LUCID VISION LABS

Helios Flex Technical Manual

V1.0.2

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Contents

Product Specification

Basic Information	
Model	HLF003S-001
Resolution	0.3MP (640 x 480 px)
Framerate	30fps
Sensor	Sony DepthSense™ IMX556PLR CMOS
Optical Format	½”
Pixel Size	10um

Physical, Interface and Power Information	
Interface	4-Lane MIPI D-PHY CSI-2 (FFC)
Dimension	55 x 55 x 43.7 mm
Lens Mount	Integrated S-mount lens (not user changeable)
Weight	107 g
Power Consumption	<15W

Imaging Properties	
Working Range	Near Mode: up to 1.5m; Far Mode: up to 6m
Lens Field of View	59^{o} x 45^{o} (nominal)
Illumination	4 x VCSEL laser diodes @ 850nm

Camera Features	
Exposure Control	Manual with 2 modes
Output Formats	3D Point Cloud, Intensity and Confidence
Platform Support	NVIDIA Jetson TX2

Standard and Certification	
Compliance	RoHS, REACH, WEEE, Eye Safety IEC 60825-1:2014
Operating Case Temperature	-10°C to 60°C (case temperature)

Accuracy & Precision			
Accuracy	+/- 5mm over range 0.3-1.5m (1.5m mode)		
	+/- 10mm over range 0.3-6.0m (6m mode)		
Precision	**Distance (m)**	**1.5m Mode (mm)**	**6m Mode (mm)**
	0.5	0.69	0.53
	1	1.6	1.25
	1.5	3.11	2.24
	2	-	3.17
	3	-	6.81
	4	-	10.8
	5	-	16.8
	6	-	25.4

Welcome

HLF003S is a Time of Flight camera module featuring Sony's DepthSense ToF sensor, along with 4 VCSEL laser diodes operating at 850nm. The camera module along with the Jetson TX2 platform is capable of computing depth data by measuring the time it takes for light emitted from the diodes to reflect off objects in the scene and return to the sensor for each point of the image. HLF003S along with the Jetson TX2 platform can produce 3D point cloud data, confidence value as well as raw intensity image data.

Safety and Precautions

Follow these guidelines carefully before using your Helios Flex camera.

Definitions and Symbols

Below is some warning, safety, and/or tips icons used in this document.

	The **Warning** icon indicates a potentially hazardous situation. If not avoided, the situation can result in damage to the product.
	The **ESD** icon indicates a situation involving electrostatic discharge. If not avoided, the situation can result in damage to the product.
	This symbol is used in this manual to indicate a procedure that may cause hazardous exposure to laser radiation.
	The **Help** icon indicates important instructions and steps to follow.
	The **Light Bulb** icon indicates useful hints for understanding the operation of the camera.
	The **Computer** icon represents useful resources found outside of this documentation.

General Safety Notices

	**Powering the Camera** The camera may not work, may be damaged, or may exhibit unintended behavior if powered outside of the specified power range. The supplied power must be within the stated voltage range. See the Power section for further information.
	**Operating Temperature** The camera may not work, may be damaged, or may exhibit unintended behavior if operated outside of the specified temperature range. See the Temperature section for further information.

	• Caution, use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure. • Do not open the Helios camera housing. • Do not contact the laser apertures with any objects. Damage to the laser modules could produce hazardous radiation levels.
	**Electrostatic Discharge** Ensure proper precautions are implemented to prevent damage from an electrostatic discharge.
	**Image Quality** Dust or fingerprints on the sensor may result in a loss of image quality. Work in a clean and dust-free environment. Use only compressed ionized air or an optics cleaner to clean the surface of the sensor window. Pleaser refer to the Maintenance section for details.

Laser Radiation

The Helios Flex camera emits infrared radiation that is invisible to the human eye. Helios has been tested to IEC / EN 60825-1: 2014 and classified as Class 1 (eye safe). The location and a sample of the laser safety classification label are shown in Figure 1. The location and a sample of the product label are shown in Figure 2.

Emission is produced by 4 VCSEL (Lasers) with integrated diffusers that illuminate the field of view. The laser apertures are shown in Figure 3.

	The diffusers are integral to the eye safety classification and must not be damaged or removed. The emission characteristics are as follows: • Wavelength: 850 nm +/- 10 nm • Divergence (FWHM): 60°×45° • Maximum average power: 2.2 mW (through IEC / EN 60825-1: 2014 limiting aperture)

