Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC

Application of Space Logistics, LLC	)	File No. SAT-LOA- _______
for Authority to Launch and Operate a Mission	)	
Extension Vehicle	)	

APPLICATION FOR AUTHORITY TO LAUNCH AND OPERATE A MISSION EXTENSION VEHICLE

Space Logistics, LLC ("Space Logistics"), a wholly-owned subsidiary of Orbital ATK, Inc. ("Orbital ATK"), hereby applies for authority to launch and operate the MEV-1 spacecraft. MEV-1 is a mission extension vehicle ("MEV"), which has the capability to service multiple in-orbit satellites in geosynchronous orbit ("GSO") by cooperatively docking with the satellites and performing the station keeping and attitude control functions for the satellites as a combined vehicle stack ("CVS"). For MEV-1's initial mission, Space Logistics has contracted with Intelsat Satellite LLC ("Intelsat") to provide life extension service to the Intelsat 901 ("IS-901") spacecraft, the client vehicle ("CV"). Space Logistics and Intelsat will operate the satellites as a CVS with Space Logistics using the MEV to perform all station keeping and attitude control of the CVS under the direction of Intelsat.

As Space Logistics approaches the completion of the Intelsat contract, the company will seek approval to relocate MEV-1 and perform services for another GSO satellite. The MEV-1 is able to perform several types of services including the following:

- Inclination reduction;
- Long-term station keeping and attitude control of customer satellites;
- Relocation of customer satellites to different GSO orbital slots or to different orbits;
- Relocation of customer satellites into the graveyard orbit; and

- Performance of cooperative inspections of customer satellites.

MEV-1 will be the first commercial spacecraft of its kind, and its success will open new markets and create new opportunities.[1] By enhancing in-orbit flexibility and end-of-life options for GSO satellite operators, Space Logistics will be able to assist those operators in maximizing the value of their in-orbit assets and allow them to better respond to customer demand.[2] Space Logistics will conduct the operations of MEV-1 at all times in a responsible, transparent, and cooperative manner, consistent with the rules of the Federal Communications Commission ("FCC") and U.S. treaty obligations, as discussed herein.[3] For these reasons, Space Logistics submits that grant of the application is in the public interest.

I. BACKGROUND AND SYSTEM DESCRIPTION

Orbital ATK is a global leader in the manufacturing and operations of commercial, civil, and U.S. national security satellites and launch systems.[4] For decades, Orbital ATK has built spacecraft busses for a variety of missions, including geosynchronous orbit, medium-Earth orbit,

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[1] *See Satellite Mission Extension Services*, Orbital ATK, https://www.orbitalatk.com/space-systems/human-space-advanced-systems/mission-extension-services/default.aspx (last visited Jan. 12, 2017).

[2] *See* Press Release, Pioneers in Space: Orbital ATK Announces Intelsat as Anchor Customer for New Satellite Life Extension Service, Orbital ATK (Apr. 12, 2016), http://www.orbitalatk.com/news-room/release.asp?prid=137; Jason Rhian, *Intelsat Taps Orbital ATK's MEV-1 to Extend Life of Orbiting Satellites*, Spaceflight Insider (Apr. 13, 2016), http://www.spaceflightinsider.com/organizations/orbital-sciences-corp/intelsat-taps-orbital-atks-mev-1-extend-life-orbiting-satellites/.

[3] Space Logistics is also aware of the requirement for MEV-1 to obtain from the National Oceanic and Atmospheric Administration ("NOAA") a private remote sensing license for the operation of its onboard cameras and will obtain that license prior to launch. *See* http://www.nesdis.noaa.gov/CRSRA/licenseHome.html (last visited Jan. 12, 2017).

[4] Orbital ATK was formed from the merger of Orbital Sciences Corporation and the aerospace and defense groups of Alliant Techsystems Inc.

low-Earth orbit, and interplanetary missions.[5] Orbital ATK's proposed mission extension services, beginning with MEV-1, are an outgrowth of Orbital ATK's experiences and pioneering efforts in the provision of space services.

MEV-1 is based on Orbital ATK's GEOStar bus, which is used to provide broadcasting satellite service, fixed satellite service, and other applications.[6] Orbital ATK has built and flown more than 30 GEOStar-2 satellites and is currently building three GEOStar-3 satellites, as well as many more civil and national security satellites for the U.S. government.

The GEOStar-2 is a fully redundant, flight-proven spacecraft bus designed for GSO missions.[7] The bus is designed specifically for the 1,000 to 5,550 watt payload class and provides a low- to medium-power platform. Orbital ATK's first application of the GEOStar-2 bus design, N-STAR c, was successfully launched in July 2002 on the Ariane rocket.

The GEOStar-3 satellite platform represents an evolutionary growth of Orbital ATK's GEOStar-2 platform, providing an expansion of the flight-proven GEOStar-2 product line.[8] Enhancements include an increase in battery capacity and solar array power, enabling GEOStar-3 to provide up to 8,000 watts of power to the payload at end-of-life. The larger solar arrays and additional battery capacity retain the 100 percent successful flight heritage 36-volt regulated power bus. The GEOStar-3 bus structure's mass carrying capability and propellant tank

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[5] *See Spacecraft Busses*, Orbital ATK, https://www.orbitalatk.com/space-systems/spacecraft-buses/default.aspx (last visited Jan. 12, 2017).

[6] *See Communications Satellites*, Orbital ATK, https://www.orbitalatk.com/space-systems/commercial-satellites/communications-satellites/ (last visited Jan. 12, 2017).

[7] Fact Sheet: GEOStar-2 Bus, Orbital ATK, https://www.orbitalatk.com/space-systems/science-national-security-satellites/national-security-systems/docs/GEOStar2_Fact_Sheet.pdf (last visited Jan. 12, 2017).

[8] Fact Sheet: GEOStar-3 Bus, Orbital ATK, http://www.orbitalatk.com/space-systems/spacecraft-buses/docs/GEOStar-3.pdf (last visited Jan. 12, 2017).

accommodation enable optimal use of launch vehicle performance, and can include tandem launch missions that use heritage bi-propellant apogee engines to ensure fast and reliable orbit raising. For heavier missions involving the GEOstar-3 bus, a flight-proven electric propulsion system replaces the heritage improved electrothermal hydrazine thrusters for station-keeping operations.

Orbital ATK is also a leader in the emerging space logistics market. Orbital ATK is one of only two companies in the world providing commercial cargo resupply services to the International Space Station ("ISS") for the National Aeronautics and Space Administration ("NASA"). In support of those missions, Orbital ATK developed the Antares launch vehicle and the Cygnus advanced maneuvering spacecraft, which performs rendezvous and proximity operations and berthing maneuvers to provide supplies to the ISS.[9] Since 2013, Orbital ATK has built and flown six Cygnus spacecraft to the ISS.[10] Orbital ATK commenced its most recent cargo delivery mission in October 2016, carrying approximately 5,300 pounds of supplies to support science and research studies conducted by space station crews.

MEV-1 is based on the GEOStar bus structure and avionics architecture, and the rendezvous, proximity operations, and docking ("RPOD") subsystem is derived from the Cygnus spacecraft. The architecture includes fully cross-strapped and redundant avionics and a structure designed for dual launch. Other design features include 10-kilowatt end-of-life solar array

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[9] *See Antares*, Orbital ATK, https://www.orbitalatk.com/flight-systems/space-launch-vehicles/antares/ (last visited Jan. 4, 2017); *Company Overview*, Orbital ATK, https://www.orbitalatk.com/about/company-overview/ (last visited Jan. 12, 2017); *Commercial Resupply Services*, Orbital ATK, https://www.orbitalatk.com/space-systems/human-space-advanced-systems/commercial-resupply-services/ (last visited Jan. 12, 2017).

[10] *See* Press Release, Orbital ATK Successfully Launches Sixth Cargo Delivery Mission to International Space Station, Orbital ATK (Oct. 17, 2016), https://www.orbitalatk.com/news-room/release.asp?prid=192.

power, a dual C-band and Ku-band flexible frequency communications system, and a hydrazine propulsion system as well as an electric propulsion system. The RPOD subsystem uses optical, infra-red, and LIDAR-based sensing systems.[11]

A. Space Segment

MEV-1 has a 15-year design life and sufficient fuel to enable more than 15 years of operations while docked with a typical 2000 kg GSO communications satellite.[12] MEV-1's RPOD systems are designed for several dockings and undockings during the life span of the MEV, allowing it to service multiple GSO satellites.

As discussed in more detail in the Technical Appendix, MEV-1 will only have telemetry, tracking, and command ("TT&C") communications capability, which can operate in the C-band frequencies (5925 – 6425 MHz (uplink) and 3700 – 4200 (downlink)) and/or the Ku-band frequencies (13750 – 14500 MHz (uplink) and 11450 – 12250 MHz (downlink)) depending on the specific mission needs.[13] This ability to operate in two common satellite frequency bands, along with the ability to select the specific frequency within the band while in orbit, enhances the spacecraft's flexibility to serve different in-orbit satellites by operating within the customer's licensed and coordinated frequency band or, otherwise, on a non-interference basis.

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[11] LIDAR means light detection and ranging.

[12] *See* Fact Sheet: Mission Extension Services, Orbital ATK, http://www.orbitalatk.com/space-systems/human-space-advanced-systems/mission-extension-services/default.aspx (last visited Jan. 12, 2017).

[13] Such TT&C capability will include the transmission of imaging and other data to support RPOD operations. *See* Technical Appendix at Sections 3.1.1, 4.1 and 11.4. Space Logistics is providing technical information for both frequency bands, consistent with FCC precedent. *See, e.g.*, Letter to Daniel C.H. Mah, Regulatory Counsel for SES, from Robert G. Nelson, Chief, Satellite Division, International Bureau, FCC, 25 FCC Rcd. 2112 (March 2, 2010).

B. Ground Segment

The Mission Operations Center ("MOC") for MEV-1 will be located in Orbital ATK's Dulles, Virginia facilities. The MOC will provide monitoring and control and on-call engineering support around the clock and include a team of full-time engineering support staff.

During orbit raising and drift, MEV-1 will be supported by a network of ground stations operating in the C-band frequencies and Ku-band frequencies. At its operating location, the MEV-1 will be supported by a network of ground stations using frequencies authorized and coordinated for the CV, as discussed below. Although Space Logistics and Intelsat will use the same ground stations to communicate with the two satellites, there will be separate data paths for the communications to the respective MOCs.

II. AUTHORITY REQUESTED FOR MEV-1

By this application, Space Logistics requests FCC authority to launch and operate MEV-1.[14] The requested authority includes post-launch operations of MEV-1 as it: (i) is deployed from the launch vehicle; engages in orbit-raising maneuvers and conducts various post-launch system verification tests; and moves through the geosynchronous transfer orbit ("GTO"); (ii) raises its orbit to the GSO "graveyard" orbit 300 km above the GSO orbital arc; (iii) performs RPOD with IS-901 in the graveyard orbit; (iv) relocates with IS-901, as a CVS, to replace an operational Intelsat satellite to be specified at a later date and operates at that location for an expected five years; (v) relocates to the graveyard orbit with IS-901 at the completion of the mission; and (vi) undocks from the IS-901, leaving it to be decommissioned by Intelsat.

[14] Consistent with 47 C.F.R. § 25.113(f), Space Logistics has commenced construction of MEV-1 at its own risk. *See* Attachment 1 to this Narrative.

MEV-1 is expected to be launched by a Proton rocket in the fourth quarter of 2018. After deployment into the GTO, Space Logistics will communicate with MEV-1 for TT&C using the C-band frequencies to configure the MEV and perform initial checkout, including conducting a number of in-orbit tests in both the C-band and Ku-band frequencies, with ground stations authorized to communicate with MEV-1. All such operations and testing in the GTO will be coordinated with potentially affected GSO satellite operators.

