[4910-13]

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Parts 401, 404, 415, 417, 431, 435, 437, 450, and 453

[Docket No.: FAA-2023-1858; Notice No. 23-13]

RIN 2120-AK81

Mitigation Methods for Launch Vehicle Upper Stages on the Creation of Orbital Debris

AGENCY: Federal Aviation Administration (FAA), Department of Transportation (DOT)

ACTION: Notice of proposed rulemaking (NPRM)

SUMMARY: To limit the growth of orbital debris, the FAA proposes to require that upper stages of commercial launch vehicles and other components resulting from launch or reentry be removed from orbit within 25 years after launch, either through atmospheric disposal or maneuver to an acceptable disposal orbit. Any artificial object left in orbit around the Earth which no longer serves a useful purpose can become a debris hazard in space. Orbital debris is all such human-generated debris in Earth orbit that is greater than 5 millimeters (mm) in any dimension. Collisions between and with orbital debris are a growing concern because prior to the establishment of the Inter-Agency Space Debris Coordination Committee (IADC) practices allowed these objects to accumulate in Earth orbit. Additionally, an increasing number of launch operators are launching assets into space at greater rates. If left unchecked, this accumulation can clutter useful orbits and present a hazard to operations on-orbit. This proposed rule would reduce the amount of additional debris created, as well as limit potential collisions with functional spacecraft and other debris already on-orbit.

DATES: Send comments on or before [INSERT DATE 90 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER].

ADDRESSES: Send comments identified by docket number FAA-2023-1858 using any of the following methods:

- Federal eRulemaking Portal: Go to www.regulations.gov and follow the online instructions for sending your comments electronically.
- Mail: Send comments to Docket Operations, M-30; U.S. Department of Transportation, 1200 New Jersey Avenue, SE, Room W12-140, West Building Ground Floor, Washington, DC 20590-0001.
- Hand Delivery or Courier: Take comments to Docket Operations in Room W12-140 of the West Building Ground Floor at 1200 New Jersey Avenue, SE, Washington, DC 20590-0001 between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.
- Fax: Fax comments to Docket Operations at (202) 493-2251.

Privacy: In accordance with 5 USC 533(c), DOT solicits comments from the public to better inform its rulemaking process. DOT posts these comments, without edit, including any personal information the commenter provides, to www.regulations.gov, as described in the system of records notice (DOT/ALL-14 FDMS), which can be viewed at www.dot.gov/privacy.

Docket: Background documents or comments received may be read at www.regulations.gov at any time. Follow the online instructions for accessing the docket or go to the Docket Operations in Room W12-140 of the West Building Ground Floor at 1200 New Jersey Avenue, SE, Washington, DC 20590-0001, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.

FOR FURTHER INFORMATION CONTACT: Brenda Robeson, Office of Commercial Space Transportation, Federal Aviation Administration, 800 Independence Avenue SW, Washington, DC 20591; (202) 267-4712; brenda.robeson@faa.gov.

SUPPLEMENTARY INFORMATION:

Authority for this Rulemaking

The Commercial Space Launch Act of 1984, as codified and amended at 51 U.S.C.—Commercial Space Transportation, ch. 509, Commercial Space Launch Activities, 51 U.S.C. 50901-50923 (the Act), authorizes the Department of Transportation and thus the FAA, through delegations, to oversee, license, and regulate commercial launch and reentry activities, and the operation of launch and reentry sites as carried out by United States (U.S.) citizens or within the United States. Section 50905 directs the FAA to exercise this responsibility consistent with public health and safety, safety of property, and the national security and foreign policy interests of the United States. Pursuant to § 50903, the FAA is also responsible for encouraging, facilitating, and promoting commercial space launches by the private sector.

List of Definitions and Acronyms Frequently Used In This Document

Disposal (storage) orbit—an orbit intended for post-mission long-term storage where atmospheric effects and solar radiation will not move the disposed object into a protected orbit for at least 100 years.

ISS—International Space Station.

NASA—National Aeronautics and Space Administration.

Spacecraft—vehicles, payloads, and other manmade objects that are designed to for placement or operation in outer space. For example, spacecraft include satellites, inhabitable space stations, inhabitable capsules, and cargo vehicles.

Transfer orbit—a temporary orbit on which an object travels to move from one orbit to another.

Upper stage—a segment of a launch vehicle that reaches orbit.

I. Overview of Proposed Rule

This proposed rule would require an operator licensed or permitted under this chapter to perform a launch or reentry with a planned altitude greater than 150 kilometers (km) to limit or dispose of debris at the end of a launch or reentry to maintain a sustainable space environment. The FAA proposes to require that operators licensed or permitted under parts 415, 417, 431, 435, 437, or 450, to perform a launch or reentry with a planned altitude greater than 150 km submit an Orbital Debris Assessment Plan (ODAP)—including physical evidence, test results, and analyses to demonstrate removal activities—prior to each operation. This notice proposes that if debris—including spent upper stages and other components—is released during launch or reentry, during on-orbit aspects of launch or reentry, or during disposal operations, any pieces greater than 5 mm in size must be removed from highly-used regions within 25 years. The FAA proposes to allow operators to meet this criterion by performing one of five disposal options. Operators may choose to dispose of the debris within 30 days of mission completion through (1) controlled disposal; (2) maneuver to a disposal orbit; or (3) Earth-escape orbit. Alternatively, an operator could elect to (4) retrieve the debris within 5 years of mission completion; or (5) perform atmospheric uncontrolled disposal or natural decay within 25 years, if the debris disposal meets the risk criteria.

The FAA notes that many launches, as they are currently conducted, would already be in compliance with the operational requirements of the proposed regulation. The FAA also proposes to amend the reporting requirements governing debris creation. The FAA would require the reporting of a non-nominal launch or a debris-creating anomaly to the FAA.

II. Background

A. Statement of the Problem

Orbital debris is made up of fragmented material (resulting from anti-satellite tests, upper stage explosions, accidental collisions, etc.), nonfunctional spacecraft, rocket bodies, and mission-related items (explosive bolts, vehicle shrouds, etc.),[1] but excludes naturally-occurring debris such as meteoroids. As more and more spacefaring nations launch objects into Earth orbit, space is becoming increasingly crowded with orbital debris.[2] If left unchecked, orbital debris can diminish the usefulness of certain orbits and present a hazard to operations on-orbit. Current international modeling indicates that even if there were no further space launches, collisions between objects already in space will eventually become the major source of debris.[3] This threat could soon escalate dramatically with the deployment of large constellations of small satellites in the already-congested Low Earth Orbit (LEO) region.

As of 2021, the number of orbital objects sized 10 centimeters (cm) or greater is estimated to be over 23,000. Recent debris projections estimate a total of half a million objects sized between 1 and 10 cm on orbit, and over 100 million objects larger than 1 mm.[4]

Each Earth orbit has a specific usefulness and needs to be protected from accumulated orbital debris. LEO is commonly used for Earth observation, communications, and scientific experiments. LEO is also the region where most human spaceflight activities take place. Medium

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[1] Belk, C.A., J.H. Robinson, M.B. Alexander, W.J. Cooke, and S.D. Pavelitz. (1997). Meteoroids and Orbital Debris: Effects on Spacecraft. *NASA Reference Publication 1408, Marshall Space Flight Center, AL.*

[2] Inter-Agency Space Debris Coordination Committee. (April 2013). *Space Debris IADC Assessment Report for 2010.*

[3] Inter-Agency Space Debris Coordination Committee. (January 2013). *Stability of the Future LEO Environment.*

[4] The NASA Orbital Debris Program Office. (Retrieved April 28, 2020). *Frequently Asked Questions.* orbitaldebris.jsc.nasa.gov/faq/#

Earth Orbit (MEO) contains space navigation satellites and some communications missions covering the North and South poles. Space objects in Geostationary Earth Orbit (GEO) typically support communications and weather missions. A transfer orbit is a temporary orbit that a launch vehicle uses to move from one orbit into another. A common transfer orbit is the GEO transfer orbit used to place spacecraft into GEO. The upper stage often remains in the GEO transfer orbit with an apogee near the GEO region and the perigee in LEO. Spacecraft typically occupy LEO, MEO, or GEO, but can operate in other less congested orbits. The areas outside LEO, MEO, and GEO have been known as acceptable disposal orbits for upper stages and discarded satellites because they are not frequently used by active satellites. Figure 1 illustrates the various levels of Earth orbit including disposal orbit regions.

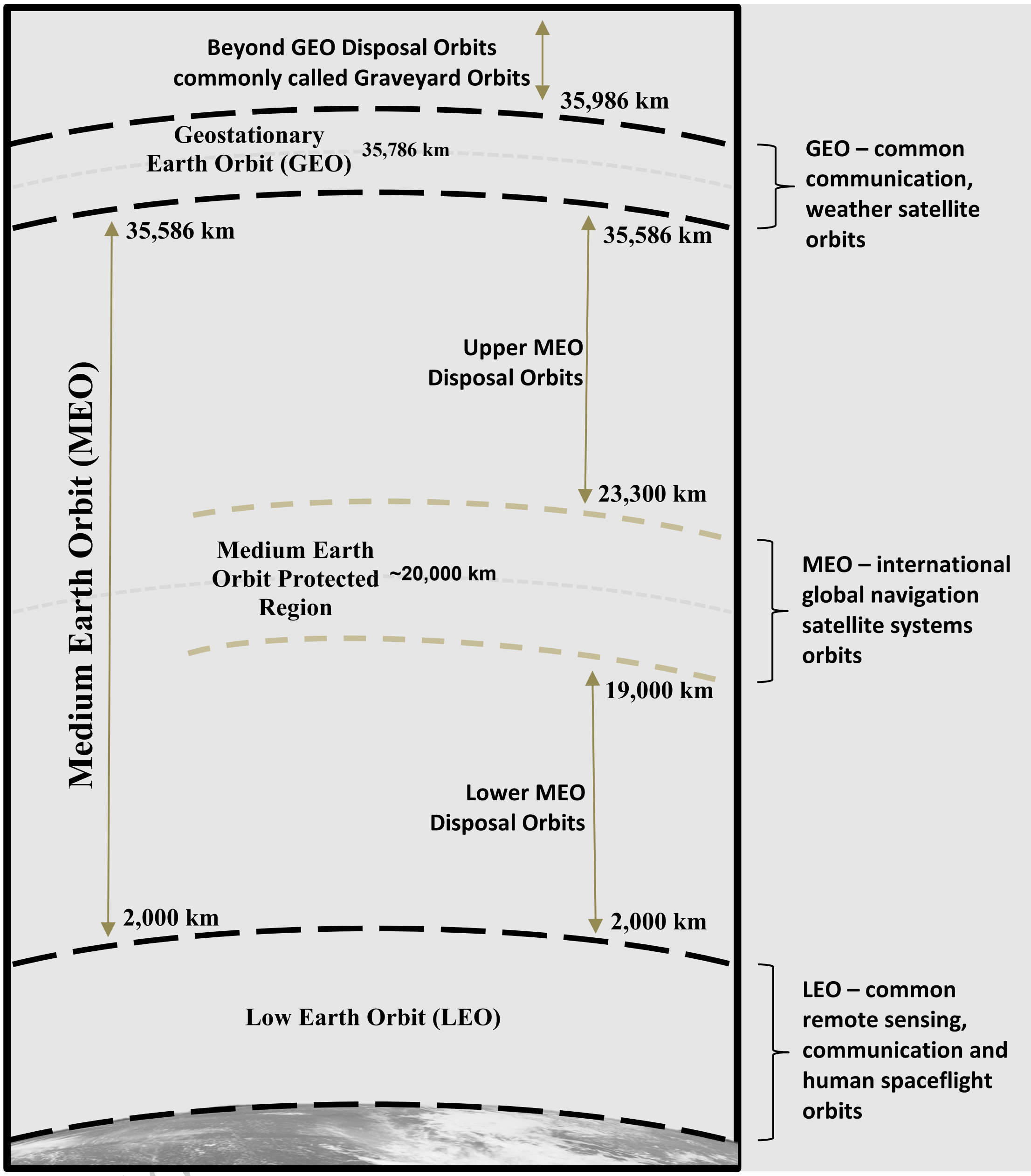

Figure 1: Operating and Disposal Orbits

Debris in space travels at hypervelocities. On average, collisions in LEO occur at a closure rate, or combined velocity at impact, over 10 km per second.[5] This is more than 11 times faster than a bullet. At those speeds, an impact to a typical operational spacecraft by debris 5 mm and larger will most likely cause damage to critical systems that ends the mission of the

[5] Portree, D.S.F. and Loftus, J.P. (January 1999.) Orbital Debris: A Chronology. NASA/TP-1999-208856.

spacecraft.[6] As seen in Figure 2, the main threat to operational spacecraft (abbreviated to "S/C" in Figure 2) in LEO is the debris in the range of 5 mm to 1 cm, primarily due to the sheer number of objects in this range. However, large objects greater than 1 meter, including discarded upper stages, are the main driver for debris growth.

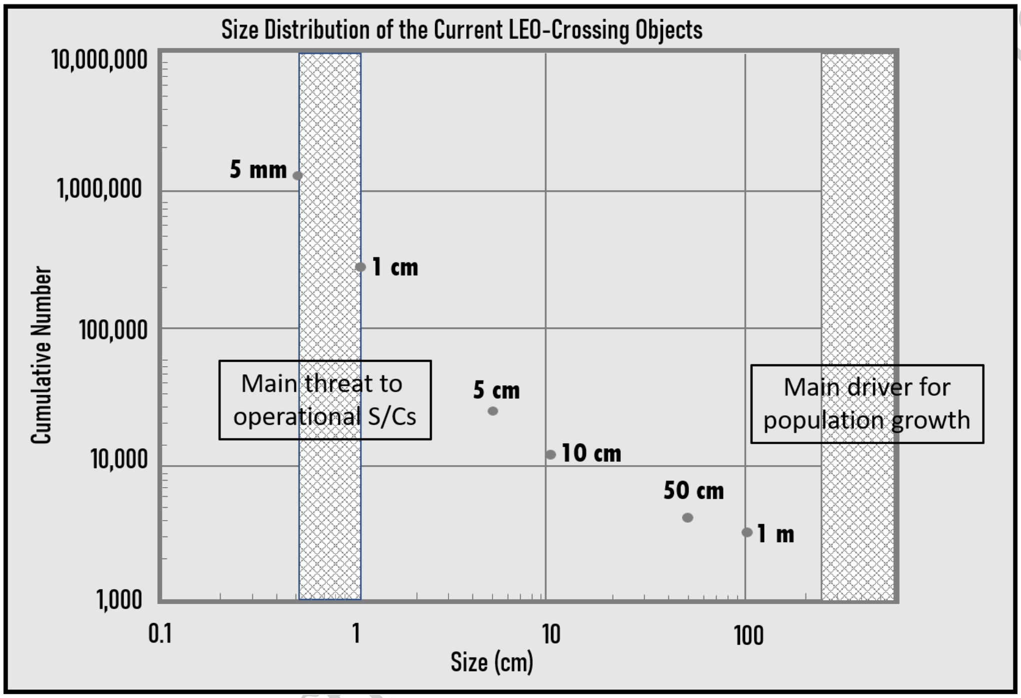

Figure 2: Notional cumulative size distribution of LEO-crossing objects[7]

In addition to causing catastrophic breakups, orbital debris impacts on functioning satellites or spacecraft can also degrade performance, pit or crack windows, mar surfaces of solar panels, damage optics, and degrade surface coatings.[8, 9] In 1984, a piece of orbital debris

[6] Squire, M., et al. (2015). Joint Polar Satellite System (JPSS) Micrometeoroid and Orbital Debris (MMOD) Assessment, NASA/TM-2015-218780.
[7] Liou, J. C. (2011). Engineering and Technology Challenges for Active Debris Removal. Figure 4, page 8. Presented at the 4th European Conference for Aerospace Sciences. *Ibid*.
[8] Williamson, M. (2006). Space: The Fragile Frontier, American Institute of Aeronautics and Astronautics, Inc.
[9] The NASA Orbital Debris Program Office. (April 2009). Satellite Collision Leaves Significant Debris Clouds. NASA JSC Orbital Debris Quarterly News, 13(2), page 1-2.

damaged the windshield of the Space Shuttle Challenger. A 4 mm diameter crater was made by a fleck of white paint approximately 0.2 mm in diameter, traveling 3-6 km/sec.[10]

As of 2021, approximately 95 percent of the total mass of human-generated objects in orbit is rocket bodies (i.e. upper stages)[11] and spacecraft. The remainder is mission-related debris and fragmentation debris.[12] The more mass an object has, the more debris it will create in the event of an explosion or collision.

The U.S. Government, for launches it conducts, has taken steps to mitigate orbital debris generation. Similarly, other countries are taking steps to mitigate debris generation during operations they oversee. This proposed rule would align U.S. commercial orbital debris mitigation practices for U.S. commercial launch operations with orbital debris mitigation practices accepted by the U.S. Government and certain other countries. For example, the European Space Agency (ESA) is implementing a Zero Debris Approach to stop the growth of orbital debris from their operations by 2030. ESA's policy acknowledges that if the status quo of orbital debris generation continues, future on-orbit operations will be hindered unless actions like remediation (active debris removal) are enacted.[13]

If no mitigation measures are implemented, the projected growth of orbital debris is expected to rapidly increase, as Figure 3 shows. The growth rate, as estimated in 2011, assumed a steady launch rate based on annual launch rates and did not address the increase in satellite constellations. SpaceX alone has launched over 1,500 satellites in its Starlink constellation as of

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[10] Center for Orbital and Reentry Debris Studies, Aerospace Corporation. (December 2004). *Space Debris Basics: What Are the Risks?*
[11] Only some of the upper stages on-orbit result from U.S. commercially licensed launches.
[12] The NASA Orbital Debris Program Office. (May 2019). Monthly Mass of Objects in Earth Orbit by Object Type. *NASA JSC Orbital Debris Quarterly News*, *23*(1 & 2), page 13.
[13] European Space Agency. (Accessed on April 4, 2023). Short Introduction to ESA's Zero Debris Approach, blogs.esa.int/cleanspace/2023/01/12/short-introduction-to-esas-zero-debris-approach/#:~:text=The%20ESA%20Zero%20Debris%20Approach%20is%20the%20Agency%E2%80%99s,the%20catastrophic%20degradation%20of%20the%20Low-Earth%20Orbit%20environment

August 2021. Several more companies have launched their own small satellite constellations. These small satellites are expected to have relatively short lifetimes, on the order of 5 years. Even though many operators are following current best practices, those practices allow multiple generations of spent satellites to co-exist on-orbit. The graph in Figure 3 is based on trackable debris. Current technology tracks objects 10 cm and larger, though debris between 5 mm and 10 cm pose risks. The shaded areas around the solid lines are the 1-sigma uncertainty from 100 Monte Carlo runs of the growth model.

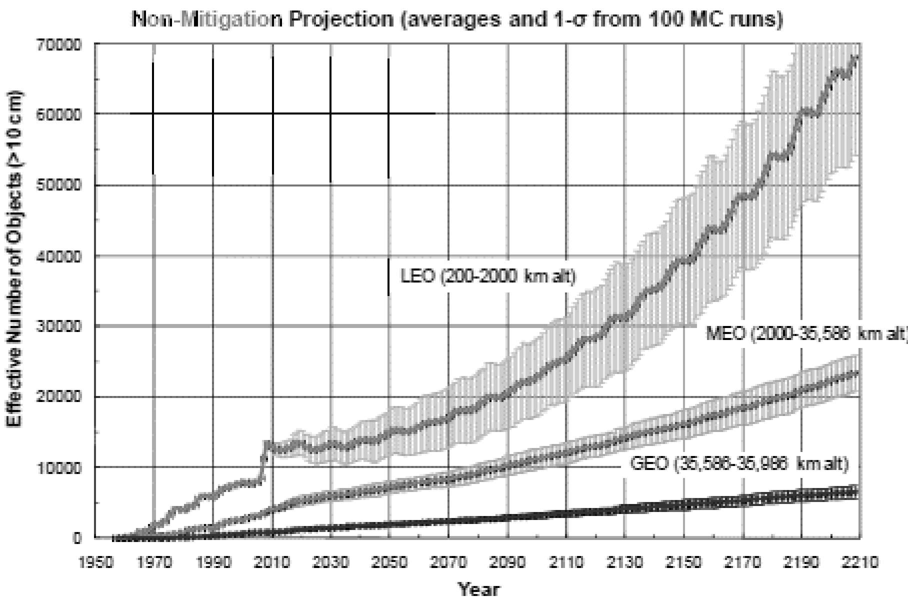

Figure 3: Projected growth of the trackable ≥ 10 cm debris population in LEO, MEO, and GEO for the next 200 years.[14]

A launch vehicle is made up of a first stage and usually one or more upper stages. When a vehicle is launched into space, the first stage typically propels the vehicle through the bulk of the atmosphere, but does not reach orbit. The first stage falls back to Earth shortly after launch. The upper stage then ignites to put the payload into LEO or a transfer orbit. Typically, the upper

[14] Liou, J.-C. (2011). Engineering and Technology Challenges for Active Debris Removal. Presented at the 4th European Conference for Aerospace Sciences.

stage deploys the payload in LEO, if that is the final payload destination; otherwise, it usually deploys the payload in the transfer orbit for payload destinations higher than LEO.

