

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of)
Space Exploration Holdings, LLC) IBFS File No. SAT-MOD-20181108-00083
Request for Modification of the Authorization for) Call Signs S2983 and S3018
the SpaceX NGSO Satellite System)

ORDER AND AUTHORIZATION

Adopted: April 26, 2019

Released: April 26, 2019

By the Chief, International Bureau:

I. INTRODUCTION

1. In this Order and Authorization (Order), we grant the application¹ of Space Exploration Holdings, LLC (SpaceX) to modify its previously authorized 4,425 non-geostationary orbit (NGSO) satellite constellation using Ku- and Ka-band spectrum.² Specifically, we authorize SpaceX to slightly reduce the number of satellites in this constellation, to operate a substantial portion of these satellites at a lower orbital altitude than previously authorized, and to include the use of Ku-band gateway earth stations for fewer than 75 of these lower-altitude satellites.³ Grant of this modification will allow SpaceX to make efficient use of valuable spectrum resources more safely, quickly, and cost-effectively as it initiates a new generation of broadband services available to customers worldwide, including those in areas previously underserved or even totally unserved by other broadband solutions.⁴

II. BACKGROUND

2. Application. On November 8, 2018, SpaceX filed an application requesting that the Commission modify the authorization for its NGSO fixed-satellite service (FSS) constellation to allow SpaceX to: (1) reduce the number of satellites in the constellation from 4,425 to 4,409; (2) relocate 1,584 satellites authorized to operate at an altitude of 1,150 km to operate at an altitude of 550 km; and (3) make related changes to the operations of the satellites in this new lower shell of the constellation. The application also addresses three conditions included in the SpaceX Authorization related to orbital debris mitigation, compliance with applicable limits on equivalent power flux-density (EPFD), and protection of

¹ Space Exploration Holdings, LLC, Request for Modification of the Authorization for the SpaceX NGSO Satellite System, IBFS File No. SAT-MOD-20181108-00083, filed November 8, 2019 (SpaceX Modification Application).

² See Space Exploration Holdings, LLC, Application for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System, IBFS File Nos. SAT-LOA-20161115-00118, SAT-LOA-20170726-00110, 33 FCC Rcd 3391 (2018) (SpaceX Authorization).

³ See Letter from William H. Wiltshire, Counsel to SpaceX, to Marlene H. Dortch, Secretary, FCC (dated Apr. 15, 2019) at 2.

⁴ SpaceX Modification Application, Narrative at 3.

fixed services in the Ka-band.⁵ In this application, SpaceX proposes to operate in the same Ku- and Ka-band frequency bands that SpaceX was previously licensed to operate: 10.7-12.7 GHz (space-to-Earth), 12.75-13.25 GHz (Earth-to-space), 13.85-14.5 GHz (Earth-to-space), 17.8-18.6 GHz (space-to-Earth), 18.8-19.3 GHz (space-to-Earth), 19.7-20.2 GHz (space-to-Earth), 27.5-29.1 GHz (Earth-to-space), and 29.5-30 GHz bands (Earth-to-space). In connection with its application, SpaceX requests waivers of certain Commission rules.⁶

3. *Comments.* On December 14, 2018, the SpaceX Modification Application was accepted for filing.⁷ WorldVu Satellites Limited (OneWeb) and Kepler Communications, Inc. (Kepler) filed petitions to deny the SpaceX Application.⁸ The Commercial Smallsat Spectrum Management Association (CSSMA), Spire Global, Inc. (Spire), Planet Labs Inc. (Planet), and Astro Digital U.S., Inc. (Astro Digital) filed petitions to defer grant of SpaceX's modification.⁹ SES/O3b filed comments.¹⁰ SpaceX opposed the petitions to deny or defer and responded to all comments.¹¹ OneWeb, CSSMA, and Kepler filed reply comments.¹² EchoStar, Hughes, and Intelsat also filed consolidated reply comments.¹³ Several *ex parte* communications were also made in connection with the proposed modification.¹⁴

III. DISCUSSION

4. After review of the record, we conclude that grant of the SpaceX Modification Application will serve the public interest, subject to the requirements and conditions specified herein. Below, we address the various outstanding issues raised by commenters on SpaceX's Modification Application. Where appropriate, we defer matters of general applicability to ongoing or potential future rulemakings.

5. As part of our grant, we also address SpaceX's waiver requests.¹⁵ Generally, the Commission may waive any rule for good cause shown.¹⁶ Waiver is appropriate where the particular facts make strict compliance inconsistent with the public interest.¹⁷ In making this determination, we may take into account considerations of hardship, equity, or more effective implementation of overall policy

⁵ *SpaceX Authorization*, 33 FCC Rcd at 3407, paras. 40n, 40p, and 40q.

⁶ SpaceX requests waiver of Sections 25.157 and 25.146(a) of the Commission's rules, as well as conditional waivers of two other conditions imposed in the SpaceX Authorization: (1) submission and approval of an updated orbital debris mitigation plan prior to initiation of service; and (2) approval of a modification containing an updated technical showing that its operations in the 17.8-18.6 GHz and 18.8-19.3 GHz bands will protect terrestrial fixed stations with characteristics described in Recommendation ITU-R SF.1483.14. SpaceX also requested waivers in view of various limitations in the Commission's Schedule S, in connection with this application.

⁷ Policy Branch Information, Space Stations Accepted for Filing, Public Notice, Report No SAT-01364 (IB Sat. Div. Dec. 14, 2018).

⁸ Petition to Deny or Defer of WorldVu Satellites Limited (filed February 8, 2019) (OneWeb Petition to Deny) and Comments and Conditional Petition to Deny of Kepler Communications Inc. (filed January 29, 2019) (Kepler Petition).

⁹ CSSMA Comments and Petition to Defer (filed January 29, 2019) (CSSMA Petition), Petition to Defer of Spire Global, Inc., (filed January 29, 2019) (Spire Petition), Petition to Defer of Planet Labs Inc. (Planet), (filed January 29, 2019) (Planet Petition), Petition to Defer of Astro Digital, Inc. (filed January 29, 2019) (Astro Digital Petition).

¹⁰ Comments of SES Americom, Inc. and O3b Limited (filed February 8, 2019) (SES and O3b Comments).

