AIAA
SP-016-2-1999

Special Project

MEO/LEO Constellations: U.S. Laws, Policies, and Regulations on Orbital Debris Mitigation

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Sponsored by

American Institute of Aeronautics and Astronautics

Approved

Abstract

This special report focuses on the emerging legal regime for orbital debris mitigation. It contains an overview of the relevant laws, policies, and regulations on orbital debris mitigation and will serve as a useful reference for the space community.

Published by
American Institute of Aeronautics and Astronautics
1801 Alexander Bell Drive, Suite 500, Reston, VA 20191

Printed in the United States of America

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Foreword

As part of a public policy effort to stem the growth of orbital debris, the American Institute of Aeronautics and Astronautics (AIAA) in October 1992 formed the Orbital Debris Committee on Standards (Commit-tee). The Committee succeeded the AIAA Study Group on Orbital Debris, which was formed in May 1989. The work of the Study Group culminated in the AIAA Special Projects Report on Orbital Debris Mitigation Techniques: Technical, Legal, and Eco-nomic Aspects (SP-016-2-1992). The Study Group was chaired by Paul F. Uhlir, National Academy of Sciences. The Committee's members are drawn from government and industry, including the insurance and legal communities. While participating in their individual capacities, many Committee members are affiliated with major U.S. aerospace companies and government agencies with space regulatory and operating responsibilities. The Committee is co-chaired by Pamela L. Meredith, Esq., of Zuckert, Scoutt & Rasenberger, L.L.P., and Dr. Darren S. McKnight of Titan Cor-poration.

At the request of the AIAA Standards Executive Council and Public Policy Committee, the Committee has prepared this overview of the emerging U.S. legal regime for orbital debris mitigation. The overview addresses current U.S. laws, policies, and regulations that impose orbital debris mitigation requirements on U.S. government and commercial space operations. The particular focus is on debris mitigation for commercial space operations, Medium Earth Orbit and Low Earth Orbit (MEO/LEO) satellite constellations.

The focus on debris mitigation was selected since other efforts were either planned or underway at the time the Committee's work began that would assess the debris environment, including the risk and effect of debris impact, debris population distribution, and debris characterization. These include *Orbital Debris: A Technical Assessment* (National Academy of Sciences, National Research Council, 1995); *Interagency Report on Orbital Debris* (Office of Science and Technology Policy, 1995); *Position Paper on Orbital Debris* (International Academy of Astronautics, 1995); *NASA Safety Standard* 1740.14, "Guidelines and Assessment Procedures for Limiting Orbital Debris," NSS 1740.14 (1995)*; NASA Management Instruction* 1700.8, "Policy for Limiting Orbital Debris Generation," NMI 1700.8 (1993) replaced by *NASA Policy Directive* 8710.3, "Policy for Limiting Orbital Debris Generation," NPD 8710.3 (1997); *Protecting the Space Station from Meteoroids and Orbital Debris* (National Research Council, 1997); *Protecting the Space Shuttle from Meteoroids and Orbital Debris* (National Research Council, 1997); *Space Surveillance: DoD and NASA Need Consolidated Requirements and a Coordinated Plan*, GAO/NSIAD-98-42 (1997).

The Committee decided to place particular emphasis on these constellations because they more than any other development of space highlight the need for debris mit-igation measures. Indeed, the White House's Office of Science and Technical Policy (OSTP) concluded that "[t]hese constellations could present a significant new concern for the orbital debris environment."[1]

The following Committee members deserve special mention for their contribution to this report: William D. English, Esq., Iridium, LLC; Sean P. Fleming, Esq., of Law Offices of Pamela Meredith; Mike Fudge of ITT Systems and Sciences; John B. Gantt, Esq., of Mizrack & Gantt; Dr. Timothy Maclay of Orbital Communications Corporation; Dr. Darren S. McKnight; Pamela L. Meredith, Esq.; and Robert E. Penny of Motorola.

The AIAA Orbital Debris Committee on Standards includes the following members:

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Dr. Darren S. McKnight, Co-Chair (Titan Corporation)
Dennis Ahearn (Comsat)

[1] *See* OSTP Report, *supra* note 2, at 55.

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The Committee completed all reviews of the document on April 5, 1999.

The Standards Executive Council accepted the document for publication on April 30, 1999.

1 Recent Developments Focusing Attention on Debris Regulation of Commercial Space Operations

1.1 MEO/LEO Constellations

Over the past five years, the U.S. Federal Communications Commission ("FCC") has licensed the operations of 12 MEO/LEO communications constellations with proposed satellites numbering between two and 288 in altitudes ranging from 700 km to 20,182 km.[2] The orbits of planned MEO/LEO constellations vary not only altitude, but also in inclination and eccentricity. The number of orbital planes per constellation differ along with the dispersion of satellites among the orbital planes. At least twenty-five applications are on file with the FCC for additional MEO/LEO constellations. Several foreign entities are proposing MEO/LEO constellations as well.[3] The table below summarizes licensed and planned U.S. MEO/LEO constellations, including approximate orbital altitude (as licensed by the FCC or requested by applicants) and FCC licensing status.[4]

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[2] See In re Application of Motorola Satellite Communications, Inc., for Authority to Construct, Launch, and Operate a Low Earth Orbit Satellite System in the 1616-1626.5 MHz Band, 10 FCC RCD 2268 (1995); In re Application of Loral/Qualcomm Partnership, L.P., for Authority to Construct, Launch and Operate Globalstar, a Low Earth Orbit Satellite System to Provide Mobile Satellite Services in the 1610-1626.5 MHz/2483.5-2500 MHz Bands, 10 FCC RCD 2333 (1995); In re Application of TRW , Inc., for Authority to Construct, Launch, and Operate a Low Earth Orbit Satellite System in the 1610-1626.5 MHz/2483.5-2500 MHz Band, 10 FCC RCD 2263 (1995); In re Application of Mobile Communications Holdings, Inc., for Authority to Construct, Launch and Operate an Elliptical Low Earth Orbit Mobile-Satellite System, 12 FCC RCD 9663 (1997); In re Application of Constellation Communications, Inc. for Authority to Construct, Launch, and Operate a Low Earth Orbit Mobile-Satellite System, 12 FCC RCD 9651 (1997); In the Matter of Application of Orbital Communications Corporation for Authority to Construct, Launch and Operate a Non-Voice, Non-Geostationary Mobile-Satellite System, 9 FCC RCD 6476 (1994); In the Matter of the Application of Starsys Global Positioning, Inc., for Authority to Construct, Launch and Operate a Satellite System in the Non-Voice, Non-Geostationary Mobile-Satellite Service, 11 FCC RCD 1237 (1995); In the Matter of the Application of Volunteers in Technical Assistance for Authority to Construct, Launch and Operate a Non-Voice, Non-Geostationary Mobile-Satellite System, 11 FCC RCD 1358 (1995); In the Matter of Teledesic Corporation Application for Authority to Construct, Launch, and Operate a Low Earth Orbit Satellite System in the Domestic and International Fixed Satellite Service, Order and Authorization, 12 FCC RCD 3154 (1997) [hereinafter "Teledesic Authorization"]; In the Matter of Final Analysis Communication Services, Inc. for Authority to Construct, Launch and Operate a Non-Voice, Non-Geostationary Mobile-Satellite System in the 148-150.05 MHz, 400.15-401 MHz, and 137-138 MHz bands, 13 FCC RCD 6618 (1998); In the Matter of the Application of Leo One USA Corporation for Authority to Construct, Launch and Operate a Non-Voice, Non-Geostationary Mobile Satellite System in the 137-138, 148-150.05, and 400.15-401 MHz Frequency Bands, 13 FCC RCD 2801 (1998); In the Matter of the Application of E-Sat, Inc. for Authority to Construct, Launch and Operate a Non-Voice, Non-Geostationary Mobile-Satellite System in the 137-138 and 148-150.05 MHz Frequency Bands, 13 FCC RCD 10859 (1998). The FCC distinguishes between the "Big LEO" constellations which will operate in the 1600/2400 MHz bands and provide voice and data communications, and the "Little LEO" constellations, whose satellites are smaller and less powerful and which will be used for data communications below the 1000 MHz band.

[3] Among the other foreign proposed systems are: ICO Global Communications' ICO (England), Kennett International Technology's KITComm (Australia), Matra Marconi's WEST (France), SAIT Systems' IRIS (Belgium), OHB Teledata's Safir R (Germany), Telespazio's Temisat (Italy), and Russia's Gonets-D and Gonets-R. ASSOCIATE ADM'R FOR COMMERCIAL SPACE TRANSP., FED. AVIATION ADMIN., 1998 LEO COMMERCIAL MARKET PROJECTIONS (May 1998), at 3-9.

