GEOSAT Program

Request for Proposal
of
Ku-Band 200W TWTA/LTWTA

(RFP No.: **SAC/GEOSAT/JAN/2025/01**)

JANUARY 2025

Government of India
Indian Space Research Organization
Space Applications Centre
Ahmedabad-380015
INDIA

REQUEST FOR PROPOSAL (RFP)
200W Ku-Band TWTA/LTWTA

INTRODUCTION

Indian Space Research Organisation (ISRO), Department of Space, Government of India requests your company to submit quotation for space-qualified Ku-band TWT Amplifiers with and without Linearizer (LTWTAs/TWTAs)[1] as described in this document. These will be used in the Flight Models of the Communication Payloads of spacecraft under GSAT Program of ISRO. This document consists of Six Exhibits:

EXHIBIT-A: Provides general background / end use and scope of the document. This also contains general guidelines and conditions, which should be carefully studied and followed by all the vendors, before submitting the bid.

EXHIBIT-B: Provides electrical and mechanical requirements of TWTA / LTWTA.

EXHIBIT-C: Provides Bus-interface requirements.

EXHIBIT-D: Provides Reliability and Quality Assurance (R&QA) requirements.

EXHIBIT-E: Provides details of additional information, which vendor shall enclose in the proposal.

EXHIBIT-F: Provides details on Quantity, Delivery Schedules and Warranty.

[1] LTWTA: Linearized TWTA

EXHIBIT-A

SR NO.	DESCRIPTION	C/NC	VENDOR COMMENTS
EXHIBIT-A			
A1.0	**Background:** Indian Space Research Organization (ISRO) of Department of Space, Government of India has the responsibility of realization, launch and in-orbit maintenance of satellites for communication and navigation purposes in India. The Geo-Stationary Satellite System (GEOSAT) is a domestic multipurpose system, using satellites in geo-stationary orbit, for long distance telecommunications, Radio and TV program distribution, satellite news gathering, societal applications, navigation services, meteorological earth observation, data relay, search and rescue etc. The GSAT satellite series is designed to be compatible with the Indian Geo-Synchronous Launch Vehicle (GSLV) and most of the commercially available launchers. For realization of GEOSAT Spacecraft, the Department of Space of the Government of India, through SAC/ Indian Space Research Organization (SAC/ISRO), is planning to purchase TWTA & LTWTA in Ku-Band; to be used for communication payloads of future satellites.		
A2.0	**Request for Proposal (RFP):** Vendors are requested to submit detailed proposal against this request for proposal for supplying Ku band 200W TWTAs with and without Linearizer (LTWTAs & TWTAs) for these communication satellites.		
A3.0	**SCOPE OF THE DOCUMENT** This document covers the requirement of Flight & Proto Flight Model of LTWTAs & TWTAs, required mainly for the communication payload of GSAT series of Satellites. Unless otherwise specified, all performance requirements shall apply simultaneously and shall be fully met over the specified temperature range and other environmental conditions, R & QA provisions and with interface characteristics as detailed in subsequent sections. The document will be treated as a baseline specification document (Technical) and will be taken as a reference in future. The contents of this document will be mutually agreed by SAC/ISRO and vendor, and will be binding on both. The contents of this document		

SR NO.	DESCRIPTION	C/NC	VENDOR COMMENTS
	can be refined before PO. These changes will be incorporated in the present document to evolve FINAL SPECIFICATION DOCUMENT (TECHNICAL).		
A4.0	From the point of view of evaluation, it is very important that proposal by Vendors includes sufficient technical data for proper evaluation of the offered product. If this technical data is not in public domain, we request the vendors to apply in advance for a license from their respective Governments to export this technical data.		
A5.0	**SCOPE OF THE PROCUREMENT:** The current requirement is for ***Ku-band 200 Watts LTWTA & TWTA*** for use in communication satellite, to provide operational services to users, hence this procurement is not a developmental project. Only Space qualified product with sufficient space heritage should be quoted against this enquiry. The realization of LTWTA & TWTA can be broadly comprised of following activities – Design, Fabrication, Optimization, Integration and Flight Acceptance / Proto-flight testing. i. The design of product offered must have successfully undergone space Qualification testing and have heritage of long life operational satellite missions. ii. The sub-modules of the LTWTA & TWTA should be realized using space grade parts/ materials; by operators qualified for space grade fabrication. iii. The integration of sub-modules and optimization to ensure LTWTA & TWTA units which are compliant to the performance requirements. iv. Testing of all LTWTA & TWTA units, as per the requirements of this RFP.		
A6.0	**General Guidelines and Conditions**		
A6.1	The offer by Vendor must contain sufficient data and material to prove their company has at least ten years of experience in manufacturing space qualified LTWTAs/TWTAs. The offered Ku-band LTWTAs & TWTAs must have successful heritage of continuous operation on board a communication spacecraft in Geostationary orbit.		

SR NO.	DESCRIPTION	C/NC	VENDOR COMMENTS
A6.2	It is desirable that the product offered by the vendors against this tender is compliant to all specifications. All offers shall be evaluated against requirements and specifications given in this RFP. Vendors are advised that their offer needs to be at least **fully compliant to key specifications** related to parameters given below, otherwise their offer shall not be accepted.: **Rated Power Output, input drive at saturation, DC Power Consumption at saturation, Inter-Modulation Product, Operating Frequency band and compatibility to the specified primary Spacecraft Bus.**		
A6.3	Likewise, there is a set of **supplementary performance parameters**, required for the intended application. However, SAC (ISRO) also understands that TWTA technology is very complex and that various performance parameters are interrelated and sometimes their values have to be traded among themselves. Hence, vendors are advised to submit **the best expected performance** *even when they are not fully compliant against the supplementary performance parameters* (other than the key specifications related to parameters mentioned in previous paragraph). The technical part of the offers shall be evaluated by SAC (ISRO) against overall system performance and may be considered, even with minor deviations in the supplementary specifications, in case it is found that overall system objectives are achievable in spite of these deviations. The decision of SAC (ISRO) will be final in this respect. Only the technically compliant offers will be considered for further evaluation.		
A6.4	Vendors may further note that SAC (ISRO) also reserves the right to reject an offer, if there is a large deviation in delivery-schedule, commercial and/or general terms and conditions offered against the requirements; even if the offer is technically suitable.		
A6.5	Vendor may seek any clarification or may point out any error or omission in the proposal within one week of publishing of tender, so that requirement is met correctly and adequately.		
A6.6	In case of receipt of a bid against this tender, it will be assumed by SAC (ISRO) that all the guidelines and conditions mentioned above, have been carefully read and accepted by the bidder.		

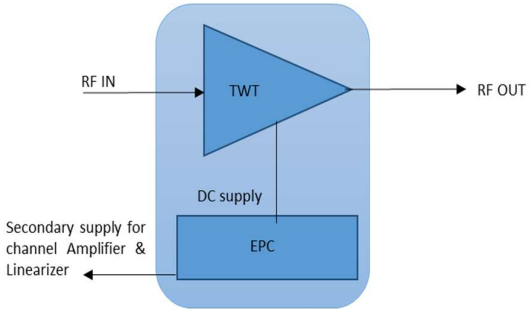
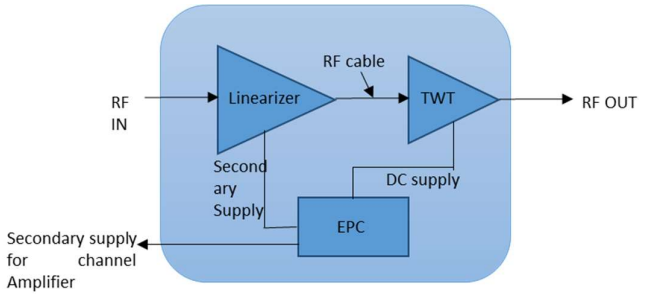
<table>
<tr><th>SR NO.</th><th>DESCRIPTION</th><th>C/NC</th><th>VENDOR COMMENTS</th></tr>
<tr><td>A6.7</td><td>
Commercial Bid Requirements:
The commercial bid must contain the breakup under the following price heads:
<table>
<tr><th>Sr No.</th><th>Price Head</th><th>Qty.</th><th>Offered Price</th></tr>
<tr><td>1</td><td>FM Unit charges as per RFP No. SAC/GEOSAT/JAN/2025/01

Type 1: TWTAs with 100 V bus
Type 2: LTWTAs with 70 V bus</td><td>a. Type1: 15-17 units;
18-20 units
21-24 units
b. Type2: 9-11 units;
12-14 units
15-17 units</td><td rowspan="2">“ONLY IN COMMERCIAL BID”</td></tr>
<tr><td>2</td><td>Miscellaneous charges including documentation and PFM Testing charges on 1no. of FM unit from above lot (all additional tests applicable only to PFM unit as per RFP, such as Sine vibration, Full EMI/EMC tests etc)
Type 1: TWTAs with 100 V bus
Type 2: LTWTAs with 70 V bus</td><td>

1 No.
1 No.</td></tr>
</table>
NOTE:
1. Break up of Miscellaneous charges shall be provided along with price bid. No price related information whatsoever shall be put in the Technical bid. Disclosure of prices and/or any other kind of charges, in the technical offer will lead to outright rejection of offer.
</td><td></td><td></td></tr>
</table>

EXHIBIT B

Technical (RF) Specifications for Ku-band LTWTAs

Sr no.	SAC REQUIREMENTS	C/NC	VENDOR COMMENTS
EXHIBIT-B: TECHNICAL SPECIFICATIONS OF LTWTAs			
1.0	**SCOPE** This Exhibit contains the Technical specifications of the **200W Ku-band Radiation Cooled traveling wave tube amplifiers with and without Linearizer (LTWTAs/TWTAs)** required for satellite payloads**.** The TWTA should include one number each of 200Watts Ku-Band Radiation cooled TWT, and one Electronic Power Supply Module (Electronic Power Conditioner – EPC). The LTWTA shall have a Linearizer with TWTA.  **Fig B1.1A Scope of Supply for TWTA**  **Fig B1.1B Scope of Supply for LTWTA**		
B2.0	**GENERAL REQUIREMENTS**		
	Unless and otherwise specified, all performance requirements shall apply simultaneously and shall be fully met over the operating range of Bus voltage, specified frequency range, operating temperature range and other environmental conditions. Interface requirements are also provided in the subsequent sections. The manufacturers shall devote special attention and efforts to achieve the following:		
	a) Highest possible DC to RF efficiency and proper thermal design		

<table>
<tr><th>Sr no.</th><th>SAC REQUIREMENTS</th><th>C/NC</th><th>VENDOR COMMENTS</th></tr>
<tr><td></td><td>b) Unconditionally stable performance ensuring long term stability</td><td></td><td></td></tr>
<tr><td></td><td>c) Minimum mass and volume</td><td></td><td></td></tr>
<tr><td></td><td>d) Provide adequate protections for the units and the Spacecraft Bus,</td><td></td><td></td></tr>
<tr><td></td><td>e) Meet all the provisions of R&QA, as detailed in this document for high reliability.</td><td></td><td></td></tr>
<tr><td></td><td>f) Ensure useful life in space of unit to be more than 15 years</td><td></td><td></td></tr>
<tr><td>B3.0</td><td>GENERAL DESCRIPTION</td><td></td><td></td></tr>
<tr><td>B3.0.1</td><td>The radiation cooled TWTAs & LTWTAs shall deliver a minimum output power of 200W in Ku-band in the frequency range from 10.7 GHz to 11.7 GHz. Detailed specifications are as per subsequent sections.
The TWT shall provide minimum RF output power as per Table- B3.1 below, at saturation. (The small change in the rated power, if any, shall be communicated later)
Table No -B3.1
Type, Bandwidth, Power and Bus Requirement
<table>
<tr><th>Type</th><th>Tentative Operating Frequency (Bandwidth)</th><th>Output Power (EOL @ sat)</th><th>Bus Voltage</th></tr>
<tr><td>TWTA</td><td>10.7 – 11.7 GHz (1 GHz)</td><td>200 W</td><td>100 V</td></tr>
<tr><td>LTWTA</td><td>10.7 – 11.7 GHz (1 GHz)</td><td>200 W</td><td>70 V</td></tr>
</table>
NOTE: Vendor shall quote for only for Radiation Cooled TWTAs/LTWTAs.</td><td></td><td></td></tr>
<tr><td>B3.0.2</td><td>The TWTA shall include one unit of TWT, a suitable EPC and all necessary cables for inter connecting above components. The LTWTA shall include a Linearizer along with TWTA. DC voltage required by Linearizer shall be connected directly from EPC to the Linearizer. The TWTAs and LTWTAs shall meet the required performance in the full operating band as given in Table No B4.0.1 and Table No B4.0.2 respectively in sections of Para B4of Exhibit B. In case of discrepancy the Table No B4.0.1 and Table No. B4.0.2 to be treated as requirement for TWTA and LTWTA respectively. Vendor should also provide saver connectors for DC and RF.</td><td></td><td></td></tr>
</table>

Sr no.	SAC REQUIREMENTS	C/NC	VENDOR COMMENTS
B3.0.3	All the components used in a given LTWTA, including coaxial attenuator (along with its value of attenuation) used for tuning of Linearizer and TWT should be assigned with unique Sr. no (from original manufacturer or assigned by LTWTA vendor) for proper record keeping and easy identification.		
B3.1	**TRAVELLING WAVE TUBE (TWT)** **Radiation Cooled TWT** shall provide necessary and sufficient RF gain, with minimum saturated RF output power at EOL as specified in respective Table B4.0.1.		
B3.2	**ELECTRONIC POWER CONDITIONER (EPC)** The required DC power for the TWT shall be provided by the EPC. The EPC shall operate on the space-craft bus as specified in Exhibit-C.		
	The EPCs should also process the ON/OFF tele-command signals, which control the operation of LTWTA and provide appropriate telemetry signals for monitoring the health of TWT and of the EPC. The EPC should also have built-in protection mechanisms to safeguard the unit and the spacecraft DC-bus against any failure inside the unit. The RF parameters of LTWTA Units should not be affected due to any failure in TC/TM circuits. The detailed requirements are specified in Exhibit-C.		
B3.3	**Channel Amplifier (CAMP) Power Supply** The EPC shall also be able to provide auxiliary DC supply (available on DC interface connector of EPC) for CAMP, which are used to drive TWTA. **It may be noted that CAMP is not in the scope of this RFP.**		
B3.4	**Linearizer** a) The Linearizer shall be the integral part of the LTWTA unit. DC supply of the linearizer shall be generated inside the EPC. b) The RF cable from Linearizer output to TWTA input shall be delivered along with the LTWTA. The typical length of the cable shall be about 40 to 60 cm; however exact length of the cable shall be specified at an appropriate time before RF testing of LTWTA. c) Vendor shall also provide separately, technical details about the Linearizer, along with the offer.		

