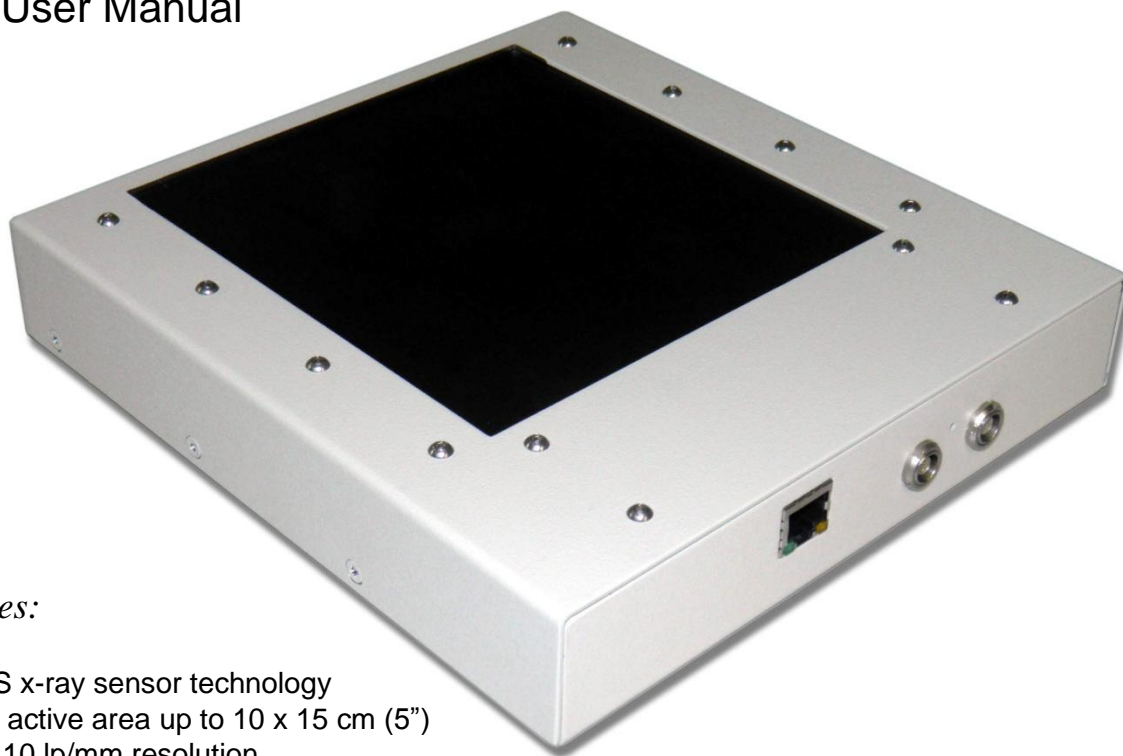


# Shad-o-Box HS

## High-Speed Industrial X-Ray Cameras

### Detector User Manual



#### *Key Features:*

- CMOS x-ray sensor technology
- Large active area up to 10 x 15 cm (5")
- Up to 10 lp/mm resolution
- GigE interface (Camera Link optional)
- 14-bit digital video output
- Energy Range from 10 to 225kV
- Ready-to-run software and drivers

The Shad-o-Box HS product family leverages Teledyne DALSA's advanced CMOS image sensing technology to capture low-dose X-ray images and deliver higher image quality than a-Si flat panels and image intensifier devices. Shad-o-Box HS cameras contain a large-area, high-resolution CMOS detector with a photodiode pixel array featuring three standard size options of approximately 3x4, 4x6 and 5x5 inches. The cameras are available in different resolutions featuring either a 135µm, 99/100µm or 49.5µm pixel size. All detectors are capable of real-time, full-resolution imaging at frame rates up to 40 fps. The detectors are optimized for the 40-160 kV energy range but cover both the low (10-50 kV) and extended (up to 225 kV) energy ranges, making this camera an ideal choice for industrial inspection, biomedical and scientific X-ray imaging applications.

# 1. Safety Information

## Installation Warning

The operators of this equipment are responsible for the safe and prudent installation of the detector in their own system. All X-ray sources and controls, shielding, personnel safety monitoring devices, and personnel safety precautions involved in the acquisition and display of data are the responsibility of the end user.

