TECHNICAL APPENDIX

SES-20 AT 135° W.L AND SES-21 AT 103.05° W.L

1.0 Overall Description: §25.114(d)(1)

This technical appendix is submitted in support of the applications of SES Americom Inc. (SES) for authority to launch, test, and operate two satellites, SES-20 and SES-21. SES-20 will be located at 135° W.L and will serve as a replacement satellite for AMC-8 and the C-band capacity of AMC-4. SES-21 will be located at 103.05° W.L. +/- 0.1 degrees[1] and will serve as a replacement satellite for the C-band capacity of SES-3. SES-20 and SES-21 are currently under construction by The Boeing Corporation and are technically identical.

SES-20 and SES-21 will primarily serve the Contiguous U.S. (CONUS), Alaska, Hawaii, and parts of Canada, Mexico, Central America and the Caribbean in the C-band using linear polarization (LH, LV).[2] Both spacecraft will operate in the conventional C-band frequencies, with downlink frequencies from 3.7 to 4.2 GHz[3] and uplink frequencies from 5.925 to 6.425 GHz.

SES is also requesting authority to perform in-orbit testing (IOT) of the satellites following launch in order to confirm spacecraft operating parameters. As discussed in the legal narrative, IOT locations have not yet been finalized, and SES is seeking authority to test at any location between 141.2° W.L. and 142.8° W.L. with an east-west stationkeeping tolerance of +/- 0.1 degrees.

2.0 Telemetry, Telecommand and Control Facilities

Telemetry, telecommand and control (TT&C) for the SES-20 and SES-21 satellites will be carried out from SES earth stations in the United States identified on the most recent SES report pursuant to §25.172.[4]

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[1] The Schedule S rounds the SES-21 orbital location to 103.0° W.L., but the requested orbital location is 103.05° W.L.

[2] As SES has explained, its proposed new satellites "have been designed to ensure substantially the same or better service to current customers and Incumbent Earth Station operators. While these satellites will include incidental coverage of areas around the United States (similar to current SES satellites at 101° W.L., 103° W.L. and 105° W.L.), such as Mexico, SES does not intend to provide international-only services over these satellites." *See* Letter of Brian D Weimer, Counsel to SES Americom, Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 20-173, filed July 7, 2021, attaching SES Americom, Inc. Accelerated C-band Transition Implementation Plan at 8-9 (footnote omitted).

[3] As discussed in the legal narrative, operations in CONUS will be limited to the 4.0-4.2 GHz band segment, while operations outside of CONUS will use the full 3.7-4.2 GHz frequencies.

[4] *See* Report of SES Americom, Inc., submitted in File Nos. SAT-MOD-20170810-00115 *et al.*, June 30, 2021.

The TT&C carrier center frequencies and bandwidths for nominal operations are provided in Schedule S. During emergency and transfer, or LEOP, operations, the TT&C carriers are received through omni-directional (pipe) antennas, which may be set to either right or left-hand polarization in either direction.

3.0 Interference Analysis and Certifications: §25.140

SES certifies that the SES-20 and SES-21 downlink EIRP densities will not exceed 3 dBW/4kHz for digital transmissions or 8 dBW/4kHz for analog transmissions in the C-band, unless higher levels are coordinated with the operators of authorized co-frequency space stations at assigned locations within six degrees of 135.0° W.L or 103.0° W.L., and except under the provisions of §25.140 (a)(3)(i) and notified as described in §25.140(d). SES has previously notified the Commission of non-routine power levels at these locations.[5]

Furthermore, SES certifies that the levels of the uplink emissions in the C-band will not exceed the limits set in §25.218 unless appropriately coordinated with operators of authorized co-frequency space stations at assigned locations within six degrees of 135.0° W.L or 103.0° W.L. and except as provided in §25.140 (a)(3)(i) and notified as described in §25.140(d).

4.0 Mitigation of orbital debris: 25.114(d)(14)

Debris release.

SES has assessed and limited the amount of debris released in a planned manner during the normal operations of the SES-20 and SES-21 satellites. During the satellite ascent, after separation from the launcher, no debris will be generated. As with all recent SES satellite launches, all deployments will be conducted using pyrotechnic devices designed to retain all physical debris. No debris is released during normal on-station operations, and the spacecraft will be in a stable configuration.

Collision with small objects.