After completion of these tests, MEV-1 will perform its orbit-raising from the initial GTO to the graveyard orbit 300 km above the GSO arc. Separately, Intelsat will apply for the necessary authority and, upon approval, relocate IS-901 to the graveyard orbit. MEV-1 will use its RPOD system to reliably and safely rendezvous and dock with IS-901 at the graveyard orbit.[15] Transmissions during relocation and RPOD will be coordinated with potentially affected GSO satellite operators.

After successfully completing the RPOD in graveyard with IS-901, MEV-1 will perform all station keeping and attitude control functions for the CVS. MEV-1 will then relocate the CVS from the graveyard orbit to the orbital location (the "Replacement Orbital Location") of another operational Intelsat satellite (the "Replaced Satellite"). Transmissions during this relocation will be coordinated with potentially affected GSO satellite operators.

Intelsat will specify at a subsequent date both the Replacement Orbital Location and the Replaced Satellite in its application for modification of the IS-901 license seeking authority to relocate, dock, and operate with MEV-1 as a CVS. That modification application would be subject to public notice and comment and FCC approval, ensuring transparency and opportunity

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[15] MEV-1 will not have power or data interfaces with IS-901, or any CV with which it has docked, and the docking system will be the only physical connection between MEV-1 and IS-901.

for informed public comment.[16] Space Logistics will also update its application or license, as applicable, at that later time to identify the specific operating orbital location of the CVS.[17]

After the docking of the two spacecraft, IS-901 will not engage in any station keeping or attitude control maneuvers. Rather, those functions will be conducted by MEV-1. IS-901 will continue to communicate satellite health and telemetry data on its authorized TT&C frequencies and as coordinated between the parties. Intelsat will continue to operate the IS-901 communications payloads and manage its other subsystems.

Space Logistics anticipates that MEV-1 will operate as a CVS with IS-901 for at least five years. After completion of that service, MEV-1 will relocate with IS-901 as a CVS to the graveyard orbit and undock from the IS-901, leaving it to be decommissioned by Intelsat. Prior to the expiration of its contractual arrangement with Intelsat, Space Logistics will seek FCC approval, as well as any other applicable regulatory approvals, to relocate MEV-1 and perform its next mission.[18]

Based on the initial successful safe docking operations with the IS-901 satellite in the graveyard orbit and the verification of the RPOD debris mitigation systems and procedures described in the Technical Appendix, Space Logistics intends to perform all future RPOD missions at or near the GSO arc, as requested by the client satellite operators. Allowing a proven MEV to have the flexibility for such operations would minimize service disruptions to end users

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[16] *See* 47 C.F.R. § 25.151.

[17] *See infra* Section III.B.

[18] If the client satellite operator for future missions is foreign-licensed, then the Commission and foreign administrators may need to exchange letters of understanding regarding the operations of the CVS, consistent with the Commission's practice regarding the use of shared orbital assets. *See, e.g.*, Stamp Grant, *Intelsat License LLC*, Call Sign S2801, File No. SAT-A/O-20091208-00141 (granted June 4, 2012); *PanAmSat Licensee Corp.*, Order and Authorization, 18 FCC Rcd. 19680, 19685-88 (Sat. Div. 2003).

and expand the scope of satellite operators which could take advantage of the life extension services.[19] Moreover, allowing RPOD at or near the GSO arc would significantly enhance the value of life extension services and encourage the development of the satellite servicing business.

III. WAIVER REQUESTS

A. Bond Requirement

Space Logistics requests waiver of the FCC's bond requirement.[20] No "new" spectrum is effectively being requested for use by MEV-1. As explained above, for its initial mission, MEV-1 will dock with IS-901, which operates in C-band and Ku-band frequencies. MEV-1 will then relocate the CVS to the Replaced Satellite Location, where MEV-1 is expected to use only those C-band and/or Ku-band frequencies already authorized and coordinated for use by the Replaced Satellite.[21] To the extent that the CVS would use any frequencies not already authorized at the Replaced Satellite Location, Intelsat would be expected either to post a bond or seek a waiver of the bond as part of Intelsat's request to relocate IS-901, and there would be no purpose in requiring that Space Logistics also post a bond for those same frequencies.[22] Thus, there can be no risk or threat of spectrum warehousing by MEV-1, the prevention of which is the underlying

[19] For example, some satellite operators could not mitigate service interruption through the use of other satellites, and could not bear the costs of a service interruption resulting from conducting RPOD at the graveyard orbit.

[20] 47 C.F.R. § 25.165(a).

[21] Space Logistics and Intelsat also will have coordinated the use of the TT&C frequencies as between MEV-1 and IS-901.

[22] *See, e.g., Telesat Canada*, Order, 22 FCC Rcd. 588, 588 ¶ 1 (IB 2007) (granting Telesat's request to add the C- and Ku-band payloads of ANIK F3 to the Commission's Permitted Space Station List and waiving the bond requirement "in light of the fact that another party ha[d] already filed a bond for ANIK F3").

purpose of the bond requirement.[23] Moreover, requiring Space Logistics to divert resources from the development and deployment of MEV-1 when there can be no spectrum warehousing concerns is counter to the Commission's recently stated policy goals and efforts to revise its bond requirement "to encourage the rapid deployment of new spacecraft and the optimal utilization of scarce orbital and spectrum resources."[24]

B. Requested Orbital Location

Space Logistics requests waiver of the requirement to specify an operating GSO orbital location for MEV-1 in this application.[25] Allowing Intelsat to delay the identification and selection of the Replaced Satellite until a time closer to the replacement of that satellite by the CVS enhances the flexibility and value of the MEV service by allowing Intelsat to direct the CVS to the orbital location in the greatest need of service at that time. Further, allowing the identification of the Replacement Orbital Location at a later date is consistent with Intelsat's practice of providing 6 to 12 months' notice of a satellite transition to end-user customers and, thus, meets Intelsat's business needs.

Importantly, the omission of the specific GSO orbital location of MEV-1 in this application does not prejudice any potentially affected parties. As part of the application, Space Logistics has demonstrated that MEV-1 complies generally with the FCC's two-degree spacing

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[23] *See, e.g.*, *Comprehensive Review of Licensing and Operating Rules for Satellite Services*, Further Notice of Proposed Rulemaking, 29 FCC Rcd. 12116, 12123-24 ¶ 19 (2014) ("*2014 Satellite Services NPRM*"); *see also Comprehensive Review of Licensing and Operating Rules for Satellite Services*, Second Report and Order, 30 FCC Rcd. 14713, 14735 ¶ 53 (2015) ("*2015 Satellite Services Order*").

[24] *2015 Satellite Services Order* at 14735 ¶ 53.

[25] *See* 47 C.F.R. § 25.114(c)(5).

policy with respect to its TT&C operations.[26] The subsequent Intelsat modification application for IS-901, which will be placed on public notice for comment, will either demonstrate or certify that the operations of the CVS at the Replacement Orbital Location will comply with the two-degree spacing policy and that the CVS will operate at that location with a safe flight profile. Space Logistics accepts that its MEV-1 license will be conditioned on a requirement to operate the CVS within frequencies and technical parameters authorized in the IS-901 license for the Replacement Orbital Location. Space Logistics further accepts that its MEV-1 license may be conditioned on a subsequent demonstration that the CVS will have a safe flight profile at the Replacement Orbital Location.

C. Requested Frequencies

Space Logistics believes that this application for use of a subset of the IS-901 C-band and/or Ku-band frequencies by MEV-1 for TT&C can be processed without waiver of the Commission's rules.[27] The CVS will replace an operational Intelsat C-band and/or Ku-band satellite. Intelsat is authorized or will be authorized to operate in those frequencies at the Replacement Orbital Location. MEV-1 will coordinate with Intelsat and operate on a subset of the frequencies authorized to and coordinated for IS-901 at the Replacement Orbital Location. Thus, the use of frequencies pursuant to this application is not mutually exclusive with and will not cause harmful interference to IS-901. As stated above, Space Logistics accepts that its license will be conditioned on a requirement to operate within frequencies and technical parameters authorized to IS-901 at the Replacement Orbital Location.

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[26] *See* Technical Appendix at Section 9.1, Annex E, and Annex F.

[27] *See* 47 C.F.R. §§ 25.112, 25.155, 25.158.

For the same reasons, the operations of MEV-1 on the requested frequencies do not violate the FCC's two-degree spacing requirement.[28] Nonetheless, to the extent necessary, Space Logistics requests waiver of any Commission rules, including the U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106, necessary to process Space Logistics' application for use of the C-band and Ku-band frequencies for TT&C at the same location as IS-901 and as identified in this application.

D. Schedule S

Space Logistics clarifies certain of its responses to the Schedule S and, to the extent necessary, requests a limited waiver of the Commission's rules, which requires certain information to be provided in the Schedule S.[29]

- In response to the Schedule S question regarding "Orbital Longitude Information," Space Logistics entered a value of "0" because the program would not permit completion of the Schedule S form without an entry in that field. As discussed above, Space Logistics requests a waiver of the requirement to specify an operating orbital location for MEV-1 in this application.[30]

- The Schedule S requests channel width and center frequency information for each transmit and receive channel. As discussed in more detail in the Technical Appendix, the MEV-1 TT&C system is tunable in increments of 100 kHz. Accordingly, providing this information would require thousands of entries and would be burdensome. Instead, Space Logistics has provided a representative sample in the Schedule S using the center of the C-band and Ku-band frequencies for each data mode.[31]

- In response to the Schedule S questions requiring minimum and maximum saturation flux density for the command beams, Space logistics entered "-1" and "0," respectively, because the program would not permit completion of the

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[28] *See* 47 C.F.R. §§ 25.114(d)(7), 25.140(a).

[29] *See* 47 C.F.R. § 25.114(c).

[30] *See supra* Part III.B.

[31] *See* Technical Appendix at Section 4.1.

Schedule S form without entries in those fields. The provision of this information is not applicable to command beams, and MEV-1 has no other receiving beams.[32]

- The polarization for the Ku-band beams is switchable. However, the Schedule S form would not permit an entry in that field, and accordingly, there is no response.

Further, strict application of the rules here is unnecessary to serve the purposes of the rules, which is to ensure that the Commission has all the relevant information to evaluate the application. Because Space Logistics has provided all relevant information in the Narrative, Technical Appendix and Schedule S, waiver of these Schedule S requirements is appropriate.[33]

IV. PUBLIC INTEREST

Grant of this application will serve the public interest by extending the service life of the IS-901 satellite and ensuring continuity of service to customers at the orbital location of the Replaced Satellite.[34] MEV-1's life-extending ability makes efficient use of resources and maximizes the value of investments by satellite operators. Further, the use of an MEV generally allows operators to better manage in-orbit satellite assets and increases flexibility with respect to the timing of construction of new replacement satellites. The Commission has consistently recognized the "huge costs of building and operating satellite space stations" and has historically adopted policies that enhance the value of those investments.[35] Moreover, grant of this

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[32] *See* 47 C.F.R. § 25.114(c)(v).

[33] *See* 47 C.F.R. § 1.3; *see, e.g.*, Stamp Grant, ViaSat, Inc., SAT-LOI-20140204-00013 (granted Jun. 18, 2014) (waiving Schedule S requirements because they were found to be unnecessary for the space station application).

