

APPLICATION NOTE

```
// Create an instant camera object with the first
Camera_t camera( CT1Factory::GetInstance().Creat

// Register an image event handler that accesses
camera.RegisterImageEventHandler(_new CSampleIma
Ownership_TakeOwnership);

// Open the camera.
camera.Open();
```

Basler Low Resolution Cameras: CCD to CMOS Migration Guide

Document Number: AW001500
Version: 02 Language: 000 (English)
Release Date: 9 July 2018

Contacting Basler Support Worldwide

Europe, Middle East, Africa

Basler AG
An der Strusbek 60–62
22926 Ahrensburg
Germany

Tel. +49 4102 463 515
Fax +49 4102 463 599

support.europe@baslerweb.com

The Americas

Basler, Inc.
855 Springdale Drive, Suite 203
Exton, PA 19341
USA

Tel. +1 610 280 0171
Fax +1 610 280 7608

support.usa@baslerweb.com

Asia-Pacific

Basler Asia Pte. Ltd.
35 Marsiling Industrial Estate Road 3
#05–06
Singapore 739257

Tel. +65 6367 1355
Fax +65 6367 1255

support.asia@baslerweb.com

www.baslerweb.com

All material in this publication is subject to change without notice and is copyright Basler AG.

Table of Contents

1	Overview and Aspects to Consider for Migration.....	2
1.1	CCD and CMOS Technologies.....	3
1.2	Optical Considerations.....	4
1.2.1	Optical Size.....	4
1.2.2	Pixel Size.....	4
1.2.3	Optical Adjustment.....	6
1.2.4	Selecting the Correct Lens.....	6
1.3	Housing.....	7
1.4	Interfaces.....	8
1.5	GenICam Standard and Node Name Updates.....	9
1.6	Advantages of the Low Resolution CMOS Sensors.....	10
1.6.1	Improved EMVA Performance.....	10
1.6.2	New Features.....	11
2	Application Examples	13
2.1	Migrating From ICX445 to IMX273.....	13
2.2	Migrating From ICX414 to IMX287.....	14

1 Overview and Aspects to Consider for Migration

In March 2015, Sony announced the discontinuation of its complete line of CCD sensors. This means that Sony is not going to develop any CCD sensors in the future.

To ensure long-term availability and good support of our cameras, Basler now encourages all camera integrators to switch to CMOS sensor-based cameras.

Based on the Sony Pregius second-generation IMX273 and IMX287 CMOS sensors, Basler introduces eight new cameras in the ace series to fill the gap in the area of low-resolution sensors. Both sensors are featuring the global shutter technology. The GigE models are already available and will soon be followed by the USB 3.0 models:

Camera Model	Sensor	Resolution [Pixel x Pixel]	Frame Rate [fps]	Variant	Interface
acA720-290gm	IMX287	720 x 540	291	Mono	GigE
acA720-290gc	IMX287	720 x 540	291	Color	GigE
acA1440-73gm	IMX273	1440 x 1080	73	Mono	GigE
acA1440-73gc	IMX273	1440 x 1080	73	Color	GigE
acA720-520um	IMX287	720 x 540	525	Mono	USB 3.0
acA720-520uc	IMX287	720 x 540	525	Color	USB 3.0
acA1440-220um	IMX273	1440 x 1080	227	Mono	USB 3.0
acA1440-220uc	IMX273	1440 x 1080	227	Color	USB 3.0

Table 1: Overview of the Basler Low Resolution Cameras

This application note gives an overview of the main differences between CCD and CMOS technologies, and will then focus on the practical questions that everybody encounters when switching from CCD to CMOS low-resolution camera sensors.

Questions could be for example:

- Is the current setup still mechanically and electrically compliant with the new cameras?
- Are there any influences on the image quality when switching from CCD to CMOS technology?

1.1 CCD and CMOS Technologies

The role of an image sensor is to capture light and convert it into an electrical signal.

The CCD technology (**C**harge **C**oupled **D**evice) was first presented in the early 70ies. It is based on the charge accumulation of light-sensitive **Metal-Oxide Semiconductor** (MOS) capacitors. Each capacitor is associated to a control circuitry which transfers the collected charge to an amplifier, converting it into an output voltage. This analog voltage is then turned into a digital value. All the collected data constitutes the raw image data, i.e. the data provided by the sensor without any further processing.