[4] ICO and KITComm are included because they have filed a Letter of Intent with the FCC to access the U.S. satellite services market. *See ICO Services Limited Letter of Intent to Provide Mobile Satellite Service to, From and Within the U.S. Market Within the 2 GHz MSS Frequency Bands 1990-2025 MHz and 2165-2200 MHz*, File No. SAT-LOI-19970926-00163 (Sep. 26, 1997); and *Letter of Intent of KITComm Satellite Communications Ltd.*, File No. SAT-LOI-19980130-00011 (Jan. 30, 1998). Note that the information in the table is based on FCC licensing orders and applications filed at the FCC but does not necessarily reflect current company plans. For example, Motorola will operate at 780 km not 775 km.

Constellation	Owner	Number of Satellites	Location	FCC Status
Iridium	Iridium, LLC	66	775 km	Licensed ‘95
Globalstar	Loral/Qualcomm	48	1406 km	Licensed ‘95
Odyssey[5]	TRW	10	10,000 km	Licensed ‘95
Ellipso	MCHI	16	Elliptical	Licensed ‘97
ECCO	Constellation	48	1018 km	Licensed ‘97
Orbcomm[6]	Orbital Comm.	36 (48)	775 (825) km	Licensed ‘94
Starnet[7]	Starsys	24	1000 km	Licensed ‘95
Vitasat	VITA	2	800 km	Licensed ‘95
E-Sat	E-Sat, Inc.	6	1262 km	Licensed ‘98
GE Americom	GE Americom	24	800 km	Withdrawn
LEO One USA	LEO One USA	48	950 km	Licensed ‘98
GEMNET	CTA	38	1000 km	Withdrawn
FAISAT	Final Analysis	26	1000 km	Licensed ‘98
Teledesic	Teledesic Corp.	840 (288)	700 (1375) km	Licensed ‘97
Teledesic VBS	Teledesic	72	1375 km	Pending
Teledesic KuBS	Teledesic	30	10,320 km	Pending
M-STAR	Motorola	72	1350 km	Pending
Celestri	Motorola	63	1400 km	Pending
Iridium NextGen	Iridium LLC	96	850 km	Pending
SkyBridge	Alcatel	80	1469.3 km	Pending
SkyBridge II	Alcatel	96	1468 km	Pending
LM-MEO	Lockheed Martin	32	10,352 km	Pending
@Contact	@Contact	16	10,400 km	Pending
SpacewayNGSO	Hughes	20	10,352 km	Pending
StarLynx	Hughes	20 (Hybrid)	10,352 km	Pending
HughesLINK	Hughes	22	15,000 km	Pending
HughesNET	Hughes	70	1490 km	Pending
GS-40	Globalstar	80	1440 km	Pending
GS-2	Globalstar	64 (Hybrid)	1420 km	Pending
Orblink	Orblink LLC	7	9000 km	Pending
GESN	TRW	15 (Hybrid)	10,355 km	Pending
ICO	ICO Services	10	10,355 km	Pending
Boeing 2 GHz	Boeing	16	20,181 km	Pending
Boeing Ku-Band	Boeing	20	20,182 km	Pending
Pentriad	Denali Telecom	14	Elliptical	Pending
Ellipso 2G	MCHI	26	Elliptical	Pending
Virgo	Virtual Geosatellite	15	Elliptical	Pending
Constellation-II	Constellation	46	2000 km	Pending
KITComm	KITComm	21	2800 km	Pending

[5] TRW returned its license to the FCC in January 1998. International Bureau, FCC, Public Notice, Rep. No. SPB-114 (Jan. 15, 1998), at 4.

[6] Orbcomm modified its system to add 12 satellites for a total of 48 satellites and changed the constellation's orbital altitude to 825 km. *In the Matter of Orbital Communications Corporation for Modification of Its Authorization to Construct, Launch and Operate a Non-Voice, Non-Geostationary Mobile-Satellite System in the 137-138, 148-150.05, and 400.15-401 MHz Frequency Bands*, 13 FCC RCD 10828 (1998) [hereinafter "Orbcomm Modification"].

[7] GE Starsys returned its license to the FCC in August 1997.

Iridium, LLC of Washington, D.C. has completed deployment of its 66-satellite constellation and began operation in November 1998. Orbital Communications Corporation ("Orbcomm"), of Dulles, Virginia, has deployed its original 28-satellite constellation and is fully operational. Globalstar is in the midst of deployment. Other prospective constellation operators are in various stages of design, construction, and financing. Note that the FCC generally requires satellite licensees to begin satellite construction within one year of receiving a license. The FCC considers a licensee to have begun construction when the licensee executes a non-contingent satellite construction contract.[8] Additional milestone requirements for construction completion and launching apply as well. Failure to meet the milestone renders the licensee "null and void," unless the FCC grants an extension.

The information in the above table is based on the FCC license orders and applications filed at the FCC but does not necessarily reflect current company plans. For example, Teledesic Corporation has modified its constellation to include only 288 satellites.[9] Motorola will operate at 780 km not 775 km.

1.2 Debris Mitigation Measures

The FCC does not assign orbital altitudes for MEO/LEO constellations and, so far, it has licensed MEO/LEO constellations without coordinating the orbital altitudes selected by the licensees. As a result, several constellations have been licensed in close orbital proximity, given the fact that certain orbital regions are particularly attractive for MEO/LEO constellations. This was the case, e.g., for Motorola and Orbcomm, whose systems both were licensed at 775 km. The companies have since adjusted the altitudes for their constellations. Motorola's Iridium will now be operating at 780 km and Orbcomm will be at 825 km.[10] Motorola and Orbcomm have negotiated a memorandum of understanding which provides for regular exchange of orbital trajectory information between the companies. The information will be used to monitor the probability of collision and will alert operators of both constellations in advance of upcoming close approaches.

Applications for MEO/LEO constellation now pending before the FCC show that several constellations are being planned at approximately the same orbital altitude. For example, M-Star, Celestri, Globalstar 2 GHz, Globalstar 40 GHz and Teledesic (Ka-band[11] and V-band) have proposed orbits around 1,400 km, and Lockheed Martin, @Contact, Hughes' Spaceway, Hughes' StarLynx, ICO, TRW have proposed systems at altitudes around 10,350 km. (See the table above). While it is true that some of these systems may be combined, especially those proposed by the same company, considerable coordination will be required between and among the operators if the systems are licensed as proposed.

The FCC also has not imposed post-mission requirements on MEO/LEO constellation operators, thus leaving it up to the individual operators to determine end-of-life disposal methods. (See Section 2.5.3 regarding proposed FCC satellite disposal guidelines). Currently, proposed end-of-life procedures vary greatly among the MEO/LEO constellation operators, depending upon the orbital altitude and the spacecraft characteristics. Motorola and Teledesic, for example, plan to re-orbit to lower altitudes their satellites at end-of-life. Loral/Qualcomm has announced plans to place satellites in a disposal, or "graveyard," orbit, possibly above its operational orbit of about 1,400 km. Orbcomm, whose satellites are extremely lightweight (about 50 kg at launch), will rely on atmospheric drag and natural orbit decay. The

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8 *Norris Satellite Communications, Inc.*, Memorandum Opinion and Order, 12 FCC RCD 22299, ¶ 9 n.26 (1997).

9 The FCC licensed Teledesic's original constellation of 840 satellites at an orbit of 700 km. *See* Teledesic Authorization, *supra* note 4. In 1999, the FCC approved Teledesic's request for an orbit at 1375 km and a constellation of 288 satellites. *See In the Matter of Teledesic LLC for Minor Modification of License to Construct, Launch and Operate a Non-Geostationary Fixed Satellite Service*, Order and Authorization, DA 99-267 (Jan. 29, 1999) [hereinafter "Teledesic Modification"].

10 *See* Orbcomm Modification, *supra* note 8.

orbital decay will be accelerated by placing the Orbcomm satellite in a maximum drag configuration which increases the drag efficiency by a factor of four.

Motorola reports that it is planning the following procedure: When a satellite reaches end-of-life, the satellite (which is deployed at 780 km) will 1) lower itself, through the use of hydrazine propulsion, out of the constellation by 10 km (both perigee and apogee); and then 2) complete a series of perigee-lowering burns until no fuel is left. The satellite perigee will then be at 250 km and the apogee at 770 km. From this orbital position, it will take about one year for the orbit to decay and for the satellite to reenter the atmosphere and burn up. The nominal life of the Iridium satellites is five years. End-of-life is reached when the satellite is no longer capable of operation or when the satellite only has enough fuel to complete the described re-orbit maneuvers.

