Request for Proposal

FOR

"MULTI ARRAY CCD-IN-CMOS TDI IMAGE SENSOR"

SPACE APPLICATIONS CENTRE
INDIAN SPACE RESEARCH ORGANIZATION
DEPARTMENT OF SPACE
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1. Introduction

Space Applications Centre (SAC, ISRO), is responsible for the development of electro-optical payloads in the spectral range from visible to IR. To cater to the requirements of future payloads for HRSAT and high resolution Cartography Payloads, it has been planned to go for the procurement of space qualified multi-array TDI CCD in CMOS image sensors which will meet the required specifications of the projects. The required image sensor will be operated in the 400nm to 900nm spectral range and should have 2 panchromatic and 6 multi-spectral bands with 12k and 6k pixel elements respectively.

Two Part Bids are invited from the reputed vendors for the procurement of space qualified multi-array CCD in CMOS image sensor operating in 400nm to 900 nm spectral range. This document gives details on the required image sensor along with the specifications of the filter and screening & qualification guidelines.

Vendor shall submit technical and commercial bid separately. Vendor shall also include masked price bid in the submitted technical offer.

It is very important for evaluation of the offer that the proposals include sufficient technical data on form, fit and function. The proposal submitted in response shall be in conformity with requirements laid down in subsequent sections of this document. The response should also include the previous flight history of proposed or similar imaging sensor. If corresponding technical data and compliance statement are not provided along with the offer, SAC reserves the right to reject the proposal.

The vendor shall provide slab-wise cost break-up for image sensor coated with filters and shall submit all supporting documents, related to previous developments, qualifications etc. SAC reserves the right to include or exclude any test depending on the flight history and cost.

Requirements given in this document may be modified by SAC before the finalization of the contract. After the award of the contract, any modification will be done as per the terms of the contract.

SAC reserves the right to participate and review the progress of procurement at various stages. A suggested review scheme shall be supplied along with the proposal, which will be finalized at the time of award of contract.

2. General Description

The CCD in CMOS TDI image sensor will be a charge domain TDI CCD with CMOS on a single chip, with on-chip clock drivers and ADCs. The sensor shall consist of 2 panchromatic (P) and 6 multi-spectral (Mx) bands having 12000 pixels and 6000 pixel elements respectively (Refer Fig-2.1). The 2 panchromatic bands and

6 multi-spectral bands should have 7µm x 7µm pixel size and 14µm x 14µm pixel size respectively. Also, panchromatic bands and multi-spectral bands should have 128 and 64 TDI stages respectively in each of the bands. To enable super-resolution imaging, the panchromatic bands should have an offset of ½ pixel pitch (3.5µm), in both horizontal and vertical directions (Refer Fig-2.2). To achieve higher quantum efficiency, the image sensor has to be backside illuminated.