In a CMOS image sensor (**C**omplementary **Metal-Oxide Semiconductor**), each photosensitive cell has its own charge amplifier. This allows much higher data transfer rates from the sensor, increasing the camera's maximum frame rates. However, as the photosensitive area was reduced in order to give space to the electronics, early CMOS sensors were offering lower sensitivity. Due to the implementation of micro-lens arrays, this is now no longer the case.

The [EMVA Data Overview](#) document on the Basler website shows you the relevant EMVA data of Basler cameras so you can get a good overview about quantum efficiency, saturation capacity, and other values.

Generally speaking, CMOS sensors have a higher saturation capacity, leading to a wider dynamic range than their CCD equivalent.

The following sections show some technical details that have to be considered if you want to migrate to the new Basler IMX273 and IMX287 CMOS sensors.

1.2 Optical Considerations

When upgrading to IMX273 or IMX287 Basler low-resolution cameras, the most significant change to perform is to adjust the working distance. This is the distance between the camera and the object it is focusing on. This section explains how to modify your application to get sharp images and how to find the optimum optical size.

1.2.1 Optical Size

If you want to compare two sensors, the first step consists in checking if the optical sizes differ. The IMX273 and IMX287 sensors have a 1/2.9" image circle. The following table indicates the image circle of the low-resolution Sony CCD sensors and of the IMX273 and IMX287 CMOS sensors in Basler cameras:

Optical Image Circle	Corresponding Sensors
2/3 "	ICX285
1/2 "	ICX205, ICX267, ICX414 and ICX415
1/2.9 "	New: IMX273 and IMX287
1/3 "	ICX204, ICX409, ICX424 and ICX445
1/4 "	ICX618

Table 2: Optical Image Circle of the Low-resolution Sony Sensors

Whether you have to adapt the lens depends on the image circle you've used before:

- If you've used a **larger image circle** (such as 1/2" or 2/3"), you can keep the same lens you've used before.
- If you've used a **smaller image circle**: Depending on the lens you've used, you may have to take into account the "**vignetting effect**" (see Figure 1). This means a reduction of an image's brightness or saturation toward the periphery compared to the image center. This effect occurs when the light going through the lens is reaching an area smaller than the sensor area.

Most of the lenses on the market have an optical image circle larger than 1/3", so vignetting effects shouldn't be a problem.



Figure 1: Vignetting Effect in an Image

1.2.2 Pixel Size

The sensor pixel size is the second parameter to take into account when you want to upgrade your CCD camera to one of the Basler low-resolution CMOS cameras.

The IMX273 pixels are 3.45 μm wide whereas the IMX287 pixels are twice as big, with 6.90 μm .

The pixel size depends on the sensor. The following table lists the pixel size of common low-resolution ICX sensors compared to the IMX273 and IMX287 sensors.

Sensor Name	Pixel Size [μm]
ICX414	9.90
ICX415	8.30
ICX424	7.40
IMX287	6.90
ICX409	6.50
ICX285	6.45
ICX618	5.60
ICX204	4.65
ICX205	4.65
ICX267	4.65
ICX445	3.75
IMX273	3.45

Table 3: Pixel Size of Low Resolution ICX and IMX Sensors

There is no one-to-one replacement regarding the pixel size. This is why you have to adjust your working distance.

Based on Table 3, you can see how to handle a transition to CMOS sensors. If your CCD sensor has a pixel size of 4.65 μm , two options are available.

- If you choose the **IMX287** sensor with a pixel size of 6.90 μm :
As the pixel size of the IMX287 is larger than 4.65 μm , your lens is going to deliver sharp images as it used to do before. You don't have to exchange the lens.
However, take into account that the new resolution of your application is going to be lower (720 x 540).
- If you select the **IMX273** sensor with a pixel size of 3.45 μm :
Because your lens may now be unable to resolve the small pixels, you may get blurred images.
The resolution is unchanged, but you may have to upgrade your optics.

One additional option to deal with the different pixel sizes is the Binning feature. This feature is now available on Basler mono cameras with IMX273 and IMX287 sensors and it offers you the flexibility to combine pixel data. For more information regarding the Binning feature, please refer to the [FAQ](#) on our website and the [Basler Product Documentation](#).

