Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of Application of	)	
	)	File No. SAT-MOD-20111021-00207
ORBCOMM License Corp.	)	File No. SAT-AMD-20120809-00125
	)	File No. SAT-AMD-20130212-00020
For Authority to Modify its Non-Voice, Non-Geostationary Satellite Service Space Segment License (S2103) to Revise the Next-Generation Satellite Deployment Plan	)	File No. SAT-AMD-2014________

THIRD AMENDMENT NARRATIVE EXHIBIT

By this submission (the "Third Amendment"), ORBCOMM License Corp. ("ORBCOMM") further amends and updates the above-captioned application to modify its Non-Voice, Non-Geostationary Satellite Service FCC space segment license (the "Modification Application").[1] Specifically, this Third Amendment modifies the target orbit inclination and

[1] *See*, FCC Call Sign S2103. *See, also, In the Matter of Applications by ORBCOMM License Corp. For Authority to Modify its Non-Voice, Non-Geostationary Satellite System*, Order & Authorization, DA 08-633 (March 21, 2008), 23 FCC Rcd 4804 (2008) (the "Next-Generation Space Segment License"). *Modification Application*, File No. SAT-MOD-20111021-00207, *FCC Public Notice*, Report No. SAT-00825, released December 2, 2011. *See, also, Modification Application Amendment*, File No. SAT-AMD-20120809-00125, *FCC Public Notice*, Report No. SAT-00893, released August 31, 2012. *Modification Application Further Amendment & Supplement*, File No. SAT-AMD-20130212-00020, *FCC Public Notice*, Report No. SAT-00933, released March 1, 2013. On October 2, 2012, the *Modification Application* was granted in part & deferred in part to permit the launch of the first OG2 satellite on October 7, 2012. *Stamp Grant, Slip Op.,* File Nos. SAT-MOD-20111021-00207 & SAT-AMD-20120809-00125, FCC International Bureau, Satellite Division, Satellite Policy Branch, October 2, 2012, *FCC Public Notice*, Report No. SAT-00903, released October 5, 2012. On April 25, 2013, the *Modification Application* was further granted in part & deferred in part to authorize an additional feeder link, centered at 150.025 MHz, for use by all currently operating first-generation ORBCOMM satellites as well as the authorized OG2 satellites. *Stamp Grant*, *Slip Op.,* File Nos. SAT-MOD-20111021-00207, SAT-AMD-20120809-00125 & SAT-AMD-20130212-00020, FCC

target operational orbital altitude for the remaining seventeen ORBCOMM Generation 2 ("OG2") satellites, provides commensurate revisions of the related information required by the Commission's Rules, and otherwise updates, revises, and amends the Modification Application.

MODIFIED OG2 SATELLITE DEPLOYMENT PLAN

Under the modified OG2 satellite deployment plan provided for in this Third Amendment, the seventeen remaining OG2 satellites will be deployed in four (4) evenly phased operational orbit planes, each with a target inclination of 47°, and a target operational orbital altitude of 715 kilometers. Three of these planes will consist of four satellites each, and the fourth plane will consist of five satellites.[2] ORBCOMM's modified OG2 satellite deployment plan will optimize ORBCOMM space segment coverage and capacity for evolving worldwide service requirements, in furtherance of the public interest, convenience, and necessity.

The accompanying FCC Form 312, amended FCC Form 312 Schedule S, and the attachments to this Narrative Exhibit listed in the Table below provide revised and amended information required by the Commission's Rules relating to ORBCOMM's modified orbit plan for the seventeen remaining OG2 satellites. As demonstrated in these supporting materials, the

---

International Bureau, Satellite Division, Satellite Policy Branch, April 25, 2013, *FCC Public Notice*, Report No. SAT-00945, released April 26, 2013.

2 ORBCOMM has contracted Space Exploration Technologies Corp. ("SpaceX") to deploy the seventeen remaining OG2 satellites as primary payloads on two launch missions using a SpaceX Falcon 9 v1.1 launch vehicle. To facilitate pre-operational configuration of the OG2 satellites into their respective operational orbit planes, ORBCOMM will utilize onboard propulsion to maneuver OG2 spacecraft from their launch insertion orbits into temporary parking orbits above and below the target circular 715 km operational orbit altitude. Once nodal separation is accomplished, each OG2 satellite plane will be maneuvered into the target 715 km circular orbit.

Modification Application, as amended by the revised OG2 satellite deployment plan set forth in this Third Amendment, is in compliance with all applicable Commission Rules and policies.

Narrative Exhibit Attachments

Attachment	Description of Showing	FCC Rule Part	Previous Version Filed
1	Design and operational strategies that will be used to mitigate orbital debris	**§ 25.114(d)(14)**	August 9, 2012 [1]
2	Power Flux Densities at the surface of the earth and protection of Radio Astronomy Services	**§ 25.142(a)(2)**	October 21, 2011 [2]
3	Representative coverage contour maps	**§ 25.114(d)(3)**	October 21, 2011 [3]
4	Link Budgets	**§ 25.114(d)(4)**	May 31, 2007 [4]

Previous Version Reference Citations:

1. *Modification Application Amendment*, File No. SAT-AMD-20120809-00125, Exhibit Attachment 2.
2. *Modification Application*, File No. SAT-MOD-20111021-00207, Narrative Exhibit, at pp. 12 & 30-31.
3. *Modification Application*, File No. SAT-MOD-20111021-00207, Narrative Exhibit, at 10 & Appendix A.
4. *Modification Application*, File No. SAT-MOD-20111021-00207, Narrative Exhibit, at 12 (filed October 21, 2011), *incorporating by reference previously filed Link Budgets, See, 2007 ORBCOMM Next-Generation Space Segment License Modification Application*, File No. SAT-MOD-20070531-00076, at Appendix B (filed May 31, 2007).

CONCLUSION

Please associate this submission with the record of ORBCOMM's Modification Application. ORBCOMM respectfully requests that the Commission act promptly to grant the above-captioned modification application to modify the ORBCOMM Non-Voice, Non-

Geostationary Satellite Service FCC space segment license, as further amended by this submission.