## Safety Statement

The general safety precautions that follow must be observed during all phases of installation, operation, service and repair of this system. Failure to comply with these precautions, or with specific warnings noted in this manual, violates the safety standards of design, manufacture and the intended use of this system. Teledyne Rad-icon Imaging assumes no responsibility for the user's failure to comply with these requirements.



**Warning:** This digital camera system, when installed, is subject to exposure from X-rays during operation.

To ensure personnel safety, it is necessary that a radiation meter be used to check for radiation leakage after installation of the digital camera in the end user's system.

Teledyne Rad-icon Imaging assumes no responsibility for the proper installation of X-ray shielding, X-ray shield enclosure testing, or safe and prudent operation of the camera system in the end user's installation. It is the end user's responsibility to ensure that local and federal guidelines regarding the installation and operation of X-ray sources are followed.

For those parties supplying the power requirements to the Shad-o-Box HS, the voltage specifications must be strictly adhered to or the system will no longer be considered covered under warranty.

## No User Serviceable Components

There are no components in this system which need to be replaced, modified, or adjusted by the end user. Please contact Teledyne Rad-icon Support for assistance if needed.



**Safety Warning:** Tampering with this product voids the warranty and may degrade the detector's image quality, resulting in a possibly unsafe condition.

The system has been designed to minimize the amount of interference it may generate in a typical installation. This equipment generates and can radiate radio frequency energy and, if not installed and operated in accordance with the instructions, may cause harmful interference to other devices in the area.

## Disposal of Product

The detector contains lead shielding but no batteries. Dispose the unit in accordance with local regulatory guidelines.

## 2. EMC compliance

To ensure EMC compliance, follow these specific guidelines:



- Ensure that all cable shields have a 360° electrical connection to the connector.
- Fasten and secure all connectors.

### Warning

- The detector can influence the performance of very sensitive equipment.
- Strong EMC disturbances can influence the detector's performance.

## 3. System precautions

The following are precautions that must be taken in order to prevent possible damage to your Teledyne Rad-icon Imaging Detector system:

### Warning:

The use of accessories, power supplies and cables other than those supplied or specified, with the exception of cables sold by Teledyne Rad-icon as replacement parts, may result in increased emission or decreased immunity of the Shad-o-Box HS Detector.



### Static precautions

Observe proper ESD/static control procedures when handling system components. The use of properly grounded wrist strap is highly recommended.

### Installation Precautions

Never connect or disconnect cables while power to the detector is on. Damage to the detector electronics will occur if the cables are connected and/or disconnected while the detectors power is on.

### Service by Qualified Personnel Only

This equipment is to be installed by a qualified technician only. The system can only be used in conjunction with a properly installed X-ray source with the appropriate shielding and a properly configured computer workstation that meets the minimum system requirements discussed later in this manual.

## 4. Detector Maintenance

Before performing any of the following operations, make sure that the power to the detector is switched OFF.

### Protecting the Detector Front Cover

The imaging area is marked on the front cover of the detector and should be treated with extreme care, as scratches or debris in this area may produce artifacts in the X-ray image. If visible scratches are present, X-ray test images should be taken to ensure that the scratches do not adversely affect the image quality.

### Cleaning the Detector Body and Front Cover

The detector body and front cover can be cleaned with a mild, non-abrasive cleanser such as isopropyl alcohol. Place a small amount of cleanser on a soft cloth and rub gently over the detector body surface. Wipe off with a clean soft cloth. Do not use any harsh cleansers or solvents that may damage the paint or other finishes on the detector. In the event of detector exposure to bio-hazardous materials, proper cleaning procedures should be undertaken prior to removal or maintenance of the detector.

### Periodic Maintenance

No periodic maintenance or service is needed.

### Calibration

To have the best image performance the raw image data output from the detector should be corrected at the host by using dark offset and flat field correction. Advised is to re-calibrate the dark offset image as frequently as feasible during detector standby. The raw flat field image should be re-calibrated at least once every year.

The detector can contain deviating and/or not working pixels. To have the best possible image quality it is advised to perform a defect pixel correction at the host. Advised is to update the defective pixel map at least once every year.