Historically, the largest contributor to orbital debris was the explosion of upper stages.[15] Defunct upper stages with charged batteries or partially fueled tanks would often experience catastrophic failures attributed to stored energy. Current regulations adequately address this issue by requiring launch operators to ensure that stored energy is removed from all launch vehicle stages or components.[16] However, now the greatest risk regarding the growth of orbital debris population is collision between objects including upper stages on orbit. The strength of upper stage structures, along with their mass and size, pose a risk of catastrophic collisions that would create substantial amounts of orbital debris. The threat of fracturing such a large object can be mitigated by removing it from populated orbits. With this proposed rule, the FAA intends to ensure upper stages are properly disposed of at the end of launch to limit the growing orbital debris population.

The impact of even one collision has a significant effect on the growth of orbital debris. Figure 4, generated by the NASA Orbital Debris Program Office,[17] shows the predicted growth rate of orbital debris in LEO, as estimated in 2022. This growth rate is based on the population of objects greater than or equal to 10 cm, which is primarily fragmented material. This figure portrays the growth of the orbital debris environment. The figure highlights collisions and intentional destruction of spacecraft as the largest contributors to the debris environment. The

[15] Anz-Meader, P.D., Johnson, N., Cizek, E., and Portman, S. (July 31, 2001). *History of On-Orbit Satellite Fragmentation, 12th ed.* NASA Lyndon B. Johnson Space Center Orbital Debris Program Office, Houston, TX, JSC29517.
[16] 14 C.F.R. § 417.129(b) and (c) and § 450.171.(a)(2)-(3).
[17] Liou, J.-C. (8 Feb 2022). U.S. Space Debris Environment and Activity Updates. 59th Session of the Scientific and Technical Subcommittee, Committee on the Peaceful Uses of Outer Space, United Nations.

figure also highlights the recent and rapid growth of operational spacecraft as large constellations continue to proliferate.

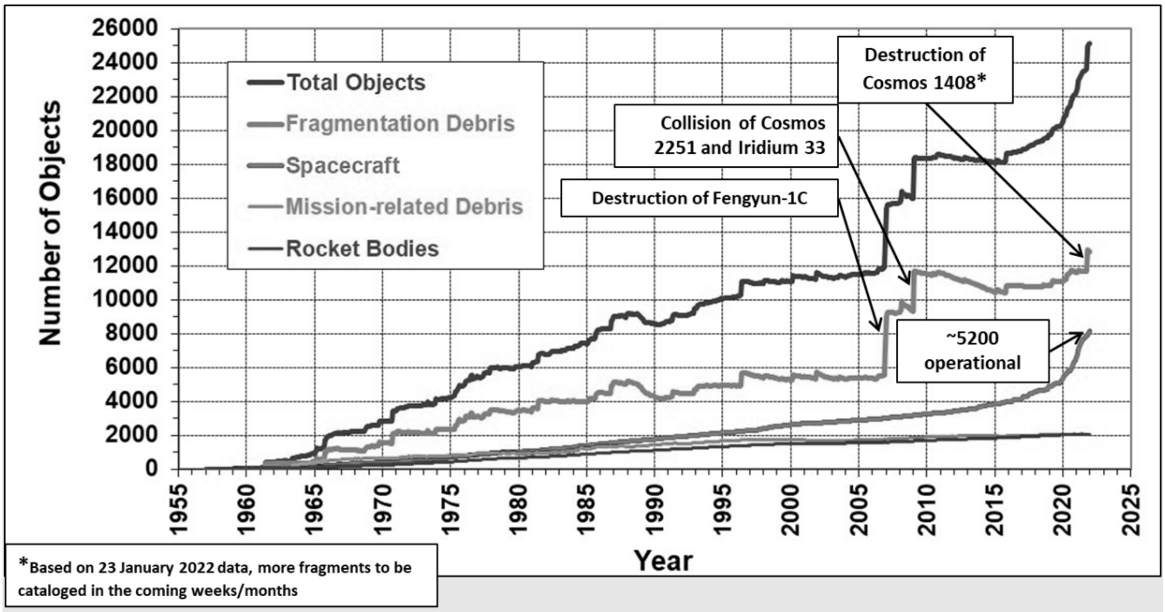

Figure 4: Predicted Growth of the LEO Debris Population.

The Iridium 33/Cosmos 2251 collision and the Chinese Fengyun-1C anti-satellite test have been the worst debris creating events ever recorded. These two events contributed approximately 5,900 catalogued objects to the environment. Launch vehicle upper stages are significantly more massive than any of the objects involved in these events and a catastrophic collision involving an upper stage would produce many more times the debris created in these events.

Debris imposes a cost on active satellites. Maneuvering an active spacecraft to avoid collision with space debris will mitigate the immediate threat of collision, but doing so uses up valuable resources. It takes time and effort to plan a maneuver; and, in some cases, the fuel expended on the maneuver will lead to a shortened mission life for the spacecraft. Most importantly, only active spacecraft are capable of maneuvering, whereas upper stages have no maneuverability after the end-of-launch. Removing upper stages from congested orbits would lessen the likelihood of debris-on-debris collisions and would reduce the probability of active satellites maneuvering to avoid a collision.

The first accidental hypervelocity collision between two intact spacecraft occurred in February 2009. The operational U.S. Iridium 33 communications satellite and the defunct Russian Cosmos 2251 communications satellite collided at a speed of 11.7 km/sec (26,172.2 mph), above northern Siberia.[18] The collision destroyed both satellites and produced more than 2,300 pieces of trackable debris.

The Chinese anti-satellite test and the Iridium/Cosmos collision were not the only orbital debris events to occur. In July 1996, a collision occurred between a French Cerise satellite and a briefcase-sized piece of debris left in orbit from an exploded Ariane third stage. The impact tore off a 4.2 m section of the Cerise's gravity-gradient stabilization boom.[19]

An example of orbital debris colliding with other orbital debris occurred on January 17, 2005, when a 31-year-old U.S. rocket body and a Thor-Burner 2A collided with a fragment from an exploded third stage of a Chinese CZ-4 launch vehicle. The collision occurred at an altitude of 885 km above the South Polar Region.[20]

If the amount of debris is not curtailed, the risk of future collisions between spacecraft and orbital debris will increase at a greater rate which will create more debris and degrade the usefulness of popular orbits. Fragments generated from one breakup can be large enough to

[18] The NASA Orbital Debris Program Office. (April 2009). Satellite Collision Leaves Significant Debris Clouds. *NASA JSC Orbital Debris Quarterly News, 13*(2), page 1-2.
[19] C.A. Belk, J.H. Robinson, M.B. Alexander, W.J. Cooke, and S.D. Pavelitz. (August 1997). Meteoroids and Orbital Debris: Effects on Spacecraft. *NASA Reference Publication 1408, Marshall Space Flight Center, AL.*
[20] Williamsen, J., Blacklock, K., Evans, H.J., and Guay, T.D. (1999). Quantifying and Reducing International Space Station Vulnerability Following Orbital Debris Penetration. *Journal of Spacecraft, 36*(1), page 1333-141.

catastrophically break up another target mass of the same size, continuing the cycle to create more debris. This cycle is referred to as the "Kessler Syndrome."[21]

Figure 5 shows the projected accidental collision activity in LEO as determined using 100 Monte Carlo runs in NASA's LEGEND model from 2010. An average of 8 to 9 collisions were expected to occur over the next 40 years (approximately 1 collision every 5 years).[22] The uppermost line shows the increasing number of collisions based on a non-mitigation scenario. The middle line shows the effects if 90 percent of all launchers worldwide[23] followed the proposed orbital debris mitigation standards. However, this model did not account for the large constellations that have now started to populate LEO.

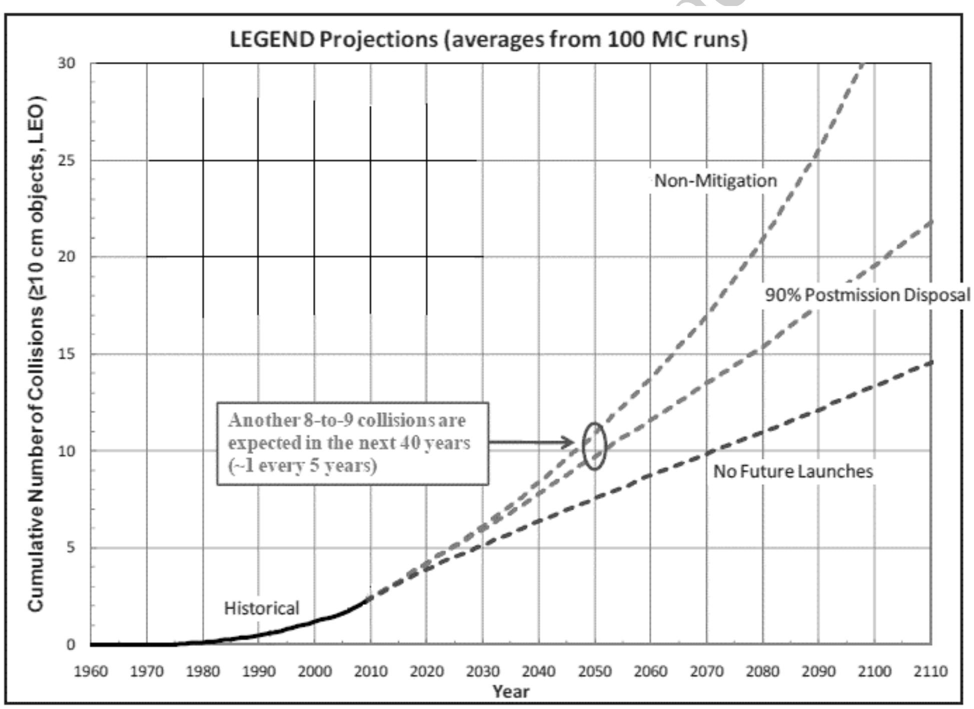

Figure 5: Predicted Accidental Collision Activities in LEO.[24]

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[21] Kessler, D.J., Johnson, N., Liou, J.-C., and Matney, M., "The Kessler Syndrome: Implications to Future Space Operations", Presented at the 33rd Annual AAS Guidance and Control Conference, Paper AAS 10-016, Breckenridge, CO, February 6-10, 2010, Published in Vol. 137 of the Advances in the Astronautical Sciences Series.

[22] *NASA JSC Orbital Debris Quarterly News 14*(1), page 7-8.

[23] In 2021, there were 135 successful worldwide orbital launches of which 39 were FAA licensed.

[24] *NASA JSC Orbital Debris Quarterly News 14*(1), page 7-8.

Figure 6 shows the updated collision expectation taking into account large constellations. With an addition of 8,300 spacecraft in constellations, the number of on-orbit collisions are expected to range from 1 every 2.2 years, up to more than 1 collision per year. The variance depends on the post-mission disposal (PMD) rate of the spacecraft in constellations, which is the probability that the spacecraft will be removed from LEO after its mission is complete. This study assumed that the constellations were refreshed with new satellites every 20 years, so the large constellations were renewed and remained on orbit, just swapping out individual satellites. After 200 years, for a PMD rate of 90 percent, a total of 260 catastrophic collisions are estimated to have occurred in LEO. With the accumulation of large constellations in LEO, it is imperative that large mass upper stages are removed from orbit so as to prevent collisions between upper stages and constellation spacecraft that could create large amounts of debris in already crowded orbital regions.

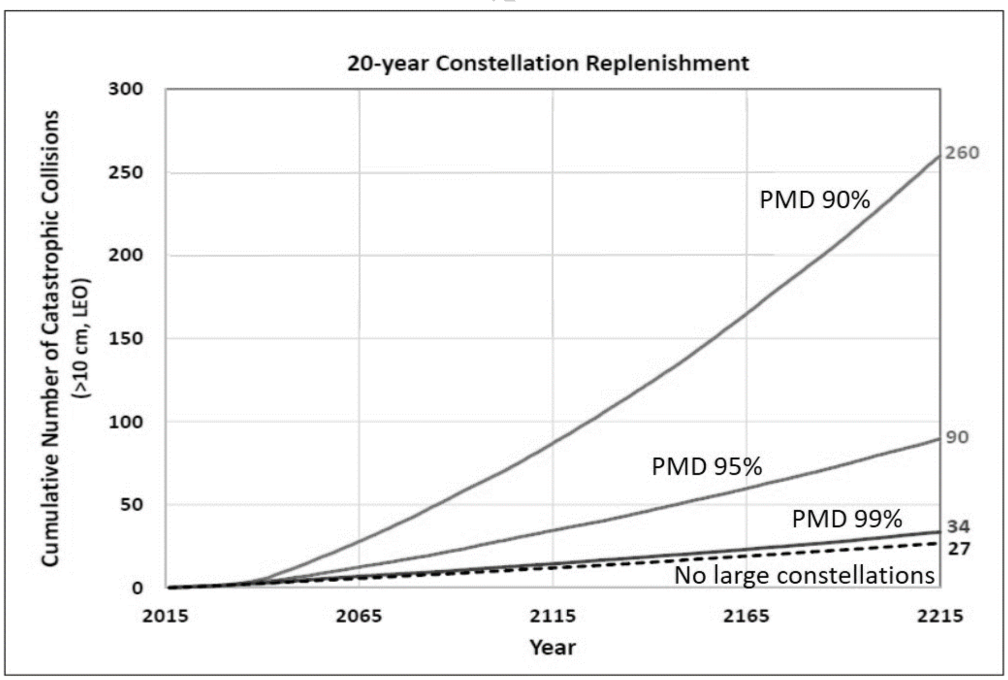

Figure 6: Cumulative Number of Catastrophic Collisions in LEO.[25]

Orbital debris also poses a high risk to safety for the International Space Station (ISS). The ISS is a high-value asset occupied by a constant human presence; therefore, it requires more protection than that provided by its protective shielding. Through shielding, the U.S. modules of the ISS are protected against impacts from debris ranging from 1 mm to 1 cm in size. During the first 8 years of ISS operations between 1999 and 2007, 6 successful maneuvers were conducted to avoid debris. However, since the Chinese anti-satellite test and the Iridium/Cosmos collision, the ISS has on average made an evasive maneuver twice a year due to debris from those events. Each maneuver costs millions of dollars in fuel usage and to perform the risk calculations to determine whether to move the station or shelter the crew.[26] Collision events and their risk to the ISS, and other on-orbit human activity, highlight the need to remove upper stages and prevent more debris creation.

Orbital debris mitigation is crucial to stem the increase of accumulation of large objects in orbit. Projections indicate that orbital debris in the LEO environment will increase approximately 75 percent in the next 200 years, even if 90 percent of spacecraft and upper stages reenter the Earth's atmosphere within 25 years of the end of the mission.[27] This projection was done before the proliferation of large constellations and the increased launch rate seen in the past few years. Launch and reentry operators' compliance with the U.S. Government Orbital Debris Mitigation Standard Practices (USGODMSP)[28] and any action to remove a number of large

[25] J.-C. Liou, M. Matney, A. Vavrin, A. Manis, and D. Gates. (September 2018). NASA ODPO's Large Constellation Study. *Orbital Debris Quarterly News, 22*(3), pages 4-7.
[26] Discussion with NASA VIPER office, January 2012.
[27] *NASA JSC Orbital Debris Quarterly News 14*(1), page 7-8.
[28] The USGODMSP apply to all U.S. government space launches.

objects from orbit would help prevent this increase.[29] This proposed rule reflects the best practices agreed to in the USGODMSP and is reflective of international consensus for orbital debris mitigation. Currently, research efforts are underway to develop the technology necessary to economically remove the critical debris pieces; however, there are no operational systems and the costs are expected to be high, approximately $30 million to $50 million per large object[30] (large objects are objects weighing roughly over 5,000 kilograms). These large objects are primarily rocket body upper stages. A recent paper[31] introduced at the 2020 International Astronautical Congress identified the 50 most dangerous pieces of orbital debris. The paper identified 39 of the 50 objects as upper stages capable of producing large amounts of space debris were they to collide.

With this proposal, the FAA also seeks to mitigate the risk to the public posed by uncontrolled disposals. Uncontrolled disposals of large upper stages, such as the Chinese Long March stage that reentered on May 9, 2021, and the Falcon 9 upper stage that reentered as an uncontrolled atmospheric disposal over the Pacific Northwest in March 2021, pose a significant risk to people on the ground due to their mass and the uncertainty of where they will land. Such disposals occur frequently, from upper stages, defunct spacecraft, and other debris. Per NASA, "During the past 50 years an average of one cataloged, or tracked, piece of debris fell back to Earth each day."[32] Large upper stages carry the most risk to people on the ground; risk that is above the common acceptable risk limit of 1 x 10^{-4}. This is the same risk limit codified in

[29] D.J. Kessler, N. Johnson, J.-C. Liou, and M. Matney. (February 6-10, 2010). The Kessler Syndrome: Implications to Future Space Operations; Paper AAS 10-016. *Advances in the Astronautical Sciences Series, 137.* Presented at the 33rd Annual AAS Guidance and Control Conference, Breckenridge, CO.
[30] Braun, V., Schulz, E., and Wiedemann, C. (August 2014). *Cost Estimation for the Active Debris Removal of Multiple Priority Targets.* Presented at the 40th COSPAR Scientific Assembly.
[31] McKnight, D., et al. (April 2021). Identifying the 50 statistically-most-concerning derelict objects in LEO. *Acta Astronautica, 181*, page 282-291.
[32] Frequently Asked Questions: Orbital Debris, www.nasa.gov/news/debris_faq.html

14 CFR § 450.101 for purposeful reentries, in International Standard (ISO) 24113, and in the USGODMSP, and the risk limit has been in common practice in the launch safety industry for more than 20 years. Although there are currently no documented cases of reentering debris causing casualties, uncontrolled disposal of large upper stages presents a significant safety risk to persons and property on the ground, or aircraft in flight. That risk can be mitigated by the operator performing a controlled disposal into an unpopulated area shortly after the end of launch, and providing advance notice to aircraft and vessels in the area. Uncontrolled disposals would not be permitted under the proposed orbital debris mitigation rule unless the operator can demonstrate that the effective casualty area, in total spread over the entire projected path, for the sum of all surviving debris will be less than 7 square meters or the expected average number of casualties will be less than 1×10^{-4}.

B. History

There have been many national and international efforts to protect against the effects of orbital debris. Early spaceflight operated under the theory that, because space was large, collisions were unlikely. Recent events discussed previously have demonstrated that to continue to operate under this theory is dangerous.

On February 11, 1988, President Reagan issued a Presidential Directive[33] on national space policy which included a requirement to limit the accumulation of orbital debris. This directive was the foundation for a coordinated effort among U.S. agencies and other nations to increase the understanding of the hazards caused by orbital debris and to establish effective techniques to manage the orbital debris environment. The National Security Council produced a

[33] The White House. (February 11, 1988). Presidential Directive on National Space Policy, spp.fas.org/military/docops/national/policy88.htm#:~:text=The%20directive%20states%20that%20the%20national%20security%20space%20sector%20will,Space%20Control

Report on Orbital Debris[34] in 1989 outlining the problem and recommended more study of the orbital debris situation. An updated Interagency Report on Orbital Debris[35] by the new National Science and Technology Council was released in 1995, directing government agencies to develop a coordinated orbital debris work plan, to consult with U.S. industry, and to continue efforts to achieve international consensus on dealing with the orbital debris problem.

In response, NASA and the Department of Defense, coordinating with other space-related Federal agencies, developed a draft set of USGODMSP, derived in large measure from NASA Safety Standard 1740.14.[36] These standard practices, applicable to launches by the U.S. Government, were adopted by the U.S. Government in February 2001 and mandated by the National Space Policy of 2006.[37] The Department of Defense and its service and defense agencies issued their own detailed orbital debris mitigation requirements to meet the USGODMSP standard.