1.2.3 Optical Adjustment

The pixel sizes of the Basler low-resolution CMOS sensors differ from their CCD counterparts. This requires an optical adjustment of the new setup:

- If the pixel size of your new camera is **bigger**, you have the following options:
 - If you want to use the **same lens** as before, you will have to mount the camera closer to your object to get similar results.
 - Alternatively, you can use **another lens** with a greater focal length and position your camera farther away from the object.
- If the pixel size of your new camera is **smaller**, you have the following options:
 - If you want to use the **same lens** than before, you will have to mount the camera farther away to get similar results.
 - If you can't increase the working distance, you can use **another lens** with a smaller focal length and position your camera closer to the object.

1.2.4 Selecting the Correct Lens

As mentioned above, upgrading to an IMX273- or IMX287-based camera may require changing the optics. Make sure that the resolution of the lens you select is high enough for the sensor (in line pairs per millimeter, LP/mm).

- The IMX273 sensor with a pixel size of 3.45 μm requires a lens which is able to distinguish around 150 LP/mm.
- The IMX287 sensor tolerates lower lens resolutions. The 6.90 μm pixel size allows around 75 LP/mm.

To get information about the lens resolution, look at the manufacturer specification. For example, Basler provides the following curves for the 1/2.5" Basler lens:

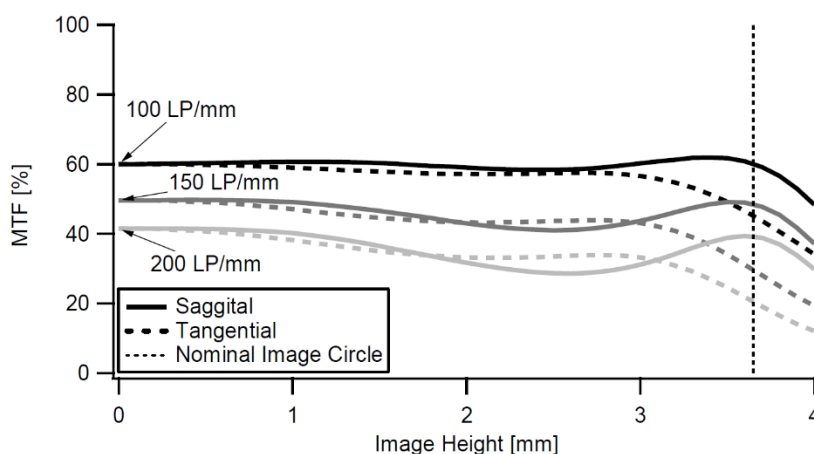


Figure 2: Modulation Transfer Function (MTF) of the Basler 1/2.5" Lens

The 150 LP/mm MTF waveform remains well over 40 %. Therefore, the resolution of the lens is high enough for both IMX273 and IMX287 sensors.

Our [Basler Lens selector](#) is an excellent tool to find out which lens is the best fit for your application.

1.3 Housing

The IMX273- or IMX287-based low-resolution ace cameras are available in the 29 mm x 29 mm “sugar cube” housing with a standard C-mount.

To help you mounting your camera properly in your system, see the technical drawings (including drill positions) in the [Basler Product Documentation](#).

Examples

- If you have been using a CCD sensor-based Basler **ace camera**, there is no need to change anything. The housing stays the same and you simply have to exchange your camera.
- If you migrate from the Basler **scout series**, the housing is **much smaller**. When space is a key issue, the low-resolution Basler ace CMOS cameras are a good choice.

1.4 Interfaces

Choosing the right interface depends on many parameters, as for example:

- Required cable length
- Target bandwidth
- Frame rate

Our [Interface Advisor](#) helps you to find the best interface for your application.

The Basler low-resolution CMOS cameras are available with two standard interfaces, USB 3.0 and GigE. If your application is already using one of these interfaces, there is no need to change.

For **legacy scout models** with the FireWire (IEEE 1394) interface, we strongly recommend to upgrade to the USB3.0 interface. For more information, see the white paper [USB3 Vision Instead of FireWire - Better Performance and Lower Costs when Switching Camera Interfaces](#) on the Basler website. Essentially, transitioning to a USB3.0 interface will drastically reduce your CPU load and give you the chance to use longer cables.

Regarding **power supply**, the IMX273 and IMX287 sensor-based cameras are tolerating a supply voltage up to 24 V. The 12 V ($\pm 10\%$) limit of the ace classic series can now be exceeded, allowing you to supply your camera with the 24 V industry standard voltage.