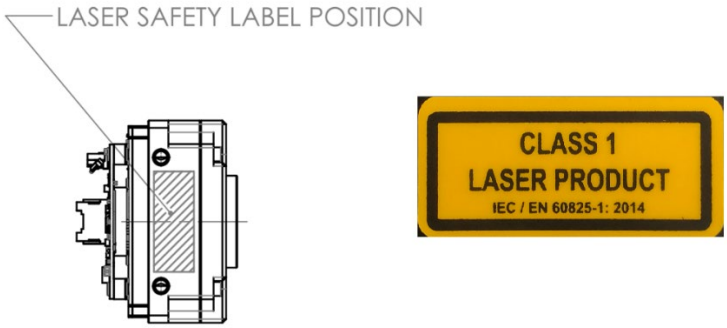


Figure 1. Location and Sample of Laser Safety Classification Label

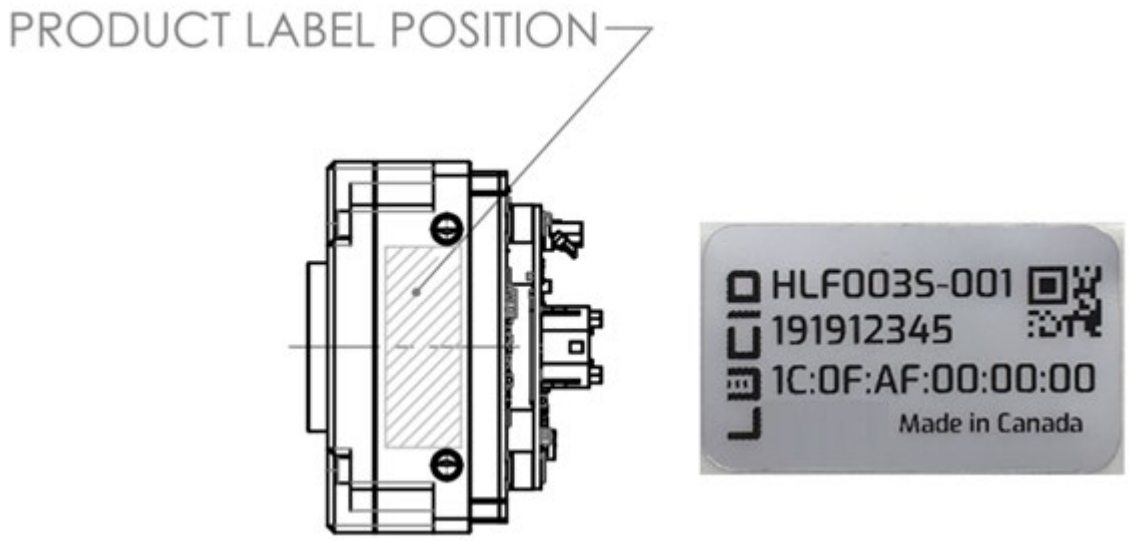


Figure 2. Location and Sample of Product Label

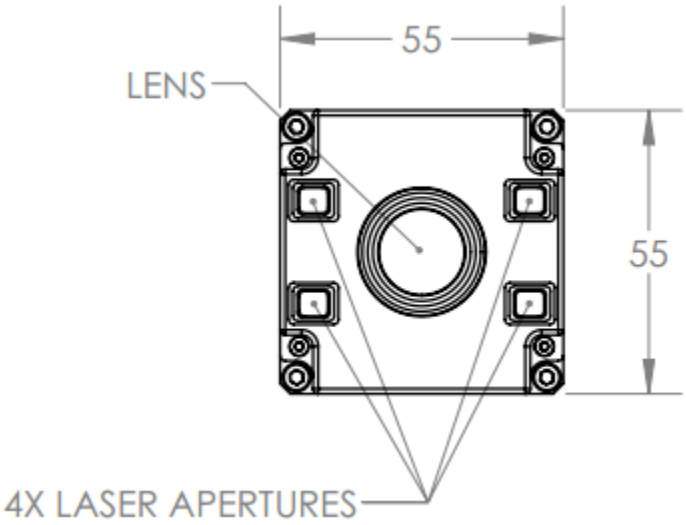


Figure 3 Locations of 4 Laser Apertures

Service and Maintenance

Service

Helios is a precision optical instrument and contains no user serviceable parts.

	If the unit sustains any damage or ceases to function as expected please contact Lucid Vision Labs, Inc. to begin the RMA process.

Maintenance

	Ensure the Helios Flex is unpowered during inspection and cleaning.

The laser apertures should be kept clear and clean.

	The laser apertures should only be cleaned with a gentle dust blower such as a hand-squeeze type lens blower. Do not contact the laser apertures during cleaning or any other process. Do not use solvents to clean the laser apertures. If a laser aperture becomes contaminated, e.g., splattered with paint, oils or other hard to remove sources, contact LUCID Vision Labs, Inc. to begin the RMA process.

To achieve the specified accuracy of the Helios, the lens (see Figure 3) must be kept clean. Avoid touching the lens – fingerprints will significantly degrade performance. Dust should be blown off with a gentle clean air source (do not use aerosol cans) and or lens brush if necessary. Any smudges on the glass should subsequently be removed by applying a very small amount of optical grade lens cleaning solution or isopropanol to an optical grade swab and gently removed.

Contact Us

Think LUCID. Go LUCID.

Contact Sales

https://www.thinklucid.com/contact-us/

Contact Support

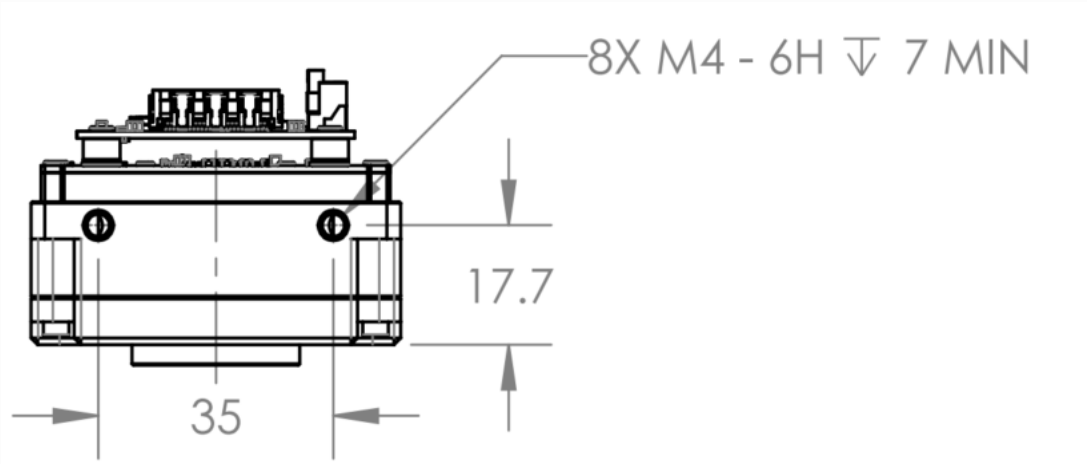
https://thinklucid.com/support/

Installing the Camera Hardware

	**Camera Installation** • Systems must be installed and operated by trained personnel. • Safety warnings and procedures specified in this user manual must be observed.

Mounting

The camera is equipped with four pairs of M4 mounting holes. Each of the 4 side walls of Helios Flex is equipped with a pair of M4 holes.



FFC Cable

- The Helios Flex camera interfaces with the Jetson TX2 board via the 4-Lane MIPI D-PHY CSI-2 interface via an FFC cable
- The manufacturer part number of the FFC cable that is included in the Helios Flex kit is 15021-1233.

	When using the included FFC cable, make sure the blue side is facing **toward** the locking tab. Engage the FFC connector's locking tab to its **horizontal** position to lock it.

JST Power Cable

The Helios Flex camera is powered via the interface PCB through a 4 pin JST cable

- The manufacturer part number of the JST connector used is PAP-04V-S.
- The manufacturer part number of the 4 wires are JST APAPA22K305.

