Panasonic Avionics Corporation
60-Day STA Request for ESAA Blanket License to
Communicate with GSAT-14 Satellite

Technical Appendix

GSAT-14

I. Orbital Debris Management Report

भारत सरकार
अन्तरिक्ष विभाग
उपग्रह संचार कार्यक्रम कार्यालय
अन्तरिक्ष भवन, न्यू बी. ई.एल.रोड,
बेंगलूर – 560 231, भारत
दूरभाष : +91-80-2341 5301
फैक्स : +91-80-2341 2141

सत्यमेव जयते

Government of India
Department of Space
SATELLITE COMMUNICATION PROGRAMME OFFICE
Antariksh Bhavan, New BEL Road,
Bangalore - 560 231, India
Telphone : +91-80-2341 5301
Fax : +91-80-2341 2141

No. SCPO/F. 631/115/2020

March 16, 2020

Sub: Orbital Debris Management report on GSAT-14 satellite.

Ref: Our letter of even number dated 14.2.2020.
Your email received on 13th March 2020.

With reference to the above, as desired, please find enclosed the revised Orbital Debris Management report on GSAT-14 satellite.

(Hanumantharayappa)
Associate Director, SGAPI

M/s . Tatanet Services Ltd.
EL-6, Electronics Zone,
MIDC, Mahape
Navi Mumbai- 400710

Kind Attn: Shri Brajendra Bhuwan Urmalia

Satellite Communication Programme Office
ISRO Headquarters

GSAT-14 ORBITAL DEBRIS ANALYSIS REPORT

Indian Space Research Organisation (ISRO) provides the following document regarding compliance with 47 C.F.R. § 25.114(d)(14)(i)-(v) and §25.283 of the Federal Communications Commission's ("FCC") rules regarding the orbital debris mitigation/end-of-life disposal of the GSAT-14 satellite. In addition, ISRO acknowledges that the GSAT-14 orbital debris mitigation/end-of-life disposal plan is consistent with the Inter-Agency Space Debris Co-ordination (IADC) and UN Space Debris Mitigation Guidelines.

GSAT-14 was launched on January5, 2014 by India's Geosynchronous Satellite Launch Vehicle (GSLV) to the 74°E.L. orbital location. The pre-launch estimated operational life of the spacecraft was approximately 12 years and the expected end-of-life is February 2027.

The satellite employs ISRO's I–2K class bus (a standard 2000 kg class bus) with a power handling capability of around 2.5 KW and a lift-off mass of 1980 kg.GSAT-14 utilizes 6 extended C-band transponders, 6 Ku-band transponders, and Ka-band beacons. Each beam covers the country of India.

a. Debris Release Assessment-§25.114(d)(14)(i).

ISRO assessed the operation of GSAT-14 and determined that no debris was released by the spacecraft. All separation and deployment mechanisms were fully controlled by ISRO and were successfully conducted using pyrotechnic devices designed to retain all physical debris. No debris is generated during on-orbit operations and satellite is operated in a momentum biased three-axis stabilized mode.

The design of GSAT-14 locates all sources of stored energy (ex. batteries, wheels, etc.) within the body of the structure which provides the protection from small orbital debris. To limit the effect of small debris collision, (1) critical elements are located inside the cuboid of the spacecraft body and properly shielded and (2) all spacecraft subsystems have redundant components to address potential single point failures. These steps ensure that the structure is resilient enough to protect satellite components and reduces generation of space debris to the maximum extent possible in the event of a collision with small debris or meteoroids.

The GSAT-14 spacecraft is controlled by one 2mand one 2.2 m single shell shaped reflector antennae to both transmit and receive signals. The Master Control Facility (MCF) at Hassan in Karnataka and Bhopal in Madhya Pradesh monitors and controls GSAT-14 satellite. The MCF is responsible for orbit raising, in-orbit payload testing, and on-orbit operations throughout the life of geo-stationary & geosynchronous satellites.

