Attachment A

TECHNICAL ANNEX

A.1 Scope and Purpose

The purpose of this Attachment is to provide the Commission with the salient technical characteristics of the Inmarsat-5 F3 satellite, as required by 47 C.F.R. §25.114 and other sections of the FCC's Part 25 rules, that cannot be captured by the Schedule S software.

A.2 General Description of Overall System Facilities, Operations and Services (§25.114(d)(1))

The Inmarsat-5 F3 satellite will operate at the nominal 180° E.L. orbital location and will provide fixed-satellite service ("FSS") to earth stations in the Pacific Ocean region (see coverage diagram in Figure A.2.1). The satellite will be operated at an offset location of 0.3 degrees from 180º E.L. to center the station-keeping box at 179.7º E.L. The satellite will operate in the 27.5-30.0 GHz band (Earth-to-space) and 17.7-20.2 GHz band (space-to-Earth) portions of the Ka band. The satellite network will employ two large gateway antennas and will provide service to widely-deployed, small user antennas.

The gateway antennas will be capable of communicating with the spacecraft throughout the 27.5-30.0 GHz and 17.7-20.2 GHz bands. One gateway antenna will be located in Auckland, New Zealand and the other one will be in Warkworth, New Zealand.

TT&C operations will be provided by one of these gateway earth stations. On-station TT&C transmissions will occur in the Ka band, and the spacecraft also will be capable of using C-band frequencies for TT&C during transfer orbit and for emergency purposes. Because the TT&C, feeder link frequencies and gateway antennas are not located in the United States, they are not the subject of this application.

This application seeks authority to serve the United States using only the 29.5-30.0 GHz and 19.7-20.2 GHz portions of the Ka band. In this band, the user antennas will operate within the "Global Payload Beams" or "GP Spot Beams" on the spacecraft. The Global Payload Beams operate in the 29.5-30.0 GHz and 19.7-20.2 GHz bands and consist of 89 contiguous, fixed spot beams. A representative depiction of the coverage of these beams is depicted in Figure A.2.1. A sample Global Payload Beam coverage pattern is shown in Figure A.2.2.