Sr no.	SAC REQUIREMENTS	C/NC	VENDOR COMMENTS
B4.0	**SPECIFICATIONS OF TWTAs/LTWTAs** **a) TWTAs** The electrical requirements given in this section shall be met over the entire operating conditions of bus voltage, temperature and environment. Consolidated electrical specifications have been tabulated as below in Table No. B4.0.1 **b) LTWTAs** The electrical requirements given in this section shall be met over the entire operating conditions of bus voltage, temperature and environment. Consolidated electrical specifications have been tabulated as below in Table No. B4.0.2		

	Table B4.0.1: Specifications of TWTA				
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
B4.0.1.	Frequency Band	10.7 GHz to 11.7 GHz	Ref. Para B4.1		
B4.0.2.	Bandwidth	1.00 GHz	Ref. Table B3.1, Para B3.0.1		
B4.0.3.	RF Input (Pin)	4 dBm max	Ref. Para B4.2.3		
B4.0.4.	RF Power Output at saturation (Po)	200W minimum (EOL)	Ref. Table B3.1, Para B3.0.1		
B4.0.5.	RF Gain (at Single carrier saturation)	49± 1 dB	Ref Para 4.4.1		
B4.0.6.	RF Gain at Small Signal	Not exceeding 8 dB w.r.t. gain at Sat.	Ref Para 4.4.2 ***Small Signal is defined as signal, 20dB below the input level at Saturation.***		
B4.0.7.	Gain Stability with Time (24 hours)	Pin sat. 0.1dB p-p Pin-6dB 0.15 dB p-p Pin-20dB 0.25 dB p-p			
B4.0.8.	Gain Response at saturated output power	0.5 dB max p-p over full band 0.2 dB max p-p over any 40 MHz			
B4.0.9.	Gain Response at small signal	2.0 dB max p-p over full band 0.7 dB max p-p over any 40 MHz			
B4.0.10.	DC to RF Efficiency at saturation	55 % minimum	Ref Para B4.3		

	Table B4.0.1: Specifications of TWTA				
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
B4.0.11.	Over Drive capability	10 dB Without any damage or degradation in performance when overdrive is removed.	Ref. Para B4.2.4		
B4.0.12.	DC Input Power	363 W max.	Ref. Para B4.3		
B4.0.13.	Saturated Output Power stability over any 20 Degree Celsius change: -15 to +5 °C +5 to +25 °C +25 to +45 °C +45 to +65 °C +65 to +85 °C##	0.3dBpp max (saturation) 0.9 dBpp max(20 dB IBO)	Ref. Para B4.5 ##: EPC up to +65°C TWT up to + 80°C 20 deg variation test on PFM only.		
B4.0.14.	Output power stability over 24 hours at 25°C		Ref. Para B4.5		
	(a) At saturation	(a) 0.10 dB (p-p) max			
	(b) At 20 dB IBO	(b) 0.25 dB (p-p) max			
B4.0.15.	Output Power variation at Saturation; over freq. band	< 0.4 dB pp	Ref. Para B4.2.2		
B4.0.16.	Noise Figure	35 dB max			
B4.0.17.	Gain Slope at Saturated Output Power	≤ 0.02 dB/MHz	Ref Para B4.4.5 & B4.4.6		
B4.0.18.	Gain Slope at Small Signal	≤ 0.03dB/MHz	Ref Para B4.4.7		

	Table B4.0.1: Specifications of TWTA				
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
B4.0.19.	AM/PM Conversion Coefficient (deg/dB)		Ref Para B4.6.2		
	0dB IBO	6.0 Deg/dB			
	3dB IBO	5.0 Deg/dB			
	20dB IBO	1.0 Deg/dB			
B4.0.20.	Phase Shift	50 deg max change when Input is changed from Saturation to 20dB IBO	Ref Para B4.6.1		
B4.0.21.	Third Order IMD Input back off each carrier from Pinsat (single carrier)		Ref Para B4.7		
	3 dB IBO	-9.5 dBc max			
	6 dB IBO	-11.5 dBc max			
	10 dB IBO	-15.5 dBc max			
	17 dB IBO	-23 dBc max			
B4.0.22.	Spectral Purity, Harmonic Related, at Saturation	a) 2nd Harmonic < -15dBc			
		b) 3rd harmonic < -25 dBc			
B4.0.23.	Spectral Purity, Non-Harmonic Related	(a) In-band spurious other than due to EPC ripple < - 60dBc (Goal: -70 dBc)			
		(b) Out of Band Spurious < -45 dBc			
		(c) In band spurious due to EPC ripple < - 55dBc (Goal: -70 dBc)			

Table B4.0.1: Specifications of TWTA					
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
		(d) In-band spurious due to heater supply frequency < -55 dBc (Goal: -60 dBc)			
		(e) Spurious in CS test of 3 Vp-p amplitude < -60 dBc			
B4.0.24.	RF Emission	At carrier frequency: < 100 dBµV/m	Ref Para 8.13 of Exhibit-D		
		For lower than 100MHz and carrier harmonics: < 85 dBµV/m			
		Other frequencies (in/out of band): < 45dBµV/m			
B4.0.25.	Noise Power Density at LTWTA output	Within the operating frequency band < - 70dBm/Hz at no RF condition			
B4.0.26.	Noise Power Ratio at	dB	Ref Para B4.9		
	3dB OBO	>11			
	4dB OBO	>13.5			
	6dB OBO	>17			
	9dB OBO	>22			
	12dB OBO	>22			
	15dB OBO	>22			
B4.0.27.	Group Delay.	Linear - 0.015ns/MHz maximum Ripple - 1.0ns (p-p) maximum			
B4.0.28.	Spurious Phase Modulation	As per para B4.10 and Fig. 4.10.1			
B4.0.29.	Stability	Unit shall be unconditionally stable and shall not oscillate or get damaged, even			

Table B4.0.1: Specifications of TWTA					
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
		if input/output terminal are open/short circuited **Under No drive condition.**			
B4.0.30.	Insertion loss	> 70 dB	Refer Para B4.8		
B4.0.31.	VSWR, Input/ Output (maximum)	Input Cold 1.7: 1.0			
		Output Cold 1.5: 1.0			
		Output Hot 3.0: 1.0			
B4.0.32.	Load VSWR	**(a)** Unit shall meet all requirements when terminated in a load of in-Band VSWR up to 1.1: 1.0 (any phase) and out of band VSWR up to infinity (any phase).			
		(b) The TWTA should be capable of operating with input drive corresponding to saturation, to a load that has in-band VSWR 1.5 (any phase) & out of band VSWR up to infinity (any phase), for a duration of 24 hours. Subsequent to such operation, there should be no performance degradation under normal operating conditions.			
B4.0.33.	RF interface connectors and Impedance	(a) Input port: Coaxial SMA, 50 Ohm	Refer Para B4.11		
		(b) Output Port: WR 75 Waveguide			

Table B4.0.1: Specifications of TWTA					
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
	(RF In/Out ports)				
B4.0.34.	Electrical Interface DC Power & TC/TM	(a) DC interface through Standard D-type Connector(s) (b) RF Input connector shall be coaxial and output through suitable waveguide interface (WR-75)	Refer Para B4.11		
		(c) Additional mating D type connectors & D type and RF savers are to be provided.			
B4.0.35.	Bus Supply voltage	100 ± 3.0V (97 V to 103 V) DC	Refer Exhibit-C		
B4.0.36.	In-rush Current Transients	Refer Bus-Interface Specifications Exhibit “C”			
B4.0.37.	Tele command	Refer Bus-Interface Specifications Exhibit “C”			
B4.0.38.	Telemetry outputs	Refer Bus-Interface Specifications Exhibit “C”			
B4.0.39.	Protection Circuit	Refer Bus-Interface Specifications Exhibit “C”			
B4.0.40.	Voltage Ripple From Main Bus	Refer Bus-Interface Specifications Exhibit “C”			
B4.0.41.	Voltage Transients	Refer Bus-Interface Specifications Exhibit “C”			
B4.0.42.	Main Bus Impedance	Refer Bus-Interface Specifications Exhibit “C”			

Table B4.0.1: Specifications of TWTA					
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
B4.0.43.	EPC Specification	As per description given in Para B4.13			
B4.0.44.	Auxiliary Output Voltages from EPC	(a) Positive Output: +6.9 V ± 0.4V with nominal current value between 300 mA to 700 mA. The magnitude of positive voltage shall be > 6.5 V under all operating conditions. (b) Negative Output: -6.9 V ±0.4V with nominal current value between 30 mA to 100 mA. The magnitude of negative voltage shall be > 6.5V under all operating conditions. (c) The return of the auxiliary output shall be isolated from input bus return & TC return. (d) Provide measured value of Ripple and Spike, preferably the value should be in the range of (i) Ripple 30 mVpp, up to 10 MHz and (ii) Spikes 100mVpp	Note: 1. Vendors may propose slightly different voltages if in-orbit heritage exists for same. 2. Exact output specifications will be finalized at the time of placement of order. 3. Load regulation details to be provided		

	Table B4.0.1: Specifications of TWTA				
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
B4.0.45.	EMI/EMC Requirements	Refer Bus-Interface Specifications Exhibit "C" & Para 8.13 of Exhibit"D"			
B4.0.46.	Mass of unit	For TWTA (1 TWT + 1 EPC) Mass of the unit shall be as small as possible. It shall be <3 kg excluding HV Cable and RF cable mass	Ref Para B4.14.1		
B4.0.47.	Mounting Details	As per Para B4.14.2			
B4.0.48.	Size/Shape	As per Para B4.14.3			
B4.0.49.	Venting	As per Para B4.14.4			
B4.0.50.	Surface finishing	As per Para B4.14.5			
B4.0.51.	Ground Isolation	As per Para C10.0			

	Table B4.0.2: Specifications of LTWTA				
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
B4.0.52.	Frequency Band	10.7 GHz to 11.7 GHz	Ref. Para B4.1		
B4.0.53.	Bandwidth	1.00 GHz	Ref. Table B3.1, Para B3.0.1		
B4.0.54.	RF Input (Pin)	-2 dBm max	Ref. Para B4.2.3		
B4.0.55.	RF Power Output at saturation (Po)	200W minimum (EOL)	Ref. Table B3.1, Para B3.0.1		
B4.0.56.	RF Gain (at Single carrier saturation)	≥ 55 dB	Ref Para 4.4.1		
B4.0.57.	RF Gain at Small Signal	Not exceeding 4 dB w.r.t. gain at Sat.	Ref Para 4.4.2 ***Small Signal is defined as signal, 20dB below the input level at Saturation.***		
B4.0.58.	Gain Stability with Time (24 hours)	Pin sat. 0.1dB p-p Pin-6dB 0.15 dB p-p Pin-20dB 0.25 dB p-p			
B4.0.59.	Gain Response at saturated output power	0.5 dB max p-p over full band 0.2 dB max p-p over any 40 MHz			
B4.0.60.	Gain Response at small signal	2.5 dB max p-p over full band			
B4.0.61.	DC to RF Efficiency at saturation	55 % minimum	Ref Para B4.3		

Table B4.0.2: Specifications of LTWTA					
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
B4.0.62.	Over Drive capability	20 dB Without any damage or degradation in performance when overdrive is removed.	Ref. Para B4.2.4		
B4.0.63.	DC Input Power	362 W max.	Ref. Para B4.3		
B4.0.64.	Saturated Output Power stability over any 20 Degree Celsius change: -15 to +5 °C +5 to +25 °C +25 to +45 °C +45 to +65 °C +65 to +85 °C##	0.3dBpp max (saturation) 1 dBpp max(20 dB IBO)	Ref. Para B4.5 ##: EPC up to +65°C TWT up to + 80°C 20 deg variation test on PFM only.		
B4.0.65.	Output power stability over 24 hours at 25°C		Ref. Para B4.5		
	(a) At saturation	(a) 0.10 dB (p-p) max			
	(b) At 20 dB IBO	(b) 0.25 dB (p-p) max			
B4.0.66.	Output Power variation at Saturation; over freq. band	< 0.4 dB pp	Ref. Para B4.2.2		
B4.0.67.	Noise Figure	40 dB max			
B4.0.68.	Gain Slope at Saturated Output Power	≤ 0.02 dB/MHz	Ref Para B4.4.5 & B4.4.6		
B4.0.69.	Gain Slope at Small Signal	≤ 0.03dB/MHz	Ref Para B4.4.7		

	Table B4.0.2: Specifications of LTWTA				
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
B4.0.70.	AM/PM Conversion Coefficient (deg/dB)		Ref Para B4.6.2		
	0dB IBO	3.0 Deg/dB			
	3dB IBO	2.0 Deg/dB			
	20dB IBO	0.8 Deg/dB			
B4.0.71.	Phase Shift	15 deg max change when Input is changed from Saturation to 20dB IBO	Ref Para B4.6.1		
B4.0.72.	Third Order IMD Input back off each carrier from Pinsat (single carrier)		Ref Para B4.7		
	3 dB IBO	-11.5 dBc max			
	6 dB IBO	-16.5 dBc max			
	10 dB IBO	-26.5 dBc max			
	17 dB IBO	-32 dBc max			
B4.0.73.	Spectral Purity, Harmonic Related, at Saturation	a) 2nd Harmonic < -15dBc			
		b) 3rd harmonic < -25 dBc			
B4.0.74.	Spectral Purity, Non-Harmonic Related	(a) In-band spurious other than due to EPC ripple < - 60dBc (Goal: -70 dBc)			
		(b) Out of Band Spurious < -45 dBc			
		(c) In band spurious due to EPC ripple < - 55dBc (Goal: -70 dBc)			

Table B4.0.2: Specifications of LTWTA					
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
		(d) In-band spurious due to heater supply frequency < -55 dBc (Goal: -60 dBc)			
		(e) Spurious in CS test of 3 Vp-p amplitude < -60 dBc			
B4.0.75.	RF Emission	At carrier frequency: < 100 dBµV/m	Ref Para 8.13 of Exhibit-D		
		For lower than 100MHz and carrier harmonics: < 85 dBµV/m			
		Other frequencies (in/out of band): < 45dBµV/m			
B4.0.76.	Noise Power Density at LTWTA output	Within the operating frequency band < - 70dBm/Hz at no RF condition			
B4.0.77.	Noise Power Ratio at	dB	Ref Para B4.9		
	3dB OBO	>14			
	4dB OBO	>17			
	6dB OBO	>22			
	9dB OBO	>25			
	12dB OBO	>25			
	15dB OBO	>25dB			
B4.0.78.	Group Delay.	Linear - 0.02ns/MHz maximum Ripple - 1.2ns (p-p) maximum			
B4.0.79.	Spurious Phase Modulation	As per para B4.10 and Fig. 4.10.1			

	Table B4.0.2: Specifications of LTWTA				
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
B4.0.80.	Stability	Unit shall be unconditionally stable and shall not oscillate or get damaged, even if input/output terminal are open/short circuited **Under No drive condition.**			
B4.0.81.	Insertion loss	> 70 dB	Refer Para B4.8		
B4.0.82.	VSWR, Input/ Output (maximum)	Input Cold 1.7: 1.0			
		Output Cold 1.5: 1.0			
		Output Hot 3.0: 1.0			
B4.0.83.	Load VSWR	**(a)** Unit shall meet all requirements when terminated in a load of in-Band VSWR up to 1.1: 1.0 (any phase) and out of band VSWR up to infinity (any phase).			
		(b) The LTWTA should be capable of operating with input drive corresponding to saturation, to a load that has in-band VSWR 1.5 (any phase) & out of band VSWR up to infinity (any phase), for a duration of 24 hours. Subsequent to such operation, there should be no performance degradation under normal operating conditions.			