Respectfully submitted,

Walter H. Sonnenfeldt, Esq.
Regulatory Counsel
ORBCOMM License Corp. &
Vice President, Regulatory Affairs
ORBCOMM Inc.
Direct Tel: (585) 461-3018
E-Mail: sonnenfeldt.walter@orbcomm.com

January 15, 2014

Application of ORBCOMM License Corp.
For Authority to Modify its Non-Voice, Non-Geostationary
Satellite Service Space Segment License (S2103) to
Revise the Next-Generation Satellite Deployment Plan

THIRD AMENDMENT NARRATIVE EXHIBIT

ATTACHMENT 1
AMENDED ORBITAL DEBRIS MITIGATION SHOWING[1]

§ 25.114(d)(14) A description of the design and operational strategies that will be used to mitigate orbital debris:

As demonstrated below, the ORBCOMM Next-Generation space segment, as modified in accordance with this Third Amendment, will remain in compliance with the Commission's orbital debris mitigation Rules and policies.[2]

(1) OG2 Spacecraft Hardware Design. ORBCOMM has assessed the potential for any debris to be released into the space environment in connection with the OG2 satellite program, and has taken all possible spacecraft hardware design and operational planning measures to minimize the possibility of any such orbital debris. There are no planned intentional releases of any objects during any OG2 mission phase, including deployment, operations, and disposal. The OG2 satellite design does not utilize any shrouds or other temporary covers to be removed upon deployment, no shrapnel will

---

[1] *See, Modification Application Amendment*, File No. SAT-AMD-20120809-00125, Exhibit Attachment 2 (filed August 9, 2012).

[2] 47 C.F.R. § 25.114(d)(14). *See, also,* FCC Public Notice DA 05-2698, Report No. SPB-112, *Disclosure of Orbital Debris Mitigation Plans, Including Amendment of Pending Applications* (Rel. October 13, 2005).

be generated as a result of antenna and solar array deployments, and the specified OG2 satellite launch vehicle separation system uses non-explosive actuators that retain all separation hardware.

ORBCOMM understands and appreciates that small debris and meteoroids have the potential of colliding with and doing damage to spacecraft components. Such impacts pose a risk to a satellite's mission, its ability to maintain control, and its ability to perform post-mission disposal maneuvers. Using NASA's Debris Assessment Software (DAS v2.0.1), ORBCOMM has assessed the probability of OG2 satellite collisions with untrackable particles larger than one centimeter. At the target nominal operational orbital altitude of 715 km and with a 47 deg inclination, DAS produces the annual collision probability for OG2 satellites of 6.3×10^{-5}, as summarized in Table 1 below.

Table 1 Annual Collision Probability (Debris >1cm)				
ORBCOMM Satellite	Nominal Inclination	Nominal Altitude	Avg. Cross Sectional Area	P(Impact w/ debris >1cm)/yr
OG2	47°	715 km	2.43 m^2	6.3×10^{-5}

It is unknown what the minimum particle size is that could potentially cause critical damage to an OG2 satellite in the event of an impact. Among other things, that threshold depends on impact location, angle, and velocity. Due, however, to the fact that the debris population increases logarithmically with decreased debris size, the probability of impact similarly increases above 10^{-4} when debris smaller than one centimeter is considered.

The OG2 satellites have been designed to be tolerant of small-particle impacts, with particular focus on minimizing the vulnerability of critical systems. For example, external exposure is minimized for components critical to OG2 functionality, and internal components are provided with physical protection by the bus structure and thermal insulation. These protective layers serve as shielding that will either prevent small debris and meteoroids from reaching critical components or break up incoming projectiles prior to penetrating to the satellite's interior. It is also important to note that OG2 spacecraft use the same subsystems (*e.g.*, propulsion system) for operation and disposal, so the disposal operation is no more susceptible to small debris impacts than normal operational functions. These design features mitigate the possibility of critical component damage resulting from impacting debris during all phases of deployment, mission operations, and end-of-life disposal.

In summary, there is a low probability of impact for debris larger than 1 cm, and the risk of an OG2 satellite being disabled by debris smaller than 1 cm is negligible, owing to the protective spacecraft design measures employed on the OG2 program.

(2) Minimizing Accidental Explosions. There is virtually no possibility that an OG2 spacecraft will accidentally explode on-orbit, either during normal operations or during end-of-life disposal. As discussed more fully below, all components involved in the retention and control of energy sources are space-qualified, and energy sources will be managed autonomously, minimized, or depleted upon disposal of the spacecraft.

These sources include pressurized fuel tanks for propulsion, chemical batteries, and momentum wheels. To further support this showing, on October 21, 2011, ORBCOMM submitted in the record of the Modification Application copies of hazard analyses, related presentation materials prepared by the OG2 satellite manufacturer, and information presented to NASA during the Falcon 9 ORBCOMM mission safety coordination process, together with a Request For Confidential Treatment. Those submissions are incorporated herein by reference.

Each OG2 satellite will carry up to 10.3 kg of hydrazine fuel at launch. Propellant will be used during all phases of the mission, from attaining the initial operational orbit, to performing maintenance thrusts throughout the operational life, and through end-of-life disposal maneuvering. While fuel is budgeted for disposal, any additional fuel remaining after an OG2 satellite reaches the target disposal altitude will be consumed while continuing to lower the orbit, and thereby the orbital lifetime. Thus, OG2 satellite fuel tanks will be left with very small, residual amounts of fuel, very little pressure, and no potential for chemical combustion.[3] The thermal management devices used to maintain the hydrazine fuel temperature during operations are not capable of causing the hydrazine to disassociate. Fuel tank heaters will not heat the hydrazine to a

---

[3] The OG2 fuel tank manufacturer has indicated that the unusable amount of residual fuel that will remain in the tank will be approximately 0.27 kg. The residual internal pressure in the fuel tank from the GN2 pressurant will be less than 100 psi. Although the tank valves cannot be left in an open position indefinitely due to the design of the OG2 propulsion system, they will be exercised in the disposal operation until there is no discernable pressure drop or delta V associated with the exercise.

point where it will be a hazard, even in the presence of a failure that sets the fuel heaters to the full-on setting.

The OG2 satellite power subsystems use lithium-ion batteries and are designed to maximize the possibility for recovery from low states of charge. As a consequence, the OG2 design does not permit permanent disconnection of the batteries from the solar arrays. In fact, the satellites have a hard-coded protection mechanism (the load disconnect switch, or LDS) that triggers at low battery states-of-charge to prevent total battery depletion and premature mission failure. The LDS disconnects the satellite bus and payload from the battery and connects all solar array strings to the battery to optimize power recovery. Then, once charging (by drifting through an attitude that illuminates the solar arrays sufficiently), as the battery reaches state-of-charge that support minimum satellite operation, the LDS sequentially powers on various elements of the satellite bus and payload.