U.S. regulatory agencies, particularly the FAA, the National Oceanic and Atmospheric Administration (NOAA), and the Federal Communications Commission (FCC), have also addressed orbital debris mitigation by establishing requirements for space activities that they regulate. In a final rule published September 19, 2000,[38] the FAA adopted some, but not all, debris mitigation practices that were widely accepted by NASA and the commercial space industry at the time, such as the removal of stored energy sources that could generate debris.[39]

[34] National Security Council. (February 1989). Report on Orbital Debris by Interagency Group (Space), ntrs.nasa.gov/citations/19900003319.
[35] The National Science and Technology Council Committee on Transportation Research and Development. (November 1995). Interagency Report on Orbital Debris, www.hsdl.org/?view&did=722496.
[36] NASA. (August 1995). *NSS 1740.14, NASA Safety Standard: Guidelines and Assessments for Limiting Orbital Debris.*
[37] The White House. (August 31, 2006). *U.S. National Space Policy.*
[38] Commercial Space Transportation Reusable Launch Vehicle and Reentry Licensing Regulations, 65 FR 182 (September 19, 2000).
[39] 64 FR 19586, 19608 ("The FAA has elected to adopt only selected debris mitigation practices that are of almost universal applicability.")

The only collision mitigation measure the FAA established was to require avoiding any unplanned contact between the launch vehicle and the payload after payload separation.[40] At that time, the FAA aimed to align with then-current international practice without negatively affecting U.S. launch competition in the international market.

Since then, there has been considerable progress in addressing requirements to reduce orbital debris. Most notably, the FCC adopted a comprehensive set of regulations that apply to U.S. satellites and to satellites that provide communications services to the United States.[41] The FCC regulations closely reflect the USGODMSP.

The international community is also adopting practices that reduce orbital debris generation. The Inter-Agency Space Debris Coordination Committee (IADC), in which NASA represents the U.S., issued Space Debris Mitigation Guidelines in 2002. The IADC coordinates activities related to orbital debris issues and is comprised of representatives from space agencies around the world. Member States are encouraged to use the consensus-based IADC guidelines. These include implementing a mitigation plan for each launch that details how the operator will limit debris from normal operations, minimize the potential of unplanned breakup, and dispose of spacecraft and stages post-mission.[42] The USGODMSP, which apply to U.S. Government launches, are consistent with, and in parts surpass, the IADC guidelines. The FAA's current regulations do not meet all the USGODMSP or the IADC guidelines. The FAA currently only requires passivation at the end of launch and prevention of collisions between the payload and upper stage. The current FAA regulations do not otherwise address debris mitigations or post-

[40] 14 C.F.R. § 417.129(a).
[41] Mitigation of Orbital Debris, 69 FR 54581 (September 9, 2004).
[42] IADC. (October 2002). *IADC Space Debris Mitigation Guidelines; IADC-02-01.*

mission disposal, and do not restrict uncontrolled reentries based on the risk posed to public safety.

In 2010, the National Space Policy specifically encouraged the development and adoption of industry standards for the purpose of minimizing debris and preserving the space environment for the responsible, peaceful, and safe use of all users.[43] Subsequent policies have retained similar language.

In 2011, the National Research Council recommended incorporating orbital debris mitigation practices into regulations:

> NASA should continue to engage relevant federal agencies as to the desirability and appropriateness of formalizing NASA's Orbital Debris Mitigation Standard Practices, including the "25-year rule,"[44] and NASA Procedural Requirements for Limiting Orbital Debris as legal rules that could be applicable to U.S. non-NASA missions and private activities.[45]

In response, NASA engaged with relevant agencies: NOAA, regarding implementing orbital debris mitigation standard practices as part of NOAA's commercial remote sensing licensing program; FCC, regarding licensing of communications spacecraft; and the FAA, regarding launch vehicles.

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[43] The White House. (June 28, 2010). *National Space Policy of the United States of America.*
[44] NASA requires that "[a]ll debris released during the deployment, operation, and disposal phases shall be limited to a maximum orbital lifetime of 25 years from date of release (Requirement 56398)." NASA-STD-8719.14A, 2012-05-25.
[45] The National Academy of Sciences. (September 2011). *Limiting Future Collision Risk to Spacecraft: An Assessment of NASA's Meteoroid and Orbital Debris Programs*.

In 2019, in response to the National Space Council's Space Policy Directive 3,[46] the U.S. Government released an updated version of the USGODMSP[47] to address the effects of large constellations and small satellites. The updates consist of a quantitative limit on debris released during normal operations, a probability limit on accidental explosions, probability limits on accidental collisions with large and small debris, and a reliability threshold for successful post-mission disposal. The new standard practices updated disposal options and incorporated new sections to clarify and address operating practices for large constellations, rendezvous and proximity operations, small satellites, satellite servicing, and other classes of space operations.

For this proposed rulemaking, the FAA considered the orbital debris requirements of NASA, FCC, NOAA, and the IADC, in an effort to align commercial standards and government standards and to address the persistent risks associated with heavy upper stages abandoned in orbit. The FAA focused on NASA because it has the most detailed orbital debris requirements and guidance, and is an internationally recognized leader in orbital debris and space exploration whose expertise in space and mission planning is a benchmark for the FAA's rulemaking efforts. The effort to establish common standards is consistent with the U.S. Space Transportation Policy, which states the Secretary of Transportation shall execute exclusive authority, consistent with existing statutes and executive orders, to address orbital debris mitigation practices for U.S.-licensed commercial launches, to include launch vehicle components such as upper stages, through its licensing procedures.[48]

[46] The White House. (June 18, 2018). *Space Policy Directive-3, National Space Traffic Management Policy.* trumpwhitehouse.archives.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/

[47] United States Government. (November 2019) *U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update.* orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf

[48] The White House. (November 21, 2013). *National Space Transportation Policy of the United States of America.* www.nasa.gov/sites/default/files/files/national_space_transportation_policy_11212013.pdf

The FAA believes the proposed regulations would not hinder U.S. companies from competing in the international launch market because regulations of foreign countries are also expected to comply with IADC guidelines, and some countries' regulations are stricter than the requirements proposed in this rule. For example, the French space agency, Centre National d'Études Spatiales (CNES), issued technical regulations in 2009 that extend beyond the requirements of the IADC guidelines and spell out the acceptable reentry risk from orbital debris for those with French space operation licenses. The IADC guidelines are a consensus document originally based on the USGODMSP. Due to the consensus nature of the IADC guidelines, an agreed-upon document between 13 different space agencies, the guidelines are not as thorough and specific as the USGODMSP. Several of the IADC's 13 participating space agencies are currently working to implement regulations that align with the IADC guidelines; however, not all IADC participants have launch capability.

III. Discussion of the Proposal

The FAA proposes several new requirements for limiting the lifetime of debris in LEO and in GEO. First, the FAA proposes to amend the definition of "disposal" in § 401.7 to include each of the disposal options proposed for part 453. The existing definition describes controlled atmospheric disposal, and would exclude the other four options proposed in §§ 453.14 through 453.18 for the disposal of spent upper stages and launch or reentry vehicle components. The FAA therefore proposes to define "disposal" as the execution or attempt to execute "controlled atmospheric disposal, heliocentric disposal, uncontrolled atmospheric disposal, disposal orbit, or direct retrieval of launch vehicle stages or components of launch or reentry vehicles under part 453 of this chapter."

The FAA also proposes to add definitions to § 401.7 for "Low Earth Orbit (LEO)," "Medium Earth Orbit (MEO)," "Geostationary Earth Orbit (GEO)," "the geosynchronous region," and "orbital debris." "LEO" would be defined as any Earth orbit with both apogee and perigee below 2,000 km altitude. "MEO" would be defined as any Earth orbit in which an object's apogee and perigee both remain between LEO and GEO. "GEO" would be defined as any Earth orbit where the orbiting object orbits at the same angular velocity as the Earth and the object appears stationary from the ground. The altitude of this zero-inclination, zero-eccentricity orbit is 35,786 km. "The geosynchronous region" would be defined as the band of orbital space surrounding GEO. It is bound by altitude limits of 35,786 km +/- 200 km altitude and +/- 15 degrees latitude.

The IADC defines Space Debris as "all man-made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional."[49] The FAA agrees with the IADC definition of space debris and refines the debris issue further by establishing the size of debris applicable for regulation. "Orbital debris" would be defined as all human-generated debris in Earth orbit that is greater than 5 mm in any dimension. This includes, but is not limited to, payloads that can no longer serve a useful purpose, rocket bodies and other hardware (e.g., bolt fragments and covers) left in orbit as a result of normal launch and operational activities, and fragmentation debris produced by failure or collision. The FAA proposes to expressly exclude released gases and liquids from the definition of orbital debris. The release of gases and liquids is often deliberate for the purpose of maneuvering or to evacuate excess gases and liquids at the end of launch. The FAA does not believe addressing the release of gases and liquids is necessary at this time because the risk is low. One of the debris mitigation

[49] IADC Space Debris Mitigation Guidelines, IADC-02-0, Revision 2, Mar 2020.

actions at the end of launch is the release of pressurized gases and propellants because the risks of accidental explosion outweigh the risks of released gases and liquids. Based upon this understanding, the FAA finds that it is unnecessary to regulate released gases and liquids at this time.

The FAA proposes 5 mm as the threshold size because an object of that size, traveling at 10 km per second, a speed typical of objects on orbit, can incapacitate a functioning satellite, which in turn may contribute to the creation of more debris. Most active satellites on orbit are protected against small pieces of debris and micrometeoroids less than 5 mm in size with shielding or thermal blankets. However, pieces as small as 5 mm can do significant damage to satellite operations. The kinetic energy that a 5 mm cube of titanium (4.43 g/cm^3 density) has, while traveling 10 km per second in LEO, is 27,700 Joules. Comparably, the energy of a .30-06 rifle bullet (11.7 grams) when exiting a gun muzzle is only 3,700 Joules.

Spacecraft vary in design and material composition, so it is hard to identify an exact threshold size of debris that could significantly damage a spacecraft. Nevertheless, the National Research Council found in its 2011 report on orbital debris that typical spacecraft are not well shielded from small debris, and that objects 5 mm and larger can cause substantial damage.[50] For this reason, the FAA proposes to use 5 mm as the size threshold for orbital debris. However, the FAA requests comments on further lowering the size threshold to below 5 mm.

The FAA recognizes that a launch operator cannot prevent the release of all small debris fragments, such as paint flakes and solid rocket motor (SRM) slag. SRMs—used to boost satellites into higher orbits—are potentially a significant source of numerous pieces of aluminum oxide slag up to 5 cm in diameter. Likewise, flaking paint is a debris hazard, albeit of very small

[50] The National Academy of Sciences. (September 2011). *Limiting Future Collision Risk to Spacecraft: An Assessment of NASA's Meteoroid and Orbital Debris Programs*.

size. Debris of this size usually will not disable a spacecraft, but it does pose a hazard to spacewalkers, and over time it causes erosion damage and more debris. The FAA is not, however, proposing to regulate debris smaller than 5 mm, paint flakes, or solid rocket motor slag of any size, due to the current impracticality of tracking and mitigating the propagation of such small items. At this time, the only practical mitigation for debris smaller than 5 mm is to harden spacecraft to make them less susceptible to small debris.

Proposed § 453.1 would provide the scope of part 453: the requirements of a launch or reentry operator for orbital debris mitigation, including collision avoidance analysis, prior to launch or reentry operations licensed or permitted under this chapter with a planned altitude greater than 150 km. The FAA proposes to require in § 453.1(b) that for each licensed or permitted launch or reentry with a planned altitude greater than 150 km, an operator must submit (1) an ODAP containing the information required by this part, not less than 60 days before the licensed or permitted launch or reentry, unless the Administrator agrees to a different time frame in accordance with § 404.15; and (2) a Collision Avoidance Analysis Worksheet in accordance with § 453.11(f). The submittals must be emailed to the address provided in proposed § 453.1(c) or otherwise submitted as agreed to by the Administrator in the license or permit. The FAA proposes to require that operators submit their ODAP no later than 60 days prior to the launch or reentry subject to part 453 to be consistent with the timeframes in part 450 and in the legacy regulations. The FAA proposes no change to the timeline for submitting the Collision Avoidance Analysis Worksheet, which is currently required by § 450.169 and would be moved to § 453.11(f).

Proposed § 453.3 would state that part 453 applies to launches and reentries licensed or permitted under this chapter with a stage or other component with a planned altitude greater than

150 km. Few satellites operate below the altitude of 150 km, hence mitigation of orbital debris below 150 km is not necessary.

A. Limitations on Orbital Lifetime of Debris Released During Normal Operations

Current §§ 417.129 and 450.171 do not address the planned release of debris during normal operations, such as the deliberate planned release of payload spacers, retaining rings, or tension rods. To reduce the amount of debris in orbit, the FAA proposes to require that launch operators ensure that no vehicle stages or components release orbital debris during normal operations that will remain in orbit for more than 25 years. Proposed § 453.5(a) would require a launch operator to ensure that no vehicle stages or components that reach Earth orbit release orbital debris into LEO that would remain in orbit for more than 25 years. The 25-year rule is a common standard recommended by the IADC and a requirement for U.S. Government launches under the USGODMSP.

For the lowest region of LEO—orbits with perigee altitudes below 600 km—debris typically has an orbital lifetime of less than 25 years, and smaller pieces of debris here may reasonably be expected to burn up on reentry into Earth's atmosphere within the allowable time limit. This proposed requirement would have a greater impact on operations releasing debris above 700 km, where debris may remain on-orbit for hundreds of years. The most efficient and practical approach to comply with the proposed requirements would be to avoid creating any debris in the upper portions of LEO and higher altitudes. For example, if a launch operator cannot demonstrate that it will remove all debris larger than 5 mm from orbit within 25 years, as required by § 453.5, then the launch operator must prevent such objects from separating from the launch vehicle. A launch operator could do so by redesigning the separation system (a common source of debris) or by using lanyards or other means to prevent debris release.

Given that most current launch vehicles have been designed to minimize or eliminate normal operations debris release, the FAA anticipates that this proposed requirement would impose no more than a minimal burden on operators for compliance. Operators usually meet this requirement because they want to minimize the release of debris and the possibility of damage to their deployed payloads. Since commercial launches are deploying increasing numbers of payloads, which could result in additional debris release, the FAA finds it appropriate to require that all operators limit their release of debris.

The FAA also proposes to require in § 453.5(a) that the total object-time product for all debris planned to be released into LEO shall not exceed 100 object-years per licensed or permitted launch. Object-time is a unit of measure used by NASA. It means the number of objects multiplied by the unit of time, typically years. A higher object-time means more objects on orbit for a higher cumulative amount of time. Limiting the object-time reduces the number of objects in orbit. The more objects released, the less time they can spend in orbit to meet the object-time requirement. For example, if an operator plans to release 5 debris objects, none of those objects can remain in Earth orbit longer than 25 years, and the total orbital lifetime of all 5 debris objects cannot exceed 100 years. The regulation would specify that the total object-time product in LEO is the sum of the orbit dwell time in LEO for all planned released objects, excluding the upper stage and any released payloads. The requirement would target debris released into LEO since, as discussed above, this small spatial area is heavily used and currently contains the most debris. This requirement is consistent with the USGODMSP guidelines and is necessary to limit the number of released objects per launch. The FAA supports the USGODMPS object-time standard and notes the standard is particularly relevant to space launch activities that use payload deployment devices.

The FAA notes that the 100 object-years limit would apply to debris that the operator plans to release during launch activities, and would not include debris released due to non-nominal conditions or launch or reentry activity outside the 3-sigma trajectory provided for collision avoidance. However, an operator would be required to immediately notify the FAA and provide the information required by § 453.20 at the detection of a debris-creating event or any launch or reentry outside the 3-sigma trajectory provided for collision avoidance.

The FAA solicits comments on its proposal to limit the total object-time product of all debris released by a single launch into LEO to 100 object-years. Although, as noted above, this standard derives from the USGODMSP, the FAA recognizes that this standard is new, and the commercial space industry has not had an opportunity to weigh in on the effectiveness or operational implications of this requirement. As a result, FAA seeks insight into stakeholders' opinions on limiting the total object-time product of all debris released by a single launch into LEO to 100 object-years, and whether a smaller object-time should be imposed.

The FAA would also require that debris released into the geosynchronous region be removed within 25 years after release. Proposed § 453.5(b) would require a launch operator to ensure that any orbital debris released into the geosynchronous region enters an orbit with an apogee that would not remain within the geosynchronous region within 25 years of the release. Operators would need to submit analysis showing that the debris will stay below the geosynchronous region 25 years after release, and that it will not enter the operational geosynchronous region again. Released debris can only move into lower orbits. Debris released above GEO would eventually return to the GEO protected region.

The FAA solicits public comments on its proposal to require that debris be removed within 25 years, as opposed to a shorter deadline. While the FAA recognizes the current IADC and USGODMSP guidelines, which limit post-mission lifetimes in LEO to 25 years, the FAA recognizes that increases in the numbers and kinds of activities in Earth orbit may render the 25-year timeframe inadequate to prevent the growth of orbital debris. Given that the entire mission lifetime of upper stages and their components is quite short, and spent upper stages pose a significant risk of debris propagation the longer they are in orbit, it may be appropriate to have a shorter disposal timeline of 5 years or another time period less than 25 years. Shortening the removal deadline would decrease the risk of orbital debris causing damage to spacecraft, which could create more debris, shorten another spacecraft's mission, or endanger the lives of human spaceflight participants. The FAA requests comments on the degree to which a shorter timeline for removal from LEO or GEO within 5 years or another period shorter than 25 years would further encourage the minimization of released debris, as well as the relative impact of a shorter timeframe on operational capabilities.

Proposed § 453.5(c) would specify the information that must be included in an ODAP to demonstrate compliance with § 453.5(a) and (b). Specifically, the ODAP must include (1) a demonstration through environmental qualification and acceptance testing that the system is designed to limit the release of orbital debris; and (2) a statistical analysis, including inputs and assumptions, demonstrating that any orbital debris released will be disposed of within 25 years and satisfy the 100 object-year requirement. The environmental qualification and acceptance testing could include vibration, shock, vacuum, or any other appropriate testing to demonstrate that debris will not be released from the upper stage. Operators should provide the FAA specific verifiable analysis or test results that demonstrate the mitigation measures the launch operator would take to prevent release of debris greater than 5 mm in size or to ensure that it departs LEO or GEO within 25 years. Results of hardware and software tests, if performed on the separation system, would fulfill the requirement to demonstrate the effectiveness of debris prevention measures. The testing should apply to the entire lifetime of the system. If debris will be released, an orbital lifetime analysis using the methods described in ISO 27852[51] or NASA's Debris Assessment Software (DAS) or similar software would be acceptable. The inputs and assumptions referenced in § 453.5(c)(2) would include the initial orbit, the altitude of the release, and information about the debris objects planned to be released, such as their mass, area, and estimated orbital lifetime. The FAA seeks public comments on the proposed demonstration through specific analysis and testing of debris release prevention.

B. Collision Mitigation Between Launched Objects

The current FAA regulations in parts 415, 417, 431, 435, and 450 require that launch operators prevent the unplanned physical contact between a launch vehicle and each payload after payload separation. The FAA proposes to move these current requirements for safety at the end of launch to § 453.9(a). The FAA proposes to add a requirement in § 453.9(b) to limit the probability of collision with orbital objects greater than 10 cm to less than 1 in 1,000 over the orbital lifetime of the upper stage. This proposal matches the standard in USGODMSP and is necessary to lower the risk of debris impacts with the upper stage and its components. The probability of collision during orbital lifetime can be reduced by removing the upper stage and components from orbit, as discussed in the next section, and by operating the upper stage in an orbit with a low density of orbital objects.

Proposed § 453.9(c) would require launch operators to include in their ODAP for each launch or reentry a procedure for preventing vehicle and payload collision after payload separation. The end-of-life activities, including any propellant depletion burns and compressed

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[51] International Organization for Standardization. (September 7, 2010). *ISO 27852:2010(E), "Space Systems—Estimation of orbit lifetime*."

gas releases, could increase or decrease the probability of subsequent collisions; therefore, the launch operator should explain in the ODAP how these activities will affect potential collision risks. The ODAP must also include the results of a probability of collision analysis between the upper stage and its components and orbital objects. The analysis must use commonly accepted engineering and probability assessment methods, such as those available in NASA's DAS tool.