Table B4.0.2: Specifications of LTWTA					
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
B4.0.84.	RF interface connectors and Impedance (RF In/Out ports)	(a) Input port: Coaxial SMA, 50 Ohm	Refer Para B4.11		
		(b) Output Port: WR 75 Waveguide			
B4.0.85.	Electrical Interface DC Power & TC/TM	(a) DC interface through Standard D-type Connector(s) (b) RF Input connector shall be coaxial and output through suitable waveguide interface (WR-75)	Refer Para B4.11		
		(c) Additional mating D type connectors & D type and RF savers are to be provided.			
B4.0.86.	Bus Supply voltage	70 ± 5.0V (65 V to 75 V) DC	Refer Exhibit-C		
B4.0.87.	In-rush Current Transients	Refer Bus-Interface Specifications Exhibit "C"			
B4.0.88.	Tele command	Refer Bus-Interface Specifications Exhibit "C"			
B4.0.89.	Telemetry outputs	Refer Bus-Interface Specifications Exhibit "C"			
B4.0.90.	Protection Circuit	Refer Bus-Interface Specifications Exhibit "C"			
B4.0.91.	Voltage Ripple From Main Bus	Refer Bus-Interface Specifications Exhibit "C"			

	Table B4.0.2: Specifications of LTWTA				
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
B4.0.92.	Voltage Transients	Refer Bus-Interface Specifications Exhibit "C"			
B4.0.93.	Main Bus Impedance	Refer Bus-Interface Specifications Exhibit "C"			
B4.0.94.	EPC Specification	As per description given in Para B4.13			
B4.0.95.	Auxiliary Output Voltages from EPC	(a) Positive Output: +6.9 V ± 0.4V with nominal current value between 300 mA to 700 mA. The magnitude of positive voltage shall be > 6.5 V under all operating conditions. (b) Negative Output: -6.9 V ±0.4V with nominal current value between 30 mA to 100 mA. The magnitude of negative voltage shall be > 6.5V under all operating conditions. (c) The return of the auxiliary output shall be isolated from input bus return & TC return. (d) Provide measured value of Ripple and Spike, preferably the value should be in the range of	Note: 1. Vendors may propose slightly different voltages if in-orbit heritage exists for same. 2. Exact output specifications will be finalized at the time of placement of order. 3. Load regulation details to be provided		

	Table B4.0.2: Specifications of LTWTA				
Sr No.	**DETAILS**	**SPECIFICATIONS**	**REMARKS**	**C/NC**	**NUMERICAL VALUES & COMMENTS**
		(i) Ripple 30 mVpp, up to 10 MHz and (ii) Spikes 100mVpp			
B4.0.96.	EMI/EMC Requirements	Refer Bus-Interface Specifications Exhibit "C" & Para 8.13 of Exhibit"D"			
B4.0.97.	Mass of unit	For LTWTA (1 TWT + l Linearizer + 1 EPC) Mass of the unit shall be as small as possible. It shall be <3 kg excluding HV Cable and RF cable mass	Ref Para B4.14.1		
B4.0.98.	Mounting Details	As per Para B4.14.2			
B4.0.99.	Size/Shape	As per Para B4.14.3			
B4.0.100.	Venting	As per Para B4.14.4			
B4.0.101.	Surface finishing	As per Para B4.14.5			
B4.0.102.	Ground Isolation	As per Para C10.0			

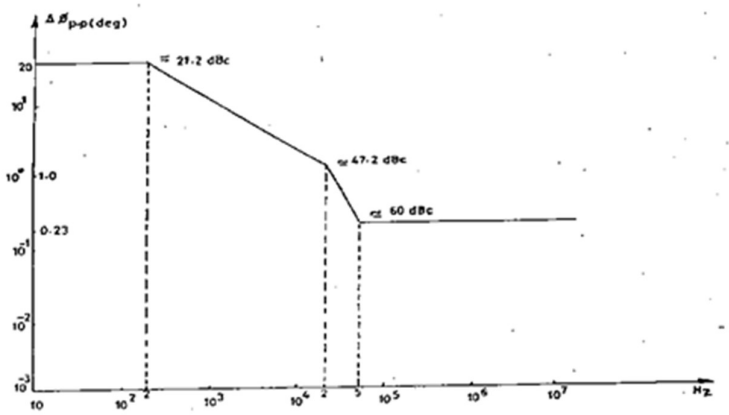
	DESCRIPTION OF SPECIFICATIONS	C/NC	VENDOR COMMENTS
B4.1	**FREQUENCY BAND OF OPERATION** The LTWTA/TWTA is required to operate anywhere in the frequency bands specified in table B.3.1/Table B4.0.1.		
B4.2	**RF OUTPUT and INPUT POWER**		
B4.2.1	**RATED RF POWER OUTPUT (Po)**		
	The LTWTA/TWTA is required to operate anywhere in the frequency band specified in Table B4.0.1. The RF power output of LTWTA/TWTA, measured with single carrier, shall be as per respective Table-B4.0.1 in saturated condition over the specified operating frequency band, operating temperature, and all other operating conditions. Power output shall be achievable immediately after turning HV 'ON'.		
	The BOL output power shall have adequate margin to account for degradation due to ageing, radiation and other long-term effects. LTWTA/TWTA shall be optimized for adequate power output and maximum DC-RF efficiency in the entire respective frequency bands.		
	At the time of submitting the offer, vendor shall also furnish the following details:		
	(a) Minimum RF output power at worst-case operating condition over the frequency range, operating temperature range, bus voltage variation range and environmental condition.		
	(b) Maximum output power delivered under any operational conditions.		
	(c) Estimated degradation of output power over life, due to aging, radiation and other long-term effects.		
	Vendor shall also provide detailed worst-case analysis accounting for the total variation over the life, at the time of Design Review.		
	Note: The vendor has to ensure & demonstrate compliance (by calculation and by test data)) to the power output under all operating conditions at EOL.		

	DESCRIPTION OF SPECIFICATIONS	C/NC	VENDOR COMMENTS
B4.2.2	**OUTPUT POWER VARIATION** The output power variation (i) in full frequency band, (ii) over the time 24hrs, and (iii) over the temperature, shall not exceed values specified in respective Table-B4.0.1 at saturation, over all specified environmental & other conditions.		
B4.2.3	**INPUT DRIVE (Pin)** The maximum RF input level required to drive the LTWTA/TWTA to saturation shall be as per Table B4.0.1.		
B4.2.4	**OVERDRIVE CAPABILITY** The units shall be capable to withstand overdrive, as specified in respective Table B4.0.1, beyond the drive level required for rated saturated output, for prolonged period without any degradation in the performance and life. **Over drive shall be demonstrated for 24 Hrs in PFM unit and for 2 Hrs in FM units.**		
B4.3	**DC POWER CONSUMPTION & DC-RF EFFICIENCY** The DC.-RF efficiency of the Units at rated output power level should be as high as possible. Total DC input power consumption shall not exceed the value specified in the respective Table B4.0.1. The worst case DC input power drawn by the LTWTA/TWTA from the spacecraft bus, shall not exceed the value specified in respective Table B4.0.1 under the worst case operating condition of bus voltage, operating frequency-range & temperature.		
	Vendor shall provide the followings at the time of submitting offer:		
	a. Power dissipation in TWT & EPC for different drive levels		
	b. Estimated degradation in the Gain, efficiency and power consumption over life due to aging, radiation and other long-term effect on TWT and EPC.		
	Vendor shall provide power consumption test data and calculated efficiency values along with the End Item Data Package (EIDP).		
	DC-RF efficiency, RF Output power and DC power Consumption values in tabulated format at zero to 20dB input back off, in 1dB steps, should also be provided.		

	DESCRIPTION OF SPECIFICATIONS	C/NC	VENDOR COMMENTS
	Vendor shall also provide detailed worst-case analysis accounting for the total variation over the life at the time of design review.		
B4.4	**RF GAIN** The RF-gain, defined as the ratio of output power to input power, shall be measured at saturated power and at small signal.		
B4.4.1	**RF GAIN AT SATURATION (SINGLE CARRIER)** The gain of the TWTAs at room temperature shall be as per respective Table B4.0.1 specification to produce single carrier saturation at the center frequency at nominal input level. Vendor shall furnish estimated degradation in the saturated gain over life due to aging, radiation and other long-term effects at the time of submitting offer. Vendor shall also provide detailed worst-case analysis accounting for the total variation over the life at the time of Design Review.		
B4.4.2	**RF GAIN AT SMALL SIGNAL** The small signal gain shall be as per respective Table B4.0.1 specification. Small signal input is defined as the signal, 20 dB below the input level at saturation (i.e. Pin sat -20 dB.). The Pin/Po curve should be smooth. Vendor shall furnish estimated degradation in the small signal gain over life due to aging, radiation and other long-term effects at the time of submitting the offer. Vendor shall also provide detailed worst-case analysis accounting for the total variation over the life at the time of Design Review.		
B4.4.3	**GAIN RESPONSE AT SATURATION** The gain response of the units shall not exceed the requirements specified in table B4.0.1 at saturation under all operating temperature ranges.		
B4.4.4	**GAIN RESPONSE AT SMALL SIGNAL** The gain response of the units shall not exceed the requirements specified in table B4.0.1 at small signal (20dB IBO from saturation point) under all operating temperature ranges.		

	DESCRIPTION OF SPECIFICATIONS	C/NC	VENDOR COMMENTS
B4.4.5	**GAIN SLOPE** The gain slope specified in respective Table-B4.0.1 is absolute and not the relative change. The sign ± indicates the positive/negative slope only and not the variation.		
	GAIN RIPPLE The peak to peak small signal ripple shall not exceed 3.5 dB, over full bandwidth.		
B4.4.6	**GAIN SLOPE AT SATURATED OUTPUT POWER** The gain slope measured at any point within full operating frequency band shall not exceed the value specified in respective Table-B4.0.1, at saturated power output (Po) (under all operating temperature ranges)		
B4.4.7	**GAIN SLOPE AT SMALL SIGNAL** The gain slope shall be less than the value specified in respective Table-B4.0.1, at any point over the full frequency range after adjusting the input drive level corresponding to small signal. (under all operating temperature ranges)		
B4.5	**OUTPUT POWER STABILITY WITH TIME/TEMPERATURE** The output power stability for all TWTAs with time and temperature shall be better than the values given in respective sections of Table-B4.0.1.		
	Power Stability will also be measured at nominal bus voltage on PFM in thermal vacuum condition, after 2 hours stabilization at each temperature for every 20 deg C change in temperature: –15 to +5, +5 to +25, +25 to +45, +45 to +65 and +65 to +85 (EPC up to +65°C and TWT up to +85°C) deg C.		
B4.6	**PHASE CHARACTERSTICS** The phase characteristics shall include the following measurements.		
B4.6.1	**PHASE SHIFT** The total phase shift shall not exceed values specified in respective Table-B4.0.1, when input drive is varied from Pin (Saturation) to Pin (small-signal). Also, change in total-phase-shift over the temperature shall not exceed value-defined in the respective Table-B4.0.1		

	DESCRIPTION OF SPECIFICATIONS	C/NC	VENDOR COMMENTS
B4.6.2	**AM/PM CONVERSION COEFFICIENT** AM/PM conversion coefficient for the Units shall not exceed values specified in respective Table-B4.0.1., when the RF input level is swept from saturation to Pin (small-signal).		
B4.7	**THIRD ORDER IMD** The Third Order Inter-mod distortion, measured with two carriers separated by 1 MHz, shall be less than the values given in respective Table-B4.0.1. The curve for input drives (from small signal to saturation) versus single carrier, two carriers and inter-mod shall be provided.		
B4.8	**INSERTION LOSS** The Insertion loss in non-operating condition, when measured from input to output, shall be more than value specified in respective Table-B4.0.1, over the entire frequency band of operation.		
B4.9	**NOISE POWER RATIO (NPR)** The Noise Power Ratio for the multi-tone signal shall be as per Table B4.0.1		
B4.10	**SPURIOUS PHASE MODULATION** **1.** The periodic phase modulation generated by the unit shall not exceed the limits as given in fig. 4.10.1 when driven by the TDMA signal (duty cycle 1:1) from 0 to 20 dB IBO. The maximum phase modulation shall not exceed 20 degrees peak to peak.		
	2. Vendor shall describe the exact method for characterization of the unit under TDMA operation		

	DESCRIPTION OF SPECIFICATIONS	C/NC	VENDOR COMMENTS
	 **Fig. 4.10.1 Limits for Spurious Phase Modulation**		
B4.11	**ELECTRICAL INTERFACES** The Bus voltage, TC and TM interface shall be through multi-pin space qualified D-Type connector(s) (qualified as per GSFC spaces or NASA/ESA specs; preferably D-sub type Rectangular DC connector). The input RF connector should be coaxial SMA and output should be through WR-75 waveguide interfaces. Vendor to supply following drawings/schematics along with proposal: a) TC interface circuit, b) TM interface circuit c) Grounding diagram d) secondary power interface e) Input Bus-interface circuit as per Exhibit C.		
B4.12	**INPUT DC POWER** The maximum input DC power drawn by the LTWTA/TWTA from the spacecraft bus, shall not exceed the value specified in respective Table B4.0.1 under the worst case operating condition of bus voltage, temperature and RF drive including overdrive.		

	DESCRIPTION OF SPECIFICATIONS	C/NC	VENDOR COMMENTS
	Vendor shall specify the power requirement for TWT and EPC and LTWTA/TWTA separately for saturation condition, 3dB OBO condition, No-drive condition, and over drive condition and worst-case dissipation condition. Vendor should provide the information in the attached POWER-EFFICIENCY DATA TABLE as per given in Table 4.12.1.		
B4.13	**EPC SPECIFICATIONS** Vendor shall provide the typical performance data of the EPC, proposed to be used in the units. It should include the following:		
	(a) Brief design description of EPC circuits, design topology and stability margins for the safe operation of EPC over the specified input bus voltage and at different drive RF conditions of TWT.		
	(b) Different types of protection circuits and its threshold and activation time.		
	(c) Helix current protection circuit and its response at different drive current.		
	(d) Output voltage Turn on and turn off waveforms for auxiliary supplies. Vendor shall also furnish the data of voltages, currents and other performance requirements of each TWT and provide the detailed EPC test data package along with End Item Test Data.		
B4.14	**MECHANICAL REQUIREMENTS**		
B4.14.1	**MASS** The Mass of LTWTA/TWTA shall be specified by the vendor and should be as small as possible; to meet the requirements as specified in Table-B4.0.1. Vendor shall provide mass-breakup, along with mass of HV cables per unit of their length.		
	Note: Manufacturer shall offer best minimum mass of their qualified-design.		
B4.14.2	**MOUNTING DETAILS** The Units will be mounted on Honeycomb panel in the satellite. The vendor should provide mounting lug positions and mounting surface accuracy requirements etc.		
	Note: Normally Units will be mounted in horizontal position; however, there should not be any constraint for mounting it in vertical plane. SAC follows following procedure for mounting units on		

	DESCRIPTION OF SPECIFICATIONS	C/NC	VENDOR COMMENTS
	the panel: M4 Metric SS A2-70 fasteners with Metric coarse pitch threads, with 1.8 Nm torque and Thermal Grease interface. Vendor shall Confirm/suggest fasteners and torque along with flatness requirement & measuring method.		
B4.14.3	**SIZE/SHAPE** The vendor shall specify the size and shape of the units. Size should be as small as possible.		
	Note: The vendor shall provide complete Interface Control Drawing (ICD) including Moment of Inertia (MI), Centre of Gravity (CG), and mounting surface roughness with the Proposal.		
B4.14.4	**VENTING** The equipment shall be vented sufficiently to meet space use requirements as per the R & QA requirements.		
B4.14.5	**SURFACE FINISH** All the external surfaces except the bottom-mounting surface shall be black using; black thermal paint or alternative; with emissivity of 0.85 or better. The bottom surface shall be left unpainted.		
	Note: The vendor shall provide the thermal profile of the bottom surface, so that the heat distribution is known.		
B4.14.6	**CAD & THERMAL MODEL (softcopy):** Vendor should provide CAD Model (STEP / XT file) & Analytical Thermal Model in softcopy at the time of design review.		

