. In addition to advancing space systems technologies and contributing to space-based research, CubeSat programs have allowed dozens of U.S. universities to produce graduates with invaluable experiences in space systems development, integration and testing, and space mission operations. These experienced graduates have already contributed significantly to the U.S. space and defense workforce.

An optimal approach to orbital debris mitigation policy consists of:

1. Requiring reasonable informational disclosures as part of the license application to ensure the risk of orbital debris is mitigated ahead of launch as well as on orbit; and
2. Requiring satellite operators to obey appropriate operational constraints and post-mission disposal procedures.

The Commission views this regulatory approach as best allowing "operators sufficient flexibility in implementing their systems, while achieving results consistent with the public interest in preserving access to space for the long term, as well as the safety of persons and property."[6] The Commission alternatively seeks comment on whether "changes in operations and disposal procedures" is the best regulatory approach toward orbital debris mitigation.[7] More broadly, the Commission asks whether regulation of orbital debris of U.S. Commission-licensed space stations "will help limit such debris and result in a net benefit, even if it may give rise to some regulatory costs."[8] Finally, while the Commission seems committed to maintaining some regulatory role in mitigating orbital debris risks, it asks how it can avoid overlap and duplicative regulatory oversight with other governmental agencies (e.g., NOAA and the FAA).[9]

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[6] *See Orbital Debris NPRM* ¶ 94.
[7] *Id.* at ¶ 94.
[8] *Id.* at ¶ 88.
[9] *Id.* at ¶ 17.

We agree that informational and operational requirements are preferable to other styles of potential Commission regulation, such as placing a hard cap on the number of satellites launched, heavy-handed regulation of the engineering and design of satellites, or merely incentivizing private parties to establish coordinated orbital debris mitigation practices on their own.[10] The Commission is in a unique position to provide significant benefit to university-led satellite missions while ensuring that space remains an environmentally sustainable resource in the long term through its debris mitigation policy.

This comment addresses a number of ways that the Commission can strike this balance. First, the Commission should avoid adopting an orbital debris policy that compromises the utility of a streamlined small satellite application process. Next, we urge the Commission to avoid regulating in a way that impedes universities from meaningfully launching satellite missions and engage in space-based research given the heavily constrained budgets for the average university satellite operation,. The Commission should do this by creating safe harbors for quantitative informational disclosures, by avoiding broad-sweeping operational requirements like onboard propulsion at low altitudes, and by modernizing the 25-year disposal guideline in a way that preserves flexibility for academic missions. Finally, the Commission should ensure that the total regulatory burden from application informational disclosures should not have the effect of unduly delaying university launch timelines. A balanced regulatory solution exists for this proceeding that addresses these concerns while still allowing the Commission to safeguard outer space as an invaluable resource for all.

I. Any orbital debris mitigation policy changes should not significantly interfere with the utility or advantages of the streamlined small-satellite licensing process.

In our previous comments, we commended the Commission for proposing a streamlined application process for small satellite missions.[11] Given reasonable application fees[12] and eligibility

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[10] *Id.* at ¶¶ 92-97.

[11] *See SmallSat Researcher Comments* at 2.

[12] In order to be accessible to university missions as well as commercial operations, we suggested that a streamlined application fee for small satellites be in line with the FCC's $70.00 experimental

requirements, we noted that a streamlined application process would be of enormous value to university and commercial small satellite operations alike.[13] Streamlined application procedures will further propel a booming new sector of space technologies and research, promote the United States' economic and academic leadership in the industry, and facilitate the public benefits that accrue from the deployment of innovative satellite technologies. For all these reasons, the Commission should not allow this rulemaking to interfere with the availability, the utility, or the advantages of a streamlined licensing procedure for small satellite applications.

There are a number of inquiries in this NPRM which track closely (or are identical) to those in the *SmallSat NPRM*. To the extent that proposals or issues between the two NPRMs are congruent, the Commission should take the same approach.