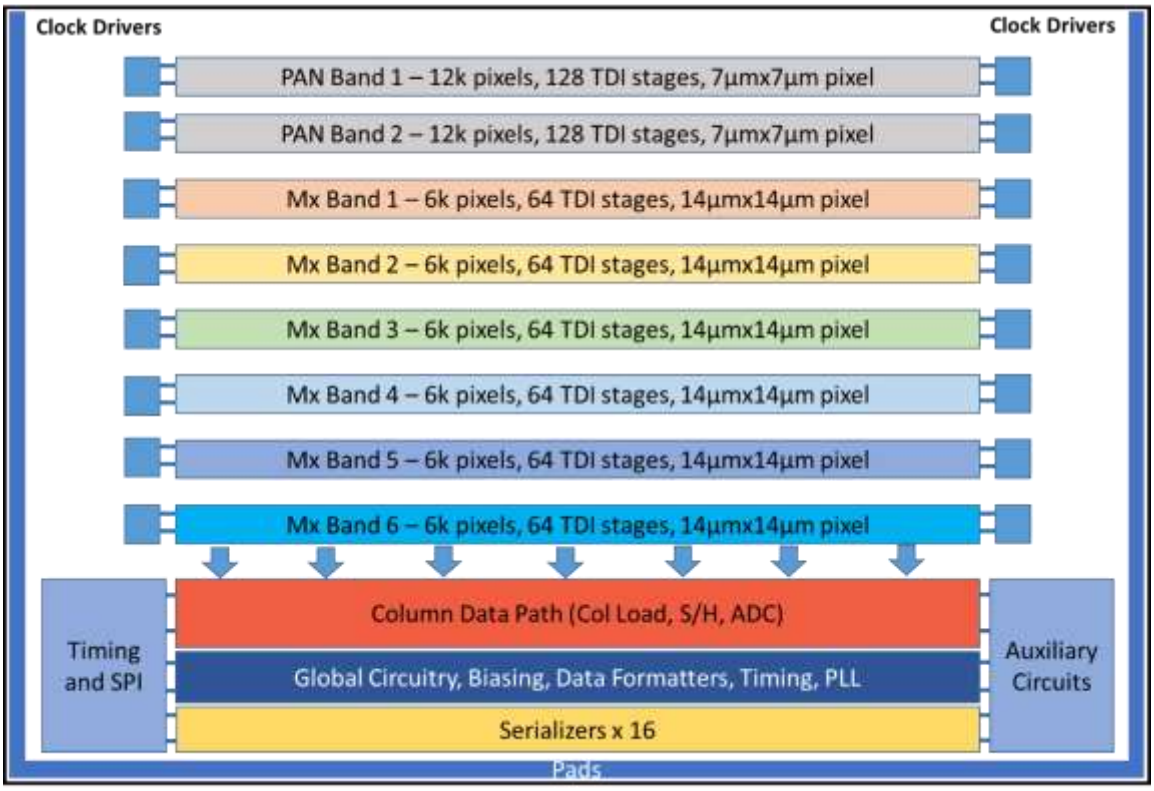

Fig-2.1: Block diagram of multi-array CCD in CMOS image sensor

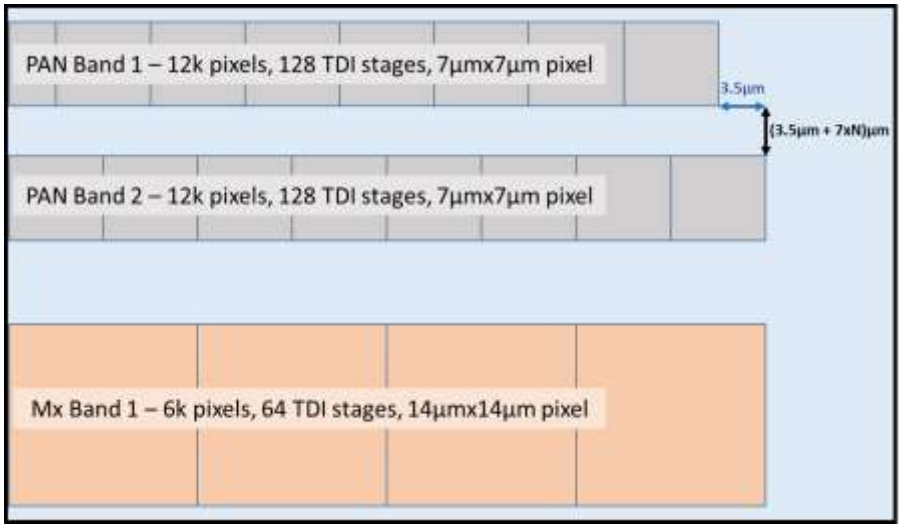

Fig-2.2: Enlarged view of multi-array CCD in CMOS image sensor

3. Physical, Electrical, Electro-Optical and Package Requirements

This section gives details about electrical, physical and electro optical requirement of CCD in CMOS image sensor.

3.1 Image sensor physical requirements:

Table-3.1 shows physical requirement of the CCD in CMOS image sensor

Table-3.1: Physical requirement of Image sensor

Sr. No.	Parameter	Specifications
1	Pixel architecture	4-Phase CCD type
2	Peripheral analog, digital and Mixed signal circuit	1.8V/3.3V/5V compatible CMOS, LVDS/CML
3	No. of Bands	PAN: 2 Bands (half pixel offset between PAN Band 1 and 2 in horizontal direction and offset in vertical direction with N < 20 as shown in figure-2.2) Mx: 6 Bands (Mx Band 1-6)
4	Square Pixel dimensions	PAN: 7µm x 7µm Mx: 14µm x 14µm
5	Pixel Pitch	PAN: 7µm Mx: 14µm
6	No. of pixels on each TDI row	PAN: 12000 or more Mx: 6000 or more
7	TDI Direction	Bi-directional (user selectable)
8	No. of selectable TDI stages	PAN: 4,8,16,32,48,64,96,128 or more Mx: 2,4,8,16,24,32,48,64 or more
9	Illumination direction	Back side illumination
10	Total video outputs	Typically 16 (selectable to 8 o/p for reduced power and line rate)

3.2 Electrical Parameters:

Table-3.2 gives electrical requirement of the CCD in CMOS image sensor

Table-3.2: Electrical requirement of CCD in CMOS image sensor

Sr. No.	Parameter	Specifications
1.	Video output type per array	Differential (i.e. CML/LVDS) with frequency 2.0Gb/s or more
2.	Sensor Electrical Interface	SPI / I2C / JTAG
3.	ADC resolution	11 bits or more
4.	Full Chip power dissipation (at maximum line rate)	≤ 7.5W
5.	Readout mode	Time Delayed Integration (both reverse and forward) with line rate control (external or internal trigger)

6.	Integration time control in full frame mode readout	Based on the set line time
7.	Output data stream	2.0Gb/s or more per channel
8.	Bias Requirement	Vendor shall provide details of required biases for various analog, digital and mixed signal blocks of the sensor along with required currents on each line
9.	Clock Input	LVDS/CML (Freq. 120MHz or less)
10.	Gain settings	1x to 2.0x or more with min. five intermediate steps

Vendor shall provide details of required biases along with range, required currents on each bias lines to meet the required power consumption specifications.