[34] *See, e.g., Amendment of the Commission's Space Station Licensing Rules & Policies*, 18 FCC Rcd. 12507, 12519 ¶ 8 n.16 (2003) ("*2003 Space Station Order*") ("Commission policy favors continuity of service") (citing *Loral Spacecom Corp*., Memorandum Opinion and Order, 16 FCC Rcd. 12490, 12490 ¶ 1 (Int'l Bur., Sat. and Rad. Div., 1995)); *2015 Satellite Service Order* at 14878, Appendix C (listing "ensuring continuity of service" among the objectives of its rule revisions).

[35] *Loral Spacecom* at 12492 ¶ 7; *see also 2003 Space Station Order* at 12509-10 ¶ 7.

application will facilitate the development of innovative technologies, help maintain U.S. leadership in the satellite industry, and support the growth of U.S. jobs.

Importantly, in the provision of the proposed MEV services, Space Logistics is committed to acting responsibly, transparently, and cooperatively. Prior to filing this application, Space Logistics has communicated with all relevant government agencies, including the Department of State, NASA, NOAA, the National Security Council, the White House Office of Science and Technology Policy, the Federal Aviation Administration ("FAA"), and the FCC, to ensure that each such agency has full knowledge about the mission and flight plan and has had opportunity to provide feedback.[36] In all instances, Space Logistics has received positive support from these government agencies to proceed with the instant FCC application for launch and operation of MEV-1. Moreover, for the operational lifetime of MEV-1, Space Logistics and its relevant customer satellite operators will continue to work closely with these agencies to ensure they are aware of and understand MEV-1's plans and activities.[37]

Operationally, Space Logistics will use experienced personnel and organizations for manufacturing, integration, testing, and operations. The MEV-1 design itself is firmly based on flight-proven equipment with extensive heritage, as discussed above, and all manufacturing will be subject to industry standard requirements review and verification, including extensive ground

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[36] Further, Orbital ATK has engaged NASA through a Collaboration for Commercial Space Capabilities Space Act Agreement to review the mission and receive lessons learned and advice regarding the RPOD concept of operations and systems. *See Commercial Space Transportation*, NASA, https://www.nasa.gov/content/collaborations-for-commercial-space-capabilities-ccsc (last visited Jan. 12, 2017); NASA Space Act Agreements, NASA, https://www.nasa.gov/open/space-act.html (last visited Jan. 12, 2017).

[37] Space Logistics also will work closely with Intelsat and the launch vehicle manufacturer to establish detailed mission operations plans and procedures. As discussed in the Technical Appendix, the Space Logistics and Intelsat MOCs will be connected for safety of flight coordination. *See* Technical Appendix at Sections 3.2, 11.1, and 11.4.

testing and demonstrations. Space Logistics will incorporate a mission safety oversight committee to review each RPOD mission. Space Logistics will conduct a thorough compatibility verification and validation for each future CV and will conduct functional in-orbit tests for MEV-1 prior to docking. To further reduce potential mission risk, Space Logistics will perform the initial RPOD in the graveyard orbit, allowing MEV-1 to validate RPOD operations and functions while minimizing the theoretical risk to other operational satellites in the GSO arc. After validating the MEV's RPOD capability through this initial docking mission at the graveyard orbit, Space Logistics expects to conduct future RPOD operations at the GSO arc.[38]

All of Space Logistics' missions and activities will be conducted cooperatively with the operator of the CV and pursuant to commercial arrangements. To be clear, there will be no uncoordinated near approaches to other known resident space objects. The MEVs themselves will typically be procured and launched on a manifested basis with dedicated anchor customer contracts. All resolvable imaging will be restricted per a NOAA remote sensing license and limited to the CV. For the avoidance of doubt, Space Logistics will cease transmissions and/or disengage from IS-901 or any CV with which MEV-1 is docked to comply with any U.S. statute or Commission regulation or order, including but not limited to any direction under Section 706(c) of the Communications Act of 1934, as amended.[39]

Grant of the application would be consistent with U.S. obligations pursuant to the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space,

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[38] *See supra* Section I.A.

[39] 47 U.S.C. § 606(c).

including the Moon and Other Celestial Bodies.[40] The activities of MEV-1 will be authorized by the FCC and subject to the FCC's continuous supervision.[41] As demonstrated in the Technical Appendix, Space Logistics has taken actions to minimize the risk of potential orbital debris and will operate in a responsible, transparent and cooperative manner to ensure that MEV-1 will not cause harmful interference to the spacefaring activities of other administrations.[42]

V. INTERNATIONAL TELECOMMUNICATION UNION ("ITU") COMPLIANCE

At its operational orbit, MEV-1 will operate under the ITU filing(s) of the Replaced Satellite. Accordingly, no new ITU filings are required for the proposed operations of MEV-1 under this application.

Space Logistics will submit any ITU filings for the future operations of MEV-1 at other customer satellite locations, if needed, at the appropriate time. In that regard, Space Logistics is aware that processing fees are currently charged by the ITU for satellite filings, and that Commission applicants are responsible for any and all fees charged by the ITU.[43] Space

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[40] *See* United Nations, Office for Outer Space Affairs, 2222(XXI) Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Dec. 19, 1966), *available at* http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html.

[41] *Id*. at Article VI ("The activities of non-governmental entities in outer space, including the moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty."). FCC licensing for satellites covers the full mission cycle from construction, through deployment by launch, to end-of-life disposal. Each RPOD or any other major modification to the MEV-1 would require public notice and FCC approval. Similarly, Space Logistics will need to notify NOAA for each RPOD.

[42] *Id*. at Article IX (a State Party shall pursue studies of space and conduct exploration "so as to avoid ... harmful contamination;" a State Party should not engage in an activity that "would cause potentially harmful interference with activities of other State Parties" without appropriate consultation).

[43] *See Implementation of ITU Cost Recovery Charges for Satellite Network Filings*, Public Notice, DA 01-2435 (Oct. 19, 2001).

Logistics is aware of and unconditionally accepts this requirement and responsibility to pay any ITU cost recovery fees associated with any ITU filings that the Commission may make on behalf of Space Logistics for MEV-1 in the future.[44]

[44] *See* attached Attachment 2 (providing a signed ITU cost recovery letter).

VI. CONCLUSION

Based on the foregoing, Space Logistics respectfully requests that the Commission grant the request for authority to launch and operate the MEV-1 spacecraft.

Respectfully submitted,

/s/ Thomas L. Wilson

Thomas L. Wilson
President
Space Logistics, LLC

Tony Lin
Sarah Leggin
HOGAN LOVELLS US LLP
555 13th Street, N.W.
Washington, DC 20004

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Exhibit A

FCC Form 312, Response to Question 34: Foreign Ownership

Section 310(b)(4) of the Communications Act of 1934, as amended, establishes certain limitations on indirect foreign ownership and voting of certain common carrier and broadcast licensees. By definition, these limitations do not apply to the non-broadcast, noncommon carrier operations of Space Logistics proposed in this application.

Exhibit B

FCC Form 312, Response to Question 40
Officers, Directors, and Ten Percent or Greater Shareholders

The following are the Officers of Space Logistics, LLC ("Space Logistics"):

Officers

Thomas L. Wilson, President

Sean E. Maclean, Secretary

The address of Space Logistics and its officers is:

45101 Warp Drive
Dulles, Virginia 20166

There are no directors of Space Logistics. Space Logistics is wholly owned by Orbital Sciences Corporation, which is the 100% shareholder of Space Logistics LLC. Orbital Sciences Corporation is a wholly owned subsidiary of Orbital ATK Inc. ("Orbital ATK"), which is a Delaware corporation and is a publicly held company. The ownership of Orbital ATK is widely dispersed, and to the best of the company's knowledge no single shareholder (foreign or domestic) owns 10% or more of the equity or voting rights of the company.

The following are the executive officers of Orbital ATK:

David W. Thompson, President and Chief Executive Officer
Blake E. Larson, Chief Operating Officer
Garrett E. Pierce, Chief Financial Officer
Antonio L. Elias, Executive Vice President and Chief Technical Officer
Frank L. Culbertson, Jr., Executive Vice President and President, Space Systems Group
Michael A. Kahn, Executive Vice President and President, Defense Systems Group
Scott L. Lehr, Executive Vice President and President, Flight Systems Group
Thomas E. McCabe, Senior Vice President, General Counsel and Secretary
Christine A. Wolf, Senior Vice President, Human Resources

The following are the directors of Orbital ATK:

General Ronald R. Fogleman, U.S. Air Force (retired)
General Kevin P. Chilton, U.S. Air Force (retired)
Roxanne J. Decyk
Martin C. Faga
Dr. Lennard A. Fisk
Robert M. Hanisee
Lieutenant General Ronald T. Kadish, U.S. Air Force (retired)
Tig H. Krekel
Douglas L. Maine

Roman Martinez IV
Janice I. Obuchowski
Dr. James G. Roche, U.S. Navy (retired)
Dr. Harrison H. Schmitt
David W. Thompson
Scott L. Webster

The address for the principal executive officers and directors of Orbital ATK is:

Orbital ATK
45101 Warp Drive
Dulles, Virginia 20166

ATTACHMENT 1

Notification of Commencement of Space Station Construction

Space Logistics, LLC, pursuant to Section 25.113(f) of the Commission's rules, hereby notifies the Commission that it has commenced construction, at its own risk, of MEV-1, the space station it proposes to launch and operate in the application associated with this notification.

ATTACHMENT 2

ITU Cost Recovery Letter

DECLARATION

I, Thomas L. Wilson, hereby declare the following:

Space Logistics LLC ("Space Logistics") is aware that as a result of actions taken at the International Telecommunication Union's 1998 Plenipotentiary Conference, and further modified by the ITU Council in subsequent years (1999, 2001, 2002, 2004, 2005, 2008, 2012 and 2013), processing fees will now be charged by the ITU for satellite network filings. As a consequence, Commission applicants are responsible for any and all fees charged by the ITU. Space Logistics hereby states that it is aware of this requirement and unconditionally accepts all cost recovery responsibilities associated with the ITU filings for the MEV-1 satellite network. Please address all correspondence related to the MEV-1 satellite network to the following point of contact:

Point of Contact Name: Joseph Anderson

Organization Name: Space Logistics LLC

Address: 45101 Warp Drive
Dulles, Virginia 20166

E-Mail: joseph.anderson@orbitalatk.com

Telephone Number: 703-406-5000

Sincerely,

/s/Thomas L. Wilson

Thomas L. Wilson
President
Space Logistics, LLC

February 24, 2017

TECHNICAL APPENDIX

1 INTRODUCTION

This Technical Appendix to the Space Logistics, LLC ("Space Logistics") application for authority to launch and operate the MEV-1 spacecraft provides information in response to Section 25.114(d) of the Commission's rules and to support the application.

2 CONTACT INFORMATION

Joseph Anderson
Vice President, Operations & Business Development
Space Logistics, LLC
45101 Warp Drive
Dulles, Virginia 20166

3 GENERAL DESCRIPTION OF MEV-1 SYSTEM

MEV-1 is a mission extension vehicle ("MEV"), which has the capability to service in-orbit geosynchronous satellites by cooperatively docking with a satellite, a client vehicle ("CV"), and performing the station keeping and attitude control functions for the CV as a combined vehicle stack ("CVS"). For MEV-1's initial mission, Space Logistics has contracted with Intelsat Satellite LLC ("Intelsat") to provide life extension service to the Intelsat 901 ("IS-901") spacecraft, operating the satellites as a CVS.

Specifically, MEV-1 is capable of performing the following services:

- Inclination reduction;
- Long-term station keeping and attitude control of customer satellites;
- Relocation of customer satellites to different orbital slots or to different orbits;
- Relocation of customer satellites into the graveyard orbit; and
- Performance of inspections of customer satellites.