- Both NPRMs discuss potential requirements of onboard propulsion for collision avoidance.[14] The Commission should not require onboard propulsion for missions operating below 600km. Requiring propulsion below these altitudes would be tremendously prohibitive to university small satellite missions that frequently operate in the 400-600km range of altitudes.[15]
- Both NPRMs include a proposal to require satellites to "include a unique telemetry marker allowing it to be readily distinguished from other satellites or space objects."[16] In both proceedings, the Commission should adopt a more flexible and functional approach to trackability, allowing applicants to make a showing that satellites are trackable rather than dictating specific design parameters.[17]
- Both NPRMs propose requiring a human casualty risk assessment from surviving debris where applicants can calculate the risk of casualty by using the NASA Debris Assessment Software

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licensing fee, with no more than a modest increase to reflect additional processing and interference protection benefits. *Id.* at 16.

[13] *SmallSat Researcher Comments* at 2.

[14] *SmallSat NPRM* at 4167-68, ¶¶ 33-35, *Orbital Debris NPRM* at ¶ 34.

[15] *See SmallSat Researcher Comments* at 9-12.

[16] *SmallSat NPRM* at 4169, ¶ 38, *Orbital Debris NPRM* ¶ 36.

[17] *See also SmallSat Researcher Comments* at 11-12.

(DAS) or by using another high fidelity model.[18] The Commission should require applicants to conduct these casualty risk assessments and allow use of DAS or higher fidelity models for compliance. However, the Commission should recognize that some scientific missions involve small quantities of metal that melt at high temperatures and do not ablate upon reentry. In such missions where a calculated casualty risk is greater than zero, the Commission should allow researchers to mitigate a nonzero risk by allowing researchers to carry third-party insurance.

In the *Orbital Debris NPRM*, the Commission also makes a number of proposals that have thematic overlap with the *SmallSat NPRM*. Here, we recognize that not every rule that makes sense as an eligibility requirement for a streamlined small satellite application should be required in a broader debris mitigation policy (and vice versa). However, to the extent that thematic overlap exists between the *SmallSat NPRM* and the *Orbital Debris NPRM*, the Commission should act consistently where policy goals and analytic criteria are the same.

The Commission should view orbital debris mitigation and streamlined licensing procedures for small satellite applications as complementary. Accordingly, it should refrain from imposing orbital debris requirements that would compromise the utility of a streamlined application for the small satellite community.

Concerning liability insurance for satellite operators, the Commission has suggested exactly this type of policy balancing when it asks whether liability insurance should be required in order to economically incentivize debris mitigation best practices.[19] In this context, the Commission asks whether "small satellites applying under the streamlined process…be exempt…since space stations [under the streamlined category] would be relatively lower risk from an orbital debris perspective."[20] Given a broader liability insurance requirement, the Commission should create such an exemption

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[18] *SmallSat NPRM* at 4170, ¶ 39 (proposing that small satellites eligible for a streamlined process should have a casualty risk of zero), *Orbital Debris NPRM* ¶ 62 (proposing that applicants demonstrate the casualty risk of a mission using the DAS software and disclose re-entry modelling assumptions when the calculated risk is greater than zero).
[19] *Orbital Debris NPRM* ¶ 80.
[20] *Id.*

for small satellites applying under the streamlined process, and apply this logic more broadly throughout its debris mitigation policy. Small satellites that are eligible for a streamlined application will be relatively lower risk from an orbital debris perspective and should receive exemptions from debris mitigation requirements that are better-suited for addressing high-risk deployments, such as large NGSO constellations.

II. The Commission should not adopt changes to orbital debris mitigation policy that prevent universities from engaging meaningfully in satellite research.

The Commission seeks comment on various proposals for satellite mission operational requirements and pre-license informational disclosures. We are specifically concerned with requirements that would significantly increase burdens and costs for small satellite missions, including propulsion and maneuverability requirements as preconditions for operating at certain altitudes, inflexible end-of-life disposal requirements, collision risk assessments (and other quantitative disclosures) without firm guidelines.[21]

Compared to larger commercial operations, university satellite projects are often conducted with small and heavily-constrained budgets. For small satellite missions, even sophisticated educational and scientific research projects typically have access to budgets averaging approximately $300,000 or less.[22] This amount must cover the entirety of the university satellite operation, from research and manufacture to regulatory compliance, and finally to mission operation and subsequent post-mission disposal.