3.3 Electro Optical Requirements:

Table-3.3 gives electro-optical requirement of the sensor

Table 3.3 Electro-Optical Requirements

Sr No.	Parameter	Specifications
1	Full Well Capacity	PAN: ≥90Ke$^-$ Mx: ≥280Ke$^-$
2	Dark Noise RMS	PAN: ≤70e$^-$ Mx: ≤200e$^-$
3	Dynamic Range	$\geq$ 60 dB
4	Max. Line Rate	PAN: 40 kHz or more Mx: 20 kHz or more
5	CTE per Transfer	0.999 or better
6	Antiblooming operation	$\geq$ 50X
7	Avg Dark Current Density @25°C	≤15 nA/cm^2
8	Output Nonlinearity (% of Sat)	≤ 2%
9	Fixed Pattern Noise (% Sat, peak-to-peak)	≤ 5%
10	PRNU (Global), all stages at 50% of Sat (peak-to-peak)	≤ 7.5% for PAN ≤ 7.5% for bands with wavelengths >500nm ≤ 2.5% for bands with wavelengths <500nm
11	Spectral Ranges	PAN band 1 and 2: 400-900 nm Mx band 1: 400-450 nm Mx band 2: 450-520 nm Mx band 3: 520-590 nm Mx band 4: 630-690 nm Mx band 5: 700-750 nm Mx band 6: 770-890 nm *kindly refer filter section

<table>
<tr><td>12</td><td>Mean Quantum efficiency (PAN and Mx)</td><td><table>
<tr><th>λ</th><th>QE</th></tr>
<tr><td>400 nm</td><td>≥80%</td></tr>
<tr><td>450 nm</td><td>≥85%</td></tr>
<tr><td>500 nm</td><td>≥85%</td></tr>
<tr><td>550 nm</td><td>≥85%</td></tr>
<tr><td>600 nm</td><td>≥80%</td></tr>
<tr><td>650 nm</td><td>≥80%</td></tr>
<tr><td>700 nm</td><td>≥75%</td></tr>
<tr><td>750 nm</td><td>≥70%</td></tr>
<tr><td>800 nm</td><td>≥60%</td></tr>
<tr><td>850 nm</td><td>≥50%</td></tr>
<tr><td>900 nm</td><td>≥35%</td></tr>
<tr><td>950 nm</td><td>≥20%</td></tr>
<tr><td>1000 nm</td><td>≥10%</td></tr>
<tr><td>1050 nm</td><td>≥5%</td></tr>
</table></td></tr>
<tr><td>13</td><td>Radiation tolerance</td><td>TID: > 20 krad (Si), Co60
SEL: No destructive latch-up (SEL) ≥70 MeV/mg/cm2</td></tr>
<tr><td>14</td><td>Defective Columns</td><td>Defective Column (TDI column with all stages active) meets the following criteria.
(i)FPN > 5% SAT < 10% SAT or
(ii)PRNU > 7.5% SAT < 15% SAT or
(iii)VCTE > 0.9999 < 0.99993

Maximum number of defective columns ≤ 25 per PAN band and ≤ 15 per MS band.
No Clusters with > 5 neighboring Defective Columns.
Minimum distance of 50 columns between the Clusters.
Defective columns will be excluded from electro-optical performance tests.</td></tr>
</table>

3.4 Absolute Rating:

Ratings for which the manufacturer shall guarantee that the device can be exposed during the use or storage without any permanent deviation or degradation when operated again within specified limits, applicable to all screened deliverable devices are specified below:

Table 3.4 Absolute Ratings

Sr No.	Parameter	Minimum	Maximum
1	Storage Temperature	-40°C	80°C
2	Operating Temperature	0°C	60°C

3.5 Package requirement:

All eight arrays (02 PAN + 06 Mx) shall be mounted on same ceramic package. Sensor Package should be made from either Aluminum Nitride or Alumina. Table 3.5 gives details of requirement/specification of the package along with required die to die separation.

Table 3.5 Package Specification Requirement

Sr No.	Parameter	Value	Tolerance (if any)
	Dimensional details:		
1	Package Length	120±5mm	±0.20mm
2	Package Width	55±5mm	±0.20mm
3	Package Height with Filter or Glass Window (excluding pins)	5±1mm	±0.50mm
4	Separation between PAN-1 and PAN-2	<0.1225mm	
5	Separation between Mx Arrays	<2.1mm	±0.07mm
6	No. of Package Pin Counts	≤400	
7	Package Pin length	>6mm	±0.25mm
8	Package Type	PGA with Pin pitch: 1.5mm	
9	Sensor mounting surface on the front of package	To be proposed by vendor for adequate mounting on FPA	

Package mass including sensor, filter window shall not be more than 100 gm.

3.6 Filter Specifications:

The filter window will have 8 band spectral filter (6 for Mx Bands and 1 for PAN bands), which will serve as cavity sealing as well as spectral definition of different arrays. Both PAN bands (PAN1 and PAN2) have same spectral wavelength and other filter specs. There will be one PAN band coating which will cover both PAN bands. Since these filters are to be used for space application, they need to have very good environmental stability and mechanical durability. The Filter window shall be vacuum compatible and shall be qualified during screening and qualification tests of sub-sequent sections. The 6 Mx bands spectral filter consists of six different spectral bands covering wavelength range of 400nm – 890 nm and the 2 PAN bands filter will cover broader spectral bands from 400nm - 900nm. Spectral filter coating will be on an optical substrate like Fused Silica/NBK7/Sapphire or equivalent glass and it is also preferred to have all the spectral bands on the single substrate.

