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**VIA IBFS**

Marlene H. Dortch
Secretary, Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: Orbital Debris Mitigation Plan
*WorldVu Satellites Limited, Petition for a Declaratory Ruling Granting Access to the U.S. Market for the OneWeb System*, File No. SAT-LOI-20160428-00041

Dear Ms. Dortch:

WorldVu Satellites Limited, d/b/a OneWeb ("OneWeb"), by its counsel, submits the attached Orbital Debris Mitigation Plan to supplement the above-captioned application seeking access to the U.S. market for OneWeb's planned low earth orbit, non-geostationary orbit satellite system. As noted in its pending application, OneWeb's orbital debris mitigation plan is also subject to direct and effective regulatory oversight by the United Kingdom Space Agency.

Respectfully submitted,

*/s/ Jennifer D. Hindin*

Jennifer D. Hindin

cc: Jose P. Albuquerque

Attachment

# OneWeb Orbital Debris Mitigation Plan

November 10, 2016

# 1.0 INTRODUCTION

## 1.1 PURPOSE

OneWeb takes orbital debris mitigation very seriously and is pleased to submit this Orbital Debris Mitigation Plan to the Federal Communications Commission ("Commission") to supplement its application for United States market access.[1] Although OneWeb and its orbital debris mitigation plans are already subject to direct and effective oversight by the United Kingdom Space Agency, OneWeb nevertheless submits information sufficient to satisfy all the requirements of Section 25.114(d)(14) of the Commission's rules.[2] OneWeb stands ready to work with the Commission to address any questions the agency may have with regard to OneWeb's orbital debris mitigation plans.

This Orbital Debris Mitigation Plan addresses the four critical elements of orbital debris mitigation identified by the Commission: (1) spacecraft hardware design, (2) minimizing accidental explosions, (3) safe flight profiles, and (4) post-mission disposal.[3] In particular, OneWeb emphasizes it will utilize atmospheric re-entry for post-mission disposal, which will result in each satellite burning up in its entirety during re-entry with no material surviving below an altitude of 65 km. Given the size of the OneWeb constellation, this method for post-mission disposal is the most environmentally responsible and OneWeb is proud to adopt it.

# 2.0 SPACECRAFT HARDWARE DESIGN

In accordance with the requirements of Section 25.114(d)(14)(i) of the Commission's rules, OneWeb has assessed and limited the amount of debris released in a planned manner during normal operations, and has assessed and limited the probability of the space station becoming a source of debris by collisions with small debris or meteoroids that could cause loss of control and prevent post-mission disposal.[4] OneWeb submits the following information regarding spacecraft hardware design.

## 2.1 INTENTIONAL RELEASE OF DEBRIS

No debris is intentionally released from any OneWeb satellite during any phase of its mission. The spacecraft does not employ any detachable lens caps or shrouds, and no objects are discarded in the activation of deployables (e.g., solar arrays and gateway antennas).

## 2.2 COLLISIONS WITH SMALL DEBRIS

The risk of a OneWeb satellite becoming a source of debris by collisions with small debris causing a loss of control and preventing post-mission disposal has been assessed and determined to be compliant with NASAs Technical Standard[5], which requires this probability to be <0.01.

OneWeb used NASA's ORDEM3 model to predict the estimated flux of debris of different sizes the spacecraft will encounter during each mission phase, and these were then summed to provide an aggregate risk over the entire orbital mission life. For this preliminary analysis, OneWeb made the

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1 *See* IBFS File No. SAT-LOI-20160428-00041.

2 47 C.F.R. § 25.114(d)(14). *See also* 47 C.F.R. § 25.283; Public Notice, *Disclosure of Orbital Debris Mitigation Plans, Including Amendment of Pending Applications*, 20 FCC Rcd 16278 (2005) ("Orbital Debris Public Notice").

3 Orbital Debris Public Notice at 2. *See also* 47 C.F.R. § 25.114(d)(14).

4 47 C.F.R. § 25.114(d)(14)(i).