C. Post-Mission Disposal

In the current debris environment, the greatest risk to operational orbits is collision between objects having considerable mass. Spent upper stages are large, strong structures that contribute to the debris threat because their size increases the chance of a collision, and because their mass provides an ample source of fragmentation debris in the event of a collision. As noted above, the amount of orbital debris is projected to rapidly increase based on the current population of objects greater than 10 cm.[52]

Disposal, either through reentry or another form of disposal, is necessary to mitigate the propagation of orbital debris because it removes upper stages and other vehicle components from the most populated orbits. If proper disposal is not implemented, spacecraft operators would need to employ increased shielding of payloads, along with additional on-orbit collision avoidance, in order to continue to utilize the most populated orbits. However, neither of these options would mitigate the volume of dormant upper stages in orbit, and therefore, the growth of orbital debris. The only option in the future for these upper stages would be remediation—dedicated missions to remove them from orbit. This kind of remediation is forecasted to be

[52] See Figures 3 and 4 in the Statement of the Problem.

expensive and has not yet been shown to be a viable operation. Research and development is still on-going into debris removal techniques.[53]

Given that disposal is at this time the only viable means of mitigating the threat of orbital debris in populated orbits, the FAA is proposing to require in § 453.13 that launch operators dispose of all launch vehicle stages or jettisoned components using one of five methods: (1) controlled atmospheric disposal, (2) Heliocentric, Earth-escape disposal, (3) direct retrieval, (4) uncontrolled atmospheric disposal, or (5) maneuver to a disposal orbit. The proposed requirements for each disposal method are set forth in §§ 453.14 through 453.18, respectively. A launch or reentry subject to part 453 must identify the chosen disposal method in the ODAP and satisfy the regulatory requirements applicable to that disposal method. Table 1 provides a list of disposal options derived from the USGODMSP. Options that promptly remove the upper stage and its components from orbit are the preferred disposal options according to the USGODMSP, as they significantly reduce both long term collision and debris generation risks. Delayed disposals through either direct retrieval or uncontrolled atmospheric disposal impose some risks to other on-orbit spacecraft until removal. Disposal orbits may become overly populated in the future which would preclude the future use of them for disposal. The FAA notes that while the USGODMSP identifies disposal methods in order of preference in the following table, the proposed rules do not allocate preference or distinguish between disposal methods in order to provide flexibility to operators to perform any of these valid methods of debris disposal. However, the FAA expects that as space continues to become more congested, orbital debris requirements will tighten in response, such that delayed disposal options that pose some additional risk to on-orbit spacecraft (i.e. uncontrolled atmospheric disposal, highly eccentric

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[53] Zhao, et.al. (2020) Science China Technological Sciences, *Survey on research and development of on-orbit active debris removal methods*.

long-term disposal, or use of a disposal orbit) may be restricted or eliminated. FAA requests comments on whether the prompt and safest disposal options (controlled atmospheric, heliocentric, and direct retrieval) should be the preferred disposal methods based upon expected growing orbital congestion. Additionally, the FAA seeks comment on whether it should impose a requirement to use the prompt disposal options unless shown to be impracticable.

Disposal Method	*453 Section*	*Time Frame*
Controlled Atmospheric Disposal	453.14	Within 30 days of mission completion
Heliocentric (Earth-escape)	453.15	Within 30 days of mission completion
Direct Retrieval	453.16	Not to exceed 5 years post mission completion
Uncontrolled Atmospheric Disposal	453.17(b)	Not to exceed 25 years after launch
Highly Eccentric Long-Term Disposal	453.17(c)	Not to exceed 200 years after mission completion
Disposal Orbit	453.18	Within 30 days of mission completion into a perpetual disposal orbit

Table 1: Disposal Options

a. Controlled Atmospheric Disposal

Upper stage-controlled reentry is the most effective method of orbital debris prevention and the safest reentry method. Controlled reentry eliminates the upper stage as a piece of orbital debris and therefore mitigates the risk of future debris creation through collision because the reentry would occur shortly after the end of launch. The FAA proposes to allow operators to perform controlled disposal by reentering Earth's atmosphere if they meet the requirements of § 453.14. The requirements of § 453.14 would only apply if the operator elects controlled disposal for its disposal method, as required by § 453.13.

A controlled disposal means a planned burn of the upper stage engine to aim for a low-risk area on the surface of the Earth. The FAA acknowledges that the upper stage is not "controlled" during the entire atmospheric disposal. Variations in the engine burn, the atmospheric density, and other factors beyond the operator's control can affect the actual disposal location. Therefore, those uncertainties must be accounted for in the disposal risk assessment or in the determination of the disposal ellipse in a broad ocean area, in accordance with § 453.14(d).

In order to perform controlled disposal, proposed § 453.14(b) would require a launch operator to ensure the return of the upper stage and each of its components to the Earth's surface within 30 days after mission completion in a controlled manner that ensures the effective casualty area of any surviving debris is less than 7 square meters, targets a broad ocean area, or meets the risk criteria set forth in § 450.101(d)(1)(iii)(A) through (C). This proposal would effectively require launch and reentry operators to consider disposal risks in their vehicle and mission designs—for instance, by designing components that demise when heated by atmospheric reentry or by reentering in remote locations.

The FAA's proposal to allow operators to target a broad ocean area or meet the risk criteria set forth in § 450.101(d)(1)(iii)(A) through (C) is substantively equivalent to the current text of § 450.101(d), which requires that all disposals—currently defined as controlled atmospheric disposal in § 401.7—either target a broad ocean area or meet the risk criteria in § 450.101(b). As discussed later in this preamble, the FAA proposes to amend § 450.101(d) to specify the risk criteria applicable to atmospheric disposals, rather than relying on the reentry risk criteria in § 450.101(b), since disposal is distinct from reentry. The FAA therefore proposes to extend the safety criteria applicable to licenses under part 450 to all launches or reentries covered by part 453, including experimental permits. The FAA is proposing that all launches or reentries authorized by the FAA that exceed 150 km be required to meet the risk criteria in

§ 450.101(d)(1)(iii)(A) through (C), target a broad ocean area, or have an effective casualty area less than 7 square meters for the following reasons.

Disposal into a broad ocean area would reduce the risk of casualties to near zero. The FAA considers an area 370 km (200 nm) from land to be "broad ocean area," as used in § 450.101(d) and proposed part 453. Two hundred nautical miles is also the recognized limit of exclusive economic zones (EEZ), which are zones prescribed by the United Nations Convention on the Law of the Sea[54] over which the owning State has exclusive exploitation rights over all natural resources. Deorbiting beyond an EEZ further reduces the chance of disrupting economic operations such as commercial fishing.

For massive objects reentering the atmosphere, a controlled disposal into the broad ocean area may be necessary for safety because it would ensure that the casualty expectation of reentry could be kept below 1 in 10,000. Because the broad ocean area has a population density of nearly zero, objects that survive reentry in this area can be fairly large without inordinate risk of human casualties. Alternatively, the operator could show that the 1×10^{-4} collective risk and 1×10^{-6} individual risk limits are met for the controlled disposal in another area. The expectation of casualty alternative might allow for controlled disposal into areas near islands or coast lines with low populations. The operator could also choose to demonstrate that the cumulative effective casualty area of surviving debris will be less than 7 square meters. That small casualty area ensures that the expectation of casualty will be met without requiring a full expectation of casualty calculation.

The effective casualty area for inert debris is the region associated with a fragment's impact location where it is assumed a person would become a casualty. Debris from atmospheric

[54] United Nations Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397.

reentry of an upper stage is usually made up of multiple pieces, as the upper stage breaks up due to heating and friction. The total effective casualty area is determined by adding up the casualty area of each of those pieces.

An expectation of casualty calculation requires determination of the effective casualty area along with analysis of the expected trajectory and exposed populations to determine how many people could become a casualty due to the uncontrolled disposal of the upper stage. Due to uncertainty and growth in population, that calculation can be difficult to complete for disposals that are expected on long timeframes like 25 years. As a result, FAA is proposing to allow an operator to demonstrate that the effective casualty area of surviving debris will be less than 7 square meters.

The FAA proposes to require in § 453.14(c) that operators performing controlled disposal notify the public of any region of land, sea, or air that contains, with 97 percent probability of containment, all debris resulting from normal flight events capable of causing a casualty. The FAA currently imposes this requirement on operators performing disposal operations under a part 450 license, and would extend the part 450 requirement to proposed § 453.14(c). The FAA finds that all operations required to comply with part 453 should provide this degree of notification to the public. These measures could include arrangements with the FAA or U.S. Coast Guard to provide Notice to Air Mission (NOTAM) and Notice to Mariners (NOTMAR).

The FAA proposes that an operator would be required to implement a controlled reentry within 30 days after the completion of the mission, which is also how long a launch operator must have insurance coverage under § 440.11. The FAA further proposes to require that operators accomplish any actions necessary to end a launch and commence controlled disposal within the insurance coverage timeframe. As discussed later in this preamble, the FAA proposes to apply the 30-day deadline to the Earth-escape and orbit disposal options as well.

Additionally, the FAA finds that 30 days would almost always provide sufficient time to assess the possible consequences of a launch anomaly, such as delivery to a wrong orbit or failure of a payload to separate from the vehicle's upper stage. Current technologies and practices are adequate to require the following within 30 days (1) perform final maneuvers to direct controlled disposal, (2) relocate to a lower orbit where the upper stage will decay within 25 years, or (3) relocate to a disposal orbit.

Another reason for the proposed requirement to implement a disposal option within 30 days is the short time frame an upper stage would have to maneuver. Typically, most upper stages have limited electrical power supplied by flight batteries, and, by design, must maneuver expeditiously after payload separation. In order to mitigate the possibility of an explosion occurring, the FAA requires a launch operator to power down its batteries at the end of launch. Accordingly, an affirmative act such as controlled reentry, placement to ensure reentry within 25 years, or maneuvering to a disposal orbit would have to occur within that time frame. Upper stages in orbits with an expected lifetime below 25 years would have no additional required actions to meet the post-mission 25-year rule. However, these upper stages may be required to move to disposal orbits if they cannot be safely deorbited due to excessive risk in uncontrolled reentries.

The FAA proposes to require in § 453.14(d) that operators submit a description of the controlled disposal in the ODAP prior to each launch or reentry pursuant to § 453.1(b). The ODAP must include verification through hardware and software testing or analysis that the system has at least a 90 percent probability of successfully executing the controlled atmospheric disposal as planned. The FAA proposes to require a probability of success of at least 90 percent. The FAA is adopting a 90 percent probability of success criteria that is consistent with the IADC Guidelines, ISO Standard 16126[55] and USGODMSP guidelines. ISO Standards represent a consensus international standard for specialized space activities. The testing and analysis can include engine re-light qualification tests or reliability analysis or similar. The ODAP must also include a description of how the system will achieve controlled atmospheric disposal under nominal and off-nominal conditions, such as a partial burn failure or off-trajectory scenario. Lastly, unless the operator is targeting a broad ocean area, the ODAP must include the calculated total collective and individual casualty expectations for the proposed operation or the effective casualty area of any surviving debris, pursuant to § 453.14(d)(3).

b. Heliocentric, Earth-escape Disposal

The FAA proposes to allow operators to perform heliocentric, Earth-escape disposal if they meet the performance-based requirements of § 453.15. The requirements of proposed § 453.15 would only apply if the operator elects heliocentric, Earth-escape disposal as its disposal method under § 453.13. Proposed § 453.15(b) would require that the operator ensure, within 30 days after mission completion, that the upper stage and each of its components is placed in a hyperbolic trajectory that no longer orbits Earth. This option would remove the upper stage from orbit completely and also result in zero risk to the people of Earth. The upper stage and its components would travel into an orbit around the Sun rather than remain as debris in Earth orbit. The FAA recognizes that this disposal option is prohibitively costly for operators not already planning inter-planetary missions, as the energy needed to fully escape Earth orbit is

[55] International Organization for Standardization. (April 1, 2014). *ISO 16126:2014, "Space systems—Assessment of survivability of unmanned spacecraft against space debris and meteoroid impacts to ensure successful post-mission disposal."*

greater than the energy needed for other disposal options. Operators without the available fuel will not be able to execute this option.

Operators who elect to perform heliocentric, Earth-escape disposal would be required under proposed § 453.15(c) to include a description of the Earth-escape disposal in the ODAP submitted prior to each launch or reentry. The description must include (1) verification through hardware and software testing or analysis that the system has at least a 90 percent probability of successfully executing the planned heliocentric, Earth-escape disposal, and (2) a description of how the system will achieve a controlled disposal under nominal and off-nominal conditions, such as a partial burn failure or off-trajectory scenario. The testing and analysis could include engine re-light qualification tests, reliability analyses, or similar tests.

c. Direct Retrieval

Another means by which an operator could dispose of the upper stage of a vehicle, or any other orbital debris released, would be direct retrieval, also called Active Debris Removal or remediation, in which an operator retrieves the upper stage and removes it from orbit via a controlled disposal or maneuver into a disposal orbit. Direct retrieval would require the launch of a device or spacecraft that attaches to or otherwise affects the upper stage and causes it to deorbit in a controlled manner or move to a disposal orbit. Current research and economic feasibility studies performed by commercial operators and international space agencies suggest this option could be commercially viable within a few years.[56] Demonstrations of this capability have already been conducted.[57] For this reason, the FAA proposes to include as § 453.16 the option

[56] Yamamoto, et.al (2017) 7th European Conference on Space Debris, *Cost analysis of active debris removal scenarios and system architectures*.
[57] On August 25, 2021, a Japanese spacecraft successfully captured a simulated piece of space debris as a first step to demonstrate technology to remove orbital debris. On October 24, 2021, China launched a mission with the stated aim of testing space debris removal technologies.

for operators to perform direct retrieval if they meet the requirements of § 453.16. The requirements of § 453.16 would only apply if the operator elects direct retrieval as its disposal method under § 453.13.

Proposed § 453.16 would require that operators retrieve the upper stage by either removing it from orbit in a controlled manner or maneuvering it to a disposal orbit no more than 5 years after completion of the mission. The FAA proposes to allow operators up to 5 years from mission completion to perform the direct retrieval as a means of balancing the burden on operators to carry out the subsequent retrieval mission against the compelling need to remove the spent upper stage and its components from orbit. A 5-year timeline is consistent with USGODMSP recommendations and would require operators to demonstrate that they are capable of performing the direct retrieval based on actual technical capabilities, rather than hypothetical future capabilities. Operators will have 5 years to perform the direct retrieval, however, removal should occur as soon as possible to reduce the risk of creating more debris. Under proposed § 453.16(b), if the result of the direct retrieval is a controlled disposal of the upper stage into a planned disposal area, then the retrieval would be required to meet the disposal safety requirements in § 453.14(b) and (c). Conversely, if the result of the direct retrieval is a maneuver into a disposal orbit, then the retrieval would need to meet the disposal orbit lifetimes and analysis requirements of § 453.18.

Under proposed § 453.16(c), an operator would be required to describe its plan for direct retrieval in its ODAP, and demonstrate a probability of successful disposal of at least 90 percent. The description must include verification through hardware and software testing or analysis that the system has at least a 90 percent probability of successfully executing the planned direct retrieval. If the planned retrieval will result in a controlled disposal, then the operator must include in its ODAP (i) a description of how the system will achieve a disposal under nominal and off-nominal conditions; and (ii) the total collective and individual casualty expectations for the proposed operation or the effective casualty area of any surviving debris, if the operator will not dispose of the debris into a broad ocean area. The operator should identify the intended disposal location so that the FAA can discern whether the operator will target a broad ocean area or verify the expectation of casualty from disposal into that location. Alternatively, if the operator intends to retrieve and maneuver the debris to a disposal orbit, under proposed § 453.16(c)(3), the operator would need to include in their ODAP (i) a description of how the system will achieve and maintain the planned disposal orbit for the required time limit as specified in § 453.18(b) through (d); and (ii) a statistical analysis demonstrating that the probability of collision with operational spacecraft and debris is within the lifetime limit of § 453.18(e). The testing and analysis performed in accordance with § 453.16(c) should include qualification tests, reliability analyses, or similar tests.

d. Uncontrolled Atmospheric Disposal

The FAA proposes to allow launch or reentry operators to perform uncontrolled atmospheric disposal to meet the requirement of § 453.13 by using one of two methods. Under proposed § 453.17, an operator could either dispose of debris from LEO through natural decay by leaving the upper stage and its components in an orbit where the debris will gradually lower until it falls to Earth, or from MEO or higher orbit by maneuvering the debris to a highly elliptical orbit for long-term atmospheric disposal. The requirements of proposed § 453.17 would only apply if the operator elects to perform uncontrolled atmospheric disposal to meet the disposal requirement of § 453.13.

In order to dispose of debris from LEO—an orbit below 2,000 km—an operator would be required in § 453.17(b)(1) to leave an upper stage and its components in an orbit where, accounting for the mean projections for solar activity and atmospheric drag, the orbital lifetime is as short as practicable, but does not exceed 25 years after launch. Instead of reentering immediately, the orbit of the upper stage and its components would gradually lower over months or years until the debris falls to Earth. The disposal would be considered uncontrolled in the sense that the operator would not initiate the disposal at a particular time, and the disposal could occur anywhere on Earth under its orbital path.

The 25-year rule, which the FAA also proposes to implement in § 453.5, is a common standard recommended by the IADC and a requirement for U.S. Government launches under the USGODMSP. The IADC's *Support to the IADC Space Debris Mitigation Guidelines*, *Oct 2004 Working Group Report* states that a 25-year post-mission lifetime appears to be a good compromise between an immediate (or very short lifetime) de-orbit policy which is very effective but much more expensive to implement, and a 50 or 100 year lifetime de-orbit policy which is less costly to implement but can lead to higher collision risks in the long-term.[58] Greater depth of technical analysis is available in the IADC working group report.

While the FAA concurs with the current IADC and USGODMSP guidelines, which limit post-mission lifetimes in LEO to 25 years, the FAA recognizes that increases in the numbers and kinds of activities in Earth orbit may necessitate reevaluation of the adequacy of a 25-year post-mission lifetime in the future. The FAA seeks public comment on whether a shorter deadline should be imposed. The FAA notes that upper stages of launch vehicles become debris as soon as the payloads are released; upper stages in orbits with perigee altitudes below 350 km typically

[58] Inter-Agency Space Debris Coordination Committee. (October 2004). Support to the IADC Space Debris Mitigation Guidelines. *Oct 2004 Working Group Report*, section 5.3.2.

have orbital lifetimes less than 5 years. Given that the entire mission lifetime of upper stages and their components is quite short, and spent upper stages pose a significant risk of debris propagation the longer they are in orbit, it may be appropriate to have a shorter disposal timeline of 5 years. A shorter deadline of 5 years that removes the highest-mass objects from orbit would vastly reduce the risk of creating more debris and would make U.S. commercial space a leader in orbital debris mitigation.

Uncertainties in modeling should be accounted for in evaluation of the orbital lifetime of an object. The use of publicly available software such as NASA's DAS and the French Space Agency's STELA (Semi-analytic Tool for End of Life Analysis) regularly update model inputs for atmospheric density, which is responsible for the largest uncertainty, could be used to estimate orbital lifetime prior to launch.

In addition to meeting the 25-year requirement of § 453.17(b)(1), the FAA would require in § 453.17(b)(2) that operators performing uncontrolled atmospheric disposal from LEO satisfy either an expected casualty (E_C) of 1×10^{-4}, or an equivalent effective casualty area of 7 square meters. The FAA proposes to delay the effective date of § 453.17(b)(2) until 1 year after the effective date of the rule, so as to avoid interference with current planned launches and provide operators additional time to come into compliance with the requirement. The FAA proposes to regulate uncontrolled atmospheric disposal in this manner due to the inherent risks posed to people and property on Earth whenever upper stages reenter the Earth's atmosphere in either a controlled or uncontrolled manner. Upper stages are designed to be robust systems capable of withstanding the stresses and temperatures of launch. Therefore, most upper stages are composed of heat-resistant material that does not burn-up upon reentry and can be expected to survive reentry to impact the ground. Although tracking and analysis can be done to help narrow down where an uncontrolled reentry may occur, and the appropriate civil authorities can be notified, there are no means to stop or move the impact location of reentering debris. Furthermore, the science of predicting impact points for uncontrolled disposals is limited. Re-entry Assessment is difficult. It is virtually impossible to precisely predict where and when space debris will impact. This is due to limitations in the U.S. tracking system as well as environmental factors that impact on the debris.[59]

National U.S. policy guidelines cited above, as well as those of NASA[60], Department of Defense[61], and the FCC[62], along with a growing international consensus, recommend that the risk to the public on the ground not exceed 1 E_C in 10,000 events or 1×10^{-4}. This applies to reentries of orbital debris, whether they are a deliberate controlled disposal or an uncontrolled disposal through natural decay. The E_C should be calculated to one-significant figure unless an uncertainty analysis justifies a more precise estimate of risk.

