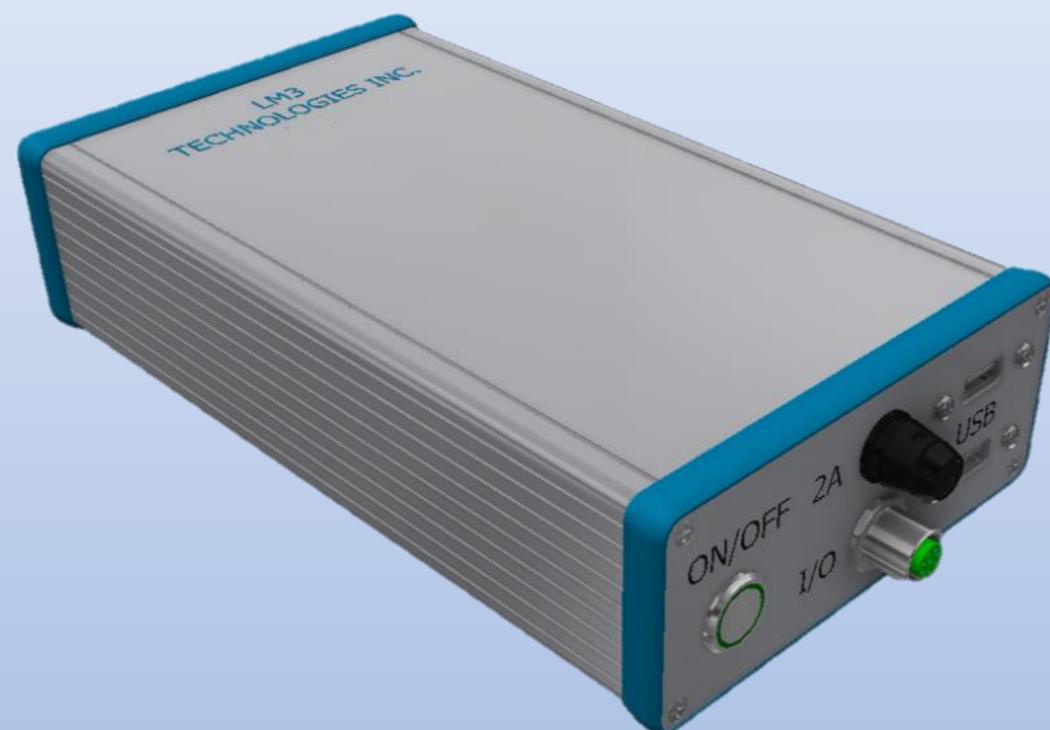




# Picture Acquisition and Inspection

The “PAQi”

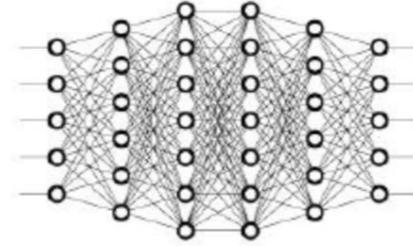
August 2019



## The PAQi main components inside



Intel NUC Gen8 Windows 10 Enterprise  
Version with Solid State M.2 Internal Hard  
Drive and up to 32GB RAM



Deep Learning Server: The PAQi comes standard with a deep learning inference server for processing trained object detection models for advanced product inspection.

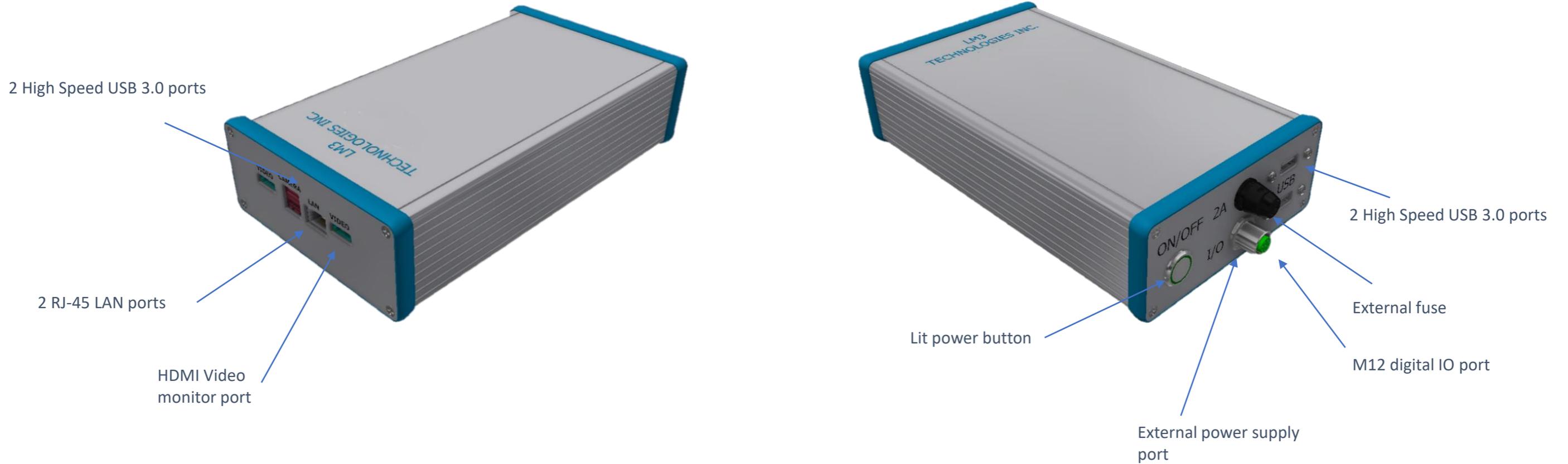


Optionally licensed: National Instruments image processing software called VBAI: Vision Builder Automated Inspection. This allows a set up machine vision tools to inspect parts traditionally.



A Programmable Logic Controller with Modbus RTU and TCP communications. This allows communication directly to other PLCs and allows control directly to digital input and output devices.

## The PAQi main outside component description



\* LM3's 2<sup>nd</sup> generation PAQi includes a Thunderbolt 3 port for connecting to an external GPU for fast AI deep learning inference.

# The PAQi main outside component detail

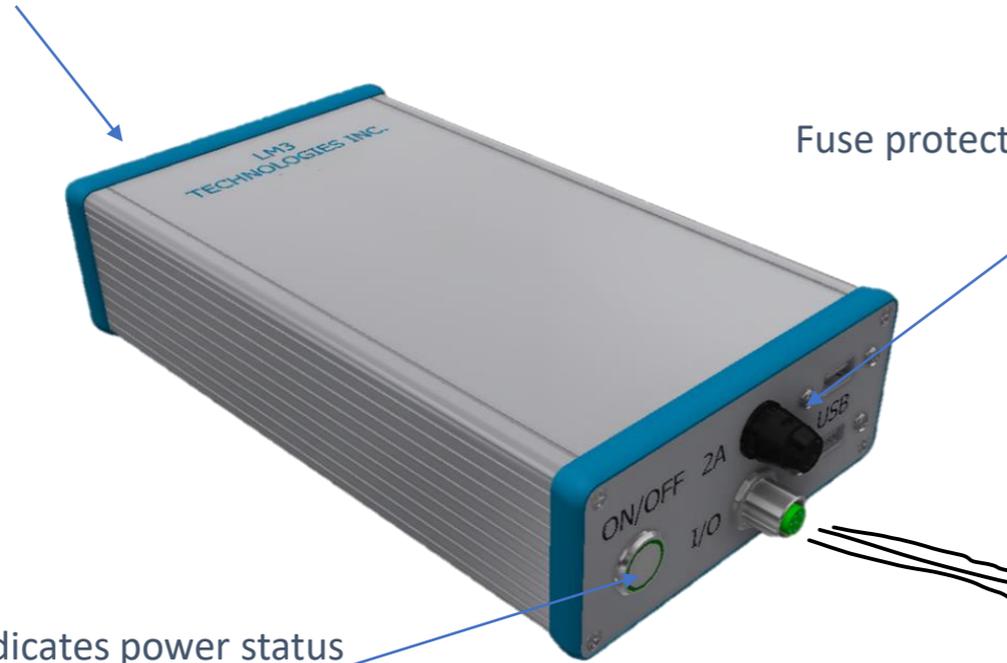
LAN ports allow connectivity to plant network to store info, transmit failure information, external "port-in" capability, communication to MES via Modbus TCP

Digital IO can run stack lighting for visibility or other outputs to external devices and receive sensor signals to trigger cycle

Fuse protected internal components

Lit on/off indicates power status at a glance

External power supply allows PAQi to be low voltage DC, allows multiple country AC voltage input, ie 100VAC to 240VAC  
Also allows quick replacement if failure of power supply



# The PAQi main outside component detail



Video output port allows connection of monitor to display failures, status, detection information, program setup/change screen, etc.