This feature cannot be disabled, but upon decommissioning, OG2 satellites are expected to tumble randomly. This will keep the batteries at low states-of-charge as the power production will be small and reconnection of spacecraft elements will consume stored charge. Nevertheless, to further reduce any possibility of overcharge, decommissioned satellites will be re-configured to maximize power drain when the first elements are turned back on, thereby driving the battery charge back down. This will be facilitated with a software upload that limits charge accumulation in the initial satellite boot sequence, unless the battery charging capability of the particular satellite undergoing decommissioning does not require such intervention.

Furthermore, in the unlikely event that an overcharge condition occurs despite this design, the batteries are designed such that the pressure disc integrated into the battery cell will burst and vent/leak before a catastrophic burst of the battery occurs. Thus, the OG2 batteries have a mechanical overcharge disconnect and a leak-before-burst architecture, and therefore do not pose an explosion risk even if overcharge conditions were to occur. In addition, it is also important to note that the batteries being used in OG2 satellites are on the list of approved satellite components issued by the Eastern Test Range.

Finally, the principal source of internal kinetic energy is the satellite's suite of four momentum wheels. There are no credible failure scenarios in which this rotational kinetic energy could become sufficient to fragment the spacecraft.

(3) Safe Flight Profiles. ORBCOMM recognizes that there is some small possibility of physical collision with large objects in low-Earth orbit (including other operational satellites, spent hardware, and debris). Such a collision would clearly generate additional orbital debris. While ORBCOMM is unaware of other operators currently occupying or planning to occupy orbits identical to its own operational orbit, 715 km is a relatively populated region of LEO, and objects will most certainly be passing through this altitude regime.

To assess the likelihood of colliding with objects large enough to render an OG2 satellite a source of debris, ORBCOMM again turned to NASA's Debris Assessment Software. The calculated annual collision probability with objects larger than 10 cm for the OG2 operational orbit is shown in Table 2 below. This debris size corresponds roughly with the lower size threshold for cataloged objects in LEO and is in keeping with the analysis requirement for large debris specified in the U.S. Government Orbital Debris Mitigation Standard Practices (Objective 3-1). The upper risk threshold identified in DAS is 10^{-3} for the orbital life of any individual OG2 spacecraft. As computed by DAS, the accumulated risk over the entire orbital life (five years of operational life and up to 25 years for disposal) for each OG2 spacecraft comes to $3.2x10^{-4}$.

Table 2 Annual Collision Probability (Debris >10cm)				
ORBCOMM Satellite	Nominal Inclination	Nominal Altitude	Avg. Cross Sectional Area	P(Impact w/ debris >10cm)/yr
OG2	47°	715 km	2.43 m^2	$6x10^{-6}$

Based on these findings, OG2 satellites do not constitute a significant risk of further contributing to the debris environment. The low probability of catastrophic collision over the life of the OG2 satellite mission satisfies the intent of the Commission's orbital debris mitigation Rules and policies.

Because there are no mission requirements to do so (nor any Commission requirements to do so, unlike requirements for geostationary satellites), no active measures are necessary to maintain OG2 satellite orbital parameters to any prescribed accuracy. During the operational life of the OG2 satellites, the orbit altitude is expected to decay less than 10 kilometers. The inclination should remain stable at the specified operational inclination, and the eccentricity will exhibit small oscillations above its target value of zero. The ascending node and true anomaly will obviously take on all possible values as they secularly and continuously precess. Nonetheless, as demonstrated above, the risk of collision in the selected target altitude and inclination is *de minimis*.

Despite the low collision probabilities demonstrated above, ORBCOMM obviously has a clear business interest in protecting its on-orbit assets. ORBCOMM also takes very seriously the potential environmental impact that collisions can have in LEO. In this regard, with respect to the OG2 satellites, ORBCOMM intends to continue its established practice of coordinating with U.S. Government organizations and other satellite operators to improve space situational awareness and avoid physical collisions. For example, ORBCOMM currently receives daily conjunction summary messages (CSMs) from the Joint Space Operations Command (JSpOC), identifying conjunctions predicted 72 hours into the future between any ORBCOMM asset and any tracked object. ORBCOMM, in turn, provides JSpOC with high-accuracy ephemeris predictions for involved assets, as available, and keeps JSpOC informed of all anticipated maneuvering plans (including pre-operational maneuvers). This enables JSpOC to provide more accurate warning services to the entire operator community regarding the location of ORBCOMM satellites.

ORBCOMM also coordinates directly with other operators. For example, established lines of communication are maintained with Iridium and Radarsat, both of which operate assets in the same altitude regime as ORBCOMM's current satellite constellation. Informal coordination arrangements among LEO satellite operators have proven quite effective, due among other things, to the mutually beneficial incentives for cooperation. Typically, if an operator has a concern over an upcoming conjunction, contact is initiated with the other affected operator to jointly review the severity of the situation and coordinate any maneuvering plans that may be deemed warranted. ORBCOMM definitely intends to continue this practice with regard to the deployment, operation, and post-mission disposal of the OG2 satellites.

(4) End-Of-Life Disposal. ORBCOMM recognizes that responsible disposal of post-mission hardware is the most practical and effective means of preserving the orbital environment for future use. Upon completion of its mission, the perigee altitude of each OG2 satellite will be lowered using its on-board propulsion system to facilitate a more rapid, uncontrolled re-entry into the atmosphere. In each case, the perigee of the satellite will be lowered sufficiently to ensure that following completion of the disposal maneuver, the orbital lifetime of the hardware will be less than the Commission's guideline of twenty-five years.

In order to determine the required target disposal perigee altitude, ORBCOMM again utilized NASA's DAS software. The target nominal operational altitude of 715 km was used as the apogee altitude, and the required disposal perigee altitude and corresponding delta velocity are given in Table 3 below.

Table 3
Required Disposal Perigee Altitude & Delta Velocity

ORBCOMM Satellite	Apogee Altitude	Average Area/Mass	Required Perigee Altitude	Required Delta Velocity
OG2	715 km	.0139 m^2/kg	615 km	26.7 m/sec

Sufficient fuel is being budgeted on each OG2 spacecraft to perform these disposal maneuvers. The propulsion system uses hydrazine fuel, with an Isp of 222 sec. Thus, from the following equation, the average fuel efficacy ratio of 13.6 m/sec per kg is derived, and the nominal disposal reserve is to be 26.7/13.6 = 1.96 kg.

$$dV = Isp \times g \times \ln(M_{initial}/M_{final})$$

Fuel levels during the mission will be closely monitored both through direct measurements of tank pressure and temperature and by tracking usage. Comparing two measurement techniques will provide a check on expected fuel efficacy and fuel gauging uncertainty during the course of the mission. It is expected that inefficiencies from nozzle misalignment, CG misalignment, and ACS pointing error will sum to less than one percent loss. Nevertheless, a margin of 5% is added to the nominal disposal reserve to account for inefficiencies and gauging uncertainties, yielding a total disposal reserve of 2.06 kg.

