LLAMAS Camera Qualification Report

Version 1.1
16th December 2020

1. Scope

This document details the results measured on the Qualification Cameras against the desired technical specifications of the cameras for the MIT Kavli Institute's Large Lenslet Array Magellan Spectrograph, or "LLAMAS."

2. Compliance Matrix

Key:

T	Test	Compliance is verified through quantitative measurement of device operation under specific conditions.
A	Analysis	Where compliance by test is impractical, analysis can be used to verify compliance by mathematical, logical or scientific calculation.
D	Design	Compliance is by design
I	Inspection	Compliance is verified by physical inspection of the item or by inspection of accompanying third-party documentation, e.g. a data sheet or Certificate-of-Compliance

Requirement Identification	Qual Unit Verification Method	Qual Unit Result
REQ-1. Sensor Type	I	**PASS**
REQ-2. Sensor Specification	T	**PASS**
REQ-3. Camera Weight	T	**PASS**
REQ-4. Camera Label	I	**PASS**
REQ-5. Documentation	I	**PASS**
REQ-6. GUI	T	**PASS**
REQ-7. Camera External Dimensions	D	**PASS**
REQ-8. Input Power Requirements	T	**PASS**
REQ-9. Bias voltage DC/DC Converter module	D	**PASS**
REQ-9a: Bias Voltage Module Cables Lengths	I	**PASS**
REQ-10. Reverse Voltage	T	**PASS**
REQ-11. Default Camera Parameter Configuration	T	**PASS**
REQ-12. Indicators	T	**PASS**
REQ-13. Housekeeping Data	T	**PASS**
REQ-14. Transient Voltage/Current Suppression	T	**PASS**
REQ-15. Image Data Bit Depth	T	**PASS**
REQ-16. Image Data Readout	T	**PASS**

REQ-17. Video Format	T	**PASS**
REQ-18. Bias Voltages	T	**PASS**
REQ-19. Electrical Connectors	D	**PASS**
REQ-20. Digital Buffer	T	**FAIL**
REQ-21. Cooling Control Circuitry	T	**FAIL**
REQ-22. Command Interface	T	**PASS**
REQ-23. Camera Conversion Factor	T	**PASS**
REQ-24. Readout Rates	T	**PASS**
REQ-25. Sensor Cooling	T	**PASS**
REQ-26. Serial Communication	T	**PASS**
REQ-27. Trigger modes	T	**PASS**
REQ-28. Trigger out	T	**PASS**
REQ-29. Trigger in	T	**PASS**
REQ-30. Mechanical Shutter	D	**PASS**
REQ-31. Integral Cooling Fan	D	**PASS**
REQ-32. Binning	T	**PASS**
REQ-33. Signal Noise	T	**PASS**
REQ-34. Signal linearity	T	**PASS**
REQ-35. Integration Time	T	**PASS**
REQ-36. Frame rate	T	**PASS**
REQ-37. Bi-directional Parallel Shifting (Charge Shuffling)	T	**PASS**
REQ-38. Operational Temp	T	**PASS**
REQ-39. Storage Temp	T	**PASS**
REQ-40. EMC	D	**PASS**
REQ-41. Firmware Update	T	**PASS**
REQ-42. PCB Replaceability	D	**TBC**
REQ-43. Reliability	D	**PASS**
REQ-44. Configuration Status	T	**TBC**
REQ-45. Conformal Coating	I	**PASS**
REQ-46. Coolant Connections	D	**PASS**
REQ-47. Sensor Orientation	I	**PASS**
REQ-48. Optics Mounting Interface	T	**FAIL**
REQ-49. Sensor Location	T	**PASS**
REQ-50. Window	I	**PASS**
REQ-51. Electrical Connector Locations	D	**PASS**
REQ-52. Mechanical Mounting Locations	D	**PASS**

2.1 General Requirements

2.1.1 REQ-1. Sensor Type PASS

The Camera will use the e2v CCD42-40 sensor, NIMO, back-illuminated, full frame devices. LLAMAS will have three different passbands, requiring three separate variations of the e2v 42-40 NIMO:

The "Blue" cameras will use the e2v "Enhanced Broadband" process, and have an AR coating optimized for 350-500 nm. These cameras will use Cosmetic Grade 1 sensors.