USB ports allow connection to mouse, keyboard, scanner, printer, etc



Digital inputs allow cycle start, part presence sensors, light curtain input, etc.



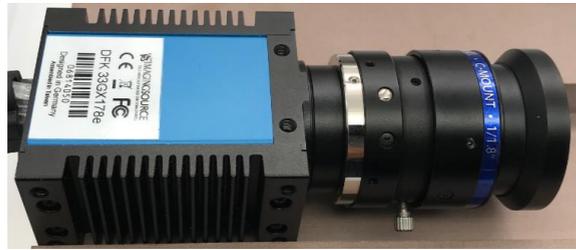
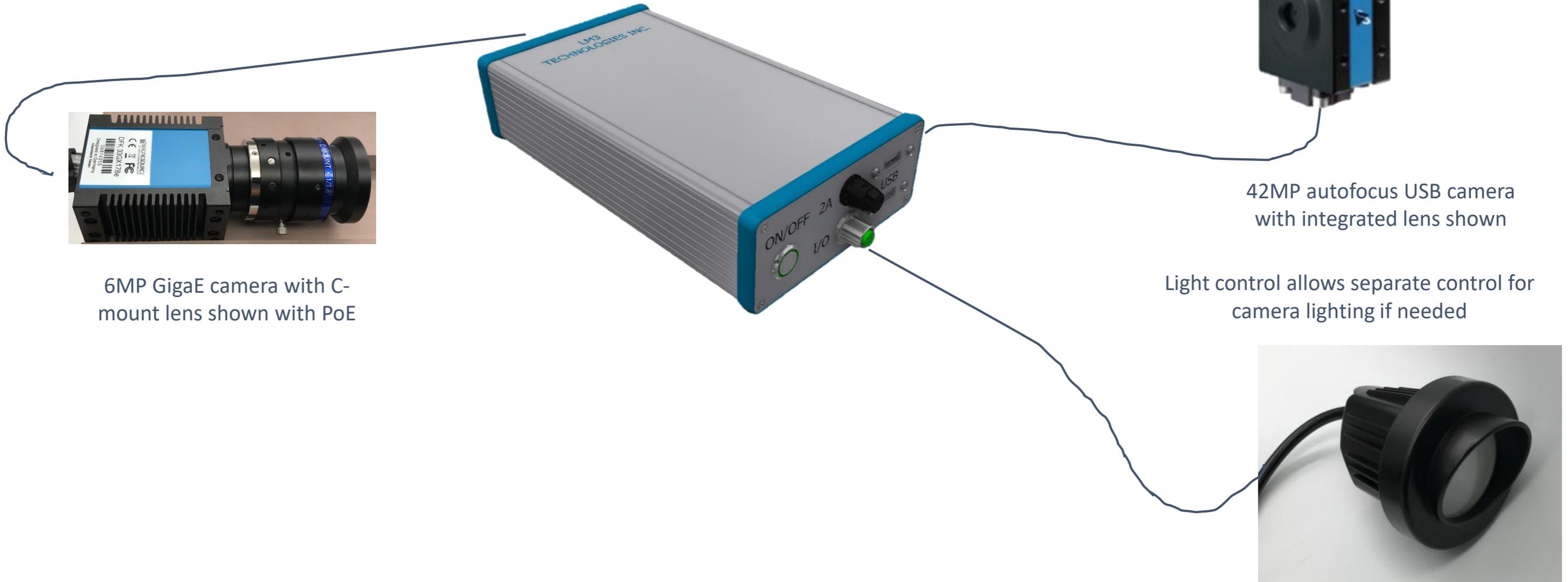
PAQi also contains a wireless controller for both WIFI and Bluetooth Support

## The PAQi main outside component detail

Using the main LAN connector and an external PoE Switch, PAQi can be expanded to acquire from up to 6 cameras

USB 3.0 ports allow for connection of high speed USB3 cameras up to 42 MP. However, any digital camera can be connected.

Currently the PAQi has drivers pre-loaded for Image Source industrial cameras



6MP GigaE camera with C-mount lens shown with PoE



42MP autofocus USB camera with integrated lens shown

Light control allows separate control for camera lighting if needed



6MP GigaE camera with C-mount lens shown with PoE

## The PAQi History

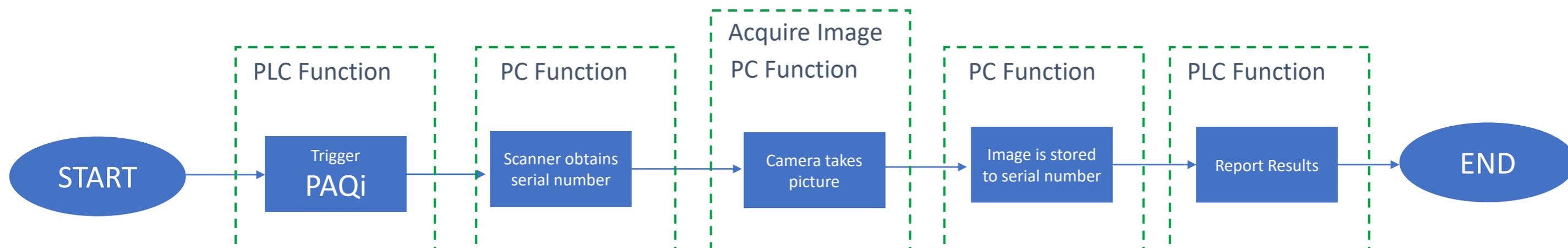


History: The PAQi was created for containment in a production environment. The first goal was to have a camera device or system that when triggered would simply take a photo and save the photo(s) to a file locally or over the network. The second goal was to link the photo to the product for traceability. This was initially designed to be triggered by the scan of the product serial number resulting in an image stored by that serial number. The purpose was to have traceability pictures for the customer as proof of assembly and assistance in problem solving. Many other cases were similar, and the pictures are named by a unique serial number commonly referred to as “warranty photos”. The third objective was to have a unit which could break the price barrier of traditional systems. Current vision systems are expensive and by reducing the cost of hardware, customers are able to deploy machine vision analysis across a wider range of applications, leading to a quality control standard. The system would have to be simple and low cost in such a way that if there was a failure, it would be quicker to unplug the unit, install a new unit with the program and be back in production very quickly. The system would have to be able to handle multiple cameras. The system would have to connect to a robot and be moved. The system would have to be able to change parameters and programs of the camera on the fly. Finally, the system would have to provide easy to use configuration tools to avoid consuming plant personnel’s time which is better spent on production.

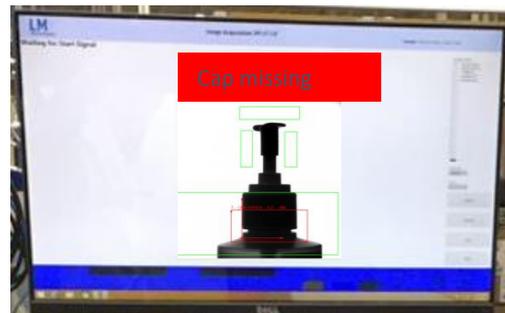
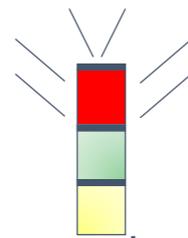
## The PAQi Functionality



Overview 1: The simplest function is for the PAQi to take photos and store them to a file. This is accomplished by connecting a USB camera or a GigaE camera to the PAQi. A scanner can be connected to a USB port, or the camera can be used to acquire the bar code information. A trigger, like a part presence, PLC, or start button can be connected to the digital input. The operation: The start button is pressed (and/or part presence detected sensor), the scanner turns on and acquires the unique bar code serial number, the camera takes a picture and then stores the image under the serial number as the file name. The indicator LEDs indicate status and green when complete and picture saved. This all happens in a few seconds. For storage on the server, the LAN port is used and IT can connect.