DAS modeling of the basic OG2 satellite physical elements indicates that, upon atmospheric re-entry, the OG2 satellites will disintegrate and almost completely burn up, with only two small blocks of ballast surviving to hit the surface of the Earth. In general, spacecraft components that are most likely to survive re-entry are those that are protected by multiple layers of material (*e.g.*, those inside a box that is inside another …), or of particularly high density (*e.g.*, solid metal ballast blocks). Therefore, it was not necessary to construct a minutely detailed OG2 satellite model to conduct the DAS re-entry analysis. Focus was placed instead on the "nested-ness" and density of representative components. Toward this end, ORBCOMM created a satellite model consisting of an OG2 outer bus structure with the following internal components: the fuel tank; structural pylons; ballast blocks, reaction wheels; and a representative internal electronics box. External spacecraft elements, such as the solar array and the antenna were not included in the model, as these components will most certainly disintegrate early in the re-entry trajectory.

The OG2 fuel tank was included because of the unique aerodynamics characteristics that spherical tanks possess. The structural pylons, ballast, and reaction wheels were included because of their density, and because they are the most solid elements on an OG2 spacecraft. Finally, the internal box was chosen as being representative of the multiple internal OG2 satellite structures that house circuit cards and other smaller components.

The DAS analysis indicated that the OG2 outer bus will yield at an altitude of 78 km, exposing internal components to aerodynamic forces and heating. None of the modeled components other than the ballast blocks were predicted to survive to an altitude of lower than 49 km. DAS estimates the risk of human casualty for an OG2 satellite reentering the atmosphere to be 1 in 48,300, well below the guideline threshold of 1 in 10,000. It can be concluded, therefore, that the OG2 satellite end-of-life disposal plan fully complies with the Commission's orbital debris mitigation Rules and policies.

Application of ORBCOMM License Corp.
For Authority to Modify its Non-Voice, Non-Geostationary
Satellite Service Space Segment License (S2103) to
Revise the Next-Generation Satellite Deployment Plan

THIRD AMENDMENT NARRATIVE EXHIBIT

ATTACHMENT 2
AMENDED PFD & RADIO ASTRONOMY PROTECTION ANALYSIS[1]

§ 25.142(a)(2) Power Flux Densities at the Surface of the Earth and Protection of Radio Astronomy Services:

The revisions to the OG2 satellite deployment plan proposed in this Third Amendment (reducing the target operational orbital altitude from 750 km to 715 km) do not require any change of the currently authorized radio frequency emission characteristics for the OG2 satellites to maintain compliance with the applicable power flux density threshold and Radio Astronomy Service protection criteria. As demonstrated below, the power flux density produced at the Earth's surface in the 137-138 MHz band by OG2 satellites operating at the modified target operational orbital altitude of 715 km will still be less than the -125 dB (W/m^2/4 kHz) coordination trigger specified by the ITU. Table 1 shows the worst case maximum power flux density values for the OG2 satellite downlinks operating at the target 715 km orbital altitude.

---

[1] *See, Modification Application,* File No. SAT-MOD-20111021-00207, Narrative Exhibit, at pp. 12 & 30-31 (filed October 21, 2011).

Table 1
Worst Case OG2 Satellite Power Flux Density Values
715 km Target Operational Orbital Altitude

	Elevation Angle at max	**Subscriber Downlink**	**Gateway Downlink**	**Units**
Max EIRP	5	13.5	1.3	dBW
Max PFD at Earth Surface	90	-125.4	-145.4	dBW/m^2 /4 kHz
Frequency Band		137-138	137-138	MHz

With respect to the Radio Astronomy Service ("RAS"), ORBCOMM will limit OG2 satellite out-of-band emissions to protect RAS operations in the 150.05-153 MHz and 406.1-410 MHz bands from harmful interference. The factors providing protection include spectrum roll-off, diplexer or filter attenuation and the path loss between the satellites and radio telescopes.

The OG2 satellites are designed to be very quiet in the 148-150.05 MHz band to facilitate optimum performance of their VHF uplink receivers. As demonstrated in Table 2 below, the OG2 satellites will also be very quiet in the neighboring 150.05-153 MHz RAS band. The diplexer and filter isolations reflected in Table 2 are minimum isolation values measured at 153 MHz. At other intermediate points between 150.05-153 MHz the isolation is even greater. The OG2 satellite downlinks will also comply with all applicable out-of-band limits to protect against harmful interference to RAS operations in the 406.1-410 MHz band.

Table 2
Worst Case OG2 Satellite Out-of-Band Emissions into Radio Astronomy Bands
(715 km Target Operational Orbital Altitude)

	Subscriber Downlink	Gateway Downlink
EIRP at Subsatellite (dBW)	3.5	-8.7
Channel Bandwidth (KHz)	6.72	40.3
Spreading Loss (dB/M^2)	-128.1	-128.1
PFD ($dBW/m^2/4$ kHz)	-125.4	-145.4
Bandwidth Conversion	-36	-36
Spectrum Rolloff Mask	-55	-50
System Filtering	-45	-28
151 MHz Band Power Density (dBW/m2/Hz)	-261.4	-259.4
RAS Protection Criteria ($dBW/m^2/Hz$)	-259	-259

Application of ORBCOMM License Corp.
For Authority to Modify its Non-Voice, Non-Geostationary
Satellite Service Space Segment License (S2103) to
Revise the Next-Generation Satellite Deployment Plan

THIRD AMENDMENT NARRATIVE EXHIBIT

ATTACHMENT 3
AMENDED REPRESENTATIVE CONTOUR MAPS[1]

Figure 1
Representative Single OG2 Satellite Footprint
Altitude = 715 km, User Minimum Elevation Angle Mask = 5º

[1] *See*, *Modification Application*, File No. SAT-MOD-20111021-00207, Narrative Exhibit, at 10 & Appendix A (filed October 21, 2011).