Table – 4.12.1A
POWER AND EFFICIENCY DATA (TWTA)

Vendor to provide following details at the time of submitting the offer

Worst case minimum output power at BOL = _____
Ageing & Radiation = _____
Temp variation = _____
Frequency Variation = _____
BOL power output at room temp. & Fo = _____

	TWT				EPC					TWTA				
	NO RF	SAT	OVER DRIVE	3 dB OBO	NO RF	SAT	OVER DRIVE	3 dB OBO	Stand By	NO RF	SAT	OVER DRIVE	3 dB OBO	Stand By
AVERAGE														
DC Input power														
Dissipation														
Efficiency														
WORST CASE														
DC input power														
Dissipation														
Efficiency														

Table – 4.12.1B
POWER AND EFFICIENCY DATA (LTWTA)

Vendor to provide following details at the time of submitting the offer

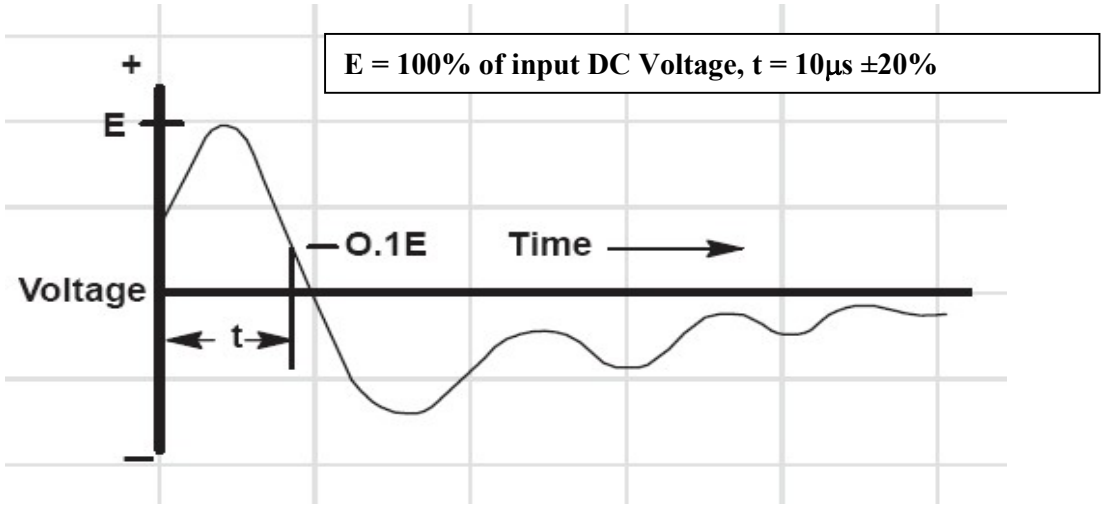
Worst case minimum output power at BOL = _____
Ageing & Radiation = _____
Temp variation = _____
Frequency Variation = _____
BOL power output at room temp. & Fo = _____

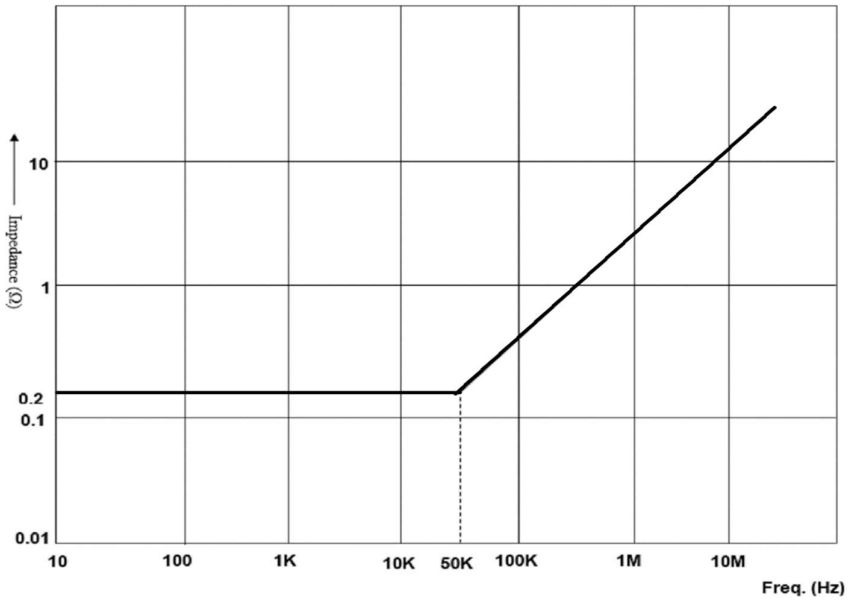
	TWT				EPC					LTWTA				
	NO RF	SAT	OVER DRIVE	3 dB OBO	NO RF	SAT	OVER DRIVE	3 dB OBO	Stand By	NO RF	SAT	OVER DRIVE	3 dB OBO	Stand By
AVERAGE														
DC Input power														
Dissipation														
Efficiency														
WORST CASE														
DC input power														
Dissipation														
Efficiency														

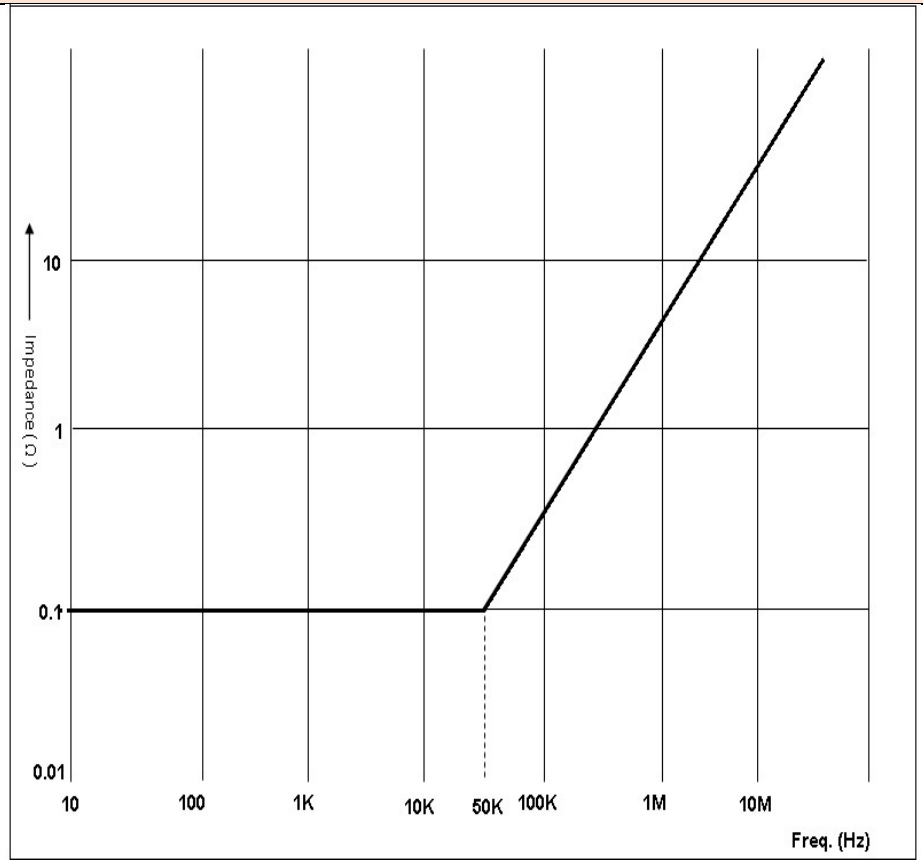
EXHIBIT C

Sr No.	SAC Requirement	C/NC	Numerical Values and comments
C1.0	**Bus Supply voltage:** **Type-1 (TWTA)** — **100 ± 3.0 V DC** **Type-2 (LTWTA)** — **70 ± 5.0 V DC** The input power to the Units shall be supplied directly from the spacecraft bus though protection. The input voltage variation in the specified range should not cause any degradation in performance and the units shall be protected from damage..		
C2.0	**In-rush Current Transients: Peak value of in-rush should not exceed four times the nominal current.** During Bus Voltage Plug-in, Heater ON and HV-ON conditions, Vendor shall specify		
	(a) The peak value of inrush current		
	(b) Rate of change inrush current		
	(c) Total charge delivered to the circuit expressed in Coulombs		
	(d) Wave shape of the inrush current transient		
	(e) Front-End Circuit seen by the bus including the capacitors values.		
	The current inrush at switch on shall be limited to 3.2 times the nominal input current during Heater and HV turn on. However, this inrush shall be limited to 14A peak.		
C3.0	**Main Bus Interface Circuits:** Vendor shall provide the main bus interface circuit, indicating the value of all front end bus interface components. Provide following details		

<table>
<tr><th>Sr No.</th><th>SAC Requirement</th><th>C/NC</th><th>Numerical Values and comments</th></tr>
<tr><td></td><td>Table C3.1: Interface Details
<table>
<tr><td>Unit</td><td>Type</td><td>Rating</td><td>Remark if any</td></tr>
<tr><td>EPC input /output connector</td><td></td><td></td><td></td></tr>
<tr><td>TWT Input connector</td><td></td><td></td><td></td></tr>
<tr><td>Fuse</td><td></td><td></td><td></td></tr>
<tr><td>Linearizer DC connector</td><td></td><td></td><td></td></tr>
<tr><td>Input Capacitance</td><td></td><td></td><td></td></tr>
</table></td><td></td><td></td></tr>
<tr><td>C4.0</td><td>Voltage Ripple from Main Bus
CS101 test on power lines. Ripple as per Para 8.13 of exhibit “D” .</td><td></td><td></td></tr>
<tr><td>C5.0</td><td>Voltage Transients on Bus:
As requirement given in Para 8.13 of Exhibit-D, the units shall not exhibit any degradation of performance when the transient as shown in figure C5.1 peak voltage, Vpeak = 100% of the maximum operating DC input supply voltage, pulse width t=10 micro sec ± 20 %, is applied to the DC power input leads. However, total bus voltage including spike to be limited to the maximum rating of input capacitor. Such voltage transient could occur any time during the operation. Unit shall be capable to withstand such transients without any degradation; and in any case, the unit performance shall not degrade.
This transient could get applied with positive polarity at the highest DC supply voltage. The transient could get applied for duration of up to 15 minutes at a repetition rate of 10 pps.</td><td></td><td></td></tr>
<tr><td></td><td>Testing for transient performance shall be carried out in accordance with MIL-STD 461C/462C and as per CS06 test method.</td><td></td><td></td></tr>
</table>

Sr No.	SAC Requirement	C/NC	Numerical Values and comments
	 **Figure No. C5.1 Transient susceptibility test specification for CS06 test**		
C6.0	**Main Bus Impedance** The typical bus impedance shall be assumed to have the characteristics as shown in Figure C6.1 & C6.2. Changes, if any, in bus impedance will be communicated before P.O finalization.		
	Vendor shall provide the information about the interaction margin between the input impedance of EPC and the input filter (including the spacecraft input harness and bus impedance). Vendor should clearly mention the tolerable input bus and spacecraft harness impedance for proper functioning of the LTWTA.		

Sr No.	SAC Requirement	C/NC	Numerical Values and comments
	 **Figure No. C6.1 Bus Impedance Eclipse Condition.**		

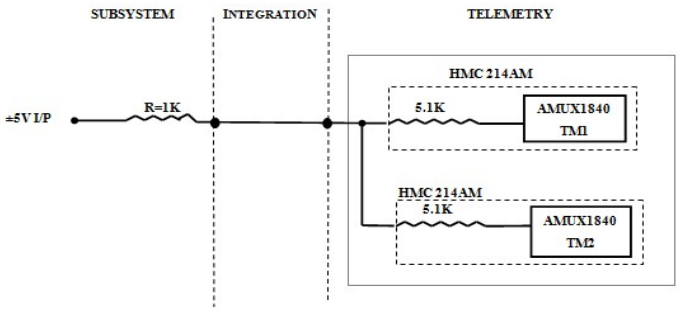
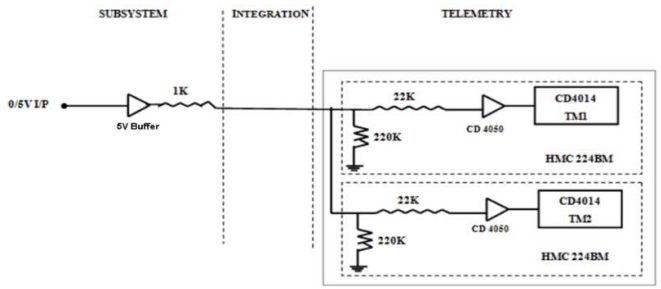
Sr No.	SAC Requirement	C/NC	Numerical Values and comments
	 **Figure No. C6.2 Bus Impedance Sunlit Condition.**		

<table>
<tr><th>Sr No.</th><th colspan="4">SAC Requirement</th><th>C/NC</th><th>Numerical Values and comments</th></tr>
<tr><td>C7.0</td><td colspan="4">Telecommand
Table C7.1 List of Telecommand</td><td></td><td></td></tr>
<tr><td></td><td>(i)</td><td>Tele command Interface</td><td colspan="2">Tele-command signal will be +29V±1 V with a pulse width as per below table and with the drive capability of 1A (max).
In addition, a discontinuity in command pulse up to 100µsec shall not affect the Tele command functioning (Desirable).
Refer para C7.1
Table C7.1.1<table><tr><th>Min</th><th>Max</th></tr><tr><td>64 ms ± 2 ms</td><td>100 ms ± 2ms</td></tr><tr><td>128 ms± 2 ms</td><td>164 ms ± 2ms</td></tr><tr><td>256 ms± 2 ms</td><td>292 ms ± 2ms</td></tr><tr><td>512 ms± 2 ms</td><td>548 ms ± 2ms</td></tr><tr><td>(n x 1536 ms)±1ms</td><td>(n x 1536 ms + 36 ms ± 2ms</td></tr></table>Where n = 1, 2, 4 and 8.</td><td></td><td></td></tr>
<tr><td></td><td>(ii)</td><td>Telecommand signals</td><td>a. TWTA ON
b. TWTA- OFF
c. HOCPC Disable
d. HOCPC Enable
Refer Para C7.2</td><td rowspan="4">Vendor shall provide applicable values along with compliance</td><td></td><td></td></tr>
<tr><td></td><td>(iv)</td><td>Noise immunity</td><td colspan="2">Refer Para C7.3</td><td></td><td></td></tr>
<tr><td></td><td>(v)</td><td>Maximum allowable Tele command Pulse</td><td colspan="2">Vendor shall indicate the maximum duration of the Telecommand pulse which could be applied causing no damage (Refer Para C7.4)</td><td></td><td></td></tr>
<tr><td></td><td>(vi)</td><td>Isolation</td><td colspan="2">Telecommand return shall be isolated from the Bus-return inside the EPC and shall be brought</td><td></td><td></td></tr>
</table>

Sr No.	SAC Requirement	C/NC	Numerical Values and comments
	out separately on the connector pin. However, the TC return and Bus-return will be connected at the spacecraft end. TC return shall be isolated from chassis. **(Refer Para C7.5)**		
C7.1	**Tele command Interface** The nature of all tele-command shall be signal of +29V±1, maximum drive current <1A with the pulse width as per Table C7.1.1. Vendor shall provide the drive requirement with the offer. Expected drive current should be minimum possible (max 1A). The Units shall be able to switch ON and OFF, and also accept other commands applied to EPC of the unit through tele-command subsystem of the spacecraft.		
C7.2	Tele-command signals The units will have provision for the following tele-commands:		
	➢ **TWTA ON:** For turning-on the unit. (High Voltage should be turned ON automatically after the pre-determined filament warm-up delay).		
	➢ **TWTA OFF**: For Turning-Off the Units. (Auxiliary supply to Linearizer, H.V and Heater should Turn-Off)		
	➢ **Helix Over Current Protection Circuit (HOCPC) Disable/Enable:** For disabling/enabling helix over-current protection using tele-command**.** There can be one pin **(**toggle type function**)** or two separate pins for receiving these commands **(**Disable/Enable**).** Vendor shall describe the wake-up mode along with offer**.**		
C7.3	Noise-immunity of each TWTA/LTWTA tele-command input is defined as maximum width of a pulse of +29V±1 V at the tele-command input, for which the tele-command gets un-recognized as a valid tele-command hence no event gets triggered. (a) All tele command interface shall have min. 100us Noise immunity.		