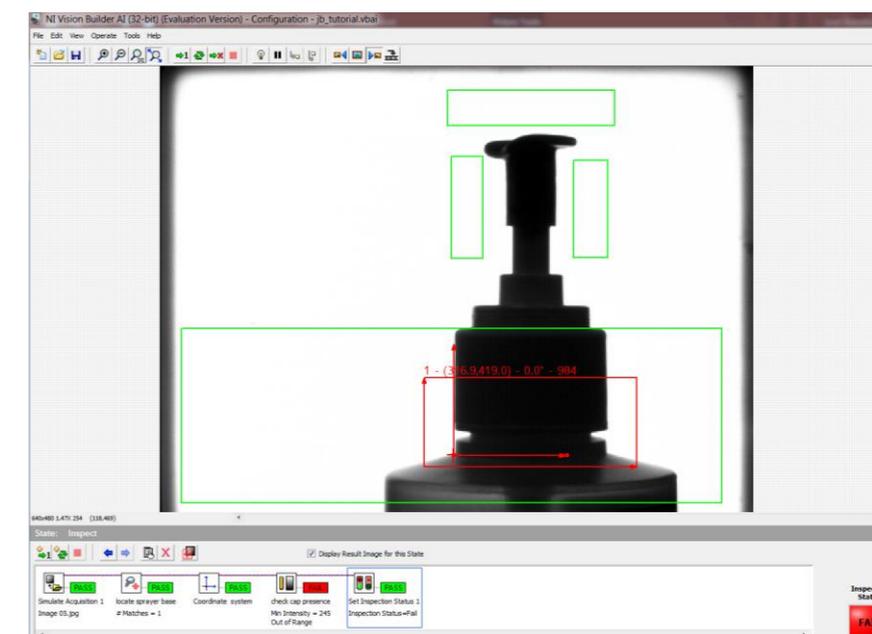
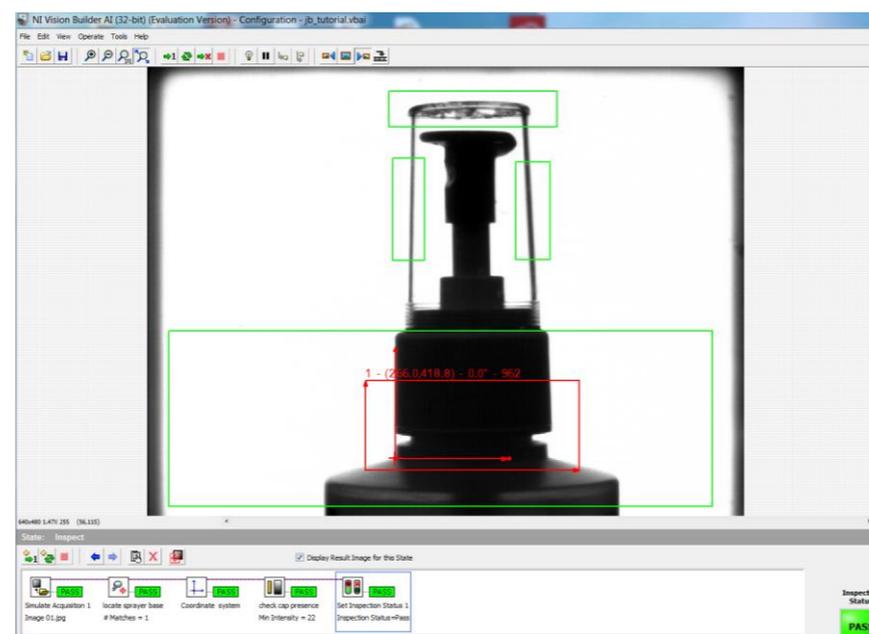


## The PAQi Functionality



Overview 2: Another function for the PAQi is to take photos, analyze them, store them to a file, & output. The analyzing is accomplished utilizing National Instruments (NI) VBAI software to process the image to the criteria that has been set up. See a typical NI screen is shown below. In this example you can see 3 distinct regions of interest (ROI) set up around the cap. The NI software is looking for dark pixels in that area indicating a cap is present. If the regions are white, or blank, then the cap is missing and the NI software fails the image. Notice the large ROI along the bottom, this is looking for the bottle. The bottle is allowed to move in that region and the cap ROI move too with the location allowing processing even if the bottle is not in the exact location. Rotation of a part can also be set up if needed.

Another note of processing that may be interesting, are the process steps shown along the bottom in the lower right screen example. The first step is acquire image & it did (green), then the software looks for the bottle base & found it (green), then determines if it is in the correct coordinate plane & it is in the window (green), then it looks for the cap presence & it is missing & failed (red), then it outputs the information & it outputted the failure box in the lower right hand corner correctly (green). The analysis worked and either found a cap or it didn't.

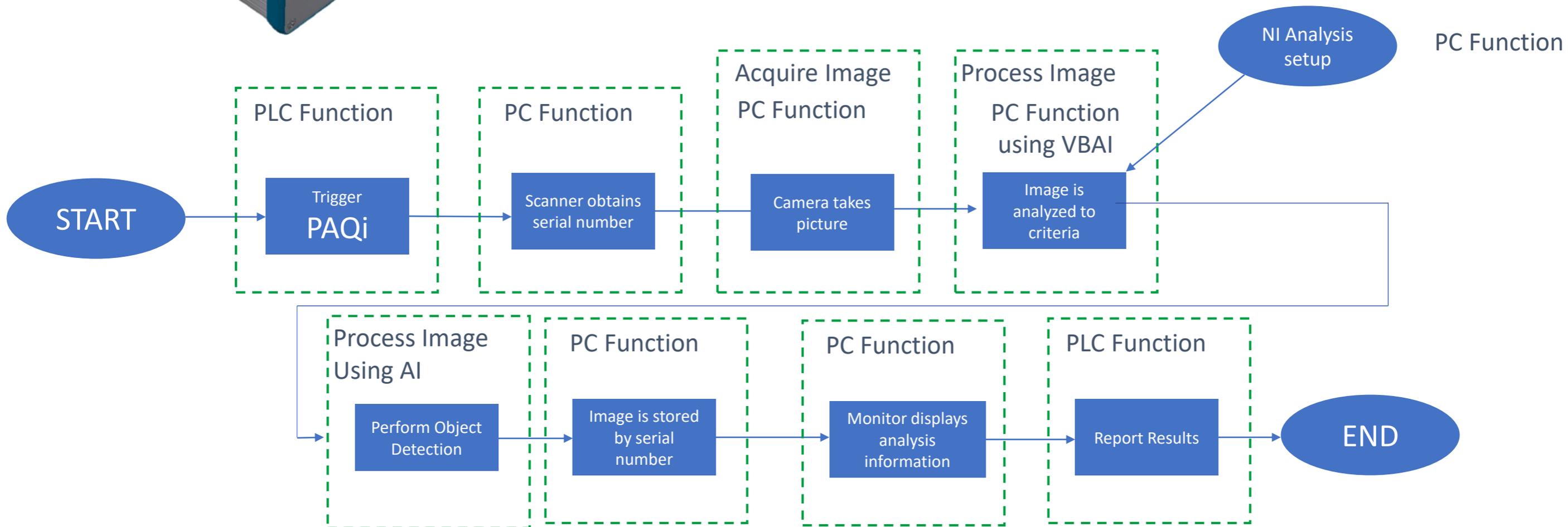


## The PAQi Functionality



Overview 2 (continued): Another function for the PAQi is to take photos, analyze them, and store them to a file and output information.

This function utilizes a licensed version of VBAI loaded into the PAQi or an included AI deep learning inference server. Utilizing the NI VBAI software the user can set up the areas of interest to be inspected. Analyzing regions can be set up by anyone internally or externally. The analysis is done from multiple images. This is where lighting and resolution are important for the user to develop a repeatable photo that highlight the components or areas that need to be evaluated. This may involve using different light color options as well as UV or IR lighting. NI offers many tools to evaluate images including color, intensity, particle detection etc. that allows the analysis to be robust.

