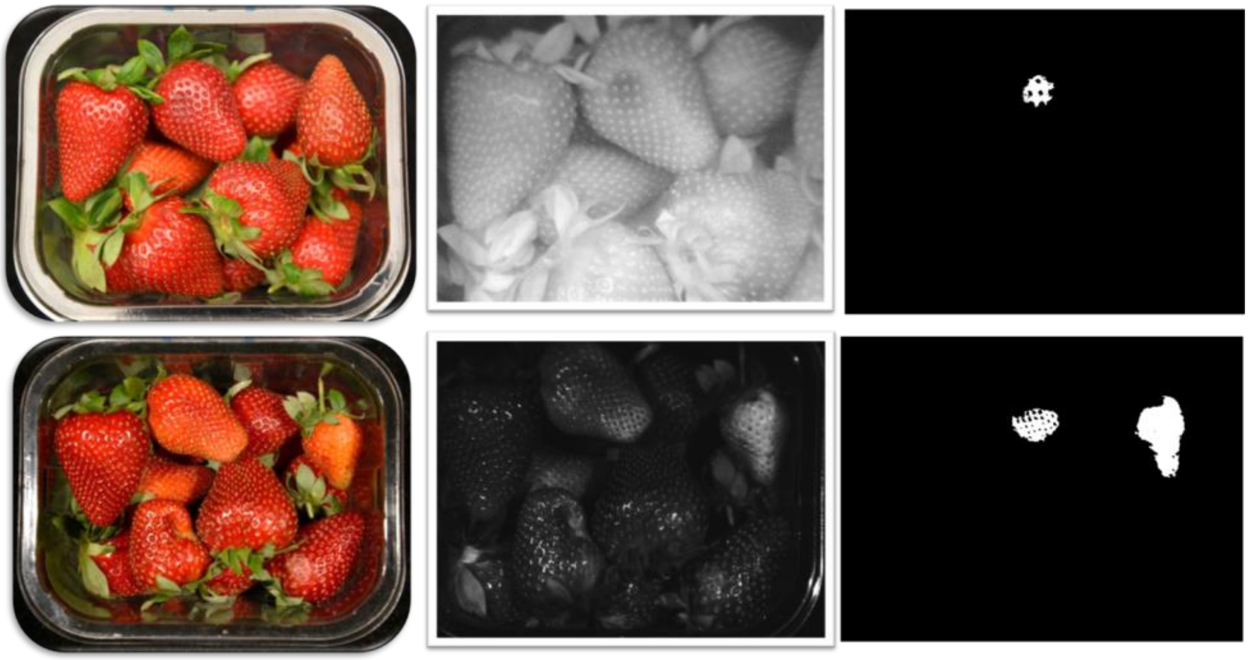
DESIGN: Punnet Quality Assurance



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ABSTRACT

This document develops the design for the Quality Assurance System for packed strawberries. This is a working document and is subject to change.

DISCLAIMER

Ver	Date	Initial	Changes
0.1b	14/1/2016	RFB	First draft ONLY.
0.2	22/01/2016	RFB	Updated hardware components based on calculations & feedback.
0.5	12/2/2016	RFB	Add software requirements.
0.6	23/2/2016	RFB	Added bandpas filter and conveyor concepts.
0.9d	10/3/2016	RFB	Several updates including, Operator changed to Supervisor after feedback from Chaehyun Lim (David) and added UI and more detail on conveying.
1.0	14/3/2016	RFB	Version 1.0 being finalised DRAFT ONLY

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1. Introduction

The machine vision based Quality Assurance System (System) for checking strawberry punnets that is under development will enable cost-effective, repeatable and accurate quality control of packed punnets versus the grower requirements.

This design seeks to exploit advances in machine vision that enable complex tasks such as quality assurance of fruit to be undertaken with better reliability, more rapidly and at a lower cost.

The System must be able to accurately and reliably check that each punnet meets the customer's quality standards at a speed of up to two punnets per second.

2. Layout

The System will be designed to fit between the strawberry packing benches and the punnet-sealing machine. The System will thus fit between the two existing conveyors and will conveyor the packed punnets through the System uninterrupted unless a non-compliance is detected. If non-compliance is detected then the System will eject the punnet from the conveyor so that the non-compliance can be addressed.