## 5. Specifications

<i>Device</i>	<i>Pixels</i>	<i>Active Area</i>	<i>Resolution</i>	<i>Frame Rate</i>
Shad-o-Box 512 HS	768 x 512	10.4 x 6.9 cm	135 $\mu\text{m}$	35 fps
Shad-o-Box 1024 HS	768 x 1024	10.4 x 13.8 cm	135 $\mu\text{m}$	35 fps
Shad-o-Box 1280 HS	1280 x 1280	12.8 x 12.8 cm	100 $\mu\text{m}$	30 fps
Shad-o-Box 688 HS	1032 x 688	10.2 x 6.8 cm	99 $\mu\text{m}$	40 fps
Shad-o-Box 1548 HS	1032 x 1548	10.2 x 15.3 cm	99 $\mu\text{m}$	20 fps
Shad-o-Box 3K HS	2304 x 1300	11.4 x 6.4 cm	49.5 $\mu\text{m}$	10 fps
Shad-o-Box 6K HS	2304 x 2940	11.4 x 14.6 cm	49.5 $\mu\text{m}$	5 fps

<i>Detector Specifications</i>		<i>Units</i>
Typ. dark current (23°C) <sup>(1)</sup> <sup>(4)</sup>	12	ADU/s <sup>(2)</sup>
Read noise (rms)	4-8	ADU
Typ. dynamic range	3000:1	
Digitization	14	bits
Image lag	< 0.1	%
Non-linearity (10..90%FS)	< 1.5	%
Readout period <sup>(3)</sup> <sup>(4)</sup>	22	ms
Output data rate	40	MHz

<sup>(1)</sup> dark current doubles approx. every 8°C

<sup>(2)</sup> ADU = Analog-Digital Unit  $\equiv$  1 LSB (Least Significant Bit)

<sup>(3)</sup> time required to transfer image from sensor to camera memory

<i>Camera Specifications</i>	<i>1280HS</i>	<i>All Others</i>	<i>Units</i>
Typical supply voltage	12.0	6.5	Volts
Supply voltage range	11 to 13	6.0 to 8.0	Volts
Maximum supply current	1.0	1.5	Amps
Typical power dissipation	< 10	< 10	Watts
Data interface	GigE	GigE	
Trigger interface	TTL	TTL	

<b>General Specifications</b>		<b>Units</b>
Operating Temperature	0 to 40	°C
Storage Temperature	-10 to +55	°C
Humidity (non-condensing)	10 to 80	% R.H.
Weight <sup>(4)</sup>	< 3.5	kg

<sup>(4)</sup> depends on camera model

## 6. Connectors, Cables and Status Indicators

The Shad-o-Box 1280 HS detector uses the following connectors:

- An RJ-45 connector for Gigabit Ethernet signals, data signals
  - o CAT6 Ethernet cable
- One 2-pin Lemo connector for power
  - o Lemo EGG.0B.0302
  - o Mating connectors:
    - elbow type: FHG.0B.302.CLAD52Z
    - straight type: FGG.0B.302.CLAD52



pin	Description
1	Supply voltage (+12V/ 2A)
2	Ground

The power input is protected by a resettable fuse. If the fuse is activated, power cycle (off/on) the detector to reset.

- One 4-pin Lemo connector for triggering
  - o Lemo EGG.0B.0304
  - o Mating connectors:
    - elbow type: FHG.0B.304.CLAD52Z
    - straight type: FGG.0B.304.CLAD52

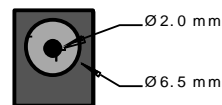


pin	Description
1	Trigger Output (+)
2	Trigger Output (-)
3	Trigger Input (+)
4	Trigger Input (-)

Optocoupler with 680Ω series resistor (max. rev. voltage 6V).

All other Shad-o-Box HS detectors use the following connectors:

- An RJ-45 connector for Gigabit Ethernet signals, data signals
  - o CAT6 Ethernet cable
- One DC power jack, 2 mm center pin for power



pin	Description
1	Supply voltage (+6.5V/ 2A)
2	Ground

The power input is protected by a resettable fuse. If the fuse is activated, power cycle (off/on) the detector to reset.

- One 4-pin FCI connector for triggering
  - o FCI 78208-104HLF
  - o Mating connector:
    - FCI 78211-004LF



pin	Description
1	Trigger Output (+)
2	Trigger Output (-)
3	Trigger Input (+)
4	Trigger Input (-)

Optocoupler with 680Ω series resistor (max. rev. voltage 6V).