Figure A.2.1. Representative Global Payload Spot Beam Coverage

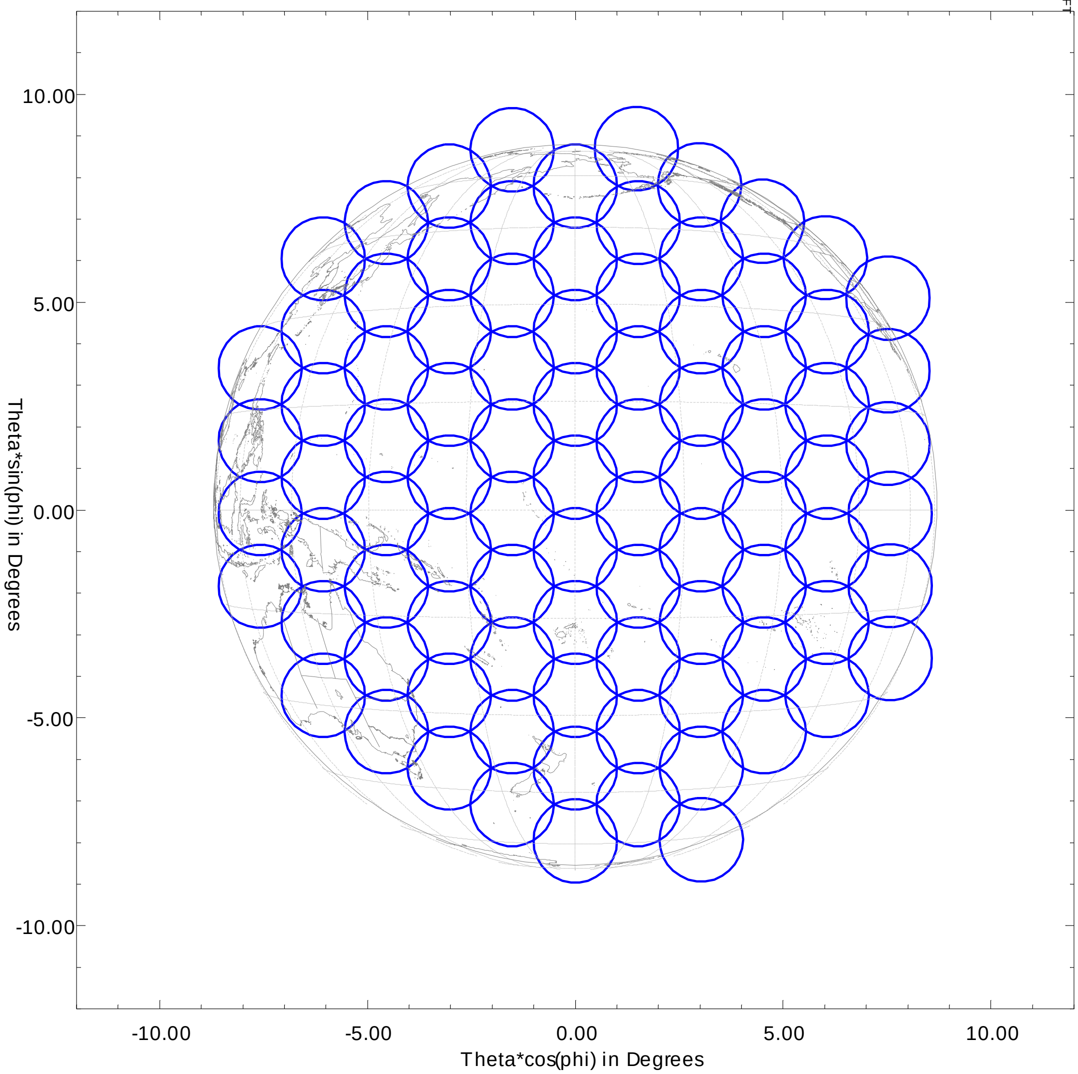
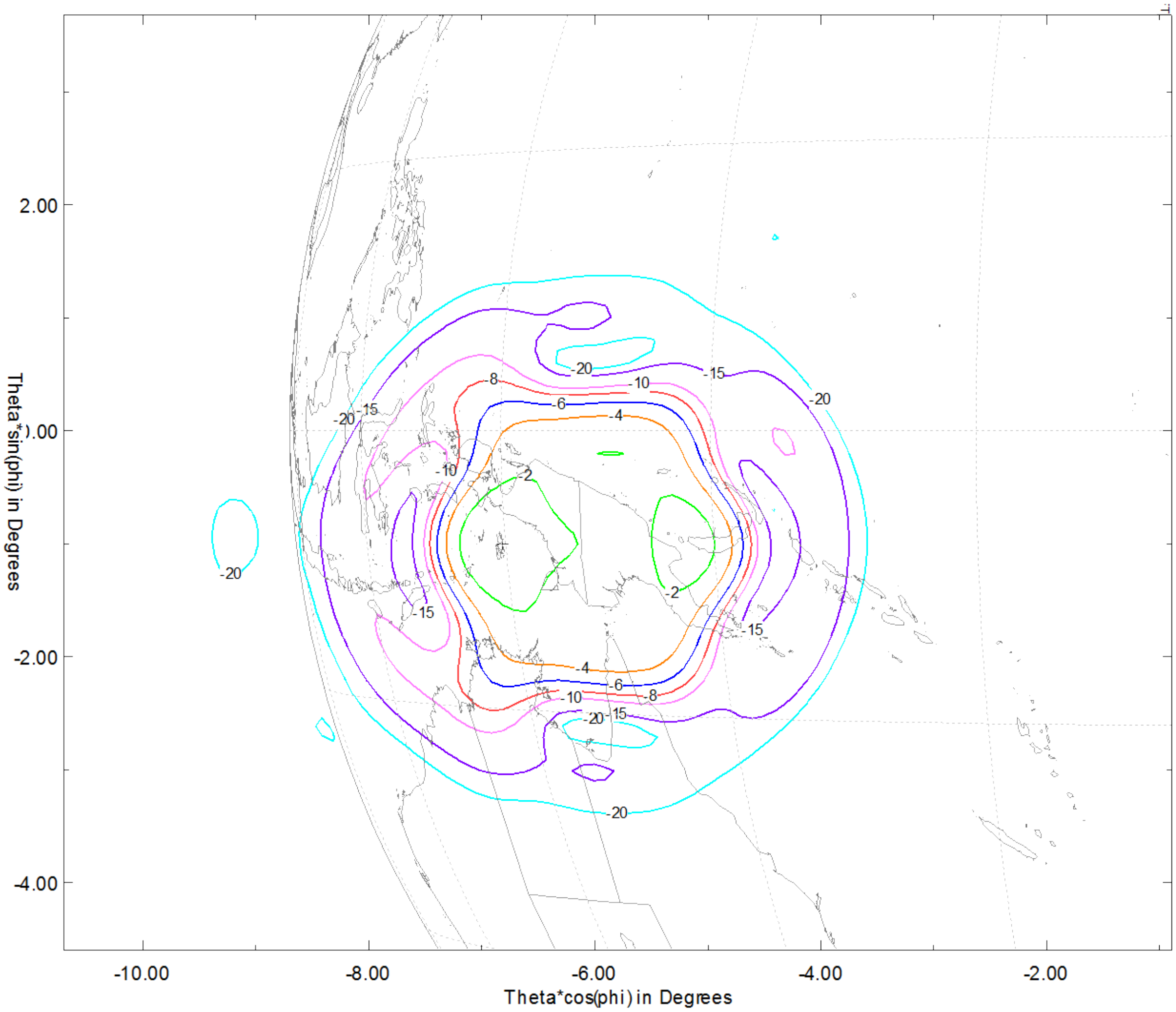