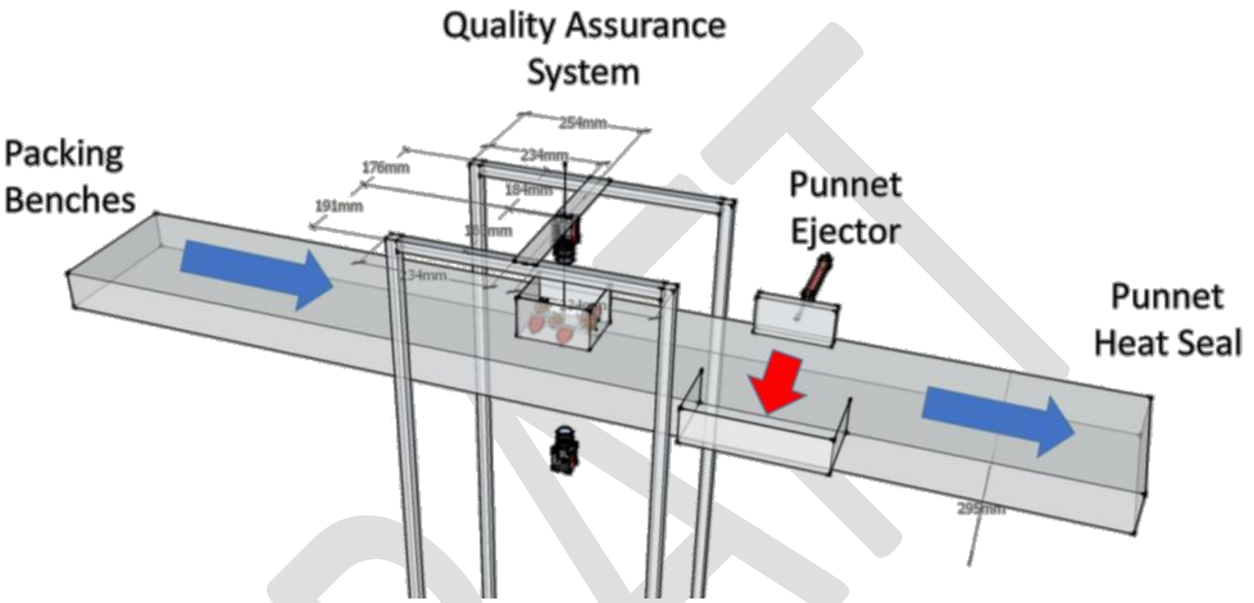


Figure 1: Conceptual layout of the System

3. Machine Vision

Machine vision is the core of the System and critical to the functionality. The key requirements for the machine vision components are:

The machine vision component (camera and lighting) must be able to capture images of the punnet:

1. With sufficient resolution to be able to quantify seediness of strawberries (see **Error! Reference ource not found.**).
2. So that the images remain sharp when the punnet is moving at 1 km/h.
3. Colours especially reds are clearly discernible.
4. The infra-red band (specifically at 980nm) is clearly visible.
5. So that the illumination is uniform with minimal shadowing.
6. So that the illumination has minimal specular reflections.

3.1 Cameras

Interface

The interface for machine vision cameras has considerably evolved. USB3 is now readily available at competitive prices while GigE (Gigabyte Ethernet Vision standard) including PoE (power over ethernet) has become common and far more price competitive.

GiGE with PoE offers simple robust wiring and connectors but sacrifices speed versus USB3 plus will likely require a network interface card (NIC) if load on the CPU is to be kept to a minimum.

USB3 option is preferred as:

1. Cable lengths are less than the maximum of 3 meters for USB3.
2. Lower cost as NIC and PoE will not be required or no spearate power cord is required.
3. Simpler and probably more reliable as fewer components.

Table 1: GigE with PoE versus USB3 interface.

	USB3	GigE with PoE
Throughput	400MB/s	125MB/s
Cable length	3m	100M
Power over cable	Yes 4.5W	Yes 15W
CPU Usage	directly to memory (no CPU)	very little if using NIC

Vision Sensor

The performance of Sony's Pregius CMOS technology is at least better than CCD sensors in the same price range and is able to capture using global shutter for distortion-free images at high speeds. These sensors outperform traditional CMOS sensors with excellent signal to noise (SNR), dynamic range and well capacity but providing digital advantages of CMOS like high speed and image correction (see Table 2).

Table 2: IMX174 vs CMOS and CCD sensors (http://www.1stvision.com/cameras/Sony-Pregius-global-shutter-CMOS-sensors.html).

Sensor	IMX174 (CMOS)	CMV2000 (CMOS)	ICX274 (CCD)
Manufacturer	Sony	CMOSIS	Sony
Resolution	1920 x 1200	2048 x 1088	1920 x 1200
Pixel size	5.86 µ	5.5µ	4.7 µ
Temporal dark noise	**7 e-**	13 e-	8.35 e-
Saturation Capacity	**32513 e-**	9400 e-	7969 e-
Dynamic Range	**73 dB**	60 dB	59 dB
Quantum Efficiency @525nm	**76%**	63%	59%

Sony's Pregius CMOS IMX range is the preferred sensor.