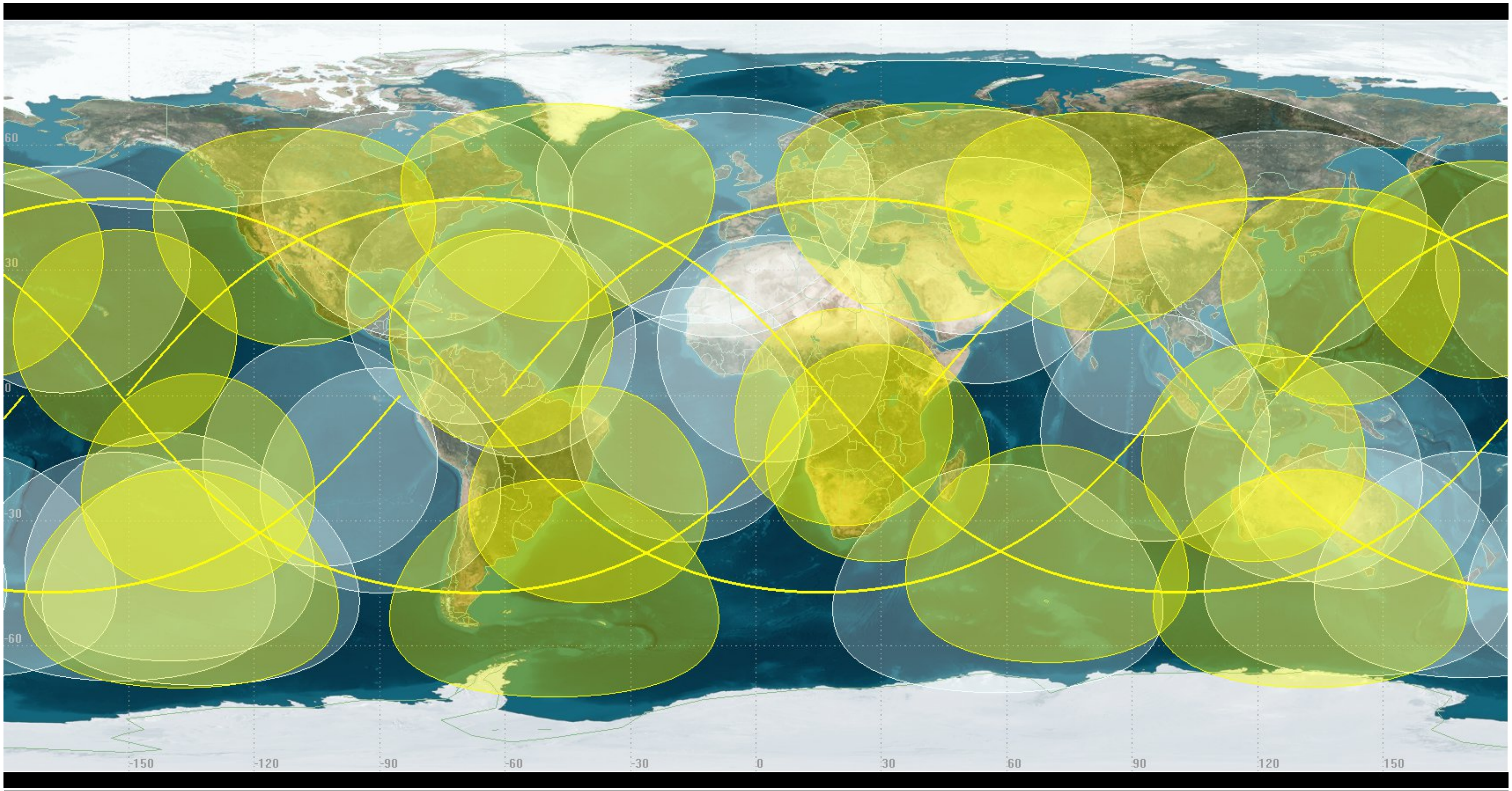

Figure 2
Representative Full ORBCOMM Satellite Constellation Worldwide Coverage
OG2 Satellite Altitude = 715 km, Inclination = 47º
17 OG2 Satellites in Four Orbit Planes (Yellow Footprints)
Current operational ORBCOMM First-Generation Satellites (White Footprints)

Application of ORBCOMM License Corp.
For Authority to Modify its Non-Voice, Non-Geostationary
Satellite Service Space Segment License (S2103) to
Revise the Next-Generation Satellite Deployment Plan

THIRD AMENDMENT NARRATIVE EXHIBIT

ATTACHMENT 4
LINK BUDGETS

Link budgets for the various authorized OG2 service and feeder ("Gateway") uplinks and downlinks are set forth below in this Attachment 4. Separate link budgets are provided in Tables 1 - 9 for each of the new enhanced-capability OG2 links, as well as the backwards-compatible ORBCOMM First-Generation ("OG1") links, and the Automatic Identification System ("AIS") signal reception uplink.

Prior to the submission of this Third Amendment, the Modification Application did not propose to change the currently authorized 750 km target OG2 satellite operational orbital altitude, or any other relevant authorized parameter that would merit submission of new link budgets.[1] Accordingly, no link budgets have previously been filed in connection with the Modification Application. ORBCOMM is including new link budgets in this submission because the modified OG2 satellite deployment plan specified in this Third Amendment changes the currently authorized 750 km OG2 satellite orbital altitude to 715 km, which results in slightly modified link budget calculations.[2]

[1] *See, Modification Application*, File No. SAT-MOD-20111021-00207, Narrative Exhibit, at 12 (filed October 21, 2011), *incorporating by reference previously filed Link Budgets, See, 2007 ORBCOMM Next-Generation Space Segment License Modification Application*, File No. SAT-MOD-20070531-00076, at Appendix B (filed May 31, 2007).

[2] As reflected in the revised link budgets provided in this submission, the 35 km reduction in target operational altitude results in a slight reduction in signal attenuation, and a slight increase in link margin.