The E_C can vary greatly due to factors outside of the launch vehicle designer's control. Growing world populations and various orbital inclination choices have direct correlations to the E_C rating for reentries. The FAA realizes that the E_C prediction can be difficult to calculate; therefore, the FAA sought an alternative method in addition to E_C.

As alternatives to a launch operator's calculating and satisfying of an E_C of 1×10^{-4}, the FAA is also proposing to allow an operator to demonstrate that it can limit the casualty area during disposal by natural decay. Some companies may find the debris casualty area determination to be a more simplified analysis, and this analysis relies only on vehicle design

[59] United States Space Command. (Retrieved on August 26, 2021). Reentry Assessment - US Space Command Fact Sheet. *SpaceRef.* www.spaceref.com/news/viewpr.html?pid=4008
[60] NPR 8715.6B, *NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environments*.
[61] Department of Defense Instruction 3100.12 and Air Force Instruction 91-202.
[62] FCC Statute 25.114 *Applications for Space Authorizations.*

and operation. Both analyses, E_C and debris casualty area, would be adequate to protect the public from disposal risk. Therefore, the FAA proposes disposal to be acceptable if a size limit is satisfied or if the E_C limit is met.

The FAA would permit uncontrolled reentry as an acceptable form of disposal if the surviving debris casualty area measured 7 square meters or less. This proposed casualty area matches that stated in the USGODMSP, guideline 4-1(e).[63] The casualty area is derived from the acceptance of a risk criteria of 1×10^{-4}. Applying the 1×10^{-4} expectation of casualty to uncontrolled disposal, NASA calculated the risk to account for the 2019 population of the world that could be affected and the size of the debris that could impact the ground. On average, analysis showed that a casualty area of 7 square meters of surviving debris would produce a 1×10^{-4} expectation of casualty. The debris casualty area takes into account that the force of impact of the debris is at least 11 ft-lb, the threshold for injury on an unsheltered person.[64] Specifying an acceptable casualty area as an alternative to a risk criterion eliminates the uncertainty inherent in risk calculations, including such variables as population counts and event probability assumptions.

The total effective casualty area is determined by adding up the casualty area of each piece of debris that impacts Earth. The upper stage will not land intact, but is expected to breakup in the atmosphere during reentry. The total casualty area of all pieces added together would be required to be less than 7 square meters.

The second option for performing an uncontrolled atmospheric disposal under proposed § 453.17 would be to maneuver the debris to a highly elliptical orbit for long-term atmospheric

[63] United States Government. (November 2019) *U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update.* orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf

[64] SANDIA National Laboratories. (April 1997). *Hazards of Falling Debris to People, Aircraft, and Watercraft*.

disposal. Under proposed § 453.17(c), an operator would maneuver the upper stage and its components from semi-synchronous Molniya orbits, synchronous Tundra orbits, and other elliptical orbits, to a long-term disposal orbit where orbital resonances will increase the eccentricity for long-term atmospheric disposal of the upper stage. This proposal of up to a 200-year disposal matches the USGODMSP guidelines to allow the upper stage to be maneuvered to a disposal where orbital resonances keep increasing the eccentricity and eventually decrease the perigee for an uncontrolled atmospheric disposal. During the development of the USGODMSP, the FAA, NASA, and the Department of Defense reviewed various timeframes for highly elliptical orbit disposals. Objects in highly elliptical orbits are affected by gravitational forces from the Earth, the Moon, and the Sun. These forces, over time, alter the object's orbit and eventually cause the object to reenter Earth's atmosphere. The FAA foresees that very few commercial operations would fall within this scenario, because it is rarely used by commercial operators.

If an operator maneuvers the debris to a highly elliptical orbit in accordance with § 453.17(c), the orbital lifetime must be as short as practicable, but must not exceed 200 years after mission completion. The responsible behavior is to remove debris objects from orbit as soon as practical. Highly elliptical objects have very high apogees; therefore, atmospheric drag only affects them during a small portion of their orbit. Drag is a major factor in atmospheric disposal, so these disposals take a long time to occur. These objects spend a smaller portion of time within congested orbits, so over a 200-year timeframe, the time in congested orbits equals that of objects that are in LEO for 25 years. The probability of collision with operational spacecraft and debris 10 cm and larger should also be limited to less than 0.001 for the entire lifetime. The FAA proposes to delay the effective date of the risk requirement so as not to interfere with current planned launches. The FAA finds that delaying the effective date of this requirement by 1 year will allow operators sufficient time to implement disposal options that meet the risk criteria, without jeopardizing public safety. After 1 year, the launch operator must show that when the upper stage reenters, the risk will meet the criteria of 1 x 10^{-4} or that the effective casualty area will be less than 7 square meters.

Proposed § 453.17(d) would identify the information that an operator must include in its ODAP prior to each launch or reentry in order to perform uncontrolled atmospheric disposal in accordance with this section. The ODAP must include (1) verification through hardware and software testing or analysis that the system has at least a 90 percent probability of successfully executing the planned disposal option; (2) an estimate of the E_C or the effective casualty area for any surviving debris; and (3) a statistical analysis demonstrating compliance with the requirements of § 453.17(b) or (c) to dispose of the debris within the prescribed time limit. The testing and analysis could include an analysis using NASA's DAS or similar material that demonstrates compliance with the 25-year rule in the case of natural decay from LEO, or the 200-year rule for highly elliptical orbits. Alternatively, an analysis should be provided showing that the upper stage can meet the casualty area limit or expectation of casualty limit.

e. Maneuver to a Disposal Orbit

The FAA proposes to give launch or reentry operators the option in § 453.18 of disposing of debris by maneuvering it to a disposal orbit. In this scenario, the operator would move the upper stage and its components into a less-populated disposal orbit. Disposal or storage orbits are orbits intended for post-mission long-term storage, where atmospheric effects and solar radiation will not move disposed objects into a protected orbit for at least 100 years. Disposal orbits protect LEO, a narrow band in MEO bounded by 20,182 km plus or minus 300 km, and the GEO region. The band in MEO is used by Global Positioning System (GPS) spacecraft and other global positioning constellations. On-orbit disposal is not a permanent solution, and some of these storage orbits may be used for future space operations. Even spacecraft orbiting beyond GEO will eventually degrade and reenter populated orbits. While use of disposal orbits fails to remove debris from orbit and therefore reduce the chance of debris-making collisions, on-orbit disposal remains an effective alternative to atmospheric disposal in today's environment and is preferable to clogging LEO and intersecting GEO with spent upper stages. This option is consistent with the USGODMSP. In addition, for some operators, all other methods of disposal would be costly. The FAA therefore proposes to allow operators to maneuver orbital debris to a disposal orbit in order to meet the disposal requirement of § 453.13. Disposal orbits still impose some risk for future space programs and interplanetary missions. The FAA seeks comments on whether disposal orbit options should be phased out. And, if so, what an appropriate timeframe for phasing out should be.

The requirements of § 453.18 would only apply if the operator elects to maneuver to a disposal orbit as its disposal method under § 453.13. To comply with § 453.18, the operator would move the upper stage and its components into a less-populated orbit within 30 days after mission completion. To prevent interference with active spacecraft for a significant length of time, the FAA proposes as disposal orbits those identified in the USGODMSP. If an operator elects to use a disposal orbit between LEO and GEO, then the operator would be required to place the upper stage and its components into either (1) an eccentric orbit where the perigee altitude remains above 2,000 km, the apogee altitude remains below the geosynchronous region for at least 100 years, and the time spent by the upper stage between 20,182 plus or minus

300 km is limited to 25 years or less over 200 years[65]; or (2) a near-circular disposal orbit that avoids altitudes 20,182 plus or minus 300 km, the geosynchronous region, and altitudes less than 2,000 km, for at least 100 years. Under proposed § 453.18(c)(1)(iii), an orbit that remains completely within the region bounded by 20,182 km plus or minus 300 km would not qualify as a disposal orbit. The orbital lifetime of any debris placed within this region would therefore be limited to 25 years or less over 200 years. If an operator elects to use a disposal orbit above GEO, the FAA proposes to require in § 453.18(d) that the operator place the upper stage and its components into an orbit with a perigee altitude above 36,100 km for a period of at least 100 years after disposal.

In addition to implementing the disposal orbits identified by the USGODMSP, the FAA proposes to require in § 453.18(e) that operators limit the probability of collisions with operational spacecraft and debris 10 cm and larger to less than 0.001 for 100 years after disposal. This requirement would be consistent with USGODMSP recommendations, as well as the requirement in proposed § 453.9(b) to limit the probability of collision between launched objects after the end of launch.

Proposed § 453.18(f) would prescribe the information that an operator must include in its ODAP to maneuver debris to a disposal orbit in accordance with § 453.18. Under proposed § 453.18(f), the ODAP must include: (1) verification through hardware and software testing or analysis that the system has at least a 90 percent probability of successfully executing the planned maneuver to the disposal orbit; (2) a description of how the system will achieve and maintain the planned disposal orbit for the required time limit; and (3) statistical analysis demonstrating compliance with the probability of collision lifetime limit with operational

[65] All figures match the guidelines in the USGODMSP. A 200-year timeline ensures that the upper stage will avoid the altitude range commonly used by global navigation satellite systems.

spacecraft and debris. ISO Standard 16126[66] provides an acceptable method for conducting the post-mission disposal probability of success analysis of § 453.18(f)(1). The testing and analysis can include engine re-light qualification tests or reliability analysis or similar.

D. Explosion Mitigation

The FAA proposes minor changes to its current requirement that a launch operator prevent fragmentation or explosion of its upper stage.[67] Currently, under §§ 417.129(c) and 450.171(a)(3), a launch operator must ensure the removal of stored energy from an upper stage by depleting residual fuel and leaving fuel lines open.[68]

Proposed § 453.7(a) would require that, except for energy sources that are safety critical on-orbit or during reentry, a launch operator must ensure: (1) the integrated probability of debris-generating explosions or other fragmentation from the conversion of energy sources (i.e. chemical, pressure, kinetic) of each upper stage is less than 0.001 (1 in 1,000) during operations; and (2) stored energy is removed by depleting residual propellants, venting any pressurized system, leaving all batteries in a permanent discharge state, and removing any remaining source of stored energy. The proposed rule would replace §§ 417.129(c) and 450.171(a)(3), and would not contain a specific requirement to leave valves open. After promulgation of its original debris requirements, the FAA has found on several occasions, through the licensing process, that leaving the valves open long enough for all fuels and oxidizers to vent and then permitting them to close, has provided a level of safety equivalent to leaving the valves open. Either approach removes the source of explosion risk—namely, the fuels and oxidizers. The FAA proposes a

[66] International Organization for Standardization. (April 1, 2014) *ISO 16126:2014.*
[67] See proposed § 417.129(b) and (c).
[68] See § 417.129(c).

probability limit of 0.001, which matches the limit in the USGODMSP, in order to provide operators a quantitative requirement.

Proposed § 453.7(b) would identify the information that an operator would need to include in its ODAP to demonstrate compliance with § 453.7(a), specifically: (1) analysis, using commonly accepted engineering and probability assessment methods, showing how the operation meets paragraph (a)(1); and (2) test results or analysis, with 95 percent confidence levels,[69] of the planned end-of-mission passivation procedure that verifies dissipation of all energy sources to levels that will prevent explosion of any launch vehicle component. The test results or analysis submitted in accordance with § 453.7(b)(2) would be required to show that all residual propellants contained in the system can be purged or passivated to an acceptable level at the end of the launch, all pressurized systems can be purged or passivated, and all energy storage systems have sufficient structural design to prevent rupture and subsequent explosion. This proposal marks a departure from current requirements, which only ask for a demonstration, without specifying that the demonstration be made with analysis and verification. The FAA now considers the latter necessary because operators have historically only stated that they would comply without providing the test or analysis to show how they would comply. The FAA seeks to clarify in regulation that asserting compliance is not a demonstration of compliance that satisfies this requirement. The FAA seeks feedback on the proposed analysis and testing requirements.

[69] In statistics, a confidence interval is the range of values that includes the true value at a specified confidence level. A confidence level of 95 percent is commonly used which means that there is a 95 percent chance that the true value is encompassed in the interval.

E. Collision Mitigation Between Launched Objects

The FAA proposes minor changes to its current requirements that a launch operator prevent unplanned physical contact between the launch vehicle and payload. Currently §§ 417.129(a) and 450.171(a)(1) require a launch operator to ensure that there is no unplanned physical contact between the launch vehicle and its components and the payload. Proposed § 453.9(a) would require a launch operator to prevent unplanned physical contact between a launch vehicle or any of its components and each payload after payload separation, and would replace the requirements in §§ 417.129 and 450.171.

The FAA proposes to add a requirement in § 453.9(b) to take into account the probability of collision with orbital objects 10 cm and larger when designing the mission profile of an upper stage. The operator should ensure that the probability of collision is less than 0.001 (1 in 1,000) after the end of launch. Upper stages are the highest mass of orbital debris by far. It is important to prevent breakups of massive upper stages due to collisions with large debris. The proposed requirement also matches ODMSP Objective 3-1.

Proposed § 453.9(c)(1) would specify the information that an operator must include in its ODAP to demonstrate compliance with § 453.9: (1) the operator's procedure for preventing vehicle and payload collision after payload separation, including any propellant depletion burns and compressed gas releases that minimize the probability of subsequent collisions; and (2) the results of a probability of collision analysis, using commonly accepted engineering and probability assessment methods, meeting paragraph (b) of this section. This marks a departure from current requirements, which only require a demonstration, without specifying that the demonstration must consist of a written procedure. The FAA has received non-actionable demonstrations in previous applications and now proposes requiring complete procedures in the

ODAP. The FAA now considers the latter necessary for purposes of clarification as to what the FAA seeks. The analysis should use commonly accepted engineering and probability assessment methods.

F. Launch and Reentry Collision Avoidance.

The FAA proposes to move the collision avoidance analysis requirements from § 450.169, which are currently applicable to all orbital launches and reentries authorized by the FAA that exceed 150 km to § 453.11. The FAA would replace the current text in § 450.169 with a reference to § 453.11, and replace all references to § 450.169 outside of part 450 with a reference to new § 453.11, which would be called "Collision Avoidance with Orbital Objects." Proposed § 453.11 is substantially similar to the existing requirements in § 450.169, but would differ from the existing regulation in the following respects.

First, the FAA would omit from proposed § 453.11 the exclusion provided in § 450.169(d), which states that collision avoidance analysis is not required if the maximum planned altitude for any launched object is less than 150 km. This exclusion is necessary under current § 450.169 because part 450 is not limited to launch or reentry activity above 150 km. Since the FAA would relocate the collision avoidance analysis requirements to part 453, which would only apply to launch or reentry activity that exceeds 150 km, the exclusion found in § 450.169(d) is no longer necessary. As such, the FAA would exclude the phrase "except as provided in paragraph (d)," which appears in § 450.169(a) from proposed § 453.11(a).

The text of proposed § 453.11(a)(1) would match current § 450.169(a)(1).

The FAA proposes to refer to "active payloads" in § 453.11(a)(2), instead of "objects that are neither orbital debris nor inhabitable" as used in current § 450.169(a)(2). The updated language clearly states the intent of this section and is consistent with U.S. Space Force terminology and current practice. Active payloads do not include inhabitable objects like the ISS, which require more stringent screening.

In § 453.11(a)(2), the FAA proposes to retain the probability of collision and spherical separation distance options from § 450.169(a)(2)(i) and (ii), but add a third option for operators to screen against active payloads: ellipsoidal screening. The FAA would accept an ellipsoidal separation distance of 25 km in-track and 7 km cross-and-radial-track ellipsoidal separation from active payloads for collision avoidance analyses. The FAA looked at collision risk associated with the radial component greater than 7 km and found that it posed a risk less than 1 x 10^{-5}. These ellipsoidal distances also match current practice identified by the Range Commanders Council. Operators would therefore have three options for screening against active payloads: probability of collision (§ 453.11(a)(2)(i)), ellipsoidal screening (§ 453.11(a)(2)(ii)), and spherical screening (§ 453.11(a)(2)(iii)).

The FAA proposes to add a requirement in § 453.11(a)(3) to perform launch and reentry collision avoidance analysis against small objects with a radar cross section greater than 0.04 m^2. Currently, § 450.169(a)(3) only requires operators to screen against large objects with radar cross section greater than 1 m^2 and medium objects with radar cross section 0.1 m^2 to 1 m^2. However, small objects, including CubeSat-sized objects, can cause vehicle breakups and orbital debris if a collision were to occur between the object and a launching or reentering vehicle. The FAA did not include small debris in its recent Streamlined Launch and Reentry License Requirements rulemaking, as the FAA was still investigating the implications of the increase of small objects in the debris catalog due to the addition of the Department of Defense Space Fence. It is current practice at the Federal ranges to screen against all objects in the debris catalog, including small objects with a radar cross section greater than 0.04 m^2. Therefore, the FAA proposes to add launch and reentry collision avoidance analysis screening against those small objects. The FAA would retain under § 453.11(a)(3) the screening options provided in § 450.169(a)(3): an operator would be required to ensure either (i) that the probability of collision between the launching or reentering objects and any known orbital debris does not exceed 1×10^{-5}; or (ii) that the launching or reentering objects maintain a spherical separation distance of 2.5 km. Window closures that meet these requirements will ensure that launch and reentry vehicles do not collide with known objects during launch or reentry operations. Note that probability of collision is different than probability of casualty used elsewhere for public risk. Probability of collision is only the odds that two objects will occupy the same location at the same time. Probability of casualty factors in the odds of collision plus the vulnerability of a person. Thus, there are separate risk measures.

The FAA proposes to move the screening time requirements of § 450.169(b) to § 453.11(b), with several modifications. First, to enhance clarity the FAA would refer to "150 kilometers altitude" in § 453.11(b)(1) and (2), instead of "150 km," which appears in § 450.169(b)(1) and (2). The text of proposed § 453.11(b)(3) would match current § 450.169(b)(3). Second, to accommodate the additional disposal options proposed in part 453, the FAA proposes to specify appropriate screening times for controlled atmospheric disposal and maneuver to a storage orbit, rather than refer to "disposal" generally, as done in current § 450.169(b)(4). Under proposed § 453.11(b)(4), an operator performing controlled atmospheric disposal would need to screen during descent from initial disposal burn to 150 km altitude. To maneuver to a disposal orbit, under § 453.11(b)(5), an operator would need to screen during initial disposal operation until removal from LEO or GEO.

The FAA proposes to move § 450.169(c) to § 453.11(c) without any changes. Since the FAA would not include the exclusion in § 450.169(d) because it is redundant of proposed part 453, the *Analysis* requirements found in § 450.169(e) would appear under paragraph (d) of proposed § 453.11.

The FAA proposes to move the language currently found in § 450.169(e) to § 453.11(d), with two revisions. First, to enhance clarity, the FAA proposes to revise the first sentence of § 453.11(d) to use the active voice ("An operator must obtain a collision avoidance analysis…"). Second, the FAA proposes to identify in § 453.11(d)(2) the uncertainties that should be included in the vehicle trajectory and covariance calculation used in the collision avoidance analysis. Specifically, the FAA proposes to require that collision avoidance analyses account for uncertainties, "including launch or reentry vehicle performance and timing, atmospheric changes, variations in drag, and any other factors that affect position and timing of the launch or reentry vehicle." It is important for a scientific and complete analysis to include these uncertainties because at the velocities of the objects in orbit, small variations or uncertainties can affect the collision prediction. By revising this provision, the FAA emphasizes the use of uncertainty at the beginning of collision analysis, whereas the previous language in § 450.169(e)(2) directed that uncertainties be used to modify the final analysis results.

The FAA proposes to move § 450.169(f) to § 453.11(e) without any substantive changes.