5 NASA-STD-8719.14A, § 4.5.2.2, NASA Technical Standard, *Process for Limiting Orbital Debris*, approved May 25, 2012, available at http://www.hq.nasa.gov/office/codeq/doctree/871914.htm.

conservative assumption that an impact anywhere on the main body of the spacecraft would render it unable to execute its disposal maneuvers and evaluated the probability of impact from a debris particle > 1cm. The resulting risk, aggregated over the orbital life of a satellite, is $3x10^{-4}$.

OneWeb is pursuing a Space Act Agreement with NASA to have a higher fidelity analysis performed using their BUMPER model. Included will be a refinement of the vulnerable areas of the spacecraft. The placement of internal components and the existence of dual-walled, honeycombed outer panels provides considerable resilience against very small impacts, so OneWeb expects this analysis to confirm its compliance with the 0.01 probability threshold. Although the OneWeb space station design does not involve use of a sub-system or a set of sub-systems distinct from systems used in connection with the primary communications mission to accomplish end of life disposal,[6] the reliability of the components on each spacecraft required for disposal maneuvers (debris impacts notwithstanding) is specified to be the highest-reliability function of the spacecraft, and greater than the 0.9 benchmark set in NASA's Technical Standard.[7]

## 3.0 MINIMIZING ACCIDENTAL EXPLOSIONS

In accordance with the requirements of Section 25.114(d)(14)(ii) of the Commission's rules, OneWeb has assessed and limited the probability of accidental explosions during and after completion of mission operations.[8] OneWeb submits the following information regarding minimizing accidental explosions.

### 3.1 FRAGMENTATION FROM INTERNAL ENERGY SOURCES

OneWeb believes there is no credible scenario for any internal energy source (whether kinetic, chemical, or pressure in nature) to cause a fragmentation of the satellite at any point during its orbital life.

The internal kinetic energy sources on each spacecraft are extremely limited. For example, the only moving parts are reaction wheels, solar array drive motors, and gateway antennas, all of which are very low energy sources. Failure of these components would most likely present as friction or lack of commandability and result in any moving parts coming to rest. This may be accompanied by a temporary increase in component temperature, but insufficient kinetic energy exists to cause a fragmentation of the satellite.

The spacecraft battery represents one source of potential energy. The battery employs lithium-ion cells and charging will be actively controlled by software in the on-board computer, with provisions to protect against battery rupture that would lead to any fragmentation of the satellite.

One other source of potential energy is the propulsion system's fuel tank. Each tank is constructed with composite-overwrapped aluminum walls and is rated to a proof pressure of 1.25 times the Maximum Expected Operating Pressure (MEOP).

A Failure Modes and Effects Analysis (FMEA) is being conducted in conjunction with preparations for the satellite's Critical Design Review (CDR).

### 3.2 ENERGY DEPLETION AT END-OF-LIFE

For satellites with a significant orbital lifetime remaining after disposal maneuvers are completed, the recommended practice is to deplete all remaining internal energy sources by venting lines, depleting residual fuel, discharging batteries, etc. However, OneWeb's disposal plan calls for lowering the perigee sufficiently to facilitate rapid atmospheric re-entry, making energy depletion activities unnecessary.

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[6] Orbital Debris Public Notice at 2.

[7] NASA-STD-8719.14A, § 4.6.2.4(a).

[8] 47 C.F.R. § 25.114(d)(14)(ii).

# 4.0 SAFE FLIGHT PROFILES

In accordance with the requirements of Section 25.114(d)(14)(iii) of the Commission's rules, OneWeb has assessed and limited the probability of the space station becoming a source of debris by collisions with large debris or other operational space stations.[9] OneWeb submits the following information regarding safe flight profiles.

## 4.1 MITIGATION OF COLLISION RISK WITH LARGE OBJECTS

OneWeb has designed its satellite network to minimize the possibility of colliding with other operational space stations and large debris. For example, the operational altitude of 1,200 km was chosen in part for its low population of resident objects, and we will manage conjunctions with tracked objects throughout the satellites' orbital lifetimes.[10]

OneWeb has conducted a statistical collision risk assessment for objects larger than 10 cm using the same methodology described in section 2.2 (but using a larger spacecraft cross sectional area that includes the solar arrays) to determine the aggregate collision probability of a spacecraft over its entire mission. The requirement specified in NASA's Technical Standard[11] for 10 cm risk is 0.001, and OneWeb's assessment compares favorably at $<4.4 \times 10^{-5}$. Note that this is a conservative estimate in that it does not reflect the benefit of any collision avoidance activities.

