APPENDIX B

MITIGATION OF ORBITAL DEBRIS ASSESSMENT

Each of the Capella Space Corp. ("Capella") Synthetic Aperture Radar ("SAR") satellites (the "Capella Satellites") proposed in this application will release two small debris during the deployment of their solar panels. These consist of two structural vectran tie lines that will be cut in order for the solar panels to deploy. The generated debris meets NASA-STD 8719.14 Requirement 4.3-1.

Capella intends to utilize the Capella Satellites for their intended purposes from the point at which the satellites are placed into their operational orbits until final re-entry into the atmosphere is imminent. Reentry will be imminent at an altitude of approximately 200 km. At all altitudes down to the reentry altitude, Capella will maintain the Capella Satellites' power flux density at levels within the applicable International Telecommunication Union limits by reducing satellite transmitter power on a graduated basis as the Capella Satellites near the Earth.[1]

Capella has assessed and limited the possibility that the Capella Satellites could become a source of debris as a result of collision with large debris or other operational spacecraft. Capella does not intend to place the Capella Satellites in an orbit that is identical to or very similar to an orbit used by other space stations. Capella will also work closely with its launch providers to ensure that the Capella Satellites are deployed in such a way as to minimize the potential for collision with any other spacecraft, specifically including manned spacecraft.

To the best of Capella's understanding, the International Space Station and China's Tiangong-2 Space Station module are the only presently or imminently inhabited orbiting objects.[2] The operational altitude of the International Space Station is approximately 400 km,[3] and the altitude of the Tiangong-2 space module is approximately 393 km.[4] While both facilities are significantly below the Capella Satellites' operational orbit altitudes of 550 km or higher, Capella will be proactive in ensuring that any risks to inhabitable orbiting objects posed by the Capella Satellite are mitigated. This will include coordinating with the National Aeronautics and Space Administration ("NASA") to ensure protection of the International Space Station on an

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1 Capella satellite transmitters are able to adjustment the RF output power from 0.01 to 10W.

2 The Tiangong-2 spacecraft is an experimental space module that is destined to be part of a larger space complex over the next decade. It will be intermittently inhabited.

3 *See* AstroViewer, NASA, Current Position of the ISS, *available at* http://iss.astroviewer.net/.

4 See Chinadaily.com.cn, Tiangong-2 space lab enters preset orbit for docking with manned spacecraft, at http://www.chinadaily.com.cn/china/2016-09/26/content_26891749.htm.

ongoing basis, and coordinating with the China National Space Agency with respect to Tiangong-2 and successor vehicles. Capella will provide both agencies with any information they need to assess risks and ensure safe flight profiles, and with contact information for Capella personnel on a 24 hours per-day/7 days per-week basis. Through these measures, Capella will be able to avoid collisions even if, at some point in the future, there is less separation in orbits than is anticipated today.[5]

Capella has also assessed the possibility of the Capella Satellites becoming a source of debris by collision with small debris or meteoroids of less than 1 cm in diameter that could cause loss of control and prevent post-mission disposal. At an altitude of 600 km, the probability of mission failure from a small object is 0.001435%, as predicted by the NASA DAS v2.0.2.

Capella has assessed the possibility of accidental explosions during and after completion of mission operations through a failure mode verification analysis. As part of the satellite manufacturing process, Capella has taken steps to ensure that debris generation will not result from the conversion of energy sources onboard the Capella Satellites into energy that fragments the satellites. All sources of energy onboard the Capella Satellites will have been depleted or safely contained when they are no longer required for mission operations or to accomplish post-mission disposal.

Subsection 25.114(d)(14)(iii) of the Federal Communications Commission's rules calls upon applicants to specify the accuracy with which the orbital parameters of their non-geostationary satellite orbit space stations will be maintained.[6] The Capella Satellites will include a propulsion system and, as a result of regular corrective propulsive maneuvers by Capella, are anticipated to remain in their planned orbit within the accuracy ranges given in Table 1 below. At end of life, the Capella Satellites will be in orbits that gradually decay over time until the satellites reenter the atmosphere. At the maximum initial altitude of 600 km, the Capella Satellites in their nominal end of life configuration will reenter the atmosphere in approximately 6 to 12 months, as calculated by NASA Software DAS v2.0.2.