By enhancing in-orbit flexibility and options for GSO satellite operators, Space Logistics will be able to assist those operators in maximizing the value of their in-orbit assets and allow them to better respond to customer demand. Consistent with Space Logistics' operating philosophy, the company at all times will conduct operations in a responsible, transparent and cooperative manner, as discussed in the accompanying Narrative and this Technical Appendix.[1]

The MEV-1 system consists of the space segment (all aspects of the spacecraft and associated design) and the ground segment (all ground-based services and hardware – including test equipment, mission operations centers, transportation and launch site). Both segments are described below.

3.1 Space Segment

The MEV-1 spacecraft leverages extensive heritage from Orbital ATK's GEOStar product line of communications satellites, as well as the Cygnus spacecraft, which delivers cargo to the International Space Station (ISS).[2] The 3-axis stabilized MEV-1 spacecraft bus is designed for an in-orbit service lifetime of 15 years at or near GSO. A brief description of each subsystem is given in the following sections.

3.1.1 Tracking, Telemetry and Commanding ("TT&C")

MEV-1 will have only TT&C communications capability. Specifically, MEV-1 will have a single Ku-band transmitter (11450 – 12250 MHz space-to-Earth) and two C-band transmitters (3700 – 4200 MHz space-to-Earth), each of which is tunable in 100 kHz increments. This transmission flexibility is necessary to minimize interference and facilitate coordination with the CV and adjacent satellite operators. All three systems are circular polarized and can be

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[1] *See* Narrative at 13-16.

[2] *See* Narrative at 4.

switched between Right-Hand Circular Polarization ("RHCP") and Left-Hand Circular Polarization ("LHCP"). To the extent the TT&C transmissions are considered part of the service provided by MEV-1, such transmissions are provided on a non-common carrier basis.[3]

The uplink communication consists of command and ranging data for MEV-1. The downlink communication for MEV-1 consists of ranging data, state-of-health telemetry information, and imaging data during Rendezvous, Proximity Operations and Docking ("RPOD") operations. The C-band telemetry system has the capability to operate in three different bandwidths or modes depending on the mission phase and operational requirements, as outlined in Table 3-1. The Ku-band telemetry system operates only in low rate mode. The command uplink has a bandwidth of 1 MHz.

Downlink Telemetry Mode	**Bandwidth**	**Data Rate**
Low rate (C-band, Ku-band) – drift, RPOD, and servicing operations	200 kHz	4.8 kbps
Medium rate (C-band) – pre-rendezvous operations	400 kHz	18 kbps
High rate (C-band) – RPOD operations	2 MHz	1 Mbps

Table 3-1. Bandwidths for each MEV-1 telemetry mode.

3.1.2 Fault Management ("FM")

The mission class for MEV-1 is Single-Fault Tolerant ("SFT") rendezvous and docking with additional redundancy to address joint operations safety considerations. Safety considerations are focused on effects to entities other than MEV-1, such as the CV or other resident space objects ("RSOs"). MEV-1 is required to be SFT to catastrophic and critical

[3] *See* 47 C.F.R. § 25.114(c)(11).

hazardous mishaps as defined by systems safety. Specific FM and safety design considerations are applied to each phase of the MEV-1 mission, from pre-launch to decommission, to address the distinct activities and constraints.

3.1.3 Guidance, Navigation and Control ("GNC")

The GNC subsystem is fully redundant and cross-strapped to provide the fault tolerant, on-board functions of maintaining the attitude/pointing control, momentum control, and orbit/position control during all phases of the mission. These functions utilize a number of sensors including star trackers, sun sensors, attitude rate sensors, a specialized set of RPOD sensors (described in more detail below) and data provided from ground command. The on-board GNC flight software processes these sensor data and ground commanded inputs, to command actuators and establish the desired attitude, orbit and relative position/attitude to the CV. MEV-1's actuators include: momentum wheels; chemical propulsion (hydrazine) thrusters; and steerable electric propulsion (xenon) thrusters.

3.1.4 Electric Power Subsystem ("EPS")

The MEV-1 EPS is fully redundant and cross-strapped to provide the fault tolerant power needed during all phases of the mission including during eclipse or other periods when external power is not available. The vehicle is powered by two 5 kilowatt flat-panel solar arrays and two 110 amp-hour lithium-ion batteries. Battery charge control is managed autonomously by fault tolerant hardware and flight software running on the flight computer.

3.1.5 Command and Data Handling ("CDH")

The CDH processes ground and internal commands and distributes them to appropriate fight avionics systems for execution. The CDH also collects, stores, and downlinks telemetry data to the ground. The CDH avionics is fully redundant and cross-strapped to provide the fault tolerant command and control functions for MEV-1, leveraging heritage radiation-hardened processors. The command and telemetry streams are protected through a unique spacecraft identifier and National Security Agency-approved AES-256 encryption.

3.1.6 Propulsion

MEV-1 has both electric propulsion ("EP") and chemical propulsion ("CP") capability. The CP and EP propulsion systems are fully redundant and cross-strapped, providing fault tolerant attitude and orbit control. The EP subsystem uses hall current thrusters ("HCTs") to perform most of the mission's delta-V maneuvers including station keeping. The CP subsystem is used for relative position and attitude control during the final phases of the RPOD when greater agility and control authority is required than the EP subsystem can provide.

3.1.7 Thermal Control Subsystem (TCS)

The TCS uses passive and active thermal management strategies to maintain the spacecraft hardware within allowable temperature limits. The system consists of radiators and heat pipes for thermal distribution and control. In addition, heaters are also used to keep the components from exceeding their lower allowable temperatures. Heaters are controlled by flight software and thermostats.

3.1.8 Rendezvous, Proximity Operations and Docking Subsystem

The RPOD subsystem consists of the sensors, electronics, algorithms and mechanisms required for detecting and tracking the CV during rendezvous and proximity operations, sensing the relative position and attitude of the CV, and mechanically docking to and releasing the CV. The sensing hardware includes:

- A visible stereo camera suite with both narrow field of view ("FOV") and wide FOV to provide far-range and near-range relative position and attitude data
- A long wavelength infrared stereo camera suite with both narrow FOV and wide FOV to provide far-range and near-range relative position and attitude data
- A LIDAR with two active sensing modes that provide bearing and range measurement and/or full relative attitude and position
- Image processing (on-board and ground-based)
- Illumination for near-range visual wavelength cameras

The docking mechanisms include a retractable capture mechanism and stanchions. The capture mechanism is designed to interface with the CV's liquid apogee engine ("LAE") nozzle that is located on the zenith deck of the CV. This mechanism is designed to be compatible with a large variety of LAE engines used in the industry. The stanchions on MEV-1 provide the mechanical interface with the CV launch vehicle interface adapter ring. These stanchions are designed to work with all the standard launch adaptor ring sizes.

During the docking phase, the capture mechanism is extended into the LAE and expands once it is beyond the throat of the engine; this creates a soft capture. The capture mechanism is then retracted to pull the stanchions against the launch adaptor ring creating a hard dock. After successful docking, the combined MEV and CV stack is referred to as the CVS. A simulation of the docking process can be found at https://www.youtube.com/watch?v=H8pKF6G7Jp4.

3.1.9 Station keeping

MEV-1 will maintain the CVS within a station-keeping box of ± 0.05° N-S and ± 0.05° E-W consistent with the Commission's rules.[4] The antenna axis attitude of MEV-1 can be maintained within a value of 0.06° with respect to roll and pitch and 0.1° with respect to yaw.

3.2 Ground Segment

The MEV-1 ground segment supports the operation of MEV-1 during all phases of the mission. The ground segment consists of the MEV-1 primary and backup mission operations centers ("MOC") for controlling MEV-1, ground stations, and networks providing the radiofrequency communications links to MEV-1 from the primary and backup MEV-1 MOCs and the network connectivity and communications links between the MEV-1 MOCs and the CV MOC(s).[5]

The MEV-1 MOC will be located in Dulles, Virginia at the Orbital ATK operations facility, co-located with other mission operation centers, including the Cygnus and the GEOStar orbit raising and on-orbit support centers. The MEV-1 backup MOC will be located at Orbital ATK's Gilbert, Arizona facility to provide geographic diversity, avoiding common weather events or power grid issues.

During orbit raising, in-orbit testing ("IOT"), and drifting, MEV-1 will utilize a leased global network of C-band and Ku-band TT&C earth stations networked to the MEV-1 MOC.

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[4] *See* 47 C.F.R. §§ 25.114(c)(5), 25.210(j).

[5] The backup MOCs are for emergency operations in case the primary MOCs are unavailable.

During RPOD and CVS operations, MEV-1 will use the CV's primary and redundant TT&C stations and ground antennas with redundant communication links between the TT&C stations and the MEV-1 MOC.

A dedicated communications link will be established between the MEV-1 MOC and the CV MOC during joint operations and CVS servicing to support coordination of activities and safety of both spacecraft. This link will be used to share critical state of health telemetry of both vehicles and coordinate orbit and maneuver data.

3.3 Concept of Operations

After the launch service insertion of MEV-1 into the geosynchronous transfer orbit ("GTO"), MEV-1 will perform various orbit-raising maneuvers to reach the GSO "graveyard" orbit 300 km above the GSO arc. This orbit-raising period is expected to last approximately 45 days. Space Logistics will conduct most of the MEV-1 IOT during this orbit-raising period. During the latter part of the MEV-1 orbit raising, Intelsat will raise the orbit of the IS-901 satellite from the GSO arc to the graveyard orbit for rendezvous with MEV-1. Once both satellites are at the graveyard orbit, MEV-1 will use its RPOD system to reliably and safely rendezvous and dock with the IS-901 satellite. Performing the initial RPOD in the graveyard orbit allows the demonstration of critical RPOD operations and functions while minimizing any potential risk to other operational satellites in the GSO arc. After validating MEV-1's RPOD capability and safe operations through this initial docking mission at graveyard, Space Logistics expects to conduct future RPOD operations with CVs at or near the GSO arc, as requested by the client.

The RPOD phase of the mission begins several days in advance of the docking event with the initial phasing maneuvers of both MEV-1 and the CV. These maneuvers are performed to align the rendezvous capture box and lighting conditions desired for the final stages of the RPOD operations and to avoid other RSOs that may be in proximity. Initial orbital phasing maneuvers are performed based on ground measured orbit parameters. As MEV-1 approaches within the station-keeping box of the CV, the RPOD sensors begin to track the CV and provide additional relative position data that is used to control the relative position between the two satellites. MEV-1 will use a safe trajectory design that prevents the potential for collision with the CV due to over- or under-performance of maneuvers, until the final R-bar (*i.e.*, the radial vector between the center of the earth and the CV) approach is initiated from close proximity to the CV.

During the final R-bar approach, MEV-1 autonomously maneuvers from one ground commanded waypoint to the next using its on-board sensors and navigation flight software. MEV-1 holds at each waypoint until authorized by ground command to proceed to the next waypoint. MEV-1 will slowly approach the CV from the aft end along the R-bar ultimately stopping within the capture hold box of the CV immediately behind the CV. At this point, following coordination with the CV MOC, the final authorization from ground is given for MEV-1 to initiate docking. Upon receiving this authorization, the MEV-1 RPOD capture mechanism is extended and achieves soft capture of the CV LAE. Then the mechanism retracts pulling MEV-1 and the CV together to establish a hard docking with MEV-1's stanchions against the CV launch adaptor ring. A pre-loaded tension is applied on the capture mechanism to firmly secure the docking.

Once docking is completed, MEV-1 will maintain the attitude and orbit control of the CVS, as directed by Intelsat pursuant to the contractual agreement between the parties. Operational control of MEV-1 is maintained throughout this process, including post docking, by Space Logistics at the MEV-1 MOC.