## Ethernet Connection LED

Steady green indicates that an Ethernet connection is successfully established at 1Gbps.

## Data Transmission LED

Steady yellow indicates that the detector is ready for data transmission. Flashing yellow indicates that the detector is transmitting or receiving data.

## Detector Status LED

The detector is equipped with a color LED used to display the status of the detector's operation. The table below summarizes the operating states of the detector and the corresponding LED states.

### *Shad-o-Box 1280 HS*

Color of Status LED		Meaning
1	Off	No power
2	Green	Detector is operational
3	Red	Power applied, Hibernate or Standby mode

### *All other Shad-o-Box HS Models*

Color of Status LED		Meaning
1	Off	No power
2	Green	Detector is operational, Free-running mode
3	Yellow	Detector is operational, Snapshot mode
4	Blue	Detector is operational, External Trigger mode
5	White	Boot error: power cycle camera or contact customer support

## 7. Setting up the Detector

### GigE Network Adapter

If the computer to be used with the detector does not have a Gigabit network adapter or second built in Gigabit NIC, a PCI bus Gigabit NIC needs to be installed. Typically under Windows XP the PCI Gigabit NIC is recognized automatically when Windows boots. An example of a high performance NIC is the Intel PRO/1000 MT adapter. Review the NIC documentation concerning any special driver required for Windows. Install the PCI bus Gigabit NIC as described by the NIC manufacture's documentation.

### Connect trigger cable

If using the detector in snapshot mode, connect the trigger cable to the detector.

### Connect Ethernet cable

Connect the Ethernet cable from the detector to the computer Ethernet jack. Secure the RJ-45 connector to the detector.

### Connect power cable

Connect a power cable from the detector to a +12V or +6.5V power supply depending on the Shad-o-Box HS model.

### Status Light

Verify that the status light is solid green. This can take a few seconds.

### Software Installation

Refer to the next chapter for instructions on installing and running the detector software.



## 8. Software Installation and Setup

The recommended software for the Shad-o-Box HS detector is Sapera LT with CamExpert and a generic GigE-Vision driver (for GigE devices) to grab images. Sapera LT is compatible with Windows XP, Vista, 7 and 8, and is available in both 32-bit and 64-bit versions. You may also use our ShadoCam Imaging application with built-in image correction functions and display look-up table controls to acquire images directly to your desktop.

Please make sure both Sapera LT (or an equivalent application) and the supplied driver are installed before attempting to connect the detector.

### Connecting

1. After the install is complete, plug in the detector communication cable.
2. Power up the detector.
3. After powering up the detector, the application automatically detects the detector. This may take up to 30 seconds. Wait until the detector connected indicator in the task bar (shown below) has confirmed that a connection has been established (the red cross over the camera icon disappears).



### Checking detector status and information in Gigabit Ethernet

When you add or remove a detector from the network, it is automatically detected by the GigE server. A manual network scan can also be launched by right-clicking the camera icon and selecting “Scan Network” from the menu options. This action will refresh the information of the device connected to the network.

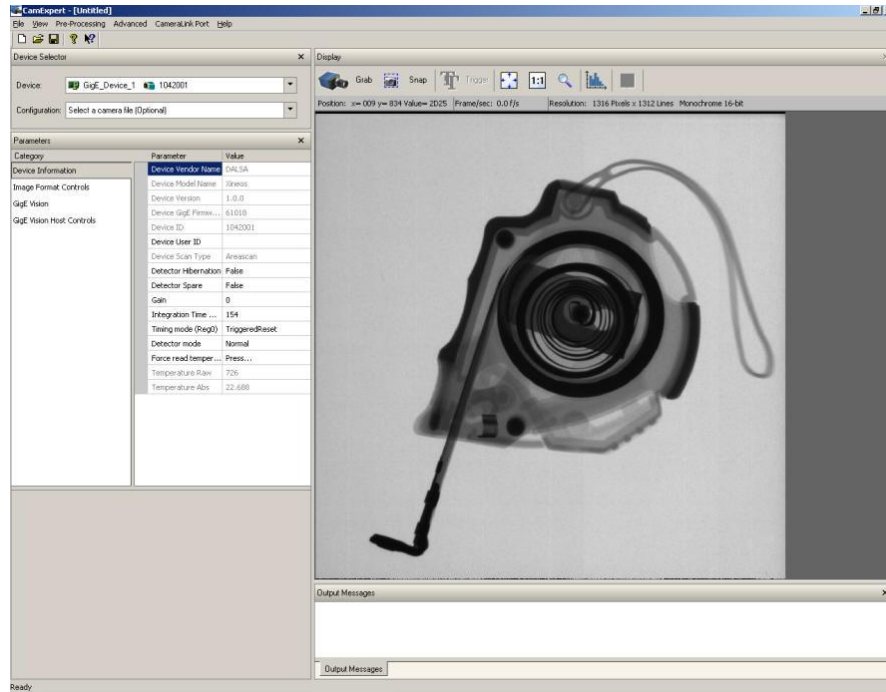
After the detector connection has been established, the status of the connection can be displayed by double-clicking the camera icon in the task bar. The device status window displays the serial number of the detector that has been detected on the network and its current status. Additional information with respect to the detector model, serial number and MAC address is also displayed.