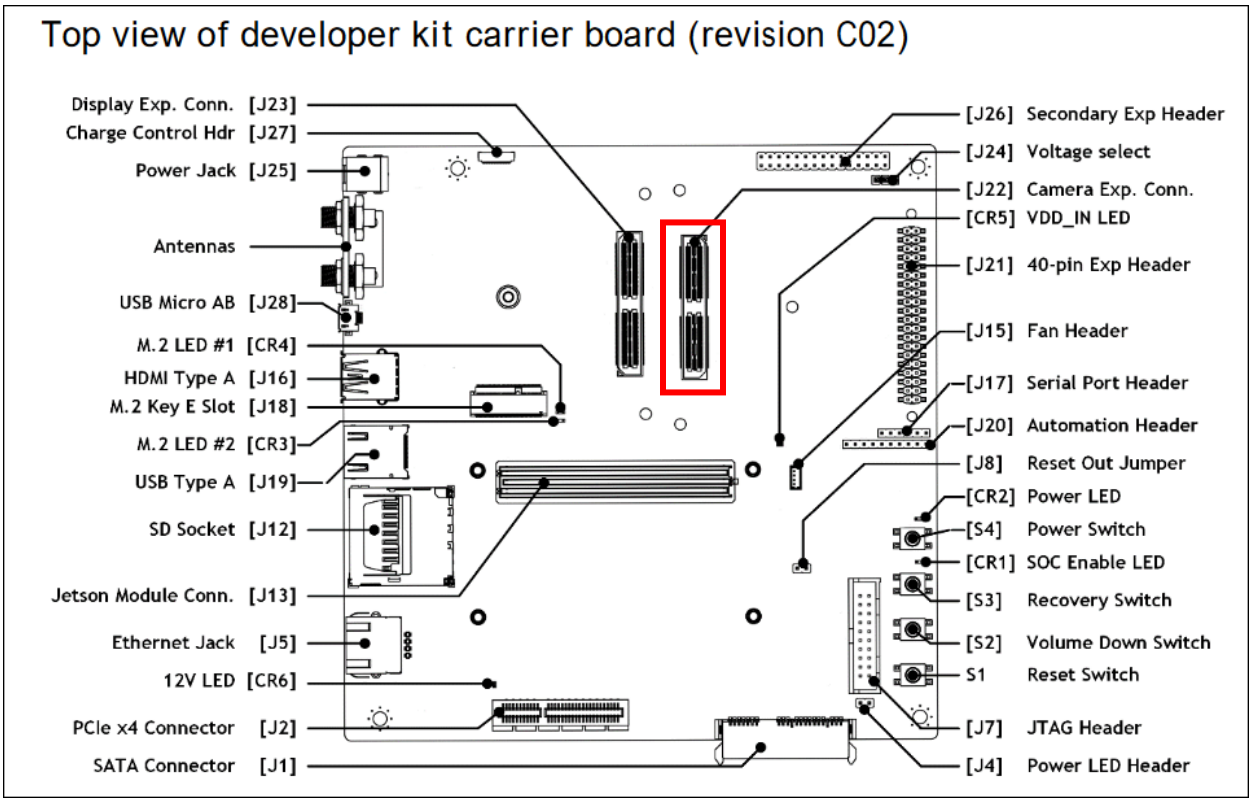
Lens

The M12 integrated lens is designed specifically for the Helios camera. The lens is 6mm in focal length and has a nominal field of view of 59° x 45° (nominal).

	To get the best performance, the lens needs to be perfectly clean. The slightest smudge or fingerprint on the glass vastly more inaccurate depth data.

Helios Flex Camera Adapter Board

The Helios Flex adapter board must be installed to the Jetson TX2 development board's Camera Expansion Connector.



Configuring the Jetson TX2

Flashing the custom LUCID Linux4Tegra Image

This method will install a new Linux4Tegra image on your TX2 board with LUCID's custom kernel.

> **Note**
>
> All data existing data on your TX2 will be lost in this flashing process. Back up any important items before proceeding.

Requirements

- Ubuntu Linux x64 18.04 host PC with at least 40GB of free space
- USB Micro-B to Female USB A cable
- Jetson TX2 carrier board (revisions B02, B04, or C02)

The following steps are performed from the Ubuntu Linux x64 16.04 or 18.04 host PC.

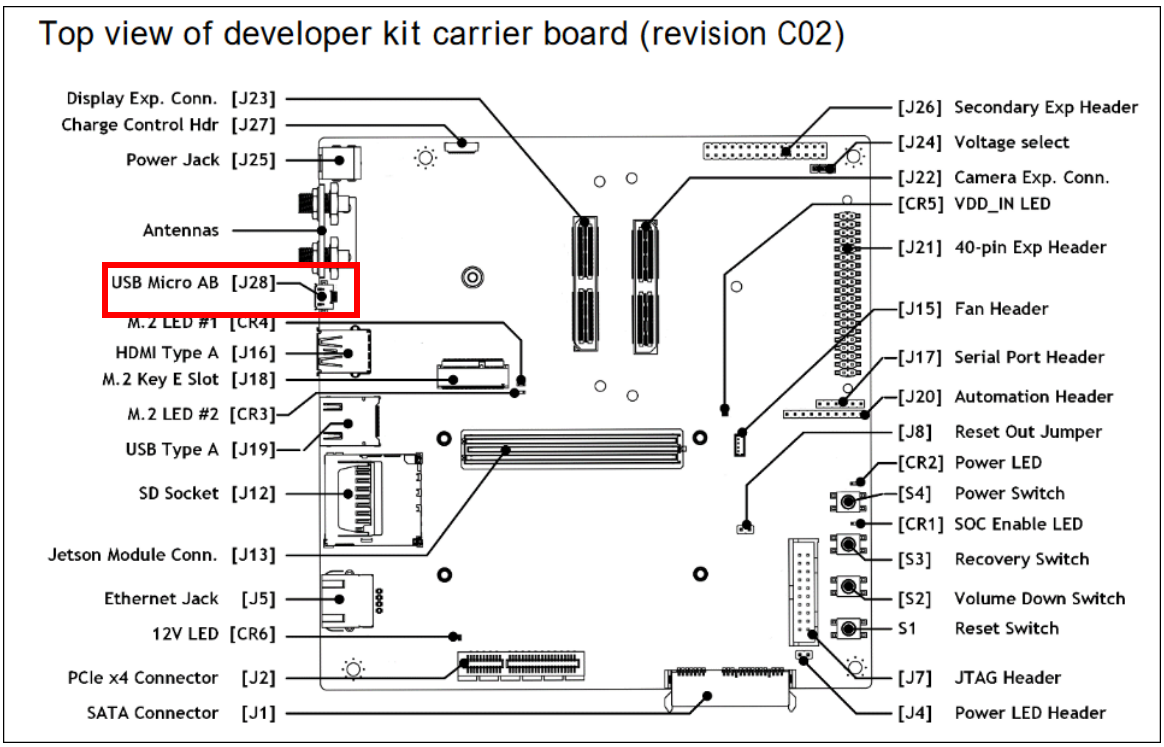
1. **Untar the custom LUCID Linux4Tegra tarball**

   ```
   sudo tar -xvpf L4T_R32_2_LUCID.tar.gz -C ~
   ```

   The above command will untar the LUCID Linux4Tegra tarball to your home directory.