After the rendezvous and docking is completed with IS-901 at graveyard, MEV-1 will maneuver the CVS to the nominal orbital location of an operational Intelsat satellite. As discussed in more detail in the Narrative, Intelsat will specify this orbital location at a subsequent date.[6] The MEV-1/IS-901 CVS will temporarily collocate at the nominal orbital location with that operational Intelsat satellite to enable a transition of traffic to the IS-901 satellite. Subsequently, the replaced satellite will depart the nominal orbital location. Space Logistics anticipates that MEV-1 will operate as a CVS with IS-901 for at least five years. After completion of that service, MEV-1 will relocate to the graveyard orbit with IS-901 as a CVS and undock from the IS-901, leaving it to be decommissioned by Intelsat.[7] Prior to the expiration of its contractual arrangement with Intelsat and undocking with IS-901, Space Logistics will seek FCC approval, as well as any other applicable regulatory approvals, to relocate MEV-1 and perform its next mission.[8]

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[6] Intelsat will request the necessary authority from the FCC to operate the CVS at the nominal orbital location of the satellite to be replaced and also to relocate that satellite. *See* Narrative at 7.

[7] To the extent necessary, Intelsat will seek new de-orbit authority for IS-901.

[8] If the client satellite operator for future missions is foreign-licensed, then the Commission and foreign administrators may need to exchange letters of understanding regarding the operations of the CVS, consistent with the Commission's practice regarding the use of shared

4 RADIO FREQUENCIES, POLARIZATION AND LINK BUDGETS

4.1 Radio Frequencies and Polarization Plan

Table 4-1 provides the tunable frequency range for the TT&C system. The center frequency of the command and telemetry communications links can be any frequency (subject to the bandwidth of the transmission) within the tunable frequency range in increments of the 100 kHz tuning resolution. MEV-1 is capable of ceasing radio emissions, as required.[9]

	Command - Uplink		Telemetry - Downlink	
	Tunable Frequency Range (MHz)	Polarization	Tunable Frequency Range (MHz)	Polarization
C-Band	5925 – 6425	LHCP or RHCP	3700 – 4200	LHCP or RHCP
Ku-Band	13750 – 14500	LHCP or RHCP	11450 – 12250	LHCP or RHCP

Table 4-1. MEV-1 TT&C Tunable Frequency Ranges and Polarizations

For the avoidance of doubt, selectable center frequencies for the C-band channel may be calculated as:

C-band Uplink Center Frequency (MHz) = $5925 + 0.1*n_1$

C-band Downlink Center Frequency (MHz) = $3700 + 0.1*n_2$

Where n_1 and n_2 are integers from 0 to 5000, inclusive.

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orbital assets. *See, e.g.*, Stamp Grant, *Intelsat License LLC,* Call Sign S2801, File No. SAT-A/O-20091208-00141 (granted June 4, 2012); *PanAmSat Licensee Corp.*, Order and Authorization, 18 FCC Rcd. 19680, 19685-88 (Sat. Div. 2003).

[9] *See* 47 C.F.R. § 25.207.

Similarly, the selectable center frequencies for the Ku-band channel may be calculated as:

Ku-band Uplink Center Frequency (MHz) = 13750 + 0.1*m_1

Ku-band Downlink Center Frequency (MHz) = 11450 + 0.1*m_2

Where m_1 is an integer from 0 to 7500 (inclusive) and m_2 is an integer from 0 to 8000 (inclusive).

As stated in the Narrative, the CVS will replace an operational Intelsat C-band and/or Ku-band satellite (the "Replaced Satellite"). Intelsat is and will be authorized to operate in those frequencies at the orbital location of the Replaced Satellite (the "Replacement Orbital Location"). MEV-1 will coordinate with Intelsat and operate on a subset of the frequencies authorized to and coordinated for IS-901 at the Replacement Orbital Location. Space Logistics accepts that its license will be conditioned on a requirement to operate within frequencies and technical parameters authorized to IS-901 at the Replacement Orbital Location.

Space Logistics understands that MEV-1's operations in the 11.45-11.70 GHz, 12.20-12.25 GHz, and 13.75-14.0 GHz frequencies may be subject to certain limitations and obligations, which Space Logistics accepts and will fulfill. Provided below is a table identifying the relevant frequency bands and potentially applicable limitations and obligations.

Frequency Band	**Limitations and Obligations**
11.45-11.70 GHz space-to-Earth	• Use of this band is subject to 47 C.F.R. § 2.106, US211, which urges applicants to take all practicable steps to protect radio astronomy observations in the adjacent bands from harmful interference, consistent with footnote 47 C.F.R. § 2.106, US74. • Operations in this band are limited to international-only services. 47 C.F.R. § 2.106, NG 52.
12.20-12.25 GHz space-to-Earth	• FSS operations in the 12.2-12.25 GHz band are limited to ITU Regions 1 and 3. 47 C.F.R. § 2.106. • Space stations shall not cause harmful interference to, or claim protection from, broadcasting-satellite service stations operating in accordance with the ITU Regions 1 and 3 plans in ITU Radio Regulations Appendix 30. 47 C.F.R. § 2.106 n. 5.487.

13.75-14.00 GHz Earth-to-space	• Receiving FSS space stations must not claim protection from radiolocation transmitting stations operating in accordance with the U.S. Table of Frequency Allocations. 47 C.F.R. § 2.106, US356. • Any earth station in the U.S.[10] communicating with MEV-1 in the 13.75-13.80 GHz (Earth-to-space) band is required to coordinate with the Frequency Assignment Subcommittee of the Interdepartment Radio Advisory Committee of the National Telecommunications and Information Administration to minimize interference to NASA's Tracking and Data Relay Satellite System, including manned space flight. 47 C.F.R. § 2.106, US337. • Operations of any earth station in the U.S. communicating with MEV-1 in the 13.75-14.00 GHz (Earth-to-space) band must comply with 47 C.F.R. § 2.106, US356, which specifies a mandatory minimum antenna diameter of 4.5 m and a minimum EIRP of 68 dBW and a maximum EIRP of 85 dBW for any emission. Operations of any earth station located outside the U.S. communicating with MEV-1 in the 13.75-14.00 GHz (Earth-to-space) band must be consistent with No. 5.502 to the ITU Radio Regulations, which allows a minimum antenna diameter of 1.2 m for earth stations and specifies that the power flux-density produced by an earth station in a FSS GSO network with an antenna diameter smaller than 4.5 m shall not exceed: ○ -115 dB(W/(m^2 • 10 MHz)) for more than 1% of the time produced at 36 m above sea level at the low water mark, as officially recognized by the coastal State; ○ -115 dB(W/(m^2 • 10 MHz)) for more than 1% of the time produced 3 m above ground at the border of the territory of an administration deploying or planning to deploy land mobile radars in this band, unless prior agreement has been obtained. For those earth stations located outside the U.S. having an antenna diameter 4.5 m or greater, the EIRP of any emission should be at least 68 dBW and should not exceed 85 dBW. • Operations of any earth station in the U.S. communicating with MEV-1 in the 13.77-13.78 GHz (Earth-to-space) frequency band must comply with 47 C.F.R. § 2.106, US357, which specifies that the maximum EIRP density of emissions not exceed 71 dBW in any 6 MHz band within that band. Operations of any earth station located outside the U.S. communicating with MEV-1 in the 13.77-13.78 GHz (Earth-to-space) frequency band must comply with No. 5.503 of the ITU Radio Regulations, which specifies a required maximum EIRP density of emissions varying with the diameter of the antenna: ○ 4.7D + 28 dB (W/40 kHz), where D is the FSS earth station antenna diameter equal to or greater than 1.2 m and less than 4.5 m; ○ 49.2 + 20 log (D/4.5) dB(W/40 kHz), where D is the FSS earth station antenna equal to or greater than 4.5 m and less than 31.9 m; ○ 66.2 dB(W/40 kHz) for any FSS earth station for antenna diameters equal to or greater than 31.9 m; or ○ 56.2 dB(W/4 kHz) for narrow-band emissions (less than 40 kHz) from any FSS earth station having an antenna diameter of 4.5 m or greater.

Table 4-2. Limitations and Obligations on Use of Certain Frequencies.

[10] All references to the U.S. in this table include U.S. possessions.

4.2 Emission Compliance

The carrier frequency of each transmitter for MEV-1 shall be maintained within 0.002% of the reference frequency.[11] All emissions from MEV-1 shall meet the out-of-band emission limits specified in the Commission's rules.[12]

4.3 Coverage Areas

The respective coverage areas for the C-band and Ku-band TT&C beams for MEV-1 will encompass the entire portion of the visible Earth from the MEV-1 operating location.[13]

5 LINK BUDGETS

5.1.1 C-Band Link Budgets

The C-band link budgets for the commanding and ranging uplink and the telemetry and ranging downlink are provided in Annex A. Both uplink and downlink budgets show positive margin.

5.1.2 Ku-Band Link Budgets

The Ku-band link budgets for the commanding and ranging uplink and the telemetry and ranging downlink are provided in Annex B. Both uplink and downlink budgets show positive margin.

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[11] *See* 47 C.F.R. § 25.202(e).

[12] *See* 47 C.F.R. § 25.202(f).

[13] *See* 47 C.F.R. § 25.114(c)(7).

6 ANTENNA CHARACTERISTICS

MEV-1 will only receive command beams from the ground stations. Therefore, pursuant to Section 25.114(c)(4)(v) of the FCC's rules, Space Logistics has specified the command beam peak flux density at the command threshold in Annex C. Maximum EIRP and EIRP density for the C-band and Ku-Band channels are provided in Annex D.

7 ANTENNA GAIN CONTOURS

Both the TT&C C-band and Ku-band telemetry antennas for MEV-1 provide ±17° beam width from GSO orbit. The Earth's diameter occupies roughly ±8 degrees within that beam width. Therefore, the entire portion of the Earth visible from the MEV-1 operating location is encompassed within the C-band and Ku-band coverage areas of the MEV-1 TT&C beams. The gain contours of the TT&C telemetry downlink antenna vary by less than 8 dB across the surface of the Earth. Accordingly, the gain at 8 dB below the peak falls beyond the edge of the Earth. Therefore, pursuant to Section 25.114(c)(4)(vi)(A) of the FCC's rules, contours for these beams are not required to be provided and the associated GXT files have not been included in Schedule S.

8 POWER FLUX DENSITY

The maximum PFD levels for MEV-1's transmissions were calculated for both the C-band and Ku-band TT&C downlink bands indicated in Table 3-1. The results are provided in Schedule S and show that the downlink PFD levels of MEV-1's TT&C do not exceed the limits specified in Section 25.208 of the Commission's rules.

9 INTERFERENCE ANALYSIS

9.1 Interference Analysis for Hypothetical, Identical Space Station within 2 Degrees of MEV-1

Space Logistics has performed an interference analysis based on a hypothetical space station at an orbital separation of 2° and operating with the same transmission parameters as MEV-1. Annex E captures the interference analysis for the telemetry downlink, and Annex F provides the interference analysis for the command uplink. All C/I margins in the analyses are positive.

9.2 Band Edge Interference

TT&C signals shall be transmitted within the frequency bands specified in Table 4-1. Such transmissions shall cause no greater interference and require no greater protection than the communications traffic authorized for IS-901 at its operational orbital location.[14] Alternatively, the TT&C signals shall be coordinated with operators of co-frequency space stations at orbital locations within six degrees of the assigned orbital location.[15]

10 ORBITAL LOCATION REQUESTED

As discussed in the Narrative, after testing and docking with IS-901 at the GSO graveyard orbit, MEV-1 and IS-901 will relocate as a CVS to the orbital location of an operational Intelsat satellite to be specified by Intelsat at a later date.[16] Intelsat will provide the

[14] *See* 47 C.F.R. § 25.202(g).