The FAA proposes to move part 450 Appendix A, the Collision Avoidance Analysis Worksheet, to § 453.11(f), with several revisions. First, the FAA proposes in § 453.11(f)(1) to update the launch and reentry information that must be included in the Collision Avoidance Analysis Worksheet. The FAA proposes to combine the "Segment Number" and "Orbiting objects to evaluate," currently found in paragraphs (a)(5) and (a)(7) of Appendix A, into one requirement, § 453.11(f)(1)(v). These current requirements are redundant, and the updated requirement uses plain language to describe the objects that should be evaluated in the analysis: all free-flying launch vehicle stages, payloads, and components that reach orbit. The FAA also proposes to more clearly convey in § 453.11(f)(1)(vi) the orbital parameters of each free-flying launch vehicle stage, payload, or component achieving orbit that must be identified. The FAA would also refer to both launch and reentry in § 453.11(f)(1)(ii) and (iv), unlike the existing Appendix A, which inconsistently addresses launch and reentry. This is a correction, as all parts of the Collision Avoidance Analysis Worksheet are applicable to both launch and reentry.

G. Real-time Reporting of Orbital Safety Hazards.

The FAA proposes to add a requirement in § 453.20 that would require a launch or reentry operator to submit certain information to the FAA and, if applicable, to other requesting Federal agencies, at the detection of any launch or reentry activity outside the 3-sigma trajectory provided for collision avoidance or any debris-creating event. Orbital safety is implemented through the pre-launch or reentry assessment of planned trajectories. If either an operator or Federal tracking capabilities detect activity outside the 3-sigma planned trajectory or a debris-generating event, the operator should contact the FAA to provide as much information as possible on the characteristics (size and mass), last known orbital or trajectory information, and other details determined necessary by the FAA to locate and categorize orbital objects. This should be done by phone or email as soon as the event is detected. The United States Strategic Command (USSTRATCOM) would be the Federal agency most likely to detect an event covered by § 453.20(a) and request information from the operator. This information may provide critical warning time to inhabited and active payloads on orbit, and allow USSTRATCOM to update its models and recalculate projected orbits. If a launch does not go as planned, and the vehicle ends up in a different orbit than expected, the original Collision Avoidance Analysis Worksheet would be moot. The FAA would need to reassess the collision probability against the new trajectory.

Specifically, proposed § 453.20(a) would require an operator to immediately submit the information identified in § 453.20(b) to the FAA and, if applicable, a requesting Federal agency, at the detection of any launch or reentry activity outside the 3-sigma trajectory provided for collision avoidance or any debris-creating event. If an operator identifies such an event, or is notified by a Federal agency (such as U.S. Space Force and NASA), then the operator would need to report to the FAA and, if applicable, the requesting Federal agency: (1) the size and mass of the affected objects; (2) the last known orbital or trajectory information; and (3) any other details determined necessary by the FAA to locate and categorize orbital objects, such as the vehicle orientation, whether it is tumbling, or the operator's ability to control the object.

H. Revisions to Existing Regulations

The FAA's proposal to consolidate existing requirements for orbital debris mitigation and end-of-launch safety under part 453 necessitates the following revisions to current regulations.

Under part 404, the FAA proposes to replace the reference to § 450.169 in Table A404.1 with a reference to § 453.11.

Under part 415, the FAA proposes to revise § 415.2(b) to reference part 450 as well as part 453. The proposed revision would make clear that operations licensed under part 415 must comply with the critical asset protection requirements in § 450.101(a)(4) and (b)(4) and, for launches with a planned altitude greater than 150 km, the launch collision avoidance requirements in § 453.11. The FAA also proposes to revise § 415.35(d) to require that launch vehicles be operated "in a manner that ensures that flight risks meet the criteria of paragraph

(a) of this section and in accordance with collision avoidance requirements in § 453.11 and critical asset protection requirements in § 450.101(a)(4) and (b)(4).”

The FAA also proposes to revise § 415.39 by revising the heading to read, “Demonstration of Orbital Debris Mitigation,” instead of “Safety at End of Launch,” and by replacing the reference to § 417.129 with a reference to the sections of proposed part 453 under which those end of launch requirements would appear: §§ 453.7 and 453.9. Similarly, the FAA proposes to revise § 415.133 by revising the heading to read, “Orbital Debris Mitigation,” and by replacing the reference to § 417.129 with a reference to the sections of proposed part 453 under which those end of launch requirements would appear: §§ 453.7 and 453.9. These revisions would direct readers to the Code of Federal Regulations (CFR) part under which the FAA’s safety at end of launch requirements would be relocated under this proposal, and affirm that any FAA-licensed launches exceeding 150 km would be required to comply with part 453. Lastly, the FAA would revise Appendix B to part 415 to reflect the revised heading of § 415.133 (Orbital Debris Mitigation).

Under part 417, the FAA proposes to revise § 417.113(c)(1) to reference the collision avoidance analysis requirements of proposed § 453.11, instead of § 450.169. The FAA proposes to replace the requirements in § 417.129 for safety at end of launch with a reference to the sections of proposed part 453 under which those end of launch requirements would appear: §§ 453.7 and 453.9. This revision would direct readers to the CFR part under which the FAA’s safety at end of launch requirements would be relocated under this proposal, and affirm that any FAA-licensed launches exceeding 150 km would be required to comply with part 453. As discussed above, the FAA proposes changes to the end of launch requirements under part 453, consistent with USGODMSP guidelines.

The FAA proposes to revise §§ 431.2(b) and 435.2(b) to reference part 450 and part 453. The proposed revisions would make clear that operations licensed under part 431 and 435 must comply with the critical asset protection requirements in § 450.101(a)(4) and (b)(4) and, for launches with a planned altitude greater than 150 km, the launch collision avoidance requirements in § 453.11. The FAA proposes to revise § 431.43(a)(1) to reference § 453.11 instead of § 450.169. The FAA also proposes to replace the reference to § 450.169 in § 431.43(c)(3) with a reference to the sections of proposed part 453 under which those end of launch requirements will appear: §§ 453.7 and 453.9. As discussed above, the FAA proposes to change the end of launch requirements consistent with USGODMSP guidelines. This revision would direct readers to the CFR part under which the FAA's safety at end of launch requirements would be relocated under this proposal, and affirm that any FAA-licensed launches or reentries exceeding 150 km would be required to comply with part 453.

Under part 437, the FAA proposes to replace the reference to § 450.169 in § 437.65 with a reference to § 453.11. The FAA also proposes to remove the word, "maximum" from § 437.65 because it is an unnecessary modifier to the phrase, "permitted flight with a planned altitude greater than 150 km."

Under part 450, the FAA proposes to revise § 450.101(d), titled Disposal Safety Criteria, to specify the risk criteria applicable to controlled and uncontrolled atmospheric disposals. As discussed earlier in this preamble, the current definition of "disposal" in § 401.7 includes only controlled atmospheric disposal. As a result, the disposal safety criteria currently identified in § 450.101(d) only apply to controlled atmospheric disposal. Since the FAA is proposing to amend the "disposal" definition to include all five disposal options proposed in §§ 453.14 through 453.18, and the disposal risk criteria currently identified in § 450.101(d) would not apply to all five disposal methods, the FAA must therefore revise § 450.101(d) to identify the risk criteria applicable to each disposal method. Additionally, § 450.101(d) currently refers to the reentry risk criteria in (b), which may create confusion since reentry is distinct from disposal.

The risk criteria outlined in § 450.101 would only apply to disposals that result in orbital debris returning to Earth's surface or atmosphere—that is, controlled or uncontrolled atmospheric disposal. There is no need to calculate collective or individual risks to the public, or aircraft risk if an operator elects to maneuver orbital debris to a disposal orbit or a hyperbolic trajectory that no longer orbits Earth (Earth-escape disposal). Thus, the FAA proposes to revise § 450.101(d) to limit the applicability of the risk criteria to controlled atmospheric disposal performed in accordance with § 453.14, direct retrieval resulting in controlled atmospheric disposal per § 453.16(b)(1), and uncontrolled atmospheric disposal performed in accordance with § 453.17. The risk criteria applicable to controlled atmospheric disposal would appear in paragraph (d)(1), while the risk criteria applicable to uncontrolled atmospheric disposal would appear in paragraph (d)(2).

With respect to controlled atmospheric disposal, the FAA's proposed revision to § 450.101(d) is substantively equivalent to the current regulation. Operators performing controlled atmospheric disposal will still have the option of targeting a broad ocean area or meeting the same collective, individual, and aircraft risk criteria required for reentries under § 450.101(b). The FAA proposes to add a third alternative for compliance as § 450.101(d)(1)(i): ensuring that the effective casualty area of any surviving debris is less than 7 square meters. This revision renders the disposal risk criteria in § 450.101(d)(1) consistent with the safety criteria for controlled atmospheric disposal under proposed § 453.14.

The risk criteria applicable to uncontrolled atmospheric disposal will similarly match the criteria proposed in § 453.17. As noted in this section of this preamble discussing proposed § 453.17, the FAA will not require operators to calculate individual or aircraft risk as would an operator performing controlled atmospheric disposal because the science of predicting impact points for uncontrolled disposals is limited. Due to limitations in the U.S. tracking system and environmental factors that impact debris, it is virtually impossible to precisely predict when and where debris disposed through natural decay will impact. Instead, consistent with the USGODMSP, the FAA would require that operators performing uncontrolled atmospheric disposal ensure that either (i) the effective casualty area for any surviving debris will be less than 7 square meters; or (ii) the risk to the public on the ground will not exceed 1 E_C in 10,000 events or 1 x 10^{-4}.

The FAA also proposes to revise § 450.101(e) to reflect the scope of proposed part 453. Specifically, the FAA would require in § 450.101(e)(1) that operators prevent collisions between a launch or reentry vehicle stage or component with a planned altitude greater than 150 km and people, property, and debris on orbit, in accordance with the requirements in § 453.11. Similarly, the FAA would require in § 450.101(e)(2) that operators perform debris mitigation in accordance with part 453 for any launch or reentry vehicle stage or component with a planned altitude greater than 150 km. The FAA also proposes to replace the reference to § 450.169 in § 450.165(a)(3) with a reference to § 453.11, and in § 450.213 with a reference to § 453.11(f). As discussed above, the FAA proposes to move the collision avoidance analysis requirements set forth in §§ 450.169 to 453.11, and replace the current language of § 450.169 with a reference to § 453.11.

The FAA also proposes to revise the equivalent level of safety requirements in § 450.37 to allow operators the option to seek an equivalent level of safety for collision avoidance analysis requirements (which would be located under § 453.11) and all other orbital debris mitigation requirements under part 453. Previously, § 450.37 did not include an equivalent level of safety for collision avoidance analysis. Upon further consideration, the FAA decided that an equivalent level of safety is appropriate. The FAA has found a need for flexibility in the current regulation, which does not allow an equivalent level of safety for collision avoidance analysis, to accommodate deployments of large numbers of satellites and for new launch operators. The FAA has found that collision avoidance is a difficult task for new launch operators, and options need to be available to get the operators to meet compliance. The FAA believes operators might be capable of proposing alternatives to the collision avoidance analysis requirements such as active debris avoidance that provide a level of safety equivalent to FAA regulations. The FAA also proposes to amend the flight safety analysis scope requirements of § 450.113 regarding disposal. The current regulation requires an operator to perform and document a flight safety analysis for all phases of flight, including for "disposal," from the initiation of the deorbit through final impact. As discussed earlier in this preamble, the FAA is proposing to expand the definition of "disposal" in § 401.7 to include all 5 disposal options proposed in §§ 453.14 through 453.18. The FAA does not believe it would be necessary or feasible to prepare a flight safety analysis for each of the 5 disposal methods proposed in part 453. The FAA will continue to only require a flight safety analysis for controlled atmospheric disposals. The FAA therefore proposes to replace the word "disposals" in § 450.113(a)(3) with "controlled atmospheric disposal performed in accordance with § 453.14 or direct retrieval resulting in controlled atmospheric disposal under § 453.16(b)(1)." Additionally, in order to reflect the safety criteria alternatives proposed in §

453.14(b), the FAA proposes to specify in § 450.113(c) that an operator would not need to prepare a flight safety analysis if the Administrator agrees that the disposal will target a broad ocean area or have an effective casualty area less than 7 square meters.

Lastly, the FAA proposes to replace the current requirements of § 450.171 for safety at end of launch with a reference to the sections of part 453 under which those requirements will now be found: §§ 453.7 and 453.9. As discussed above, the FAA is proposing changes to the requirements for safety at end of launch to include all orbital debris mitigation requirements. As such this revision will expand the scope of § 450.171, but as discussed earlier, should present no more than a minimal burden on operators for compliance.

IV. Regulatory Notices and Analyses

Federal agencies consider impacts of regulatory actions under a variety of executive orders and other requirements. First, Executive Order 12866 and Executive Order 13563, as amended by Executive Order 14094 ("Modernizing Regulatory Review"), direct that each Federal agency shall propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify the costs. Second, the Regulatory Flexibility Act of 1980 (Public Law 96-354) requires agencies to analyze the economic impact of regulatory changes on small entities. Third, the Trade Agreements Act (Public Law 96-39) prohibits agencies from setting standards that create unnecessary obstacles to the foreign commerce of the United States. Fourth, the Unfunded Mandates Reform Act of 1995 (Public Law 104-4) requires agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate that may result in the expenditure by State, local, and tribal governments, in the aggregate, or by the private sector, of $100,000,000 or more (adjusted annually for inflation) in any 1 year. The current threshold after adjustment for inflation is

$165,000,000, using the most current (2021) Implicit Price Deflator for the Gross Domestic Product. The FAA has provided a detailed Regulatory Impact Analysis (RIA) in the docket for this rulemaking. This portion of the preamble summarizes the FAA's analysis of the economic impacts of this rule.

In conducting these analyses, the FAA has determined that this rule: would result in benefits that justify costs; is a "significant regulatory action" as defined in section 3(f) of Executive Order 12866, as amended by Executive Order 14094 ("Modernizing Regulatory Review"); would not have a significant economic impact on a substantial number of small entities; would not create unnecessary obstacles to the foreign commerce of the United States; and would not impose an unfunded mandate on State, local, or tribal governments, or on the private sector.

A. Summary of the Regulatory Impact Analysis

To limit the growth of orbital debris, the FAA is proposing to require that upper stages of commercial launch vehicles and other components be removed from orbit within 25 years after launch using an acceptable means of disposal. This document provides the FAA's analysis of the impact of this regulatory change.

Assumptions:

- All monetary values are expressed in 2020 dollars.
- A 15-year analysis period is used based on the available forecast and cost information.
- Present values using 3 percent and 7 percent discount rate as prescribed by OMB in Circular A-4.

Entities Potentially Affected by this Rulemaking:

- Licensed and permitted operators for launches and reentries with a planned altitude above 150 km.
- All space users.
- Commercial space transportation suppliers.
- Satellite operators and owners.
- The Federal Aviation Administration and other government agencies.
- The general public.

Currently, the FAA has no regulations requiring post-mission disposal of upper stages. In this rulemaking, the FAA considers the U.S. Government Orbital Debris Mitigation Standard Practices (USGODMSP) and policies of NASA, Federal Communications Commission (FCC), National Oceanic and Atmospheric Administration (NOAA), and the Inter-agency Space Debris Coordination Committee (IADC) in an effort to establish common standards as the commercial space industry evolves and utilization of space grows.

This proposed rule would prevent an estimated 427 used upper stages from becoming large orbital debris over the next 15 years. Furthermore, this proposed rule would likely result in cost savings resulting from avoiding orbital remediation costs in the long run. The proposed rule would reduce risks to human spaceflight and space property, and internalize the externality to benefit the satellite industry. In addition, the proposed mitigation requirements are in line with the public demand for a sustainable space environment and the commercial space industry's interest in driving down orbital debris awareness costs. Therefore, this rulemaking would improve public safety and eventually save the industry money in the long run.

The FAA assesses scenarios of compliance costs using low, central, and high scenarios, which vary by the number of controlled disposals per year. Cost of present values and annualized costs for the lower case, central case and higher case are presented in the following table.

Low, Central, and High-Cost Scenarios in 2022 US Dollars

Million Dollar	Present Value at a 7% discount rate	Present Value at a 3% discount rate	Annualized Cost at a 7% discount rate	Annualized Cost at a 3% discount rate
Lower Case	$16	$20	$2	$2
Central case	$24	$31	$3	$3
High Case	$48	$59	$5	$5

The central estimate of the present value of total costs over 15 years is $24 million at a 7 percent discount rate or $31 million at a 3 percent discount rate. The annualized costs at a 7 percent discount rate would be $2.6 million or $2.6 million at a 3 percent discount rate. Without post-mission disposal, the upper stages contribute to the majority of orbital debris due to their mass. Moreover, prevention of large orbital debris would reduce risks to human spaceflight and space property.

The following table is the summary of the total costs for central estimate, the FAA's preferred estimate.

Present Value and Annualized Cost in 2022 US Dollars

Summary of Costs ($ Million)	Present value at a 3% rate	Present value at a 7% rate	Annualized Cost at a 3% discount rate	Annualized Cost at a 7% discount rate
Mitigation Costs	$31.1	$23.9	$2.6	$2.6

The following table summarizes benefits and costs.

Summary of Benefits and Costs

Benefits
- Preventing 427 used upper stages from becoming orbital debris over the 15 years

- Avoiding orbital remediation costs in the long run - Mitigating risks to valuable space assets - Internalizing the externality (spill-over cost) to benefit the satellite industry - Aligning FAA requirements with interagency policies and common standards for orbital debris mitigation, and encouraging reciprocal regulatory action in foreign countries, which will further benefit U.S. commercial and government space operations by reducing space debris - Preventing collisions and protecting human spaceflight
Costs
- Present-value cost over 15-years (7 percent) would be $24 million ($3 million annualized). The costs are categorized into five groups: four disposal methods and reporting costs.

The FAA encourages the public interest parties to read a full context of the regulatory impact analysis (RIA) of this proposed rule in the docket for this rulemaking.

B. Regulatory Flexibility Determination

The Regulatory Flexibility Act of 1980 (Public Law 96-354) (RFA) establishes "as a principle of regulatory issuance that agencies shall endeavor, consistent with the objectives of the rule and of applicable statutes, to fit regulatory and informational requirements to the scale of the businesses, organizations, and governmental jurisdictions subject to regulation." To achieve this principle, agencies are required to solicit and consider flexible regulatory proposals and to explain the rationale for their actions to assure that such proposals are given serious consideration." The RFA covers a wide range of small entities, including small businesses, not-for-profit organizations, and small governmental jurisdictions.

Agencies must perform a review to determine whether a rule will have a significant economic impact on a substantial number of small entities. If the agency determines that it will, the agency must prepare a regulatory flexibility analysis as described in the RFA.

However, if an agency determines that a rule is not expected to have a significant economic impact on a substantial number of small entities, section 605(b) of the RFA provides that the head of the agency may so certify and a regulatory flexibility analysis is not required. The certification must include a statement providing the factual basis for this determination, and the reasoning should be clear.

Currently, there are five FAA-licensed United States commercial space launch orbital vehicle manufacturers and operators under the Small Business Administration small-entity criteria of 1,200 employees. Two of the five small entities are either a suborbital launcher whose space vehicles would not reach high space altitude to become orbital debris against the 25-year rule or not an active launcher, but listed as a launch license holder. The other three of the five are considered to be rocket builders, whose products as low-cost suborbital rockets would not be affected by this proposed rule. Therefore, as provided in section 605(b), the head of the FAA certifies that this rulemaking will not result in a significant economic impact on a substantial number of small entities.

The FAA invites interested parties to submit data and information regarding the potential economic impact that would result from the proposal.

C. International Trade Impact Assessment

The Trade Agreements Act of 1979 (Public Law 96-39), as amended by the Uruguay Round Agreements Act (Public Law 103-465), prohibits Federal agencies from establishing standards or engaging in related activities that create unnecessary obstacles to the foreign commerce of the United States. Pursuant to these Acts, the establishment of standards is not considered an unnecessary obstacle to the foreign commerce of the United States, so long as the standard has a legitimate domestic objective, such as the protection of safety, and does not operate in a manner that excludes imports that meet this objective. The statute also requires consideration of international standards and, where appropriate, that they be the basis for U.S. standards. The FAA has assessed the potential effect of this proposed rule and determined that it would respond to a domestic safety objective and would not be considered an unnecessary obstacle to trade.