2. Flash the Jetson TX2 board

To flash the TX2 board, you will need to connect the board to the host PC using the USB Micro-B port to Female USB A cable.



Once the TX2 board is connected to the host PC, put the board into recovery mode. From power off state:

- Hold the **Recovery** button
- Press the **Power** button
- Release the **Recovery** button after 3 seconds

To confirm your TX2 is in recovery mode, you can use the `lsusb` command on your host PC and find your board in the output, for example:

```
Bus 001 Device 008: ID 0955:7c18 NVidia Corp.
```

After confirming your board is in recovery mode, go to your host PC's `Linux_for_Tegra` folder.

```
cd ~/Linux_for_Tegra
```

In this directory, there is a script named flash.sh which will be used to flash the board:

```
sudo ./flash.sh jetson-tx2 mmcblk0p1
```

It will take a few minutes to flash the board. When the board is finished flashing, you should see output similar to the following to the following to indicate a successful flash.

```
[ 235.4658 ] Flashing completed
[ 235.4660 ] Coldbooting the device
[ 235.4685 ] tegradevflash_v2 --reboot coldboot
[ 235.4706 ] Bootloader version 01.00.0000
[ 235.4776 ]
*** The target t186ref has been flashed successfully. ***
Reset the board to boot from internal eMMC.
```

Please reboot the TX2 and follow your TX2's on-screen setup to configure your new Ubuntu setup on your TX2.

Install CUDA on the Jetson TX2

Note
These steps assume the TX2 has a valid network address.

Please go to https://developer.nvidia.com/nvidia-sdk-manager and install the NVIDIA SDK Manager tool on your Ubuntu host PC. You will need NVIDIA Developer Account to use this tool to install the Vision Tools package.

Install the NVIDIA SDK Manager with a command similar to the following:

```
sudo dpkg -i sdkmanager_1.0.0-5517_amd64.deb
```

where `1.0.0-5517_amd64` is the version of NVIDIA SDK Manager to be installed

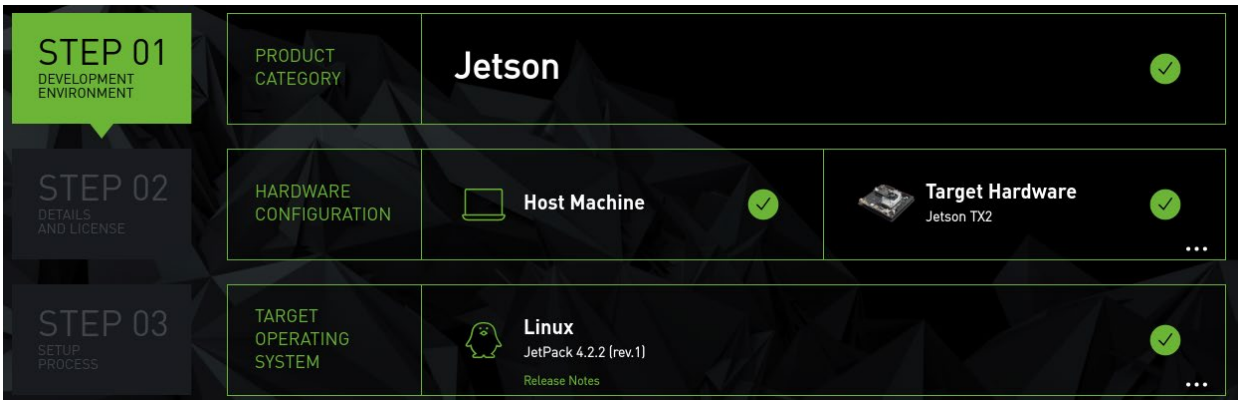
Once the NVIDIA SDK Manager tool is installed, you can launch it with the terminal command:

```
sdkmanager
```

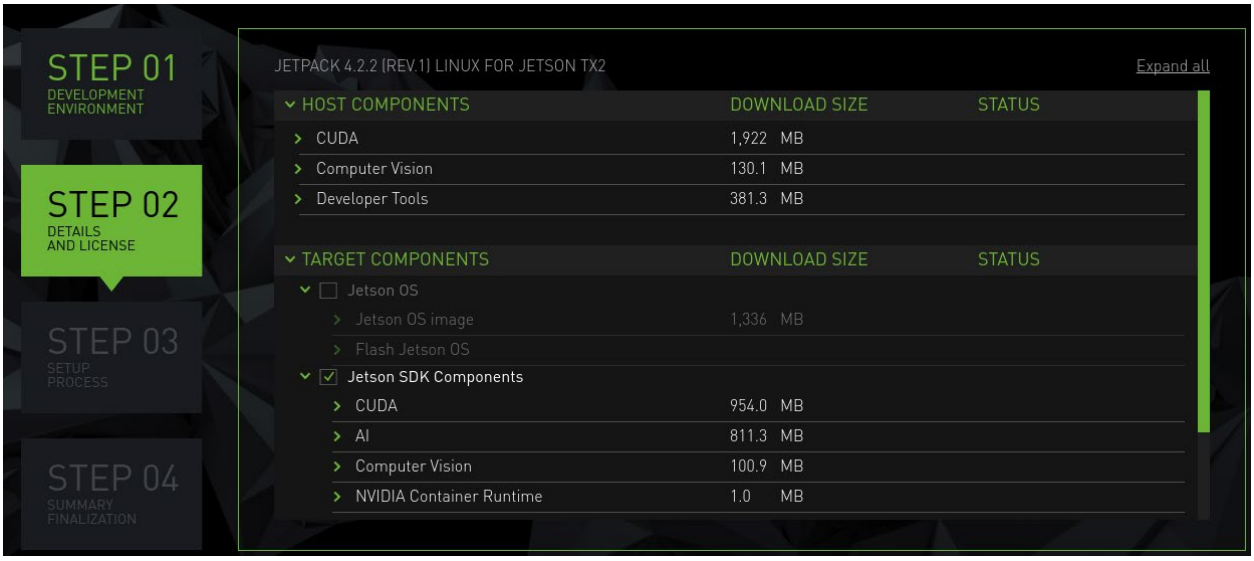
Fill in your NVIDIA Developer Account credentials to log in.

In **Step 01** of the NVIDIA SDK Manager, choose the following:

- Target Hardware: Jetson TX2
- Target Operating System: JetPack 4.2.2 (rev 1)



In **Step 02** of the NVIDIA SDK Manager, we will select only the Jetson SDK Components. It is important to **uncheck** Jetson OS option because we do not want to replace the custom LUCID kernel that was just flashed to your Jetson TX2 board.