Supplier

Point Grey's web based distribution model has meant that Point Grey's pricing has in the past been very competitive. Point Grey has also been the first manufacturer to adopt the Sony Pregius technology and is the only supplier contacted who had the IMX249 based cameras available off the shelf (XIMEA had a 6 month wait). Preferred supplier for the cameras is thus Point Grey.

Camera Model

The Point Grey BFLY-U3-23S6C-C colour camera uses the IMX249 sensor while the BFLY-U3-23S6M-C is the monochrome option (see Appendix B: Camera Specifications).

While there are many factors to consider such as for example sensors with a better response in the infra-red range it is recommended that the BFLY-U3-23S6M-C be initially trialled for infra-red sensing as while the IMX249 has a relatively poor IR response compared to other cameras the low noise and better dynamic range will likely compensate for this shortcoming.

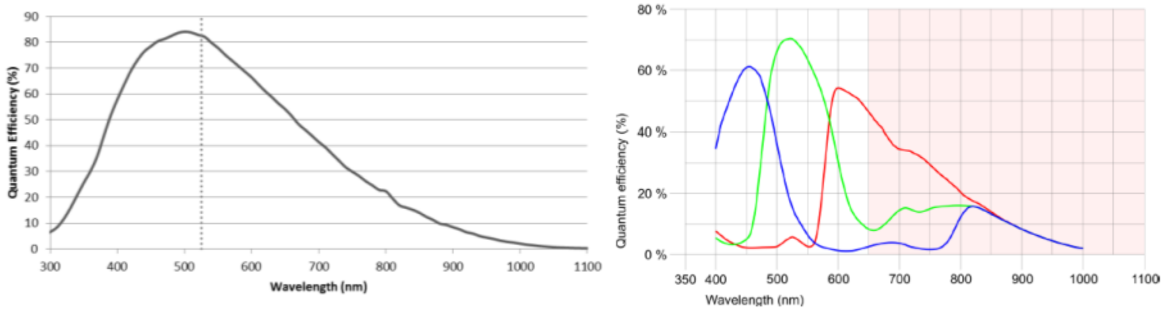


Figure 2: IMX249 Performance (shading indicates with IR filter).

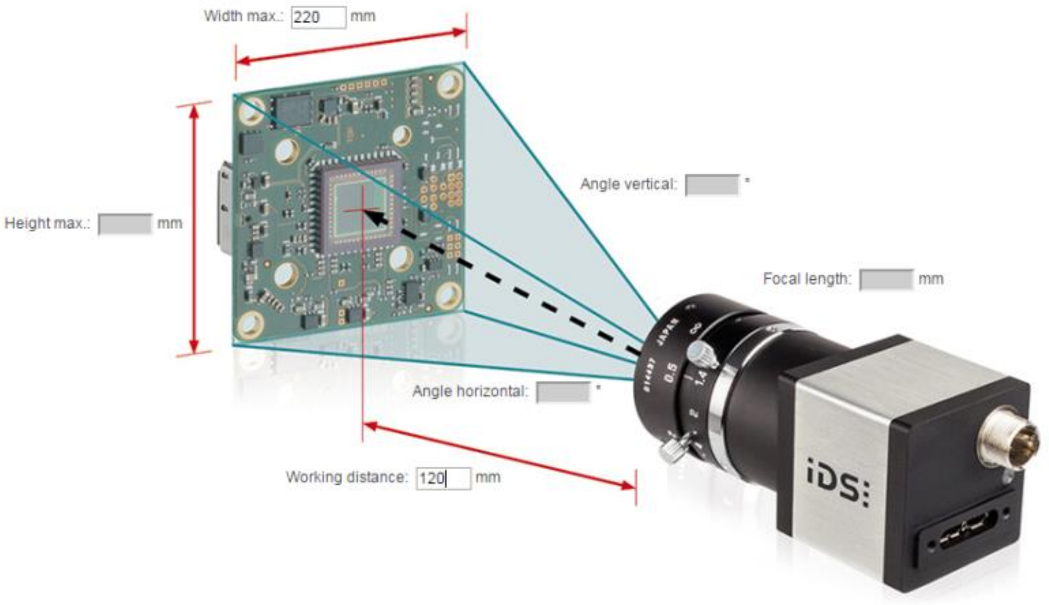
Equivalent IDS (en.ids-imaging.com) cameras are the UI-3260CP-C-HQ Rev.2 and UI-3260CP-M-GL Rev.2.