Table-3.6 gives the filter requirement of the CCD in CMOS image sensor:

Table 3.6 Filter Requirements

Sr. No.	Parameters	Specifications
1	Material	Fused Silica/NBK7/Sapphire
2	Shape	Rectangle
3	Surface Figure (λ=633nm) (rms)	0.2λ per 25mm step
4	Flatness (λ=633nm) (filter substrate before any coating) (PV)	1λ per 25mm step
5	Parallelism / Wedge between two faces (filter substrate before any coating) (arc-sec)	≤ 5
6	Scratch & Dig (S-D) inside clear aperture (before and after coating)	20-10
7	Scratch & Dig (S-D) outside clear aperture (before and after coating)	40-20
8	Surface Roughness (filter substrate before coating) (A) (rms)	< 50
9	Mask (Color and Black) Coating (Location)	Surface facing die
10	Mask (Color and Black) Coating (Extent)	Entire surface
11	Mask should have absorbing coating (free from pinholes) with transmission < 0.5 % and reflection ≤ 5% in the entire visible/ NIR (300 - 1100 nm) range @ 0° angle of incidence	To be complied
12	Average In-Band Transmission (P1, P2, B3-B6)	≥ 90 %
13	Average In-Band Transmission (B1 & B2)	≥ 88 %
14	Ringing	≤ 10 % (Target ≤ 5 %)
15	Edge tolerance for 50% transmission points	≤ 1 %
16	Average Transmission @ Blocking Range (300-1100 nm)	< 0.1 % (Target < 0.05 %)
17	Blocking spikes (absolute transmission)	≤ 2 % (Target ≤ 1%)
18	Central Wavelength (nm)	650 ± 6 (P1 & P2) (Target: ± 5)
		425 ± 4 (B1) (Target: ± 3)
		485 ± 4 (B2) (Target: ± 3)
		555 ± 5 (B3) (Target: ± 3)
		660 ± 5 (B4) (Target: ± 3)
		725 ± 5 (B5) (Target: ± 3)
		830 ± 6 (B6) (Target: ± 4)
19	Band width (nm)	500 ± 5 (P1 & P2)
		50 ± 3 (B1)

		70 ± 3 (B2)
		70 ± 3 (B3)
		60 ± 3 (B4)
		50 ± 3 (B5)
		120 ± 3 (B6)
20	Cut-on and cut-off slope for bands P1 & P2	< 5%
21	Shape factor for all Bands except P1 & P2	
	% peak Transmittance	HPBW multiplying factor
	(i) 90%	> 0.85
	(ii) 10%	< 1.3
	(iii) 1%	< 1.7
	(iv) 0.10%	< 2.0
	(v) 0.01%	< 2.4
22	The optical specifications should be complied with F# 9.25 system with angle of incidence 0° and at room temperature (20 ± 3 °C.)	To be complied
23	Coating	Coating shall be uniform and the non-uniformity in CWL should be ≤ 2 nm.
24	Variation in the average transmission	≤ 2%
25	Variation in the bandwidth	≤ 1 nm (should be demonstrated by carrying out spectral measurements minimum at 3 points, two edges and centre)

4. Reliability & Quality Assurance Requirement

4.1 Introduction:

Reliability and Quality are important prerequisites of any Space program hardware. It is therefore very essential to understand and implement the R & QA requirements judiciously. This section provides the details on Product Assurance requirements, which shall be implemented, for the device under consideration.

Vendor may propose any change in product assurance plan and it shall be accompanied with impact analysis. SAC reserves the right to finalize the product assurance plan before ordering.

4.2 Reference Documents:

Latest revisions of following documents form part of this requirement and shall be read in conjunction with this. Corresponding relevant ESA / ISO standards can be used where ever applicable/ required.

ESCC-9020	Test requirements for CCD photo-detector devices
MIL-STD-883	Test methods for Microcircuits
MIL-PRF-13830B	Optical components for fire control instruments; General specifications governing the manufacture, assembly and inspection of
ECSS-Q-ST-70-02C	Thermal vacuum outgassing Test for the screening of space materials
FED-STD-209	Clean Room and work station requirements, controlled environment
NHB-5300.4(IC)	Inspection system provisions for aeronautics and space system materials, parts, components and service.
ASTM-E-595	Standard test method for TML & CVCM from outgassing in a vacuum environment

4.3 Life:

a) Operating life: The unit shall meet all the design requirements for use onboard a spacecraft having a minimum life of 7 years in low earth orbit with 99% Reliability (at 60% confidence level). Vendor to provide reliability analysis report in support of this requirement.

b) Shelf life: The unit shall be capable of meeting all the functional requirements after various stages of storage and spacecraft assembly as follows:

- 5 years in controlled environmental conditions.
- 3 years storage at various levels of spacecraft assembly and operation under clean room environment with temperature and humidity control.

Vendor shall specify the exact method of storage for the detector assembly; as well as the recommended criteria for their retest, in case of long duration storage.

4.4 Environmental Conditions:

The units shall be capable of withstanding the following environmental conditions:

4.4.1 Storage Environment:

1. Temperature: -40°C to +80°C
2. Vacuum: Ambient to better than 1E-6 torr
3. Relative Humidity: 50 ±5 % RH @ 25±3ºC

4.4.2 Operating Environment (During Ground and On-orbit Operation):

1)Temperature: 0°C to +60°C

2)Vacuum: Ambient to 1E-6 torr

3)Relative Humidity (during Lab use): Better than 50% @ 25±3°C

4.4.3 Space Radiation Tolerance:

Vendor shall ensure operation of the detector, without degradation, due to particle and high-energy radiation, by appropriate choice of materials and processes. Radiation flux expected to be received by the detector during the design life of the satellite mission (7 years) is given below. Vendor may provide test results of radiation test carried out on similar detectors to provide compliance to this requirement.