¹¹ Space X Consolidated Opposition to Petitions and Response to Comments (filed February 11, 2019) (SpaceX Opposition). SpaceX Further Consolidated Opposition to Petitions and Response to Comments (filed February 21, 2019) (SpaceX Further Opposition).

¹² WorldVu Reply Comments (filed March 5, 2019) (OneWeb Reply). CSSMA and several of its members filed a Joint Reply to the Consolidated Opposition to Petitions and Response to Comments (filed February 22, 2019) (CSSMA Joint Reply). Reply Comments of Kepler Communications Inc. to Consolidated Opposition of Space Exploration Holdings, LLC (filed February 22, 2019) (Kepler Reply).

on an individual basis.¹⁸ Waiver is therefore appropriate if special circumstances warrant a deviation from the general rule and such deviation will serve the public interest.¹⁹ We address the specific requests for waivers below.

A. Waiver of Processing Round Rules and Modification of License

6. SpaceX requests a waiver of the processing round rules in place for NGSO-like space station applications.²⁰ Section 25.157 requires us to establish a processing round for NGSO applications that are not filed in response to a public notice.²¹ The applications for the SpaceX system that is being modified were filed in response to public notices for the appropriate processing rounds and have been granted.²² Accordingly, the appropriate rules governing the modification request of SpaceX are not the processing round considerations of Section 25.157, but rather the Commission's rules governing modification of space station licenses.²³ Consequently, we dismiss SpaceX's waiver request as moot and will instead consider its request under the framework for modification of a space station license.

7. Section 25.117 governs the modification of space station licenses.²⁴ Section 25.117 states that "applications for modifications of space station authorizations will be granted,"²⁵ with limited exceptions, two of which are relevant to the SpaceX request.²⁶ Thus, we will grant a modification application unless one of the enumerated exceptions of Section 25.117(d) applies. The first exception is when "granting the modification request would not serve the public interest, convenience, and necessity."²⁷ The second states that "applications for modifications of space station authorizations to increase the authorized bandwidth will not be considered in cases in which the original space station

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¹³ Reply of EchoStar Satellite Operating Corporation, Hughes Network Systems, LLC, and Intelsat License LLC (filed March 5, 2019) (GSO Satellite Operators Reply).

¹⁴ Letter from Tony Lin, Counsel to Planet, to Marlene H. Dortch, Secretary, FCC (dated Mar. 29, 2019); Letters from Brian D. Weimer, Counsel to WorldVu Satellites Ltd., to Marlene H. Dortch, Secretary, FCC (dated Apr. 3, Apr. 10, Apr. 12, Apr. 17, 2019); Letters from William H. Wiltshire, Counsel to SpaceX, to Marlene H. Dortch, Secretary, FCC (dated Mar. 18, Mar. 21, Mar. 25, Mar. 28, Apr. 15, and Apr. 23, 2019).

¹⁵ See *supra*, note 6.

¹⁶ 47 CFR § 1.3.

¹⁷ *Northeast Cellular Tel. Co. v. FCC*, 897 F.2d 1164, 1166 (D.C. Cir. 1990).

¹⁸ *WAIT Radio v. FCC*, 418 F.2d 1153, 1159 (D.C. Cir. 1969), *cert. denied*, 409 U.S. 1027 (1972); *Northeast Cellular*, 897 F.2d at 1166.

¹⁹ *Northeast Cellular*, 897 F.2d at 1166.

²⁰ SpaceX Modification Application, Waiver Requests at 1-3.

²¹ 47 CFR § 25.157(c).

²² *SpaceX Authorization*, 33 FCC Rcd at 3405, para. 39.

license application was granted pursuant to the procedures set forth in [Section] 25.157(e)...²⁸ We address each of the two exceptions below in opposite order.

8. SpaceX does not seek to increase the authorized bandwidth of its original space station license that was granted in the relevant processing round. SpaceX seeks to operate its modified system using the same frequencies that were previously authorized for SpaceX's operations. Although SpaceX does propose to use some of the authorized frequencies in a different manner than previously authorized (that is, for gateway stations in addition to customer service links), such a use does not rise to a request to "increase the authorized bandwidth" of its original application as granted. Such additional use of the authorized spectrum is more appropriately addressed under the next exception and will be discussed below. Accordingly, the "increase in authorized bandwidth" exception does not apply.

9. The second exception we discuss is broader in nature. Under this exception, we will grant an application to modify a space station license unless we determine that the modification requested will not serve the public interest. Section 25.117 by itself does not set forth the criteria for making this public interest determination. In the *Teledesic LLC* decision, the International Bureau provided criteria that would be applied when determining whether a modification request would be granted.²⁹ In that case, which involved changes being proposed to an NGSO satellite constellation subject to a processing round, the International Bureau stated that, "If the proposed modification does not present any significant interference problems and is otherwise consistent with Commission policies, it is generally granted."³⁰ This focus on the public interest in avoiding radiofrequency interference is consistent with the purpose of the Commission's processing round procedure, which is designed to establish the interference environment in which participants in the processing round could operate their systems.³¹ If a modification would worsen the interference environment, that would be a strong indication that grant of the modification would not be in the public interest.³²

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²³ Unlike amendments, the Commission's rules do not provide for "minor" or "major" modifications and lack provisions to remove modification requests from consideration in current processing rounds. Compare Section 25.116(c) (considering an application for a NGSO-like satellite license as a newly filed application when amended by a major amendment) with Section 25.117 (lacking distinction between "major" and "minor" modifications). 47 CFR §§ 25.116(c) and 25.117.

²⁴ 47 CFR § 25.117.

²⁵ 47 CFR § 25.117(d)(2).

²⁶ The remaining exceptions—Section 25.117(d)(2)(iii) & (v)—involve GSO-like space stations or a service band not requested by SpaceX or involve a determination that grant of the modification would make the applicant unqualified to operate a space station under the Commission's rules. 47 CFR §§ 25.112(d)(2)(i), (iii) & (iv). None of these possible exceptions have been raised in connection with SpaceX's modification request.

²⁷ 47 CFR § 25.117(d)(2)(ii).

²⁸ 47 CFR § 25.117(d)(2)(iv).

²⁹ *Teledesic LLC*, Order and Authorization, 14 FCC Rcd 2261 (IB 1999).

³⁰ *Id.* at 2264, para. 5.