Despite this low passive risk, OneWeb will actively and regularly screen for conjunctions between its own satellites and other objects in the Joint Space Operations Center's ("JSpOC") published catalog. We will also monitor and assess conjunction warnings issued by JSpOC and maneuver as necessary to avoid collisions with tracked objects and other operational spacecraft.

Each satellite has redundant GPS receivers on-board, and automated ground processes will compute and maintain precise orbit solutions on all of our spacecraft throughout their orbital lifetimes. Ephemeris and maneuvering information will be shared with other operators as necessary to manage conjunctions with other active satellites, and OneWeb has established data sharing agreements with the JSpOC to facilitate close cooperation and information exchanges. OneWeb is also exploring membership in the Space Data Association to assist with data exchanges with other operators.

## 4.2 ORBIT MAINTENANCE

OneWeb's constellation will operate at a mean semimajor axis (SMA) of 7,578 km, inclined 87.9˚ to the Equator. The apogee and perigee will be maintained to less than one percent of the mean SMA, and the inclination will be maintained to less than 1˚ of this target. Because OneWeb space stations will be operating in low-Earth-orbit (LEO), the ascending nodes will precess and span the full range of 0˚-360˚.

## 4.3 MITIGATION OF COLLISION RISK FOR INHABITABLE ORBITING OBJECTS

OneWeb will be operating in LEO and will be particularly cautious when passing through altitude bands occupied by habitable orbiting objects. All of our satellites will be deployed from their launch vehicles well above the International Space Station (ISS), but disposal operations will result in a brief period of overlap upon descent. OneWeb will maintain precise orbit ephemerides during this phase of the mission and will coordinate with operators of any inhabited space object and maneuver to avoid it as necessary.

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[9] 47 C.F.R. § 25.114(d)(14)(iii).

[10] OneWeb's analysis does not include non-operational systems, such as Boeing's proposed V-band system. OneWeb will engage in good faith discussions to determine the degree of separation required between large NGSO constellations to operate safely.

[11] NASA-STD-8719.14A, § 4.5.2.1.

# 5.0 POST-MISSION DISPOSAL

In accordance with the requirements of Section 25.114(d)(14)(iv) of the Commission's rules, OneWeb submits the following information regarding the post-mission disposal plans for the space stations at end of life.[12]

## 5.1 SATELLITE DISPOSAL

Upon decommissioning of each satellite in the network, OneWeb will conduct a deorbit operation in which the decommissioned satellite's altitude is first reduced to extract it from the constellation, and then perigee-lowering maneuvers will be conducted to remove the satellite from orbit.

The propulsion systems on OneWeb satellites use electric thrusters, fueled by Xenon gas. The propulsion tank is loaded with approximately 12 kg of fuel at launch and is instrumented with temperature and pressure sensors to gauge remaining fuel with an uncertainty of less than 100g. Sufficient fuel is allocated to achieve a 200 km x 1,100 km elliptical disposal orbit, which amounts to approximately 4.4 kg.

The satellite is designed for a mission life of at least five years. The post-mission disposal operation is anticipated to take less than one year, and the remaining orbital lifetime for a satellite with a perigee of 200 km is expected to be less than three months.

## 5.2 RE-ENTRY CASUALTY RISK

OneWeb has conducted a preliminary re-entry risk analysis using NASA's DAS software. The spacecraft was modeled to a level of fidelity that included 192 components (28 unique) and three levels of encasement. As modeled, DAS indicates the entire satellite will burn up during uncontrolled re-entry with no material surviving below an altitude of 65 km.[13] Accordingly, the risk of human casualty on the ground from OneWeb satellites re-entering the atmosphere is zero.

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[12] 47 C.F.R. § 25.114(d)(14)(iv).

[13] *International Bureau Satellite Division Information*, Public Notice, SPB-208, DA 04-1724 (rel. June 16, 2004).