Teledesic reports it will employ similar procedures to those proposed by Motorola. The company will begin re-orbiting to lower altitudes when a satellite is unable to maintain a sufficiently high quality of service or when the remaining propellant is capable only of performing a re-orbit perigee lowering procedure. To accomplish these lowering maneuvers, Teledesic will use a low thrust propulsion system based on the inert gas Xenon stored in a metal-lined, composite overwrapped pressure vessel with debris shielding.

2 U.S. Laws, Policies, and Regulations

2.1 Congressional Legislation

Relatively little exists today in the way of Congressional legislation on orbital debris. Over the years, Congress has made modest attempts to address the debris problem, primarily by way of Congressional findings expressed in National Aeronautics and Space Administration ("NASA") authorizing legislation. This legislation has encouraged efforts already underway at NASA and the Department of Defense ("DoD") to adopt policies for orbital debris mitigation – in NASA's case even extensive guidelines. Although, its impact is only now beginning to register for commercial space operations, as some Federal regulatory agencies are proposing rules designed to minimize debris. The following provision found in the NASA Authorization Act for FY 1993 typifies Congressional legislation on orbital debris. It provides that

> a vigorous and coordinated effort by the United States and other spacefaring nations is needed to minimize the growth of orbital debris, and space activities should be conducted in a manner that minimizes the likelihood of additional orbital debris creation.[12]

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11 *See* Teledesic Modification, *supra* note 11.

12 *National Aeronautics and Space Administration Authorization Act, Fiscal Year 1993*, Pub. L. No. 102-588, § 101(10) (1992). *Compare National Aeronautics and Space Administration Authorization Act, Fiscal Year 1991*, Pub. L. No. 101-611, § 118 (1990), which expressed that

> [i]t is the sense of Congress that the goal of the United States policy should be that 1) the space related activities of the United States should be conducted in a manner that does not increase the amount of orbital debris; and 2) the United States should engage other spacefaring Nations to develop an agreement on the conduct of space activities that ensures that the amount of orbital debris is not increased.

Id., § 188(b). *See also* National Space Policy Directive-1 (NSPD-1), which called on agencies to "seek to minimize the creation of space debris." OSTP Report, *supra* note 2, at 27. Further, NSPD-1 ordered that "[d]esign and operation of space tests, experiments and systems will strive to minimize or reduce accumulation of space debris consistent with mission requirements and

The NASA Authorization Act for Fiscal Years 1994 and 1995 represents the boldest Congressional attempt yet to address the debris problem. The legislation called upon the White House's Office of Science and Technology Policy ("OSTP") to submit within one year "a plan . . . for the control of orbital debris."[13] The plan was to be developed in coordination with NASA, the Department of Defense, the Department of State, and other pertinent agencies, and was to include "proposed launch vehicle and spacecraft design standards and operational procedures to minimize the creation of new debris."[14] In addition, the plan was to "propose a schedule for incorporation of the standards into all United States civil, military, and commercial space activities."[15] The plan also was to "include a schedule for the development of an international agreement on the control of orbital debris."[16]

2.2 White House Policy Initiatives

2.2.1 Interagency Policy Coordination

Responding to the Congressional call for a plan to address orbital debris, OSTP, in its 1995 report entitled "Interagency Report on Orbital Debris,"[17] recommended that the government (specifically DoD and NASA) create draft guidelines for debris minimization and invite industry to aid in the final drafting.[18] OSTP further recommended that:

> NASA, with the participation of DoD, [the Department of Transportation ("DOT"), the Department of Commerce ("DOC")], and other relevant federal agencies . . . convene a workshop with U.S. industry on debris mitigation and LEO systems. The workshop should serve as a first step in identifying possible measures for debris mitigation that LEO operators could incorporate in the design of future systems. The workshop could also identify possible mitigation measures for launch vehicle operators contemplating service for LEO systems.[19]

Accordingly, on January 27, 1998, OSTP convened a workshop entitled "U.S. Government Orbital Debris Workshop for Industry" in Houston, Texas. The purpose of the workshop was to provide industry a more complete understanding of a set of debris mitigation guidelines developed by NASA and DoD and, to the extent possible, reach a consensus on such guidelines as voluntary debris mitigation measures. The following guidelines[20] provided the baseline for discussions during the Workshop:

1. <u>Control of Debris Released During Normal Operations:</u> Programs and projects will assess and limit the amount of debris released in a planned manner during normal operations.
In all operational orbit regimes: Spacecraft and upper stages should be designed

cost effectiveness." *Id.*

13 *National Aeronautics and Space Administration Authorization Act, Fiscal Years 1994 and 1995*, H.R. 2200, 103d Cong. § 309 (1993). The bill was passed by the full House but not by the Senate.

14 *Id.* Emphasis added. For reasons unrelated to these provisions, the NASA Authorization Act for FYs 1994 and 1995 was never enacted into law.

15 *Id.*

16 *Id.*

17 OSTP Report, *supra* note 2.

18 *Id.*, at 56.

19 *Id.*

to eliminate or minimize debris released during normal operations. Each instance of planned release of debris larger than 5 mm in any dimension that remains on orbit for more than 25 years should be evaluated and justified on the basis of cost effectiveness and mission requirements.

2. Minimizing Debris Generated by Accidental Explosions: Programs and projects will assess and limit the probability of accidental explosion during and after completion of mission operations.

Limiting the risk to other space systems from accidental explosions during mission operations: In developing the design of a spacecraft or upper stage, each program, via failure mode and effect analyses or equivalent analyses, should demonstrate either that there is no credible failure mode for accidental explosion, or, if such credible failure modes exist, design or operational procedures will limit the probability of the occurrence of such failure modes.

Limiting the risk to other space systems from accidental explosions after completion of mission operations: All on-board sources of stored energy of a spacecraft or upper stage should be depleted or safed when they are no longer required for mission operations or postmission disposal. Depletion should occur as soon as such an operation does not pose an unacceptable risk to the payload. Propellant depletion burns and compressed gas releases should be designed to minimize the probability of subsequent accidental collision and to minimize the impact of a subsequent accidental explosion.

3. Selection of Safe Flight Profile and Operational Configuration: Programs and projects will assess and limit the probability of operating space systems becoming a source of debris by collisions with man-made objects or meteoroids.

Collision with large objects during orbital lifetime: In developing the design and mission profile for a spacecraft or upper stage, a program will estimate and limit the probability of collision with known objects during orbital lifetime.

Collision with small debris during mission operations: Spacecraft designs will consider and, consistent with cost effectiveness, limit probability that collisions with debris smaller than 1 cm diameter will cause loss of control to prevent post-mission disposal.

Tether systems will be uniquely analyzed for both intact and severed conditions.

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[20] U.S. Government Orbital Debris Workshop for Industry Materials, Tab 1, *DRAFT U.S. Government/Industry Orbital Debris Mitigation Practices* (Dec. 1997).

4. Postmission Disposal of Space Structures: Programs and projects will plan for, consistent with mission requirements, cost effective disposal procedures for launch vehicle components, upper stages, spacecraft, and other payloads at the end of mission life to minimize impact on future space operations.

Disposal for final mission orbits: A spacecraft or upper stage may be disposed of by one of three methods:

a. Atmospheric reentry option: Leave the structure in an orbit in which, using conservative projections for solar activity, atmospheric drag will limit the lifetime to no longer than 25 years after completion of mission. If drag enhancement devices are to be used to reduce the orbit lifetime, it should be demonstrated that such devices will significantly reduce the area-time product of the system or will not cause spacecraft or large debris to fragment if a collision occurs while the system is decaying from orbit. If a space structure is to be disposed of by reentry into the Earth's atmosphere, either the total debris casualty area for components and structural fragments surviving reentry will not exceed 8 m^2, or it will be confined to a broad ocean or essentially unpopulated area.

b. Maneuvering to a storage orbit: At end of life the structure may be relocated to one of the following storage regimes:

I. Between LEO and MEO: Maneuver to an orbit with perigee altitude above 2000 km and apogee altitude below 19,700 km (500 km below semi-synchronous altitude)

II. Between MEO and [Geostationary ("GEO")]: Maneuver to an orbit with perigee altitude above 20,700 km and apogee altitude below 35,300 km (approximately 500 km above semi-synchronous altitude and 500 km below synchronous altitude)

III. Above GEO: Maneuver to an orbit with perigee altitude above 36,100 km (approximately 300 km above synchronous altitude)

IV. Heliocentric, Earth-escape: Maneuver to remove the structure from Earth orbit, into a heliocentric orbit.

Because of fuel gauging uncertainties near the end of mission, a program should use a maneuver strategy that reduces the risk of leaving the structure near an operational orbit regime.

c. Direct retrieval: Retrieve the structure and remove it from orbit as soon as practical after completion of mission.

Tether systems will be uniquely analyzed for both intact and severed conditions performing trade-offs between alternative disposal strategies.

