APPENDIX B

MITIGATION OF ORBITAL DEBRIS ASSESSMENT

The Capella Space Corp. ("Capella") Synthetic Aperture Radar ("SAR") satellite (the "Capella Satellite") proposed in this application will release no small debris commissioning or operations.

Capella intends to utilize the Capella Satellite for its intended purposes from the point at which the satellite is placed into its operational orbit 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 Satellite's power flux density at levels within the applicable International Telecommunication Union limits by reducing satellite transmitter power on a graduated basis as the satellite nears the Earth.[1]

Capella has assessed and limited the possibility that the Capella Satellite 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 Satellite 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 Satellite is 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 baseline minimum operational orbit altitude of 450 km. for the Capella Satellite, 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 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

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1 Capella satellite transmitters are able to adjustment the RF output power from 0.01 to 5W.

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, 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.

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 Satellite 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. The probability of mission failure from a small object is 0.0126%, as predicted by the NASA DAS v2.1. The probability of collision with a large object in LEO has also been computed to be 0.006%.

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 Satellite into energy that fragments the satellite. All sources of energy onboard the Capella Satellite 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 ("FCC" or the "Commission") 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 Satellite will include a propulsion system and, as a result of regular corrective propulsive maneuvers by Capella, is anticipated to remain in its planned orbit within the accuracy ranges given in Table 1 below. At end of life, the Capella Satellite will be in orbits that gradually decay over time until the satellite reenters the atmosphere. At the minimum initial altitude of 425 km., the Capella Satellite will reenter the atmosphere in approximately 1.8 years; at the maximum initial apogee of 630 km, reentry will occur within 3.7 years (as calculated by NASA Software DAS v2.1).

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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 when Capella spacecraft 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 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 orbit of the Capella Satellite will decay because of atmospheric drag. The Capella Satellite will eventually naturally de-orbit by atmospheric reentry. At the end of the mission operations, the attitude control system can orient the Capella Satellite 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 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 Satellite in or passing through LEO, the altitude of the Capella Satellite is computed from its initial circular orbit at the altitude of 620 km., in its end of mission configuration. The atmospheric reentry occurs less than 4 years after launch, assuming the highest possible apogee (620 km.). Even in the worst case where the minimum drag configuration is maintained throughout the entire lifetime, the Capella Satellite will reenter within 14 years, which is well within the acceptable 25-year reentry time.

Additionally, in connection with post-mission disposal of the Capella Satellite in Earth orbit, the maximum drag configuration is the dynamically stable orientation, which means that

[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.

even in the case of massive power or ADCS failure, the Capella Satellite 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 1:84300 by NASA Software DAS v2.1. The results are summarized in the table below.

Component	Qty	Material	Shape	Mass (kg)	Dem. Alt. (km)	Cas. Area (m^2)	En. (J)
Bus Structure	1	Aluminum	Box	24	66.1	0	0
Batteries	64	Aluminum	Cylinder	0.0625	76.6	0	0
Reaction Wheels	3	Aluminum	Cylinder	3.2	66.3	0	0
Avionics	1	Aluminum	Box	24.9	50.5	0	0
Tanks	2	Titanium	Box	0.15	0	1.04	15
Radio Stack 1	1	Aluminum	Box	1	72.5	0	0
Radio Stack 2	1	Aluminum	Box	2.5	65.6	0	0
SAR Antenna	40	Aluminum	Cylinder	1	75.6	0	0
Solar Array	2	Aluminum	Flat Plate	2.4	75.8	0	0
Torque Rods	3	Copper	Cylinder	0.6	75.0	0	0
Star Trackers	2	Aluminum	Box	0.3	75.3	0	0
Thruster	1	Aluminum	Box	2.5	65.6	0	0
Payload	1	Aluminum	Box	4	67.1	0	0

Table 2. Human Casualty Risk Analysis