3.2 Lens & Filters

Using the Point Grey BFLY-PGE-23S2C-CS camera with a 6 mm lens will give sufficient working space between the camera mounting point and the conveyor (see Table 3) while minimising distortion.

Table 3: Lens calculations

Sensor size	1/1.2"	1/1.2"
Sensor width	8	8
Field of view	140	140
Focal length	**6**	**8**
Working distance	**111**	**148**
+Lens & camera	40	40
+Height of punnet	50	50
Camera mount to surface	**201**	**238**



Lens: Kowa, LM6HC, 6 mm, 1"

- Focal length: 6 mm
- Maximal image circle: 1"
- Aperture range (F): 1.8-16
- Minimal object distance (M.O.D.): 0.1 m
- Angel of view (HxV): 96.8° x 79.4°
- Back focal length: 11.1 mm
- Immersion depth: 5.7 mm

Lens for Infra-red

Silicon, hence most types of glass, is invisible to near IR. So, careful selection of IR lens is required.

Narrow bandpass filters will likely be required for IR images (see Figure 3).

Use Kowa, LM6HC with different focus.

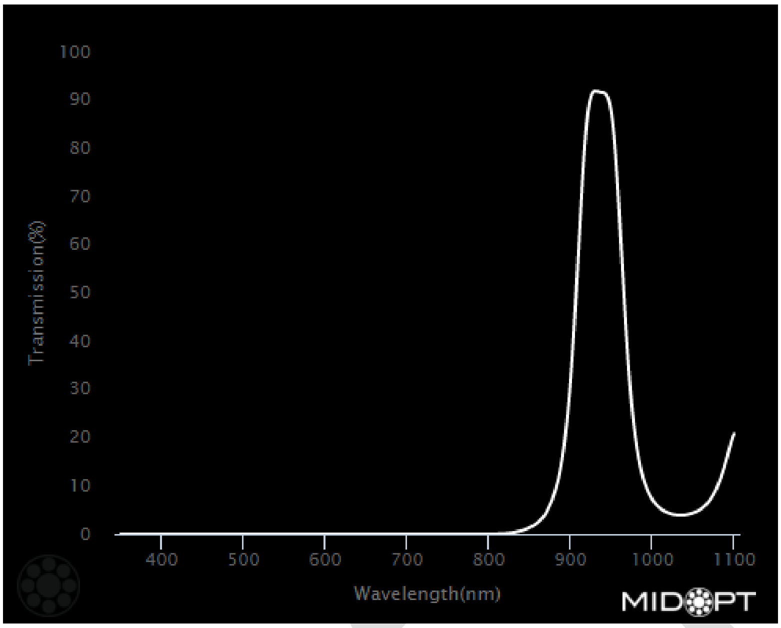


Figure 3: Midopt narrow bandpass filter.

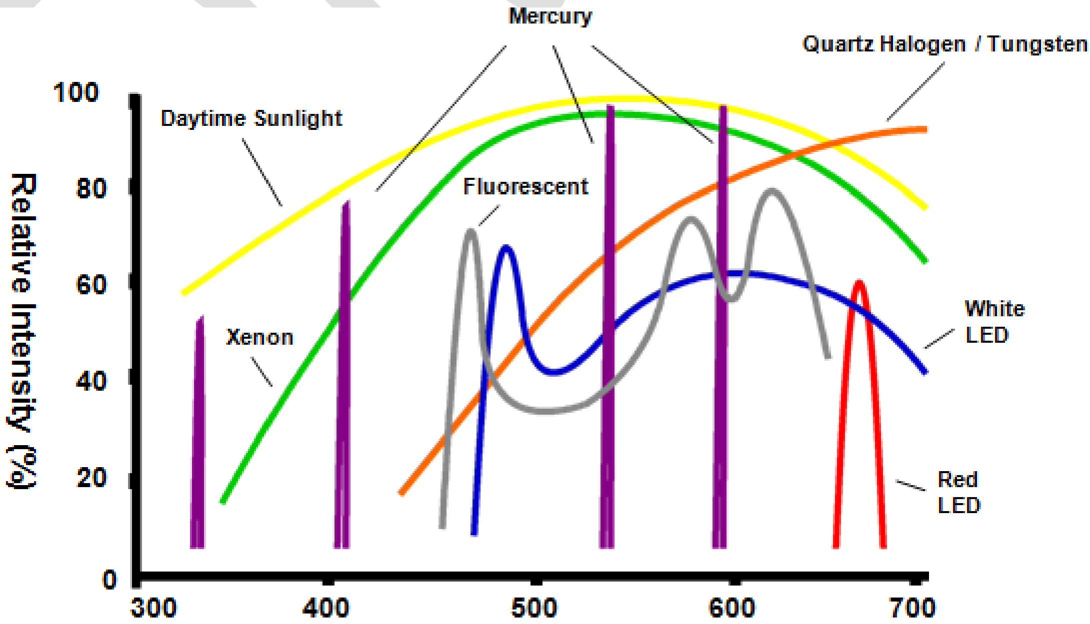
3.3 Lighting

Lighting needs to provide:

1. Sufficient warm white light for sharp images of the moving punnets.

2. Lighting at 980 nm for bruise detection.

3. Diffuse lighting so that the images are not impacted by shadowing or uneven light distribution.



Light Source

LED lights are well suited to machine vision applications because of their cost, longevity and robustness. While LEDs can provide specific light bands, readily available IR LED lighting seems to be limited to around the 840-860 nm band except for low power LEDs at the 940-960 nm range.

Halogen light sources provide good illumination at the warm end of the visible spectrum which is excellent for the reds in strawberries and also are provide good illumination across the IR spectrum. Halogens do not have the longevity or output stability of LEDs so will require greater maintenance and will require that the design is better able to dissipate the extra heat generated by halogens.

Initially trialling vision System with off the shelf halogen work lights (see Figure 4). Also trial smaller more compact halogens typical used as downlights. The light levels of AC powered halogens fluctuated excessively so it was necessary to switch to DAC halogens (car headlights).

Figure 4: Off the shelf Halogen work lights (Bunnings).

H4 P43t car headlights provide a warm halogen

Reflections and shadows

The specular surface of strawberries is highly reflective which can make analysis by machine vision very difficult. To minimize specular reflections:

1. Use diffuse bright field lighting (or as close to bright field as possible with practicality and budget limits- see Figure 5).

   a) Partial dome using rolled sheet metal.

b) Interior surfaces to be mat white

c) Area behind target should be mat black to a width of 2 times the field of view (also better for image background).

2. Light source should be polarised with cross polarisation in front of the camera lens.

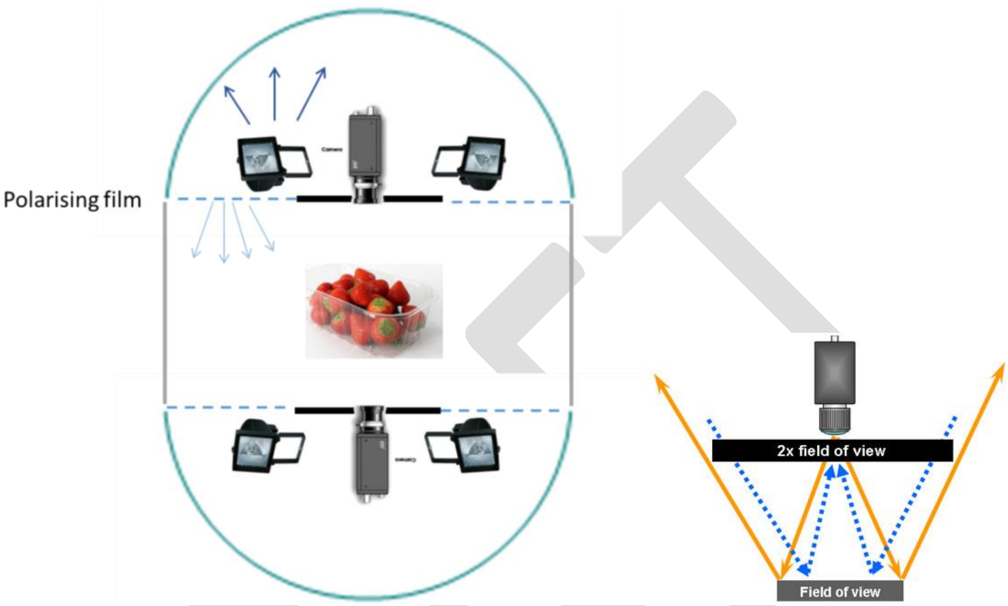


Figure 5: Design for diffuse bright field lighting.

The bottom camera has to view the fruit through the bottom of the punnet so lighting will have an even more critical impact. Bright field lighting should eliminate reflection from the punnet, but a more stringent design of bright field lighting may be required such as a dome shaped reflector with better placement of the lights (see Figure 6). It is likely that top and bottom cameras will need to be offset to minimize interference and make best use of polarised light and bright field lighting.

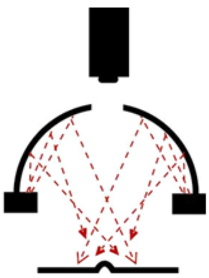


Figure 6: Bright field lighting.