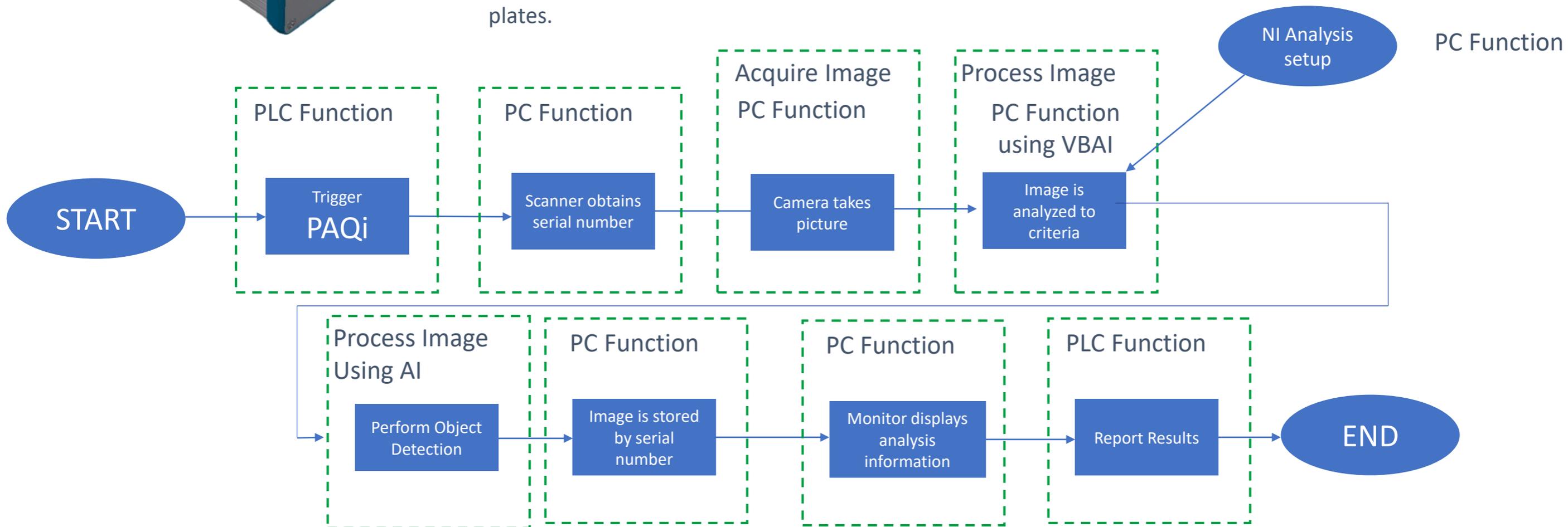


## The PAQi Functionality



Overview 3 (continued): In addition to traditional machine vision using VBAI, the PAQi is loaded with an AI Deep Learning Inference Server.

This function utilizes a licensed version of VBAI loaded into the PAQi or an included AI deep learning inference server. Utilizing AI, the PAQi is able to detect and locate objects of interest to determine if all expected objects are present and of good quality. Deep learning provides a means to detect objects without the need for a vision specialist to configure the inspection. Under this scenario, the PAQi is first used to collect images at which time LM3 provides training services to train a model capable of detecting objects of interest. The system is also capable of detecting the presence of unwanted items such as wrinkles in vehicle seats and dents and scratches on metal plates.



## The PAQi Functionality

Overview 3: Since the PAQi has multiple camera capability, it can take “warranty” pictures with some cameras and analyze pictures from other cameras. There are cases installed where 2 cameras are taking warranty pictures and 2 cameras are taking pictures and analyzing them. The different combinations are up to the user to configure. Areas that need lighting control are enclosed to prevent ambient light from affecting the image.



## The PAQi Function



Overview 4: The PAQi can be attached to a robot to take pictures and analyze if needed. The function is similar to previous functions, however, the same camera is not taking multiple pictures. This is referred to “stepping”. A robot will be moving to various locations, each location is stepped through. As an example: Step 1 may be at the top of a door panel, step 2 may be at the middle of a door panel and step 3 may be at the bottom of a door with an image required at each step, and perhaps the images are analyzed or just warranty pictures are required, etc. The robot must communicate to the PAQi and the PAQi must communicate to the robot. This communication is called handshaking. It is generally done through the PLC of the robot using EthernetIP communications but can be done using digital IO as well.

To describe anthropomorphically the communication would be something like this:

Robot: I’m at step 0 now

PAQi: I took an image to determine the serial number, Robot go to step 1

Robot: I’m at step 1 now

PAQi: I took an image, Robot go to step 2

Robot: I’m at step 2 now

PAQi: I took an image, Robot go to step 3

Robot: I’m at step 3 now

PAQi: I took an image, Robot go home

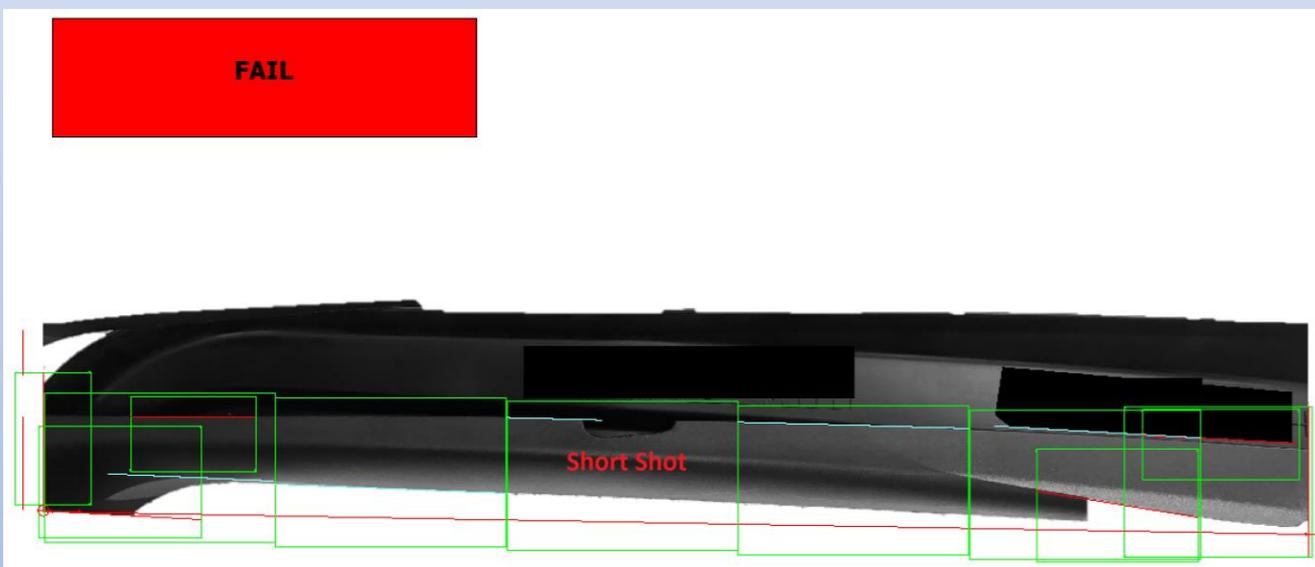
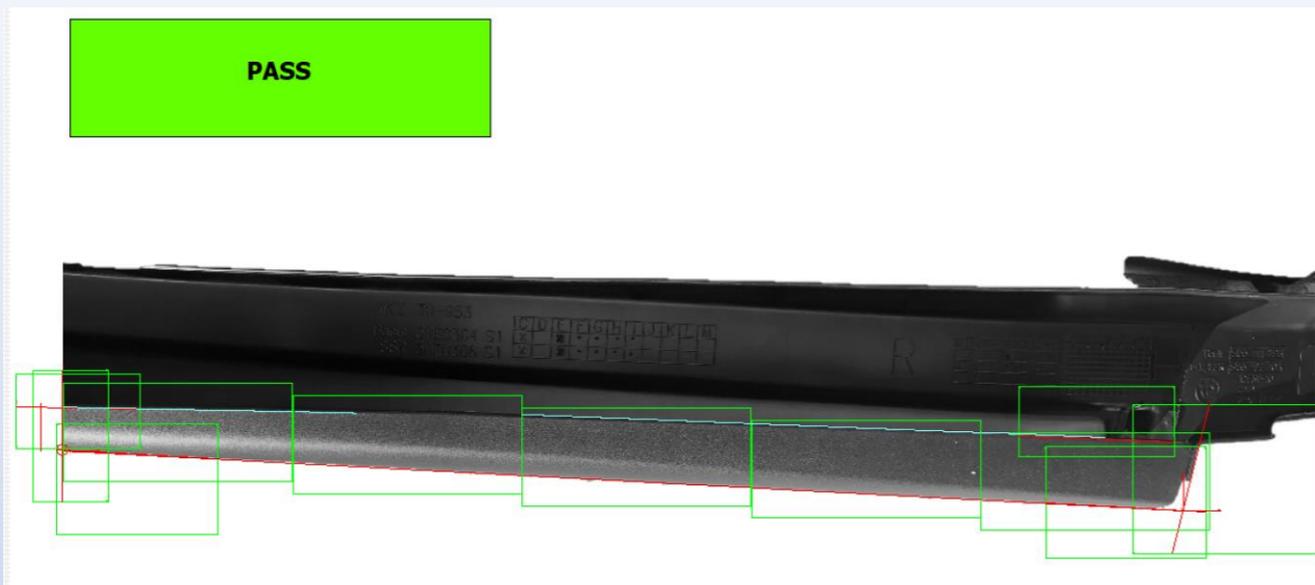
Robot: I’m at home now