Click **Continue** to begin downloading the Jetson SDK Components. You will be asked for your sudo password. After the package has been downloaded, you will be asked to input your Jetson TX2's IP address and credentials to install the components onto the Jetson TX2.

Note
You can find out your Jetson TX2's IP address with the `ifconfig` command

Install OpenCV on the Jetson TX2

LUCID's ArenaFlex software uses a custom version of OpenCV, so we will need to purge the pre-installed OpenCV installation from your Jetson TX2.

On your Jetson TX2, run `sudo apt-get update` first to make sure your board has the latest repositories cached.

Remove the existing OpenCV version from your Jetson TX2 with the following command:

```
sudo apt-get purge libopencv*
```

Download LUCID's OpenCV deb files:

- `OpenCV-3.4.1-9-gec0bb66e5e-dirty-aarch64-libs.deb`
  Required runtime libraries, used by ArenaFlex
- `OpenCV-3.4.1-9-gec0bb66e5e-dirty-aarch64-dev.deb`
  Optional development files, if you need to link your own software against this library
- OpenCV-3.4.1-9-gec0bb66e5e-dirty-aarch64-python.deb
  Optional Python bindings, if you need to use OpenCV with Python

Install LUCID's OpenCV deb files:

```
sudo dpkg -i OpenCV-3.4.1-9-gec0bb66e5e-dirty-aarch64-libs.deb
sudo dpkg -i OpenCV-3.4.1-9-gec0bb66e5e-dirty-aarch64-dev.deb
sudo dpkg -i OpenCV-3.4.1-9-gec0bb66e5e-dirty-aarch64-python.deb
```

Setting up FlexView

Initial Setup

The following steps will set up FlexView, the viewer software used by the Helios Flex, on your Jetson TX2.

1. **On your Jetson TX2, install the dependencies used by FlexView:**

```
sudo apt-get install libglfw3 libglew2.0
```

2. **Untar the ArenaFlex tarball:**

```
tar -xvpf ArenaFlexSDK_v0.1.0_Tx2.tar.gz -C ~
```

   The above command will untar the ArenaFlex tarball to your home directory.

The following commands will enable you to use your Helios Flex via I2C without using sudo.

1. **Create new user group called i2c:**

```
sudo groupadd i2c
```

2. **Change the group ownership of /dev/i2c-2 to i2c:**

```
sudo chown :i2c /dev/i2c-2
```

3. **Change the file permissions of the device /dev/i2c-2 so users of the i2c group can read and write to the device**

```
sudo chmod g+rw /dev/i2c-2
```

4. **Add your username to the group i2c**

```
sudo usermod -aG i2c <username>
```

5. **Change to root user**

```
sudo -i
```

6. **Set udev rules to apply the settings to the i2c busses on boot**

```
echo 'KERNEL=="i2c-[0-9]*", GROUP="i2c"' >> \
/etc/udev/rules.d/10-local_i2c_group.rules
```

7. **Reboot your tx2**

```
sudo reboot
```

Running FlexView

1. Navigate to your ArenaFlex SDK folder

```
cd ~/ArenaFlexSDK_Tx2
```

> **Note**
>
> These instructions assume ArenaFlex SDK is installed into the home directory.

2. Add the following to `~/.bashrc` to ensure ArenaFlex can find the ArenaFlex libraries and run the functions in `~/.bashrc` to apply the changes for the current terminal session

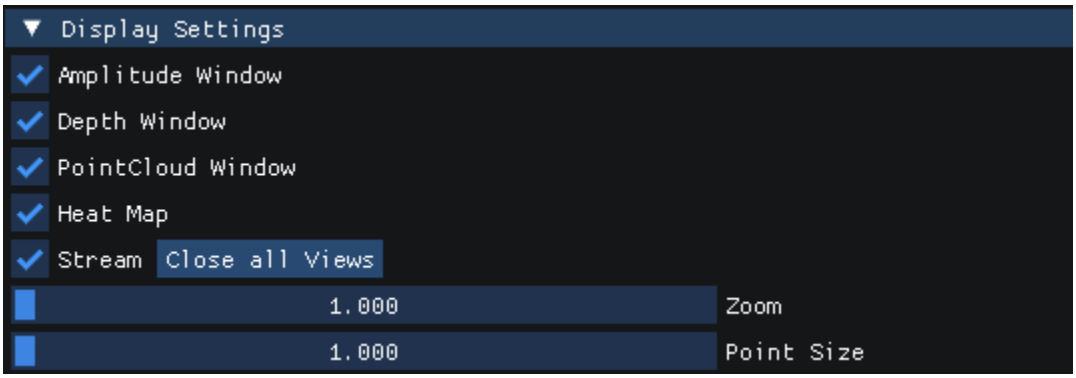
```
export LD_LIBRARY_PATH=~/ArenaFlexSDK_Tx2/lib:$LD_LIBRARY_PATH
source ~/.bashrc
```

3. Run FlexView by navigating to the ArenaFlexSDK_Tx2/flexview/output directory

```
cd ~/ArenaFlexSDK_Tx2/flexview/output
./flexview
```

FlexView Window Controls

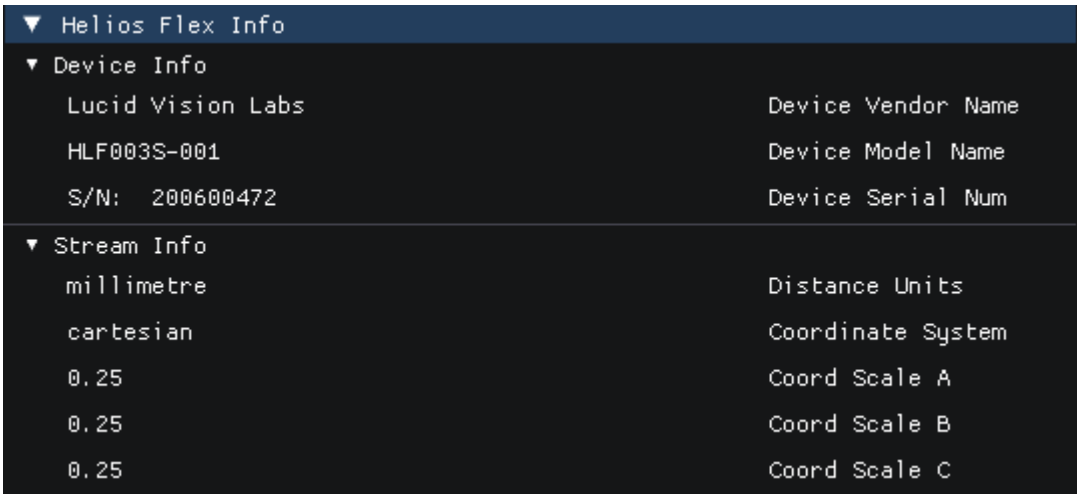
FlexView allows the user to display various output types from the captured image under **Display Settings**.