³¹ See *Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, Report and Order and Further Notice of Proposed Rulemaking, 32 FCC Rcd. 7809, 7829, para. 61 (2017) (*NGSO FSS Report and Order*), (stating that, "The purpose of the recent processing rounds was to establish a sharing environment among NGSO systems, to provide a measure of certainty in lieu of adopting an open-ended requirement to accommodate all future applicants.")

³² This criterion is analogous to the criteria used in Section 25.116 of the Commission's rules to determine whether an amendment to a pending NGSO-like space station application is "major" and thus necessitates consideration outside of the processing round of the original application. 47 CFR § 25.116. Under Section 25.116, an amendment

10. Several NGSO FSS operators raise concerns about interference that could result from SpaceX's proposed modified NGSO system. Kepler argues, among other things, that SpaceX's use of the Ku-band for gateway transmissions, as opposed to both the Ku-and Ka-bands, will further increase the potential for interference to Kepler's system.³³ Kepler therefore urges the Commission to deny SpaceX's application unless certain conditions are imposed on the grant.³⁴ OneWeb asserts, among other things, that SpaceX's proposal to add new Ku-band gateway links is likely to significantly increase interference to other NGSO FSS operators, and that SpaceX's technical analysis fails to show that interference to the other constellations will not increase.³⁵ OneWeb also argues that the Commission should deny SpaceX's modification or defer its consideration to a subsequent NGSO processing round.³⁶ SES/O3b assert that SpaceX's technical analysis does not demonstrate that there will be no increased risk of interference to NGSO FSS operators, and, therefore, the Commission should require SpaceX to provide a supplemental technical analysis,³⁷ or relegate its application to a new processing round.³⁸ SpaceX disagrees with the contentions set forth by Kepler, OneWeb, and SES/O3b and provides additional evidence that its NGSO FSS system will not increase interference to the other NGSO FSS systems.³⁹

11. After a review of the information provided, we find that the modification proposed by SpaceX does not present significant interference problems and is in the public interest. As a result, for the reasons discussed below, we deny the petitions to deny of OneWeb and Kepler. First, we note that there is no increase in the number of satellites in the SpaceX constellation. On the contrary, SpaceX proposes a very small reduction in the number of satellites initially granted (4,425 to 4,409). We thus conclude that the number of spatial configurations that have the potential for generating interference between SpaceX and any other NGSO FSS system in the same processing round is expected to remain approximately unchanged. We consider this to be a fundamental element in assessing whether there would be significant interference problems as a result of granting the proposed modification. The central interference concerns raised by other parties relate to the 1) decrease in the operational altitude of the satellites from 1,150 km to 550 km and 2) the use of 10.7-12.7 GHz (space-to-Earth) and 14.0-14.5 GHz (Earth-to-space) for

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is "major" if, among other things not relevant here, it "increases the potential for interference, or changes the proposed frequencies or orbital locations to be used." 47 CFR § 25.116(b)(1). An amendment will not be considered major, however, if resolves frequency conflicts with authorized stations or other pending applications but does not create new or increased frequency conflicts."

³³ See Kepler Petition at 2-5. See also Kepler Reply at 2-7. Kepler argues that the location of SpaceX's satellites at the 550 km altitude, below the altitude of Kepler's system, restricts its ability to use limited uplink power to reduce interference to SpaceX's shell at 1150 km since the SpaceX constellation as modified would now be below Kepler's, potentially presenting significant implications for Kepler's operations such that new strategies would need to be developed to avoid the SpaceX satellites. Kepler Petition at 3,5.

³⁴ Kepler Petition at 5.

³⁵ See OneWeb Petition at 1-12. See also OneWeb Reply at 1-7. OneWeb further argues that grant of the modification should be on the condition that SpaceX accept all additional interference received as a result of the modification. OneWeb provides its own analysis, purportedly showing "a near five-fold increase" in the probability of in-line interference events and an increase of long-term interference into other NGSO satellites of at least 7 dB. *Id.* at 3. As with Kepler, OneWeb also criticizes SpaceX's interference analysis with respect to NGSO networks. OneWeb Petition at 3-4, 5-8.

³⁶ OneWeb Petition at 3; see also OneWeb Reply at 12.

³⁷ SES and O3b Comments at 2. SES and O3b argue that the Commission must require SpaceX to demonstrate that SpaceX's modification will not increase the potential for harmful interference to other NGSO systems, including the operating O3b NGSO constellation and its authorized expansion. *Id.* at 3-5. They also criticize the interference study performed by SpaceX. *Id.* at 3

³⁸ *Id.* at 5.

³⁹ SpaceX Consolidated Opposition at 9-11; SpaceX Further Consolidated Opposition at 3-11.

gateway transmissions in addition to transmissions to and from user terminals. We address each of these concerns in turn.

1. Reducing the Operational Altitude-Operations with User Terminals

12. *Potential of Interference Increase to Other NGSO FSS Systems: space-to-Earth.* We find that the SpaceX Modification Application will not increase the potential of interference from SpaceX satellites into the earth station operations of other NGSO FSS systems or other terrestrial spectrum users. SpaceX is already authorized to transmit in the space-to-Earth direction up to the applicable PFD limits set forth in Article 21 of the Radio Regulations of the International Telecommunication Union (ITU).⁴⁰ These PFD limits cap the amount of energy received at any point on the surface of the Earth from transmissions from satellites. SpaceX has not sought any change to its authorization to operate at higher power levels than these pfd limits. Accordingly, the lower orbital altitude proposed by SpaceX will not change the interference environment for earth stations communicating with other NGSO constellations or cause more interference to other primary spectrum users.

13. *Potential of Interference Increase to Other NGSO FSS Systems: Earth-to-space.* SpaceX's proposal to operate at a lower altitude is expected to result in lower power needed to be transmitted from earth stations to SpaceX's satellites. This conclusion follows from the fact that shorter distances between the earth station and the satellite will result in smaller path losses. Even if SpaceX elects not to reduce the power level of its earth station transmissions, we note that the only limitation the *SpaceX Authorization* imposes on transmissions from earth stations of a NGSO FSS system is compliance with the applicable EPFD_{up} limits. The decision that no other limits on earth station transmissions are necessary was recently reaffirmed by the Commission.⁴¹ Accordingly, the interference environment in the Earth-to-space direction will either be better, or at least no worse, than that under the existing authorization.