The "Green" cameras will use the e2v "Basic Midband" process, and have a broadband AR coating optimized for 480-700 nm. These cameras will use Cosmetic Grade 1 sensors.

The "Red" cameras will be deep depletion, and use the e2v "NIR" AR process with fringe suppression, and be optimized for 680-980 nm. These cameras will use Cosmetic Grade 0 sensors.

Camera SN20001 (RED) uses CCD42-40-0-169 Serial Number 12194-06-03
Camera SN20003 (BLUE) uses CCD42-40-1-114 Serial Number : 01064-24-03

2.1.2 REQ-2. Sensor Specification PASS

The sensor specifications are listed below.

Number of Active Pixels (H × V):	2048 x 2048
Pixel Size (μm²)	13.5 × 13.5
Active Area (mm²)	27.6 × 27.6
QE	As per e2v: Enhanced BB AR process for "Blue" cameras Basic MB AR for "Green" cameras Deep depleted Si NIR AR coating process for "Red" cameras
Pixel Well Depth (e-, typical)	150k
Cosmetic Grade	0 (Red), 1 (Blue and Green)
Sensor Window	Removable

Camera SN20001 (RED) meets Grade 0 cosmetic specification with well depth 119ke-/pixel (Minimum 100ke-/pixel)
Camera SN20001 (BLUE) meets Grade 1 cosmetic specification with well depth 149ke-/pixel (Minimum 100ke-/pixel)

2.1.3 REQ-3. Camera Weight PASS

The cameras should be less than 3 kg. This mass limit does not include the mass of external DC/DC converters.

Mass of camera SN20001 measured as 2.3kg; SN20003 measured as 2.3kg.

2.1.4 REQ-4. Camera Label PASS

The Camera will be labeled with model number, serial number and revision status. All labeling should not be phosphorescent.

2.1.5 REQ-5. Documentation PASS

An Interface Control Document (ICD) for the camera will be provided which details:

a) The physical interfaces.
b) The command protocol.
c) Detailed list of commands and expected responses.

An Instruction Manual (IM) for the camera shall be provided which details:

a) The power requirements.
b) The operating modes.
c) Firmware upgrade procedure.
d) Field replacement of PCBs.

Instruction manual MAGS_II_IM_V0.3.pdf.

2.1.6 REQ-6. GUI PASS

A simple GUI control for test purposes only, allowing control of camera commands, queries, feature and functions, will be made available.

Cameralink based GUI 'MAGS II Test GUI 261119.exe' supplied on mini-PC shipped with Prototype camera SN20001

2.1.7 REQ-7. Camera External Dimensions PASS

Excluding electrical and cooling connections, the camera volume must be less than 130mm × 130mm × 150mm. The front face of camera should be square and must exceed 100mm × 100mm.

Measured assembled camera dimensions SN20001 = (126.0 x 126.0 x 123.9)mm^3; SN20003 = (126.0 x 126.0 x 124.1)mm^3;

2.2 Electrical / Electronic Requirements

2.2.1 REQ-8. Input Power Requirements PASS

The camera will be driven by a single (12.0 ± 0.5) V supply.
When using +10°C coolant and driving to minimum sensor temperature, the input power will be ≤ 120W.
Power drawn in steady state: SN20001 = 110.6W; SN20003 = 103.2W

2.2.1 REQ-9. Bias voltage DC/DC Converter module PASS

The DC/DC converters for the CCD electronics should be external to the CCD cameras as a separate module. The DC/DC converter module for the cameras must have no fan or heat transfer fins, and should have a flat mounting surface that can be mounted to a cold plate in the spectrograph housing. Cables connecting the DC/DC converter module to the camera housing should be delivered with the cameras.
Individual modules labelled and used during Qual testing. Modules and cables used shipped with camera heads.