PAQi: OK thanks, I’ll wait for you to go to step 0



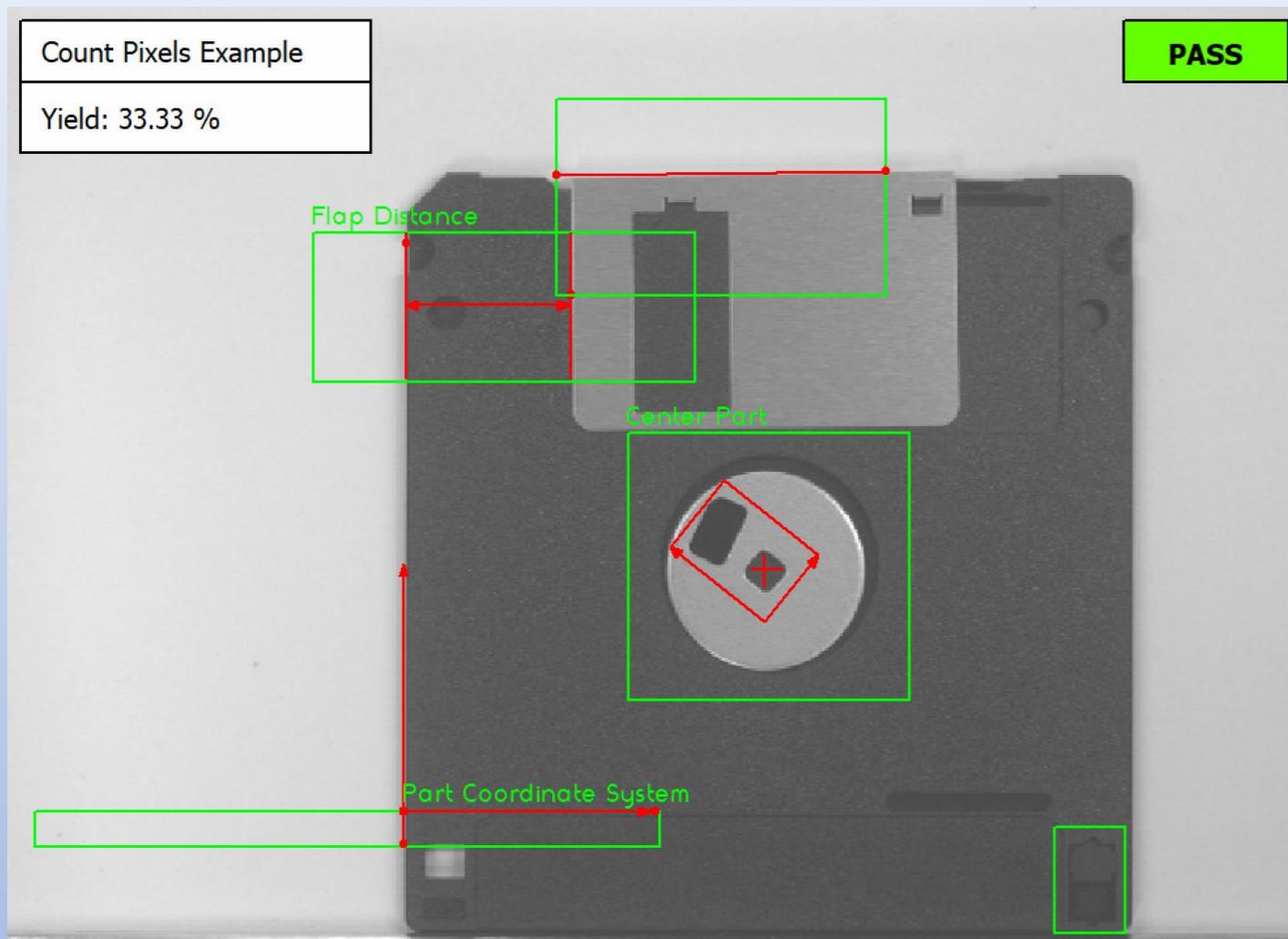
Of course the communication happens very quickly, but this type allows for the most robust form and eliminates “timers” and assuming the robot is in position. The images can be analyzed at each step or at the end depending on the preference and efficiency.

# Analysis Applications



1 – Molding Short Shot Detection

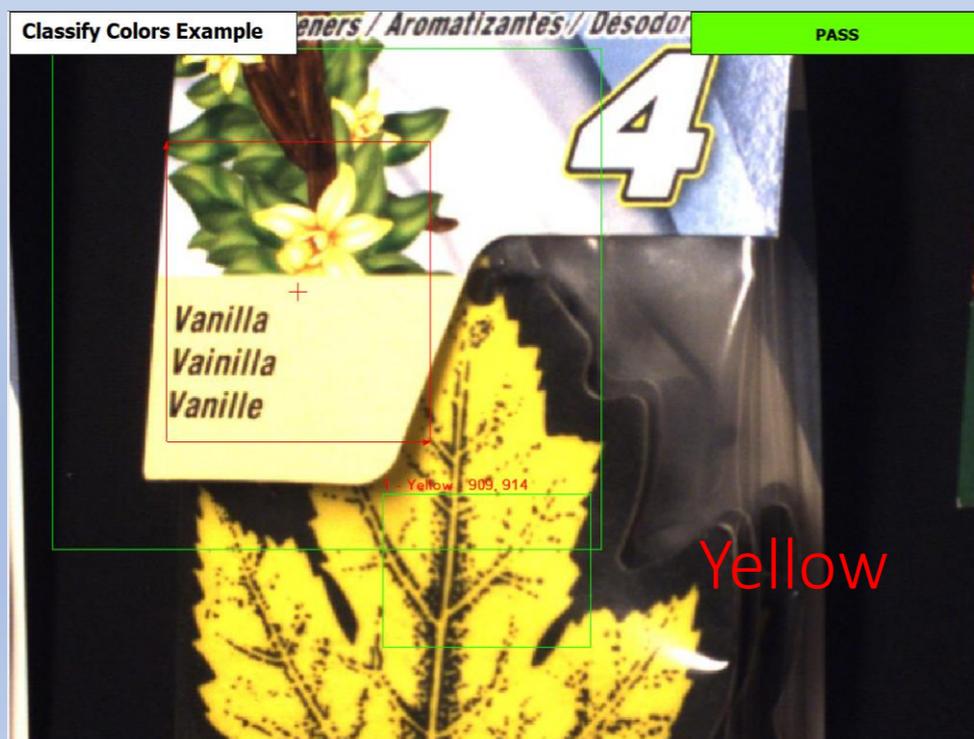
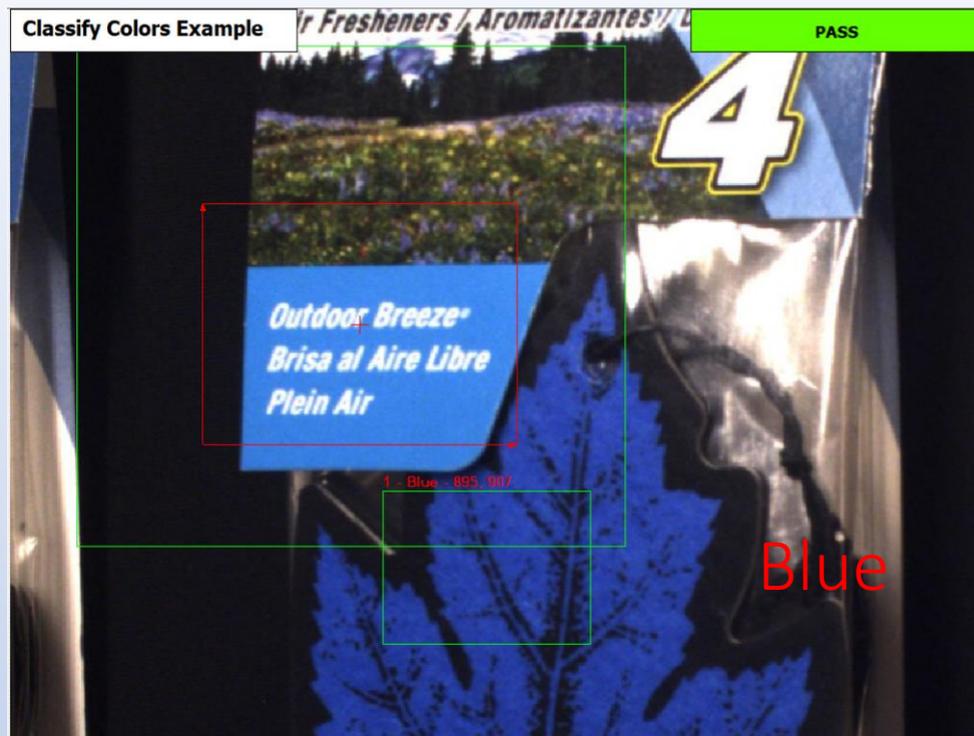
# Analysis Applications