Display Option	Description
Amplitude Window	Shows/Hides the 2-dimensional amplitude image (intensity image).
Depth Window	Shows/Hides the 2-dimensional colorized depth image.
Point Cloud Window	Shows/Hides the 3-dimensional colorized depth data visualized as a point cloud. Rotate the point cloud data by clicking and dragging your mouse in the window.
Heat Map	Enables/Disables point cloud colorization.
Stream	Enables/Disables live streaming view for all display windows.
Zoom	Zoom in and out of the point cloud data. You can also zoom with your mouse wheel if present.
Point Size	Increase or decrease the point cloud point size

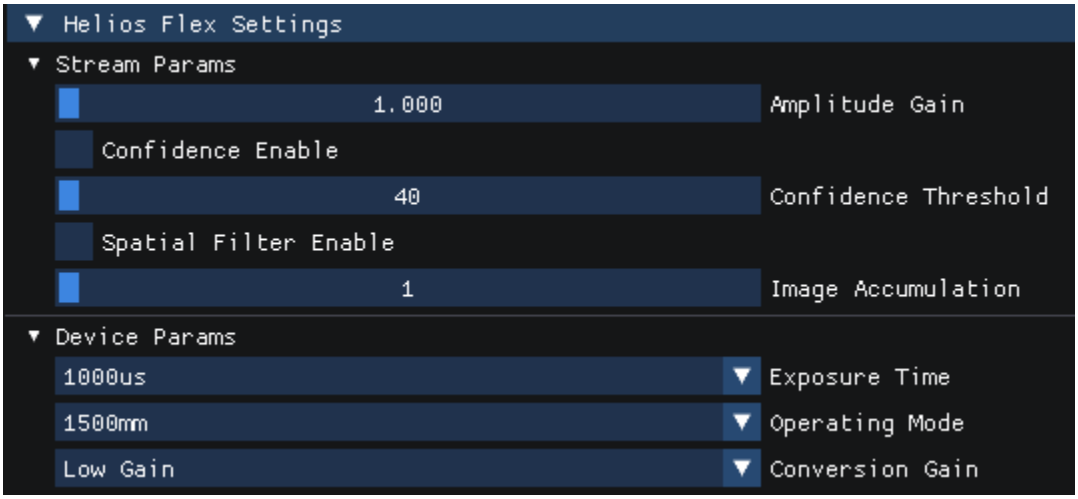
Helios Flex Information

Information about the connected Helios Flex is presented in the **Helios Flex Info** section.



Helios Flex Settings

Controls for Helios Flex Settings are presented in the **Helios Flex Settings** section.



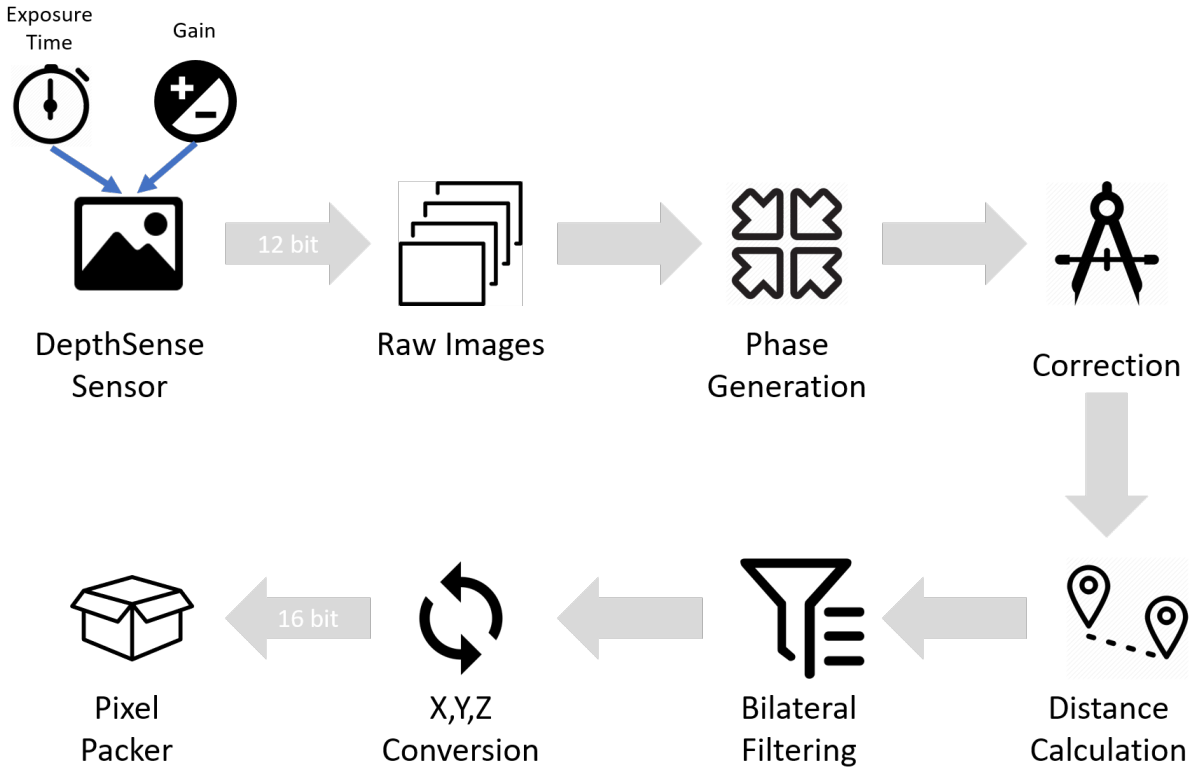
Using Arena Flex SDK

The Arena Flex Software Development Kit (SDK) is designed from the ground up to provide customers with access to the latest in computer technology. The SDK supports the LUCID Helios Flex camera on the Jetson TX2 ARM platform.

Camera Features

Image Processing Controls

The HLF003S camera is equipped with the following image processing control flow.



The details of each of the image processing controls are described below.