2.2.1a REQ-9a. Bias voltage module cable lengths PASS

The cables from the DC/DC converter modules to the cameras should have the following lengths:
10x 1m cables; 8x 500mm cables; 8x 375mm cables
1m cables used during testing of Qual cameras – shipped with camera heads.

2.2.2 REQ-10. Reverse Voltage PASS

The camera shall withstand reverse polarity of the specified DC voltage input.
Camera powered from benchtop PSU (12V 10A output) with polarity reversed for 10secs, current constant at 10A, voltage dropped from 1.03V to 1.00V over duration of test. Unit powered-off, then re-powered with correct polarity, both COMMs and image data verified – PASS.

2.2.3 REQ-11. Default Camera Parameter Configuration PASS

On power up the camera will default to the following parameter configuration until changed via user intervention:

Parameter	Status
TEC Drive (i.e. Cooling)	OFF
TEC Set Point	-90°C
Pixel Readout Rate	2 MHz
Gain Mode	High
Trigger Mode	Internal Trigger (ITR)
Exposure Time	100 ms
Region of Interest	Full Frame (2048 × 2048) pixels
Binning	1 × 1 pixels

Table 1: Default Parameter Configuration at Power up

Camera configuration at power up agrees with requested configuration.

2.2.4 REQ-12. Indicators PASS

The LED connectivity indicators for any RJ-45 connectors used in TCP/IP connectivity shall either be disabled electrically, or a system to permanently mask them in a light-tight fashion should be devised.

LEDs could not be disabled electrically – black epoxy was used to mask them after camera assembly. There may be additional LEDs on the Pleora PCB which are inside the camera head, these were not masked on the Qual cameras.

2.2.5 REQ-13. Housekeeping Data PASS

The temperature within the camera head shall be measured, with precision of ≤±0.1°C, at the following three locations: a) CCD Package, b) TEC hot side and c) Main printed circuit board. The TEC current shall be monitored with ≤±5mA precision.

The CCD bias voltages (V_{SS}, V_{OD}, V_{RD}, V_{DD} and V_{OG}) shall be monitored with ≤±10mV precision.

All this housekeeping data will be written to registers and will be accessible via TCP/IP interface.

The following table details the resolution of the Tec current and the CCD supply rails.

1	TEC Current	2.5mA/ADU
2	VSS	1.22mV/ADU
3	VOD	7.47mV/ADU
4	VRD	5.53mV/ADU
5	VDD	6.29mV/ADU
6	VOG	1.22mV/ADU

The ADU measurements for each of these parameters is made available in the Housekeeping data which is tagged on the end of each frame.

2.2.6 REQ-14. Transient Voltage/Current Suppression PASS

The cameras shall have a transient voltage suppressor installed and will have a resettable fuse in the housing, in series with the main DC supply.

Verified by design.

2.2.7 REQ-15. Image Data Bit Depth PASS

The readout ADC will have 16-bit resolution.

16-bit image data saved and analysed during Qual process.

2.2.8 REQ-16. Image Data Readout PASS

The CCD42-40 has two output nodes, but the LLAMAs cameras will be designed to only use the left one.

Only the left amplifier was connected out to the ADC circuitry and used for all image data transfer.

2.2.9 REQ-17. Video Format PASS

The read images shall be downloadable via a TCP/IP interface, in an uncompressed and unprocessed binary format. The TCP/IP interface must also be capable of receiving commands via a TCP or UDP socket, and of receiving an IP address via DHCP.

Sample images transferred across TCP/IP interface on both cameras.

For test purposes, the camera shall also produce mono, progressive scan, digital video output to Camera link standard.

Test images transferred across camera link interface.

2.2.10 REQ-18. Bias Voltages PASS

The CCD bias voltages shall be adjustable via the TCP/IP interface, with their current values stored in non-volatile memory.

The CCD bias voltages are adjustable via the TCP/IP interface; new values may be saved in non-volatile memory. Raptor does not recommend that the bias voltages are changed by the customer as they are set as per the CCD manufacturer's guidelines during factory test and characterization.