[15] *See* 47 C.F.R. § 25.140.

[16] *See* Narrative at 7. Space Logistics has also sought a waiver of the requirement to specify an operating location in the application.

specific two-degree compliance showing for the operation of the CVS at that location. Space Logistics accepts that its license will be conditioned on a requirement to operate within frequencies and technical parameters authorized to IS-901 at the Replacement Orbital Location.

11 ORBITAL DEBRIS MITIGATION PLAN

11.1 MEV Flight Safety

Space Logistics has established a Systems Safety Program Plan ("SSPP") for the identification, evaluation, mitigation, and tracking of all potential hazards associated with the MEV-1 mission. The SSPP defines an MEV Safety Review Process ("SRP"), which outlines the exact procedures for executing the mitigation and tracking of identified potential hazards. The SRP is a general Orbital ATK practice that Space Logistics has tailored specifically to the MEV program. All potential hazards are categorized by mission phase, including flight operations covering activities after launch and separation. Detailed analyses for each potential hazard in applicable flight operations are documented in the Flight Safety Data Package ("FSDP"). Orbital debris generation is a subcategory under the FSDP.

MEV-1 is designed such that no debris is generated as a result of normal operations. This leaves four primary sources for potentially generating debris from the MEV-1 mission including:

1) Accidental explosions from internal or external sources;
2) Collision during non-RPOD operations;
3) RPOD operations; and
4) End-of-life decommissioning.

Space Logistics leverages four key mitigation layers that address these sources of debris generation, each applying to a unique set of mitigation strategies. The mitigation layers for these debris generation sources include: spacecraft design, autonomous fault protection, the ground segment, and mission operations including trajectory design. Figure 11-1 illustrates how these mitigations are layered to prevent the generation of orbital debris during the MEV-1 mission. The layers progressively involve mission operators to fully mitigate the potential generation of orbital debris.

In the first layer, the spacecraft hardware is designed such that nominal operating conditions do not generate orbital debris. This layer has the least amount of operator intervention since the spacecraft hardware cannot be modified once in orbit. The next layer consists of the MEV-1 on board fault protection, which can autonomously identify, isolate and recover from potential safety issues. In the next layer, the ground segment provides for operator interaction with and configuration of MEV-1 and provides for coordination between the MEV-1 MOC and the CV MOC. The ground systems in the MEV-1 MOCs also actively monitor available spacecraft telemetry and issue alarms to alert the operator and enable ground intervention if necessary. The final layer is mission operations including trajectory design. Mission operations establishes and executes MEV-1 operating sequences including trajectories, which are designed passively safe to protect against collisions with the CV and other tracked RSOs. This layer involves significant mission operator involvement and active coordination with other GSO spacecraft operators.

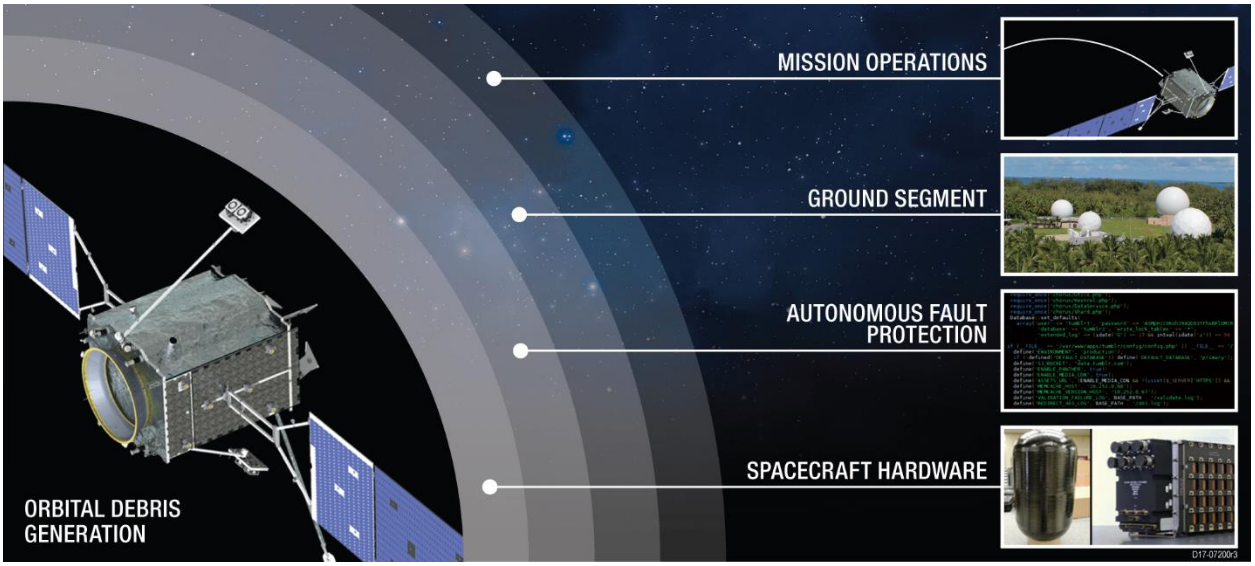

Figure 11-1. The MEV-1 mission layers mitigations to protect against orbital debris generation

In addressing each of the possible sources of orbital debris generation, the strategies employed within each of the layers discussed above will be identified and elaborated.

11.2 Mitigation Against Accidental Explosion Events

Mitigation Layer: Spacecraft Design

Space Logistics has assessed the probability of accidental explosions caused by either internal or external sources during and after completion of mission operations.[17] MEV-1 is designed in a manner to minimize the potential for such explosions. Propellant tanks and thrusters are isolated using redundant valves and electrical power systems are shielded in accordance with standard industry practices. Pressure regulators are redundant, providing an extra safeguard to overpressurizing and bursting the tanks.

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[17] 47 C.F.R. § 25.114(d)(14)(ii).

The propulsion subsystem component construction, preflight verification (through both proof testing and analysis), and quality standards have been designed to ensure a very low risk of leakage or over-pressurization with a potential to cause explosions.

The batteries are designed with sufficient factors of safety to prevent any accidental explosions due to over pressurization. On-board systems manage the charging and discharging of the batteries to ensure that these factors of safety are maintained. At the end of life, the batteries can also be remotely discharged from the ground.

Space Logistics has designed MEV-1 to contain the majority of energy-storage components within the central cylinder, including the propellant storage tanks. This provides the highest level of protection against collisions with micrometeoroids or other space debris.

Mitigation Layer: Autonomous Fault Protection Design

The MEV-1 autonomous fault protection is designed to continuously monitor subsystem conditions during mission operations which could lead to over-pressurization of the propellant tanks or stressing the batteries. The primary cause of propellant or battery explosion is over-pressurization due to high temperature and/or overcharging. Additionally, there are autonomous responses for voltage spikes in the battery cells that could lead to a failure or potential explosion.

Mitigation Layer: Ground Segment Design

In addition to the on-board autonomous fault protection of the subsystems, the spacecraft transmits state of health information for all subsystems including telemetry for propulsion tank pressures and temperatures, as well as battery pressures, temperatures, and cell voltages.

All of these telemetry points are monitored by the ground software with autonomous limit checking. Out-of-limit conditions are flagged on the MOC displays with a prominent alert and require operator acknowledgement. Conditions detected by limit or other signatures in the ground systems can also initiate activities such as alerting off-console support engineers.

Mitigation Layer: Mission Operations

Mission Operations employs flight rule constraints to avoid potentially hazardous conditions, trends subsystems data to actively avoid risks leading to a hazardous condition, and re-actively responds to ground system alerts. At the completion of the mission and upon disposal of the spacecraft, Space Logistics will ensure the removal of all stored energy on the spacecraft by depleting all propellant tanks, venting all pressurized systems and by leaving the batteries in a permanently discharged state.

11.3 Mitigation Against Collisions with Other GSO Satellites and Tracked RSO's (non-RPOD)

Mitigation Layer: Mission Operations and Trajectory Design

Space Logistics will take standard measures to ensure that MEV-1 will not collide with other RSOs. This includes the utilization of both commercial and U.S. government orbit determination services (such as the Space Data Association and the Joint Space Operations Center) to coordinate MEV-1 mission planning and trajectory design.

11.4 Rendezvous, Proximity Operations and Docking

RPOD is a unique feature of the MEV-1 mission compared to other vehicles operating in the GSO arc. MEV-1 is designed to approach and dock cooperatively with another satellite. This mission activity introduces debris-generating risks which Space Logistics has diligently mitigated through a layered approach based on heritage rendezvous and proximity operations and berthing operations of the Cygnus system with the manned International Space Station. Space Logistics has also engaged with NASA through a Collaboration for Commercial Space

Capabilities Space Act Agreement to receive lessons learned from rendezvous, proximity, docking and berthing missions dating back to the Gemini program in the 1960s. Through this agreement the company has been and continues to receive recommendations and commentary on the RPOD design, testing and concept of operation from NASA experts. The docking is the most safety critical phase of the mission and there will be both manual ground-based and autonomous on-board elements to preclude and detect failures and respond appropriately.

Mitigation Layer: Spacecraft Design

Redundant RPOD sensors onboard MEV-1 provide visual imaging and telemetry that are used both onboard and on the ground to determine relative position and attitude between MEV-1 and the CV. During RPOD, MEV-1 provides high data rate telemetry of these sensors to support ground based monitoring and authorization to proceed. MEV-1's capture mechanism is designed to minimize contact forces to prevent unwanted relative dynamic motion between MEV-1 and the CV. The mechanical docking components are designed to operate safely by use of design margins (mechanical and electro-mechanical). Design elements have also been included to address any electrical charge potential between MEV-1 and the CV which could result in damaging Electro-Static Discharge ("ESD") events. Full six-degree of freedom control is implemented on MEV-1 using the chemical propulsion system, in conjunction with momentum wheels providing additional margins on control authority needed for the proximity operations.

Mitigation Layer: Autonomous Fault Protection

At any point during RPOD, the MEV-1 can autonomously detect anomalies either in MEV-1 itself, or the relative position and orientation with the CV and take appropriate action from recovering from the fault to aborting the approach and causing a retreat to a safe orbit.

Mitigation Layer: Ground Segment

The MEV-1 ground segment is designed to provide redundancy during mission operations. The primary MEV-1 MOC is located in Dulles, VA while the backup MOC is located in Gilbert, AZ. This provides enough geographical separation to isolate the two MOCs from common weather hazards and other contingencies that may occur. Additionally, the TT&C ground stations utilize multiple redundant and diverse ground networks for added reliability.

During the RPO&D phase, both the MEV-1 MOC and the CV MOC are connected through a continuous, real-time interface to ensure critical data is passed between operators of the two spacecraft. Autonomous telemetry monitors continuously check for events and alarms, while an independent ground-based system correlates relative position and attitude information using telemetered RPOD sensor data from MEV-1. Mission operators are provided both graphical and tabular data displays to provide full situational awareness.

Mitigation Layer: Mission Operations and Trajectory Design

Well before launch of MEV-1, nominal and contingency procedures will be developed for all identified practicable scenarios. These procedures will be executed on simulators and the actual spacecraft when feasible. Space Logistics will conduct multiple rehearsals for both nominal and contingency mission scenarios to further train the operations staff and test all software and ground systems under flight like conditions. During the mission, critical operations such as the RPOD phase are fully staffed by a team of experts with a wealth of mission operations and technical experience.