The MCF's activities include round-the-clock tracking, telemetry and commanding (TT&C) operations, and special operations like eclipse management, station-keeping manoeuvres, and recovery actions in case of contingencies. The MCF interacts with users for effective utilisation of the satellite payloads and to minimise the service disturbances during special operations.

The GSAT-14 spacecraft is the twenty-third geostationary communication satellite of India built by ISRO. GSAT-14 was designed and manufactured with internationally accepted standards and the spacecraft operates as expected.

b. Accidental Explosion Assessment-§25.114(d)(14)(ii).

Each potential hazard relating to accidental explosions is reviewed and cleared by experts/committees of ISRO. Each sub-system is analysed for potential hazards, and the safety design package is provided for each phase of the program running from design phase, qualification, manufacturing, operational, and post-operational phase of the spacecraft.

ISRO generates a Failure Mode Effects and Criticality Analysis for all the spacecrafts to identify all potential mission failures. GSAT-14 is designed in such a way that the risk of explosion is minimized both during and after mission operations. It is ensured that debris generation will not result from the conversion of energy sources on-board. Burst tests are performed on all pressure vessels during qualification to demonstrate a margin of safety against bursts. Bipropellant mixing is prevented by the use of valves that prevents backwards flow in propellant and pressurization lines. All pressures all monitored carefully on-ground through telemetry.

The tanks are designed as leak-before-burst to minimize the risk of break up. All pyrotechnic systems are fired at the early stages of operation so they pose no long-term risk. As discussed in *Section d* below, stored energy is either depleted or secured.

c. Assessment Regarding Collision with Larger Debris and Other Space Stations-§25.114(d)(14)(iii).

ISRO assessed and limited the probability of the space station becoming a source of debris by collisions with large debris or other operational space stations. The satellite is co-located with GSAT-7,11,18 and INSAT-3DR, all of which are operated by ISRO.

Directorate of Space Situational Awareness and Management (DSSAM) of ISRO has protocols and procedures in place to conduct proximity analysis and safe flight of space objects, including co-located satellites. As a result, ISRO developed significant experience maintaining co-located satellite formations within station-keeping volume parameters.

GSAT-14 in particular is always maintained within a control box of +/- 0.1 deg in inclination and +/-0.1 deg in longitude as per ITU guidelines. Periodic orbital correction manoeuvres are carried out to keep the satellite within the control box thereby ensuring adequate safe distance from other satellites in geosynchronous orbits.

As discussed above, the MCF is responsible for control of the spacecraft, including orbit maintenance, control, and co-location of spacecraft. Co-location is achieved using the proven technique of inclination-eccentricity vector separation to ensure safe inter-satellite distance amongst co-located spacecraft. Moreover, the MCF monitors the close approach of objects in GEO/GSO based on publicly available two line elements (TLE) for debris objects and orbit determined (OD) using radio ranging for operational spacecraft. Any close encounters (i.e. inter-satellite distance of less than 10 km) are investigated in detail and avoidance manoeuvres are carried out, if required.

In addition, ISRO receives Conjunction Data Messages (CDM) and Conjunction Alert Notifications (CAN) from 18 SPCS via its Space Track account on regular basis and analyses the close approach alerts independently with updated orbital elements of the satellite.

d. Post-Mission Disposal Plans-§25.114(d)(14)(iv) and §25.283.

Post-mission disposal from operational orbit will be accomplished by carrying out Delta-V manoeuvres to raise the satellite orbit, so that there is no re-entry phase for the satellite. The propellant budget for elevating the satellite to graveyard orbit is included in the satellite design and noted below.

At the end of operational life all stored sources of energy will be rendered inactive such that debris generation will not result from conversion or dissipation of energy sources on-board the satellite. This passivation process involves the following:

- Discharge batteries and isolate them from the solar arrays to prevent further electrical energy storage;

- Switch off all momentum wheels;

- Deplete and vent the propellant tanks, which enables depressurization and results in only negligible residuals remaining that cannot be vented.