2.2.11 REQ-19. Electrical Connectors PASS

All Trigger Inputs and Outputs shall use standard, gold plated SMA connectors.
TCP/IP connection shall be made through a standard RJ-45 Ethernet connector.
The camera will have one standard miniature Camera Link connector.
DC power input shall be supplied via a latching power connector.

All electrical connectors meet specifications.

2.2.12 REQ-20. Digital Buffer FAIL

The camera shall have an internal digital buffer capable of storing a read image. The image will then be downloadable via the TCP/IP interface. The camera shall be able to upload the contents of the buffer during integration of another frame. The digital buffer shall capture and store the following parameters:

1) Actual integration time (taking into account adjustment/abort of integration)
2) Temperature set point
3) Actual CCD temperature
4) TEC Hotside Temperature
5) Main PCB Temperature
6) Binning mode
7) Gain Mode
8) Readout Rate
9) Bias Voltages (V_{SS}, V_{OD}, V_{RD}, V_{DD} and V_{OG})
10) Number of parallel shifts applied during integration
11) Firmware version identification string
12) Sensor ID
13) Camera ID

The Digital buffer is handled using the Ntx GigE module which is used as the interface between the camera and the system. Further information on the buffer capability can be found in the Pleora SDK.
The requested parameters listed above are tagged on to the end of the readout, ie an additional line has been added as part of the frame readout.

This requirement is a FAIL because at present the Sensor ID and Camera ID are not held within the "Housekeeping Data" which is tagged on to the last line of each frame. They are however captured and stored as part of Raptor's QC procedure and will be provided as a summary sheet, once all cameras ship.

2.2.13 REQ-21. Cooling Control Circuitry FAIL

a) The set point of the control loop will be user programmable.

Verified using Camera link GUI.

b) The camera shall be capable of stabilizing the sensor temperature to within ±0.5°C of the set point using a TEC and control loop.

Using =10°C coolant and Setpoint = -95.00°C Stable ROIC temperature were measured as SN20001 = -94.51°C; SN20003 = -94.81°C

c) Under constant acquisition settings and stable environmental conditions, the control loop shall hold the sensor temperature stable to within ±0.2°C.

SN20001 & SN20003 ROIC temperatures stable to within ±0.17°C, over a period of 3 hours with constant acquisition settings.

d) An over temperature flag should be set if the hot side of the TEC is exceeds +65°C. This flag should also be used to shut down power to the TEC.

Current build of code sets the flag when the temperature exceeds +80°C, however the trip point is in a register which can be configured by the user.

e) The cool-down and warm-up rates of the sensor should be limited to ≤ 5°C per minute, provided the camera is powered and the over temperature flag has not been set. Ramp rates cannot be controlled when the camera is not powered.

Higher cool-down & warm-up rates observed (worst case approximately 25°C/min). Continuously polling ROIC temperature and adjusting setpoint temperature asynchronously (in FPGA) would be cumbersome and better suited to software-based application.

2.2.14 REQ-22. Command Interface PASS

The camera should be capable of interfacing with the control computer via a command-line interface or API, and without running a dedicated GUI.
The camera should provide access to housekeeping and metadata registers via the TCP/IP interface.
Pleora provide a SDK which the customer can use to implement this feature – PASS.

2.3 Functional Requirements

2.3.1 REQ-23. Camera Conversion Factor PASS

The camera must have a 'high' and 'low' gain readout mode. The low-gain mode shall provide a (4 ± 1) e-/ADU conversion.

The high gain mode shall provide a (1.0 ± 0.2) e-/ADU conversion.

Measured conversion factors

Serial Number	Readout Rate (kHz)	High Gain Conversion Factor (e-/DN)	Low Gain Conversion Factor (e-/DN)
SN20001	75	1.12	4.22
	150	1.11	4.17
	286	1.11	4.22
	526	1.12	4.19
	909	1.13	4.18
	2000	1.16	4.27
SN20003	75	1.13	4.24
	150	1.13	4.21
	286	1.12	4.23
	526	1.12	4.21
	909	1.13	4.24
	2000	1.15	4.23

2.3.2 REQ-24. Readout Rates PASS

The camera shall have user selectable serial readout rates of 75 kHz, 150 kHz, and 2 MHz. (The 75 kHz readout will have a readout time in excess of 50 seconds with single output node, but certain observers may decide that the decreased readout noise is worth the delay.)