Figure A.2.2. Sample Global Payload Spot Beam Coverage Pattern



The spacecraft will be capable of operating in the 29.0-29.5 GHz and 19.2-19.7 GHz band segments for user terminals, but authority to operate user terminals in those band segments is not sought in this application. The spacecraft also will be capable of using C-band frequencies at 4199.0 MHz, 4199.5 MHz, 5926.2 MHz and 6422.5 MHz for TT&C during transfer orbit and for emergency purposes. Certain of the beams described above will be switchable to also enable communications in portions of the 20.2-21.2 GHz and 30.0-31.0 GHz bands, which are not allocated for commercial service in the United States. Operations in these bands would occur under the authority of Norway, pursuant to ITU filings submitted by the Norwegian Administration. Authority to serve the United States using the frequency segments described in this paragraph is not being requested in this application.

A.3 Predicted Space Station Antenna Gain Contours (§25.114(c)(vi))

The Inmarsat-5 F3 satellite antenna gain contours for the receive and transmit beams, as required by §25.114(d)(3), are given in GXT format in the GIMS container file included in this application.

A.4 Frequency and Polarization Plan (§25.114(c)(4)(i))

Details of the satellite's Ka-band frequency plan is provided in the associated Schedule S submission. The GP Spot Beams operate in RHCP on the uplink and LHCP on the downlink. Consistent with Section 25.210(f), the GP Spot Beams employ an average six-fold frequency re-use by spatial separation of co-frequency beams.

In the GP Spot Beams, 72 channels are available in the forward link direction and 72 are available in the return link direction, each with 40 MHz spacing and 32 MHz useful bandwidth. These 72 channels in each direction are allocated among the 89 GP Spot Beams, with two channels available in certain beams. The possible channel to beam allocation configurations in the GP Spot Beams are as shown below.

	Number of available channels	**Number of GP Spot Beams**	**Number of channels per GP Spot Beam**
	48 channels	48 beams	1 channel (fixed)/beam
	24 channels	12 beams	1 or 2 channels/beam
		29 beams	Up to 1 channel/beam
Total	72 channels	89 beams	

A.5 Transponder Configuration

The satellite has a total of 67 simultaneously active TWTAs, excluding TT&C functions. This consists of 61 active TWTAs in the forward link direction (gateway-to-user) and 6 active TWTAs in the return link direction (user-to-gateway).