Sr No.	SAC Requirement	C/NC	Numerical Values and comments
	(b) **Desirable:** Tele-command interface to have 500us Noise immunity. The minimum pulse-width to execute the Tele-command shall be specified by the vendor as per Table C7.1.1.		
C7.4	Maximum allowable Tele command Pulse: the maximum duration of the Tele-command pulse which could be applied causing no damage to TWTA should be specified by the vendor.		
C7.5	Isolation: All the telecommand (ON, OFF, HOCPC) live and return lines from the spacecraft will **NOT** be ground-referenced but can have a common-mode voltage. Therefore, the telecommand input pins (live and return) of the unit shall be fully isolated from chassis and from any other point in the unit.		
C7.6	Vendor shall provide following details at the time of bid-submission: - ➢ the current drive requirement by the telecommand lines ➢ Noise-immunity of each tele-command input ➢ Value of maximum duration of the Telecommand pulse which could be applied causing no damage. ➢ Interface-circuits for Input Bus interface, Telecommand interface, Telemetry interface, and Auxiliary output interface. ➢ Ground Isolation scheme for Telecommand and Telemetries.		
C8.0	**Telemetry Outputs:** It is required to monitor Filament status, Helix current, HOCPC Enable/Disable status, Anode voltage and Spurious Shut Off activation status.		
	Table C8.1 Telemetry Outputs		
	(i) Bi-level telemetries, 0V to 0.5V for 'Low' level, and — a) TWTA ON/OFF Status b) Spurious Switch Off / ARU c) TWTA HOCPC Enable/Disable status (Refer Para C8.1) — Vendor shall provide value along with compliance		

Sr No.	SAC Requirement				C/NC	Numerical Values and comments
		5V±0.5V for 'High' level.				
	(ii)	Analog telemetries: - Output shall be analog voltage from 0V to ±5V.	a) Helix Current monitoring b) Anode Voltage monitoring c) Input DC Bus Current/DC Input power consumption monitoring (Refer Para C8.2)			
	(iii)	Interface Circuits	Vendor shall supply interface circuit for all types of telemetries.	Refer Para C8.3		
C8.1	**Bi-level telemetries:** the output of these bi-level telemetries shall be 0V to 0.5V for 'Low' level and shall be 5V±0.5V for 'high' level.					
	(a) Filament Status / TWTA ON/OFF Status: It's a status telemetry for TWTA ON or OFF. 'Low' meaning the TWTA is OFF and 'high' meaning the TWTA is ON.					
	(b) Spurious Switch Off / ARU: It's a telemetry for occurrence of ARU in TWT. 'Low' meaning absence and 'high' meaning Spurious HV shut-off.					
	(c) TWTA HOCPC Enable / Disable status: It shall indicate the enable/disable status for helix-over-current-protection feature for TWTA. Vendor shall provide status-interpretation of 'high' and 'low' levels.					
C8.2	**Analog telemetries**: the output of these analog telemetries shall be analog-voltage from 0V to ±5V. Vendor shall provide their calibration curves in end-item-data-packages. a) Helix Current monitoring b) Anode Voltage monitoring c) Input DC Bus Current/DC Input power consumption monitoring					

Sr No.	SAC Requirement	C/NC	Numerical Values and comments
C8.3	**Telemetry Interface Circuits:** Telemetry shall be provided in either in MIL-STD 1553 format or as per following interface circuits:		
	(a) FOR ANALOG TELEMETRY LINES  Figure C8.1: Analog Telemetry interface		
	(b) FOR DIGITAL TELEMETRY LINES  Figure C8.2: Digital Telemetry interface		

Sr No.	SAC Requirement				C/NC	Numerical Values and comments
	Note 1: The internal circuit should be able to deliver signal to a load of TTL circuit or equivalent.					
	Note 2: In case of malfunction in telemetry circuits, the units shall continue to operate normally without any degradation in performance.					
	Note 3: The interface resistors values could be changed after mutual discussions.					
	Note 4: Telemetry return shall be isolated from the input Bus return and Tele-command return.					
	Note 5: TM voltage level for Digital lines shall be restricted to 5.5 V maximum (preferable 5.1V) by using suitable Zener or using suitable clamping circuit. Clamp should be effective during all conditions including turn on/off etc.					
	Note 6: The vendor should comply to the above mentioned (C8.0 to C8.3) standard TM-TC requirements, however any minor deviations from the mentioned values, can be considered subject to compatibility with ISRO bus interfaces.					
	Note 7: If the interface provided is other than MIL-STD-1553 or standard discrete TM/TC interface details mentioned in C8.0 to C8.3, it can be considered subject to compatibility with ISRO bus interfaces.					
C9.0	**Protection Circuits**					
	Table C9.1 Protection Circuit					
	(i)	**Protection Circuits**	a) Under voltage: Preferably in range of 92 to 93 V (Type-1 TWTA) 62 to 63 V (Type-2 LTWTA) b) Fuse c) Over Current/ Over Power d) Helix over-current protection e) Spurious Shut-OFF / Automatic restart	Vendor shall provide threshold value of each type of protection and time for activation of		

Sr No.	SAC Requirement				C/NC	Numerical Values and comments
	(ii)	Non-operating input voltage range	In case the input voltage variation exceeds the specified limits (under/over voltage), the units shall be protected from damage, up to a voltage level as specified by vendor.	protection mechanism		
	a) Provision shall be made for the TWTA unit to turn "OFF" in case the input voltage falls below the under voltage trip point, which shall be set at value specified in Table C9.1 above.					
	b) The provision for disconnecting the unit from the bus shall be incorporated in case of malfunction. The fuses (fuse network in series with a resistor of TBD ohms or a suitable heritage circuit) should be the very first elements encountered by the raw bus line entering the EPC. The fuse rating should be consistent with inrush current transients. Vendor shall provide fuse clearing characteristics, I and I^ 2t rating of the fuses.					
	c) Provision shall be made to turn-off the unit within shortest possible time (desirable: 4ms to 20ms) in the event of any malfunction causing input power to exceed the safe value (safe value to be provided by vendor, preferably 130% to 200%) of the nominal input power, for >4 ms.					
	d) Provision shall be made for the helix over current protection in case of helix current exceeding a certain safe limit. Provision for disabling this protection by telecommand shall be incorporated.					
	e) In case of any fault in the TWT/EPC causing excessive helix current or transient over current in input bus, the protection circuit should disable High Voltages (HV) (heater should remain ON) in the shortest possible time (less than 40ms desirable). The High Voltage (HV) restore must occur within 300 ms desirable maximum after a HV disable triggered by transient fault (except Bus under voltage and helix over current). In case the fault re-occurs within a specified time (≤ 5 minutes), the unit shall be completely switched off. If the second spurious shut off does not occur within the specified time, the automatic restart capability should be enabled again.					

Sr No.	SAC Requirement	C/NC	Numerical Values and comments
	ESD Protection: Bleed path of <10^6 ohms between center conductor of Co-axial RF ports to ground to be ensured for all packages using sensitive devices.		
	Notes: The units can be turned-on again only through the execution of ON command in the event of complete shut down due to any fault. The vendor shall also provide the time taken for actuation of all protection circuits.		
C10.0	**Ground Isolation** **(a)** Primary ground i.e. Bus ground and the secondary ground/chassis should be isolated from each other with a minimum of 1 M ohm resistance at the unit level.		
	(b) TC return should be isolated from primary, secondary and Chassis returns. TM return should also be isolated from Primary return. The TM & TC returns should be brought out separately on to a connector. The EPC design should be able to tolerate potential difference of around 1 V between any combination of TM, TC, Secondary / Chassis ground. All internal circuit and circuits powered by the EPC such as Linearizer should not get affected.		
	(c) Primary ground will be nominally at the same potential as TM /TC/secondary ground in the spacecraft. However, EPC should function properly even under non-nominal conditions where a non-zero potential exists between primary ground and secondary returns. (The primary return could float in a range of +1V to negative amplitude of max bus-voltage with respect to secondary returns under severe fault conditions). Vendor shall submit the ground isolation scheme at the time of CDR.		
C11.0	**EMI /EMC** The Units shall be designed and tested to meet conducted/radiated emission and susceptibility limits specified in para-8.13 of Exhibit-D		

EXHIBIT D

R&QA requirement of 200W Ku-band TWTA/LTWTA

Para No.	SAC Requirements	C/PC/NC	Vendor comment
-	**INTRODUCTION** This section provides the details on R & QA requirements, which shall be assured by the vendor for this program. The final assembly is referred as 'Unit' in this exhibit.		
1.0	**RELIABILITY**		
1.1	**Life** a) The Units shall meet all the design requirements for use on board spacecraft with a minimum life for 15 years, with a cathode life of 18 years. b) The Units shall be capable of meeting all the functional requirements at various stages of spacecraft assembly and storage as follows. • 3 years' storage and life at various levels of spacecraft assembly • 5 years in controlled environmental conditions. The vendor shall specify exact method of storage and retest criteria in case of longer storage.		
1.2	**Reliability analysis:** A. The units shall be designed and fabricated to achieve an estimated reliability figure of 0.89 at 60°C after 15 years. FIT rate for TWT shall be better than 150 and for EPC/lin, IT SHALL BE BETTER THAN 700 AT 60 °C . As part of CDR, vendor shall give failure rate (in FIT) and reliability figure at the end of 15 years in orbit, calculated at different operating temperatures (starting from 25°C till acceptance maximum temperature in steps of 10°C minimum), along with technical proposal for; a) TWT, b) EPC c) Linearizer (LIN), d) integrated LTWTA/TWTA		

Para No.	SAC Requirements	C/PC/NC	Vendor comment
	B. The vendor shall provide de-rating analysis and derating criteria followed for all the parts used in LTWTA/TWTA, including EPC, Linearizer and TWT. The maximum junction/ channel temperatures of all solid-state devices shall not exceed +110°C under any operating and environmental conditions. C. The reliability estimation shall be carried out as per the latest version of MIL-HDBK-217 (Rev F- notice 2 or later). The vendor should also specify in analysis report, the methodology used in arriving at the failure rate of TWT and other components not mentioned in MIL-HDBK-217-FN2. Vendor shall supply analysis, test data / test reports taken as reference for arriving at the failure rate values of such parts. D. The reliability estimation shall also be carried out based on the in-orbit data of similar LTWTAs/TWTAs (TWTA configuration with similar design and similar specification). Manufacturer shall supply the in-orbit data taken as reference. E. FMECA shall be carried out for all the parts & elements of the LTWTA/TWTA. F. Vendor shall provide following detailed analyses reports as a part of CDR documentation: (i) Detailed reliability analysis consisting of (a) Reliability estimation (b) Stress analysis (c) FMECA (d) Worst case drift & tolerance analysis. (also taking into account of radiation effects, aging and temperature drift for 15 years)		

Para No.	SAC Requirements	C/PC/NC	Vendor comment
	(e) Confirmation that the circuit designs are compliant to the ESA/NASA parts usage guidelines and alerts. Detailed justification along with risk assessment shall be provided for components that are used beyond the recommended configurations/limits. (ii) Thermal analysis under worst case operating conditions. Thermal conductance of 1000w/m^2-K from LTWTA/TWTA mounting surface to the base plate shall be considered. (iii) Mechanical / Structural analysis or Solid model of the assembled unit in IGES format, demonstrating margins over the mechanical environmental specifications of vibration & Shock. (iv) Radiation analysis (v) EM analysis/ Test report for TWT from heritage program (vi) Venting analysis		
1.3	**Safety** It is preferable that the unit design shall be failsafe, so that any failure within unit shall not propagate to degrade or affect the performance of other subsystems in the spacecraft. This shall be assured through adequate usage of protection mechanisms/ circuitry. Vendor should inform necessary precautions to be implemented during ground test and spacecraft level. Standard safety analysis shall be provided in CDR.		
2.0	**ENVIRONMENTAL CONDITIONS**		
2.1	**Non-operating environment** The Units shall be capable of withstanding the following environmental conditions: **(a)** Temperature range : -35 °C to +85 °C **(b)** Pressure : Ambient to 10^{-6} Torr or better **(c)** Relative Humidity : Up to 70% without condensation of water at +40°C (Short duration, applicable for ground storage during transportation and handling only)		

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td>2.2</td><td>

Operating environment

a) Turn-on

The Units shall be capable of being turned-on without any damage at following temperature. The unit however, need not meet the performance specifications at this temperature. The test should be conducted at following temperature:

<table>
<tr><th>Unit</th><th>TWT</th><th>EPC & LIN</th></tr>
<tr><td>QM/PFM</td><td>–30 °C & +85 °C</td><td>–35 °C & +65 °C</td></tr>
<tr><td>FM</td><td>–30 °C & +80 °C</td><td>–30 °C & +60 °C</td></tr>
</table>

b) Operating Temperature range

<table>
<tr><th>Unit</th><th>TWT</th><th>EPC & LIN</th><th>Radiator</th></tr>
<tr><td>QM/PFM</td><td>- 15°C to +85°C</td><td>- 20°C to + 65°C</td><td>- 180°C to +110°C</td></tr>
<tr><td>FM</td><td>- 10°C to +80°C</td><td>- 15°C to + 60°C</td><td>- 180°C to +110°C</td></tr>
</table>

Note: All temperatures are referred to the base plate near to EPC/TWT mounting lug. The TWT collector temperature shall be given by vendor in this condition. Also vendor shall ensure that operation with TWT collector temperature up to 80°C will not affect the life, operation and specifications of the LTWTA/TWTA.

c) Pressure

The unit shall be capable of operating (without RF) at any pressure between 1 atmosphere to 10^{-6} torr and hard vacuum of the order of 10^{-13} torr. The design shall allow quick depressurization during launch ascent.

</td><td></td><td></td></tr>
</table>

Para No.	SAC Requirements	C/PC/NC	Vendor comment
2.3	**Space radiation** The unit shall be designed and fabricated to operate without any degradation in performance or life for the following: a) 1.5 x 10^7 Rads Ionizing dose absorbed in silicon. b) 6.0 x 10^{14} elec. / cm^2 (3 MeV bulk damage equivalent) c) Immunity against SEE (including SEL/SEGR/SEB/SEU etc) : LET 75 Me V /mg/cm^2 The manufacturer should ensure reliable operation of the units in the presence of cosmic Radiation, while considering the shielding offered by satellite structure as 0.5 mm. The design and shielding applied should be such that RDM (Radiation Design Margin of 1.2) shall be demonstrable. Vendor shall provide Radiation analysis considering 0.5 mm shield offered by Satellite structure, for a life of 15 years in Geo-stationary orbit. Note: The dose in silicon at the center of spherical aluminum shield for the mission is as given in Figure –1		

Para No.	SAC Requirements	C/PC/NC	Vendor comment

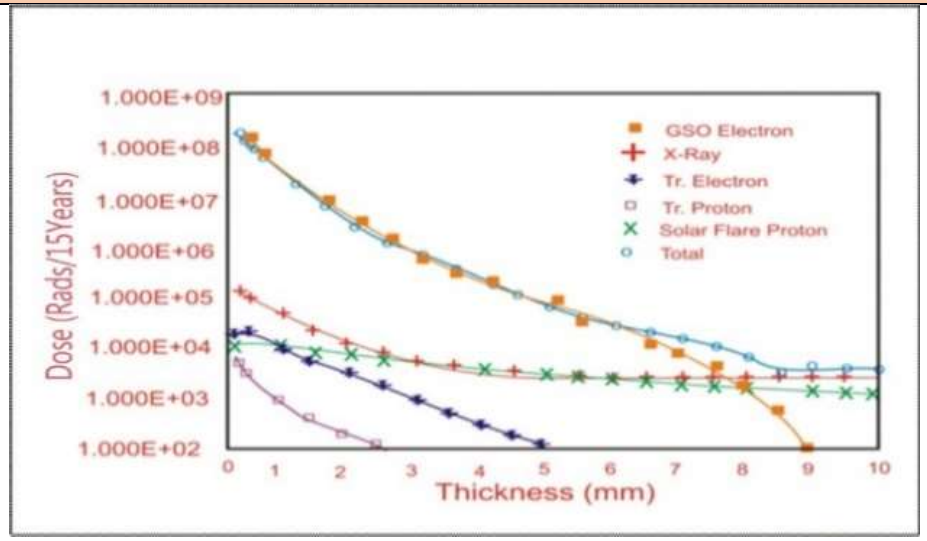


FIGURE-1 : DOSE AT CENTER OF SPHERICAL ALUMINIUM SHIELD

Dose-depth table

Thickness (mm Al)	Thickness (gm/cm^2)	Total dose (rads/15 years)
		GSO
0.05	0.0135	696 M
0.10	0.027	423 M
0.20	0.054	223 M
0.50	0.135	52.2 M

Para No.	SAC Requirements	C/PC/NC	Vendor comment
	<table><tr><td>1 2 3 4</td><td>0.27 0.54 0.81 1.08</td><td>13.8 M 2.17 M 542.0 K 161.0 K</td></tr><tr><td>5 6 7</td><td>1.35 1.62 1.89</td><td>64.8 K 29.0 K 18.6 K</td></tr><tr><td>8 9 10</td><td>2.16 2.43 2.70</td><td>12.1 K 9.98 K 8.71 K</td></tr></table> Total dose at the center of spherical shield at geostationary orbits **Note:** To calculate equivalent thickness of any other material, divide column two by the density of material.		
2.4	**Mechanical Design Specifications:** **The unit mechanical design shall comply with Steady state acceleration specifications Out of plane 25 g & In plane 15 g.** The unit shall be designed and fabricated to meet the vibration (sine and random) and mechanical shock, as per the test plans given. **The unit design shall comply with the environmental requirement without need of notching.** **Vibration/shock;** The unit shall be designed and fabricated to meet the vibration (sine and random) and mechanical shock, as per the test plans given.		