Every dollar spent on debris mitigation regulatory compliance (whether it be for pre-application informational disclosures or operational requirements such as outfitting a satellite with on-board propulsion) will affect what “core missions” can be achieved by universities given a limited budget. For this reason, the Commission should be mindful when imposing informational or operational requirements as part of an orbital debris mitigation policy. Regulations that have the effect of significantly heightening costs or delaying timelines for university satellite operations can effectively

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[21] *Id.* at ¶¶ 26, 34, 59.

[22] *Researchers FY 2018 Comments* at 4.

freeze critical research, deny our next generations of U.S. space scientists meaningful opportunities as students, and impede the ability of the U.S. to lead in New Space industries.

While we commend the Commission for investigating policies to preserve space as a workable resource for all stakeholders, it should be mindful of its regulatory burdens both at large and specifically with regard to academic satellite missions. First, the Commission should avoid specific operational requirements that threaten to increase the cost of launching and operating small satellites, including maneuverability and disposal requirements. Next, the Commission should modernize its standard 25-year disposal guideline but do so in a way that preserves flexibility for academic research. Finally, the Commission should take address a number of issues in its proposals for informational disclosures. To prevent quantitative informational disclosures—such as collision risk and design reliability assessments—from significantly impacting the cost and burden of license applications, the Commission should create safe harbors and standardized compliance methods and ensure that its required informational disclosures do not have the effect of unduly delaying university satellite design-to-launch timelines.

A. The Commission should not adopt operational requirements that will significantly decrease the ability of universities to readily participate in satellite deployments and research. (¶¶ 34, 69-75)

The Commission seeks comment on a variety of operational requirements, including onboard propulsion requirements, orbital raising maneuvers, maintaining ephemeris data, and telemetry/tracking requirements.[23] We are specifically concerned with proposals in the *Orbital Debris NPRM* that address on-board propulsion and trackability.[24]

In its orbital debris mitigation policy, the Commission should refrain from mandating satellite operational requirements that will significantly decrease the ability of universities to readily participate in satellite deployments and research. For instance, "in lieu of" a series of informational disclosures, the Commission proposes requiring all NGSO satellites operating "above a certain

[23] *Orbital Debris NPRM* ¶ 34, 69-75

[24] *Id.* at ¶¶ 34, 74-75.

altitude" to include propulsion capabilities reserved for station-keeping and to enable collision avoidance maneuvers.[25] As we have discussed in our previous filings, given the current state of propulsion system technology, requiring onboard propulsion would effectively make many educational and scientific small satellite missions impossible.[26] For this reason, the Commission should not impose propulsion requirements for any operations lower than 600km.

Propulsive technology for small satellites only currently exists in a nascent stage and isn't yet at the level needed to facilitate easy or affordable implementation in typical missions.[27] Workable propulsion systems that require 1U or more of volume would cost from $50,000 up to $200,000 or more, an unworkably large fraction of a design-to-disposal academic budget of $300,000.[28] Furthermore, such propulsion systems on small satellites would take up valuable onboard resources, would reduce available payload space, and could affect the thermal profile of small satellites.[29] If the Commission chooses to require propulsion for NGSO operations above a threshold altitude, it will effectively be barring academic university missions from being deployed at those altitudes.

Specifically, the 400-600km range of altitudes is of critical importance to university operations and should remain unencumbered by a propulsion requirement. Thus, if the FCC chooses to enact altitude-triggered onboard propulsion requirements, it should not require propulsion for any operations with altitudes lower than 600km. Setting a demarcation at 600km would strike an appropriate balance between mitigating debris risk (and enabling disposal) at higher altitudes while flexibly preserving adequate portions of LEO for academic satellite missions.