Additional readout rates of approximately 300kHz and 600kHz may be available on a 'best efforts' basis only. Full optimization / qualification of these additional readout rates does not have to be complete at the time of unit shipment.

Photon Transfer Data and Read Noise Values calculated for Readout Rates of 2MHz, 909kHz, 526kHz, 286kHz, 150kHz and 75kHz at both 'High' and 'Low' Gain settings.

2.3.3 REQ-25. Sensor Cooling PASS

a) The camera shall be capable of providing an absolute sensor temperature of -90°C, assuming +25°C ambient temperature and +10°C liquid coolant.

Minimum ROIC temperature of -100.0°C measured on SN20001, -99.4°C measured on SN20003.

b) The minimum dark current achievable must be ≤ 0.001 electrons per pixel per second.

Minimum dark current values (with sub pixel dithering ON) were measured as 0.00048 e-/pix/sec on SN20001 and 0.00067 e-/pix/sec on SN20003.

NOTE value at sensor temperature of -90°C (with sub pixel dithering ON) was 0.00088e-/pix/sec on SN20001 and 0.0046 e-/pix/sec on SN20003.

2.3.4 REQ-26. Serial Communication PASS

The cameralink communication lines will have the specifications as listed below:

Baud rate: 115200 bps
Data bits: 8
Parity: None
Stop bits: 1
Flow control: None

2.3.5 REQ-27. Trigger modes PASS

The camera shall support the following trigger modes:

Idle	No Images are read from the sensor or output to the host, camera performs 'Keep Clean' cycles to minimize dark current build-up on the device.
Internal trigger	A TCP/IP trigger signal internal to the camera will be used to start the integration and readout of the camera. The camera will run with continuous Integrate Then Read (ITR). An optional Fixed Frame Rate (FFR) mode shall be included to Start the integration at fixed time intervals
External trigger	A TTL trigger signal external to the camera will be used to start the integration and readout of the camera. Optional rising edge or falling edge trigger should be provided.
Snapshot	The camera should remain in idle mode until a software command is given to the camera that will start a single ITR cycle before returning to idle.
Abort	It should be possible to abort all trigger modes via a software command to the camera, when aborted the integration period should be immediately terminated and the sensor readout before returning to idle.

All Trigger modes observed on oscilloscope and operated as expected.

2.3.6 REQ-28. Trigger out PASS

The camera shall have two TTL trigger outputs which can be used to synchronize external equipment to the exposure and readout periods.
A TTL output (TO1) shall go 'high' to signify the integration period of the camera.
A TTL output (TO2) shall go 'high' to signify the readout period of the camera.
Both outputs observed to behave as expected on oscilloscope.

2.3.7 REQ-29. Trigger in PASS

The camera shall have two TTL trigger inputs which can be used to synchronize the camera exposure to external equipment, when the camera is set to External Trigger Mode. A TTL input (TRIG1) will be rising-edge triggered and used to start the integration period.
The delay between TRIG1 input going 'high' and TO1 output going 'high' will be the time taken to clear the image area in preparation for a new exposure.
A TTL input (TRIG2) will be rising edge triggered and used to start the parallel shift sequence defined in Section 2.3.15.
Both TRIG1 & TRIG2 inputs will be ignored if the camera is not in External Trigger Mode.
Both inputs respond as expected, delay between TRIG1 high and TO1 high is 61.6ms (i.e. the time to perform an 'image clear sequence').

2.3.8 REQ-30. Mechanical Shutter PASS

An integrated mechanical shutter is not required for this camera.

2.3.9 REQ-31. Integral Cooling Fan PASS

No integrated cooling fan/convective heat exchanger should be present in the design.

2.3.10 REQ-32. Binning PASS

The camera will support, user definable, on-chip binning. Horizontal & vertical bin sizes can be set independently, with a minimum range between 1-8 pixels inclusive.
Bin sizes 1x1 to 8x8 verified by acquisition of uniform illumination images.