1. 20 Krads Ionizing dose absorbed in silicon
2. SEL with LET of 70 MeV/mg/cm2

4.4.4 Vibration / Shock:

The detector shall be designed and fabricated to meet the vibration and mechanical shock requirements as per the test plan given herein.

4.5 Parts and Materials:

Parts/materials and processes proposed to be used in the device shall be suitable for use in a LEO spacecraft orbiting earth for a period of 7 years. Materials & processes shall be selected with low out gassing characteristics and for minimum material deterioration and maximum stability.

4.5.1 Materials:

Materials, which are nutrients for fungus, shall not be used. Organic and inorganic materials used for the fabrication of the device shall be stable as per the operating and storage conditions (specified above in section 4.4.1 and 4.4.2). 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 conducted at +125ºC and $1x10^{-6}$ torr for 24 hours.

In case use of materials / epoxies that are not meeting the out-gassing specifications becomes mandatory, they shall undergo additional treatment.

4.5.1.1 Device package/ substrate:

Device leads shall be suitably coated to protect from corrosion/environment degradation. Substrates on which the detector array shall be mounted and all other elements to be used inside the detector package shall have a space heritage and shall be procured from reputed vendor having experience of development for spaceborne projects.

4.5.1.2 Optical Filter:

The substrate material for the filter shall meet the requirements of MIL-PRF-13830. The material used for fabrication of the windows shall be free from strain, internal stresses and internal defects like bubbles, fractures etc**.**

4.5.1.2.1Coatings:

Coatings (both optical and chemical, if any) shall be space qualified. The samples of optical elements where optical coatings, such as anti-reflection and other such coatings are involved shall be in conformity with MIL-PRF-13830.

4.5.1.2.2Surface Quality:

Surface Quality (scratch/dig) of the filter shall conform of 20-10 inside clear aperture and 40-20 outside clear aperture.

4.5.1.3 Electronic Parts:

The electronic components used for fabrication of the detector shall be of space qualified quality.

4.6 Process:

The devices shall be built to the standards normally associated with long life satellite hardware. Particular attention shall be paid to the following, as a minimum:

- It is desired that all the processes used should be qualified for space use or shall have space heritage.
- Neatness & thoroughness of all Plating, Coating, Sealing etc.
- All aspects of the semiconductor assembly like die attachment, wire bonding shall be compliant the requirements of Method 2010 & 2017 of MIL-STD-883.
- 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.

Vendor shall provide a generalized flow chart of the manufacturing and assembly process, identifying the critical process steps, inspection & monitoring stages, Internal Quality control plan and Contamination control plan, for the approval of SAC.

4.6.1 Lot Formation:

The term 'Lot' is defined as a group of devices on which specific assembly steps (i.e. die bonding, wire bonding, etc.) are performed within 18 weeks time period using the same assembly process. Vendor's. Vendor's QA department shall ensure whether the material is considered to be in the same lot as the previously processed material. Vendor shall maintain a set of run cards (lot traveler) on each unit fabricated for this project, which contain detailed data on the process sequence, specifications, measured data yields and processing dates. The non – IP containing part of the lot traveler shall be kept at vendor's premises for verification by SAC personal, if required.

All out-of-specification conditions and significant deviations from standard parameter distribution shall be noted. Similarly, traceability of detector assembly lots shall be maintained. These details shall be available at Vendor's Plant for inspection by the customer.

4.7 Marking and Identification:

Each device shall be marked with:

• Part Number

• Date Code#
• Serial Number
• Indicator for Sensitivity to ESD (Desirable)
• Vendor's logo (Desirable)

#In case Date Code marking is not possible on each package, it shall be separately provided for each detector.

The permanency of device marking shall be sufficient to withstand the specified environmental conditions and normal cleaning operations employed during fabrication & assembly, using Isopropyl Alcohol and other cleaning solvents as per the requirements of MIL-STD-883 method 2015 or Handling, Storage and Cleaning guideline to be proposed by vendor.

4.8 Packaging, Storage & Transportation:

I. Each unit shall be packaged in order to protect the device against ESD, electrical, mechanical and environmental damage.

II. Further, the individual packages and the intermediate packages shall be fixed within the shipping package, which shall be resistant to mechanical shocks, humidity and dust.

III. Wherever required, the individual packages for the units and/ or transportation container shall have facility for nitrogen purging, so that the unit is purged with dry nitrogen before shipment, to prevent contamination and corrosion.

IV. It is to be noted that **"Pink poly-foam" shall not be used for packing** of the individual units, as it has a corrosive effect on gold plating of the device body and leads.

V. The shipping documentation shall be enclosed in the shipping package. In addition to other mandatory shipping markings, the following additional marking shall appear on the shipping package in bold letters:

"HANDLE WITH CARE"
"ESD SENSITIVE"
"HIGH-RELIABILITY COMPONENTS"
"TO BE OPENED UNDER CLEAN ENVIRONMENT WITH ESD PROTECTION ONLY IN PRESENCE OF SAC AUTHORIZED PERSONNEL"
"STORE IN A COOL AND DRY PLACE"

4.9 Test Programme:

The required Multi Array CCD in CMOS TDI Image Sensor is a special device with sophisticated material and complex packaging assembly. Hence it is essential that Screening and Qualification test plan addresses all levels of assembly and integration.