D. Unfunded Mandates Assessment

Title II of the Unfunded Mandates Reform Act of 1995 (Public Law 104-4) requires each Federal agency to prepare a written statement assessing the effects of any Federal mandate in a proposed or final agency rule that may result in an expenditure of 100 million or more (in 1995 dollars) in any 1 year by State, local, and tribal governments, in the aggregate, or by the private sector; such a mandate is deemed to be a “significant regulatory action.” The FAA currently uses an inflation-adjusted value of $155 million in lieu of $100 million. This proposed rule does not contain such a mandate; therefore, the requirements of Title II of the Act do not apply.

E. Paperwork Reduction Act

The Paperwork Reduction Act of 1995 (44 U.S.C. 3507(d)) requires that the FAA consider the impact of paperwork and other information collection burdens imposed on the public. According to the 1995 amendments to the Paperwork Reduction Act (5 CFR 1320.8(b)(2)(vi)), an agency may not collect or sponsor the collection of information, nor may it impose an information collection requirement unless it displays a currently valid OMB control number.

This action contains the following proposed amendments to the existing information collection requirements previously approved under OMB Control Number 2120-0608. As required by the Paperwork Reduction Act of 1995 (44 U.S.C. 3507(d)), the FAA has submitted these proposed information collection amendments to OMB for its review.

Summary: Under §§ 453.5 through 453.18, the proposed rule would require applicants to submit an ODAP that includes several analyses, descriptions, and demonstrations. The analyses would detail the release of debris during normal operations, how that debris release could be mitigated, and how any debris released will meet the 25-year rule and 100 object-year rule. An analysis detailing the end-of-mission passivation procedure and its probability of success would also be required, as well as a procedure for collision avoidance after payload separation and an analysis of the lifetime probability of collision. For post-mission disposal, analysis and description of the disposal method and its probability of success are proposed along with the calculated risk, effective casualty area, or the broad ocean location of any disposals into Earth's atmosphere.

Use: The information would be used by the FAA's Office of Commercial Space to evaluate the operator's application.

Respondents (including number of): There are approximately 13 FAA-licensed or permitted launches and reentries per year that would be affected by this proposed regulation.

Frequency: Operators would need to submit a mission-specific ODAP at least 60 days before each launch or reentry with a planned altitude above 150 km. In 2021, the FAA issued 24 space launch and reentry licenses held by 11 license holders. Many operators will be able to re-use the ODAP or parts of the ODAP for multiple operations, as some information will not change operation to operation. The FAA uses 25 ODAP per year for the calculation of the frequency.

Annual Burden Estimate: Changes in §§ 453.5 through 453.18 would result in some paperwork burden cost by requiring engineer time for analyses and documentations of mission disposal, normal operations debris release, explosion mitigation, and collision mitigation in an ODAP. The FAA estimates an aerospace engineer would spend approximately 10 hours per launch at the mean hourly wage rate of $81.28.[70] To determine reporting requirement cost, the FAA calculates the annual launch number potentially for orbital debris creation. The annual impacted launch number was estimated to be 25 by dividing the total forecasted launches subtracting sub-orbital launches (or natural decay) by 15 years. Based on impacted 25 launches, the paperwork burden would be $341,376 over 15-year analysis period.

In order to comply with § 453.20, launch operators would need to notify the FAA or, if appropriate, a requesting Federal agency, by phone call or email at the detection of a debris-creating event or any launch or reentry activity outside the 3-sigma trajectory provided for collision avoidance. The FAA estimated the time required to report by phone or email would be about 0.25 hours per launch or approximately 95 hours (0.25 x 25 x 15) over a 15-year period, assuming operators would have an event to report under proposed § 453.20 after every launch. It would cost $8,677 (see table 2, column 3) over the entire 15-year period based on the average wage rate of $81.28 for aerospace engineers.

The compliance costs for § 453.11, launch and reentry collision avoidance analysis and the associated worksheet, are unchanged from the previous part 450 burden determination.

[70] The spent hour estimate is based on FAA/AST office and government launchers data sources. The wage rate is based on U.S. Bureau of Labor Statistics (BLS), Occupation Employment and Wages, occupation code 17-2011 for Aerospace Engineers, in Feb 2019.

Combing all the reporting costs, the undiscounted total reporting requirement cost would be $350,053 ($341,376 + $8,677) over the 15-year period. The FAA believes the paperwork burden is insignificant.

The agency is soliciting comments to—

(1) Evaluate whether the proposed information requirement is necessary for the proper performance of the functions of the agency, including whether the information will have practical utility;

(2) Evaluate the accuracy of the agency's estimate of the burden;

(3) Enhance the quality, utility, and clarity of the information to be collected; and

(4) Minimize the burden of collecting information on those who are to respond, including by using appropriate automated, electronic, mechanical, or other technological collection techniques or other forms of information technology.

Individuals and organizations may send comments on the information collection requirement to the address listed in the ADDRESSES section at the beginning of this preamble by [INSERT DATE 90 DAYS AFTER PUBLICATION IN THE FEDERAL REGISTER]. Comments also should be submitted to the Office of Management and Budget, Office of Information and Regulatory Affairs, Attention: Desk Officer for FAA, New Executive Building, Room 10202, 725 17 Street, NW, Washington, DC 20053.

F. Environmental Analysis

FAA Order 1050.1F identifies FAA actions that are categorically excluded from preparation of an environmental assessment or environmental impact statement under the National Environmental Policy Act in the absence of extraordinary circumstances. The FAA has determined this rulemaking action qualifies for the categorical exclusion identified in paragraph 5-6.6f for regulations and involves no extraordinary circumstances.

V. Executive Order Determinations

A. Executive Order 13132, Federalism

The FAA has analyzed this proposed rule under the principles and criteria of Executive Order 13132, Federalism. The agency has determined that this action would not have a substantial direct effect on the States, or the relationship between the Federal Government and the States, or on the distribution of power and responsibilities among the various levels of government, and, therefore, would not have Federalism implications.

B. Executive Order 13211, Regulations that Significantly Affect Energy Supply, Distribution, or Use

The FAA analyzed this proposed rule under Executive Order 13211, Actions Concerning Regulations that Significantly Affect Energy Supply, Distribution, or Use (May 18, 2001). The agency has determined that it would not be a "significant energy action" under the executive order and would not be likely to have a significant adverse effect on the supply, distribution, or use of energy.

VI. Additional Information

A. Comments Invited

The FAA invites interested persons to participate in this rulemaking by submitting written comments, data, or views. The agency also invites comments relating to the economic, environmental, energy, or Federalism impacts that might result from adopting the proposals in this document. The most helpful comments reference a specific portion of the proposal, explain the reason for any recommended change, and include supporting data. To ensure the docket does not contain duplicate comments, commenters should send only one copy of written comments, or if comments are filed electronically, commenters should submit only one time.

The FAA will file in the docket all comments it receives, as well as a report summarizing each substantive public contact with FAA personnel concerning this proposed rulemaking, or a memorandum submitted by outside parties to memorialize communications with the FAA. Before acting on this proposal, the FAA will consider all comments it receives on or before the closing date for comments. The FAA will consider comments filed after the comment period has closed to the extent practicable. The agency may change this proposal in light of the comments it receives.

Proprietary or Confidential Business Information: Commenters should not file proprietary or confidential business information in the docket. Such information must be sent or delivered directly to the person identified in the FOR FURTHER INFORMATION CONTACT section of this document, and marked as proprietary or confidential. If submitting information on a disk or CD ROM, mark the outside of the disk or CD ROM, and identify electronically within the disk or CD ROM the specific information that is proprietary or confidential.

Under 14 CFR 11.35(b), if the FAA is aware of proprietary information filed with a comment, the agency does not place it in the docket. It is held in a separate file to which the public does not have access, and the FAA places a note in the docket that it has received it. If the FAA receives a request to examine or copy this information, it treats it as any other request under the Freedom of Information Act (5 U.S.C. 552). The FAA processes such a request under Department of Transportation procedures found in 49 CFR part 7.

B. Availability of Rulemaking Documents

An electronic copy of rulemaking documents may be obtained from the Internet by—

1. Searching the Federal eRulemaking Portal (www.regulations.gov);

2. Visiting the FAA's Regulations and Policies web page at www.faa.gov/regulations_policies; or,

3. Accessing the Government Printing Office's web page at www.GovInfo.gov.

Copies may also be obtained by sending a request to the Federal Aviation Administration, Office of Rulemaking, ARM-1, 800 Independence Avenue SW, Washington, DC 20591, or by calling (202) 267-9677. Commenters must identify the docket or notice number of this rulemaking.

All documents the FAA considered in developing this proposed rule, including economic analyses and technical reports, may be accessed from the Internet through the Federal eRulemaking Portal referenced in item (1) above.

List of Subjects

14 CFR Part 401

Organization and functions (Government agencies). Space Transportation and exploration.

14 CFR Part 404

Administrative practice and procedure. Space transportation and exploration.

14 CFR Part 415

Reporting and recordkeeping requirements, Space transportation and exploration.

14 CFR Part 417

Reporting and recordkeeping requirements, Space transportation and exploration.

14 CFR Part 431

Reporting and recordkeeping requirements, Space transportation and exploration.

14 CFR Part 435

Reporting and recordkeeping requirements, Space transportation and exploration.

14 CFR Part 437

Aircraft. Aviation safety. Reporting and recordkeeping requirements. Space transportation and exploration.

14 CFR Part 450

Reporting and recordkeeping requirements, Space transportation and exploration.

14 CFR Part 453

Reporting and recordkeeping requirements, Space transportation and exploration.

The Proposed Amendment

In consideration of the foregoing, the Federal Aviation Administration proposes to amend chapter III of title 14, Code of Federal Regulations as follows:

PART 401--ORGANIZATION AND DEFINITIONS

1. The authority citation for part 401 continues to read as follows:

Authority: 51 U.S.C. 50901-50923

§ 401.7 Definitions.

2. Amend § 401.7 to add or revise the following items, in alphabetical order, to read as follows:

* * * * *

Disposal means to execute or attempt to execute controlled atmospheric disposal, heliocentric disposal, uncontrolled atmospheric disposal, disposal orbit, or direct retrieval of launch vehicle stages or components of launch or reentry vehicles under part 453 of this chapter.

*   *   *   *   *

Geostationary Earth Orbit (GEO) means any Earth orbit where the orbiting object orbits at the same angular velocity as the Earth and the object appears stationary from the ground. The altitude of this zero inclination, zero eccentricity orbit is 35,786 km.

Geosynchronous region is the band of orbital space surrounding GEO. It is bound by altitude limits of 35,786 km +/- 200 km altitude and +/- 15 degrees latitude.

*   *   *   *   *

Low Earth Orbit (LEO) means any Earth orbit with both apogee and perigee below 2,000 km altitude.

*   *   *   *   *

Medium Earth Orbit (MEO) means any Earth orbit in which an object's apogee and perigee both remain between LEO and GEO.

*   *   *   *   *

Object time means the number of objects multiplied by the unit of time, typically years. A higher object-time means more objects on orbit for a higher cumulative amount of time.

*   *   *   *   *

Orbital debris means all human-generated debris in Earth orbit that is greater than 5 mm in any dimension. This includes, but is not limited to, payloads that can no longer serve a useful purpose, rocket bodies and other hardware (e.g., bolt fragments and covers) left in orbit as a result of normal launch and operational activities, and fragmentation debris produced by failure or collision. Released gases and liquids in a free state, and solid rocket motor slag of any size are not orbital debris.

*   *   *   *   *

PART 404—PETITION AND RULEMAKING PROCEDURES

3. The authority citation for part 404 continues to read as follows:

Authority: 51 U.S.C. 50901-50923

4. Revise Table A404.1 to read as follows:

* * * * *

Sections	Paragraphs
§ 404.5—Filing a petition for waiver	(a).
§ 413.23—License or permit renewal	(a).
§ 414.31—Safety element approval renewal	(a).
§ 420.57—Notifications	(d).
§ 437.89—Pre-flight reporting	(a), (b).
§ 440.15—Demonstration of compliance	(a)(1), (a)(2), (a)(3), (a)(4).
§ 453.11—Launch and Reentry Collision Avoidance Analysis Requirements	(e)(1).
§ 450.213—Pre-flight reporting	(b), (c), (d), (e).
§ 450.215—Post-flight reporting	(a).

PART 415—LAUNCH LICENSE

5. The authority citation for part 415 continues to read as follows:

Authority: 51 U.S.C. 50901-50923

§ 415.2 Licenses issued under this part.

6. Amend § 415.2 by revising paragraph (b) to read as follows:

* * * * *

(b) *Compliance with parts 450 and 453 of this chapter*. Operations under this part must comply with the critical asset protection requirements in § 450.101(a)(4) and (b)(4) of this chapter and, for launches with a planned altitude greater than 150 kilometers, the collision avoidance requirements in § 453.11 of this chapter.

§ 415.35 Acceptable flight risk.

7. Amend § 415.35 by revising paragraph (d) to read as follows:

* * * * *

(d) *Operation.* A launch vehicle must be operated in a manner that ensures that flight risks meet the criteria of paragraph (a) of this section and in accordance with collision avoidance requirements in § 453.11 and critical asset protection requirements in §§ 450.101(a)(4) and (b)(4). An applicant must identify all launch operations and procedures that must be performed to ensure acceptable flight risk.

* * * * *

8. Revise § 415.39 to read as follows:

§ 415.39 Demonstration of Orbital Debris Mitigation.

An applicant must demonstrate compliance with §§ 453.7 and 453.9 of this chapter for any proposed launch of a launch vehicle with a stage or component that will travel to an altitude of 150 kilometers or higher.

9. Revise § 415.133 to read as follows:

§ 415.133 Orbital Debris Mitigation.

An applicant must demonstrate compliance with §§ 453.7 and 453.9 of this chapter for any proposed launch of a launch vehicle with a stage or component that will travel to an altitude of 150 kilometers or higher.

10. Amend Appendix B to Part 415 by revising item 13.0 to read as follows:

Appendix B to Part 415—Safety Review Document Outline

* * * * *

13.0 Orbital Debris Mitigation (§ 415.133)

PART 417—LAUNCH SAFETY

11. The authority citation for part 417 continues to read as follows:

Authority: 51 U.S.C. 50901–50923

§ 417.113 Launch safety rules.

12. Amend § 417.113 by revising paragraph (c)(1) to read as follows:

* * * * *

(c) * * *

(1) The flight-commit criteria must implement the flight safety analysis of subpart C of this part, the collision avoidance requirements in § 453.11, and critical asset protection requirements in § 450.101(a)(4) and (b)(4). These must include criteria for:

* * * * *

(iii) Implementation of any launch wait in the launch window for the purpose of collision avoidance in accordance with collision avoidance requirements in § 453.11.

* * * * *

13. Revise § 417.129 to read as follows:

§ 417.129 Orbital Debris Mitigation.

A launch operator must perform orbital debris mitigation as required by §§ 453.7 and 453.9 of this chapter.

PART 431—LAUNCH AND REENTRY OF A REUSABLE LAUNCH VEHICLE (RLV)

14. The authority citation for part 431 continues to read as follows:

Authority: 51 U.S.C. 50901–50923

§ 431.2 Licenses issued under this part.

15. Amend § 431.2 by revising paragraph (b) to read as follows:

* * * * *

(b) Compliance with parts 450 and 453 of this chapter. Operations under this part must comply with the critical asset protection requirements in § 450.101(a)(4) and (b)(4) of this chapter and, for launches or reentries with a planned altitude greater than 150 kilometers, the launch and reentry collision avoidance requirements in § 453.11 of this chapter.

§ 431.43 Reusable launch vehicle mission operational requirements and restrictions.

16. Amend § 431.43 by revising paragraphs (a)(1) and (c)(3) to read as follows:

(a) * * *

(1) That ensure RLV mission risks do not exceed the criteria set forth in §§ 431.35, 450.101(a)(4) and (b)(4), and 453.11 for nominal and non-nominal operations;

* * * * *

(c) * * *

(3) A launch operator must perform orbital debris mitigation as required by §§ 453.7 and 453.9 of this chapter; and

* * * * *

PART 435—REENTRY OF A REENTRY VEHICLE OTHER THAN A REUSABLE LAUNCH VEHICLE (RLV)

17. The authority citation for part 435 continues to read as follows:

Authority: 51 U.S.C. 50901–50923

§ 435.2 Licenses.

18. Amend § 435.2 by revising paragraph (b) to read as follows:

* * * * *

(b) *Compliance with parts 450 and 453 of this chapter.* Operations under this part with a planned altitude greater than 150 kilometers must comply with launch and reentry collision avoidance requirements in § 453.11 of this chapter and critical asset protection requirements in § 450.101(a)(4) and (b)(4) of this chapter.

PART 437—EXPERIMENTAL PERMITS

19. The authority citation for part 437 continues to read as follows:

Authority: 51 U.S.C. 50901–50923

§ 437.65 Collision avoidance analysis.

20. Revise § 437.65 to read as follows:

For a permitted flight with a planned altitude greater than 150 kilometers, a permittee must obtain a collision avoidance analysis in accordance with § 453.11 of this chapter.

PART 450—LAUNCH AND REENTRY LICENSE REQUIREMENTS

21. The authority citation for part 450 continues to read as follows:

Authority: 51 U.S.C. 50901–50923

§ 450.37 Equivalent level of safety.

22. Amend § 450.37 by revising paragraph (b) to read as follows:

*   *   *   *   *

(b) Paragraph (a) of this section does not apply to § 450.101(a), (b), (c)(1) and (3), (d), and (g).

§ 450.101 Safety criteria.

23. Amend § 450.101 by revising paragraphs (d) and (e) to read as follows:

*   *   *   *   *

(d) *Disposal risk criteria*. For any controlled or uncontrolled atmospheric disposal, an operator may initiate the deorbit of a vehicle or its components only if all risks to the public satisfy the criteria in this paragraph.

(1) *Controlled atmospheric disposal*. For any controlled atmospheric disposal performed in accordance with § 453.14 or direct retrieval resulting in controlled atmospheric disposal under § 453.16(b)(1), an operator must:

(i) Ensure that the effective casualty area for any surviving debris will be less than 7 square meters;

(ii) Target a broad ocean area; or

(iii) Meet the following risk criteria:

(A) *Collective risk*. The collective risk, measured as expected number of casualties (E_C), consists of risk posed by impacting inert and explosive debris, toxic release, and far field blast overpressure. Public risk due to any other hazard associated with the proposed deorbit of a launch vehicle stage or component of a launch or reentry vehicle will be determined by the Administrator on a case-by-case basis. The risk to all members of the public, excluding persons in aircraft must not exceed an expected number of 1×10^{-4} casualties.

(B) *Individual risk*. The individual risk, measured as probability of casualty (P_C), consists of risk posed by impacting inert and explosive debris, toxic release, and far field blast overpressure. Public risk due to any other hazard associated with the proposed deorbit of a launch vehicle stage or component of a launch or reentry vehicle will be determined by the Administrator on a case-by-case basis. The risk to any individual member of the public must not exceed a probability of casualty of 1×10^{-6} per disposal.

(C) *Aircraft risk*. An operator must establish any aircraft hazard areas necessary to ensure the probability of impact with debris capable of causing a casualty for aircraft does not exceed 1×10^{-6}.

(2) Uncontrolled atmospheric disposal. For any uncontrolled atmospheric disposal performed in accordance with § 453.17, an operator must either:

(i) Ensure that the effective casualty area for any surviving debris will be less than 7 square meters; or

(ii) Meet the collective risk criterion of paragraph (1)(iii)(A) of this subsection.

(e) *Protection of people and property on orbit*.

(1) A launch or reentry operator must prevent the collision between a launch or reentry vehicle stage or component with a planned altitude greater than 150 kilometers and people, property, and debris on orbit, in accordance with the requirements in § 453.11.

(2) For any launch or reentry vehicle stage or component with a planned altitude greater than 150 kilometers, a launch operator must perform orbital debris mitigation in accordance with the requirements in §§ 453.7 and 453.9.

*   *   *   *   *

§ 450.113 Flight safety analysis requirements—scope.

24. Amend § 450.113 by revising paragraph (a) and adding paragraph (c) to read as follows:

(a) An operator must perform and document a flight safety analysis for all phases of flight, except as specified in paragraphs (b) and (c) of this section, as follows—

*   *   *   *   *

(1)   *   *   *

(3) For controlled atmospheric disposal performed in accordance with § 453.14 or direct retrieval resulting in controlled atmospheric disposal under § 453.16(b)(1), from the initiation of the deorbit through final impact; and

*   *   *   *   *

(c) An operator is not required to perform and document a flight safety analysis for a controlled atmospheric disposal if agreed to by the Administrator that the disposal will target a broad ocean area or the effective casualty area for any surviving debris will be less than 7 square meters.