The user can also view the detector and the PC IP addresses in this window. The default assigned detector IP address can be modified using the Teledyne DALSA Network Configuration Tool, which is part of the installation package.

Manufacturer	Model	Serial number	MAC address	Status	Camera IP	NIC IP	Filter driver	MaxPktSize	Firm ver	User name
DALSA	X4-20-08M01-00-R	14006817	00:01:0D:11:1B:64	Available	169.254.037.011	169.254.153.134	Enable	9212	39745	<Empty>

## 9. Acquiring Images

The CamExpert software can be started to acquire images.  
The software will display all available device parameters.



The user has the option to either snap an image or to grab multiple images. Snapping an image produces a single frame, whereas the grabbing process generates multiple frames by operating in a continuous mode.

To snap an image:

Click the *Snap* button. The Detector has now snapped a single frame. The image appears in the GUI window.

To grab multiple images:

Click the *Grab* button. The detector is now armed and ready to acquire images in continuous mode.

To stop a *Grab* process the user must press the *Freeze* button. After the *Freeze* button is pressed the detector ignores any additional triggers and no additional images are acquired.

## 10. Synchronization Modes

The detector can be used in combination with either a DC X-ray source or a pulsed X-ray source.

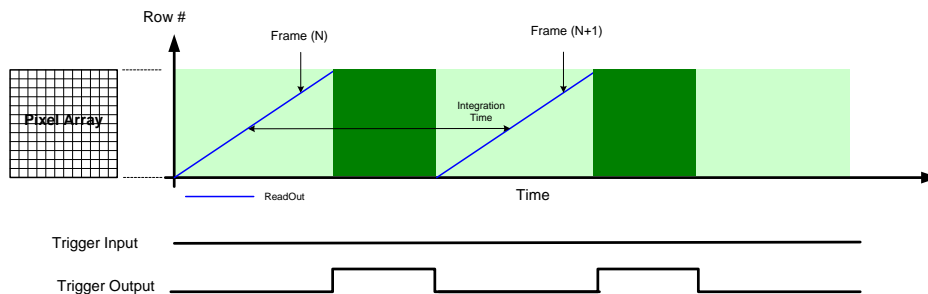
### Free running Mode

#### When using a DC X-ray source:

The detector is operating in a continuous, asynchronous mode. The integration time window equals the frame time of the detector. Immediately after the readout, the pixels are reset and a new integration period commences. The frame rate (#frames/second) is equal to  $1/(\text{integration time})$ .

#### When using a pulsed X-ray source:

The figure shows the array row read-out as a function of time. The frame ReadOut containing the image information is marked blue. The frame integration time is indicated by the horizontal distance between the two slanted ReadOut lines and the actual image-capture interval is marked with the dark green rectangle.



The period of time in between successive frame read-outs (dark green) is used to fire the pulsed X-ray source. The width of this time-period can be programmed via the detectors command interface by adjusting the ExtendedExposure parameter. The ExtendedExposure register controls the number of blanking lines between frame ReadOuts.