- Switch off all payloads and switch off telemetry systems.

- Dynamically tuned mechanical gyros used for providing attitude orientation reference and Magnetic Torque Coil (MTC) used for aiding attitude control are switched off.

- Satellite is not controlled after de-orbiting, Hence, solar panels are kept orthogonal to each other to minimise the solar radiation pressure on them.

- Propulsion passivation is made such that at least one of the Fuel (either MMH or Oxidizer) is completely expelled with attitude hold condition, except some extreme unforeseen situations of satellite losing the command link. This ensures that no further combustion possible. After that all thrusters ILVs are closed and thrusters are isolated by switching OFF the drivers.

- Unbalanced usage of propellant is not envisaged in our propulsion system. Combination is as per designed mixture ratio. Tank pressures are monitored individually in real time. Firing is carried out until the attitudes could hold and pressure sustains the flow of at least one of fuels.

- All thrusters Latch Valves are closed and thrusters are isolated. The propulsion consumption is monitored by book keeping method. While de-orbiting the depletion of fuels is ensured.

The proposed disposal orbit altitude is calculated by the use of the following IADC formula-

Minimum Disposal Orbit Perigee Altitude above GEO = 235 km + $(1000 \times CR \times A/m)$
$= 235$ km $+ 1000 \times 1.25 \times 23/854.1$
$= 235 + 33.66 = 268.66$ km

Minimum Disposal Orbit Perigee altitude $= 35786 + 268.66 = 36054.66$ km

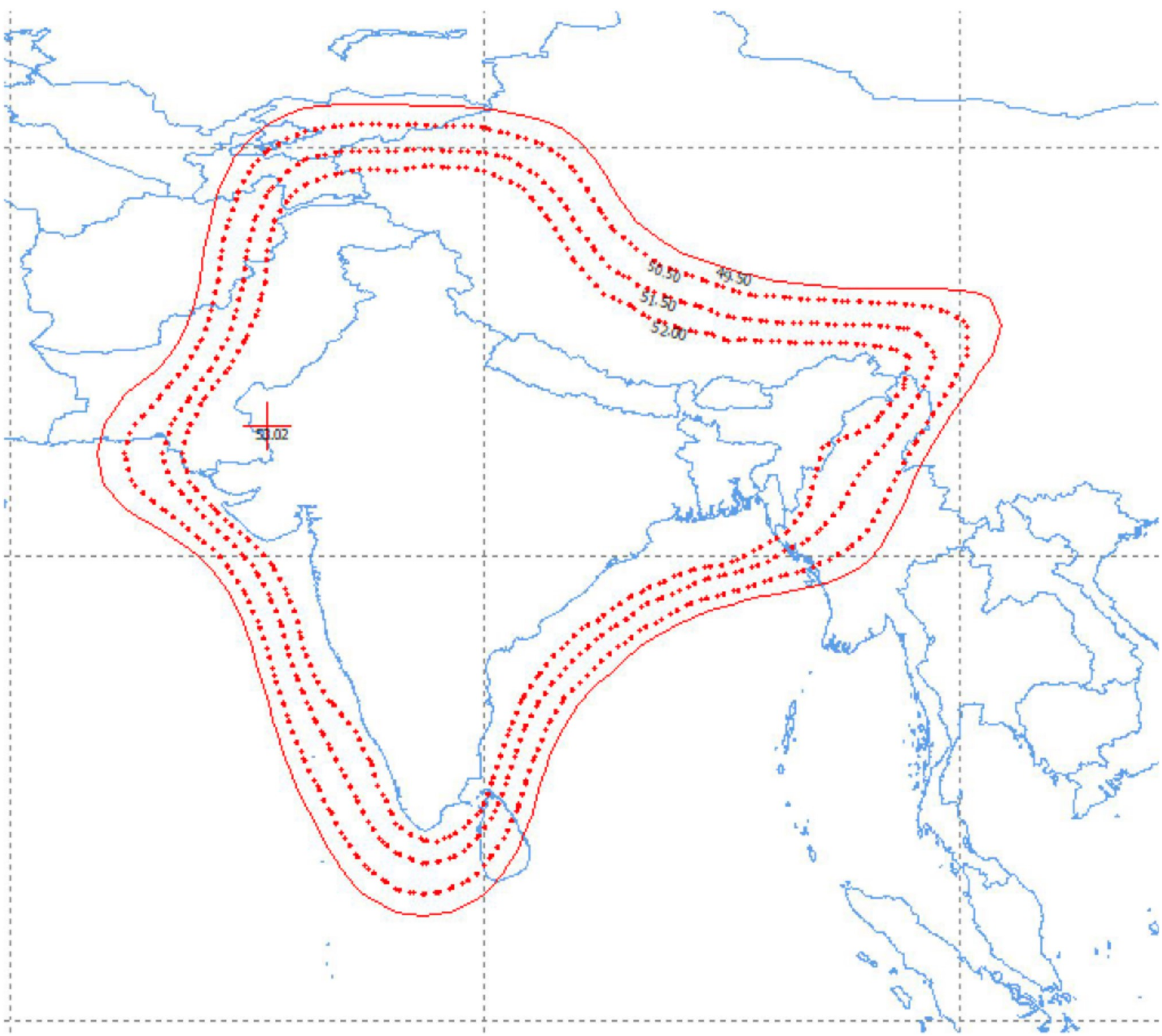
Where, Total Solar Pressure Area "A" = 23 sq-m
Dry Mass of satellite "m" = 854.1 kg
Solar pressure radiation coefficient "CR" = 1.25