14. *Potential of Increased Interference from Other NGSO FSS Systems: space-to-Earth.* We must examine not only the potential for increased interference to other NGSO FSS systems as a result of SpaceX's modified operations, but also whether SpaceX's own system may become more susceptible to interference from other NGSO FSS systems, which would change the operating environment. There should be no change to the interference environment for earth stations communicating with SpaceX satellites as a result of lowering the operational altitude. The level of the desired signal received by a user terminal will be the same, as the level of the signal transmitted from a SpaceX satellite at lower altitude will be reduced only to the amount that compensates for the shorter transmit path.

15. *Potential of Increased Interference from Other NGSO FSS Systems: Earth-to-space.* The lowering of the operational altitudes of SpaceX's satellites will result in the transmissions from earth stations of other NGSO FSS systems reaching SpaceX's satellites at a higher power level because of less spreading losses between the earth station and the satellites at closer distances than previously proposed. If SpaceX lowered the transmission power of its own earth stations to take advantage of the closer operational altitude of its modified satellites, then its satellites would be more susceptible to interference from the transmissions of earth stations communicating with other NGSO FSS systems in the same frequency band. SpaceX could, however, offset this additional interference by keeping the transmit power of its own earth stations at the same level that they are currently authorized to transmit, which would allow the SpaceX transmissions to be received in the presence of stronger signals of other NGSO FSS systems. Thus, Kepler's concern that it will need to reduce its uplink power to avoid interference with SpaceX's satellites at 550 km is unfounded. As observed above, maintaining the already authorized

⁴⁰ *SpaceX Authorization*, 33 FCC Rcd at 3405-06, paras. 40b, 40d, and 40e.

⁴¹ See *NGSO FSS Report and Order*, 32 FCC Rcd at 7827, para. 55 (stating that "given the variety of NGSO FSS system proposals and their potential to offer broadband services directly to consumers, we believe it is premature to adopt any additional technical limitations to promote sharing among NGSO FSS systems").

transmit power levels for SpaceX's Earth-to-space transmissions will not degrade the interference environment for other NGSO FSS systems.

2. Ku-Band Operations with Gateway Earth Stations

16. For the same reasons as set forth above, the existing interference environment will not be adversely affected by SpaceX's proposal to operate gateway earth stations in the same Ku-band frequencies that it is already authorized to use to operate user terminals. As noted above, in the space-to-Earth direction, SpaceX's transmissions will remain subject to the same PFD limits that were imposed on its already licensed system in the 10.7-12.7 GHz frequency band. Specifically, OneWeb suggests that there could be a five-fold increase in interference as a result of SpaceX's proposal to operate gateways in the 10.7-12.7 GHz frequency band.⁴² OneWeb's concerns arise from an assumption that a user terminal receiving in the 10.7-12.7 GHz frequency band could be co-located with a gateway receiving in the same frequency band. Although four-co-frequency beams from four different SpaceX satellites could be pointed to the same location on the ground, SpaceX has clarified that there will be no co-frequency transmissions to a co-located user terminal when the four beams are transmitting to a gateway station.⁴³ In addition, SpaceX states that transmissions to gateway stations will be 6 dB lower since the gateway stations will use larger antennas with more gain than the antennas used for user terminals. As a result, the total pfd on the ground will be the same as that transmitted by a single SpaceX satellite to a user terminal. Moreover, as these four transmissions are coming from satellites at different locations, a victim earth station of another NGSO FSS system will have some antenna gain discrimination with respect to that caused by a single satellite transmitting with 6 dB higher power to a user terminal. Even without taking into account the differences in power levels addressed above, and assuming all satellites transmitting at the same level, transmissions from four different satellites to four antennas at a given gateway location or to four user terminals close to each other would produce the same amount of interference into any given earth station of another NGSO FSS system.

17. Also, transmissions from gateway earth stations will be less interfering than already authorized transmissions from user terminals in the 14.0-14.5 GHz frequency band, since the gateways will use larger antennas with narrower beams that will be more capable of avoiding interference into satellites of other NGSO FSS systems. Regarding the potential of SpaceX's system becoming more susceptible to downlink interference as a result of operating gateway earth stations in the 10.7-12.7 GHz frequency band, the level of the desired signal received by a gateway earth station will be reduced because of its higher antenna gain, while the duration of interference events is also reduced due to the narrower receive antenna beam. Accordingly, no significant change in the potential for interference is expected.

B. Orbital Debris Mitigation

18. An applicant for a space station authorization must submit a description of the design and operational strategies that it will use to mitigate orbital debris, including a statement detailing post-mission disposal plans for space stations at the end of their operating life.⁴⁴ SpaceX's current authorization is conditioned upon Commission approval of an updated description of the orbital debris mitigation plans for its system.⁴⁵ In its modification application, SpaceX provided an updated description and analysis of its orbital debris mitigation plans for its satellites to be operated at the lower 550 km orbital altitude.⁴⁶ The Satellite Division (Division) subsequently sent a letter to SpaceX requesting

⁴² OneWeb Petition to Deny at 6.

⁴³ SpaceX Further Consolidated Opposition at 8.

⁴⁴ *Mitigation of Orbital Debris*, Second Report and Order, 19 FCC Rcd 11567, 11619 (2004); 47 CFR §25.114(d)(14)(*Orbital Debris Second R&O*).

⁴⁵ *SpaceX Authorization*, 33 FCC Rcd at 3998, para.15.

⁴⁶ SpaceX Modification Application, Technical Attachment, Section A.11, at 38-48.

additional information regarding its orbital debris mitigation plan,⁴⁷ to which SpaceX responded.⁴⁸

19. *Collision Risk Analysis.* Many of the concerns raised by commenters in response to SpaceX's proposal to operate a portion of its satellites at the lower 550 km altitude relate to the risk of collision with other satellites operating, or planned to be operated, at this altitude.⁴⁹ Commission rules require an applicant for a space station authorization to state that it has assessed and limited the probability of the space station becoming a source of debris by collisions with larger debris or other operational space stations.⁵⁰ Where a space station will be launched into a low-Earth orbit (such as the one proposed by SpaceX) that is identical, or very similar, to an orbit used by other space stations, the statement must include an analysis of the potential risk of collision and a description of what measures the space station operator plans to take to avoid in-orbit collisions.⁵¹