Polarising the light source as in Figure 5 means that reflected light off the side of the enclosure is no longer polarised. A configuration as illustrated in Figure 7 means that light is first diffused through reflection off the sides of the enclosure then further diffused through a perspex diffuser (250x470x3 mm 445 Opal) and then the resulting light is polarised. This means that the light is more diffuse and that only polarised light impacts on the target.

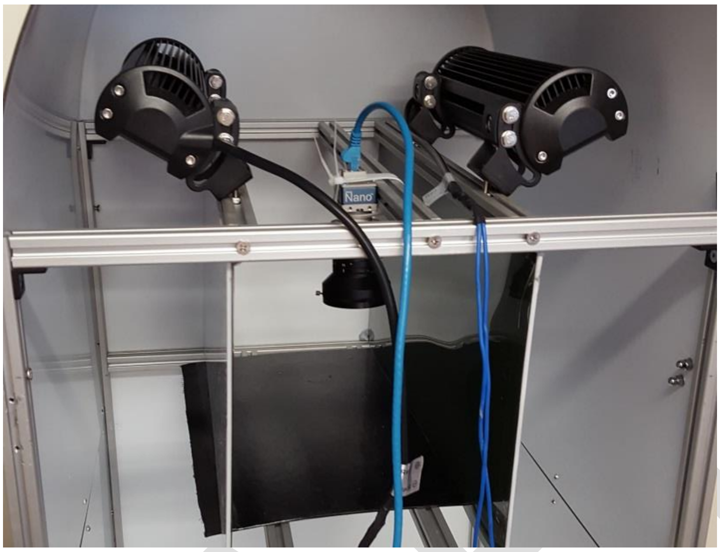


Figure 7: diffuse polarised light.

4. Hardware

The hardware components can be divided into the following main components as follows:

4.1 Light Box

The light box houses the target punnet, camera, lighting, filters (infra-red and polarising) and shielding to exclude ambient light incursion into the light box.

During the development phase, the key requirement will be flexibility as the configuration of the cameras and lighting arrangements will be subject to experimentation. The light box will be assembled from extruded aluminium that enables easy adjustment of camera and lighting positions and the easy addition/removal of additional filters etc. The light box is an immediate requirement (Stage 1 hardware) as it is a requirement for development and testing.

The configuration of the cameras/lens/lighting/filters/reflecting surfaces/shielding for the light box component must first be finalised before the production system can be developed.

Upward facing camera will require a System to prevent dust/dirt from dropping onto the lens such as a spinning transparent disc.

4.2 Conveying

A conveying System is required to convey the punnets from the in-feed conveyor to the heat seal machine conveyor.

The critical requirement of the conveying System is that it must allow inspection of the punnet from the top and from the bottom.

Possible methods to achieve this include:

a) Pinch conveyor that holds the side of the punnet leaving the underside clear for inspection. Similarly, the punnet can be supported at the rim.

b) Conveyor or similar System with side guide rails, with conveyors that supports the punnet at the underside such that only the very edges cannot be inspected.

c) A glass or transparent section such that punnets are pushed over the glass by the series of punnets behind the punnet to be inspected.

d) Conveying punnets using the rim of the punnet so that the underside is easily viewable.

Not required for Stage 1 but option (d) above using 2 V-belts is preferred??? (see Figure 8).