During RPOD, mission operations are performed collaboratively with the CV MOC. At each proximity operation waypoint mentioned above, both Space Logistics and the CV operators must provide authorizations to proceed to continue to the next waypoint. During the docking phase, MEV-1 operators utilize the CV as a viable control to help prevent the vehicles from colliding under some fault scenarios.[18] The ground operators can also send retreat, scrub, or abort commands to MEV-1 if an anomalous condition is detected in either MEV-1 or the CV. MEV-1 is designed to safely and autonomously retreat and depart (if necessary) from the defined keep-out zones around the CV following an autonomous or ground-initiated scrub or abort.

Space Logistics uses a robust trajectory design to minimize risk of collision as MEV-1 approaches the CV during the RPOD phase. This trajectory ensures that the natural motion orbit of MEV-1 does not intersect the CV including over and under thrust performance or failure to execute a maneuver, during all but the very final RPOD maneuver which has additional safety procedures incorporated to prevent collision.

The final approach trajectory is designed to minimize any chances of impacts that could generate orbital debris. During this final approach, the relative speed is decreased from 30 mm/s to about 1 mm/s just before MEV-1 enters the capture box directly behind the CV. At this speed, the potential for debris generation caused by an unintended impact has been assessed to be very low. As an added layer of protection during this phase, MEV-1 approaches the capture box in such a way as to allow dual fault tolerance to credible scenarios of loss of control of MEV-1 by enabling time for the CV mission operators to perform a collision avoidance maneuver if they determine MEV-1 is unable to respond.

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[18] *See also* Narrative at 13-16 (discussing Space Logistics' cooperative, transparent, and responsible operating philosophy).

11.5 Post-Mission Disposal

Mitigation Layer: Trajectory Design

Space Logistics plans to reserve sufficient fuel and power to dispose of MEV-1 at the end of its mission-capable life at a planned minimum altitude of 300 kilometers (perigee) above the GSO arc.[19] The proposed disposal orbit altitude complies with the altitude resulting from application of the Inter-Agency Space Debris Coordination Committee ("IADC") formula based on the following calculation:

36,021 km + (1000 × C_R × A/m) = 36,061.0 km, or 275.0 km above the GSO arc (35,786 km), where

A, Area of the satellite (average aspect area) is: 40.7 m^2
m, Mass of the spacecraft is: 1525 kg
C_R (solar radiation pressure coefficient) is: 1.5

Accordingly, MEV-1's planned disposal orbit complies with the FCC's rules.[20]

Mitigation Layer: Mission Operations and Trajectory Design

After MEV-1 reaches its final disposal orbit, all on-board sources of stored energy will be depleted, all batteries will be left in a permanent discharge state, and the transmitters will be shut off.[21] The solar arrays will also be skewed away from the sun to minimize power generation.[22]

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[19] 47 C.F.R. § 25.283(a); *see also* Inter-Agency Space Debris Coordination Committee, IADC Space Debris Mitigation Guidelines, § 5.3 (2007); *Mitigation of Orbital Debris*, Second Report and Order, 19 FCC Rcd. 11567, 11578 ¶ 21 (2004).

[20] *See* 47 C.F.R. § 25.283(a).

[21] *See* 47 C.F.R. §§ 25.283(c), 25.114(d)(14)(ii).

[22] *Id*.

Technical Certification

I, Oliver Ortiz, hereby certify, under penalty of perjury, that I am the technically qualified person responsible for the preparation of the engineering information contained in the technical portions of the foregoing application and the related attachments, that I am familiar with Part 25 of the Commission's rules, and that the technical information is complete and accurate to the best of my knowledge and belief.

/s/ Oliver Ortiz
Oliver Ortiz
Systems Engineer
Orbital ATK Inc., parent company of Space Logistics LLC

Dated: February 24, 2017

Annex A: C-band Link Budgets

C-Band Command/Ranging Budget	Units	HEMI (±75°) Transfer	HEMI (±17°) On Station	HEMI (±75°) Anomaly
Ground Station EIRP, Min	dBW	88	75	88
S/C Altitude [GSO + 350 km]	km	65,000	36,136	36,136
Ground Station Elevation Angle	deg	5	5	5
Resulting Range	km	70539	41,481	41,481
Free Space Spreading Loss	dBm^2	167.96	163.35	163.35
CMD Uplink Flux Density, Min	dBW/m^2	-79.96	-88.35	-75.35
Isotropic Aperture	$dB\text{-}m^2$	-37.6	-37.6	-37.6
Antenna Edge of Coverage [Gain]	dBi	-5.0	7.0	-5.0
Antenna Losses	dB	0.0	0.0	0.0
EP Plume interference	dB	-2.0	-2.0	-2.0
Atmospheric Loss	dB	-0.2	-0.2	-0.2
Polarization Loss	dB	0	-3.0	0
Net Antenna Edge of Coverage Gain	dBi	-7.2	1.8	-7.2
Received CMD Power @ Antenna Output	dBm	-94.77	-94.16	-90.16
Hemi Coaxial Cable	dB	2.04	2.04	2.04
Polarization Switch	dB	0.50	0.50	0.50
Coaxial Cable	dB	0.39	0.39	0.39
Hybrid Coupler	dB	3.50	3.50	3.50
Coaxial Cable	dB	0.27	0.27	0.27
Bandpass Filter	dB	0.50	0.50	0.50
Coaxial Cable	dB	0.34	0.34	0.34
Total CMD Input Loss	dB	-7.55	-7.55	-7.55
Command				
Input Level to Command Receiver Without Multipath	dBm	-102.32	-101.71	-97.71
Command Receiver CMD Threshold	dBm	-112	-112	-112
Command Margin Without Multipath	**dB**	+9.68	+10.29	+14.29
Multipath Loss [budgeted]	dB	-2.00	0.00	-2.00
Input Level to Command Receiver With Multipath	dBm	-104.32	-101.71	-99.71
Command Margin =	**dB**	**+7.68**	**+10.29**	**+12.29**
Ranging				
Input Level to Command Receiver Without Multipath	dBm	-102.32	-101.71	-97.71
Command Receiver Ranging Threshold	dBm	-109	-109	-109
Ranging Margin Without Multipath	**dB**	+6.68	+7.29	+11.29
Multipath Loss [budgeted]	dB	-1.00	0.00	-1.00
Input Level to Command Receiver With Multipath	dBm	-103.32	-101.71	-98.71
Ranging Margin =	**dB**	**+5.68**	**+7.29**	**+10.29**

C-Band Telemetry and Ranging Budget Low Data Rate	Units	HEMI (±75°) Transfer	HEMI (±17°) On-Station	HEMI (±75°) Anomaly
Telemetry Transmitter Output Power [30 Watts, EOL]	dBW	15.19	14.77	14.77
RF Coaxial Cable	dB	0.24	0.24	0.24
Transmit Band Pass Filter	dB	0.50	0.50	0.50
RF Coaxial Cable	dB	0.24	0.24	0.24
Hybrid Coupler	dB	3.50	3.50	3.50
RF Coaxial Cable	dB	0.35	0.35	0.35
Polarization Switch	dB	0.5	0.5	0.5
HEMI Coaxial Cable	dB	1.6	1.6	1.6
Total TLM Output Loss	dB	-6.98	-6.98	-6.98
Antenna Edge of Coverage [Gain]	dBi	-5.0	7.0	-5.0
Antenna Losses	dB	0	0	0
EIRP Without Multipath	dBW	3.21	14.79	2.79
Multipath Loss [budgeted)	dB	-2.0	0	-2.0
EIRP with Multipath	dBW	1.21	14.79	0.79
S/C Altitude [GSO + 350 km]	km	65,000	36,136	36,136
Ground Station Elevation Angle	deg	5	5	5
Resulting Range	km	70539	41,481	41,481
Free Space Loss	dB	-201.9	-197.3	-197.3
EP Plume interference	dB	-2.0	-2.0	-2.0
Atmospheric Loss	dB	-0.2	-0.2	-0.2
Ground Station Polarization Loss	dB	0	-3.0	0
Ground Station G/T	dB/K	35	31	35
Boltzmanns Constant	dB Hz-K/W	228.6	228.6	228.6
Receive C/No	dB-Hz	60.7	71.9	64.9
With 1 Subcarrier or Ranging:				
Required C/No for PCM Telemetry at 4.8 kb/s	dB-Hz	51.3	51.3	51.3
Telemetry Margin =	**dB**	**+9.40**	**+20.60**	**+13.60**
Required C/No for Ranging	dB-Hz	44.01	44.01	44.01
Ranging Margin =	**dB**	**+16.71**	**+27.91**	**+20.91**
With 2 Subcarriers or 1 Subcarrier + Ranging:				
Required C/No for PCM Telemetry at 4.8 kb/s	dB-Hz	54.3	54.3	54.3
Telemetry Margin =	**dB**	**+6.39**	**+17.59**	**+10.59**
Required C/No for Ranging	dB-Hz	47.11	47.11	47.11
Ranging Margin =	**dB**	**+13.61**	**+24.81**	**+17.81**
With 2 Subcarriers + Ranging:				
Required C/No for PCM Telemetry at 4.8 kb/s	dB-Hz	56.1	56.1	56.1
Telemetry Margin =	**dB**	**+4.63**	**+15.82**	**+8.82**
Required C/No for Ranging	dB-Hz	48.74	48.74	48.74
Ranging Margin =	**dB**	**+11.98**	**+23.18**	**+16.18**

C-Band Telemetry/Ranging Budget Medium Data Rate	Units	HEMI (±17°)	HEMI (±75°)
		On-Station	Anomaly
Telemetry Transmitter Output Power [30 Watts, EOL]	dBW	14.77	14.77
RF Coaxial Cable	dB	0.24	0.24
Transmit Band Pass Filter	dB	0.50	0.50
RF Coaxial Cable	dB	0.24	0.24
Hybrid Coupler	dB	3.5	3.5
RF Coaxial Cable	dB	0.35	0.35
Polarization Switch	dB	0.5	0.5
HEMI Coaxial Cable	dB	1.6	1.6
Total TLM Output Loss	dB	-6.98	-6.98
Antenna Edge of Coverage [Gain]	dBi	7.0	-5.0
Antenna Losses	dB	0	0
EIRP Without Multipath	dBW	14.79	2.79
Multipath Loss [budgeted)	dB	0	-2.0
EIRP with Multipath	dBW	14.79	0.79
S/C Altitude [GSO + 350 km]	km	36,136	36,136
Ground Station Elevation Angle	deg	5	5
Resulting Range	km	41,481	41,481
Free Space Loss	dB	-197.3	-197.3
EP Plume interference	dB	-2.0	-2.0
Atmospheric Loss	dB	-0.2	-0.2
Ground Station Polarization Loss	dB	-3	0
Ground Station G/T	dB/K	31	35
Boltzmann's Constant	dB Hz-K/W	228.6	228.6
Receive C/No	dB-Hz	71.9	64.9
With 1 Subcarrier or Ranging:			
Required C/No for PCM Telemetry at 18 kb/s	dB-Hz	57.0	57.0
Telemetry Margin =	**dB**	**+14.92**	**+7.92**
Required C/No for Ranging	dB-Hz	44.01	44.01
Ranging Margin =	**dB**	**+27.91**	**+20.91**
With 1 Subcarrier + Ranging:			
Required C/No for PCM Telemetry at 18 kb/s	dB-Hz	60.4	60.4
Telemetry Margin =	**dB**	**+11.52**	**+4.52**
Required C/No for Ranging	dB-Hz	47.11	47.11
Ranging Margin =	**dB**	**+24.81**	**+17.81**