SES has assessed and limited the probability of the space stations becoming sources of debris by collision with small debris or meteoroids of less than one centimeter in diameter that could cause loss of control and prevent post-mission disposal. The satellite design locates all sources of stored energy within the body of the structure, which provides protection from small orbital debris. SES requires that spacecraft manufacturers assess the probability of micrometeorite damage that can cause any loss of functionality. This probability is then factored into the ultimate spacecraft probability of success. Any significant probability of damage would need to be mitigated in order for the spacecraft design to meet SES's required probability of success of the mission. SES has taken the following steps to limit the effects of such collisions: (1) critical spacecraft components are located inside the protective body of

[5] *See* Letters of Petra A. Vorwig, SES, to Marlene H. Dortch, Secretary, FCC, Notification of Non-Routine Transmission Levels, Satellites at the Nominal 135° W.L. Orbital Location: AMC-4, Call Sign S2135, File No. SAT-MOD-20170518-00073; AMC-7, Call Sign S2155, File No. SAT-MOD-20150309-00010; and AMC-10, Call Sign S2432, File No. SAT-LOA-20020104-00001, and Notification of Non-Routine Transmission Levels, SES-3 at 103° W.L., Call Sign S2892, File No. SAT-RPL-20121228-00227, both filed Jan. 18, 2018.

the spacecraft and properly shielded; and (2) all spacecraft subsystems have redundant components to ensure no single-point failures. The spacecraft will not use any subsystems for end-of-life disposal that are not used for normal operations.

Accidental explosions and release of liquids.

SES has assessed and limited the probability, during and after completion of mission operations, of accidental explosions or of release of liquids that will persist in droplet form. As part of the Safety Package, an extensive analysis is completed by the spacecraft manufacturer, reviewing each potential hazard relating to accidental explosions and analyzing each subsystem for potential hazards. Also, the spacecraft manufacturer generates a Failure Mode Effects and Criticality Analysis for the spacecraft to identify all potential mission failures. The risk of accidental explosion is included as part of this analysis. This analysis indicates failure modes, possible causes, methods of detection, and compensating features of the spacecraft design.

The design of the SES-20 and SES-21 satellites minimizes the risk of explosion both during and after mission operations. In designing and building the spacecraft, the manufacturer took steps to ensure that debris generation will not result from the conversion of energy sources on board the satellite into energy that fragments the satellite. Both SES-20 and SES-21 use a Xenon Ion Propulsion System (XIPS) with a single xenon inert gas. Because Xenon is inert it requires less end of life care than chemical propellant fuels. No gases other than xenon will be used in the space stations' propulsion system. All propulsion subsystem pressure vessels, which have high margins of safety at launch, have even higher margins in orbit, since use of xenon during transfer orbit decreases the propulsion system pressure. Burst tests are performed on all pressure vessels during qualification testing to demonstrate a margin of safety against burst. The Xenon tank has a specified proof pressure of 4500 psia and burst pressure of 7500 psia although qualification testing has been demonstrated up to 9300 psia, well above the specified burst pressure. In addition, the xenon tank is designed to leak before burst. On-orbit, all pressures, including those of the batteries, will be monitored by telemetry.

At the end of operational life, after the satellite has reached its final disposal orbit, all on-board sources of stored energy will be depleted or secured, the batteries will be discharged, and the Xenon propellant will be vented per the satellite manufacturer's procedures and guidelines to a value below 5% of the tank rated proof pressure of 4500 psia. For the maximum Xenon loading of 130 kg, the projected pressure and mass of residual Xenon which could remain in the tank at mission end of life is as follows, well below the specified proof and burst pressures.

Tank	Volume [l]	Pressure [psia]	Temp. [deg C]	Xenon mass [kg]
Xenon	~233	~50	~35	4.2

No liquids that will persist in droplet form will be released during or after the completion of SES-20 and SES-21 mission operations.

Collision with large debris or other operational space stations.

SES has assessed and limited the probability of the SES-20 and SES-21 space stations becoming a source of debris by collisions with large debris or other operational spacecraft. Specifically, SES has assessed the possibility of collision with satellites located at, or reasonably expected to be located at, the requested orbital locations or assigned in the vicinity of those locations. Regarding avoidance of collisions with controlled objects, in general, if a geosynchronous satellite is controlled within its specified longitude and latitude station-keeping limits, collision with another controlled object (excluding where the satellite is collocated with another object) is the direct result of that object entering the allocated space.

SES-20 will be positioned at 135° W.L., where it will serve as a replacement satellite for AMC-8, located at 135° W.L., and the C-band payload of AMC-4, located at 134.9° W.L. SES-21 will be positioned at 103.05° W.L. +/- 0.1 degrees and will serve as a replacement satellite for the C-band capacity of SES-3. On-station operations of the satellites require station-keeping within the specified +/- 0.1 degrees N-S tolerance and the E-W tolerance of +/- 0.05 degrees for SES-20 and +/- 0.1 degrees for SES-21, thereby ensuring adequate collision avoidance distance from other satellites in geosynchronous orbit. In considering current and planned satellites that may have a station-keeping volume that overlaps the SES-20 and SES-21 satellites, SES has reviewed the FCC databases for FCC licensed satellite networks. In addition, networks for which a request for coordination has been published by the ITU near 135° W.L. and 103° W.L. have also been reviewed. Only those networks that either operate, or are planned to operate, and have an overlapping station-keeping volume with the SES-20 and SES-21 satellites, have been taken into account in the analysis.