Power over Ethernet (**PoE**) remains available, still offering the “one cable solution” for your application.

In terms of input/outputs, as part of the ace U family, the IMX273- or IMX287-based Basler low-resolution cameras offer both **opto-isolated** and **general purpose input/output (GPIO)** lines. If you migrate from a Basler scout camera, you now have the additional option to use GPIO lines. This gives you further flexibility to optimize triggering your camera and retrieving data from it.

The [ace circuit diagrams](#) provided in the [Basler Product Documentation](#) indicate the correct way to use the input/output line within your application.

1.5 GenICam Standard and Node Name Updates

Depending on the camera you were using to develop your application, your application code may show a few errors. This is probably due to changes in node names. There are two reasons for that:

- The **SFNC standard** has been introduced and established.

As the low-resolution Basler cameras are compatible with the GenICam standard, they can be easily integrated in your application. The GigE models are GigE Vision standard compliant, while the USB3.0 cameras follow the USB3 Vision standard.

The GenICam standard comprises the *Standard Feature Naming Convention (SFNC)*. This standard convention defines a common set of features, their behavior, and the related parameter names, ensuring the interoperability of cameras from different camera vendors.

The **USB3 Vision** standard compliant cameras are based on the **SFNC version 2**.

Basler GigE and **FireWire** cameras are based on **previous SFNC** versions. Therefore, the behavior of these cameras and some of their parameter names may differ, requiring an update in your source code. In order to get an overview about the differences between SFNC versions, take a look at the official [EMVA downloads](#) page, where you can find the SFNC documents. The “History” section is highlighting the updates.

- Basler has **updated some node names** on its own.

The *Programmer’s Guides* delivered with the pylon Camera Software Suite will guide you through the name changes that you may have to consider for your transition process.

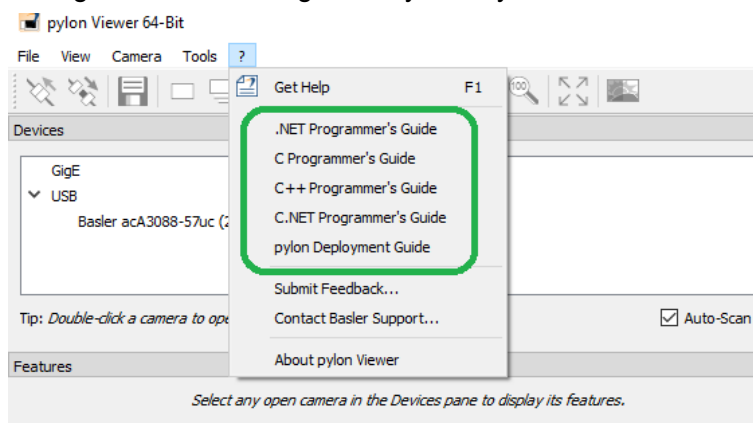


Figure 3: How to Access the pylon Viewer Programmer’s Guides

Example: Sequencer configuration

If your application is using the sequencer, you need to adjust your source code.

The sequencer can now be configured only if the Sequence Configuration Mode is activated. The corresponding parameter name is SequenceConfigurationMode.

1.6 Advantages of the Low Resolution CMOS Sensors

1.6.1 Improved EMVA Performance

The European Machine Vision Association (EMVA) defines a global standard to compare the performance of digital cameras: the [EMVA1288 standard](#).

Both IMX273 and IMX287 sensors surpass their CCD counterparts, especially regarding noise characteristics.

Furthermore, the saturation capacity of the Basler low-resolution CMOS cameras generally exceeds the capacity of the CCD sensors, leading to a considerable increase in dynamic range.

Sensitivity is the ability to deliver high image quality under low light conditions. The quantum efficiency (QE) indicates how sensitive the camera is. The second-generation Sony Pregius sensors show better values in these areas.

Sensor Data	ICX414	IMX287	ICX445	IMX273
Quantum Efficiency	37 %	70 %	57 %	70 %
Dark Noise [e-]	21.3	4	9.8	2.4
Saturation Capacity [ke-]	24.2	22.2	6.9	10.4
Dynamic Range [dB]	61.1	76.0	39.7	71.2

Table 4: ICX414 vs IMX287 and ICX445 vs IMX273 (Comparison of EMVA Data)

Keep in mind that quantum efficiency (QE) and saturation capacity have to be considered together. A higher QE means that your sensor is more efficient. However, a higher saturation capacity indicates that you need to collect more electrons to saturate the sensor. As a result, you may not systematically get brighter images than before.