The Minimum Disposal orbit perigee altitude of 36054.66 km is 268.66 km above the GSO (height of 35786 km). The quantity of propellant required is 4.40 kg which corresponds to Delta-V of 12 m/sec.

GSAT-14 has reserve propellant of 10 kg (approximately) in order to carry out post-mission disposal.

- x -

II. Coverage Map



III. Link Budgets

Forward Link Budget

eXConnect Terminal		
Antenna Type	DPA	
Lat	28.6	deg
Lon	77.2	deg
EIRP max	47.3	dBW
G/T	11.3	dB/K
Satellite		
Name	GSAT-14	
Longitude	74.0	deg
Hub Earth Station		
Site	Mumbai	
Lat	19.136	deg
Lon	72.881	deg
EIRP max	80.0	dBW
G/T	39.0	dB/K
Signal		
Waveform	DVB-S2X	
Modulation	8PSK	
Bits per symbol	3	
Spread Factor	1	
Coding Rate	0.60	
Overhead Rate	0.90	
Channel Spacing	1.05	
Spectral Efficiency (Rate/Noise BW)	1.62	bps/Hz
Data Rate	2.15E+08	bps
Information Rate (Data + Overhead)	2.39E+08	bps
Symbol Rate	1.33E+08	Hz
Chip Rate (Noise Bandwidth)	1.33E+08	Hz
Occupied Bandwidth	1.40E+08	Hz
Power Equivalent Bandwidth	1.07E+08	Hz
C/N Threshold	5.3	dB
Uplink		
Frequency	14.045	GHz
Back off	0.0	dB
EIRP Spectral Density	34.8	dBW/4kHz
Slant Range	36207	km
Space Loss, Ls	206.6	dB
Pointing Loss, Lpnt	0.0	dB
Atmosphere / Weather Loss, La	5.1	dB
Radome, Lr	0.0	dB
Transponder G/T @ Hub	3.0	dB/K
Thermal Noise, C/No	99.9	dBHz
C/(No+Io)	99.4	dBHz
Satellite		
Flux Density	-87.3	dBW/m2
SFD @ Hub	-89.0	dBW/m2
Small Signal Gain (IBO/OBO)	2.0	dB
OBO	-3.7	dB
Downlink		
Frequency	12.315	GHz
Transponder Sat. EIRP @ Beam Peak	51.5	dBW
Transponder Sat. EIRP @ Terminal	51.5	dBW
DL PSD Limit	13.0	dBW/4kHz
DL PSD @ Beam Peak	10.0	dBW/4kHz
Carrier EIRP @ Beam Peak	55.2	dBW
Carrier EIRP @ Terminal	55.2	dBW
Slant Range	36710	km
Space Loss, Ls	205.6	dB
Pointing Loss, Lpnt	0.1	dB
Atmosphere / Weather Loss, La	0.0	dB
Radome, Lr	0.5	dB
PCMA Loss	0.0	dB
Thermal Noise, C/No	89.0	dBHz
C/(No+Io)	88.6	dBHz
End to End		
End to End C/(No+Io)	88.3	dBHz
Implementation Loss	1.5	dB
End to End C/N w/ Imp Loss	5.5	dB
Link Margin	0.2	dB