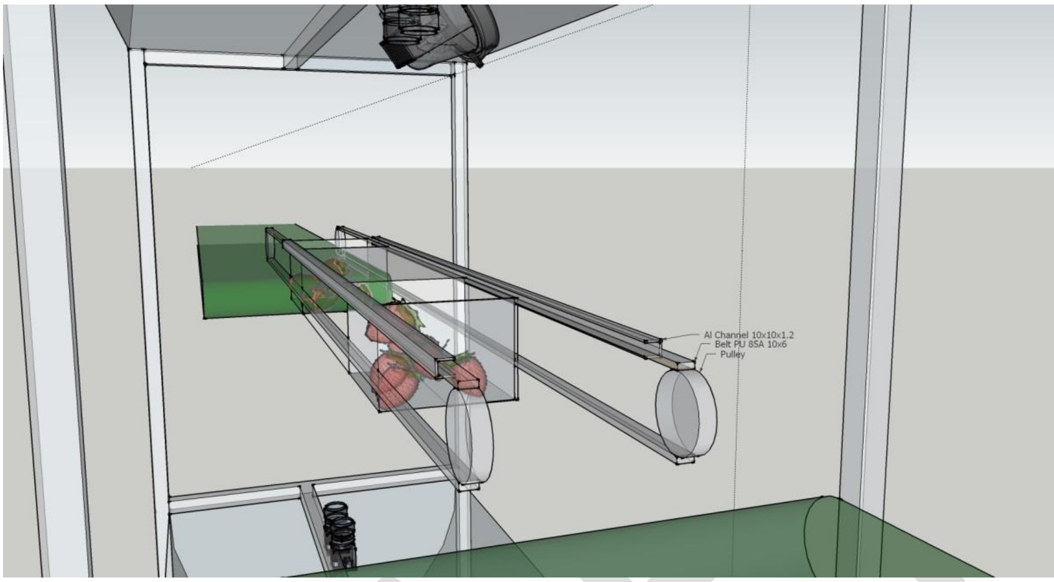


Figure 8: Concept for using V-belt to edge convey.

It is proposed to use a BEHAbelt PU Vee section 10x6mm 75A WHITE V-belt to convey the punnets (supplier Rydell). This type of V-belt is required primarily because the belt colour is critical to identifying the punnet markings.

To facilitate the possibility that future punnets may not be as high as the current punnets, the smallest diameter readily available pulley will be used (56mm).

Height above ground of top of belt = height of punnet (to under rim) + height on infeed conveyor

= 900 + 76 = 976 mm

Length of the belt = 760 *2 + pi * 56 = 1700 mm

of the top of underside of the rim must be

To keep the belts in position it is proposed to use readily available aluminium T section (20x20x1.5 – supplier Bunnings). T-section to be lined with friction reduction material such as teflon or similar (from Rydell or Dotmar). Alternative is to use Item Profile 5 and Item slide strip.

A small pulley of 56mm diameter makes it easier to switch to different size punnets with a lower height while keeping to a simply two pulley design.

Drive pulleys via a chain drive to each drive shaft – suggest bicycle chain pitch: 12.7 mm.

Belt speed at 1 km/h = 0.28 m/s with 0.04 m diameter pulley, circumference = 0.125 m, rotation speed needs to be 0.28/0.125 is 2.24 revs/sec = 134 rpm (design for 300 rpm).

Stepper motors higher torque at lower rpm.

20mm mild steel shaft for driving conveyor

Use SKF SNL 505 housing with 1205 EKTN9 bearing (2301 more rugged?) and H 205 adaptor sleeve

Bottom of punnet 90 cm above ground – need to account for levelling device.

Need punnet infeed and outfeed height adjustment?

4.3 Infeed

The System needs to pick punnets off the infeed conveyor. To achieve this guides will be required to turn the punnets to the correct orientation and to centre the punnets to the pickup V-belts.

Figure 9: Infeed 17cm wide Belt 90 cm above ground level.

4.4 Outfeed

The outfeed will be directly into the infeed of the heat seal machine. The outfeed must precisely align with the heat seal infeed.

Figure 10: Outfeed.

4.5 Punnet Ejector

The punnets will need to be ejected at the outfeed, as ejecting from the pulley conveying system will be difficult.

There are diverse methods for ejecting punnets including but not limited to:

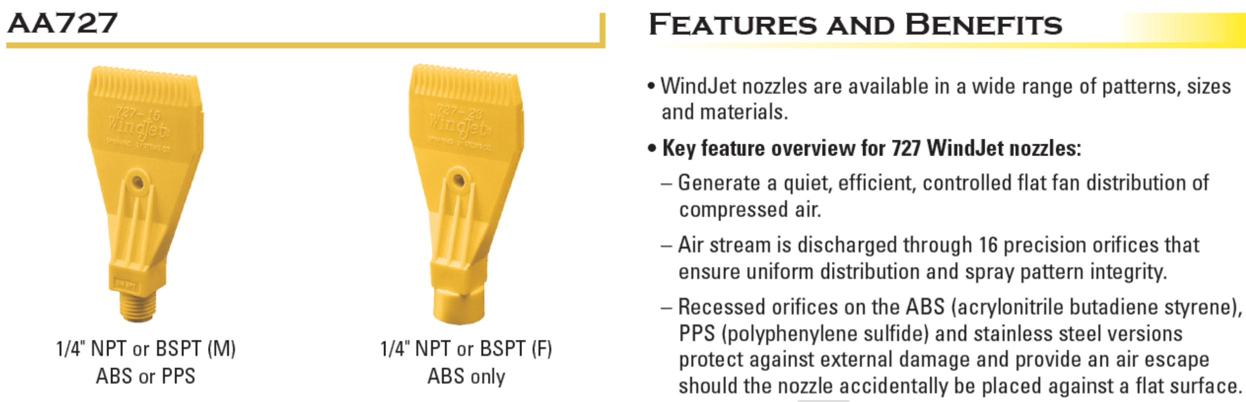
a) Mechanical ejector

b) Pneumatic ejector

c) Gate and return conveyor

David Bartlett of Punnet Mate pointed out that any mechanical means that contacts the punnets will over time gum up with chemicals emitted by the punnets. David recommended an air-ejection system, which is the system currently in use for the weigh checker.