TABLE 1
OG2 SUBSCRIBER UPLINK LINK BUDGET

Range Computation:				
Orbit Altitude	715	Km	715	km
Elevation	5	Deg	90	Deg
Slant Range	2597.0	Km	715.0	km
Modulation Characteristics:				
User Data Rate	4320	Bps	4320	bps
Frequency:				
Frequency	150.05	MHz	150.05	MHz
Wavelength	2.00	Meters	2.00	meters
Transmitter Characteristics:				
TX EIRP	7	dBW	7	dBW
Path Characteristics:				
Path Loss (Friis)	-144.3	dB	-133.1	dB
Absorption	0.2	dB	0.2	dB
Fade Margin	5.0	dB	5.0	dB
Total Loss	-149.5	dB	-138.3	dB
Rx Antenna Characteristics:				
Rx Antenna Gain	1.5	dBi	-8.5	dBi
Rx Antenna Polarization Loss	-4.1	dB	-4.1	dB
Rx Pointing Loss	0.0	dB	0.0	dB
Net Rx Antenna Gain	-2.6	dBi	-12.6	dBi
RX Noise Characteristics:				
Antenna Noise Density (Ta = 410 K)	-172.5	dBm/Hz	-172.5	dBm/Hz
Rx Receiver Noise Density (Receiver NF = 4.0 dB)	-172.7	dBm/Hz	-170.3	dBm/Hz
System Noise Density	-169.6	dBm/Hz	-169.6	dBm/Hz
Interference Noise Density	-170.5	dBm/Hz	-170.5	dBm/Hz
Total Rx Noise	-167.0	dBm/Hz	-167.0	dBm/Hz
Rx Noise Characteristics:				
Received Signal Power	-115.1	dBm	-113.9	dBm
Received Noise Power	-167.0	dBm/Hz	-167.0	dBm/Hz
Implementation Loss	2.0	dB	2.0	dB
Total Signal Power to Noise Density Ratio (C/No)	50.0	dB-Hz	51.2	dB-Hz
Link Margin:				
Required BER	1.00E-06		1.00E-06	
Required Eb/N0 (OQPSK 9/10 FEC)	8.45	dB	8.45	dB
Received Eb/N0	13.6	dB	14.8	dB
Link Margin	5.1	dB	6.4	dB

TABLE 2
OG2 SUBSCRIBER DOWNLINK LINK BUDGET

Range Computation:				
Orbit Altitude	715	km	715	km
Elevation	5	Deg	90	Deg
Slant Range	2597.0	km	715.0	km
Modulation Characteristics:				
User Data Rate	7200	bps	7200	bps
Frequency:				
Frequency	137.5	MHz	137.5	MHz
Wavelength	2.18	meters	2.18	meters
Transmitter Characteristics:				
TX EIRP	13.5	dBW	3.5	dBW
Path Characteristics:				
Path Loss (Friis)	-143.5	dB	-132.3	dB
Absorption	0.2	dB	0.2	dB
Fade Margin	5.0	dB	5.0	dB
Total Loss	-148.7	dB	-137.5	dB
Rx Antenna Characteristics:				
Rx Antenna Gain	0.0	dBi	0.0	dBi
Rx Antenna Polarization Loss	-4.1	dB	-4.1	dB
Rx Pointing Loss	0.0	dB	0.0	dB
Net Rx Antenna Gain	-4.1	dBi	-4.1	dBi
RX Noise Characteristics:				
Rx Antenna Noise Density (T = 290K)	-174.0	dBm/Hz	-174.0	dBm/Hz
Rx Receiver Noise Density (Receiver NF = 4.0 dB)	-172.2	dBm/Hz	-172.2	dBm/Hz
System Noise Density	-170.0	dBm/Hz	-170.0	dBm/Hz
Interference Noise Density	-160.7	dBm/Hz	-160.7	dBm/Hz
Total Rx Noise	-160.2	dBm/Hz	-160.2	dBm/Hz
Rx Noise Characteristics:				
Received Signal Power	-109.3	dBm	-108.1	dBm
Received Noise Power	-160.2	dBm/Hz	-160.2	dBm/Hz
Implementation Loss	2.0	dB	2.0	dB
Total Signal Power to Noise Density Ratio (C/No)	48.9	dB-Hz	50.1	dB-Hz
Link Margin:				
Required BER	5.00E-07		5.00E-07	
Required Eb/N0 (OQPSK, 3/4 FEC)	6	dB	6	dB
Received Eb/N0	10.3	dB	11.5	dB
Link Margin	4.3	dB	5.5	dB

TABLE 3
OG2 GATEWAY UPLINK LINK BUDGET

Range Computation:				
Orbit Altitude	715	km	715	km
Elevation	5	Deg	90	Deg
Slant Range	2597.0	km	715.0	km
Modulation Characteristics:				
User Data Rate	86400	bps	86400	bps
Frequency:				
Frequency	150.025	MHz	150.025	MHz
Wavelength	2.00	meters	2.00	meters
Transmitter Characteristics:				
TX EIRP	32.7	dBW	32.7	dBW
Path Characteristics:				
Path Loss (Friis)	-144.3	dB	-133.1	dB
Absorption	0.2	dB	0.2	dB
Fade Margin	5.0	dB	5.0	dB
Total Loss	-149.5	dB	-138.3	dB
Rx Antenna Characteristics:				
Rx Antenna Gain	1.5	dBi	-8.5	dBi
Rx Antenna Polarization Loss	-0.4	dB	-0.4	dB
Rx Pointing Loss	0.0	dB	0.0	dB
Net Rx Antenna Gain	1.1	dBi	-8.9	dBi
RX Noise Characteristics:				
Rx Antenna Noise Density (Ta = 410K)	-172.5	dBm/Hz	-172.5	dBm/Hz
Rx Receiver Noise Density (Receiver NF = 4.0 dB)	-172.7	dBm/Hz	-172.7	dBm/Hz
System Noise Density	-169.6	dBm/Hz	-169.6	dBm/Hz
Interference Noise Density	-166	dBm/Hz	-166	dBm/Hz
Total Rx Noise	-164.4	dBm/Hz	-164.4	dBm/Hz
Rx Noise Characteristics:				
Received Signal Power	-85.7	dBm	-84.5	dBm
Received Noise Power	-164.4	dBm/Hz	-164.4	dBm/Hz
Implementation Loss	1.0	dB	1.0	dB
Total Signal Power to Noise Density Ratio (C/No)	77.8	dB-Hz	79.0	dB-Hz
Link Margin:				
Required BER	1.00E-06		1.00E-06	
Required Eb/N0 (16 QAM, 3/4 FEC)	11	dB	11	dB
Received Eb/N0	28.4	dB	29.6	dB
Link Margin	17.4	dB	18.6	dB