§ 450.165 Flight commit criteria.

25. Amend § 450.165 by revising paragraph (a)(3) to read as follows:

* * * * *

(a) * * *

(3) Implementation of any launch or reentry window closure in the launch or reentry window for the purpose of collision avoidance in accordance with § 453.11;

* * * * *

26. Revise § 450.169 to read as follows:

§ 450.169 Launch and reentry collision avoidance analysis requirements.

A launch or reentry operator must perform collision avoidance analysis as required by § 453.11.

27. Revise § 450.171 to read as follows:

§ 450.171 Orbital Debris Mitigation.

A launch operator must perform orbital debris mitigation as required by §§ 453.7 and 453.9 of this chapter.

§ 450.213 Pre-flight reporting.

28. Amend § 450.213 to revise paragraph (e) to read as follows:

* * * * *

(e) *Collision avoidance analysis*. A licensee must submit collision avoidance information to a Federal entity identified by the FAA and to the FAA in accordance with § 453.11(f).

*   *   *   *   *

Appendix A to Part 450—Collision Analysis Worksheet [REMOVED]

29. Remove Appendix A to Part 450—Collision Analysis Worksheet.

30. Add part 453 to read as follows:

PART 453—ORBITAL SAFETY REQUIREMENTS

Sec.

453.1 Applicability

453.3 [Reserved]

453.5 Control of Debris Released During Normal Operations

453.7 Minimizing Debris Generated by Explosions

453.9 Collision Mitigation between Launched Objects

453.11 Collision Avoidance with Orbital Objects

453.13 Post-Mission Disposal

453.14 Controlled Atmospheric Disposal

453.15 Heliocentric, Earth-escape Disposal

453.16 Direct Retrieval

453.17 Uncontrolled Atmospheric Disposal

453.18 Maneuver to a disposal orbit

453.20 Real-Time Reporting of Orbital Safety Hazards

Authority: 51 U.S.C. 50901–50923

§ 453.1 Applicability

(a) This part establishes the requirements of a launch or reentry operator (operator) for orbital debris mitigation, including collision avoidance analysis, prior to launch or reentry operations licensed or permitted under this chapter with a planned altitude greater than 150 kilometers.

(b) For each licensed or permitted launch or reentry with a planned altitude greater than 150 kilometers, an operator must submit—

(1) An Orbital Debris Assessment Plan containing the information required by this part not less than 60 days before the licensed or permitted launch or reentry, unless the Administrator agrees to a different time frame in accordance with § 404.15; and

(2) A Collision Avoidance Analysis Worksheet in accordance with § 453.11(f).

(c) An operator must send the information required by this part as an email attachment to ASTOperations@faa.gov, or other method as agreed to by the Administrator in the license or permit.

§ 453.3 [Reserved]

§ 453.5 Control of Debris Released During Normal Operations

An operator must ensure for any proposed launch that for all vehicle stages and components related to launch that reach an altitude greater than 150 kilometers—

(a) The component will not release orbital debris into LEO that will remain in orbit for more than 25 years. For all planned released orbital debris, the total debris object-time product in LEO shall not exceed 100 object-years per licensed or permitted launch. The total object-time product in LEO is the sum of the orbit dwell time in LEO for all planned released debris objects, excluding the upper stage and any released payloads.

(b) Any orbital debris released into the geosynchronous region must enter an orbit with an apogee that will not remain in the geosynchronous region within 25 years of the release.

(c) Information Requirements. An operator must submit the following information in an Orbital Debris Assessment Plan—

(1) A demonstration through environmental qualification and acceptance testing that the system is designed to limit the release of orbital debris; and

(2) A statistical analysis, including inputs and assumptions, demonstrating that any orbital debris released will be disposed of within 25 years and satisfy the 100 object-year requirement.

§ 453.7 Minimizing Debris Generated by Explosions

(a) An operator must ensure for any proposed launch that for all vehicle stages or other component that reaches an altitude greater than 150 kilometers, except for energy sources that are safety critical on-orbit or during reentry:

(1) The integrated probability of debris-generating explosions or other fragmentation from the conversion of energy sources (i.e. chemical, pressure, kinetic) of each upper stage is less than 0.001 (1 in 1,000) during operations; and

(2) Stored energy is removed by depleting residual propellants, venting any pressurized system, leaving all batteries in a permanent discharge state, and removing any remaining source of stored energy.

(b) Information Requirements. An operator must submit the following information in an Orbital Debris Assessment Plan—

(1) Analysis, using commonly accepted engineering and probability assessment methods, showing how the operation meets paragraph (a)(1) of this section.

(2) Test results or analysis, with 95 percent confidence levels, of the planned end-of-mission passivation procedure that verifies dissipation of all energy sources to levels that will prevent explosion of any launch vehicle component, to show that:

(i) All residual propellants contained in the system can be purged or passivated at the end of launch;

(ii) All pressurized systems can be purged or passivated; and

(iii) All energy storage systems (e.g., batteries or fuel cells) have sufficient structural design to prevent rupture and subsequent explosion.

§ 453.9 Collision Mitigation between Launched Objects

(a) Payload Separation. A launch operator must prevent unplanned physical contact between a launch vehicle or any of its components and each payload after payload separation;

(b) Collision after the End of Launch. In developing the design and mission profile for an upper stage, the launch operator shall limit the probability of collision with objects 10 cm and larger after the end of launch to less than 0.001 (1 in 1,000);

(c) Information required. A launch operator must submit the following information in an Orbital Debris Assessment Plan—

(1) Procedure for preventing vehicle and payload collision after payload separation, including any propellant depletion burns and compressed gas releases that minimize the probability of subsequent collisions; and

(2) The results of a probability of collision analysis between the upper stage and its components and orbital objects, using commonly accepted engineering and probability assessment methods, meeting paragraph (b) of this section.

§ 453.11 Collision Avoidance with Orbital Objects

(a) *Criteria.* For an orbital or suborbital launch or reentry, an operator must establish window closures needed to ensure that the launch or reentry vehicle, any jettisoned components, or payloads meet the following requirements with respect to orbiting objects, not including any object being launched or reentered.

(1) For inhabitable objects, one of the following three criteria must be met:

(i) The probability of collision between the launching or reentering objects and any inhabitable object must not exceed 1×10^{-6};

(ii) The launching or reentering objects must maintain an ellipsoidal separation distance of 200 kilometers in-track and 50 kilometers cross-track and radially from the inhabitable object; or

(iii) The launching or reentering objects must maintain a spherical separation distance of 200 kilometers from the inhabitable object.

(2) For active payloads, one of the following criteria must be met:

(i) The probability of collision between the launching or reentering objects and the active payload must not exceed 1×10^{-5};

(ii) The launching or reentering objects must maintain an ellipsoidal separation distance of 25 kilometers in-track and 7 kilometers cross-track and radially from the active payload; or

(iii) The launching or reentering objects must maintain a spherical separation distance of 25 kilometers from the active payload.

(3) For all other known orbital debris identified by the FAA or other Federal Government entity with a radar cross section greater than 0.04 m^2:

(i) The probability of collision between the launching or reentering objects and any known orbital debris must not exceed 1×10^{-5}; or

(ii) The launching or reentering objects must maintain a spherical separation distance of 2.5 kilometers.

(b) *Screening time.* An operator must ensure the requirements of paragraph (a) of this section are met as follows:

(1) Through the entire segment of flight of a suborbital launch vehicle above 150 kilometers altitude;

(2) For an orbital launch, during ascent from a minimum of 150 kilometers altitude to initial orbital insertion and for a minimum of 3 hours from liftoff;

(3) For reentry, during descent from initial reentry burn to 150 kilometers altitude;

(4) For controlled atmospheric disposal, during descent from initial disposal burn to 150 kilometers altitude; and

(5) For maneuver to a disposal orbit, during initial disposal operation until removal from LEO or GEO.

(c) *Rendezvous*. Planned rendezvous operations that occur within the screening time frame are not considered a violation of collision avoidance if the involved operators have pre-coordinated the rendezvous or close approach. (d) *Analysis.* An operator must obtain a collision avoidance analysis for each launch or reentry from a Federal entity identified by the FAA, or another entity agreed to by the Administrator.

(1) An operator must use the results of the collision avoidance analysis to establish flight commit criteria for collision avoidance; and

(2) The collision avoidance analysis must account for uncertainties including launch or reentry vehicle performance and timing, atmospheric changes, variations in drag, and any other factors that affect position and timing of the launch or reentry vehicle.

(e) *Timing and information required.* An operator must prepare a Collision Avoidance Analysis Worksheet for each launch or reentry using a standardized format that contains the input data required by § 453.11(f), as follows:

(1) Except as specified in paragraphs (e)(1)(i) and (e)(1)(ii) of this section, an operator must file the input data with an entity identified in paragraph (d) of this section and the FAA at least 7 days before the first attempt at the flight of a launch vehicle or the reentry of a reentry vehicle.

(i) Operators that have never received a launch or reentry conjunction assessment from the entity identified in paragraph (d) of this section must file the input data at least 15 days in advance.

(ii) The Administrator may agree to an alternative time frame in accordance with § 404.15.

(2) An operator must obtain a collision avoidance analysis performed by an entity identified in paragraph (d) of this section no later than 3 hours before the beginning of a launch or reentry window; and

(3) If an operator needs an updated collision avoidance analysis due to a launch or reentry delay, the operator must file the request with the entity identified in paragraph (d) of this section and the FAA at least 12 hours prior to the beginning of the new launch or reentry window.

(f) *Collision Avoidance Analysis Worksheet*. The Collision Avoidance Analysis Worksheet must include—

(1) Launch or reentry information. An operator must file the following information:

(i) Mission name. A mnemonic given to the launch or reentry vehicle/payload combination identifying the launch or reentry mission distinctly from all others;

(ii) Launch or reentry location. Launch or reentry site location in latitude and longitude;

(iii) Launch or reentry window. The launch or reentry window opening and closing times in Greenwich Mean Time (referred to as ZULU time) and the Julian dates for each scheduled launch or reentry attempts including primary and secondary launch or reentry dates;

(iv) Epoch. The epoch time, in Greenwich Mean Time (GMT), of the expected launch vehicle liftoff time or, for reentry, the times of reentry events such as the beginning of descent, atmospheric reentry below 150 kilometers, and touchdown;

(v) Orbiting objects to evaluate. An operator must identify all orbiting object descriptions including object name, dimensions (e.g., length, width, height, and diameter), and mass. These orbiting objects include each free-flying launch vehicle stage, payload, or component achieving orbit;

(vi) Orbital Parameters. An operator must identify the orbital parameters for each free-flying launch vehicle stage, payload, or component achieving orbit including the parameters for each object after thrust ends;

(vii) Time of powered flight and sequence of events. The elapsed time in hours, minutes, and seconds, from liftoff to passivation or disposal. The input data must include the time of powered flight for each stage or jettisoned component measured from liftoff; and

(viii) Point of contact. The person or office within an operator's organization that collects, analyzes, and distributes collision avoidance analysis results.

(2) Collision avoidance analysis results transmission medium. An operator must identify the transmission medium, such as voice or e-mail, for receiving results.

(3) Deliverable schedule/need dates. An operator must identify the times before flight, referred to as "L-times," for which the operator requests a collision avoidance analysis. The final collision avoidance analysis must be used to establish flight commit criteria for a launch.

(4) Trajectory files. Individual position and velocity trajectory files, including:

(i) The position coordinates in the Earth-Fixed Greenwich (EFG) coordinates system measured in kilometers and the EFG velocity components measured in kilometers per second, of each launch vehicle stage or payload starting below 150 kilometers through screening time frame;

(ii) Radar cross section values for each individual file;

(iii) Position Covariance, if probability of impact analysis option is desired; and

(iv) Separate trajectory files identified by valid window time frames, if launch or reentry trajectory changes during launch or reentry window.

(5) Screening. An operator must select spherical, ellipsoidal, or collision probability screening as defined in this paragraph for determining any conjunction:

(i) Spherical screening. Spherical screening centers a sphere on each orbiting object's center-of-mass to determine any conjunction;

(ii) Ellipsoidal screening. Ellipsoidal screening utilizes an impact exclusion ellipsoid of revolution centered on the orbiting object's center-of-mass to determine any conjunction. An operator must provide input in the UVW coordinate system in kilometers. The operator must provide delta-U measured in the radial-track direction, delta-V measured in the in-track direction, and delta-W measured in the cross-track direction; or

(iii) Probability of Collision. Collision probability is calculated using position and velocity information with covariance in position.

§ 453.13 Post-Mission Disposal

(a) *General*. An operator must dispose of all vehicle stages or jettisoned components in accordance with one of the disposal methods identified in §§ 453.14 through 453.18.

(b) *Information requirements*. An operator must submit a description of the chosen disposal option in an Orbital Debris Assessment Plan.

§ 453.14 Controlled Atmospheric Disposal

(a) *Applicability*. This section applies to the use of controlled atmospheric disposal of vehicle stages or components by reentering the atmosphere to meet the post-mission disposal requirement of § 453.13.

(b) *Disposal safety criteria*. A launch or reentry operator must ensure the upper stage and each of its components, or any components of a reentry vehicle excluding the reentry vehicle itself, reenters the Earth's atmosphere within 30 days after mission completion in a controlled manner that:

(1) Ensures that the effective casualty area for any surviving debris will be less than 7 square meters;

(2) Targets a broad ocean area; or

(3) Meets the risk criteria of § 450.101(d)(1)(iii)(A) through (C).

(c) *Notification of planned impacts*. For any controlled atmospheric disposal, an operator must notify the public of any region of land, sea, or air that contains, with 97 percent probability of containment, all debris resulting from normal flight events capable of causing a casualty.

(d) *Information requirements*. An operator must submit a description of the controlled atmospheric disposal in an Orbital Debris Assessment Plan including—

(1) Verification through hardware and software testing or analysis that the system has at least a 90 percent probability of successfully executing the controlled atmospheric disposal as planned;

(2) A description of how the system will achieve a controlled atmospheric disposal under nominal and off-nominal conditions; and

(3) If not targeting a broad ocean area, the calculated total collective and individual casualty expectations for the proposed operation or the effective casualty area of any surviving debris.

§ 453.15 Heliocentric, Earth-escape Disposal

(a) *Applicability*. This section applies to the use of heliocentric, Earth-escape disposal to meet the post-mission disposal requirement of § 453.13.

(b) *General*. A launch operator must ensure, within 30 days after mission completion, that the upper stage and each of its components enters a hyperbolic trajectory which no longer orbits Earth;

(c) *Information requirements*. A launch operator must submit a description of the planned heliocentric, Earth-escape disposal in an Orbital Debris Assessment Plan including:

(1) Verification through hardware and software testing or analysis that the system has at least a 90 percent probability of successfully executing the planned heliocentric, Earth-escape disposal; and

(2) A description of how the system will achieve a controlled disposal under nominal and off-nominal conditions.

§ 453.16 Direct Retrieval

(a) *Applicability*. This section applies to the use of direct retrieval to meet the post-mission disposal requirement of § 453.13.

(b) *General*. No more than 5 years after completion of the mission, an operator must ensure the removal of the upper stage and each of its components from orbit by either—

(1) Performing a controlled atmospheric disposal that meets the disposal safety requirements of § 453.14(b) and (c); or

(2) Maneuvering the debris into a disposal orbit in accordance with § 453.18.

(c) *Information requirements*. An operator must submit a description of the planned direct retrieval in an Orbital Debris Assessment Plan including—

(1) Verification through hardware and software testing or analysis that the system has at least a 90 percent probability of successfully executing the planned direct retrieval; and

(2) If performing a controlled atmospheric disposal—

(i) A description of how the system will achieve a disposal under nominal and off-nominal conditions; and

(ii) If not disposing into a broad ocean area, the calculated total collective and individual casualty expectations for the proposed operation or the effective casualty area of any surviving debris; or

(3) If maneuvering to a disposal orbit—

(i) A description of how the system will achieve and maintain the planned disposal orbit for the required time limit as specified in § 453.18(b) through (d); and

(ii) A statistical analysis demonstrating that the probability of collision with operational spacecraft and debris is within the lifetime limit of § 453.18(e).

§ 453.17 Uncontrolled Atmospheric Disposal

(a) Applicability. This section applies to the use of uncontrolled atmospheric disposal to meet the post-mission disposal requirement of § 453.13.

(b) *LEO Disposal*. For orbits below 2,000 kilometers:

(1) A launch or reentry operator must leave an upper stage and its components in an orbit where, accounting for mean projections for solar activity and atmospheric drag, the orbital lifetime should be as short as practicable but does not exceed 25 years after launch, and

(2) For all launches and reentries after [ONE YEAR AFTER THE REGULATION EFFECTIVE DATE], an operator must ensure that the effective casualty area for any surviving debris will be less than 7 square meters, or the expected average number of casualties will be less than 1×10^{-4}.

(c) *Highly elliptical long-term disposal*. For highly elliptical MEO (including semi-synchronous Molniya) and highly elliptical GEO orbits (including synchronous Tundra orbits), and other orbits subject to significant eccentricity growth, the operator must maneuver the upper stage to a long-term disposal orbit where orbital resonances will increase the eccentricity for its long-term disposal. In developing this disposal plan, the operator must:

(1) Limit the orbital lifetime to be as short as practicable, but no more than 200 years after mission completion;

(2) Limit the probability of collisions with operational spacecraft and debris 10 cm and larger to less than 0.001 during orbital lifetime; and

(3) For launches after [ONE YEAR AFTER THE REGULATION EFFECTIVE DATE], a launch operator must ensure that the effective casualty area for any surviving debris will be less than 7 square meters, or the expected average number of casualties will be less than 1×10^{-4}.

(d) *Information requirements*. A launch or reentry operator must submit the following information in an Orbital Debris Assessment Plan—

(1) Verification through hardware and software testing or analysis that the system has at least a 90 percent probability of successfully executing the planned disposal option;

(2) An estimate of the expected casualties or the effective casualty area for any surviving debris; and

(3) A statistical analysis demonstrating compliance with the requirements of § 453.17(b) or (c) to dispose of the debris within the prescribed time limit.

§ 453.18 Maneuver to a disposal orbit

(a) *Applicability*. This section applies to the use of a disposal orbit to meet the post-mission disposal requirement of § 453.13.

(b) *General*. Within 30 days after mission completion, a launch or reentry operator must place the upper stage and its components either—

(1) Between LEO and GEO in accordance with paragraph (c) of this section; or

(2) Above GEO in accordance with paragraph (d) of this section.

(c) *Maneuver to disposal orbit between LEO and GEO*. The operator must place the upper stage and its components into either—

(1) An eccentric disposal orbit where—

(i) Perigee altitude remains above 2,000 kilometers for at least 100 years;

(ii) Apogee altitude remains below the geosynchronous region for at least 100 years; and

(iii) The time spent by the upper stage between 20,182 +/- 300 kilometers is limited to 25 years or less over 200 years; or

(2) A near-circular disposal orbit that avoids for at least 100 years:

(i) Altitudes 20,182 +/- 300 kilometers;

(ii) The geosynchronous region; and

(iii) Altitudes less than 2,000 kilometers.

(d) *Maneuver to disposal orbit above GEO*. The operator must place the upper stage and its components into an orbit with a perigee altitude above 36,100 kilometers for a period of at least 100 years after disposal.

(e) *Probability of Collision*. The operator must limit the probability of collisions with operational spacecraft and debris 10 cm and larger to less than 0.001 for 100 years after disposal.

(f) *Information requirements*. A launch or reentry operator must submit the following information in an Orbital Debris Assessment Plan—

(1) Verification through hardware and software testing or analysis that the system has at least a 90 percent probability of successfully executing the planned disposal option;

(2) A description of how the system will achieve and maintain the planned disposal orbit for the required time limit; and

(3) Statistical analysis demonstrating compliance with the probability of collision lifetime limit with operational spacecraft and debris.

§ 453.20 Real-Time Reporting of Orbital Safety Hazards

(a) At the detection of any launch or reentry activity outside the 3-sigma trajectory provided for collision avoidance or any debris-creating event, or if requested by a cognizant Federal agency, an operator must immediately provide information to the FAA and, if appropriate, to the requesting agency pertinent to locating and categorizing any orbital objects.

(b) The operator shall provide the following information to the FAA and, if applicable, the requesting Federal agency:

(1) The size and mass of the affected objects,

(2) The last known orbital or trajectory information, and

(3) Other details as determined by the FAA necessary to locate and categorize orbital objects.

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