During the Workshop, industry expressed concerns with the vague and general, non-mandatory formulation of the guidelines. It was the consensus of the Industry representatives that minimum debris mitigation standards for both launch vehicles and satellites should be developed and applied on a mandatory basis, keeping in mind that it is imperative that key terms in the guidelines be precise and carefully defined. Industry also expressed concern about the effect of the guidelines on its ability to compete internationally.

At the conclusion of the Workshop, the parties agreed that NASA and DoD would reconsider the guidelines in light of industry's input and modify the guidelines accordingly. This process is still ongoing.

2.2.2 National Policy on Orbital Debris

The current *National Space Policy*, which encourages debris mitigation, was adopted on September 19, 1996. It updated the 1989 *National Space Policy*.[21] The policy states that

> [t]he United States will seek to minimize the creation of space debris. NASA, the Intelligence Community, and DoD, in cooperation with the private sector, will develop design guidelines for future government procurements of spacecraft, launch vehicles, and services. The design and operation of space tests, experiments and systems, will minimize or reduce accumulation of space debris consistent with mission requirements and cost effectiveness.
>
> It is in the interest of the United States government to ensure that space debris minimization practices are applied by other spacefaring nations and international organizations. The U.S. government will take the leadership role in international for a to adopt policies and practices aimed at debris minimization and will cooperate internationally in the exchange of information on debris research and the identification of debris mitigation options.[22]

2.3 NASA Policy

Responding to a heightened orbital debris concern in its manned and other space programs, NASA in 1993 adopted Management Instruction 1700.8, entitled "Policy Limiting Orbital Debris,"[23] which encouraged "design and operations practices that limit the generation of orbital debris, consistent with mission requirements and cost-effectiveness."[24] This policy was further clarified in the 1997 NASA Policy Directive, entitled "NASA Policy for Limiting Orbital Debris Generation,"[25] which replaces the Management Instruction. It provides that it is NASA policy to:

> Employ design and operation practices that limit the generation of orbital debris, consistent with mission requirements and cost-effectiveness;
>
> Conduct a formal assessment in accordance with [the NASA Guidelines], on each NASA program/project, of debris generation potential and debris mitigation options, including design options. As a minimum, the assessment should address the following: l) The potential for orbital debris generation in both nominal operation and malfunction conditions; 2) The potential for

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21 *Id.,* at 57. This 1989 National Space Policy, promulgated by the Executive Office of the President, simply stated that "[a]ll space sectors will seek to minimize the creation of space debris [and the] United States government will encourage other space-faring nations to adopt policies and practices aimed at debris minimization." *National Space Policy*, issued Nov. 2, 1989, at 4.

22 *U.S. Policy on Foreign Access to Remote Sensing Space Capabilities*, Fact Sheet (Mar. 10, 1994)

23 NASA Management Instruction, *supra* note 2.

24 *Id.,* at ¶ 3.

25 NASA POLICY DIRECTIVE 8710.3, *NASA Policy for Limiting Orbital Debris Generation*, NPD 8710.3 (1997) [hereinafter "NASA

orbital debris generation due to on-orbit impact with existing space debris (natural or human generated) or other orbiting space systems; and 3) Postmission disposal; and
Establish and implement additional debris mitigation measures when the assessed debris contributions are not considered acceptable.[26]

Pursuant to this policy, NASA has established a set of guidelines for assessing the debris impact of NASA space operations ("NASA Guidelines").[27] The guidelines require NASA program managers to evaluate the debris impact of their programs in the following situations: 1) Normal Operations; 2) Accidental Explosions or Intentional Breakups; 3) On-Orbit Collisions; 4) Postmission Disposal; and 5) Uncontrolled Reentry. The guidelines provide as follows:

1. <u>Control of Debris Released During Normal Operations:</u> NASA programs and projects will assess and limit the amount of debris released in a planned manner during normal operations.

Operational debris passing through LEO: For operations leaving debris in orbits passing through LEO, the total amount of debris of diameter 1 mm and larger released should satisfy two conditions:

a. All debris released during the deployment and operation of the mission should be limited to a maximum orbital lifetime of 25 years.

b. The total object-time product should be no larger than 100 object-years per mission. The object-time product is the sum over all operational debris of the total time spent below 2000 km altitude during the orbit lifetime of each debris object.

Operational debris passing through GEO: For operations leaving debris in orbits passing within 300 km GEO altitude and latitude, debris of diameter greater than 5 cm should be left in orbit only if its apogee altitude will be no higher than 300 km below GEO altitude within 25 years.[28]

2. <u>Control of Debris Generated by Explosions and Intentional Breakups</u>

2.1. <u>Control of Debris Generated by Accidental Explosions:</u> NASA programs and projects will assess and limit the probability of accidental explosion during and after completion of mission operations.

Limiting the risk to other space systems from accidental explosions during mission operations: In developing the design of a spacecraft or upper stage, each program, via failure mode and effects analyses or equivalent analyses,

Policy Directive"].

26 *Id.*, at § 1.

27 *Guidelines and Assessment Procedures for Limiting Orbital Debris*, NASA SAFETY STANDARD, NSS 1740.14, On-line version (last updated Aug. 10, 1998) <http://sn-callisto.jsc.nasa.gov/mitigate/ nss1740/1740_14_index.html>.

28 *Id.*, § 3, Guidelines 3-1–3-2.

should demonstrate either that there is no credible failure mode for accidental explosion; or, if such credible failure modes exist, design or operational procedures, as are reasonable and cost-effective, should limit the probability of the occurrence of such failure modes.

Note: As a quantitative reference, when the probability of accidental explosion can be estimated to be less than 0.0001, the intent of the guidelines has been met.

Limiting the risk to other space systems from accidental explosions after completion of mission operations: All on-board sources of stored energy should be depleted when they are no longer required for mission operations or postmission disposal. Depletion should occur as soon as such an operation does not pose an unacceptable risk to the payload. In LEO propellant depletion burns should be designed to reduce the orbital lifetime of the vehicle to the maximum extent possible.

2.2. Control of Debris Generated by Intentional Breakups: NASA programs and projects will assess and limit the effect of intentional breakups on other users of space.

Limiting the long-term risk to other space systems from planned tests: Planned test explosions or intentional collisions should be conducted at an altitude such that for debris fragments larger than 10 cm the object-time product does not exceed 100 object-years. No debris larger than 1 mm should remain in orbit longer than 1 year.

Limiting the short-term risk to other space systems from planned tests: Immediately before a planned test explosion or intentional collision, the probability of debris larger than 1 mm colliding with any operating spacecraft within 24 hours of the breakup should be verified to not exceed 10-6.[29]

3. Limit the Generation of Orbital Debris From On-orbit Collisions: NASA programs and projects will assess and limit the probability of operating space systems becoming a source of debris by collisions with man-made debris or meteoroids.

Collision with large objects during orbital lifetime: In developing the design and mission profile for a spacecraft or upper stage, a program should estimate and evaluate the probability of collision with another large object during the orbit lifetime.

Note: As a quantitative reference, when the probability of collision with large objects is on the order of or less than 0.001, the intent of the guideline has been met.

Collision with small debris during mission operations: In developing the design of a spacecraft or upper stage, a program should estimate and limit the probability of collisions with small debris of size sufficient to cause loss of control

[29] *Id.*, § 4, Guidelines 4-1–4-4.

to prevent postmission disposal.

Note: As a quantitative reference, when the probability of collision with debris leading to loss of control or inability to conduct postmission disposal is on the order of 0.01 or less, the intent of the guideline has been met.[30]

4. Postmission Disposal of Space Structures: NASA programs and projects will plan for the disposal of launch vehicles, upper stages, payloads, and other spacecraft at the end of mission life. Postmission disposal will be used to remove objects from orbit in a timely manner or to maneuver to a disposal orbit where the structure will not affect future space operations.

Disposal for final mission orbits passing through LEO: A spacecraft or upper stage with perigee altitude below 2000 km in its final mission orbit should be disposed of by one of three methods:

a. Atmospheric reentry option: Leave the structure in an orbit in which, using conservative projections for solar activity, atmospheric drag will limit the lifetime to no longer than 25 years after completion of mission. If drag enhancement devices are to be used to reduce the orbit lifetime, it should be demonstrated that such devices will significantly reduce the area-time product of the system or will not cause spacecraft or large debris to fragment if a collision occurs while the system is decaying from orbit.

b. Maneuvering to a storage orbit between LEO and GEO: Maneuver to an orbit with perigee altitude above 2500 km and apogee altitude below 35,288 km (500 km below GEO altitude).

c. Direct retrieval: Retrieve the structure and remove it from orbit within 10 years after completion of mission.