TABLE 4
OG2 GATEWAY DOWNLINK LINK BUDGET

Range Computation:				
Orbit Altitude	715	km	715	Km
Elevation	5	Deg	90	Deg
Slant Range	2597.0	km	715.0	Km
Modulation Characteristics:				
User Data Rate	86400	bps	86400	Bps
Frequency:				
Frequency	137.5	MHz	137.5	MHz
Wavelength	2.18	meters	2.18	Meters
Transmitter Characteristics:				
TX EIRP	1.3	dBW	-8.7	dBW
Path Characteristics:				
Path Loss (Friis)	-143.5	dB	-132.3	dB
Absorption	0.2	dB	0.2	dB
Fade Margin	2.0	dB	2.0	dB
Total Loss	-145.7	dB	-134.5	dB
Rx Antenna Characteristics:				
Rx Antenna Gain	16.5	dBi	16.5	dBi
Rx Antenna Polarization Loss	-0.4	dB	-0.4	dB
Rx Pointing Loss	-0.3	dB	-0.3	dB
Net Rx Antenna Gain	15.8	dBi	15.8	dBi
RX Noise Characteristics:				
Rx Antenna Noise Density (Ta = 460K)	-171.9	dBm/Hz	-171.9	dBm/Hz
Rx Receiver Noise Density (Receiver NF = 4.0 dB)	-172.2	dBm/Hz	-172.2	dBm/Hz
System Noise Density	-169.0	dBm/Hz	-169.0	dBm/Hz
Interference Noise Density	-166.0	dBm/Hz	-174.0	dBm/Hz
Total Rx Noise	-164.2	dBm/Hz	-167.8	dBm/Hz
Rx Noise Characteristics:				
Received Signal Power	-98.6	dBm	-97.4	dBm
Received Noise Power	-164.2	dBm/Hz	-167.8	dBm/Hz
Implementation Loss	1.0	dB	1.0	dB
Total Signal Power to Noise Density Ratio (C/No)	64.6	dB-Hz	69.4	dB-Hz
Link Margin:				
Required BER	1.00E-06		1.00E-06	
Required Eb/N0 (16QAM, 3/4 FEC)	11	dB	11	dB
Received Eb/N0	15.3	dB	20.1	dB
Link Margin	4.3	dB	9.1	dB

TABLE 5
OG1 COMPATIBLE SUBSCRIBER UPLINK LINK BUDGET

Range Computation:				
Orbit Altitude	715	km	715	km
Elevation	5	Deg	90	Deg
Slant Range	2597.0	km	715.0	km
Modulation Characteristics:				
User Data Rate	2400	bps	2400	bps
Frequency:				
Frequency	150.05	MHz	150.05	MHz
Wavelength	2.00	meters	2.00	meters
Transmitter Characteristics:				
TX EIRP	7	dBW	7	dBW
Path Characteristics:				
Path Loss (Friis)	-144.3	dB	-133.1	dB
Absorption	0.2	dB	0.2	dB
Fade Margin	5.0	dB	5.0	dB
Total Loss	-149.5	dB	-138.3	dB
Rx Antenna Characteristics:				
Rx Antenna Gain	1.5	dBi	-8.5	dBi
Rx Antenna Polarization Loss	-4.1	dB	-4.1	dB
Rx Pointing Loss	0.0	dB	0.0	dB
Net Rx Antenna Gain	-2.6	dBi	-12.6	dBi
RX Noise Characteristics:				
Antenna Noise Density (Ta = 410 K)	-172.5	dBm/Hz	-172.5	dBm/Hz
Rx Receiver Noise Density (Receiver NF = 4.0 dB)	-172.7	dBm/Hz	-170.3	dBm/Hz
System Noise Density	-169.6	dBm/Hz	-169.6	dBm/Hz
Interference Noise Density	-170.5	dBm/Hz	-170.5	dBm/Hz
Total Rx Noise	-167.0	dBm/Hz	-167.0	dBm/Hz
Rx Noise Characteristics:				
Received Signal Power	-115.1	dBm	-113.9	dBm
Received Noise Power	-167.0	dBm/Hz	-167.0	dBm/Hz
Implementation Loss	2.0	dB	2.0	dB
Total Signal Power to Noise Density Ratio (C/No)	50.0	dB-Hz	51.2	dB-Hz
Link Margin:				
Required BER	1.00E-05		1.00E-05	
Required Eb/N0 (SDPSK)	10.3	dB	10.3	dB
Received Eb/N0	16.2	dB	17.4	dB
Link Margin	5.9	dB	7.1	dB

TABLE 6
OG1 COMPATIBLE SUBSCRIBER DOWNLINK LINK BUGET

Range Computation:				
Orbit Altitude	715	km	715	km
Elevation	5	Deg	90	Deg
Slant Range	2597.0	km	715.0	km
Modulation Characteristics:				
User Data Rate	4800	bps	4800	bps
Frequency:				
Frequency	137.5	MHz	137.5	MHz
Wavelength	2.18	meters	2.18	meters
Transmitter Characteristics:				
TX EIRP	13.5	dBW	3.5	dBW
Path Characteristics:				
Path Loss (Friis)	-143.5	dB	-132.3	dB
Absorption	0.2	dB	0.2	dB
Fade Margin	5.0	dB	5.0	dB
Total Loss	-148.7	dB	-137.5	dB
Rx Antenna Characteristics:				
Rx Antenna Gain	0.0	dBi	0.0	dBi
Rx Antenna Polarization Loss	-4.1	dB	-4.1	dB
Rx Pointing Loss	0.0	dB	0.0	dB
Net Rx Antenna Gain	-4.1	dBi	-4.1	dBi
RX Noise Characteristics:				
Rx Antenna Noise Density (T = 290K)	-174.0	dBm/Hz	-174.0	dBm/Hz
Rx Receiver Noise Density (Receiver NF = 4.0 dB)	-172.2	dBm/Hz	-172.2	dBm/Hz
System Noise Density	-170.0	dBm/Hz	-170.0	dBm/Hz
Interference Noise Density	-160.7	dBm/Hz	-160.7	dBm/Hz
Total Rx Noise	-160.2	dBm/Hz	-160.2	dBm/Hz
Rx Noise Characteristics:				
Received Signal Power	-109.3	dBm	-108.1	dBm
Received Noise Power	-160.2	dBm/Hz	-160.2	dBm/Hz
Implementation Loss	2.0	dB	2.0	dB
Total Signal Power to Noise Density Ratio (C/No)	48.9	dB-Hz	50.1	dB-Hz
Link Margin:				
Required BER	1.00E-05		1.00E-05	
Required Eb/N0 (SDPSK)	10.3	dB	10.3	dB
Received Eb/N0	12.1	dB	13.3	dB
Link Margin	1.8	dB	3.0	dB