Note that in the associated Schedule S the term "transponder" refers to the useful bandwidth of each channel (which is 32 MHz for the GP Spot Beams) and not to the number of active TWTAs.

A.6 Services to be Provided (§25.114(d)(1))

The Inmarsat-5 F3 satellite will provide a variety of two-way communications services to small user terminals including broadband Internet access, multimedia, voice and other applications.

Representative link budgets, which include details of the transmission characteristics, performance objectives and earth station characteristics, are provided in the associated Schedule S submission.

A.7 TT&C Characteristics (§25.114(c)(4)(i))

As noted above in Section A.2, on-station TT&C for Inmarsat-5 F3 will be provided by gateway earth stations located in New Zealand, and authority for TT&C is not being sought in this application.

A.8 Satellite Transponder Frequency Responses (§25.114(c)(4)(v))

The predicted receive and transmit channel filter response performance is given in Table A.8.1 below. The receive response is measured from the satellite receive antenna up to the input of the TWTA. The transmit response is measured from the input of the TWTA to the satellite transmit antenna.

Table A.8.1. GP Spot Beam Typical Receiver and Transmitter Filter Responses

Frequency offset from channel center	Gain relative to channel center frequency (dB)		Comments
	Receive	Transmit	
CF +/- 11.2 MHz	1	1	In-Band
CF +/- 12.8 MHz	1.3	1.3	Value does not exceed these p-p values
CF +/- 14.4 MHz	2	2	
CF +/- 16 MHz	3	3	
CF +/- 20.8 MHz	-1	-1	Out-of-Band
CF +/- 24 MHz	-10	-7	Attenuation is not less than these values
CF +/- 27.2 MHz	-25	-20	

A.9 Cessation of Emissions (§25.207)

All downlink transmissions can be turned on and off by ground telecommand, thereby causing cessation of emissions from the satellite, as required.

A.10 Power Flux Density at the Earth's Surface (§25.208(c))

§25.208 does not contain any PFD limits that apply in the 19.7-20.2 GHz band for GSO satellite networks, and it is noted also that Article 21 of the ITU Radio Regulations does not have any PFD limits that apply in this band.

A.11 Two Degree Compatibility (§25.138)

Transmissions in the Inmarsat-5 F3 satellite network in the 29.5-30.0 GHz and 19.7-20.2 GHz bands will not exceed the uplink off-axis EIRP density and downlink PFD levels of §25.138.

§25.138 of the Commission's rules defines the uplink and downlink parameters that permit routine blanket licensing of Ka-band earth stations in certain frequency bands which define the acceptable levels of adjacent satellite interference permitted in the Ka band by the FCC, absent specific coordination agreements with neighboring satellites.

For the 29.5-30.0 GHz and 19.7-20.2 GHz frequency bands, compliance with the Commission's two-degree spacing policy is ensured provided:

- The uplink off-axis EIRP density levels given in §25.138(a)(1) of the Commission's rules are not exceeded; and
- The maximum downlink PFD levels given in §25.138(a)(6) of the Commission's rules are not exceeded.

The clear sky uplink off-axis EIRP density limits of §25.138(a)(1) are equivalent to a maximum uplink input power density of -56.5 dBW/Hz for earth stations in compliance with off-axis transmit gain masks in §25.209(a)(2) and (4).

Table A.11.1 compares the uplink input power densities derived from the uplink link budgets that are contained in the Schedule S with the clear sky limits of §25.138 (a)(1). It can be seen that in all cases the clear sky uplink power limits are met.