2 – Pixel Counting and Measurements

# Analysis Applications

3 – Color Classification



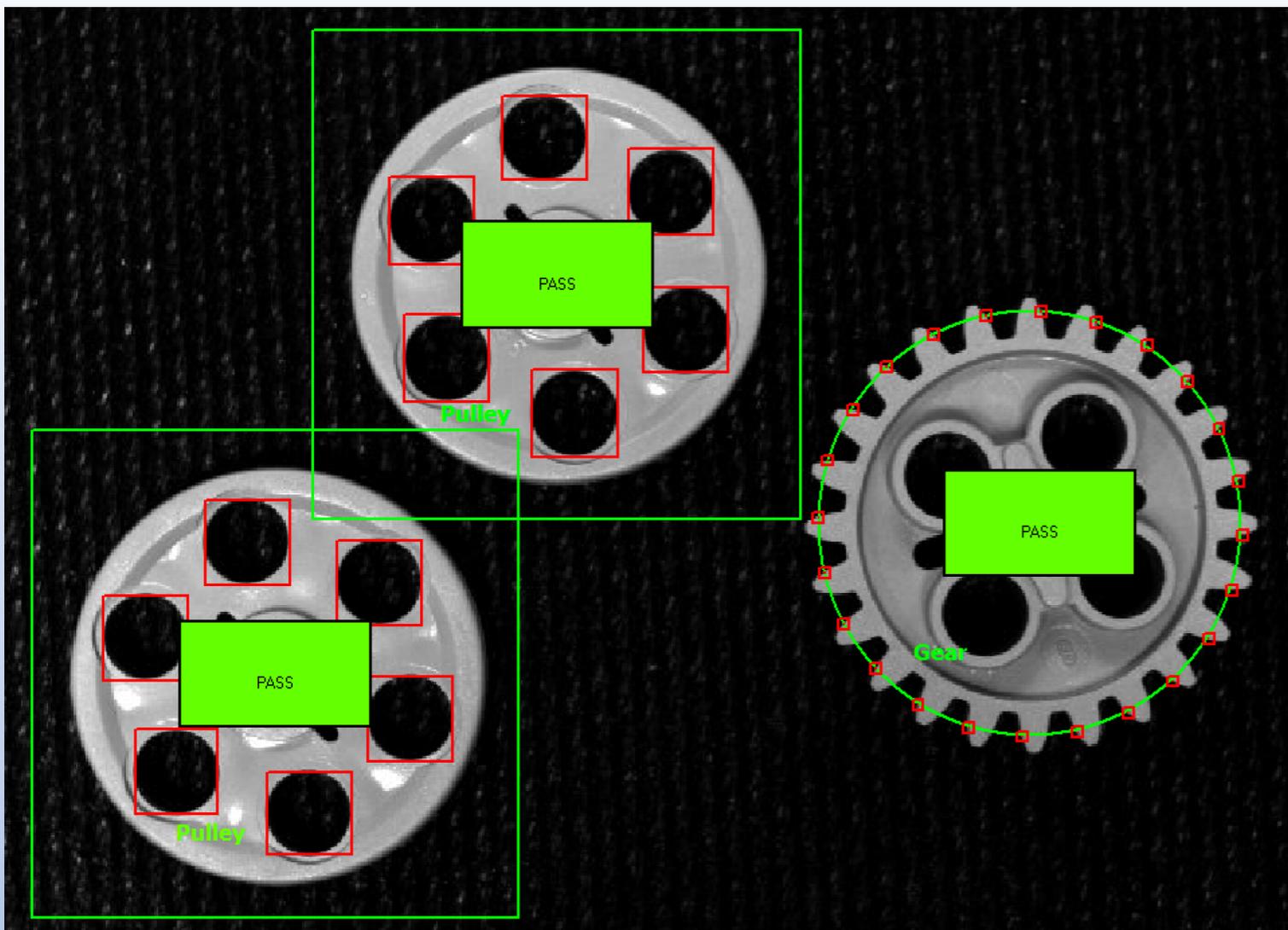
# Analysis Applications

4 – Object Tracking



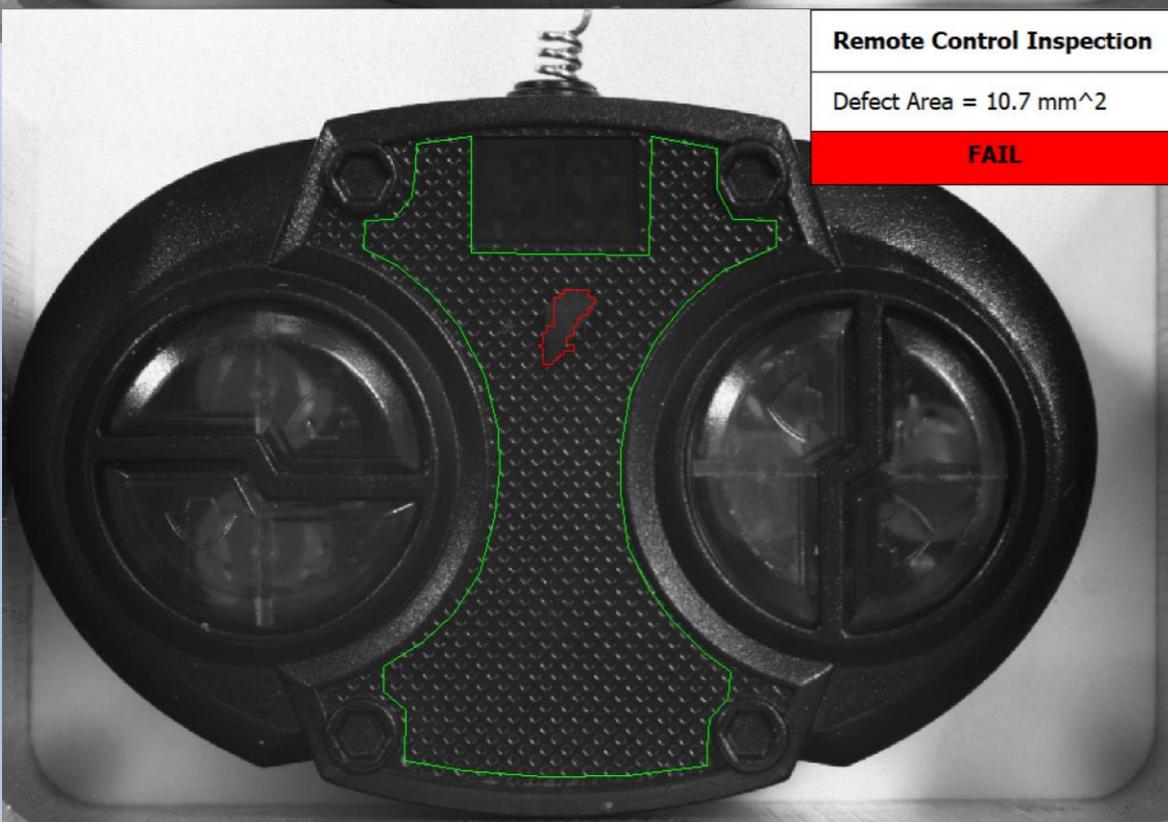
# Analysis Applications

5 – Object Classification



# Analysis Applications

6 – Defect Detection



# Analysis Applications

## 7 – Bar Code and Character Recognition



**Read Text Example**

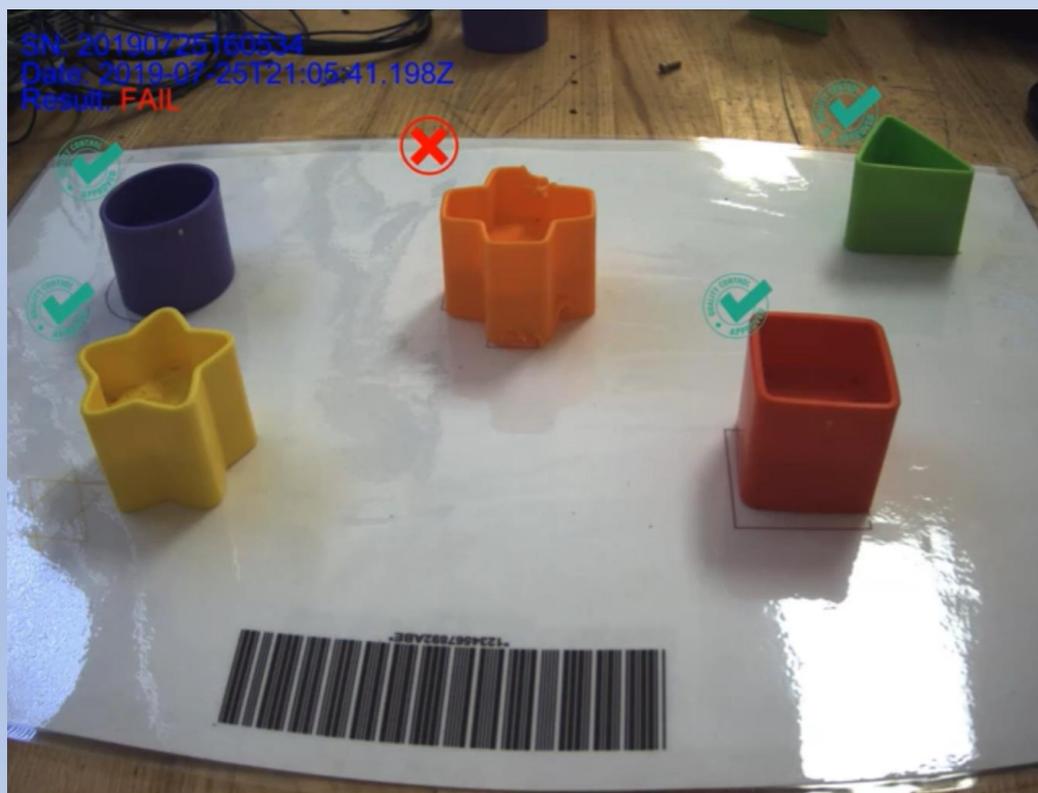