TABLE 7
OG1 COMPATIBLE GATEWAY UPLINK LINK BUDGET

Range Computation:				
Orbit Altitude	715	km	715	km
Elevation	5	Deg	90	Deg
Slant Range	2597.0	km	715.0	km
Modulation Characteristics:				
User Data Rate	57600	bps	57600	bps
Frequency:				
Frequency	150.025	MHz	150.025	MHz
Wavelength	2.00	meters	2.00	meters
Transmitter Characteristics:				
TX EIRP	32.7	dBW	32.7	dBW
Path Characteristics:				
Path Loss (Friis)	-144.3	dB	-133.1	dB
Absorption	0.2	dB	0.2	dB
Fade Margin	5.0	dB	5.0	dB
Total Loss	-149.5	dB	-138.3	dB
Rx Antenna Characteristics:				
Rx Antenna Gain	1.5	dBi	-8.5	dBi
Rx Antenna Polarization Loss	-0.4	dB	-0.4	dB
Rx Pointing Loss	0.0	dB	0.0	dB
Net Rx Antenna Gain	1.1	dBi	-8.9	dBi
RX Noise Characteristics:				
Rx Antenna Noise Density (Ta = 410K)	-172.5	dBm/Hz	-172.5	dBm/Hz
Rx Receiver Noise Density (Receiver NF = 4.0 dB)	-172.7	dBm/Hz	-172.7	dBm/Hz
System Noise Density	-169.6	dBm/Hz	-169.6	dBm/Hz
Interference Noise Density	-166	dBm/Hz	-166	dBm/Hz
Total Rx Noise	-164.4	dBm/Hz	-164.4	dBm/Hz
Rx Noise Characteristics:				
Received Signal Power	-85.7	dBm	-84.5	dBm
Received Noise Power	-164.4	dBm/Hz	-164.4	dBm/Hz
Implementation Loss	2.0	dB	2.0	dB
Total Signal Power to Noise Density Ratio (C/No)	76.8	dB-Hz	78.0	dB-Hz
Link Margin:				
Required BER	1.00E-06		1.00E-06	
Required Eb/N0 (OQPSK No coding)	10.6	dB	10.6	dB
Received Eb/N0	29.2	dB	30.4	dB
Link Margin	18.6	dB	19.8	dB

TABLE 8
OG1 COMPATIBLE GATEWAY DOWNLINK LINK BUDGET

Range Computation:				
Orbit Altitude	715	km	715	km
Elevation	5	Deg	90	Deg
Slant Range	2597.0	km	715.0	km
Modulation Characteristics:				
User Data Rate	57600	bps	57600	bps
Frequency:				
Frequency	137.5	MHz	137.5	MHz
Wavelength	2.18	meters	2.18	meters
Transmitter Characteristics:				
TX EIRP	1.3	dBW	-8.7	dBW
Path Characteristics:				
Path Loss (Friis)	-143.5	dB	-132.3	dB
Absorption	0.2	dB	0.2	dB
Fade Margin	2.0	dB	2.0	dB
Total Loss	-145.7	dB	-134.5	dB
Rx Antenna Characteristics:				
Rx Antenna Gain	16.5	dBi	16.5	dBi
Rx Antenna Polarization Loss	-0.4	dB	-0.4	dB
Rx Pointing Loss	-0.3	dB	-0.3	dB
Net Rx Antenna Gain	15.8	dBi	15.8	dBi
RX Noise Characteristics:				
Rx Antenna Noise Density (Ta = 460K)	-171.9	dBm/Hz	-171.9	dBm/Hz
Rx Receiver Noise Density (Receiver NF = 4.0 dB)	-172.2	dBm/Hz	-172.2	dBm/Hz
System Noise Density	-169.0	dBm/Hz	-169.0	dBm/Hz
Interference Noise Density	-166.0	dBm/Hz	-174.0	dBm/Hz
Total Rx Noise	-164.2	dBm/Hz	-167.8	dBm/Hz
Rx Noise Characteristics:				
Received Signal Power	-98.6	dBm	-97.4	dBm
Received Noise Power	-164.2	dBm/Hz	-167.8	dBm/Hz
Implementation Loss	1.0	dB	1.0	dB
Total Signal Power to Noise Density Ratio (C/No)	64.6	dB-Hz	69.4	dB-Hz
Link Margin:				
Required BER	1.00E-06		1.00E-06	
Required Eb/N0 (QPSK No Coding)	10.6	dB	10.6	dB
Received Eb/N0	17.0	dB	21.8	dB
Link Margin	6.4	dB	11.2	dB

TABLE 9
AUTOMATIC IDENTIFICATION SYSTEM ("AIS") RECEIVER (UPLINK) LINK BUDGET

Range Computation:				
Orbit Altitude	715	km	715	km
Elevation	5	Deg	90	Deg
Slant Range	2597.0	km	715.0	km
Modulation Characteristics:				
User Data Rate	9600	bps	9600	bps
Frequency:				
Frequency	162	MHz	162	MHz
Wavelength	1.85	meters	1.85	meters
Transmitter Characteristics:				
TX EIRP	10.8	dBW	4	dBW
Path Characteristics:				
Path Loss (Friis)	-144.9	dB	-133.7	dB
Absorption	0.2	dB	0.2	dB
Fade Margin	5.0	dB	5.0	dB
Total Loss	-150.1	dB	-138.9	dB
Rx Antenna Characteristics:				
Rx Antenna Gain	3.5	dBi	-1.5	dBi
Rx Antenna Polarization Loss	-4.1	dB	-4.1	dB
Rx Pointing Loss	0.0	dB	0.0	dB
Net Rx Antenna Gain	-0.6	dBi	-5.6	dBi
RX Noise Characteristics:				
Rx Antenna Noise Density (Ta = 817K)	-169.5	dBm/Hz	-169.5	dBm/Hz
Rx Receiver Noise Density (Receiver NF = 4.0 dB)	-172.2	dBm/Hz	-172.2	dBm/Hz
System Noise Density	-167.6	dBm/Hz	-167.6	dBm/Hz
Interference Noise Density	-170.5	dBm/Hz	-170.5	dBm/Hz
Total Rx Noise	-165.8	dBm/Hz	-165.8	dBm/Hz
Rx Noise Characteristics:				
Received Signal Power	-109.9	dBm	-110.5	dBm
Received Noise Power	-165.8	dBm/Hz	-165.8	dBm/Hz
Implementation Loss	1.0	dB	1.0	dB
Total Signal Power to Noise Density Ratio (C/No)	54.9	dB-Hz	54.3	dB-Hz
Link Margin:				
Required BER	1.00E-05		1.00E-05	
Required Eb/N0 (GMSK)	12.5	dB	12.5	dB
Received Eb/N0	15.1	dB	14.5	dB
Link Margin	2.6	dB	2.0	dB