20. SpaceX provided such a statement as part of its modification application,⁵² but commenters challenge the sufficiency of the statement as a basis for proceeding with grant of the modification. Specifically, OneWeb states that the Commission must seek additional information from SpaceX regarding the propulsive capabilities and maneuverability of its proposed initial deployment satellites to ensure that SpaceX's first-generation spacecraft satisfy appropriate and verifiable reliability standards and should not determine that SpaceX's "revised" orbital debris mitigation plan satisfies its original license conditions or should at least refrain from doing so until the ongoing orbital debris mitigation rulemaking proceeding is concluded.⁵³ CSSMA and its members argue that SpaceX has failed to provide any collision risk analysis with respect its proposed relocation or recognize other incumbent operators in substantially the same orbits.⁵⁴ CSSMA requests that the Commission defer any decision on SpaceX's Modification Application pending (i) the conclusion of the relevant rulemaking proceedings, and (ii) SpaceX's provision of the collision risk analysis. In the alternative, CSSMA requests that the Bureau condition any grant of SpaceX's Modification Application upon the company's compliance with rules and policies adopted in applicable proceedings and, pending completion of those proceedings,

⁴⁷ Letter from Jose P. Albuquerque, Chief, Satellite Division, to William M. Wiltshire, Counsel to SpaceX (dated February 26, 2019) (February 26 Letter).

⁴⁸ Letter from William M. Wiltshire, Counsel to SpaceX, to Jose P. Albuquerque, Chief, Satellite Division (dated March 13, 2019) (March 13 Letter).

⁴⁹ CSSMA Petition at 2-7 and Technical Annex at 1-5, Spire Petition at 2, Planet Petition at 1-2, Astro Digital Petition at 1-3, Kepler Petition at 5, OneWeb Petition at 15-18, CSSMA Joint Reply at 1-6, Kepler Reply at 2, OneWeb Reply at 8.

⁵⁰ 47 CFR § 25.114(d)(14)(iii).

⁵¹ 47 CFR § 25.114(d)(14)(iii).

⁵² SpaceX Modification Application, Technical Information at 43-44.

⁵³ OneWeb Petition to Deny at 2-10, 12-22. OneWeb further expresses concern that the 550 km orbit, an altitude through which OneWeb's own satellites must soon traverse during the orbit raising process and which is already populated by a multitude of small satellites, will now be populated with more than 1,500 SpaceX satellites whose operational capabilities raise important questions. *Id.* at 19. OneWeb also asserts that the Commission should not allow the LEO environment above the International Space Station to be a "move fast and fail often" test-bed for spacecraft design but should assess in-orbit spacecraft control, collision avoidance, and disposal reliability of SpaceX's system as modified. *Id.* at 15. Kepler also raises concerns that SpaceX's modification presents new physical risks to satellites operating in the region around 550 km, including Kepler's satellites. Kepler Petition at 5. Kepler Reply at 2.

⁵⁴ CSSMA Petition at 2-4. *See also* Spire Petition at 1-2, Planet Petition at 1-2, Astro Digital Petition at 1-2. Like CSSMA and Kepler, these commenters urge the Commission to hold off acting on SpaceX's modification application pending the outcome of the orbital debris mitigation proceeding. CSSMA also asserts that introduction of SpaceX's satellites at the 550 km altitude may require cubesat and other small satellite operators to execute more differential drag maneuvers in response to potential conjunction events, resulting in a noticeable capacity loss

condition any grant of the application on the company's commitment to coordinate.

21. In response, SpaceX states that petitioners' claims are not specific to SpaceX and apply to any new system applying to operate at an altitude of 400-600 km.⁵⁵ According to SpaceX, the Commission should not delay deployment of valuable services while issues that affect the entire industry are being debated in a proceeding of general applicability. Moreover, SpaceX argues, the Commission has already addressed CSSMA's and the other petitioners' request for a requirement that SpaceX coordinate its physical operations with other NGSO systems at similar orbital altitudes by imposing a condition to that effect in SpaceX's original authorizations.⁵⁶ Regardless, SpaceX claims, because all its satellites have propulsion and are maneuverable to prevent collisions, they are considered to pose zero risk to any other satellites in this orbital region.⁵⁷ Finally, SpaceX states that operating satellites at the 550 km altitude will ensure a 100% success rate of post-mission disposal within 5 years, even assuming worst-case conditions.⁵⁸

22. We find no reason to defer action on SpaceX's modification request as requested by certain commenters. Our rules do not prohibit SpaceX's selection of an orbital regime that is also used by other satellite operators, but SpaceX must provide a detailed discussion of how it will avoid potential collisions. SpaceX has done so in this instance. SpaceX has stated that its satellites have propulsion and SpaceX will maintain the ability to maneuver the satellites to avoid collisions.⁵⁹ Accordingly, consistent with current licensing practice, the collision risk is considered to be zero, or near zero, during the time in which the satellite is maneuverable, absent contrary information⁶⁰ No contrary information was provided by any party. In any event, SpaceX provided an estimate of the collision risk in the event of a system failure that renders a satellite incapable of maneuvering, under the worst-case scenario that the failure occurs immediately after launch of the satellite. This estimate is well within accepted boundaries for collision risk, even with worst-case assumptions that go well beyond any realistic scenario.⁶¹ Furthermore, SpaceX is already subject to the same orbital debris mitigation conditions as imposed on other NGSO systems authorized by the Commission or granted U.S market access, including a requirement that SpaceX coordinate its physical operations with space stations of NGSO systems operating at similar orbital altitudes.⁶² We also place this condition on our grant of SpaceX's modified

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because such satellites are not operational during those maneuvers. CSSMA Petition at 4-5. *See also* CSSMA Joint Reply at 2.

⁵⁵ SpaceX Opposition at 5.

⁵⁶ SpaceX Opposition at 7, citing to n.15.

⁵⁷ SpaceX Opposition at 1-2. Furthermore, SpaceX asserts that the issues raised by Petitioners combine to form a broad policy proposal to assign disproportionate responsibility to avoid on-orbit collisions among systems principally to propulsive systems like SpaceX, and away from smallsat operators, thus tilting the benefits of operating at these self-cleaning altitudes to non-propulsive smallsats to the great detriment of systems, like SpaceX's, that invested in more capable collision-avoidance technologies. SpaceX states that in any case, these arguments are better considered as part of the larger proceeding and should not delay consideration of SpaceX's application. *Id.*

⁵⁸ SpaceX Further Opposition at 13. *See also* SpaceX Modification, Technical Attachment at 39-41.