Note: Vendor may propose an alternate test plan along with impact and suitability.

4.9.1 Lot Screening Test Plan:

All Flight model sensors shall undergo Screening tests, at various stages of assembly/integration; as per the sequence given in Table 4.2A & B below.

TABLE 4.2A: Lot Screening Test Plan at Assembly Level[Note-1]

SR. NO.	TEST	METHOD/CONDITION	REMARKS
1	Wafer (Internal) Visual Inspection	As per vendor's procedure	100% for each wafer lot
2	Die Visual Inspection	As per vendor's procedure	100%
3	Non-Destructive Wire Bond Pull Test	As per vendor's procedure[Note-2]	On minimum 10 bond wires of 10% of the devices or 3 devices per lot whichever is more
4	Wire Bond Visual Inspection	As per vendor's procedure	100%
5	Internal Visual Inspection/Pre-Cap Inspection	As per vendor's procedure	100%
6	Filter Attach/Sealing	As per vendor's procedure	100%

Note-1: Lot traveler(s) shall be maintained to track sensor manufacturing, testing, to record any failures etc. SAC reserves the right to review the non- IP containing portion of this lot traveler when present personally at vendor's end.

Note-2: None of the tested bond wires should break at < 2.0gf. If any bond wire breaks all the bond wires of all the devices in the lot will be tested. Rework is allowed as long as the reworked bond wires pass this test. If a reworked bond wire fails this test that device is rejected.

TABLE 4.2B: Lot Screening Test Plan on Assembled Detector Level

SR. NO.	TEST	METHOD/CONDITION (MIL-STD-883)	REMARKS
1.	Stabilization Bake	Method 1008, 80°C, 48 Hrs.	100%
2.	Thermal Cycling	Method-1010, -55°C/ +80°C, No of cycles: 10	100%
3.	Constant Acceleration	Method-2001, Condition-A (5000g), Y1 direction only	100%
4.	Fine Seal Leak Test	Method 1014	100%
5.	Gross Seal Leak Test	Method 1014	100%
6.	Pre-Burn-in E-O test (Initial E-O test)	As per vendor's procedure	100%
7.	Powered burn-in	240 hours at +80°C	100%

8.	Final EO Tests	As per vendor's procedure Drift Criteria: To be mutually agreed upon	100%
9.	PDA Calculation	To be mutually agreed upon	100%
10.	External Visual Inspection	As per vendor's procedure	100%

4.9.2 Lot Quality Control Inspection & Destructive Physical Analysis Test Plan:

Samples from screened devices of each manufacturing lot shall be subjected to qualification and destructive tests as per Table-4.3 & 4.4 respectively.

TABLE 4.3: Lot QCI Test Plan[Note-3, 10]

SR. NO.	TEST	METHOD/CONDITION (MIL-STD-883)	REMARKS
1.	Initial QCI Functionality Test[Note-4]	As per vendor's procedure	1 per lot
2.	Fine Seal Leak Test	Method 1014	1 per lot
3.	Gross Seal Leak Test	Method 1014	1 per lot
4.	Thermal Shock[Note-5]	Method 1011 Cond A with temperature range of 0^oC to $+80^oC$, 15 cycles	1 per lot
5.	Mechanical Shock [Note-5]	Method 2002, condition A	1 per lot
6.	Sine Vibration [Note-5]	Method 2007, condition A	1 per lot
7.	Fine Seal Leak Test	Method 1014	1 per lot
8.	Gross Seal Leak Test	Method 1014	1 per lot
9.	Post QCI Functionality Test[Note-6]	As per vendor's procedure	1 per lot

TABLE 4.4: Destructive Physical Analysis Plan[Note-7, 9]

SR. NO.	TEST	METHOD/CONDITION (MIL-STD-883)	REMARKS
1.	External Visual Inspection	Method-2009	1 per lot
2.	Internal Visual Inspection	Method-2010, Condition-B	1 per lot
3.	Bond Strength	Method-2011, Condition-D	1 per lot
4.	Die Shear Strength	Method-2019	1 per lot
5.	SEM	Method-2018	1 per lot
6.	Solderability Test[Note-8]	Method-2003	1 per lot

Note-3: The devices selected for QCI and DPA tests need not be fully compliant for all electro-optical parameters (for Pre and Post Burn-in E-O measurements) but will be fully functional (i.e. all output taps functional).

Note-4: Functionality test involves grabbing an image (normally in Area mode). Vendor shall measure Dark offset, dark noise, linearity and FWC during measurement. If all taps (outputs) are functional the device is considered as passing this test.

Note-5: Vendor may use different devices for these tests.

Note-6: The failure during the Functionality test due to ESD damage will not be considered as a Qualification test failure. In case it is suspected that the failure of the device(s) during the Functionality test is due to ESD damage, fresh device(s) (from the same manufacturing lot) will be sent to the subcontractor for QCI tests.

Note-7: Sequence of test may be different.