Disposal for final mission orbits with perigee altitudes above LEO: A spacecraft or upper stage with perigee altitude above 2000 km in its final mission orbit should be disposed of by either of two methods:

a. Maneuvering to a storage orbit above GEO altitude: Maneuver to an orbit with a perigee altitude above the GEO altitude by a distance of at least 300 km + [1,000 x average cross-sectional area (m^2) / mass (kg)] km.

A program should use the postmission disposal strategy that has the least risk of leaving the vehicle near GEO in the event of a failure during the disposal process. Because of fuel gauging uncertainties near the end of mission, it is suggested that the maneuver be performed in a series of at least four burns which alternately raise apogee and then perigee.

b. Maneuvering to a storage orbit between LEO and GEO: Maneuver to an orbit with perigee altitude above 2500 km and apogee altitude below 35,288 km (500 km below GEO altitude).

30 *Id.*, § 5, Guideline 5-1–5-2.

Reliability of postmission disposal operations: In developing the design of a spacecraft or upper stage, a program should identify and limit all credible failure modes that could prevent successful postmission disposal.

Note: As a quantitative reference, when the probability of successfully performing the postmission disposal maneuver can be estimated to be 0.99 or greater, the intent of the guidelines has been met.[31]

5. <u>Limiting the Risk From Debris Surviving Uncontrolled Reentry</u>: NASA programs and projects that use atmospheric reentry as a means to remove space structures from orbit at the end of mission life should limit the amount of debris that can survive uncontrolled reentry. If there is a significant amount of debris surviving uncontrolled reentry, measures will be taken to reduce the risk by establishing procedures or designs to reduce the amount of debris reaching the Earth's surface or to control the location of the ground footprint.

Limit the risk of human casualty: If a space structure is to be disposed of by uncontrolled reentry into the Earth's atmosphere, the total debris casualty area for components and structural fragments surviving reentry should not exceed 8 m^2. The total debris casualty area is a function of the number and size of components surviving reentry and of the average size of a standing individual.[32]

The policy applies to NASA Headquarters and all NASA Centers.[33] "Orbital debris" is defined as

Payloads that can no longer perform their mission;

Rocket bodies and other hardware (e.g., bolt fragments and covers) left in orbit as a result of normal launch and operational activities;

Fragmentation debris produced by failure or collision. (Gases and liquids in free state are not considered orbital debris).[34]

2.4 Department of Defense Policy

The Department of Defense, in its February 1987 Space Policy, declared that it would "seek to minimize the creation of space debris in its military operations. Design and operations of space tests, experiments and systems will strive to minimize or reduce debris consistent with mission

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31 *Id.*, § 6, Guidelines 6-1–6-3.

32 *Id.*, § 7, Guideline 7-1.

33 NASA Policy Directive, *supra* note 27, at § 2. NASA also addresses orbital debris generated by its activities when conducting environmental assessments of its missions. For example, NASA in a recent environmental assessment provided that the "Stardust Project will follow the NASA guidelines regarding orbital debris and minimizing the risk of uncontrolled reentry into the Earth's atmosphere." *National Environmental Policy Act; Stardust mission*, Notice, 63 Fed. Reg. 25236, 25237 (May 7, 1998).

34 NASA Policy Directive, *supra* note 27, at § 2.

requirements."[35] The U.S. Space Command ("USSPACECOM") and the Air Force, along with other defense agencies have taken steps to implement this policy.

In 1991, the USSPACECOM issued a regulation to implement the 1987 DoD Space Policy.[36] The regulation provided that "[t]he design and documentation process for space system development, modification, or upgrade will permit clear identification of cost, schedule, and performance impacts of efforts to mitigate debris."[37] This regulation was superseded by a 1998 Instruction entitled, *Minimization and Mitigation of Space Debris* ("Instruction").[38] The Instruction establishes USSPACECOM "policy and guidance for minimizing and mitigating the proliferation and effects of space debris on military space systems."[39] The objective of the Instruction "is to safeguard space systems under USSPACECOM authority from the hazards of space debris (mitigation) and to constrain the space debris hazard that launch, operations, and end of life disposals can cause to other manmade objects in Earth orbit (minimization)."[40] The Instruction directs Service space commands to "establish processes and procedures as appropriate for adherence to space debris minimization/mitigation requirements" subject to the review and approval of USSPACECOM.[41]

The Instruction provides the following guidelines for the operation, development, and conception of current and future space systems:

> USSPACECOM fosters and participates in activities to improve understanding of the risk that space debris imposes on military, civil, and commercial space activities.
>
> Component space commands foster and maintain a high level of awareness of the requirement to minimize/mitigate space debris. They monitor space debris minimization/ mitigation efforts of their corresponding acquisition organizations and, within their authority, assure that minimization/mitigation of space debris is addressed explicitly in all space systems requirements, developments, and tests.
>
> Component space commands ensure that the design and documentation process for space system development, modification, or upgrade will permit clear identification of cost, schedule, and performance impacts of efforts to minimize/mitigate debris. System development or modification tradeoffs are reviewed and approved by the affected service component space commands and coordinated with USSPACECOM [Director of Operations (J3)/Director of Plans (J5)]. Provide to USSPACECOM sufficient information to assess the adequacy of space debris minimization and mitigation measures proposed for individual space systems and operations.
>
> Component space commands ensure the concept of operations (CONOPS) of

35 Department of Defense Space Policy (Feb. 1987).

36 USSPACECOM Regulation 57-2, *Minimization and Mitigation of Space Debris* (Jun. 6, 1991).

37 *Id.*, at ¶ 2.c. The Regulation also called upon U.S. Space Command to "foster activities to better understand the evolution of space debris and the hazards of orbital debris," while "[c]omponent space commands shall increase awareness of the requirement to mitigate space debris." *Id.*, at ¶ 2.a-b.

38 *Minimization and Mitigation of Space Debris*, USSPACECOM Instruction 13-4 (May 1, 1998) [hereinafter "USSPACECOM Instruction"].

39 *Id.*, at 1. The instruction applies to USSPACECOM headquarters and "Component Service Commands and their mission systems and operations placed in service on orbit after 1 May 1998." *Id.*

40 *Id.*

41 *Id.*, ¶ 3.

> space systems on development or upgrade includes space debris minimization/mitigation controls and operations. These CONOPS are coordinated with USSPACECOM/J3/J5.
>
> The Directorate of Analysis assesses the technical aspects of proposed space debris minimization and mitigation procedures, including confirming projections of the debris environment, assessments of projected damage, or tradeoffs among minimization/ mitigation, cost, and mission capability
>
> USSPACECOM and component space commands will strive to implement the objectives and guidelines as outlined in the Joint DoD/NASA Guidelines on Orbital Debris Mitigation Practices in accordance with cost effectiveness and mission requirements.[42]

On November 3, 1997, USSPACECOM issued a policy directive which establishes end-of-life procedures for DoD-owned satellites ("USSPACECOM Policy").[43] The policy is applicable to all satellites over which the Commander in Chief, U.S. Space Command exercises "Combatant Command authority."[44] The policy emphasizes safing as the paramount end-of-life mitigation measure.[45] It further provides that "removing a non-mission capable satellite from its operational orbit into an established disposal region is of paramount importance."[46] Satellites "designated for disposal will be placed in a position (slot/plan/orbit) of non-interference with existing systems."[47] Consideration will be given to "orbit contamination, radio frequency interference, and future constellation development."[48] The following guidelines apply to disposal of satellites:

> Properly safing the bus and all payloads is a critical step in the disposal process. All spacecraft fuel will be depleted to the maximum extent possible, all spacecraft battery charging systems will be disabled, the spacecraft will be stabilized in a neutral thermal flight mode (slow spin for most), and, when appropriate, transmitters will be disabled. Safing of the satellite takes precedence over all other disposal actions.
>
> Remove non-mission capable vehicles from operational orbits in accordance with the following guidelines in paragraphs 5.3.2.1-5.3.2.3. Disposal of vehicles approaching the end of their operational life will be recommended if further degradation precludes future removal from operational orbits:
>
> Low Earth Orbit (LEO) (160 to 1,600 km): The Defense Meteorological Satellite Program (DMSP) is the only USSPACECOM [Combatant Command] system currently in this region. These satellites do not have the capability to be repositioned for disposal due to the nature of the spacecraft and their orbit. However, the goal for future weather satellites is to move spent payloads to near circular orbits under 650 km to allow for natural orbit decay in 25 years or less.
>
> Medium Earth Orbit (MEO) (1,600 km to 35,896 km): The Global Positioning

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[42] *Id.*, ¶¶ 3.1–3.6.

[43] *Satellite Disposal Procedures*, USSPACECOM Policy Directive UPD10-39 (Nov. 3, 1997).