⁵⁹ SpaceX Opposition at 8.

⁶⁰ *Mitigation of Orbital Debris in the New Space Age*, Notice of Proposed Rulemaking, FCC 18-159 at para. 26 (rel. Nov. 19, 2018) (2018 *Orbital Debris NPRM*).

⁶¹ March 13 Letter at 2 (estimating a single satellite risk of 0.000000303, equating to an aggregate probability of collision with other large objects of 0.00048, which is less than half the 0.001 acceptable single satellite risk established by NASA).

⁶² *SpaceX Authorization* at para. 11. To the extent that SpaceX and other NGSO operators fail to come to an agreement regarding physical coordination, the Commission may intervene as appropriate.

operations. We condition our grant of SpaceX's modified operations on the requirement that SpaceX comply with any rules or policies that result from the orbital debris proceeding and any other applicable proceeding, now or in the future. This condition is already placed on SpaceX's existing authorizations, as well as other NGSO systems authorized by the Commission or granted U.S market access.

23. *Casualty Risk Analysis.* In addition to concerns about collision risks, parties raise concerns about the sufficiency of the casualty risk analysis that SpaceX provides for its satellites that will be disposed of through atmospheric re-entry at end of life.⁶³ Commission rules require entities proposing to dispose of spacecraft by means of atmospheric re-entry to assess the risk of human casualty from such atmospheric re-entry.⁶⁴ SpaceX provided a casualty risk assessment as part of its modification, which states that the risk of human casualty from the re-entry of any one of its satellites meets, or exceeds, the NASA standard of 1 in 10,000.⁶⁵

24. OneWeb challenges the sufficiency of the casualty risk analysis provided by SpaceX, specifically regarding its reliance on an analysis on a per satellite basis, rather than on an aggregated basis for all satellites in the modified constellation.⁶⁶ OneWeb acknowledges that the Commission's rules do not require an aggregate casualty risk analysis, but notes that the Commission specifically invited comment on whether it should require applicants to provide an aggregate, system-wide analysis to evaluate casualty risk.⁶⁷ OneWeb also argues that the Commission should refrain from accepting SpaceX's updated orbital debris mitigation plan until SpaceX updates its casualty risk analysis with the results of a more-refined analysis.⁶⁸ Finally, OneWeb asserts that the Commission should also refrain from accepting SpaceX's updated orbital debris showing until the orbital debris rulemaking is concluded or, in the alternative, condition grant of the Modification Application on SpaceX's future compliance with any rules adopted or modified in that proceeding.⁶⁹

25. SpaceX asserts that its modified constellation far surpasses U.S. and international standards for safety of de-orbit operations. According to SpaceX, OneWeb's argument that the Commission should apply a new and as-yet unquantified standard to SpaceX that would assess potential risks in the aggregate would effectively impose on SpaceX a standard has not been applied to other applicants in the Ku/Ka-band NGSO processing round. SpaceX argues that any new rule should be considered in the ongoing orbital debris rulemaking and, if adopted, made applicable to all NGSO system authorizations.⁷⁰ Regardless, in its reply to the Commission's request for further information, SpaceX states that it has now developed a system architecture such that satellite components will be completely demisable in all versions except for the initial deployment of no more than 75 satellites out of a constellation total of 4,409.⁷¹ After this initial deployment, according to SpaceX, no components of

⁶³ See e.g., OneWeb Petition at 20-22.

⁶⁴ See 47 CFR § 25.114(d)(14)(iv); *Orbital Debris Second R&O*, 19 FCC Rcd at 11603, para. 88).

⁶⁵ SpaceX Modification Application, Technical Information at 47, Waiver Requests at 6.

⁶⁶ OneWeb Petition at 20-21.

⁶⁷ OneWeb Petition at 21 (citing *2018 Orbital Debris NPRM* at para.6).

⁶⁸ *Id.* SpaceX and OneWeb agree that NASA's Object Reentry Survival Analysis Tool (ORSAT) is a more comprehensive (higher fidelity) model that provides a greater level of precision and insight over the standard Debris Analysis Software (DAS).

⁶⁹ *Id.* at 22-23.

⁷⁰ SpaceX Further Opposition at 14-15.

⁷¹ The initial launch will feature satellites that are not entirely demisable, which SpaceX calculates will each have a Risk of Human Casualty estimated, using NASA estimation tools, at 1:19,800. SpaceX Modification Application, Technical Information at 47.

subsequent iterations of the satellite will survive atmospheric re-entry, reducing casualty risk to zero.⁷²

26. We are satisfied that SpaceX is employing methodologies for safe design and operation for the satellites that are the subject of this modification, and that SpaceX is continuing to develop new designs that will further enhance this safety profile. Our findings are based in large part on SpaceX's representations that more than 98 percent of the satellites in its constellation (all but the initial deployment of up to 75 satellites) will have no components that survive atmospheric re-entry. Accordingly, we do not believe the public interest would be served at this time by delaying the deployment of SpaceX's system pending the outcome of the orbital debris rulemaking or the results of a more detailed casualty risk analysis. This grant is subject to SpaceX's future compliance with any rules adopted or modified in the orbital debris rulemaking.

27. Although we find that the orbital debris mitigation plan is sufficient with regard to the space stations that SpaceX proposes to operate under its modification, SpaceX has provided no new information regarding the orbital debris mitigation plans for the other satellites in its proposed system. Accordingly, SpaceX has only partially satisfied the condition on its authorizations that requires SpaceX to submit, and have approved by the Commission, an updated orbital debris mitigation plan prior to initiation of service. We retain this condition for any of the satellites other than those that will be operated at an altitude of 550 km as proposed in this modification.