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td>3.0</td><td>PARTS & MATERIALS:
Parts / materials proposed to be used in the unit shall be selected from qualified parts / material list (QPL/QML) and through a qualified sub-vendor, normally associated with long life communication satellite hardware. Quality level of parts used shall meet the following quality level requirements.</td><td></td><td></td></tr>
<tr><td>3.1(a)</td><td>Parts:
Parts to be used in Flight Model shall meet the following minimum quality requirements, given in Table-1 below. In general, the Quality of components for the actual flight deliverable units shall be S- level (minimum).
All components proposed to be used in the unit shall have previous space flight history, which shall be verifiable, through reference documents. A preliminary copy of Parts Approval Document (PAD) shall be provided as a part of CDR.
Table-1 : Parts quality level
<table>
<tr><th>Part Type</th><th>Quality Level</th></tr>
<tr><td>Standard Microcircuits</td><td>i) MIL-PRF-38535 Class-V or MIL-PRF-38510 Class S or ESCC qualified
ii) ESCC capability approved parts with LAT- 2 testing</td></tr>
<tr><td>Standard Semiconductors</td><td>i) MIL-PRF-19500 JANS or ESCC qualified
ii) JANTXV with quality conformance testing</td></tr>
<tr><td>RF Semiconductors</td><td>i) ESCC Level B
ii) Manufacturer’s in-house screening equivalent to JANS, with QCI & DPA
iii) JANTXV with 240 hours additional burn-in and quality conformance testing</td></tr>
</table></td><td></td><td></td></tr>
</table>

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td></td><td>
<table>
<tr><td>RF Passive components (Attenuators, terminations, isolators)</td><td>i) ESCC Level B
ii) ESCC approved parts with LAT-2 testing
iii) As per manufacturer’s in-house Hi-Rel programme, with screening & LAT</td></tr>
<tr><td>Passive components</td><td>i) ESCC Level C or MIL-ER, “S” failure rate
ii) MIL “R-level” failure rate only for parts not available to S-level
iii) Non- QML/QPL parts with manufacturer’s in-house screening programme equivalent to “R-level” with group A testing.</td></tr>
<tr><td>RF connectors</td><td>i) ESCC qualified
ii) As per MIL-PRF-39012 with Group A & B.</td></tr>
<tr><td>Multi-pin connectors</td><td>i) ESCC qualified
ii) NASA-GSFC approved</td></tr>
</table>
Note:
(a) For all the parts, quality level listed as (i) is preferred. Other quality levels are acceptable only if parts with quality level (i) are not available.
(b) A copy of Parts Approval Document (PAD) containing details of parts, their quality levels etc. shall be supplied as part of PDR/CDR</td><td></td><td></td></tr>
<tr><td>3.1(b)</td><td>Quality requirements for MMICs (applicable, if used):
1. Manufacturer shall have obtained ESA capability approval, for fabrication of MMICs or qualified as per MIL-PRF-38535.</td><td></td><td></td></tr>
</table>

Para No.	SAC Requirements	C/PC/NC	Vendor comment
	2. Foundry shall have capability for fabrication & testing requirements as per ESA-9010 and shall have delivered MMICs for space use with testing as per ESA-9010 level B or equivalent space grade. MMICs procured with the above quality level shall undergo following testing prior to their use in the units: a) Visual inspection as per MIL – STD – 883C, method 2010, Condition – A on 100 % of lot. b) DC probing on 100 % of lot. c) RF probing on 100 % of lot. d) WLAT on 5 samples. **In the case of bare die usage,** following tests on packaged samples from each lot: (a) RF & DC electrical test over operating temperature range. (b) Burn – in 240 hrs; followed by life test 1000 hrs on 10 samples. (c) Bond pull & die – shear on 5 samples. **In the case of packaged device usage**, the devices shall be screened per the requirements of ESA 9010 level B or equivalent space grade, with quality conformance testing to LAT-2 or equivalent VOQ testing. Preliminary PAD sheet for MMIC shall be provided as a part of CDR documents.		
3.2	**Materials** Ferrous and non-ferrous material used shall be of corrosion resistance type or suitably treated to resist corrosion caused by atmospheric conditions existent in storage or normal operational conditions. Non-magnetic materials shall only be used for parts, except where magnetic materials are essential. Materials, which are nutrients for fungus, shall not be used.		

Para No.	SAC Requirements	C/PC/NC	Vendor comment
	Organic and inorganic materials shall be stable under atmospheric and high vacuum conditions. These materials shall have a Total Mass Loss (TML) of less than 1% and Collectable Volatile Condensable Materials (CVCM) of less than 0.1% when subjected to test condition of +125°C and $1x10^{-6}$ torr pressure for 24 hrs. Only space qualified epoxies, potting materials etc. shall be used, within their shelf life and with cure schedule as specified by the vendor. However, their use shall be restricted and failure due to these shall be recorded and analyzed as and when detected. The selection and use of dissimilar materials shall be avoided, where it is impractical to avoid dissimilar metals in direct contact with each other, suitable protection shall be provided by space proven coating / plating etc. As a part of CDR, a detailed list of materials to be used shall be provided to SAC for review; along with their Quality and Out-gassing specifications.		
4.0	**Processes:** The unit shall be built to the standards normally associated with long life communication satellite hardware. Particular attention shall be paid, as a minimum, in respect to the following: (a) All the processes used should be qualified for space use, (b) Neat, clean, smooth, and fully welded homogeneous solder joints, (c) Eliminate bubble entrapment in coatings / epoxies whereever used, (d) All components including toroidal / bead inductors / coils shall be suitably supported on PCB by RTV etc. (e) Wherever wires are attached to casing for grounding etc., a higher melting point solder than that used for lid (cover) soldering, shall be used,		

Para No.	SAC Requirements	C/PC/NC	Vendor comment
	(f) The input / output connections on pins form the PCB etc. shall also be made with high melting point solder to avoid detachment of these connections while soldering the pins to external system using SN-63 solder, (g) The marking and plating etc. shall be permanent and should not get damaged during normal cleaning process using Isopropyl Alcohol and other recommended cleaning solvents. All tolerances not specified shall be consistent with the best engineering practices. Units shall be uniform in quality and free from blemishes and defects. **Cleanliness:** The TWTA shall be assembled in the usual Class 100000 (min) cleanliness conditions, compatible with IPA cleaning and at delivery a certificate of compliance to the following contamination level shall be provided : Particular contamination better than 1000ppm Note : these levels apply to the external surfaces of the unit		
5.0	**MARKING AND IDENTIFICATION:** The unit shall be identified by assigning unique serial number on the exterior surface by a suitable process applicable for space use. Marking shall not degrade the performance of the unit. In addition to functional markings like input / output, frequency etc. following marking shall appear on each unit: a) Name of the Manufacturer b) Part Number c) Part details (eg RC Power, Voltage) d) Specification Number / Contract Number e) Serial Number f) Date of Manufacture g) PFM / FM as applicable		

Para No.	SAC Requirements	C/PC/NC	Vendor comment
	The permanency of the marking shall be sufficient to withstand the specified environmental conditions and normal cleaning operations using Isopropyl Alcohol and other cleaning solvents. The test method to demonstrate the same shall be specified by the vendor.		
6.0	**TRANSPORTATION:** Suitable packaging shall be provided for the transportation of the unit by air, ship and road without any degradation / damage. Each unit shall be packaged in individual ESD protective package. This package shall be suitably evacuated or filled with dry nitrogen; to protect the unit from environmental conditions. This package shall be placed in the transportation container. The transportation container shall protect the units from environmental conditions nduring transportation heat, humidity, dust, mechanical shock & vibrations during all stages of transportation and handling, as specified in MIL-P-116. Individual unit package and transportation containers shall be clearly marked with following instructions, along with other mandatory markings. Humidity & shock sensor shall be mounted in transportation container. **"ESD sensitive units"** **"To be opened under clean environment with ESD precautions only"** **"High Reliability Space usage systems"** Note: LTWTA shall be fitted with SI unit size screws / nuts only on their carrier plate.		
7.0	**Model philosophy** Proposed unit should have, a) Flight history / heritage for use in Communication or Navigation or Data transmission payload in GEO or LEO orbit. b) Qualification for space use should have been successfully completed. Following model philosophy is applicable.		

Para No.	SAC Requirements	C/PC/NC	Vendor comment
	➢ Proto Flight Model (PFM) ➢ Flight Model (FM) In case minor design changes are incorporated at module or sub-assembly level (i.e. EPC, LIN or TWT level)for this program, that individual module or sub-assembly shall be subjected to incremental qualification level testing as per mutually agreed test plan. After successful incremental qualification of individual module, the design may be implemented in the actual FM Units. Vendor to provide EQSR (Equipment Qualification Status Report) during kick-off Vendor shall provide following details / documents to SAC for establishing qualification by similarity. a) List of space program, wherein the proposed design has been used, test philosophy followed for that program. (Separate details to be provided by Vendor for TWT , EPC and Linearizer) b) Qualification test report / summary report, clearly indicating LTWTA/TWTA withstood test severity as specified in following paras.		
7.1	**Proto Flight Model (PFM)** Wherever qualification by similarity is established, the first FM unit shall be subjected to PFM level testing. The PFM unit shall undergo testing as per Table-2 at Qualification level severity. However, the duration of the tests shall be restricted to acceptance levels.		
7.2	**Flight model (FM)** The flight model units represent the final electrical and mechanical design and configuration using screened Hi-Rel parts, materials and processes of qualified standard and workmanship. The unit fall-out during Acceptance (screening) tests shall state the number of times that each test parameter failed and quantity of units failed in one or more test parameters. This shall identify all catastrophic, degradation failures and failure modes observed. Any failure observed, shall be reported to ISRO immediately. This shall be followed by a detailed failure analysis, clearly identifying the type of failure (random or design). Any modifications		

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td></td><td>required in electrical, mechanical or process related aspects shall be approved by ISRO. In case of mechanical or electrical design related failure, a retest plan or modification in the test plan may be necessary. Based on failure analysis, such retest plan / modified test plan shall be decided and implemented after approval by ISRO.</td><td></td><td></td></tr>
<tr><td>8.0</td><td>TEST PLAN
Vendor shall provide Acceptance Test Plan and Qualification Test Plan (ATP/QTP) at the time of CDR for SAC review and approval. Tests to be performed on PFM and FM units are shown in Table-2. All electrical testing including Burn-in, EMI, Thermovac shall be carried out with LTWTA in power ON condition.
Note: Suitable buffer connectors shall be provided to minimize the mating / de-mating during testing.
Table – 2 Test plan
<table>
<tr><th>Sr. No.</th><th>Test</th><th>QM (For Reference)</th><th>PFM</th><th>FM</th></tr>
<tr><td>1</td><td>Burn-in-Test (Note 2)</td><td>T, 240 hrs.</td><td>T 240 hrs.</td><td>T, 168 hrs.</td></tr>
<tr><td>2</td><td>Physical Measurements (Note 3)</td><td>T</td><td>T</td><td>T</td></tr>
<tr><td>3</td><td>Visual Inspection (External)</td><td>T</td><td>T</td><td>T</td></tr>
<tr><td>4</td><td>Leak test (at TWT level)</td><td>T</td><td>T</td><td>T</td></tr>
<tr><td>5</td><td>Initial Functional Tests</td><td>T</td><td>T</td><td>T</td></tr>
<tr><td>6</td><td>Magnetic Field Measurement (Note4)</td><td>T</td><td>A</td><td>A</td></tr>
<tr><td>7</td><td>Temperature Tests
Temperature Storage</td><td>T</td><td>--</td><td>--</td></tr>
<tr><td></td><td>Temperature Operational Test</td><td>T</td><td>T</td><td>T</td></tr>
<tr><td>8</td><td>Sine Vibration (Note 5 & 6)</td><td>T</td><td>T</td><td>---</td></tr>
</table></td><td></td><td></td></tr>
</table>

Para No.	SAC Requirements	C/PC/NC	Vendor comment

9	Random Vibration (Note 5 &6)	T	T	T
10	Mechanical Shock (Note 5)	A & T	A & D	--
11	Corona check	T	T	T
12	Thermal – vacuum Thermo-vacuum cycling	T	T	T
	On/off cycling	T	T	--
	Multipactor	A	A	A
13	Humidity Test	T	--	--
14	EMI/EMC	T	T	T (Note 7)
15	Final Functional Tests	T	T	T
16	Final Visual Inspection	T	T	T

NOTE 1: T denotes the applicability of condition by TESTING,
D denotes compliance by PREVIOUS TEST DATA and
A denotes compliance by ANALYSIS

NOTE-2: Burn-in time for LTWTA will be cumulative, including Thermovac test.

NOTE-3: CoG by analysis

NOTE-4: Magnetic field measurement data of representative program shall be provided by Vendor at the time of EQSR / Design review.

NOTE-5: Vibration shall be done separately for TWT and remaining assembly (EPC + Linerizer), as per specified level based on weight of unit.

NOTE-6: For FM units, resonance search test only.

NOTE-7: For FM units EMI test will include RE (sniff test) and RS (spray) tests only, in TWT band.

NOTE-8: At the end of each environmental test, visual inspection and electrical performance check will be carried out.