Note-8: Solderability test shall be performed on each package lot and need not be conducted for each sensor manufacturing lot. Test report may be provided by package vendor, if not, will be conducted by vendor. This test can be conducted on a bare package i.e. only package without any die and window etc.

Note-9: If the device selected for DPA gets damaged during the lid (glass window/filter) removal process a fresh device (from the same lot) will be sent for DPA.

Note-10: The devices which go through QCI and DPA tests will not be shipped to SAC, only test results will be provided.

4.10 Reviews / Acceptance Tests:

The following Reviews / Acceptance tests shall be held online or at the site of Vendor at an appropriate time.

1. Pre-shipment Review on First FM unit

5. Deliverables & Delivery Schedule

Table-5.1 Deliverables

Sr No.	Item	Quantity
1	Flight Model Devices along with Screening Report	**8**
2	EM Devices*	**3**
3	Qualification Test Report	**1 for Each Lot**
4	DPA Test Report	**1 for Each Lot**
5	Compatible Sockets	**5**
6	Evaluation board with necessary software	**1**

Note: *The engineering grade sensors should have taped-on uncoated glass windows (i.e. no filters). These devices are not necessary to be compliant with the electro-optical performance requirements as required for the FM grade sensors but all of its outputs will have to be functional. All the electrical interfaces in terms of the sensor's bias, clock and output should be similar to the FM grade sensors. Moreover, the mechanical package, arrangement and number of pins should be same as that of FM grade

detector. These devices will not go through any environmental or mechanical tests and may have defective/dead pixels/columns.

5.1 Delivery Schedule

Sr. No	Device/Items	Quantity	Timeline
1	EM Devices	3	T1: T0 + 18 Months
2	Sockets	5	T1: T0 + 18 Months
3	Evaluation Board	1	T1: T0 + 18 Months
4	FM Devices – Batch 1	6	T2*: T1 + 03Months
5	FM Devices – Batch 2	2	T3* = T2 + 04 Months
	Qualification & DPA Test	Per Lot	T4* = T3 + 01 Month

Note-1: T0 is clearance given by SAC / export license clearance, whichever is later.
Note-2: * indicates SAC will give clearance on previous deliverables. Next timeline for deliverables will be computed based on the clearance given by SAC on previous deliverables.

5.2 Payment Terms

Payment can be disbursed to the vendor on pro rata basis. Vendor shall provide price breakup in the submitted commercial bid as per below table for each of the deliverables. SAC will disburse the payment based on the items delivered by the vendor.

Sr. No	Device/Items	Quantity	Price Details to be filled by Vendor in its commercial offer
1	EM Devices	3	
2	Sockets	5	
3	Evaluation Board	1	
4	FM Devices – Batch 1	6	
5	FM Devices – Batch 2	2	

6. Vendor's Committed Values against the Specifications

In this section, vendor is requested to provide compliance with committed values against the SAC specification values. The vendor can also give comments against the specification (if any).

Table-6.1 Compliance against the Physical requirement

Sr No.	Parameter	Specifications	Compliance with Committed value
1	Pixel architecture	4-Phase CCD type	
2	Peripheral analog, digital and Mixed signal circuit	1.8V/3.3V/5V compatible CMOS, LVDS/CML	

3	No. of Bands	PAN: 2 Bands (half pixel offset between PAN Band 1 and 2 in horizontal direction and integer multiples of half pixel staggered with N < 20 in vertical direction as shown in figure-2.2) Mx: 6 Bands (Mx Band 1-6)	
4	Square Pixel dimensions	PAN: 7µm x 7µm Mx: 14µm x 14µm	
5	Pixel Pitch	PAN: 7µm Mx: 14µm	
6	No. of pixels on each TDI row	PAN: 12000 or more Mx: 6000 or more	
7	TDI direction	Bi-directional (user selectable)	
8	No. of selectable TDI stages	PAN: 4,8,16,32,48,64,96,128 or more Mx: 2,4,8,16,24,32,48,64 or more	
9	Illumination direction	Back side illumination	
10	Total video outputs	Typically 16 (selectable to 8 o/p for reduced power and line rate)	

Table-6.2 Compliance against the Electrical Specifications

Sr. No.	Parameter	Specifications	Compliance with Committed value
1.	Video output type per array	Differential (i.e. CML/LVDS) with frequency 2.0Gb/s or more	
2.	Sensor Electrical Interface	SPI / I2C / JTAG	
3.	ADC resolution	11 bits or more	
4.	Full Chip power dissipation (at maximum line rate)	≤ 7.5W	
5.	Readout mode	Time Delayed Integration (both reverse and forward) with line rate control (external or internal trigger)	
6.	Integration time control in full frame mode readout	Based on the set line time	
7.	Output data stream	2.0Gb/s or more per channel	
8.	Bias Requirement	Vendor shall provide details of required biases for various analog, digital and mixed signal blocks of the sensor along with required currents on each line	
9.	Clock Input	LVDS (Freq. 120MHz or less)	