Operating Mode

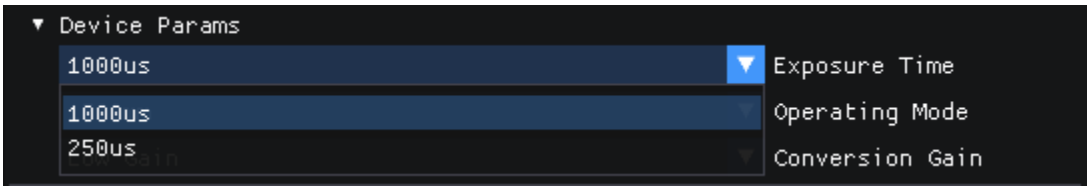
The camera allows for 2 operating modes - one is close-ranged (within 1.5m working distance) and another is far-ranged (up to 6m working distance).

Under 1.5m mode, the camera can generate depth data at 30fps; under the 6m mode, the camera is capable of generating depth data at 15fps.

Operating Mode can be adjusted in Helios Flex Settings → Device Params.

Exposure Time

The HLS003S camera enables two discrete exposure time settings - 1000us and 250us. The 1000us setting is the default exposure time and the maximum exposure time allowed. Longer exposure time should be used for scenes further away from the camera, or when imaging objects with low reflectivity. Shorter exposure time should be used for scenes closer to the camera, or objects appearing over saturated.



Exposure Time can be adjusted in Helios Flex Settings → Device Params.

Gain

The HLS003S camera allows the user to adjust to two gain settings. High gain settings should be used for objects that are further away or objects with low reflectivity. High gain setting will amplify sensor reading including any noise.

Gain can be adjusted in Helios Flex Settings → Device Params.

Image Accumulation

The HLS003S camera's processing pipeline can accumulate multiple frames of images for depth calculation. The higher number of frames accumulated on the camera's pipeline, the slower the depth data is generated as more images need to be captured to calculate the data. The higher number of images accumulated, the better the noise performance would be on the resultant depth data. Note that if 4 images are accumulated under 1.5m operating mode, the maximum frame rate achievable would be around 7fps due to 30fps slowed down by a factor of 4.

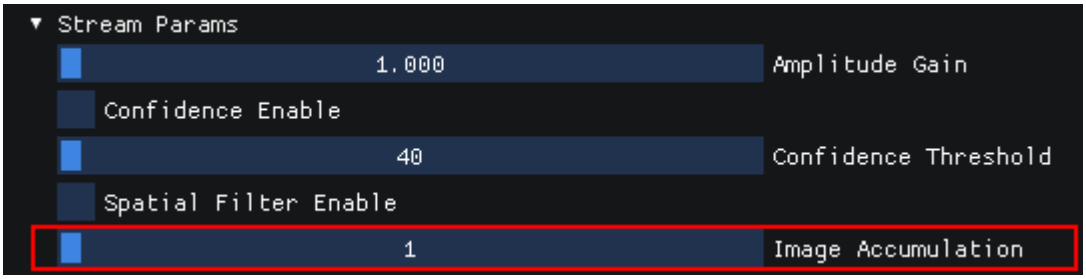
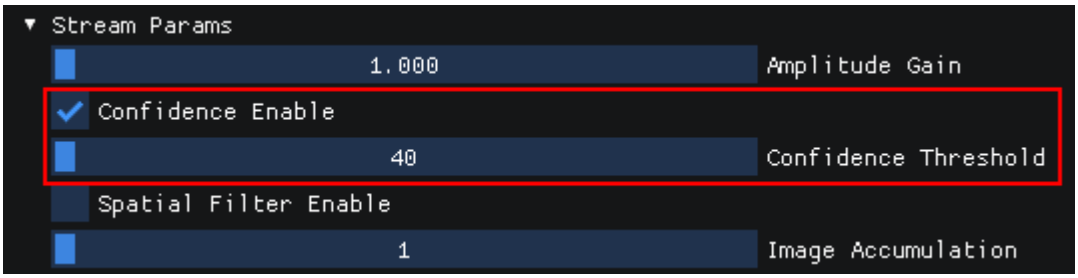


Image Accumulation can be adjusted in Helios Flex Settings → Stream Params.

Confidence Threshold

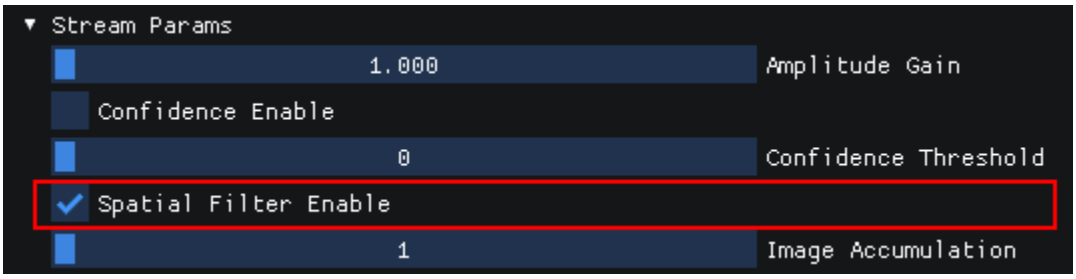
The HLS003S camera allows configuration of a confidence threshold using the Confidence Threshold parameter. To turn this feature on, please set **Confidence Enable** to True. Pixels with values above the confidence threshold are deemed valid and will have valid X, Y, Z and Y values (assuming Coord3D_ABCY16s pixel format). Values below the threshold will have their X, Y, Z and intensity values set to 0x8000 (denoting invalid).



Confidence Threshold can be toggled and adjusted in Helios Flex Settings -> Stream Params.

Spatial Filter

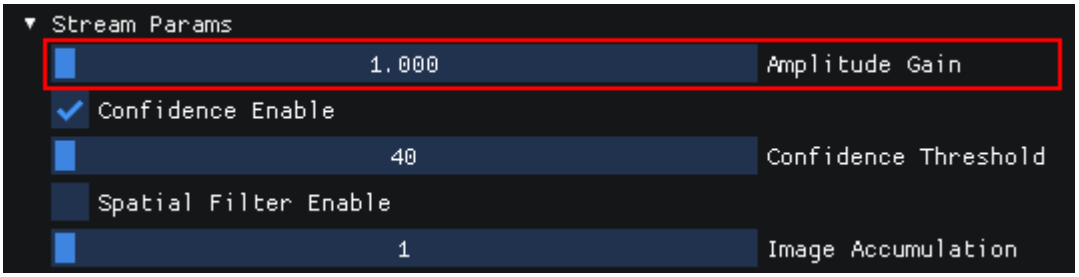
The HLS003S processing pipeline includes a bilateral **Spatial Filter** that can be enabled to improve the range data noise, for instance to obtain smoother edges.