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td>8.1</td><td>Test parameter
The test parameter in each functional environmental test to be measured shall be same as heritage GEOSAT program & are given in Annexure-1. Test matrix will be reviewed & approved during CDR.</td><td></td><td></td></tr>
<tr><td>8.1.1</td><td>Carry forward data (CFD) requirement:
Following CFD shall be provided as a part of Data package, as provided for GEOSAT heritage program. Also typical test data of LIN shall be provided in CDR.
Table-3
<table>
<tr><th>Sr No</th><th>Test to be performed</th><th>LIN (For Type-2)</th><th>TWT</th><th>EPC</th></tr>
<tr><td>1</td><td>I/O transfer Curve (Amplitude and phase)</td><td>X</td><td></td><td></td></tr>
<tr><td>2</td><td>Over-drive</td><td>X</td><td></td><td></td></tr>
<tr><td>3</td><td>Gain / Power</td><td>X</td><td></td><td></td></tr>
<tr><td>4</td><td>O/P Power stability</td><td>X</td><td></td><td></td></tr>
<tr><td>5</td><td>Input / Output VSWR</td><td>X</td><td></td><td></td></tr>
<tr><td>6</td><td>Harmonics/Spurious</td><td></td><td>X</td><td></td></tr>
<tr><td>7</td><td>Noise Power Density</td><td></td><td>X</td><td></td></tr>
<tr><td>8</td><td>Dissipation vs Drive</td><td></td><td>X</td><td></td></tr>
<tr><td>9</td><td>DC Consumption vs Drive</td><td>X</td><td>X</td><td></td></tr>
<tr><td>10</td><td>SSO& Auto-Restart</td><td></td><td></td><td>X</td></tr>
<tr><td>11</td><td>Cathode Activity, including burn-in logs</td><td></td><td>X</td><td></td></tr>
<tr><td>12</td><td>Cathode operating Point</td><td></td><td>X</td><td></td></tr>
</table></td><td></td><td></td></tr>
</table>

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td></td><td>
<table>
<tr><td>13</td><td>Vacuum check</td><td></td><td>X</td><td></td></tr>
<tr><td>14</td><td>Gain/Phase margin, switching frequency, synchronization details</td><td></td><td></td><td>X</td></tr>
<tr><td>15</td><td>Transient response</td><td></td><td></td><td>X</td></tr>
<tr><td>16</td><td>TM Calibration</td><td></td><td></td><td>X</td></tr>
<tr><td>17</td><td>Helix/Over-current Protection/Limits</td><td></td><td></td><td>X</td></tr>
<tr><td>18</td><td>UV/OV Protection</td><td></td><td></td><td>X</td></tr>
<tr><td>19</td><td>Input In-rush Current</td><td></td><td></td><td>X</td></tr>
</table>
Notes:
X : Applicable
Typical test data shall be presented during CDR</td><td></td><td></td></tr>
<tr><td>8.2</td><td>Burn-in test
TWT Level
Each TWT shall be subjected to burn-in for a minimum of 750 Hrs at 50 °C (typical, for temperature stability), during which cathode activity test shall be carried out to comply the requirement of 15-year long mission life.
LTWTA/TWTA Level:
All QM/ PFM units shall undergo cumulative 240 Hrs of operation during various tests (minimum 168 Hrs in TVAC). All FM units shall undergo cumulative 168 Hrs of operation during various tests (minimum 96 Hrs in TVAC). Durations mentioned in following table:
<table>
<tr><th>Model</th><th>Power ON Duration (Min hrs)</th></tr>
<tr><td>QM/PFM</td><td>240</td></tr>
<tr><td>FM</td><td>168</td></tr>
</table></td><td></td><td></td></tr>
</table>

Para No.	SAC Requirements	C/PC/NC	Vendor comment
	Critical DC and RF parameters shall be monitored and logged during burn-in test along with time and temperature, shall be provided in data pack. Pre and post-burn-in electrical measurements shall be carried out.		
8.3	**Physical measurement** The unit shall be examined for Mass & Dimensions at production level and analyzed for Moment of Inertia & Centre of gravity, values shall be given in ICD.		
8.4	**Visual inspection** The unit shall be inspected for surface finish, mechanical, process & workmanship related defects. Each unit shall be examined visually before and after each environmental test is carried out.		
8.5	**Leak test** Vacuum characterization shall be performed before TWT integration with EPC. The vendor shall give the details of leak test carried out on each TWT.		
8.6	**Initial functional test** The electrical parameters as specified in Annexure-1 shall be measured during Initial functional tests, and taken as reference for all the other environmental tests and final functional tests.		
8.7	**Magnetic field measurement** Magnetic field measurement data of the test performed on representative TWT during previous Qualification/ development program shall be provided by the vendor as a part of design review data package.		

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td>8.8</td><td>Temperature operational test
This test shall be performed on all FM & QM/PFM units to check the performance specifications (in TV) of the units at the specified high and low operating temperatures.
Table – 4 : Operational temperature test
<table>
<tr><th>Test</th><th>Temperature</th><th>Duration</th></tr>
<tr><td>Cold Operational</td><td>FM: -10°C for TWT and -15°C for EPC
QM/PFM : -15°C for TWT and -20°C for EPC</td><td>PFM: 24 hrs
FM: 2 hrs*</td></tr>
<tr><td>Hot Operational</td><td>FM: 80°C for TWT and 60°C for EPC
QM/PFM : 85°C for TWT and 65°C for EPC</td><td>PFM: 24 hrs
FM: 2 hrs*</td></tr>
</table>
*Vendor to ensure that total cumulative burn-in duration for FM testing should be 168 Hrs.</td><td></td><td></td></tr>
<tr><td>8.9</td><td>Vibration
Vibration shall be done separately for TWT and remaining assembly (EPC + Linearizer) as per specified level.
Resonance search (LLS or LLR):
Pre & Post Sine and Random vibration, resonance search shall be carried out in all the three axes as per following levels. The fundamental frequencies of the TWTA, in <u>hard mounted</u> condition, shall be greater than 120 Hz.
Vendor shall provide first fundamental resonance frequency and amplitude. This shall be supplied as a part of data pack for each TWT & EPC unit.</td><td></td><td></td></tr>
</table>

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td></td><td>LLS :
<table>
<tr><th>Frequency (Hz)</th><th>Amplitude</th></tr>
<tr><td>10 - 2000</td><td>0.5 g</td></tr>
<tr><td>Sweep rate</td><td>2 Oct / Minute</td></tr>
</table>
LLR : Random resonance search : equivalent to LLS
Pre & post resonance search success criteria: < 10% in frequency shifts for modes with effective mass > 10 %.

Vibration test sequence:
1. For PFM Unit (all axis) : LLS, Sine Vibration, LLS, Random Vibration, LLS
2. For FM Unit (all axis) : LLS/LLR Random Vibration, LLS/LLR</td><td></td><td></td></tr>
<tr><td>8.9.1</td><td>Sine vibration
This test is applicable for QM/PFM. The unit shall be in non- operating condition. The following test level shall be applied separately along the orthogonal axes (X, Y & Z).
Table-5
<table>
<tr><th colspan="2">Normal to mounting plane</th><th colspan="2">Parallel to mounting plane</th></tr>
<tr><th>Frequency (Hz)</th><th>Amplitude</th><th>Frequency (Hz)</th><th>Amplitude</th></tr>
<tr><td>5-20</td><td>12.4 mm (0-p)</td><td>5-18</td><td>11.5 mm (0-p)</td></tr>
<tr><td>20-70</td><td>20 g</td><td>18-70</td><td>15 g</td></tr>
<tr><td>70-100</td><td>15 g</td><td>70-100</td><td>8 g</td></tr>
<tr><td>Sweep rate:
QM
PFM</td><td>
2 oct / min
4 oct / min</td><td>Sweep rate:
QM
PFM</td><td>
2 oct / min
4 oct / min</td></tr>
</table></td><td></td><td></td></tr>
</table>

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td></td><td>Documents / report shall be submitted at the time of quotation, demonstrating that unit will meet the above sine level.</td><td></td><td></td></tr>
<tr><td>8.9.2</td><td>Random vibration
The random vibration test shall be conducted for QM/PFM & all FM unit. The unit shall be in non-operative condition. TWT shall be vibrated at TWT level. The base-line test levels t are as following:
(a) For PFM units:
Table – 6A
For mass: < 1Kg
<table>
<tr><th rowspan="2">Frequency (Hz)</th><th colspan="2">PSD (g^2/Hz)</th></tr>
<tr><th>Normal to mounting plane</th><th>Parallel to mounting plane</th></tr>
<tr><td>20-100</td><td>+3dB / oct</td><td>+3dB / oct</td></tr>
<tr><td>100-700</td><td>0.33 g^2 / Hz</td><td>0.1 g^2 / Hz</td></tr>
<tr><td>700-2000</td><td>-6 dB / oct</td><td>-3 dB / oct</td></tr>
<tr><td>Overall</td><td>19.1 grms.</td><td>11.8 grms.</td></tr>
<tr><td>Duration</td><td>1 min (PFM)
2 min (QM)</td><td>1 min (PFM)
2 min (QM)</td></tr>
</table>
Table – 6B
For unit mass: 1Kg ≥ mass ≤ 4Kg
<table>
<tr><th rowspan="2">Frequency (Hz)</th><th colspan="2">PSD (g^2/Hz)</th></tr>
<tr><th>Normal to mounting plane</th><th>Parallel to mounting plane</th></tr>
<tr><td>20-100</td><td>+3dB / oct</td><td>+3dB / oct</td></tr>
<tr><td>100-700</td><td>0.28 g^2 / Hz</td><td>0.1 g^2 / Hz</td></tr>
<tr><td>700-2000</td><td>-6 dB / oct</td><td>-3 dB / oct</td></tr>
</table></td><td></td><td></td></tr>
</table>

Para No.	SAC Requirements	C/PC/NC	Vendor comment

Overall	17.5 grms.	11.8 grms.
Duration	1 min (PFM) 2 min (QM)	1 min (PFM) 2 min (QM)

(b) FM units:

Table – 7A

For mass < 1Kg

Frequency (Hz)	PSD (g^2/Hz)	
	Normal to mounting plane	**Parallel to mounting plane**
20-100	+ 3 dB/octave	+ 3 dB/octave
100-700	0.15 g^2 / Hz	0.044 g^2 / Hz
700-2000	-6 dB/octave	-3 dB/oct
Overall	12.7 grms	7.9 grms
Duration	60 sec.	60 sec.

Table – 7B

For unit mass: 1Kg ≥ mass ≤ 4Kg

Frequency (Hz)	PSD (g^2/Hz)	
	Normal to mounting plane	**Parallel to mounting plane**
20-100	+ 3 dB/octave	+ 3 dB/octave
100-700	0.12 g^2 / Hz	0.044 g^2 / Hz
700-2000	-6 dB/octave	-3 dB/oct
Overall	11.7 grms	7.9 grms
Duration	60 sec.	60 sec.

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td>8.10</td><td>MECHANICAL SHOCK TEST (Compliance by previous data)
Vendor shall provide qualification data of design similarity showing that mechanical shock test conducted on similar units and it has successfully survived the levels mentioned below.

Table – 8
The shock levels specified are with a Q=10.
<table><tr><th rowspan="2">Frequency (Hz)</th><th colspan="2">SRS</th></tr><tr><th>Normal to mounting plane</th><th>Parallel to mounting plane</th></tr><tr><td>100 – 600</td><td>+15 dB / oct</td><td>+15 dB / oct</td></tr><tr><td>600-5000</td><td>700 g</td><td>400 g</td></tr><tr><td>5000-10000</td><td>-6dB/oct</td><td>-6dB/oct</td></tr></table>No. of shocks: 2 pulse per axis
Vendor shall provide shock test data performed on qualification unit or from heritage unit along with bid.</td><td></td><td></td></tr>
<tr><td>8.11</td><td>Corona check test
The unit shall be designed to be free from corona or arc discharge. The corona cycling shall be carried under no RF drive condition, as shown in Table below, TVAC chamber will be pumped down from ambient to vacuum within 15 minutes, thus passing the critical pressure region. The reverse process is done at the end of TVAC with a transition from vacuum to ambient pressure, again passing through the critical pressure region within 15 minutes.
Table – 9
<table><tr><th></th><th>Pressure (in torr)</th><th>Duration (in minutes)</th></tr><tr><td>a.</td><td>760 to 10^{-4}</td><td>15</td></tr><tr><td>b.</td><td>10^{-4} to 760</td><td>15</td></tr></table>If corona is observed at any stage, the pressure shall be maintained for 15 minutes, for observation.</td><td></td><td></td></tr>
</table>

Para No.	SAC Requirements	C/PC/NC	Vendor comment
8.12	**Thermo Vacuum Test:** Thermo vacuum test shall be carried out on the final assembled configuration as specified, consisting all the element like TWT, EPC, Linearizer, cable etc, as applicable.		
8.12.1	**Thermal vacuum cycling** Thermo vacuum testing shall be conducted on all units under vacuum conditions of 10^{-6} torr or better. The number of cycles shall be five minimum. The first cycle shall include stabilization at the Cold & Hot Turn-on temperature. Turn ON shall be demonstrated at specified temperature. All the remaining cycles shall include stabilization at the extreme Cold and Hot operating temperatures. The PFM unit shall be subjected to Qualification level testing and the FM units shall be tested at acceptance level. Measurements for all specified parameter shall be carried out in the first and last cycle of operating temperatures as shown in Annexure-1. Measurement during cycles may be limited to monitoring of important parameters for all units. The Thermo vacuum test profile for radiation cooled LTWTA/TWTA is shown in Figure – 2.Vendor may use heritage TV profile (ref. GEOSAT test plan doc. No. 63.7719.700.00KVP)		

Para No.	SAC Requirements	C/PC/NC	Vendor comment

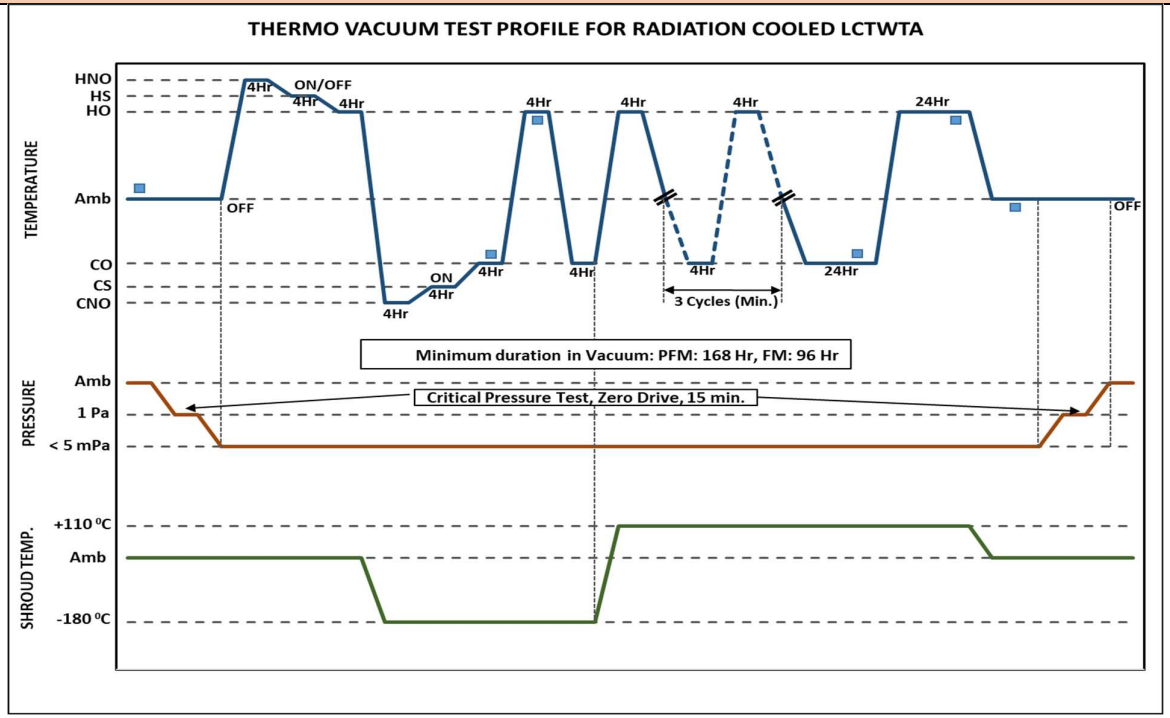


Figure-2: Thermo vacuum test profile for Radiation cooled LTWTA / TWTA

: ELECTRICAL MEASUREMENT

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td></td><td>

Table -10 Test temperature

For PFM unit:

	CNO	CS	CO	HO	HNO	HS
TWT	-35°C	-30 °C	-15 °C	+85 °C	+85 °C	+85 °C
EPC	-35 °C	-35 °C	-20 °C	+65 °C	+85 °C	+65 °C

For FM unit :

	CNO	CS	CO	HO	HNO	HS
TWT	-30°C	-30 °C	-10 °C	+80 °C	+80 °C	+80 °C
EPC	-30 °C	-30 °C	-15 °C	+60 °C	+80 °C	+60 °C

Note :

CNO : Cold Non-Operating
CS : Cold Start
CO : Cold Operating
HO : Hot Operating
HNO : Hot Non-Operating
HS : Hot Start

</td><td></td><td></td></tr>
<tr><td>8.12.2</td><td>**ON/OFF Cycling**
For units that undergo PFM Level Testing, manufacturer shall also conduct 200 EPC ON/OFF cycles test (100 ON/OFF cycles, at both extreme temperature extremes).</td><td></td><td></td></tr>
<tr><td>8.12.3</td><td>**Multipactor**
Multipaction margin of 6 dB over operating power level shall be demonstrated by analysis for LTWTA/TWTA. The Vendor shall provide test data / report of the test carried out as a part of qualification.</td><td></td><td></td></tr>
</table>

Para No.	SAC Requirements	C/PC/NC	Vendor comment

8.13	**EMI / EMC**
	Full EMI / EMC test including RE, RS, CE & CS tests shall be conducted on PFM unit and in-band RE (sniff) and RS (spray) test shall be performed on all FM units.
	