10.	Gain settings	1x to 2.0x or more with min. five intermediate steps	

Table-6.3 Compliance against the Electro-Optical Specifications

Sr No.	Parameter	Specifications	Compliance with Committed value
1	Full Well Capacity	PAN: ≥90Ke$^-$ Mx: ≥280Ke$^-$	
2	Dark Noise RMS	PAN: ≤70e$^-$ Mx: ≤200e$^-$	
3	Dynamic Range	≥ 60 dB	
4	Max. Line Rate	PAN: 40 kHz or more Mx: 20 kHz or more	
5	CTE per Transfer	0.999 or better	
6	Antiblooming operation	≥ 100X	
7	Avg Dark Current Density @25°C	≤15 nA/cm^2	
8	Output Nonlinearity (% of Sat)	≤ 2%	
9	Fixed Pattern Noise (% Sat, peak-to-peak)	≤ 5%	
10	PRNU (Global), all stages at 50% of Sat (peak-to-peak)	≤ 7.5%	
11	Spectral Ranges	PAN band 1 and 2: 400-900 nm Mx band 1: 400-450 nm Mx band 2: 450-520 nm Mx band 3: 520-590 nm Mx band 4: 630-690 nm Mx band 5: 700-750 nm Mx band 6: 770-890 nm *kindly refer filter section	
12	Mean Quantum efficiency (PAN and Mx)	**λ** / **QE** 400 nm / ≥80% 450 nm / ≥85% 500 nm / ≥85% 550 nm / ≥85% 600 nm / ≥80% 650 nm / ≥80% 700 nm / ≥75% 750 nm / ≥70% 800 nm / ≥60% 850 nm / ≥50% 900 nm / ≥35% 950 nm / ≥20%	

		1000 nm ≥10% 1050 nm ≥5%	
13	Radiation tolerance	TID: > 20 krad (Si), Co60 Proton for displacement damage: 22MeV with fluence of 5E10 protons/cm2 SEL: No destructive latch-up (SEL) ≥70 MeV/mg/cm2	
14	Defective Columns	Defective Column (TDI column with all stages active) meets the following criteria. (i)FPN > 5% SAT < 10% SAT or (ii)PRNU > 7.5% SAT < 15% SAT or (iii)VCTE > 0.9999 < 0.99993 Maximum number of defective columns ≤ 25 per PAN band and ≤ 15 per MS band. No Clusters with > 5 neighboring Defective Columns. Minimum distance of 50 columns between the Clusters. Defective columns will be excluded from electro-optical performance tests.	

Table 6.4 Compliance against filter requirements

Sr. No.	Parameters	Specifications	Compliance with Committed value
1	Material	Fused Silica/NBK7/Sapphire	
2	Shape	Rectangle	
3	Surface Figure (λ=633nm) (rms)	0.2λ per 25mm step	
4	Flatness (λ=633nm) (filter substrate before any coating) (PV)	1λ per 25mm step	
5	Parallelism / Wedge between two faces (filter substrate before any coating) (arc-sec)	≤ 5	
6	Scratch & Dig (S-D) inside clear aperture (before and after coating)	20-10	
7	Scratch & Dig (S-D) outside clear aperture (before and after coating)	40-20	

8	Surface Roughness (filter substrate before coating) (A) (rms)	< 50	
9	Mask (Color and Black) Coating (Location)	Surface facing die	
10	Mask (Color and Black) Coating (Extent)	Entire surface	
11	Mask should have absorbing coating (free from pinholes) with transmission < 0.5 % and reflection ≤ 5% in the entire visible/ NIR (300 - 1100 nm) range @ 0° angle of incidence	To be complied	
12	Average In-Band Transmission (P1, P2, B3-B6)	≥ 90 %	
13	Average In-Band Transmission (B1 & B2)	≥ 88 %	
14	Ringing	≤ 10 % (Target ≤ 5 %)	
15	Edge tolerance for 50% transmission points	≤ 1 %	
16	Average Transmission @ Blocking Range (300-1100 nm)	< 0.1 % (Target < 0.05 %)	
17	Blocking spikes (absolute transmission)	≤ 2 % (Target ≤ 1%)	
18	Central Wavelength (nm)	650 ± 6 (P1 & P2) (Target: ± 5)	
		425 ± 4 (B1) (Target: ± 3)	
		485 ± 4 (B2) (Target: ± 3)	
		555 ± 5 (B3) (Target: ± 3)	
		660 ± 5 (B4) (Target: ± 3)	
		725 ± 5 (B5) (Target: ± 3)	
		830 ± 6 (B6) (Target: ± 4)	
19	Band width (nm)	500 ± 5 (P1 & P2)	
		50 ± 3 (B1)	
		70 ± 3 (B2)	
		70 ± 3 (B3)	
		60 ± 3 (B4)	
		50 ± 3 (B5)	
		120 ± 3 (B6)	
20	Cut-on and cut-off slope for bands P1 & P2	< 5%	
21	Shape factor for all Bands except P1 & P2		
	% peak Transmittance	HPBW multiplying factor	
	(i) 90%	> 0.85	

	(ii) 10%	< 1.3	
	(iii) 1%	< 1.7	
	(iv) 0.10%	< 2.0	
	(v) 0.01%	< 2.4	
22	The optical specifications should be complied with F# 9.25 system with angle of incidence 0° and at room temperature (20 ± 3 °C.)	To be complied	
23	Coating	Coating shall be uniform and the non-uniformity in CWL should be ≤ 2 nm.	
24	Variation in the average transmission	≤ 2%	
25	Variation in the bandwidth	≤ 1 nm (should be demonstrated by carrying out spectral measurements minimum at 3 points, two edges and centre)	