Return Link Budget

eXConnect Terminal		
Antenna Type	DPA	
Lat	28.6	deg
Lon	77.2	deg
EIRP max	47.3	dBW
G/T	11.3	dB/K
Satellite		
Name	GSAT-14	
Longitude	74.0	deg
Hub Earth Station		
Site	Mumbai	
Lat	19.136	deg
Lon	72.881	deg
EIRP max	80.0	dBW
G/T	39.0	dB/K
Signal		
Waveform	MxDMA	
Modulation	QPSK	
Bits per symbol	2	
Spread Factor	2	
Coding Rate	0.30	
Overhead Rate	0.90	
Channel Spacing	1.05	
Spectral Efficiency (Rate/Noise BW)	0.27	bps/Hz
Data Rate	2.06E+06	bps
Information Rate (Data + Overhead)	2.29E+06	bps
Symbol Rate	3.81E+06	Hz
Chip Rate (Noise Bandwidth)	7.62E+06	Hz
Occupied Bandwidth	8.00E+06	Hz
Power Equivalent Bandwidth	2.45E+05	Hz
C/N Threshold	-4.2	dB
Uplink		
Frequency	14.200	GHz
Back off	0.0	dB
EIRP Spectral Density	14.5	dBW/4kHz
Slant Range	36710	km
Space Loss, Ls	206.8	dB
Pointing Loss, Lpnt	0.1	dB
Atmosphere / Weather Loss, La	0.0	dB
Radome, Lr	0.5	dB
Transponder G/T @ Terminal	3.0	dB/K
Thermal Noise, C/No	71.4	dBHz
C/(No+Io)	70.9	dBHz
Satellite		
Flux Density	-115.7	dBW/m2
SFD @ Terminal	-89.0	dBW/m2
Small Signal Gain (IBO/OBO)	2.0	dB
OBO	24.7	dB
Downlink		
Frequency	12.470	GHz
Transponder Sat. EIRP @ Beam Peak	51.5	dBW
Transponder Sat. EIRP @ Hub	51.5	dBW
DL PSD Limit	13.0	dBW/4kHz
DL PSD @ Beam Peak	-6.0	dBW/4kHz
Carrier EIRP @ Beam Peak	26.8	dBW
Carrier EIRP @ Hub	26.8	dBW
Slant Range	36207	km
Space Loss, Ls	205.5	dB
Pointing Loss, Lpnt	0.0	dB
Atmosphere / Weather Loss, La	6.6	dB
Radome, Lr	0.0	dB
PCMA Loss	0.0	dB
Thermal Noise, C/No	82.2	dBHz
C/(No+Io)	77.7113	dBHz
End to End		
End to End C/(No+Io)	70.1	dBHz
Implementation Loss	5.5	dB
End to End C/N w/ Imp Loss	-4.2	dB
Link Margin	0.0	dB