[44] *Id.*, ¶ 1.

[45] *Id.*, ¶ 5.3.1.

[46] *Id.*, ¶ 4.1.

[47] *Id.*, ¶ 5.3.

> System is the only USSPACECOM [Combatant Command] system currently in this region. The constellation is deployed around a semi-synchronous orbit of approximately 20,185 km. For disposal, boost the satellite to an orbit with perigee above 20,685 km and apogee below 35,396 km. Disposal orbits will be as circular as possible.
>
> Geosynchronous Orbit (GEO) (approximately 35,896 km):[49] The DSCS, FLTSAT, UFO, Milstar, and DSP constellations are the only USSPACECOM [Combatant Command] systems currently in this region. The constellations are deployed around a geosynchronous orbit of 35,896 km. For disposal, boost at least 300 km to an orbit with a perigee above 36,196 km. Disposal orbit will be as circular as possible.[50]

The Air Force requires its programs to comply with DoD and USSPACECOM orbital debris mitigation policy. For example, the Air Force implemented this requirement in its Evolved Expendable Launch Vehicle ("EELV") program. The EELV Request for Proposal provides that

> EELV shall comply with National, DoD and USSPACECOM orbital debris minimization policies to minimize residual orbital debris after launch. The [launch vehicle] stages which are orbital shall be safely deorbited *whenever practical*. Stages and/or components shall be designed to minimize their break-up characteristics due to explosions, hypervelocity collisions, and the effects of space environment. Where practical, EELV shall incorporate space debris minimization features. Pressurized components shall be vented and otherwise designed to minimize the likelihood of explosion if not deorbited.[51]

2.5 Federal Agency Regulation of Orbital Debris From Commercial Space Operations

2.5.1 The Federal Aviation Administration

The Federal Aviation Administration ("FAA") regulates launches of commercial launch vehicles pursuant to the Commercial Space Launch Act of 1984, as amended.[52] The act charges the FAA with "protect[ing] the public health and safety [and] safety of property" from risks associated with commercial

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48 *Id.*

49 Geostationary orbit altitude generally is 35,786 km.

50 *Id.*, ¶¶ 5.3.1–5.3.2.3.

51 EELV, Development and Initial Launch Services, Request for Proposal, RFP F04701-97-R-0008, Annex 11 – System Performance Requirements for Launch Services (Jun. 18, 1998 update), at § 3.1.10.1 (emphasis in original); *Id.*, Annex 6 – System Performance Requirements for Development, at § 3.1.12.1.

52 49 U.S.C. §§ 70101 *et seq.* (1994). *See also* FAA Commercial Space Transportation Rules, 14 C.F.R. Ch. III (1998) (implementing the Commercial Space Launch Act). Through Executive Order 12465, the Secretary of Transportation was charged with regulating commercial launch operations. 49 Fed. Reg. 7211 (1984). The Commercial Space Launch Act codified DOT's authority to license and regulate commercial launch operations. 49 U.S.C. § 70103. DOT established the Office of Commercial Space Transportation (OCST) to carry out these responsibilities under delegated authority. *See Organization and Delegation of Powers and Duties: Commercial Space Launch Act,* Final Rule, 50 Fed. Reg. 9036 (Mar. 6, 1985) (providing for delegation of DOT's responsibilities to OCST). Effective November 15, 1995, the authority for licensing and regulation of commercial space launches was redelegated to the Administrator of the FAA, who in turn delegated the authority to the Associate Administrator for Commercial Space Transportation. *See Organization and Delegation of Powers and Duties: Transfer of Delegations from the Director of Commercial Space Transportation to the Administrator of the Federal Aviation Administration,* Final Rule, 60 Fed. Reg. 62762 (Dec. 7, 1995) (providing for the transfer of OCST's responsibilities to the Federal Aviation Administration).

launches.[53] The agency will grant a license to launch a launch vehicle when it determines that the launch is "[c]onsistent with the public health and safety, safety of property, and national security and foreign policy interests of the United States . . . ."[54]

Pursuant to its authority to ensure that launch operations do not jeopardize the safety of persons and property, the FAA is proposing to restrict the generation of orbital debris from commercial launch operations. In March 1997, the FAA adopted a Notice of Proposed Rulemaking ("NPRM")[55] proposing new rules that essentially would codify existing debris mitigation practices among mature launch vehicle operators, including fuel depletion and venting of upper stages.[56] By this action, the FAA became the first Federal regulatory agency to address formally the debris issue. The FAA explained the underlying rationale as follows:

> Those involved in commercial, defense, and scientific uses of space are voicing a growing space safety concern due to the increasing number of objects being placed in orbit, which increases the potential for collisions between objects in space. Collisions in turn create additional space debris. The operation of launch vehicles in space affects and is affected by hazards associated with space debris. Accordingly, the office proposes . . . requirements . . . to mitigate hazards associated with space debris.[57]

The NPRM proposes rules which would require commercial launch vehicle operators to design and operate their vehicles in a manner which ensures that there is "no unplanned physical contact between the vehicle and its components and the payload after payload separation . . . ."[58] Furthermore, launch licensees must ensure that "[d]ebris generation will not result from conversion of energy sources into energy that fragments the vehicle or its components."[59] Energy sources include chemical (e.g., fuel), pressure (e.g., pneumatic), and kinetic (e.g., gyroscopes) energy."[60] In other words, launch operators must take care to prevent explosion and breakup of upper stages. Such explosions can occur if excess fuel is left in the spent rocket stage and overpressurization occurs as a result. Venting of fuel and fuel depletion are common methods used by launch vehicle operators today to alleviate the problem.

The FAA's regulatory authority over *payloads* is limited, however. The FAA has no licensing or regulatory authority over FCC and DOC-licensed satellites.[61] Consequently, the FAA cannot regulate the orbits or prescribe disposal measures, for example, for FCC-licensed LEO constellations. However, it has limited oversight (but not licensing) powers over U.S. payloads that are not licensed by the FCC or DOC, as well as over foreign payloads launched on U.S. launch vehicles. With respect to these payloads, the FAA may "prevent the launch if [it] decides the launch would jeopardize the public health

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53 49 U.S.C. § 70102(b)(3).

54 *Id*. § 70105(a).

55 FAA, DOT, *Commercial Space Transportation Licensing Regulations*, Notice of Proposed Rulemaking, 62 Fed. Reg. 13216 (1997) [hereinafter "NPRM"].

56 The following procedures are typically used by mature launch vehicle providers: Launch vehicle operators carefully select trajectories to minimize collision during launch; they define separation procedures so to avoid interference with the satellite payload; they vent or deplete excess fuel from upper stages after deployment in order to minimize the risk of explosion and debris generation; and they take measures to accelerate the reentry of upper stages. Launch vehicle operators typically do not actively deorbit their upper stages at end of mission.

57 NPRM, at 13230.

58 *See* NPRM, at 13242 (proposing this language in 14 C.F.R. § 415.35(b)(1)). Proposed Rule § 415.37(a)-(b), would require that launch operators design and operate their launch vehicles in conformity with § 415.35. *Id.*, at 13243. Proposed Rule § 415.91 would impose the same requirements on operators launching from non-Federal ranges. *Id.*, at 13245.

59 NPRM, at 13243 (proposing this language in 14 C.F.R. § 415.35(b)(2)).

60 *Id.* (proposing this language in 14 C.F.R. § 415.35(b)(2)).

61 49 U.S.C. § 70117(b).

and safety [and] safety of property . . . ."[62] Under this authority, if the FAA determines that such a payload would result in debris propagation that jeopardizes safety of life and property, it has the power to deny the launch.

2.5.2 The Department of Commerce's National Oceanic and Atmospheric Administration

The Department of Commerce's National Oceanic and Atmospheric Administration ("NOAA") licenses and regulates remote sensing satellites pursuant to the Land Remote Sensing Policy Act of 1992.[63] Under the act, NOAA, by delegation, is charged with licensing and regulating commercial remote sensing satellites in a manner consistent with the national security, international obligations, and foreign policy interests of the United States.[64] The act requires that any licensee obtain approval by the President of the United States before disposing of a remote sensing satellite at end-of-mission.[65] It provides that remote sensing satellite licensees "upon termination of operations under the license make disposition of any satellites in space in a manner satisfactory to the President."[66] Currently, NOAA implements this statutory requirement in individual licenses to remote sensing satellite operators.[67]

In accordance with the statutory requirement for satellite disposal, on November 3, 1997, NOAA released an NPRM proposing the following new rule:

> A licensee shall dispose of any space platforms owned or operated by the licensee upon termination of operations under the license in a manner satisfactory to the President. The licensee shall obtain approval from [NOAA] of all plans and procedures for the disposition of such platforms, e.g. uncontrolled reentry, burn on reentry, or controlled deorbit, providing sufficient notification to allow determination that the proposed procedures will minimize orbital debris and not jeopardize safety.[68]

NOAA received approximately seventeen comments on the NPRM.[69] It has not issued the final rule, as it is preparing to issue a Further NPRM in the near future.[70]

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62 *Id.* § 70104(c). Note the use of the word "would," which requires a degree of certainty, as opposed to the term "could," which requires a possibility.