2.3.11 REQ-33. Signal Noise PASS

When the sensor is cooled to -90°C, dark frames shall exhibit a noise floor of:

a) ≤3.0 e- rms (target, 2.5 e-) at a 75 kHz pixel readout frequency & bin size 1×1
b) ≤3.5 e- rms (target, 3.0 e-) at 150 kHz pixel readout frequency & bin size 1×1.
c) ≤12 e- rms (target, 10.0 e-) at a 2MHz pixel readout frequency & bin size 1×1.

Serial Number	Readout Rate (kHz)	High Gain Read Noise (e- rms)	Low Gain Read Noise (e- rms)
SN20001	75	2.62	3.38
	150	2.82	3.63
	286	3.27	4.30
	526	4.09	5.15
	909	5.31	6.65
	2000	9.02	12.25
SN20003	75	2.41	3.18
	150	2.70	3.54
	286	3.18	4.15
	526	4.03	5.14
	909	5.31	6.74
	2000	9.10	11.84

2.3.12 REQ-34. Signal linearity PASS

The Camera shall have linearity better than 99% between 0.5% and 95% of ADC range in both 'High' and 'Low' gain modes (excluding defective / saturated pixels).
All readout rate and gain mode combinations achieved non-linearity <1%.

2.3.13 REQ-35. Integration Time PASS

When operating in ITR mode the camera shall be capable of integration times from 0.01 seconds to 120 minutes, in 0.01 second increments.
Integration periods of 1ms to 120 minutes recorded.

The duration of the integration time shall be adjustable (both extended and shortened) during an integration period without requiring a frame to be readout. If the updated integration time is less than the already elapsed time the camera shall default to 'abort mode', resulting in the immediate readout of the image. The register storing the frame integration time, shall be updated to record the actual total integration time.
This feature has been implemented in the camera firmware. Testing has been conducted and the feature is working as expected – PASS.

2.3.14 REQ-36. Frame rate/dead time PASS

The camera designer should attempt to minimize the post-readout dead time to maximize the frame rate in ITR mode, with a goal of <200 ms. When operating internal trigger and FFR mode, the frame rate shall be programmable from 1 frame every 2.5 seconds to 1 frame every hour.
Post-readout dead time approximately 62ms (Image clear time).
The GUI only allows integer values for frame period, therefore 1 frame every 3 seconds to 1 frame every hour verified. This is only a limitation of the GUI and the frame rate can be programmed in 12.5ns steps using the 5 registers which control the frame rate.

2.3.15 REQ-37. Bi-directional Parallel Shifting (Charge Shuffling) PASS

The CCD drive electronics need to be capable of shifting rows of charge within the image area both towards and away from the horizontal readout register. This 'charge shuffling' will occur during an exposure when the camera is in External Trigger mode.
A register will contain an integer value to specify the number of row shifts to be performed. The user can write any integer number between 0 and 2048 to this register which will then remain fixed during the exposure period.
A register will enable the user to define the initial direction of the charge shuffling within the image area.

A rising edge TTL input to TRIG2 will initiate the 'charge shuffling' sequence defined by the user. The direction of charge shifting will be automatically toggled after each TTL input. Charge Transfer Efficiency of row shifts must be greater than 99.999% in both directions.
Charge shuffling in both directions demonstrated, register specifying number of row shifts increased to include 2048. Initial direction of shuffling can be defined.

Charge Transfer Efficiency – signal level and image standard deviation are consistent between images readout 'normally' and those undergoing 15000 (500 x 30) row shifts before readout. CTE = 99.999% with 15000 shifts would result in a signal level reduced to 86.1% of a normal readout image.

2.4 Environmental & Climate

2.4.1 REQ-38. Operational Temp PASS

The operating temperature range will be -20°C to +55°C in a test environment, with relative humidity up to 95% (non-condensing). A single representative camera from the Blue lot should be operationally tested over this range for qualification purposes.
Read noise performance of grade 5 'Blue' camera (SN15000) tested at both temperature extremes. 2MHz Bin1 'high' gain read noise consistent (8.7 ± 0.2) DN rms, at test temperature of -80°C when using coolant temperatures of +20°C (for -20°C test environment) and +40°C (for +55°C test environment).