10:50:45 AM  
Parts Inspected: 5  
Pass: 3  
Fail: 2  
Yield: 60.00 %  
**Lot Number: 10472L**

**FAIL**

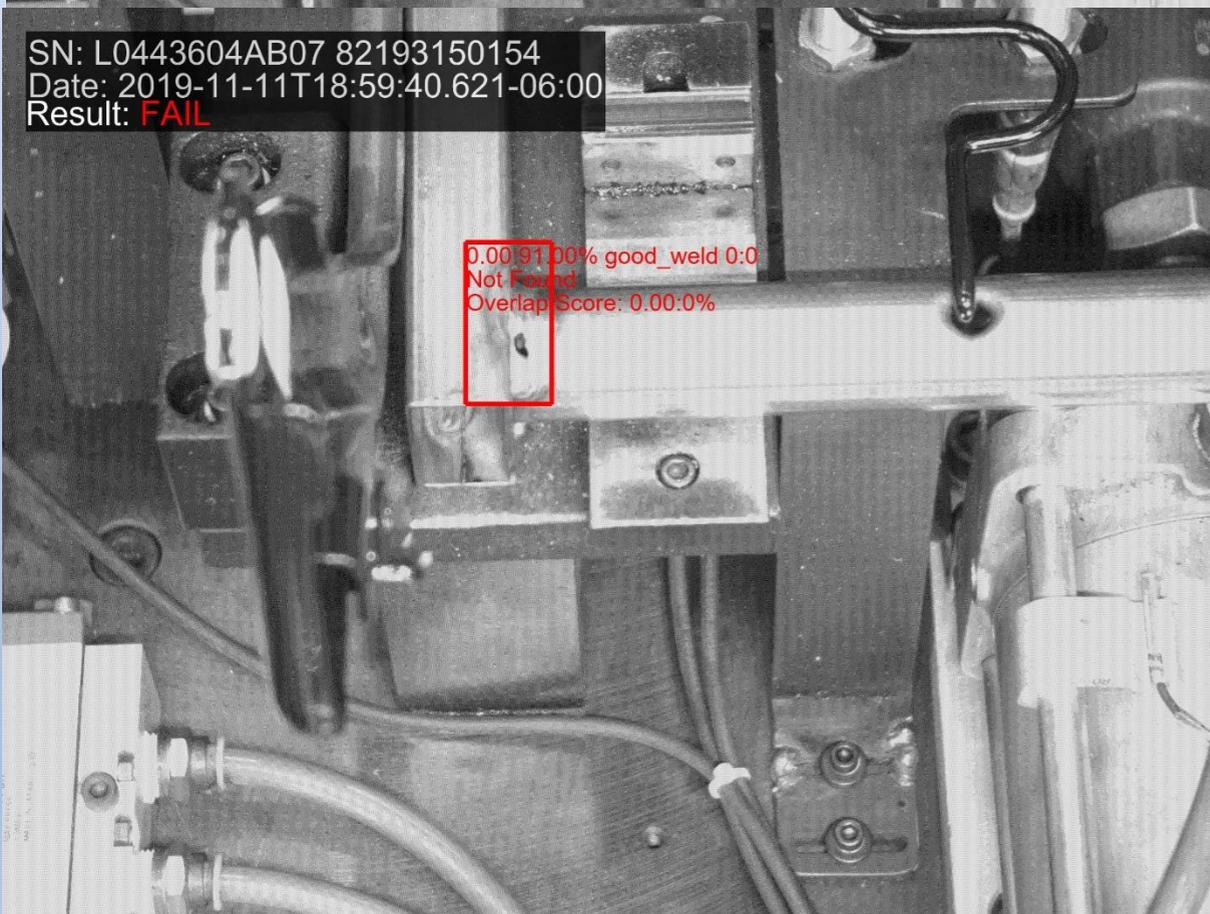
Phenylketonurics:  
Contains phenylalanine  
Store at 59° to 77° F in a dry place.  
Avoid heat and humidity.  
07-0355-15  
WARNING: THE CARRYING CASE  
MAY PRESENT A CHOKING HAZARD  
LOT 10472L  
10472L