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[5] Capella will take similar proactive measures with respect to any other inhabitable orbiting objects that may be introduced during the time the Capella Satellites are in orbit. In particular, Capella notes that testing of inhabitable space objects by Bigelow Aerospace LLC may occur during the license term.

[6] 47 C.F.R. § 25.114(d)(14)(iii).

	Capella Orbital Parameters Accuracy
Inclination Angle (deg)	+/- 0.1
Apogee (km)	+/- 20
Perigee (km)	+/- 20
Semi-major Axis (km)[7]	+/- 1.0
Right Ascension of the Ascending Node (deg)[8]	+/- 0.25

Table 1. Anticipated orbit maintenance accuracy for the Capella Satellites

Capella's disclosure of the above information can assist third parties in identifying potential problems that may result from proposed operations. This information also lends itself to coordination between Capella and other operators located in similar orbits.

Finally, the orbits of the Capella Satellites will decay because of atmospheric drag. The Capella Satellites will eventually naturally de-orbit by atmospheric reentry. At the end of the mission operations, the attitude control system can orient the Capella Satellites into a maximum drag configuration with the solar panels and SAR antenna in the direction of the velocity, thus accelerating the orbital decay. This configuration is the stable equilibrium under gravity gradient and drag, which means that even in the case of Attitude, Determination, and Control System ("ADCS") failure, the satellite will eventually assume this position naturally.

The analyses below were done assuming natural orbit decay.

With regard to the post-mission disposal of the Capella Satellites in or passing through low Earth orbit, the altitude of the Capella Satellites is computed from their initial circular orbit at the altitude of 600 km, in their end of mission configuration. The atmospheric reentry occurs less than 12 months after launch, assuming the highest possible apogee (600 km) and nominal end-of-life configuration of the Capella satellites. Even in the worst-case scenario where the minimum drag configuration is maintained throughout the entire lifetime, the Capella Satellites will reenter within 7 years, which is well within the acceptable 25-year reentry time.

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7 Semi-major axis will be maintained with a tight tolerance. Eccentricity will be kept small, but is expected to vary, causing fluctuations in apogee and perigee altitudes.

8 RAAN tolerance given is relative to a rotating sun-sync orbital plane, which regresses to match the Sun's apparent motion to the Earth.

Additionally, in connection with post-mission disposal of the Capella Satellites in Earth orbit, the maximum drag configuration is the dynamically stable orientation, which means that even in the case of massive power or ADCS failure, the Capella Satellites should eventually assume this orientation and reenter the atmosphere within a year after the end of mission operations.

The risk of human casualty for an uncontrolled entry was computed to be 1:0 by NASA Software DAS v2.0.2. This is equivalent to approximately a 0% chance of casualty. The results are summarized in Table 2 below.

Component	Qty	**Material**	**Shape**	**Mass (kg)**	**Dem. Alt. (km)**	**Cas. Area (m^2)**	**En. (J)**
Side Panels	4	Aluminum	Flat Plate	0.9	75.5	0	0
Top Panel	1	Aluminum	Flat Plate	0.54	75.5	0	0
Bottom Panel	1	Aluminum	Flat Plate	0.54	75.5	0	0
SAR Antenna	1	Aluminum	Flat Plate	0.3	78	0	0
Antenna Feed	1	Aluminum	Cylinder	2	75.3	0	0
Dplymt Arms	1	Aluminum	Cylinder	3	75.6	0	0
Avionics	1	Fiberglass	Box	22.7	69.3	0	0
Batteries	64	Molybdenum	Cylinder	0.025	0	25.74	6
Solar Panels	2	Fiberglass	Flat Plate	1	77.3	0	0

Table 2. Human casualty risk analysis