63 15 U.S.C. §§ 5601-5672 (1992). *See* NOAA, DOC, *Notice of Inquiry and Request for Public Comment,* 60 Fed. Reg. 62054 (1995) (inviting public comment issues underlying the regulations NOAA plans to adopt). Pending the adoption of new regulations, NOAA will continue to rely on the regulations which implemented the Land Remote Sensing Commercialization Act of 1984 (now repealed). *See* 15 C.F.R. Part 960 (1998).

64 15 U.S.C. §§ 5621-5625.

65 *Id.* § 5622(b)(4).

66 *Id.* The legislative history behind the act reveals that the drafters of this provision were concerned primarily with the possibility that nuclear-powered satellites might be used for remote sensing purposes and that these platforms be disposed of in a secure manner.

67 These licenses provide as follows:

> Upon termination of operations under the license, the Licensee will dispose of any satellite in space in a manner satisfactory to the President. To meet this condition and to deal with any circumstances involving the satellite's end of life/termination of mission, the licensee shall obtain *a priori* U.S. Government approval of all plans and procedures to deal with the safe disposition of the satellite (e.g., burn on reentry or controlled deorbit).

Lockheed Missiles & Space Company, License (Apr. 22, 1994), and GDE Systems Imaging, Inc., License (Jul. 14, 1995).

68 NOAA, DOC, *Licensing of Private Land Remote-Sensing Space Systems*, NPRM, 62 Fed. Reg. 59317 (Nov. 3, 1997).

69 Telephone conversation between Charles Wooldridge, NOAA, and Sean Fleming, Law Offices of Pamela Meredith (Mar. 9, 1999).

70 Telephone conversation between Karen Dacres, NOAA, and Sean Fleming, Law Offices of Pamela Meredith (Mar. 9, 1999).

2.5.3 The Federal Communications Commission

Today, the FCC licenses all types of communications satellites operated by U.S. entities pursuant to the Communications Act of 1934, as amended.[71] The act charges the FCC with "licensing and regulating of all radio stations"[72] consistent with the "public interest."[73] Prompted by applications for licenses to operate communications satellites in the late 1960's, the FCC determined in 1970 that it had the authority to license satellites since they are "radio stations" used for "communications by . . . radio."[74] The fact that a radio station happens to be in space, concluded the FCC, does not affect its regulatory powers.[75]

While the FCC has licensed dozens of geostationary ("GEO") satellites and at least one dozen MEO/LEO constellations, it has not to date imposed regulatory debris mitigation requirements on communications satellite operators. The FCC is taking an increasing interest in debris mitigation, however. It is currently considering whether to require satellite operators to follow certain debris mitigation guidelines. The FCC is using as a baseline for discussion the draft U.S. Government/Industry Orbital Debris Mitigation Practices, developed by NASA and DoD. (See Section 2.2.1 above). The FCC included the draft guidelines in a recent Notice of Proposed Rulemaking ("NPRM"), which proposes rules and policies for the licensing and operation of mobile satellite service ("MSS") systems in the 2 GHz frequency band.[76] The guidelines are as follows:

1. Control of Debris Released During Normal Operations: Programs and projects will assess and limit the amount of debris released in a planned manner during normal operations.

2. Minimizing Debris Generated by Accidental Explosions: Programs and projects will assess and limit the probability of accidental explosion during and after completion of mission operations.

3. Selection of Safe Flight Profile and Operational Configuration: Programs and projects will assess and limit the probability of operating space systems becoming a source of debris by collisions with man-made objects or meteoroids.

4. Postmission Disposal of Space Structures: Programs and projects will plan for, consistent with mission requirements, cost effective disposal procedures for launch vehicle components, upper stages, spacecraft, and other payloads at the end of mission life to minimize impact on future space operations.[77]

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71 47 U.S.C. §§ 151 *et. seq.* (1996). *See also* FCC Satellite Communications Rules, 47 C.F.R. Part 25 (1997) (implementing the Communications Act for satellite communications).

72 47 U.S.C. § 152(a). *See also id.* §§ 301, 303 (providing authority to control, license and regulate radio communications).

73 *Id.* §§ 303, 307, 309. The FCC was created in 1934 for the purpose of "regulating . . . communications by . . . radio so as to make available, so far as possible, to all people of the United States a rapid, efficient, Nation-wide and world-wide . . . radio communications service . . . ." *Id.* § 151.

74 22 F.C.C.2d 86 (1970) ("DOMSAT I"), Appx. C., entitled "Memorandum on Legal Issues."

75 *Id.*

76 *The Establishment of Policies and Service Rules for the Mobile Satellite Service in the 2 GHz Band*, Notice of Proposed Rulemaking, IB Docket No. 99-81 (Mar. 18, 1999) [hereinafter "2 GHz NPRM"].

77 *Id.*, ¶ 98.

While not specifically proposing in the NPRM to adopt the draft guidelines, the FCC seeks comment on "whether some or all of the elements of [the above-quoted guidelines] should be incorporated in the Commission's rules or authorization process for 2 GHz MSS systems."[78] In particular, the FCC seeks comment on whether it should "consider a rule requiring that 2 GHz MSS systems serving the United States adequately provide for end-of-life disposal of the spacecraft, including depletion or neutralization of sources of stored energy on the spacecraft [or should the FCC] require submission of narrative information concerning debris mitigation in connection with satellite system licensing."[79]

The FCC also seeks comment on "any transitional issues that may arise if new orbital debris mitigation requirements are adopted."[80] The FCC has tentatively concluded "that any new requirements should be applied only to systems that have not passed a stage at which such requirements reasonably can be incorporated into the design, construction, or operation of the system," as the FCC does not "wish to require expensive redesigns for systems already at an advanced stage of development."[81] Therefore, the FCC "seeks comment on what that stage may be."[82]

While the NPRM only addresses 2 GHz MSS satellite systems, the FCC in the NPRM recognizes that "debris mitigation practices are relevant to communications satellite systems operating at frequencies other than 2 GHz.[83] The FCC notes that it seeks comment on "debris mitigation practices in this proceeding in order to provide 2 GHz system proponents early notice concerning factors that may be relevant to any system modifications they may undertake, either resulting from technical rules adopted in this proceeding or technological developments in the marketplace."[84] However, the FCC also notes that "it is possible that any requirements concerning debris mitigation for 2 GHz MSS systems will not become final until the Commission has completed a separate proceeding that seeks comment from all interested parties on adopting debris mitigation practices applicable to all Commission-licensed satellite systems."[85]

So far, the FCC has queried satellite operators about satellite disposal plans without imposing specific requirements. It also has expressed concerns about orbital changes that might result in longer debris lifetimes. For example, when Orbcomm notified the FCC of a planned change in orbit for its Orbcomm constellation from 775 to 825 km, the FCC consulted NASA on the impact of debris lifetime of the new orbit.[86] With respect to the selection of operational orbits, the FCC has not formally acted on a 1995 request by Motorola to avoid licensing of constellations at the same or similar altitudes. Pointing out that new applicants for LEO satellite constellations were proposing to use orbits of "similar altitude to the IRIDIUM satellites," Motorola insisted that it is

> imperative that, in licensing any of the proposed little LEO systems, the Commission establish orbital parameters that avoid any risk of collision between the proposed LEO satellite systems and the already licensed [LEO satellite constellations].[87]

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78 *Id.*, ¶ 100. Prior to the adoption of the FCC's NPRM, the Committee discussed the following debris mitigation measures for MEO/LEO constellations: 1) Prolonging operational lives of constellation members; 2) Accelerating reentry; 3) Placing satellites in disposal orbit; 4) Limiting accidental explosions; 5) Limiting operational debris; 6) Shielding; 7) Designing satellites to incorporate anti-fragmentation devices; 8) Selecting orbit planning dates that use natural forces to de-boost; 9) Building active beacons into satellites for detection and collision avoidance; and 10) Using drag enhancers to increase cross-section area.

79 2 GHz NPRM, *supra* note 79, at ¶ 100.

80 *Id.*, ¶ 101.

81 *Id.*

82 *Id.*

83 *Id.*, ¶ 102.

84 *Id.*

85 *Id.*

86 Letter from William Kennard, Chairman, FCC to Daniel M. Goldin, Administrator, NASA (Dec. 31, 1997).

The debris mitigation guidelines currently under consideration by the FCC, concerning "Selection of Safe Flight Profile and Operational Configuration," to some extent address the point raised by Motorola.