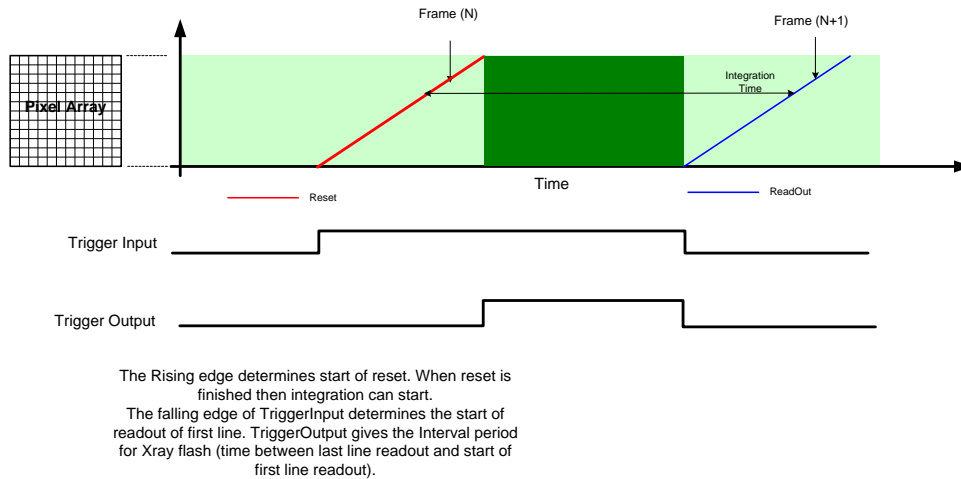
During the blanking interval, the detector delivers a positive-going synchronization signal to the outside world for synchronization with the X-ray source. The rising edge of the synchronization signal determines the start of the vertical blanking window. The falling edge of the signal determines the start of the next frame ReadOut.

For safety reasons, the Trigger Output of the detector should never be used to directly control the on-time of the X-ray source.

### Snapshot mode

In this mode the detector will take a single image at the moment a trigger signal is applied to the detector. The detector is the slave, and the host will be master.

As the sensor is continuously integrating when in idle mode, the sensor pixel signal must be reset by a dummy frame read-out (Frame N) before actual image integration can commence (Frame N+1). To allow sufficient time for this reset, the delay between trigger input and the start of the X-ray pulse should be at least equal to  $1/(\text{max. frame rate})$  for the detector model being used.

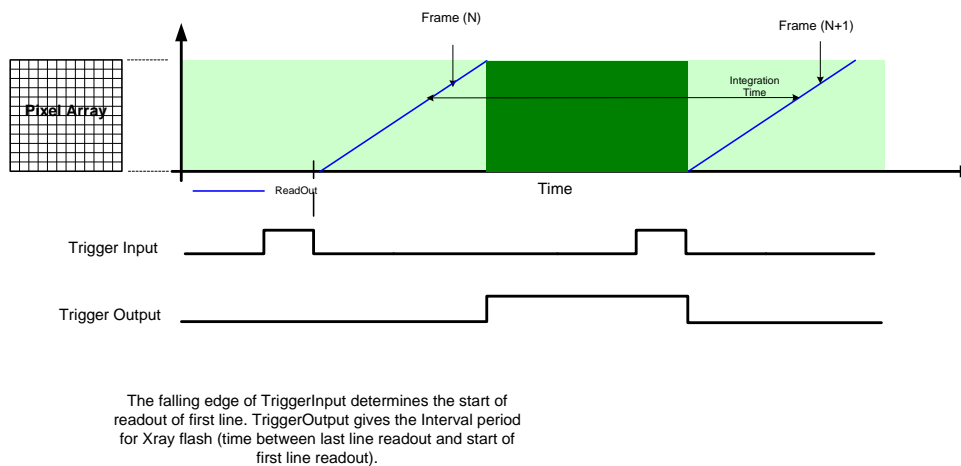


The integration time is determined by the pulse width of external trigger. The image readout time will again be equal to  $1/(\text{max. frame rate})$  for the detector model.

## External mode

In this mode the detector will take a single image at the moment a trigger signal is applied to the detector. The detector is the slave, and the host will be master.

This mode is equal to the Snapshot mode but no reset is needed before integration can start.