Table A.11.1. Demonstration of Compliance with the Uplink Power limits of §25.138 (a)(1)

Uplink Antenna Diameter	Maximum Clear Sky Uplink Input Power Density (dBW/Hz)	Clear Sky Uplink Input Power Density Limit of §25.138 (a)(1) (dBW/Hz)	Margin (dB)
13.2m	-70.0 (*)	-56.5	13.5
Typical-60cm	-58.4	-56.5	1.9
Typical-100cm	-58.5	-56.5	2.0
Typical-150cm	-57.9	-56.5	1.4

(*) Note: The Schedule S link budgets show a maximum uplink power density of -67 dBW/Hz under faded condition from the 13.2 m antenna. Under clear sky condition the uplink power density will not exceed -70 dBW/Hz.

In the band 19.7-20.2 GHz, the maximum downlink EIRP density that the Inmarsat-5 F3 satellite will transmit is 56.1 dBW in an occupied bandwidth of 32 MHz. This translates into 41 dBW in 1 MHz. The shortest distance from the satellite to the Earth is 35,786 km, corresponding to a spreading loss of 162.06 dB. Therefore the maximum possible PFD at the Earth's surface at an elevation angle of 90° will not exceed -121.06 dBW/m^2 in 1 MHz (*i.e.*, 41 -162.06).

In summary, all downlink transmissions from the Inmarsat-5 F3 satellite will comply with the -118 dBW/m^2/MHz limit set forth in §25.138(a)(6) of the Commission's rules.

A.12 Orbital Debris Mitigation Plan (§25.114(d)(14))

Inmarsat has incorporated the material objectives of §25.114(d)(14) of the Commission's Rules into the design of the satellite through the satellite's Technical Specifications, Statement of Work and Test Plans. The Statement of Work includes provisions to review orbital debris mitigation, and compliance with §25.114(d)(14), as part of the preliminary design review ("PDR") and the critical design review ("CDR") and to incorporate its requirements, as appropriate, into its Test Plan, including a formal Failure Mode Verification Analysis ("FMVA") for orbital debris mitigation involving particularly the TT&C, propulsion and energy systems.

A.12.1 Spacecraft Hardware Design (§25.114(d)(14)(i))

The satellite is based on the heritage Boeing 702 HP flight proven platform.

Inmarsat will ensure that the satellite does not release any debris during its operation. Furthermore, all separation and deployment mechanisms, and any other potential source of debris will be retained by the spacecraft or launch vehicle.

In conjunction with the satellite manufacturer, Inmarsat has assessed and limited the probability of the satellite becoming a source of debris by collisions with small debris or meteoroids of less than one centimeter in diameter that could cause loss of control and prevent post-mission disposal. Inmarsat and the satellite manufacturer have taken steps to limit the effects of such collisions through shielding, the placement of components, and the use of redundant systems.

The Inmarsat-5 F3 satellite includes redundant TT&C and propulsion subsystems to ensure successful end-of-life disposal. The spacecraft TT&C system, vital for orbit raising, will be extremely rugged with regard to meteoroids smaller than 1 cm, by virtue of its redundancy, shielding, separation of components and physical characteristics. The TT&C subsystem will have no single points of failure. Near-omni-directional antenna coverage is provided through the use of a combination of independent bicone and forward/aft pipe antennas. These antenna feeds are extremely rugged and capable of providing adequate coverage even if struck, bent or otherwise damaged by a small or medium sized particle. The command receivers and decoders and telemetry encoders and transmitters will be located within a shielded area and will be totally redundant and physically separated. Two shielded xenon tanks and a redundant pairs of thrusters provide the energy for orbit-raising.

A.12.2 Accidental Explosion Assessment (§25.114(d)(14)(ii))

The Inmarsat-5 F3 satellite will be a Boeing 702HP model spacecraft, which is designed to minimize the potential for accidental explosions through propellant leakage and fuel and oxidizer mixing or other means. Propellant tanks and thrusters are isolated using redundant valves, and electrical power systems are shielded in accordance with standard industry practices. During the mission, batteries and various critical areas of the propulsion subsystem will be monitored to avoid conditions that could result in explosion. After the Boeing 702HP spacecraft reaches its final disposal orbit, all on-board sources of stored energy will be removed by depleting all propellant tanks, venting all (exception to helium as described below) pressurized systems, discharging batteries, and turning off all active units.