2.4.2 REQ-39. Storage Temp PASS

The camera shall withstand storage temperatures between -30°C and +75°C
Camera cooling and read noise performance of grade 5 'Blue' camera (SN15000) verified after storage at each temperature extreme for ≥ 2 hours.

2.4.3 REQ-40. EMC PASS

The camera will be designed for EMC compliance.

2.5 Maintenance and Reliability

2.5.1 REQ-41. Firmware Update PASS

The camera firmware must be field upgradable through the TCP/IP interface.
Firmware update performed over TCP/IP interface.

2.5.2 REQ-42. PCB Replaceability – TO BE COMPLETED

The main camera PCB shall be field replaceable, without breaking the vacuum seal and without the use of highly specialized tools.
The manufacturer will provide training for MIT personnel on how to replace the main camera PCB, in the event that the service contract has expired.
PCBs connectorized for ease of replacement. Instructions to be documented before completion of camera deliveries.

2.5.3 REQ-43. Reliability/Warranty PASS

The camera should be designed to maximize the number of operational hours before failure. One year warranty for the electronics and a lifetime warranty for the vacuum seal. All warranties become void if PCB replacement is attempted by anyone other than camera manufacturer personnel.

2.5.4 REQ-44. Configuration Status – TO BE COMPLETED

A listing of the passband and biases of all cameras by serial number should be provided. The camera serial number should be programmed onto all cameras, and should be queryable via TCP/IP and cameralink interfaces. Cameras with identical passband configurations should be interchangeable.
List will complete once all cameras have been tested and shipped.

2.5.5 REQ-45. Conformal Coating PASS

Circuit boards shall be protected from moisture ingress via conformal coating, e.g. Electrolube APL400H or equivalent. Coating should exclude accessible connectors.

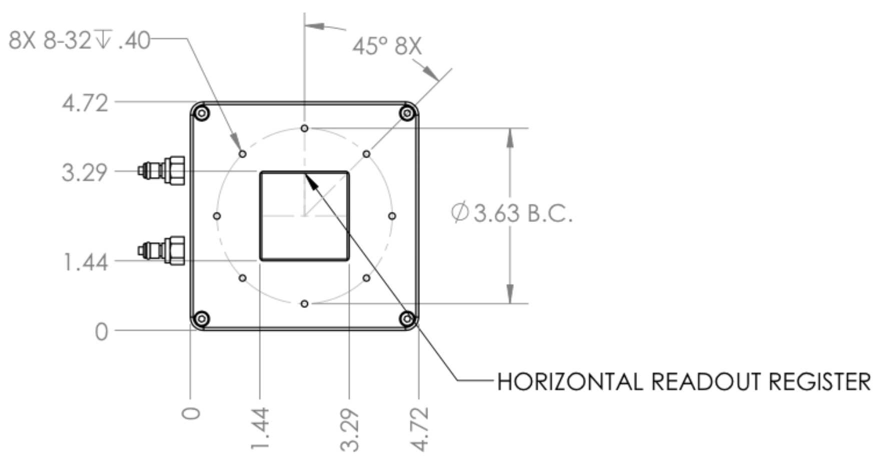
2.6 Mechanical Requirements

2.6.1 REQ-46. Coolant Connections PASS

The liquid coolant connections shall be located on a single face of the camera, parallel to the plane containing the image sensor active area.
Liquid coolant inlet and outlet connectors will seal to the coolant channel by means of PTFE tape and ⅛ NPT thread. The camera will be supplied with two valved, quick release couplings (Colder Products Company P/N MCD2402 or equivalent) installed.

2.6.2 REQ-47. Sensor Orientation PASS

The orientation of the detector shall be such that the serial registers are as indicated in the diagram below.



Note: Drawing is for quotation only.