Instead of adopting sweeping mandatory propulsion requirements, the Commission should proceed with informational disclosures for orbit selection.[30] The Commission has suggested

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[25] *Id.* at ¶ 34.
[26] *SmallSat Researcher Comments* at 10-11.
[27] *Id.* at 9-10.
[28] *Id.* at 5.
[29] *Id.* at 10-11.
[30] *Orbital Debris NPRM* ¶¶ 29-33.

informational disclosures concerning conflicts with the ISS orbit, orbital justifications for NGSO constellations at high altitudes or regions of space with high object density, and justifying missions that will remain in orbit for a long time relative to their mission lifetime.[31] All of these *ex ante* requirements will strike a better balance between mission flexibility and guaranteeing collision-free space than will imposing mandatory propulsion.

In the alternative, the Commission should seriously consider exempting academic missions if it chooses to impose propulsion requirements for maneuverability or station-keeping at altitudes lower than 600km. Exempting academic missions from such requirements would be in the public interest and would still allow the Commission to mitigate collision risk by targeting higher-risk deployments. For example, while university small satellite missions will not individually present significant collision risks, constellation operators who launch hundreds (or even thousands) of satellites may create a much larger collective debris risk and will have significantly more resources available for compliance.

The Commission also asks whether NGSO operations should be required to "include a unique telemetry marker allowing it to be readily distinguished from other satellites or space objects."[32] We share the Commission's concerns about the importance of satellite trackability, but find this language underspecified and unclear. Should the Commission require a "unique telemetry marker," it is uncertain whether operators could merely disclose a working method for distinguishing their satellite from others, or if each operation would be required to have specific telemetry hardware. In this case, the Commission should adopt a functional requirement that small satellites be trackable rather than dictating specific design parameters. The Commission should also adopt its proposal that objects with volumes greater than 10 cm x 10 cm x 10 cm (1U) be presumed trackable.[33]

Propulsion and specified trackability are just two examples of operational requirements that could be extremely prohibitive to university satellite missions. For any operational requirement

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[31] *Id.*

[32] *Id.* at ¶ 36. The same "unique telemetry marker" proposal was also addressed in the Commission's NPRM for streamlining a Part 25 small satellite application process. *See SmallSat NPRM* at 4169, ¶ 38.

[33] *Oribtal Debris NPRM* ¶ 36.

imposed as part of its debris mitigation policy, the Commission should consider costs of compliance for academic missions. In most cases, informational disclosures or functional requirements will better allow university missions to comply with debris mitigation goals while still allowing deployment with reasonable budgets.

B. The Commission should modernize its 25-year requirement and make disposal timelines proportional to mission-life but should allow disposal flexibility for academic missions. (¶¶ 32, 58-59)

The Commission asks whether its one-size-fits-all 25-year disposal guideline remains a valid benchmark in light of today's diverse space operations, including an increase in total launches and the deployment of CubeSats whose operating lifetimes are only one or two years long.[34]

In light of current orbital congestion and increasing demand for viable orbits, the Commission should modernize its 25-year disposal guideline benchmark. We recommend that the Commission make disposal deadlines proportional to mission-life but allow disposal timeline flexibility for academic missions in order to avoid excessive compliance costs.

Without specific justification, it is irresponsible in today's space environment for short-lived satellite operations to remain in orbit for decades. All satellite operators should have an onus to deorbit in as short a timeline as is reasonably feasible, and the Commission should tailor its disposal timeline requirements accordingly. Accordingly, the Commission should modernize its 25-year benchmark by making disposal timelines proportional to mission-life.

While we do not offer specific comments on the constant of proportionality that should be chosen, the Commission should avoid adopting an inflexible disposal framework that would impose excessively burdensome compliance costs on academic missions. For instance, university missions could face significant compliance difficulties with disposal guidelines proportional to mission lifetime where the coefficient of proportionality is small and fixed—i.e., following mission completion, a guideline that requires deorbit to be accomplished within twice the mission lifetime.[35]

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[34] *Orbital Debris NPRM* ¶ 59.