Forward Link Budget

eXConnect Terminal		
Antenna Type	SPA	
Lat	28.6	deg
Lon	77.2	deg
EIRP max	45.0	dBW
G/T	11.5	dB/K
Satellite		
Name	GSAT-14	
Longitude	74.0	deg
Hub Earth Station		
Site	Mumbai	
Lat	19.136	deg
Lon	72.881	deg
EIRP max	80.0	dBW
G/T	39.0	dB/K
Signal		
Waveform	DVB-S2X	
Modulation	8PSK	
Bits per symbol	3	
Spread Factor	1	
Coding Rate	0.60	
Overhead Rate	0.90	
Channel Spacing	1.05	
Spectral Efficiency (Rate/Noise BW)	1.62	bps/Hz
Data Rate	2.15E+08	bps
Information Rate (Data + Overhead)	2.39E+08	bps
Symbol Rate	1.33E+08	Hz
Chip Rate (Noise Bandwidth)	1.33E+08	Hz
Occupied Bandwidth	1.40E+08	Hz
Power Equivalent Bandwidth	1.07E+08	Hz
C/N Threshold	5.3	dB
Uplink		
Frequency	14.045	GHz
Back off	0.0	dB
EIRP Spectral Density	34.8	dBW/4kHz
Slant Range	36207	km
Space Loss, Ls	206.6	dB
Pointing Loss, Lpnt	0.0	dB
Atmosphere / Weather Loss, La	5.1	dB
Radome, Lr	0.0	dB
Transponder G/T @ Hub	3.0	dB/K
Thermal Noise, C/No	99.9	dBHz
C/(No+Io)	99.4	dBHz
Satellite		
Flux Density	-87.3	dBW/m2
SFD @ Hub	-89.0	dBW/m2
Small Signal Gain (IBO/OBO)	2.0	dB
OBO	-3.7	dB
Downlink		
Frequency	12.315	GHz
Transponder Sat. EIRP @ Beam Peak	51.5	dBW
Transponder Sat. EIRP @ Terminal	51.5	dBW
DL PSD Limit	13.0	dBW/4kHz
DL PSD @ Beam Peak	10.0	dBW/4kHz
Carrier EIRP @ Beam Peak	55.2	dBW
Carrier EIRP @ Terminal	55.2	dBW
Slant Range	36710	km
Space Loss, Ls	205.6	dB
Pointing Loss, Lpnt	0.1	dB
Atmosphere / Weather Loss, La	0.0	dB
Radome, Lr	0.5	dB
PCMA Loss	0.0	dB
Thermal Noise, C/No	89.2	dBHz
C/(No+Io)	88.5	dBHz
End to End		
End to End C/(No+Io)	88.1	dBHz
Implementation Loss	1.5	dB
End to End C/N w/ Imp Loss	5.4	dB
Link Margin	0.1	dB