C. Satisfaction of Prior License Conditions and Other Waiver Requests

28. *Waiver of ITU Finding Required Under Section 25.146(a).*⁷³ In the *SpaceX Authorization*, the Commission required that SpaceX receive a favorable or "qualified favorable" finding from the ITU with respect to compliance with applicable EPFD limits in Article 22 of the ITU Radio Regulations prior to commencing operations.⁷⁴ SpaceX asserts that the ITU will not examine the modified filing in this respect anytime soon and in light of its expedited deployment schedule, requests a waiver of this condition prior to the initiation of service. OneWeb and the GSO Satellite Operators, request that the Commission deny SpaceX's waiver request.⁷⁵ SES and O3b, argue that any waiver grant addresses the timing of the ITU filing and is conferred at SpaceX's own risk.⁷⁶ Given the ITU's timeframe for examining SpaceX's modified filing and the fact that SpaceX presents EPFD calculations using the ITU software⁷⁷, we agree that this condition should not deter SpaceX start of operations. Thus, SpaceX's request for waiver of the requirement to receive a favorable or "qualified favorable" finding prior to commencing operations is granted. We retain the requirement, however, that SpaceX receive the favorable or "qualified favorable" finding from the ITU, and in case of an unfavorable finding, adjust its operation to satisfy the ITU requirements. Accordingly, operations of SpaceX's system, as modified prior to the ITU's finding, are at SpaceX's own risk.

29. *Protection of Fixed-Service Operations in Portions of the 17.7-19.7 GHz Frequency Band.* The Commission required SpaceX to obtain approval of a modification containing an updated technical showing that its operations in the 17.8-18.6 GHz and 18.8-19.3 GHz bands will protect terrestrial Fixed stations with characteristics described in Recommendation ITU-R SF.1483. SpaceX has

⁷² March 13 Letter at 3. SpaceX also indicates that the higher fidelity ORSAT analysis by NASA has not yet been completed for this system.

⁷³ 47 CFR § 25.146(a).

⁷⁴ *SpaceX Authorization*, 33 FCC Rcd at 3402 and 3407, paras. 29 and 40n.

⁷⁵ OneWeb Petition at 23-26; GSO Satellite Operators Reply at 1-5.

⁷⁶ SES and O3b Comments at 5. Should the Commission grant the waiver, the GSO Satellite Operators agree with SES and O3b's suggestion that the Commission note that SpaceX would proceed at its own risk. GSO Satellite Operators Reply at 5.

⁷⁷ SpaceX Modification Application, Attachment A, Annex 1.

submitted the requested showing in this application.⁷⁸ Upon review of this technical showing, we find that the condition has been satisfied, thus its request for waiver of this requirement is moot.

30. *Schedule S Waiver.* As required by the Commission's rules, SpaceX submitted a completed Schedule S for its application, which contains certain technical information in a prescribed form. SpaceX has found that it cannot accurately describe its system in certain respects due to limitations in Schedule S itself. SpaceX cites five limitations in Schedule S that affected how the Schedule S was completed: (1) the impracticability of submitting complete orbital parameter data for the SpaceX system using the Schedule S web form; (2), the inability to enter for Section 25.114(c)(4)(v) requires both the minimum and maximum saturation flux density (SFD) values for each space station receive antenna that is connected to transponders; (3) the inability to enter a maximum transmit EIRP value for its downlink beams that is 0 dBW or less; (4) the inability to enter the begin and end angle for the active service arc with respect to the ascending node for each orbital plane; (5) the inability to enter the maximum EIRP for transmit beams for values less than zero. Given that SpaceX has implemented a workaround for each of these limitations to allow entry of the required information, we find that a waiver of the requirement to complete certain aspects or fields of Schedule S is warranted.

IV. ORDERING CLAUSES

31. Accordingly, IT IS ORDERED, that the Modification Application filed by Space Exploration Holdings, LLC (SpaceX) and accepted for filing IS GRANTED, as set forth in this Order and Authorization, pursuant to Section 309(a) of the Communications Act of 1934, as amended, 47 U.S.C. § 309(a).⁷⁹

32. IT IS FURTHER ORDERED that this authorization is subject to the following requirements and conditions:

a. SpaceX must timely provide the Commission with the information required for Advance Publication, Coordination, and Notification of the frequency assignment(s) for this constellation, including due diligence information, pursuant to Articles 9 and 11 of the ITU Radio Regulations. This authorization may be modified, without prior notice, consistent with the coordination of the frequency assignment(s) with other Administrations. See 47 CFR § 25.111(b). SpaceX is responsible for all cost-recovery fees associated with the ITU filings. 47 CFR § 25.111(d).

b. Operations in the 10.7-11.7 GHz (space-to-Earth) frequency band are authorized up to the applicable power flux-density limits in 47 CFR § 25.208(b), and up to the equivalent power flux-density requirements of Article 22 of the ITU Radio Regulations, as well as Resolution 76 (Rev. WRC-15) of the ITU Radio Regulations.

c. In the 10.7-11.7 GHz band, operations must be coordinated with the radio astronomy observatories listed in 47 CFR § 2.106, n.US131, to achieve a mutually acceptable agreement regarding the protection of the radio telescope facilities operating in the 10.6-10.7 GHz band. For the purposes of coordination with these listed facilities or the National Radio Quiet Zone, correspondence should be directed to the National Science Foundation Spectrum Management Unit (Email: esm@nsf.gov).

d. Operations in the 11.7-12.2 GHz (space-to-Earth) frequency band are authorized up to the power flux-density limits in Article 21 of the ITU Radio Regulations, and up to the equivalent power flux-density requirements of Article 22 of the ITU Radio Regulations, as well as Resolution 76 (Rev. WRC-15) of the ITU Radio Regulations.

⁷⁸ SpaceX Modification Application, Attachment A, 14-22.

⁷⁹ We note that most of the conditions outlined below are included in the *SpaceX Authorization*. The International Bureau finds it appropriate to include these conditions in SpaceX's modification order as they continue to apply to SpaceX's entire constellation. Certain conditions were modified as needed to reflect changes based on our approval of modified system parameters.

e. Operations in the 12.2-12.7 GHz (space-to-Earth) frequency band are authorized up to the power flux-density limits in 47 CFR § 25.208(o) and Article 21 of the ITU Radio Regulations, and up to the equivalent power flux-density requirements of Article 22 of the ITU Radio Regulations, as well as Resolution 76 (Rev. WRC-15) of the ITU Radio Regulations.

f. Operations in the 12.75-13.25 GHz (Earth-to-space) frequency band must be in accordance with footnote 5.441 to the U.S. Table of Frequency Allocations, 47 CFR § 2.106, n. 5.441, which states that operations in this band are subject to application of the provisions of No. 9.12 for coordination with other non-geostationary-satellite systems in the fixed-satellite service. Non-geostationary-satellite systems in the fixed-satellite service shall not claim protection from geostationary-satellite networks in the fixed-satellite service operating in accordance with the Radio Regulations. Non-geostationary-satellite systems in the fixed-satellite service in the 12.75-13.25 GHz (Earth-to-space) frequency band shall be operated in such a way that any unacceptable interference that may occur during their operation shall be rapidly eliminated.