2.6.3 REQ-48. Optics Mounting Interface FAIL

The front face of the camera shall be machined flat, with 8-off equi-spaced, 8-32 tapped holes (thread depth ≥ 5mm) on a PCD of (92.1 ± 0.1) mm centered on the sensor image area. The outer surface of the entrance window shall be (0.5 ± 0.1) mm behind this front face of the camera.

Thread depths and PCD meets specification. Outer surface of entrance window to front face of both cameras were measured as (0.3 ± 0.1)mm. This had been discussed previously and was deemed acceptable, provided the window did not protrude above the front face of the camera.

2.6.4 REQ-49. Sensor Location PASS

The mechanical Back Focal Distance (BFD), i.e. the physical distance between the front face of the camera and the active area of the sensor shall be (8.0 ± 0.2) mm. The plane of the active sensor surface shall be parallel to the front face of the camera to within ±0.25° (target within ±0.1°).

SN20001 BFD = (8.2 ± 0.1)mm Maximum Tilt = 0.16°

SN20003 BFD = (8.1 ± 0.1)mm Maximum Tilt = 0.19°

2.6.5 REQ-50. Window PASS

The window shall be made out of 1.5mm thick, c-cut, optical grade sapphire.
The scratch-dig specification of the window shall be 20-10.
The window shall be anti-reflection coated, optimized (<0.5% avg, per surface) for the passband of the given detector (see 2.1.1).
The shape of the window shall be square with a clear aperture ≥ (35mm × 35mm) and the corners rounded at a radius < 5mm.

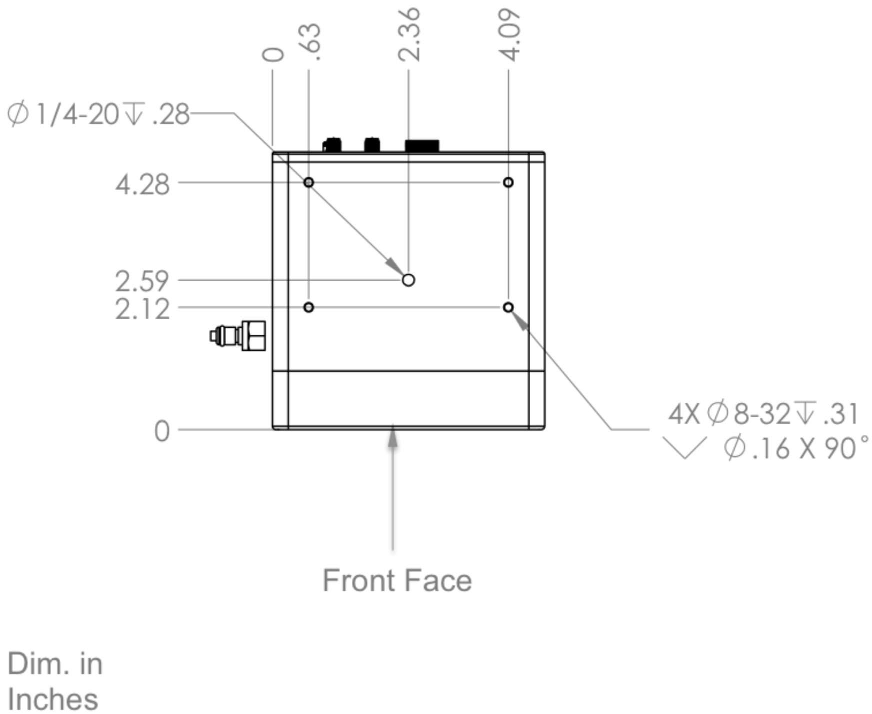
2.6.6 REQ-51. Electrical Connector Locations PASS

All electrical connectors shall be on the rear side of the camera, opposing the window and optics mounting interface

2.6.7 REQ-52. Mechanical Mounting Locations PASS

The body of the camera must provide tapped mounting holes on all four sides of the camera perpendicular to the sensor active area, as indicated in the diagram below. Each of these faces must include:

a) 1-off ¼-20UNC mounting hole, with thread depth ≥ 5mm.
b) 4-off 8-32 mounting holes, with thread depth ≥5mm in either a square or rectangular bolt pattern.



Note: Drawing is for quotation only.