# Analysis Applications

8 – Object Detection using AI

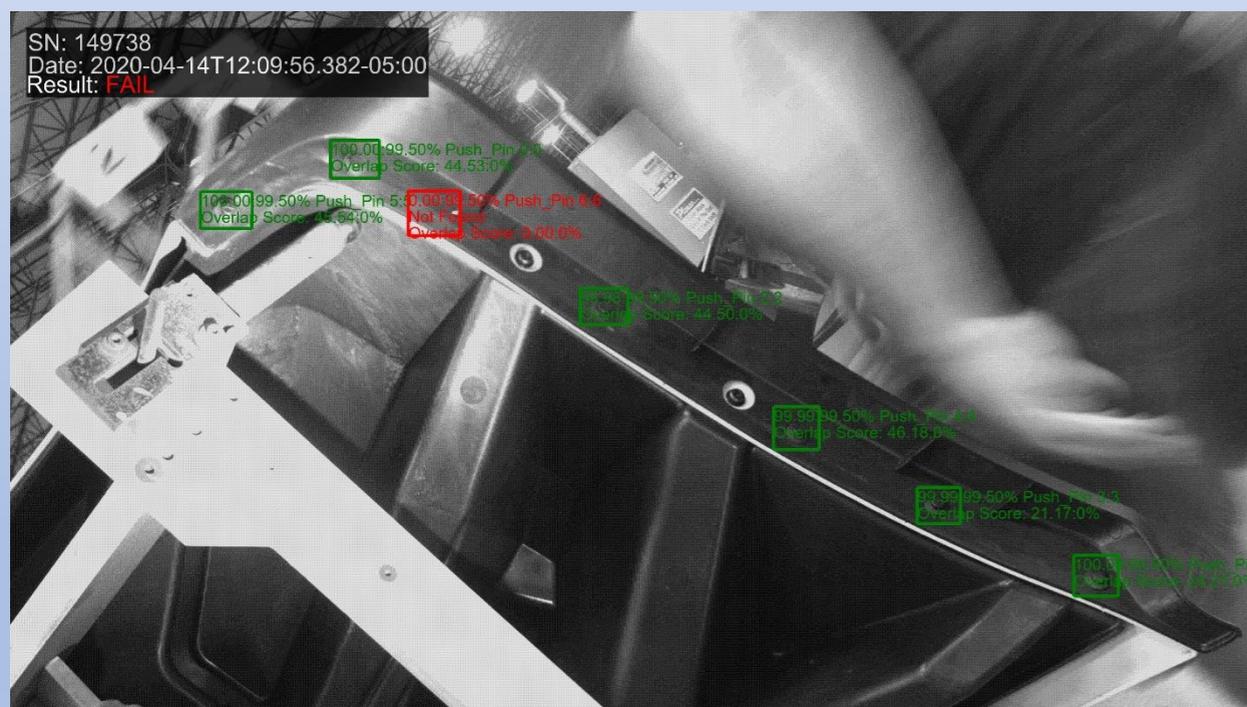


# Analysis Applications



9 – Weld Defect Detection using AI

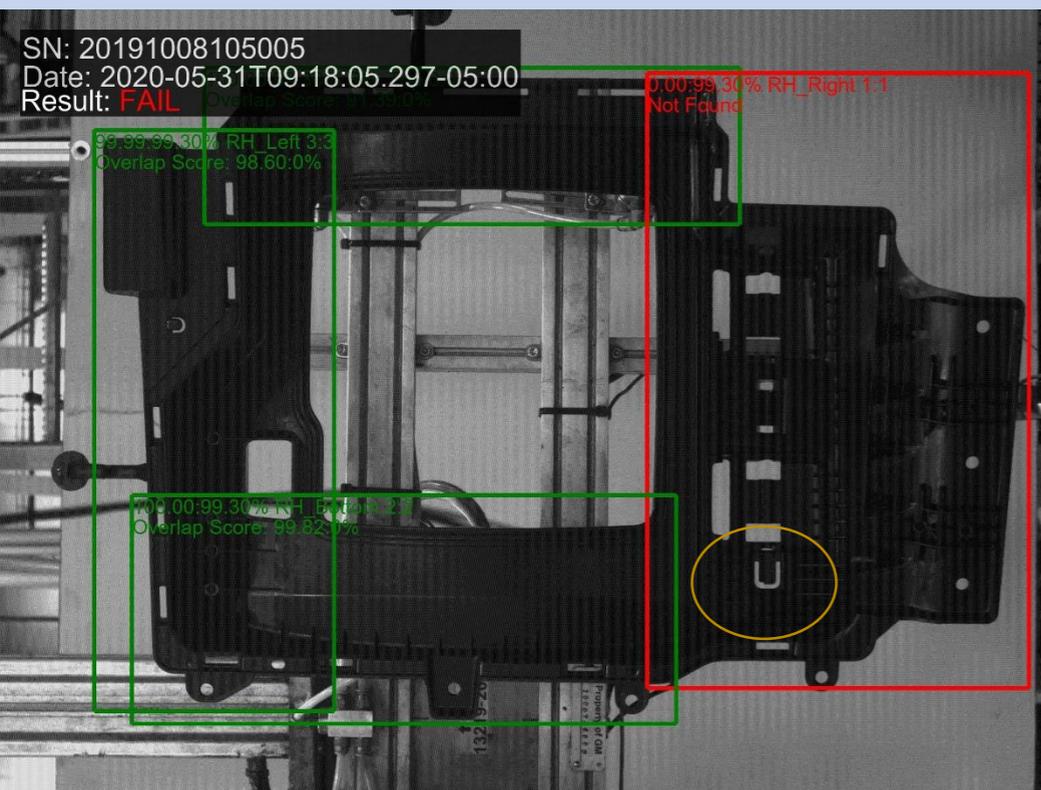
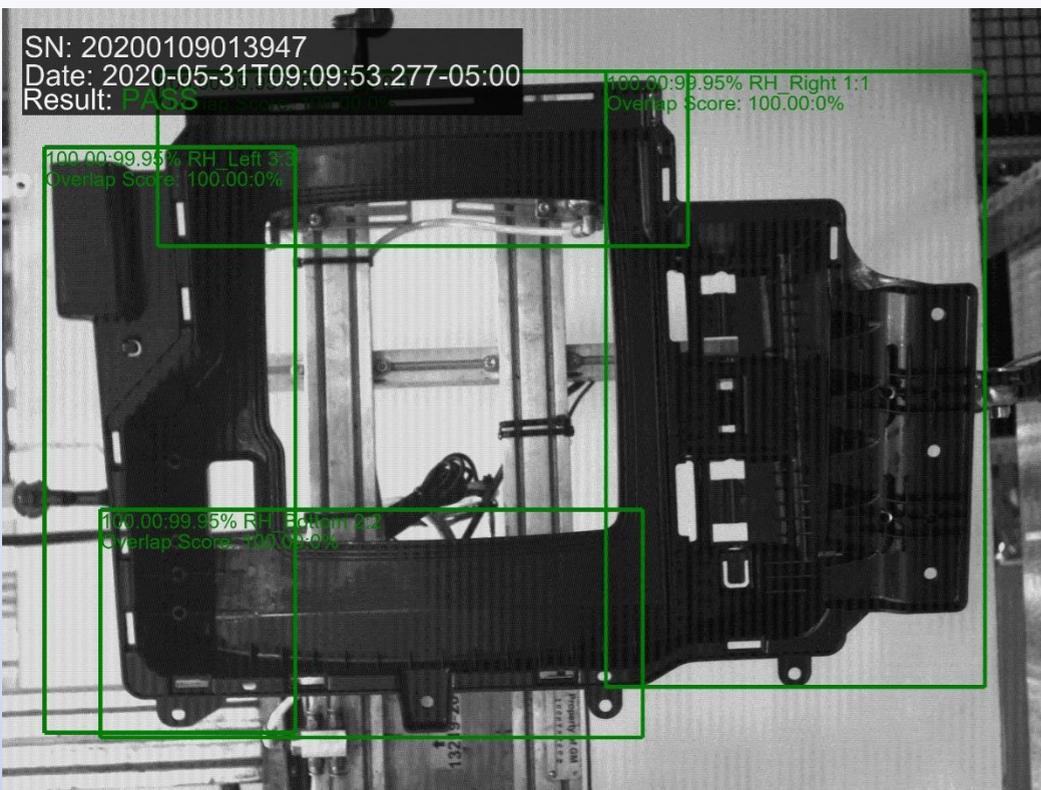
# Analysis Applications



10 – Small Parts on Large Part Presence Verification

# Analysis Applications

11 – Molded Part 100% Defect Detection



SN: 20200529055434  
Date: 2020-05-29T05:55:16.550-05:00  
Result: **PASS**



# Analysis Applications

12 – Hog Ring Presence Detection