g. Operations of non-geostationary-satellite systems in the 12.75-13.25 GHz (Earth-to-space) frequency band are restricted to individually licensed earth stations in accordance with footnote NG57 to the U.S. Table of Frequency Allocations, 47 CFR § 2.106, NG57. In the 13.85-14.5 GHz (Earth-to-space) frequency band reception is permitted for levels up to the equivalent power flux-density requirements of Article 22 of the ITU Radio Regulations.

h. In the 14.47-14.5 GHz band, operations are subject to footnote US342 to the U.S. Table of Frequency Allocations, 47 CFR § 2.106, n.US342, and all practicable steps must be taken to protect the radio astronomy service from harmful interference.

i. Space-to-Earth operations in the 17.8-18.6 GHz, 18.8-19.3 GHz, and 19.7-20.2 GHz frequency bands must complete coordination with U.S. Federal systems, in accordance with footnote US334 to the United States Table of Frequency Allocations, 47 CFR § 2.106, prior to being used. The use of space-to-Earth operations in the 17.8-18.6 GHz, 18.8-19.3 GHz, and 19.7-20.2 GHz bands must be in accordance with any signed coordination agreement between SpaceX and U.S. Federal operators. Two weeks prior to the start of any operations in the 17.8-18.6 GHz, 18.8-19.3 GHz, and 19.7-20.2 GHz bands, SpaceX must provide contact information for a 24/7 point of contact for the resolution of any harmful interference to Jimmy Nguyen, Email: Jimmy.Nguyen@us.af.mil.

j. Operations in the 18.8-19.3 GHz (space-to-Earth) frequency band are authorized up to the power flux-density limits in Article 21 of the ITU Radio Regulations.

k. In the 27.5-28.6 GHz and 29.5-30 GHz (Earth-to-space) frequency bands reception is permitted at levels up to the applicable equivalent power flux-density requirements of Article 22 of the ITU Radio Regulations.

l. Operations in the 27.5-28.35 GHz (Earth-to-space) frequency band are secondary with respect to Upper Microwave Flexible Use Service (UMFUS) operations, except for FSS operations associated with earth stations authorized pursuant to 47 CFR § 25.136 and will comply with any determinations set forth in the Spectrum Frontiers proceeding.

m. Operations in the 28.35-28.6 GHz and 29.5-30 GHz (Earth-to-space) frequency bands are on a secondary basis with respect to GSO FSS operations.

n. Under 47 CFR § 25.146(a), SpaceX must receive a favorable or “qualified favorable” finding in accordance with Resolution 85 (WRC-03) with respect to its compliance with applicable equivalent power flux-density limits in Article 22 of the ITU Radio Regulations and, in case of an unfavorable finding, adjust its operation to satisfy the ITU requirements.

o. SpaceX must cooperate with other NGSO FSS operators in order to ensure that all authorized operations jointly comport with the applicable limits for aggregate equivalent power flux-density in the space-to-Earth direction (EPFDdown) contained in Article 22 of the ITU Radio Regulations, as well as Resolution 76 (WRC-03) of the ITU Radio Regulations.

p. Upon finalization of its space station design and prior to initiation of service, SpaceX must seek and obtain the Commission's approval of a modification containing an updated description of the orbital debris mitigation plans for its system for any satellites other than those that will be operated at an altitude of 550 km as proposed in this modification.

q. This authorization is subject to modification to bring it into conformance with any rules or policies adopted by the Commission in the future.

33. IT IS FURTHER ORDERED that SpaceX is subject to the rules regarding the sharing of ephemeris data in Section 25.146(e) of the Commission's rules, 47 CFR § 25.146(e).

34. IT IS FURTHER ORDERED that SpaceX must launch 50 percent of the maximum number of proposed space stations, place them in the assigned orbits, and operate them in accordance with the station authorization no later than **March 29, 2024**, and SpaceX must launch the remaining space stations necessary to complete its authorized service constellation, place them in their assigned orbits, and operate each of them in accordance with the authorization no later than **March 29, 2027**. 47 CFR § 25.164(b).

35. IT IS FURTHER ORDERED that operations must comply with spectrum sharing procedures among NGSO FSS space stations specified in 47 CFR § 25.261 with respect to any NGSO system licensed or granted U.S. market access pursuant to the processing rounds initiated in Public Notice, DA 16-804 and Public Notice, DA 17-524. Spectrum sharing between SpaceX's operations and operations of NGSO systems granted U.S. market access, where such operations do not include communications to or from the U.S. territory, are governed only by the ITU Radio Regulations and are not subject to Section 25.261.

36. IT IS FURTHER ORDERED that SpaceX's request for waiver of the processing round rules (including Section 25.157(c) of the Commission's rules) IS DISMISSED AS MOOT.

37. IT IS FURTHER ORDERED that the request for waiver of the requirement under 47 CFR § 25.146(a) that SpaceX must receive a favorable or "qualified favorable" finding in accordance with Resolution 85 (WRC-03) with respect to its compliance with applicable equivalent power flux-density limits in Article 22 of the ITU Radio Regulations prior to commencing operations IS GRANTED.

38. IT IS FURTHER ORDERED that the request for waiver of the requirement that SpaceX must obtain approval of a modification containing an updated technical showing that its operations in the 17.8-18.6 GHz and 18.8-19.3 GHz bands will protect terrestrial Fixed stations IS DISMISSED AS MOOT.

39. IT IS FURTHER ORDERED that the request for waiver of the requirement to complete certain aspects or fields of Schedule S IS GRANTED for the reasons set forth herein.

40. IT IS FURTHER ORDERED that the Petitions to Deny of WorldVu Satellites Limited and Kepler Communications Inc. ARE DENIED.

41. IT IS FURTHER ORDERED that the Petitions to Defer of Spire Global, Inc., Planet Labs Inc., Astro Digital, Inc., and the Commercial Smallsat Spectrum Management Association ARE DENIED.

FEDERAL COMMUNICATIONS COMMISSION

Thomas Sullivan
Chief, International Bureau