Based on these reviews, the only satellites operating at the nominal 135° W.L. location are two SES spacecraft, AMC-8 at 135° W.L. and AMC-4 at 134.9° W.L. SES will develop a colocation strategy to allow SES-20 and AMC-8 to operate safely during traffic transfer. The station-keeping volume of AMC-4 is adjacent to but does not overlap with that of the proposed SES-20 satellite.

The only satellite currently at 103° W.L. that has an overlapping station-keeping volume with SES-21 is SES-3. SES is separately seeking authority for SES-19 to serve as an in-orbit spare satellite at 103.05° W.L. There is a cluster of DIRECTV spacecraft centered at 102.8° W.L., but their station-keeping ranges do not overlap or immediately adjoin that of the proposed SES-21 satellite. SES will develop a colocation strategy to allow its spacecraft at the nominal 103° W.L. location to operate safely.

During the period of colocation, SES will likely use the proven inclination-eccentricity technique to ensure adequate separation between the satellites within a shared station-keeping volume. This strategy is presently in use by SES at several orbital locations to ensure proper operation and safety of multiple satellites within one orbital box. Should the final colocation strategy that SES develops require a change in the orbital position of the satellites during traffic transfer, then SES will apply for Special Temporary Authorization to cover those temporary location changes.

There are no other pending applications before the Commission requesting authorization to use an orbital location within ±0.05° of 135° W.L. or ±0.01° of 103.05° W.L., and within the sub-arc, there are no ITU networks within the station-keeping volume proposed for SES-20

or SES-21 other than those submitted on behalf of SES. Based on the preceding, it is concluded that physical coordination of the SES-20 and SES-21 satellites with another party is not required at the present time.

SES uses the Space Data Center ("SDC") system from the Space Data Association to monitor the risk of close approach of its satellites with other objects. Any close encounters (separation of less than 10 km) are flagged and investigated in more detail. If required, avoidance maneuvers are performed to eliminate the possibility of collisions. During any relocation, the moving spacecraft is maneuvered such that it is at least 30 km away from the synchronous radius at all times. In most cases, much larger deviation from the synchronous radius is used. In addition, the SDC system is used to ensure no close encounter occurs during the move. When de-orbit of a spacecraft is required, the initial phase is treated as a satellite move, and the same precautions are used to ensure collision avoidance.

Trackability of the space station.

The SES-20 and SES-21 satellites will be trackable.

Proximity operations.

No proximity operations are planned for the SES-20 and SES-21 satellites.

Space station disposal plans.

At the end of each satellite's life, SES plans to maneuver SES-20 and SES-21 to a disposal orbit with a minimum perigee of 279 km (SES-20) and 272 km (SES-21) above the normal operational altitude. The proposed disposal orbit altitude complies with the altitude resulting from application of the IADC formula based on the following calculation:

SES-20:

Area of the satellite (average aspect area): 60.0 m^2

Mass of the spacecraft: 1369 kg

C_R (solar radiation pressure coefficient): 1.0

Therefore the Minimum Disposal Orbit Perigee Altitude, as calculated under the IADC formula, is:

36,021 km + (1000 × CR × A/m) = 36065 km, or 279 km above the GSO arc (35,786 km)

SES-21:

Area of the satellite (average aspect area): 60.0 m^2

Mass of the spacecraft: 1638 kg

C_R (solar radiation pressure coefficient): 1.0

Therefore the Minimum Disposal Orbit Perigee Altitude, as calculated under the IADC formula, is:

36,021 km + (1000 × CR × A/m) = 36058 km, or 272 km above the GSO arc (35,786 km)

SES intends to reserve 0.5 kg of fuel on each satellite in order to account for post-mission disposal of SES-20 and SES-21. SES has assessed fuel-gauging uncertainty and has provided an adequate margin of fuel reserve to address the assessed uncertainty.

DECLARATION

I, Luis Emiliani, hereby certify under penalty of perjury that I am the technically qualified person responsible for preparation of the technical information contained in the foregoing exhibit; that I am familiar with the technical requirements of Part 25; and that I either prepared or reviewed the technical information contained in the exhibit and that it is complete and accurate to the best of my knowledge, information and belief.

/s/ Luis Emiliani
Manager, Spectrum Management and Development
SES

Dated: August 12, 2021