A good side effect of the lower noise level is that you can increase the gain. This will help you getting a brighter image. Also, you can reduce the lighting without decreasing your image quality. As a result, this can reduce your overall application costs.

In addition to a good performance in the visible spectrum, the Basler low-resolution CMOS cameras are also showing a decent quantum efficiency in the near infrared (NIR) range.

1.6.2 New Features

The IMX273 and IMX287 cameras are offering some new features that are listed in the following table:

Features		IMX287		IMX273	
		acA720-290g	acA720-520u	acA1440-73g	acA1440-220u
Ultra Short Exposure Time Mode		x	x	x	x
PGI Feature	5x5 Demosaicing	Color only	Color only	Color only	Color only
	Color Anti-aliasing	Color only	Color only	Color only	Color only
	Sharpness Enhancement	x	x	x	x
	Noise Reduction	x	x	x	x
Stacked ROI feature		Not supported		Supports up to 2 ROI zones	
Precision Time Protocol (PTP)		x		x	

Table 5: Overview of Available Features

Both IMX273 and IMX287 sensors have the **Ultra Short** exposure time mode available. This feature allows extremely short exposure times down to one microsecond. This makes them particularly attractive for applications with fast movements, where image sharpness could otherwise be at stake. In the following table, the two modes are compared:

Exposure Time Mode	Minimum [μ s]		Maximum [s]	Increment [μ s]
	(8-bit Pixel Format / 12-bit Pixel Format)			
Ultra Short	All models mentioned below	1 / 1	13 μ s	1
Standard	acA1440-73g	22 / 23	10	1
	acA720-290g	22 / 20	10	1
	acA1440-220u	21 / 20	10	1
	acA720-520u	30 / 24	10	1

Table 6: Comparison: Ultra Short Exposure Time Mode / Standard Exposure Time Mode

The Ultra Short exposure time mode (the corresponding node name is ExposureTimeMode) is available if the exposure mode (ExposureMode) is set to Timed and exposure auto (ExposureAuto) is set to Off.

Furthermore, all eight ace U cameras in Table 6 are available with GigE and USB 3.0 interfaces and include Basler's proprietary PGI Feature Set. For the four **color models**, the following features are available:

- **5x5 Demosaicing** delivers cleaner transitions between colors and eliminates artifacts.
- **Color anti-aliasing** analyzes and corrects the discolorations.
- **Sharpness enhancement** delivers an excellent reproduction of black and white structures.
- **Noise reduction** produces a good low-noise image.

The experience with the **Basler PGI Feature Set** for color cameras encouraged Basler to also develop the feature set for mono cameras. The four low-resolution mono cameras provide the Sharpness Enhancement feature and the Noise Reduction feature.

The Basler PGI Feature Set considerably improves your image quality. Because it is performed inside the camera, your CPU load does not increase. For in-depth information, please refer to the white paper: [Better Image Quality with Basler PGI](#).

Additionally, the Basler low-resolution IMX273 cameras let you select **multiple regions of interest (ROI)** with the Stacked ROI feature. Selecting multiple ROIs allows you to increase the frame rate and to reduce the data load when reading image data. For more information, see the [Stacked ROI](#) feature topic in the *Basler Product Documentation*.

In addition to the features mentioned above, the GigE models also offer powerful **GigE Vision 2.0 features** such as Precision Time Protocol (PTP). This feature allows you to precisely synchronize multiple cameras in your application. You can find additional information on PTP in the [Synchronous and in Real Time: Operation of Multiple Cameras in a GigE Network](#) white paper and in the [Precision Time Protocol](#) topic in the *Basler Product Documentation*.

2 Application Examples

The following sections show two migration examples:

- Section 2.1 describes the migration to a camera with an **IMX273** sensor.
- Section 2.2 describes the migration to a camera with an **IMX287** sensor.

2.1 Migrating From ICX445 to IMX273

If you have been using an ICX445-sensor based camera, the IMX273 sensor is a good candidate for migrating.