[35] The Commission has proposed this "factor of two" metric as a possible disposal guideline. *Id.* at ¶ 32.

In this scenario, a university small satellite mission whose mission lifetime was only a year would be mandated to deorbit in only a couple of years.

Depending on the altitude and characteristics of the operating orbit, compliance with such a short disposal timeline could require propulsive capabilities or installation of a passive deorbit mechanism, such as an aerodynamic drag device. This could render small satellite missions impossible. As we mentioned above, very few small satellites are currently deployed with active propulsion, and implementing such capabilities using existing technology could cost upwards of $200,000, which is infeasible giving existing academic budgets.[36] While academic researchers are investigating passive deorbit systems (e.g., aerodynamic drag devices) as a means of accelerating disposal, and these passive systems might be used for disposal guideline compliance, such systems may still take up valuable payload space and cost a sizeable fraction of the academic budget.

The Commission should allow flexibility for academic missions in their deorbiting timelines. Specifically, the Commission should adopt disposal guidelines based on proportionality to mission life but exempt academic missions from such guidelines when a university mission requires or benefits from an orbit with a longer natural deorbit time. Exemptions could function by preserving the 25-year benchmark for exempted missions or by allowing for a specified amount of deorbit time in excess of the proportional-to-lifetime standard. For example, a university small satellite that studies the Earth's poles for a year at an altitude of over 500 km could exempted from a stricter timeline, allowing natural or passive deorbit to occur within 5–10 years.[37] Such exemptions would be in the public interest, allowing the 25-year benchmark to be generally updated and pushing the community of satellite operators at large to be environmentally responsible while preserving the ability for universities to innovate.

[36] *SmallSat Researcher Comments* at 10.

[37] Within reasonable budgetary constraints, university operators should still strive to be role models for the New Space environment and deorbit as quickly and safely as possible.

C. If the Commission adopts quantitative or threshold-based informational disclosures, it should provide safe harbors and clear guidelines on how applicants must comply. (¶¶ 26, 42-43, 46)

The Commission seeks comment on a number of proposals that would impose quantitative informational requirements as part of a license application. Among others, these proposals include applicant assessments of collision risk, probability of success for disposal methods, and design reliability requirements.[38]

If the Commission chooses to require quantitative or numerical-threshold informational disclosures as part of a debris mitigation framework, it should provide clear and definitive guidance on how applicants must effectively comply. For every quantitative informational disclosure imposed, the FCC should designate a safe harbor method of compliance.

A lack of clear guidance for quantitative informational disclosures creates uncertainty for applicants who cannot be sure that their choice of analytical method will be accepted by the Commission. In this way, requiring quantitative analysis without setting "safe harbor" compliance methods could dramatically increase compliance costs without producing practical benefits.

For example, the Commission proposes that applicants for NGSO satellites must demonstrate "that the probability that their spacecraft will collide with a large object during the orbital lifetime of the spacecraft will be no greater than 0.001."[39] While we do not dispute the soundness of such a requirement, NGSO applicants who need to demonstrate a collision probability of less than .001 should be given clear guidance on how to effectively comply. The current language makes it unclear whether applicants could use their own formulas or modelling software for calculating lifetime collision risk, or whether every applicant must arrive at the .001 number using the same analytical techniques. Similar to the *Guidance on Obtaining Licenses for Small Satellites*, the *NPRM* alludes to creating a collision risk metric "based on the current NASA Standard," but does not specify whether the only aspect being imported from the NASA Standard is the .001 threshold, or whether NASA's

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[38] *Orbital Debris NPRM* ¶¶ 26, 42-43, 46.

[39] *Id.* at ¶ 26.