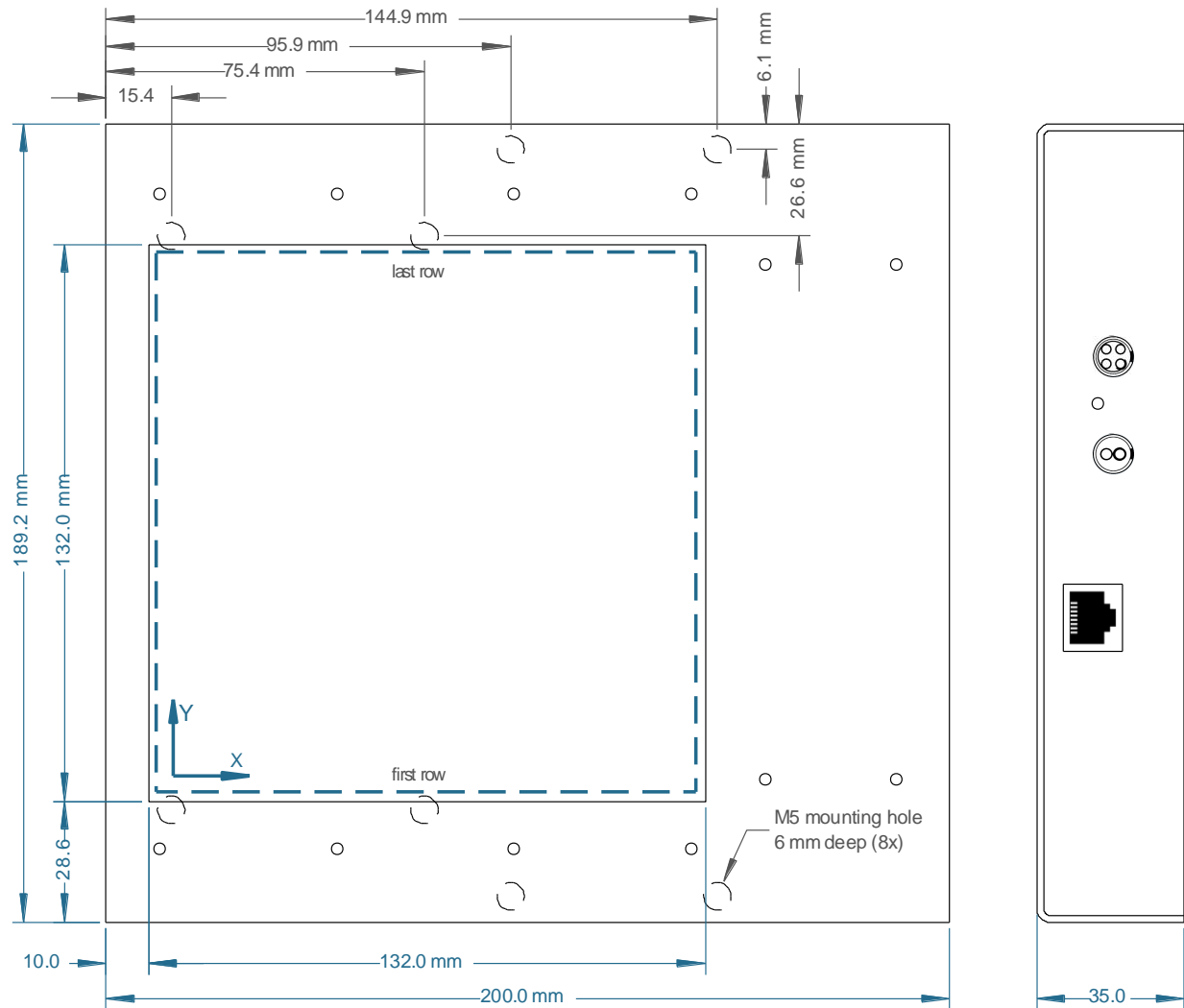
## Shuttering

Please note: the Shad-o-Box HS does not have a shuttering mechanism built into the detector. Therefore, it is imperative that the x-ray source be shuttered or turned off before readout of the detector begins. Failing to do so may cause a blur or smear effect in the x-ray image.