C-Band Telemetry Budget **High Data Rate**	Units	HEMI (±17°) On-Station
HDR Transmitter Output Power, Min	dBW	14.77
TTX Frequency [C-Band]	MHz	4,200
RF Coaxial Cable	dB	0.24
Transmit Band Pass Filter	dB	0.50
RF Coaxial Cable	dB	0.24
Hybrid Coupler	dB	3.50
RF Coaxial Cable	dB	0.35
Polarization Switch	dB	0.50
HEMI Coaxial Cable	dB	1.64
Total TLM Output Loss	dB	-6.98
Antenna Edge of Coverage [Gain]	dBi	7.0
Antenna Losses	dB	0
EIRP Without Multipath	dBW	14.79
Multipath Loss	dB	0
EIRP with Multipath	dBW	14.79
S/C Altitude	km	36,136
Ground Station Elevation Angle	deg	45
Resulting Range	km	37,764
Free Space Loss	dB	-196.5
EP Plume interference	dB	-2.0
Atmospheric Loss	dB	-0.2
Client Vehicle Blockage (budgeted)	dB	-2.0
Ground Station Polarization Loss	dB	0
Ground Station G/T	dB/K	35
Boltzmann's Constant	dB Hz-K/W	228.6
Receive C/No	dB-Hz	77.7
Demodulation Process		
Required Eb/No	dB	10.5
Demodulation Loss	dB	2.0
High Data Rate	Mbps	1.0
Required C/No at PM Demodulator Output	dB-Hz	72.5
Margin =	**dB**	**+5.24**

Annex B: Ku-band Link Budgets

Ku-Band Command/Ranging Budget	Units	HEMI (±17°)	HEMI (±75°)
		On Station	Anomaly
Ground Station EIRP, Min	dBW	85	90
S/C Altitude [GSO + 350 km]	km	36,136	36,136
Ground Station Elevation Angle	deg	5	5
Resulting Range	km	41,481	41,481
Free Space Spreading Loss	dBm^2	163.35	163.35
CMD Uplink Flux Density, Min	dBW/m^2	-78.35	-73.35
Isotropic Aperture	$dB\text{-}m^2$	-44.7	-44.7
Antenna Edge of Coverage [Gain]	dBi	7.0	-5.0
Antenna Losses	dB	0.0	0.0
Atmospheric Loss	dB	-0.4	-0.4
Polarization Loss	dB	-3.0	0
Net Antenna Edge of Coverage Gain	dBi	3.6	-5.4
Received CMD Power @ Antenna Output	dBm	-89.43	-93.43
Hemi Coaxial Cable	dB	3.60	3.60
Polarization Switch	dB	0.50	0.50
RF Coaxial Cable	dB	1.00	1.00
PNA Hybrid	dB	3.5	3.5
RF Coaxial Cable	dB	0.54	0.54
Bandpass Filter	dB	0.50	0.50
RF Coaxial Cable	dB	0.45	0.45
Total CMD Input Loss	dB	-10.09	-10.09
Command			
Input Level to Command Receiver Without Multipath	dBm	-99.52	-103.52
Command Receiver CMD Threshold	dBm	-112	-112
Command Margin Without Multipath	**dB**	**+12.48**	**+8.48**
Multipath Loss [budgeted]	dB	0.00	-2.00
Input Level to Command Receiver With Multipath	dBm	-99.52	-105.52
Command Margin =	**dB**	**+12.48**	**+6.48**
Ranging			
Input Level to Command Receiver Without Multipath	dBm	-99.52	-103.52
Command Receiver RNG Threshold	dBm	-109	-109
Ranging Margin Without Multipath	**dB**	**+9.48**	**+5.48**
Multipath Loss [budgeted]	dB	0.00	-2.00
Input Level to Command Receiver With Multipath	dBm	-99.52	-105.52
Ranging Margin =	**dB**	**+9.48**	**+3.48**

Ku-Band Telemetry/Ranging Budget Low Data Rate	Units	HEMI (±17°)	HEMI (±75°)
		On-Station	Anomaly
Telemetry Transmitter Output Power [20 watts, EOL]	dBW	13.01	13.01
RF Coaxial Cable	dB	0.72	0.72
Transmit Band Pass Filter	dB	0.50	0.50
RF Coaxial Cable	dB	0.79	0.79
Hybrid Coupler	dB	3.5	3.5
RF Coaxial Cable	dB	0.93	0.93
Polarization Switch	dB	0.5	0.5
HEMI Coaxial Cable	dB	2.93	2.93
Total TLM Output Loss	dB	-9.87	-9.87
Antenna Edge of Coverage [Gain]	dBi	7.0	-5.0
Antenna Losses	dB	0	0
EIRP Without Multipath	dBW	10.14	-1.86
Multipath Loss [budgeted)	dB	0	-2.0
EIRP with Multipath	dBW	10.14	-3.86
S/C Altitude [GSO + 350 km]	km	36,136	36,136
Ground Station Elevation Angle	deg	5	5
Resulting Range	km	41,481	41,481
Free Space Loss	dB	-206.9	-206.9
Atmospheric Loss	dB	-0.4	-0.4
Ground Station Polarization Loss	dB	-3.0	0
Ground Station G/T	dB/K	35	39
Boltzmanns Constant	dB Hz-K/W	228.6	228.6
Receive C/No	dB-Hz	63.4	56.4
With 1 Subcarrier or Ranging:			
Required C/No for PCM Telemetry at 4.8 kb/s	dB-Hz	51.3	51.3
Telemetry Margin =	**dB**	**+12.10**	**+5.10**
Required C/No for Ranging	dB-Hz	44.01	44.01
Ranging Margin =	**dB**	**+19.42**	**+12.42**
With 2 Subcarriers or 1 Subcarrier + Ranging:			
Required C/No for PCM Telemetry at 4.8 kb/s	dB-Hz	54.3	54.3
Telemetry Margin =	**dB**	**+9.09**	**+2.09**
Required C/No for Ranging	dB-Hz	47.11	47.11
Ranging Margin =	**dB**	**+16.32**	**+9.32**
With 2 Subcarriers + Ranging:			
Required C/No for PCM Telemetry at 4.8 kb/s	dB-Hz	56.1	56.1
Telemetry Margin =	**dB**	**+7.33**	**+0.33**
Required C/No for Ranging	dB-Hz	48.74	48.74
Ranging Margin =	**dB**	**+14.69**	**+7.69**

Annex C: Peak Flux Density

Ku-Band Command/Ranging Budget	Type	Cable Length (ft)	Units	HEMI (±75°) Transfer	HEMI (±17°) On Station	HEMI (±75°) Anomaly
CMD Uplink Flux Density			dBW/m^2	**-96.89**	**-93.89**	**-96.89**
Isotropic Aperture			dB-m^2	-44.7	-44.7	-44.7
Antenna Gain (Max)			dBi	9.5	9.5	9.5
Antenna Losses			dB	0.0	0.0	0.0
Atmospheric Loss			dB	-0.4	-0.4	-0.4
Polarization Loss			dB	0	-3.0	0
Net Antenna Gain			dBi	9.1	6.1	9.1
Received CMD Power @ Antenna Output			dBm	-102.46	-102.46	-102.46
Hemi Antenna Cable Loss [20 feet]	290	20	dB	3.83	3.83	3.83
PNA Hybrid			dB	3.5	3.5	3.5
Polarization Switch			dB	0.50	0.50	0.50
Bandpass Filter [TRF]			dB	1.00	1.00	1.00
CMR Cable Loss [3 feet]	290	3	dB	0.71	0.71	0.71
Total CMD Input Loss			dB	-9.54	-9.54	-9.54
Command Receiver CMD Threshold			dBm	**-112.00**	**-112.00**	**-112.00**

Annex D: TT&C Maximum EIRP and EIRP Density

C-Band Telemetry/Ranging Budget	Units	HEMI (±75°)	HEMI (±17°)	HEMI (±75°)
		Transfer	On-Station	Anomaly
Telemetry Transmitter Output Power [33 Watts, BOL]	dBW	15.19	15.19	15.19
TTX Port Cable Loss [3 feet]	dB	0.36	0.36	0.36
PNA - Hybrid	dB	3.50	3.50	3.50
Polarization Switch	dB	0.50	0.50	0.50
Transmit Band Pass Filter	dB	1.00	1.00	1.00
HEMI Cable Loss [20 feet]	dB	2.00	2.00	2.00
Total TLM Output Loss	dB	-7.37	-7.37	-7.37
Antenna Gain (Max)	dBi	9.50	9.50	9.50
Antenna Losses	dB	0.00	0.00	0.00
EIRP Without Multipath	dBW	17.32	17.32	17.32
Multipath Loss [budgeted)	dB	-2.00	0.00	-2.00
EIRP with Multipath	dBW	**15.32**	**17.32**	**15.32**
Occupied Bandwidth	KHz	200.00	200.00	200.00
EIRP Density with Multipath	**dBW/4 KHz**	**-1.67**	**0.33**	**-1.67**

Ku-Band Telemetry/Ranging Budget	Units	HEMI (±75°)	HEMI (±17°)	HEMI (±75°)
		Transfer	On-Station	Anomaly
Telemetry Transmitter Output Power [33 watts, BOL]	dBW	15.19	15.19	15.19
TTX Port Cable Loss [3 feet]	dB	0.66	0.66	0.66
PNA - Hybrid	dB	3.50	3.50	3.50
Polarization Switch	dB	0.50	0.50	0.50
Transmit Band Pass Filter	dB	1.00	1.00	1.00
HEMI Cable Loss [20 feet]	dB	3.57	3.57	3.57
Total TLM Output Loss	dB	-9.23	-9.23	-9.23
Antenna Edge of Coverage [Gain]	dBi	9.50	9.50	9.50
Antenna Losses	dB	0.00	0.00	0.00
EIRP Without Multipath	dBW	15.45	15.45	15.45
Multipath Loss [budgeted)	dB	-2.00	0.00	-2.00
EIRP with Multipath	dBW	**13.45**	**15.45**	**13.45**
Occupied Bandwidth	KHz	200.00	200.00	200.00
EIRP Density with Multipath	**dBW/4 KHz**	**-3.54**	**-1.54**	**-3.54**

Annex E: Interference Analysis for Hypothetical, Identical Spacecraft Two Degrees from MEV-1 – Telemetry

C BAND

MEV TLM		
Downlink EIRP (EOC)	dBW	14.8
Hypothetical satellite TLM		
Downlink EIRP (EOC)	dBW	14.8
Rx Ground station gain	dB	60.0
Rx Ground station off axis Gain	dB	25.0
Required C/N	dB	1.3
Required C/I	dB	15.3
Interference Analysis		
Calculated C/I	dB	35.0
Margin	dB	19.7

Ku BAND

MEV TLM		
Downlink EIRP (EOC)	dBW	13.0
Hypothetical satellite TLM		
Downlink EIRP (EOC)	dBW	13.0
Rx Ground station gain	dB	60.0
Rx Ground station off axis Gain	dB	25.0
Required C/N	dB	1.3
Required C/I	dB	15.3
Interference Analysis		
Calculated C/I	dB	35.0
Margin	dB	19.7

Annex F: Interference Analysis for Hypothetical, Identical Spacecraft Two Degrees from MEV-1 – Command

C BAND

MEV		
CMD input power to Antenna	dBW	15
Uplink EIRP (on station)	dBW	75
Hypothetical satellite		
Uplink off axis EIRP	dBW	40
Required C/N	dB	-3.0
Require C/I	dB	11.0
Interference Analysis		
C/I Total	dB	35.0
Margin	dB	24.0

Ku BAND

MEV		
input power	dBW	15
off axis EIRP	dBW	85
Hypothetical satellite		
Uplink EIRP (on station)	dBW	50
Required C/N	dB	-3.0
Require C/I	dB	11.0
Interference Analysis		
C/I Total	dB	35.0
Margin	dB	24.0