Debris Assessment Software (DAS) and standard calculation methods are required tools for compliance with Commission rules or merely recommended.[40] In this case, should the Commission require a .001 risk assessment, its official regulations should specify that all operators who accurately show a < .001 risk using DAS (and calculation methods under the NASA Standard) will be presumed to have satisfied the application requirement.[41]

Without a clear safe harbor of standardized tools like DAS and the NASA Standard, a university engineering team might have significant difficulty figuring out how to model a small satellite's collision risk integrated over mission lifetime. Furthermore, given an open-ended ".001" without FCC-sanctioned compliance methods, the university team would have no way of knowing (once they selected a given calculation technique) whether their calculations would be acceptable to the Commission. This uncertainty risks significant inefficiencies for both applicants and for the Commission when it reviews applications. When all parties have limited resources, it is paramount that applicants and the Commission "speak the same language" concerning technical requirements.

Similar problems exist with the Commission's "design and fabrication reliability requirement" for NGSO constellations. The Commission has proposed imposing a reliability requirement (giving the possible reliability standard of .999 per spacecraft) when an NGSO constellation involves a large number of satellites or is initially deployed at higher altitudes in LEO.[42] Regardless of the soundness of such a proposal, it is highly uncertain what compliance would look like. Is the Commission asking constellation operators to demonstrate functionally that each of their spacecraft will have a

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[40] Guidance on Obtaining Licenses for Small Satellites, Public Notice, DA: 13-445 (Mar. 15, 2013), available at https://www.fcc.gov/document/guidance-obtaining-licenses-small-satellites; NASA Technical Standard, Process for Limiting Orbital Debris, NASA-STD-8719.14A (with Change 1), 32, Requirement 4.5.4 (May 25, 2012), https://standards.nasa.gov/standard/nasa/nasa-std-871914.

[41] Per a "safe harbor" regime, in addition to the NASA method for risk assessment, the Commission could allow operators to flexibly use alternative modelling methods to demonstrate a < .001 risk, but the Commission could impose additional scrutiny on operators who depart form the "safe harbor" compliance method of choice.

[42] *Orbital Debris NPRM* ¶ 43. While university researchers are unlikely to launch the size of constellations that would trigger this requirement, the .999 quantification suffers from similar compliance issues.

guaranteed reliability, or would the Commission impose a prescriptive set of testing protocols? If the former, how would the Commission make sure each constellation operator meets a minimum rigor in analysis when using separate reliability methodologies? Here, the Commission could give constellation operators flexibility in demonstrating spacecraft reliability but should codify an explicit safe harbor.

Finally, the Commission should specify whether all quantitative informational disclosures requirements serve only as gatekeeping devices, or whether they are potential sources of post-operational liability. For example, if a constellation operator attests to ".999 per spacecraft" reliability during their application, but later has a large portion of their fleet suffer a standardized failure in orbit (perhaps due to bad faith or negligence in the original analysis), Commission rules should make clear any potential consequences.

D. The Commission should not impose pre-license informational disclosures that significantly extend design-to-launch timelines. (¶¶ 30-31, 40, 48-49)

The Commission seeks comment on several items that would require increased informational disclosures as parts of satellite license applications. Among others, these proposals include informational disclosures for collision risk assessments for multi-satellite deployments, operations transiting through ISS orbit, and orbital justifications for constellations operating at altitudes greater than 650km.[43]

We are concerned with the total regulatory cost of informational requirements on universities given the unique nature of university mission timelines. An average university small satellite mission will take two to three years from conception to deployment. This entails roughly a year for design and engineering analysis, and another year or so for building. Ideally, the build phase only begins after an operating team has received authorization from the Commission, allowing the engineers to design around a certain set of communication frequencies. However, many academic researchers will build and test satellites prior to license issuance.

[43] *See Orbital Debris NPRM* ¶¶ 30-31.

It is in the public interest to ensure that university small satellite missions can proceed on a quick timeline. When design-to-deployment only lasts a few years, university students are able to engage with every aspect of a particular mission, from idea pitching and hardware engineering to launch, subsequent operations, and data analysis. Facilitating this level of student participation is essential for training upcoming generations of U.S. space scientists. Furthermore, fast project timelines allow for a high turnover, meaning that universities can accomplish a number of diverse and innovative projects within a handful of academic years. Because of this, the Commission should be cognizant of the total regulatory burden of its pre-license informational disclosures so not to unduly extend design-to-launch timelines for universities.