Sensor Data	ICX445	IMX273
Shutter Mode	Global	Global
Resolution	1296 x 966	1440 x 1080
Optical Size	1/3"	1/2.9"
Pixel Size [μm]	3.75	3.45

Table 7: IMX273 as a Replacement for the ICX445

Both pixel size and sensor size of the cameras are in the same range, which makes only a few adjustments necessary.

To migrate from acA1300-22gm to acA1440-73gm (example):

Application scenario

Lens: Basler lens C125, 16 mm focal length
 Object height: 100 mm
 Working distance: 458 mm

[AOI = ROI (area / region of interest)]

1. Reduce the area of interest (AOI) and make sure that your image is centered:
 - a. Reduce the AOI setting of the IMX273 camera from 1440 x 1080 (default) to the AOI size of your previous camera, for example 1296 x 966.
 - b. Use the Center X and Center Y features to center your image.
2. Determine the lens and camera setup. You have the following options:
 - Set your camera at a **larger distance** to the object.
If you **keep the same lens** and set up a **working distance** of 495 mm, this will allow you to capture the same image area as with the old camera.
 - Use a **different lens** with a **smaller focal length** at a **closer distance**.
For example, the Basler C125, 12 mm lens mounted 373 mm away from the object offers you similar results as before.

- If you need to **keep the previous working distance**, you can use a **lens with a variable focal length** (generally called “vario focus” or “zoom” lens).
Make sure that the resolution of the selected lens is high enough for the sensor pixel size.
- If you want to use the **same lens at the same working distance** as before, you will capture a smaller image. This is probably not an option.

There is no “best choice” valid for all applications. It depends on your setup whether changing the working distance and/or the lens is an option.

Once these adjustments have been made, your new setup with the CMOS camera offers a higher EMVA performance. This allows you to make the following steps:

3. Optional:
Reduce your lighting
4. Optional:
Depending on your application (exposure time, AOI...), the maximum framerate of your new camera may be higher. This allows you to increase the speed of your application, thus gaining efficiency.

2.2 Migrating From ICX414 to IMX287

If you have been using an ICX414-based camera, the IMX287 sensor is a good candidate for migrating.

Sensor Data	ICX414	IMX287
Shutter Mode	Global	Global
Resolution	658 x 492	720 x 540
Optical Size	1/2"	1/2.9"
Pixel Size [µm]	9.9	6.9

Table 8: IMX287 as a Replacement for the ICX414

To migrate from scA640-74fc to acA720-520uc (example):

Application scenario

Lens: Basler lens C125, 8 mm focal length
 Object height: 500 mm
 Working distance: 826 mm

1. As mentioned before, the FireWire interface is no longer available.
Make sure that the system you want to migrate to is USB3 compliant.
For more information, see the following white paper: [USB3.0 \(USB3 Vision\) instead of FireWire – better performance and lower costs when switching camera interfaces](#)

2. Reduce the area of interest and make sure that your image is centered:
 - a. Reduce the AOI setting of the IMX287 camera from 720 x 540 (default) to the AOI size of your previous camera, for example 658 x 492.
 - b. Use the Center X and Center Y features to center your image.
3. Determine the lens and camera setup. You have the following options:

- Set your camera at a **larger distance** to the object.
If you **keep the same lens** as you used before and you set up a **working distance** of 1180 mm, this will allow you to capture the same image area as with the old camera.
- Use **a different lens** with a **smaller focal length** at a **closer distance**.
For example, the Basler C125, 4 mm lens mounted 600 mm away from the object offers you similar results as before.
- If you need to **keep the previous working distance**, you can use a **lens with a variable focal length** (generally called “vario focus” or “zoom” lens).
Make sure that the resolution of the selected lens is high enough for the sensor pixel size.
- If you want to use the **same lens at the same working distance** as before, you will capture a smaller image. This is probably not an option.

There is no “best choice” valid for all applications. It depends on your setup whether changing the working distance and/or the lens is an option.

Once these adjustments have been made, your new setup with the CMOS camera offers a higher EMVA performance. This allows you to make the following steps:

4. Optional:
Reduce your lighting.
5. Optional:
Depending on your application (exposure time, AOI...), the maximum framerate of your new camera may be higher. This allows you to increase the speed of your application, thus gaining efficiency.

Revision History

Document Number	Date	Changes
AW0015000 1 000	3 July 2018	Initial release version of this document.
AW0015000 2 000	9 July 2018	Removed the word Table above the Figure 3 caption. Corrected typos.