Spatial Filter can be toggled in Helios Flex Settings -> Stream Params.

Amplitude Gain

The HLS003S allows digital gain to be added to the amplitude image (intensity image) by adjusting the **Amplitude Gain** feature.



Amplitude Gain can be toggled in Helios Flex Settings -> Stream Params.

Note
Amplitude Gain does not affect the depth measurement data.

Pixel Formats

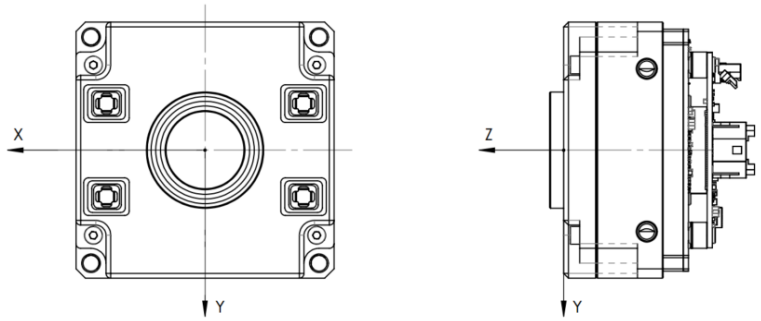
Range Data

Range data represent the depth image. These pixel formats below represent the radial distance between the target and the camera. The following pixel formats are available:

Coord3D_ABCY16s	4-channel point cloud XYZ + Intensity, 16 bits for each channel, signed output
Coord3D_ABC16s	3-channel point cloud XYZ, 16 bits for each channel, signed output
Coord3D_C16	Depth Map Z plane, 16 bits

The range data pixel formats listed above represent points in the point cloud with each of the ABC values representing the XYZ coordinates of the object's surface from which the light pulse has been reflected from. For distance value in mm, the user can query nodes under the Scan 3D control in order

to convert digital count to millimeter. For example, for a depth reading of 1000 digital count using Coord3D_C16, the real-world distance can be calculated by querying Scan 3D Coordinate Selector “Coordinate C” and Scan 3D Coordinate Scale “0.25”. Given the Scan 3D Distance Unit “Millimeter”, the real-world distance is 1000 x 0.25mm = 250mm. The image data ordering is row by row in raster order. The origin of the coordinate system is defined by: * The X and Y coordinates are zero at the center of the lens optical axis. * The Z coordinate is zero at the front of the camera housing.



TOF COORDINATE SYSTEM

Amplitude Image (Intensity Image)

The intensity image shows the brightness of the reflected laser light pulses as values per pixel. Because the wavelength of the light sent out by the camera has an influence on this, the intensity image may differ from the human perception of the targeted scene. The intensity image is useful for checking the image for over or under-saturated pixels. To avoid these, try changing the exposure time or the camera position and check whether the image improves. The following pixel formats are available:

Mono8	8 bit per pixel amplitude image
Mono16	16 bit per pixel monochrome raw image

Confidence Data

The confidence value represents a measure of how reliable the depth data is. By analyzing the temporal variations of the light pulse signal, a 16-bit integer value per pixel is generated. The higher the confidence value for that pixel, the more reliable the depth measurement. The following pixel format is available:

Confidence16	Confidence map, 16 bits

Note

ArenaFlex captures data in Coord3D_ABCY16s. ArenaFlex does not have an option to change Pixel Format. Pixel Formats can be changed using ArenaFlex SDK only.

Time of Flight Invalidation

Multipath

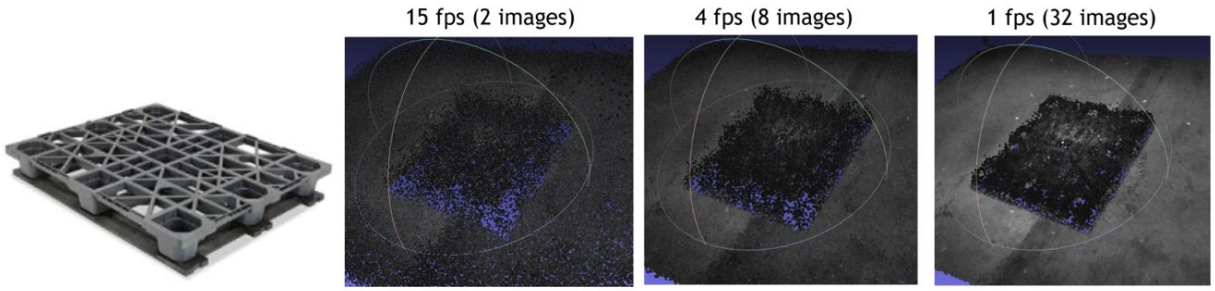
Multipath occurs when light is bounced off several surfaces before it is reflected back to the camera. These extra bounces can introduce error in the depth measurement. This phenomenon occurs commonly when imaging concave objects such as corners of a box or the bottom of a cup.

High Reflectivity

Objects with high reflectivity could cause the pixel to saturate. When this happens, the phase information is lost, and the depth calculation becomes invalid.

Low Reflectivity

When imaging objects with dark colors or low reflectivity, the return signal could be weak and close to the noise floor, making is difficult to differentiate valid data from noise. To mitigate this, averaging of frames can help improve the quality of the data.



Aliasing/Ambiguity

If an object is outside the working distance of the camera's operating mode (1.5m for near mode or 6m for far mode), the distance of the object becomes ambiguous. For example, when in near mode, an object at a distance of 1.8m will appear as 0.3m.

Veiling Glare

Lenses are inherently imperfect and could introduce stray light via scattering inside the lens which then manifest itself as image noise. When imaging a dark spot next to a bright spot (e.g. black text and white paper), veiling glare from the bright spot will cause the depth calculation for the dark spots to be less accurate.

Camera Specifications

Power

The Helios Flex can be powered via the JST connector.

Average Camera Power Consumption	< 15W
Recommended Power Supply Voltage	15W, 12V – 24Vdc via GPIO
Average Current	1 A
Peak Pulse Current	2.8A

Temperature

The HLS003S should be kept in the following storage, operating, and humidity conditions.

Storage Temperature	-30 to 60°C
Operating Temperature	-10 to 60°C case temperature
Humidity	Operating: 20% ~ 80%, relative, non-condensing

Placing the camera outside of these conditions may result in damage to the device.

Revision History

Version Number	Date	Changes
V1.0.0	November 20, 2019	First internal release of this document.
V1.0.1	November 29, 2019	Updated drawings.
V1.0.2	February 17, 2020	Added TX2 installation instructions Added ArenaFlex documentation