	This test shall be conducted as per and to meet the requirements as specified in MIL-STD-461E with the exceptions as mentioned below:
	• Conducted Emission
	  ○ CE-101: 30Hz to 10kHz
	  ○ CE-102: 10kHz to 10MHz
	• Conducted Susceptibility
	  ○ CS101: 30 Hz to 400 MHz: 1V rms or 1 W
	  ○ CS06: Transient on Power lines as per MIL-STD 461C: Vpeak = 100% of the DC supply voltage, pulse width t=10 micro sec ±20 %
	• RE-102: 10kHz to 40 GHz. In band emission up to 100 dB µV/m at CF, For lower than100MHz and carrier harmonics: < 85 dBµV/m and other frequencies (in/out of band): <45dBµV/m.
	• RS-103: 10V/m, 14 kHz to 40 GHz radiated field and in-band (Fl, Fc and Fh) to meet spurious requirements.		

8.14	**Final functional tests** The final functional test shall be conducted for both PFM as well as all FM units. Parameters as shown in Annexure-1 shall be measured.		
8.15	**Final visual inspection** Visual inspection shall be carried out to confirm that there is no degradation after FM/PFM level testing on the assembly. This test shall be carried out as per para 8.4.		

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td>9.0</td><td>Maximum allowable tolerance in test conditions
Table–11 : Tolerance in test conditions
<table>
<tr><td>Temperature</td><td>Tmax = -0°C, +3°C
Tmin = -3°C, +0°C</td></tr>
<tr><td>Atmospheric Pressure
Greater than 0.1 torr
Less than 0.1 torr</td><td>
± 5%
± 50%</td></tr>
<tr><td>Relative Humidity</td><td>± 5%</td></tr>
<tr><td>Acceleration</td><td>± 10%</td></tr>
<tr><td>Sine Vibration
Amplitude
Frequency
Sweep rate
Time</td><td>
± 10%
0.5 Hz below 25 Hz or ± 2% above 25 Hz
5 %
± 1%</td></tr>
<tr><td>Random Vibration
Overall (g-rms)
Power Spectral Density
20-300Hz
300-2000 Hz
Duration</td><td>
± 10%

± 1.5 dB
± 3.0 dB
+10%/-0%</td></tr>
<tr><td>Shock response Spectrum Test
Amplitude</td><td>
-3dB/ +6dB</td></tr>
</table>
Note: The instrument shall be capable of measuring at least 10 times better than tolerance limit.</td><td></td><td></td></tr>
<tr><td>10.0</td><td>MEASUREMENT ACCURACY
The accuracy, calibration etc., of the test instruments shall be verified and the factors shall be stated in the test plan and procedures submitted by the vendor.</td><td></td><td></td></tr>
</table>

Para No.	SAC Requirements	C/PC/NC	Vendor comment
11.0	**TEMPERATURE STABILIZATION** Temperature stabilization shall be considered reached when all the temperature readings are within ±1°C (±3°C for TVAC test) of the specified temperature for at least three consecutive readings taken at fifteen minutes intervals.		
12.0	**NON-CONFORMANCE CONTROL** The vendor shall follow an effective non-conformance procedure for preventing any non-conforming items to be used in the deliverable units. In case of failure during any stage of optimization and testing, the same shall be reported to SAC, along with cause of failure and necessary modification in the design/fabrication required to overcome the problem shall be identified, the rejection criteria being deviations from the specifications mentioned in Sec.2.		
13.0	**CONFIGURATION CHANGE CONTROL** The manufacturer shall follow an effective configuration change control procedure during the design and fabrication of units.		
14.0	**LIST OF DOCUMENTS TO BE SUPPLIED** **(a)** The following documents shall be provided along with Technical proposal / quotation. • Point by point compliance to R&QA requirement • Space History, Space Program, Qualification status details etc. • Qualification summary report, addressing test levels of previously qualified designs. • Summary of reliability analysis / estimated FR in FIT. • Tests Details, wherever specified. (b) Apart from above the documents / reports as given below, but not limited to, shall be supplied after the award of contract as a part of CDR / data package, as were supplied during previous program.		

Para No.	SAC Requirements	C/PC/NC	Vendor comment
	• List of parts, materials, their quality levels, derating, criterion followed, traceability data, purchase history etc. in PAD sheets • Failure reports (for catastrophic failures), mechanical or handling failures, malfunctioning or operative deviations from the specifications along with corrective actions. • Failure Mode, Effect & Criticality Analysis (FMECA) report. • Reliability Analysis Report as per MIL-HDBK-217F, notice-2. • Worst case analysis. • Radiation design margin analysis • Non-conformance parts and material test reports. • Vibration report • Documents containing test procedures, test and calibration facilities, environmental facilities and relevant operation details, as supplied in previous program. • ICD (c) Complete QM/PFM and all FM units test data reports for review and acceptance before shipment and list of approved drawings (soft copies – in CD)		

<table>
<tr><th>Para No.</th><th>SAC Requirements</th><th>C/PC/NC</th><th>Vendor comment</th></tr>
<tr><td>Annexure-1</td><td>

PARAMETER TEST MATRIX FOR LTWTA / TWTA

<table>
<tr><th>Sr</th><th>DETAILS</th><th>Burn In</th><th>Initial test</th><th>Thermal test</th><th>Post vibration test</th><th>CORONA</th><th>Thermo vacuum</th><th>final test</th><th>Test frequency</th><th>Test condition</th></tr>
<tr><td>1.</td><td>Input Output Transfer Curve
Record I/P drive, O/P RF power, DC input current, DC input power TM, Helix Current TM in step of 1dB</td><td></td><td>X</td><td>X</td><td>X</td><td></td><td>X</td><td>X</td><td>FL,FC,FH</td><td>SS to SAT+3dB</td></tr>
<tr><td>2.</td><td>RF Power Output & Input RF Drive</td><td>X</td><td>X</td><td>X</td><td>X</td><td></td><td>X</td><td>X</td><td>FL,FC,FH</td><td>SAT, SS</td></tr>
<tr><td>3.</td><td>Output power stability over 24 hours at ambient temperature</td><td></td><td>P</td><td></td><td></td><td></td><td></td><td></td><td>FC</td><td>SAT</td></tr>
</table>

</td><td></td><td></td></tr>
</table>

Para No.	SAC Requirements										C/PC/NC	Vendor comment
	4.	Output Power stability over operating temperature range			X					FL,FC,FH	SAT		
	5.	Output Power Variation at Saturation; over freq. band.		X	X	X		X	X	FL,FC,FH	SAT		
	6.	Overdrive Capability						X		FC	Hot Soak or Ambient		
	7.	DC Input Power	X	X	X	X		X	X	FL,FC,FH	SAT, SS		
	8.	DC-RF Efficiency at saturation.	X	X	X	X		X	X	FL,FC,FH	SAT		
	9.	RF Gain		X	X			X	X	FL,FC,FH	SAT, SS		
	10.	Gain Response		X	X				X	FL to FH	SAT, SS		
	11.	Gain Slope		X	X				X	FL to FH	SAT, SS		
	12.	Gain Compression		X	X			X	X	FL,FC,FH	SAT, SS		
	13.	Gain Variation with Temperature			X					FL,FC,FH	SAT-6dB, SAT-20dB		
	14.	Noise Figure							X	FC			
	15.	AM/PM Conversion Coefficient (deg/dB)		X	X				X	FL,FC,FH	From 20 dB input backoff to SAT		
	16.	Total Phase Shift		X	X				X	FL,FC,FH			

Para No.	SAC Requirements										C/PC/NC	Vendor comment
	17.	AM/PM Transfer Coefficient (deg/dB) Input back off from Pinsat, 0 dB IBO, 3 dB IBO 6 dB IBO, 10 dB IBO 15 dB IBO, 17 dB IBO and 20 dB IBO		X	X				X	FL,FC,FH		
	18.	Noise Power Ratio (NPR)		X	X				X	FL,FC,FH		
	19.	Third Order IMD		X	X				X	FL,FC,FH		
	20.	Spectral Purity, Non-Harmonic Related In-band		X	P				X	FM - FC PFM - FL,FC,FH	SAT, $P_{in\ SAT}$-15	
		Out of Band		X	X				X	FM-FC PFM - FL,FC,FH	SAT, $P_{in\ SAT}$-15	
	21.	Spectral Purity, Harmonic Related		X	P				P	FM: FC PFM - FL,FC,FH	FM at Ambient	

Para No.	SAC Requirements										C/PC/NC	Vendor comment
											PFM over temperature and ambient (only 2nd harmonic)		
	22.	Complete EMI/EMC Test (as specified)							P				
		Radiated Susceptibility							X				
		Radiated Emission							X				
	23.	Group Delay							X	FL to FH	SAT, SS		
	24.	Spurious Phase Modulation		X					X	FC	SAT,SS		
	25.	VSWR Input/ Output & Load VSWR		X					X	FL to FH	At TWT level		
	26.	Pre Heating time, In-rush Current		X					X		Bus on, Filament on, HV ON		
	27.	Tele command 1. TWTA - ON 2.TWTA - OFF 3.HOCPC Disable/Enable		X	X	X		X	X				
		TC Noise Immunity		P									
	28.	Telemetry outputs		X	X			X	X	FL,FC,FH	SAT, SS		

Para No.	SAC Requirements	C/PC/NC	Vendor comment

29.	Over Voltage and Under voltage Protection Circuit		X	X				X		
30.	ON-OFF Cycling						P			
31.	TDMA Test							P	FC	SAT, SS
32.	Noise Power Spectral Density at no drive (in band and out of band)			P				P		

P = PFM Unit
X = ALL Units
FC = Centre frequency of band
FL = Lower end frequency of band
FH = Higher end frequency of band
SAT = Saturation Condition
SS = Small Signal condition

Note:

1. All measurement shall be carried out at 70V, wherever not specified.
2. Qualification unit parameter test matrix shall be submitted by the vendor for SAC,ISRO review and approval, whenever applicable.

EXHIBIT-E

Sr No.	SAC REQUIREMENT	C/NC	VENDOR COMMENTS
E1.0	**ADDITIONAL INFORMATION** In addition to the details required in Exhibits–B, Exhibit-C, and Exhibit–D the vendor shall provide following details in his proposal:		
	(a) Design approach including circuit configuration of EPC, TWT and Linearizer.		
	(b) Details about the input / output characteristics of LTWTAs.		
	(c) Assessment of the loop stability for 15 year operating life in space.		
	(d) Protection circuit configuration and its functioning under fault conditions.		
	(e) The tele-command / telemetry circuit and interface details.		
	(f) List of non-standard components proposed to be used.		
	(g) Quality levels of parts for EM & FM.		
	(h) Names of the vendors for important components.		
	(i) The reliability figures and flight history for similar hardware supplied to any space mission.		
	(j) Maximum junction / channel temperatures of devices.		
	(k) The dissipation on TWT / EPC /LTWTA/TWTA during RF-OFF and RF-ON conditions		
	(l) Electronic power conditioner related information:		
	• The EPC shall be unconditionally stable under all operating conditions.		
	• Loop gain characteristic of main regulation loop, helix regulator and cathode current control loop (bode plots), input filter damping characteristics against transient, input filter converter interaction margins and the results of practical stability test data shall be made available at PDR/CDR.		
	• Vendor shall also furnish the data of voltages, currents and other performance requirements of each TWT and provide the detailed EPC test data package along with End Item Test data.		

Sr No.	SAC REQUIREMENT	C/NC	VENDOR COMMENTS
E2.0	**General Terms & Conditions** The Supplier shall prepare detailed and point-by-point compliance statement with reference to all the specifications/conditions/sub-points of this tender document (each and every section/Exhibits) clearly indicating the quantitative values offered wherever applicable along with test results or flight heritage data.		

EXHIBIT-F

<table>
<tr><th>S No.</th><th>SAC REQUIREMENTS</th><th>C/NC</th><th>VENDOR COMMENTS</th></tr>
<tr><td>F1.0</td><td>DELIVRABLES
The vendor shall quote in slab quantities for LTWTA units as mentioned below.</td><td></td><td></td></tr>
<tr><td></td><td>The requirement is primarily for Flight hardware; however, one unit will go through Proto-Flight tests as discussed under Qualification and Test Philosophy.</td><td></td><td></td></tr>
<tr><td></td><td>
<table>
<tr><th>Type</th><th>Quantities (Nos.)
(including PFM unit)</th></tr>
<tr><td>Type 1: TWTAs with 100 V bus</td><td>Type1: 15-17 units;
18-20 units
21-24 units</td></tr>
<tr><td>Type 2: LTWTAs with 70 V bus</td><td>Type2: 9-11 units;
12-14 units
15-17 units</td></tr>
</table>
Note:
The PFM unit is taken from FM lot and subjected to additional test as applicable only for PFM unit as per this RFP. PFM test charge is for all additional test to be conducted on PFM units including full EMI /EMC test as per the SAC QA test matrix.
</td><td></td><td></td></tr>
</table>

S No.	SAC REQUIREMENTS	C/NC	VENDOR COMMENTS
	Each LTWTA unit should be delivered as an integrated functional unit consisting; TWT, EPC and Linearizer. All the necessary interconnection RF cable(s) and Harness(es) should be part of the unit. The length of the RF/HV cable shall be decided before CDR.		
	Vendor should also supply: a. Flight worthy (Space grade) mating D-type connectors with Crimpable pins b. D-type DC Connector savers c. Co-axial RF savers		
	The above (a), (b) & (c) shall be along with 'each' Unit and in addition to that, 20% (rounded off to next higher integer number) spare quantities.		
F2.0	**DELIVERY SCHEDULES:** Delivery schedule: T0 + **16** months (for all the units) T_0 = Date of issuance and acceptance of P.O. *Vendor may propose their best delivery schedule (better than specified here) in the Technical bid. Consideration for offers not complying to required delivery schedule will be at SAC discretion. **Delivery Terms:** As per Latest INCOTERMS		
F3.0	**ADDITIONAL QUANTITY OPTION** As an option, SAC/ISRO can place a purchase order for additional units (maximum 25% of tender Quantity) within 18 months from the date of P.O. resulting from this RFP at the same unit rates.		
F4.0	**REVIEWS / ACCEPTANCE TESTS** The following review / Acceptance tests shall be held at the site of Vendor at an appropriate time with participation of two SAC/ISRO representatives.		
	a) ***Critical Design Review*** (***CDR***)		
	b) ***Acceptance witness testing on PFM & FM UNITs:***		

S No.	SAC REQUIREMENTS	C/NC	VENDOR COMMENTS
	The SAC/ISRO representatives will be present for part or full duration of FM/PFM units testing. They will have right to inspect /validate the actual tests setups ensuring tests are being done in accordance to PO terms. The test data pack shall be reviewed onsite by SAC/ISRO representatives; vendor shall also post the same data to SAC through suitable electronic means. Based on the test data reviewed on site or off site, subject to satisfactory closures of all the observations, SAC/ISRO will issue "Acceptance & Shipment Authorization Certificate". The Delivery of units allowed only after the issuance of such certificate.		
	Vendor will notify the expected dates for above milestones at least 60 days in advance.		
F5.0	**Mandatory Inspection Points (MIP)** (a) Vendor shall provide the standard MIP details in the technical bid. (b) SAC/ISRO Reserves the right to participate in the MIP onsite at Vendors premises for clearance. Alternately, SAC may ask vendor to submit MIP reports along with relevant photographs for clearance by SAC. (c) Vendor must inform the MIP milestone dates at least 60 days in advance to SAC.		
F6.0	**WARRANTY** The vendor shall provide Warranty as given below:		
	"The units supplied here upon shall be free from any defects in material or workmanship and in accordance with the applicable specifications and drawings".		
	This warranty shall run for a period of **four** years from the date of Delivery. This warranty shall continue to be valid for corrected or replaced units until four years after the date of final acceptance.		

----------END OF RFP----------