Return Link Budget

eXConnect Terminal		
Antenna Type	SPA	
Lat	28.6	deg
Lon	77.2	deg
EIRP max	45.0	dBW
G/T	11.5	dB/K
Satellite		
Name	GSAT-14	
Longitude	74.0	deg
Hub Earth Station		
Site	Mumbai	
Lat	19.136	deg
Lon	72.881	deg
EIRP max	80.0	dBW
G/T	39.0	dB/K
Signal		
Waveform	MxDMA	
Modulation	QPSK	
Bits per symbol	2	
Spread Factor	3	
Coding Rate	0.40	
Overhead Rate	0.90	
Channel Spacing	1.05	
Spectral Efficiency (Rate/Noise BW)	0.24	bps/Hz
Data Rate	1.83E+06	bps
Information Rate (Data + Overhead)	2.03E+06	bps
Symbol Rate	2.54E+06	Hz
Chip Rate (Noise Bandwidth)	7.62E+06	Hz
Occupied Bandwidth	8.00E+06	Hz
Power Equivalent Bandwidth	1.45E+05	Hz
C/N Threshold	-4.9	dB
Uplink		
Frequency	14.200	GHz
Back off	0.0	dB
EIRP Spectral Density	12.2	dBW/4kHz
Slant Range	36710	km
Space Loss, Ls	206.8	dB
Pointing Loss, Lpnt	0.2	dB
Atmosphere / Weather Loss, La	0.0	dB
Radome, Lr	0.5	dB
Transponder G/T @ Terminal	3.0	dB/K
Thermal Noise, C/No	69.1	dBHz
C/(No+Io)	68.6	dBHz
Satellite		
Flux Density	-118.0	dBW/m2
SFD @ Terminal	-89.0	dBW/m2
Small Signal Gain (IBO/OBO)	2.0	dB
OBO	27.0	dB
Downlink		
Frequency	12.470	GHz
Transponder Sat. EIRP @ Beam Peak	51.5	dBW
Transponder Sat. EIRP @ Hub	51.5	dBW
DL PSD Limit	13.0	dBW/4kHz
DL PSD @ Beam Peak	-8.3	dBW/4kHz
Carrier EIRP @ Beam Peak	24.5	dBW
Carrier EIRP @ Hub	24.5	dBW
Slant Range	36207	km
Space Loss, Ls	205.5	dB
Pointing Loss, Lpnt	0.0	dB
Atmosphere / Weather Loss, La	6.6	dB
Radome, Lr	0.0	dB
PCMA Loss	0.0	dB
Thermal Noise, C/No	80.0	dBHz
C/(No+Io)	75.4165	dBHz
End to End		
End to End C/(No+Io)	67.8	dBHz
Implementation Loss	3.5	dB
End to End C/N w/ Imp Loss	-4.5	dB
Link Margin	0.4	dB

IV. Letter Supplementing Orbital Debris Mitigation Report

LMI Advisors LLC
2550 M Street, NW, Suite 300
Washington, DC 20037

Carlos M. Nalda
T +1 571.332.5626
cnalda@lmiadvisors.com

December 12, 2020

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Panasonic Avionics Corp. – Section 1.65 Submission, Call Sign: E100089, File No. SES-MFS-20200513-00528

Dear Ms. Dortch:

Pursuant to Section 1.65 of the Federal Communication Commission's ("FCC") rules, 47 C.F.R. § 1.65, and in response to an inquiry from the FCC International Bureau, Panasonic Avionics Corp. ("PAC") updates certain information in connection with the above-referenced application to modify its earth station aboard aircraft ("ESAA") blanket license, Call Sign E100089. Specifically, the table below provides tank pressure (gas law) calculations and supplements the Orbital Debris Analysis/Management Report for the GSAT-14 satellite included in the Technical Appendix submitted with the application.

TABEL 1. GSAT-14 Tank Pressure (Gas Law) Calculations

	Volume (ltr)	Composition of Liquid/ Gas (e.g. He, N2O4	Maximum fuel/oxidizer remaining(kg) after de-orbiting	Maximum pressurant remaining(kg), after de-orbiting	Internal maximum temperature (DegC) in graveyard orbit	Internal maximum pressure (Bar) in graveyard orbit
Fuel Tank #1	516	MMH	2.32 Kgs	-	10oC-30oC	Less than 12 bar
Oxidizer Tank #1	516	N2O4	10 Kgs	-	10oC-30oC	Less than 12 bar
Pressurant Tank #1	35.5	He	-	0.4 Kg	10oC-30oC	Less than 75 bar
Pressurant Tank #2	35.5	He	-	0.4 Kg	10oC-30oC	Less than 75 bar

Please do not hesitate to contact me with any questions regarding this matter.

Respectfully submitted,

Carlos M. Nalda
Principal
LMI Advisors

cc: Paul Blais, FCC International Bureau
Cindy Spiers, FCC International Bureau