There is no doubt that the FCC has the statutory authority to impose orbital debris mitigation requirements on communications satellite operators should it wish to do so. The FCC has explicit statutory authority to "[d]etermine the location of classes of [radio] stations or individual stations."[88] Accordingly, the FCC can specify the location of a satellite in space. It has consistently exercised this power over GEO satellites, by assigning specific orbital locations to satellite operators and by reserving the right to require satellite operators to move their satellites to a different location.[89] The regulation of orbital locations in GEO is motivated primarily by a concern for radio interference, and not physical impact. Since the same radio interference considerations are not present in MEO/LEO, the FCC has not used its locational jurisdiction to regulate the location of MEO/LEO constellations.

The FCC also has not used its locational jurisdiction to impose end-of-life disposal requirements on satellite operators, although it has the powers to do so.[90] Most U.S. GEO satellite operators voluntarily boost their satellites several hundred kilometers above the geostationary orbit at end-of-life[91] to avoid congestion in the geostationary orbit. Likewise, some prospective MEO/LEO satellite operators are proposing voluntary end-of-life measures,[92] see Part 2.2 above, such as graveyard orbits or deboosting, in order to clear the operational orbit and/or to accelerate reentry and reduce debris lifetime.

The FCC also has the authority under the Communications Act[93] to impose design requirements on the spacecraft it licenses in order to limit debris generation, such as, e.g., shielding and employment of drag devices, although the FCC has not traditionally imposed design requirements on satellites. The courts have recognized the FCC's regulatory powers over the physical characteristics of a radio station. For example, in *Deep South Broadcasting Co. v. FCC*,[94] a federal appeals court confirmed the FCC's authority to examine the structural aspect of a radio tower. In that case, the FCC determined that Deep

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87 *In the Matter of the Applications of CTA Commercial Systems*, Comments of Motorola Satellite Communications, Inc. (filed Feb. 24, 1995), at 3.

88 47 U.S.C. § 303(d). All applications for satellite licenses must specify the location of the proposed satellite(s). *Id*. § 308(b). *See also* 47 C.F.R. § 25.114(a)(6) (requiring applicants to specify the orbital location(s) of the proposed satellite).

89 *Id.* § 25.202(c).

90 The legislative history of the Communications Act, which created the FCC, characterized the agency as possessing "broad authority" over communications. H. REP. NO. 73-1850, at 1 *cited in Illinois Citizens Comm. for Broad. v. FCC*, 467 F.2d 1397, 1399 (7th Cir. 1972). Judicial opinions have underscored the need for a flexible construction of the FCC's power to enable it to respond to changing communications technology. *See, e.g., National Broad. Co. v. United States*, 319 U.S. 190, 63 S. Ct. 997, 87 L. Ed. 1344 (1943); *Buckeye Cablevision, Inc. v. FCC*, 387 F.2d 220, 225 (D.C. Cir. 1967); and *General Television Co. v. FCC*, 413 F.2d 390, 405 (D.C. Cir. 1967). Moreover, general principles of administrative law support the notion that an agency can regulate conditions which "may directly frustrate the success of the regulation undertaken by Congress." *American Trucking Ass'ns v. United States*, 344 U.S. 298, 311 (1953). Accordingly, if debris threatens to interfere with the establishment of a "rapid, efficient, Nation-wide and world-wide . . . radio communications service, which is the FCC's mandate, the FCC can regulate debris.

91 There are several methods available to GEO satellite operators for end-of-life disposal. They can, as mentioned in the text, transfer the satellite to a graveyard orbit above GEO, or boost the satellite out of Earth orbit entirely. AIAA Special Projects Report, *supra* note 1, at 20.

92 LEO satellite operators have the option of either using excess fuel for a de-orbit burn, thereby hastening reentry, or they may deploy a drag surface to the same affect. Further, but far more costly, the LEO satellite could be removed from orbit by manned or unmanned vehicles. *Id.*

93 47 U.S.C. § 319. A construction permit from the FCC is required in order to build a satellite. *Id.* The FCC has waived the requirement for a construction permit in satellite licensing proceedings. 47 C.F.R. § 25.113(f). *See also Streamlining the Commission's Rules and Regulations for Satellite Application and Licensing Procedures*, Report and Order, 11 FCC RCD 21581 (1996).

South Broadcasting Company had failed to show that it could build a structurally sound radio tower, and the company challenged the FCC's authority to make this decision. The court held that

> we reject appellant's challenge to the Commission's statutory authority to inquire into a tower's structural suitability. Aside from its authority to determine an applicant's technical competence to operate a television station, and to ascertain whether licensed installations conform to the Commission's construction regulations, the ability of licensee to build a tower which will be safe and will provide uninterrupted service is a clearly relevant public interest consideration.[95]

Applying this standard, the FCC presumably could impose design requirements on satellite structures in order to promote uninterrupted communications service, and reduce the likelihood of collision, breakup, and other debris generation which might impact communications.[96]

2.6 Contracts Between Private Parties

As Federal institutions increasingly adopt debris mitigation requirements, government and private contracts will begin to reflect them. Government contracts are already, see the discussion of the Air Force EELV Request for Proposal at Section 2.4, above. To date, private contracts have addressed the orbital debris problem to a very limited extent. For example, some satellite manufacturing contracts impose spacecraft design requirements on the spacecraft manufacturer intended to limit debris lifetime or reduce the likelihood of breakups.[97] Private contracts, however, generally cannot be relied upon to serve as primary vehicles for imposing debris mitigation requirements since contracts tend to be reactive rather than proactive. In other words, they generally respond to legislative or regulatory requirements and court decisions rather than generating requirements beyond what existing regulations mandate.

3 Conclusion

This overview of the current and emerging debris mitigation practices and legal authorities shows that the various agencies of the U.S. government are beginning to address the orbital debris problem. Clearly, most advanced in its development of debris mitigation standards is NASA. The various military agencies are following suit with more general policies and Federal agencies regulating commercial space

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94 278 F.2d 264 (D.C. Cir. 1960).

95 *Id.*, at 267.

96 The FCC's authority may also extend to preventing situations where certain satellite designs or operational procedures would severely impede space travel or the conduct of space operations by others. In *Simmons v. FCC,* the court found that the "public convenience, interest and necessity clearly require the Commission to deny applications for construction which would menace air navigation." 145 F.2d 578, 579 (D.C. Cir. 1944). The FCC had found that Mr. Simmons' proposed directional antenna array would present a hazard to air navigation and consequently had denied him a license. Examining the satellite's structural integrity is also well within the FCC's jurisdictional bounds as defined in *Illinois Citizens Committee for Broadcasting v. FCC*, 467 F.2d 1397 (7th Cir. 1972). Here, the court drew the outer boundary of the FCC's jurisdiction when it ruled that the Commission did not have authority to issue a cease and desist order against the construction of a tall office building which, it was alleged, would interfere with television reception in the area. The court held that the FCC's authority is "limited to situations in which the interference is created by . . . a 'signal generating' or 'signal-producing' facility." *Id.,* at 1400. The court rejected the petitioners' argument that "if the 'communications' are within the FCC's power to regulate, so are all activities which 'substantially affect communications,' in this case, the construction of a very tall office building." *Id.,* at 1399. The case arose out of a complaint by a group of citizens in 1972 that the construction of the Sears, Roebuck & Company office tower ("Sears Tower") would throw "multiple ghost images" on television receivers in many areas of the greater Chicago Metropolitan Area.

97 At present, satellite insurance policies generally do not distinguish between orbital debris and other perils in their coverage of satellites against loss or damage in space. This is the case because debris has not yet proven to be a major cause of accidents that warrants special consideration in insurance policies. Accordingly, "all risk" life insurance policies issued for satellites in orbit today generally cover debris along with other risks. That may change as debris-related damage becomes more prevalent.

operations are proposing rules to mitigate debris resulting from the operators they regulate. The FAA is taking a concrete step toward codifying current debris mitigation practices among mature launch service providers. The FCC is seeking comment on debris mitigation guidelines for one type of satellite system currently undergoing licensing and has alluded to the possibility of a future rulemaking on debris mitigation for all FCC-licensed satellite systems. Providing an overall U.S. policy focus for the orbital debris mitigation effort is the interagency process spearheaded by OSTP. That process has created a focus for action and prompted debris mitigation initiatives across government and commercial space sectors. The process also has served to ensure some measure of coordination and uniformity of debris mitigation standards. There is a growing realization in the space community that a primarily voluntary debris mitigation approach may not be adequate to protect the space environment for future governmental and commercial applications.

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ISBN 1-56347-351-8