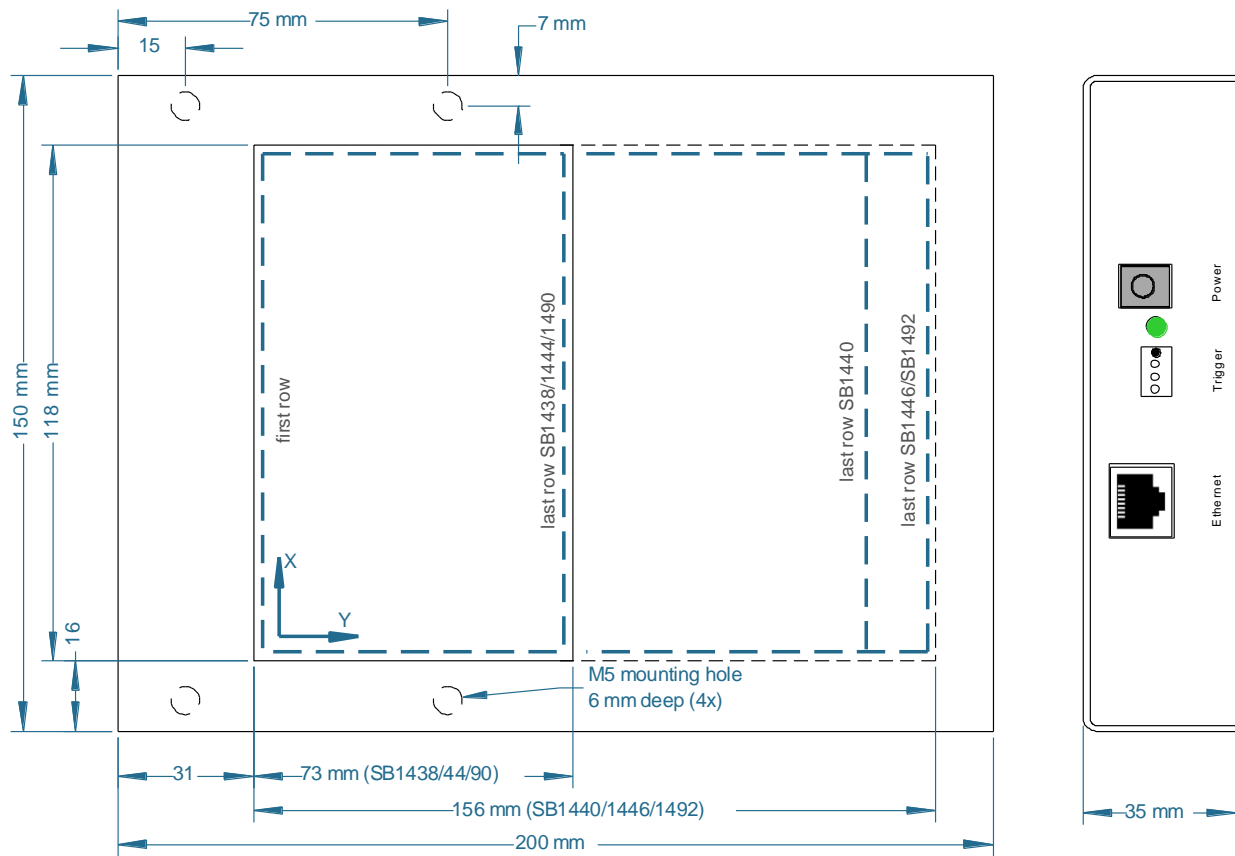
In order to ensure that x-ray emissions have completely ceased before the image readout begins; either add a shutter in front of the x-ray source or use the Readout Delay feature to add time to allow the x-ray source to fully decay.

# 11. Mechanical Drawings

## Shad-o-Box 1280 HS Model



## 3x4" and 4x6" Models



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## About Teledyne DALSA

Teledyne DALSA is an international high performance semiconductor and electronics company that designs, develops, manufactures, and markets digital imaging products and solutions, in addition to providing semiconductor products and services. Teledyne DALSA's core competencies are in specialized integrated circuit and electronics technology, software, and highly engineered semiconductor wafer processing. Products and services include image sensor components; electronic digital cameras; vision processors; image processing software; and semiconductor wafer foundry services for use in MEMS, high-voltage semiconductors, image sensors and mixed-signal CMOS chips.

Rad-icon Imaging, a division of Teledyne DALSA, specializes in the design, development and manufacture of standard and semi-custom x-ray sensors and cameras for the industrial x-ray market. Our goal is to work with OEM partners to jointly create superior imaging solutions that are distinguished from the competition. We offer comprehensive consultations and direct access to technologists who have in-depth knowledge of custom application integration. Our technical experts are available to provide customized solutions to meet your product requirements.

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