The Boeing 702HP spacecraft uses a bus that has a liquid propulsion system design consisting of two helium tanks plus two pairs of fuel and oxidizer tanks and uses a xenon ion propulsion system design consisting of two xenon tanks. Venting of the excess propellant in the fuel, oxidizer and xenon tanks is performed as part of the end-of-life shutdown operations. The helium tanks provide proper propellant tank pressurization for apogee engine firings during transfer orbit. Consistent with Boeing’s practice with respect to a number of its spacecraft buses, both helium tanks are isolated at the end of transfer orbit by firing pyro-valves. The spacecraft’s helium system will be sealed when tanks are isolated, resulting in a final pressure of ~230 psi, which is extremely low relative to the design burst pressure of 5250 psig (actual test performance at 6660 psig). Due to the low pressure at end-of-life in the helium tanks and their enclosure in the spacecraft body, an explosive event is extremely unlikely (even in the event of a tank rupture, *e.g.*, a meteorite strike), minimizing the potential of any release of orbital debris. The xenon tanks are vented by opening latch valves downstream of the tanks to allow cold flow through the xenon ion thrusters.

A.12.3 Safe Flight Profiles (§25.114(d)(14)(iii))

In considering current and planned satellites that may have a station-keeping volume that overlaps the Inmarsat-5 F3 satellite, Inmarsat has reviewed the lists of FCC-authorized satellite networks, as well as those that are currently under consideration by the FCC. In addition, networks for which a request for coordination has been published by the ITU within ±0.15° of 179.7° E.L. have also been reviewed.

Intelsat operates the C-/Ku-band Intelsat-18 satellite at 180º E.L. and with an east-west station-keeping tolerance of ±0.05°. Thus, Inmarsat will locate the Inmarsat-5 F3 satellite at 179.7º E.L. in order to eliminate the possibility of any station-keeping volume overlap with the Intelsat-18 satellite.

There are no FCC licensed satellite networks nor are there any pending applications before the Commission to operate a satellite within ±0.15° of 179.7° E.L. With respect to published ITU filings, there are several networks filed within this sub-arc however other than Intelsat-18, none are operational. Inmarsat can find no evidence that the other filed networks are currently being progressed towards launch. Accordingly, Inmarsat concludes that physical coordination of the Inmarsat-5 F3 satellite with any other party is not required at the present time.

A.12.4 Post-Mission Disposal (§25.114(d)(14)(iv))

At the end of the operational life of the Inmarsat-5 F3 satellite, Inmarsat will maneuver the satellite to a disposal orbit with a minimum perigee of 300 km above the normal GSO operational orbit. The post-mission disposal orbit altitude is based on the following calculation, according to §25.283:

Total Solar Pressure Area “A” = 93.1 m^2

“M” = Dry Mass of Satellite = 3663 kg

“CR” = Solar Pressure Radiation Coefficient = 1.29

Therefore the Minimum Disposal Orbit Perigee Altitude is calculated as:

= 36,021 km + 1000 x CR x A/M

= 36,021 km + 1000 x 1.29 x 93.1/3663

= 36,053.8 km

= 267.8 km above GSO (35,786 km)

To provide adequate margin, the disposal orbit will be increased to at least 300 km. This will require approximately 1.4 kg of xenon propellant, taking account of all fuel measurement uncertainties, which will be allocated and reserved in order to perform the final orbit raising maneuver.

ENGINEERING CERTIFICATION

I hereby declare, under penalty of perjury, that the following statements are true and correct to the best of my information and belief:

(i) I am the technically qualified person responsible for the engineering information contained in the foregoing Application,

(ii) I am familiar with Part 25 of the Commission's Rules, and

(iii) I have either prepared or reviewed the engineering information contained in the foregoing Application and found it to be complete and accurate.

/s/___________________________________

Jonas Eneberg
Vice President,
International Spectrum Management
Inmarsat

Dated: ……………, 2015