Unlike larger commercial operations, which often have employees solely dedicated to regulatory compliance, university satellite missions have small teams that are responsible for every aspect of a project. Regulatory compliance (even in the application phase) requires substantial bandwidth for university professors and students who are the primary engineers for their missions. Additional paperwork creates a number of successive delays—for university scientists in drafting, for Commission staff in reviewing, and for both in addressing subsequent amendments and compliance. For any debris mitigation framework it adopts, the Commission should ensure that universities are able to comply with regulatory burdens without unduly extending their timelines and sacrificing the public benefits that derive from expedited missions.[44]

Accordingly, the Commission should not require additional informational requirements from university small satellite operators when they are passengers to a launch that deploys multiple different satellites.[45] Requiring additional information from the university passengers here would be unreasonably burdensome since university researchers' primary means of deployment is to secure excess launch capacities where available. When a university mission secures excess capacity aboard a launch, they will not necessarily know the precise operational details of their co-passengers.

[44] It was with these concerns in mind that we continue to support a streamlined Part 25 small satellite that is accessible to university operations. *See generally SmallSat Researcher Comments.*
[45] *See Orbital Debris NPRM* ¶ 40-41.

Therefore, the Commission should not require university researchers in their applications (well before launch) to spend valuable time and resources tracking down information about speculative co-passengers for a launch they may or may not take. Other parties are more ideally situated to conduct this coordination and analysis. The FAA requires launching authorities to conduct collision avoidance analysis for their payloads and launch authorities are obligated to ensure compliance with U.S. laws before deploying their payloads, including FCC licensing.[46] It would be more practical and efficient to either require launching authorities to conduct any informational requirements involved in multi-satellite deployments, or for the FCC and FAA to engage in inter-agency coordination to share such information if it already exists.

Additionally, the Commission should not adopt informational requirements that force university researchers to commit to mission parameters in their application that are subject to change. Many university small satellite missions will not know their exact orbital characteristics—altitude, inclination, etc.—until post-build and possibly only a few months prior to deployment. This is because university small satellites often seek excess capacity aboard rocket launches that are delivering a primary payload and will advantageously select available orbits that are compatible with the academic mission. This selection process becomes difficult when receiving authorization becomes contingent on a number of precise application requirements.

For example, a number of the Commission's proposed rule changes involve altitude-based or orbit-specific triggers.[47] With these targeted informational disclosures in mind, we are concerned about a potential regulatory paradox: that university satellite operators will not be able to obtain a specific orbit by seeking out extra capacity on a launch until they have received authorization, yet will not be able to receive authorization until they disclose what specific orbit they intend to use (and

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[46] 14 C.F.R. §417.107 (e).

[47] *See Orbital Debris NPRM* ¶ 30 (informational requirement triggered for operations transiting through ISS orbit), ¶ 31 (required justification for constellations operating at 650km+), ¶ 48 (requirement for operations with final altitudes above 650km to conduct raising maneuvers to final orbit), and ¶ 49 (650km+ operations automatically initiate disposal following loss of contact with the spacecraft).

conduct the analyses specific to that orbital choice). We commend the Commission for its history of working flexibly with satellite operators, allowing applicants to provide a range of altitudes and inclinations for possible orbits (conducting analysis over that range), and for collaborating with operators when circumstances change. We hope the Commission will continue this style of collaborative oversight if it updates its debris mitigation policy with orbit-specific informational disclosures—operators should be able to amend their applications expeditiously when circumstances change, providing supplementary documentation that adequately addresses relevant changes in debris risk, but not have this unduly delay deployment timelines.

Overall, when adopting a set of pre-license informational disclosures the Commission' should balance the regulatory impositions necessary for mitigating debris risk while allowing the flexibility for academic satellite missions to innovate at a rapid pace.