The weigh checker uses the Windjet 727-25 nozzle though smaller less aggressive nozzles are available such as the 727-15 and the 727-11. It is proposed that an air-ejector identical to the one currently in use with the weight checker be used. This will simplify support and share spares with the weight checker. A more moderate ejection action will be possibly by beter regulating pressure and/or using a smaller nozzle and/or using a multi-stage pneumatic ejection system.


AA727

1/4" NPT or BSPT (M)
ABS or PPS

1/4" NPT or BSPT (F)
ABS only

FEATURES AND BENEFITS

- WindJet nozzles are available in a wide range of patterns, sizes and materials.
- **Key feature overview for 727 WindJet nozzles:**
  - Generate a quiet, efficient, controlled flat fan distribution of compressed air.
  - Air stream is discharged through 16 precision orifices that ensure uniform distribution and spray pattern integrity.
  - Recessed orifices on the ABS (acrylonitrile butadiene styrene), PPS (polyphenylene sulfide) and stainless steel versions protect against external damage and provide an air escape should the nozzle accidentally be placed against a flat surface.

Note: Side guides of the heat seal machine infeed will need to be cut to allow punnet ejection.

4.6 Overfill Sensor

A sensor that checks to determine if a punnet is filled above the lip. Overfilling can cause damage to fruit when the punnet is heat sealed.

There are many sensors which can be used to check for over-filling such as the Sick WLL180T-P434 or the Festo SOEG-RSP-Q20-PP-K-2L-TI.

4.7 Punnet Detector

A sensor is required to detect when a punnet is in position to be photographed. There are a wide variety of sensors that could be used, such as:

- Festo retro-reflective sensor SOEG-RSP-Q20-PP-K-2L-TI and SOEZ-RFS-40 ($242)
- IDEC SA1E-DN2 diffuse reflective sensor (NPN).
- **Sick VT180-P112 Photoelectric proximity sensor – preferred ?**
- Sick WL170-P122 Photoelectric retro-reflective sensor.
- DBS-101 https://oceancontrols.com.au/DBS-101.html
- Photo Electric Switch LS3-1MD https://oceancontrols.com.au/PES-004.html

4.8 Computer & User Interface

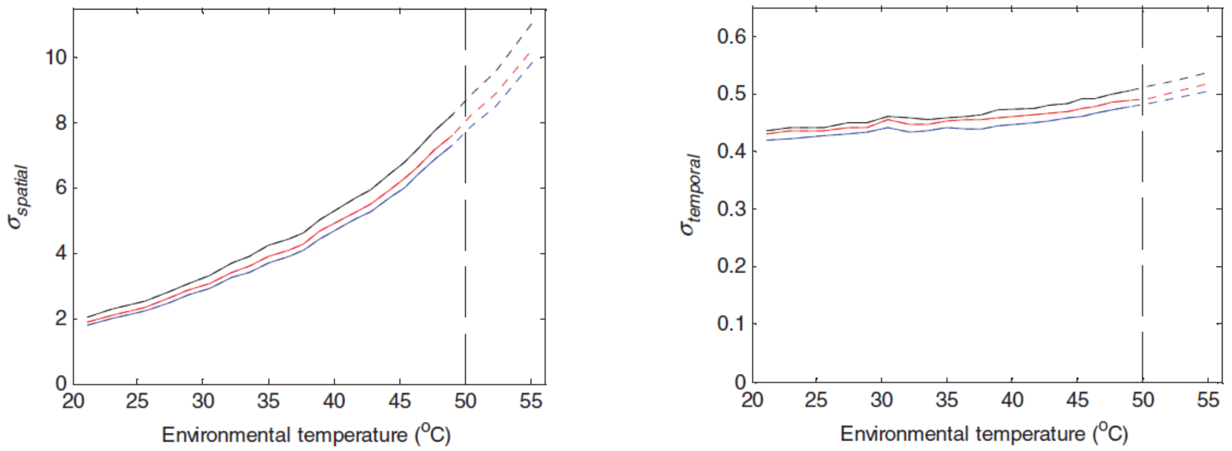
A conventional desktop computer will be used for development.

The machine interface used by the Supervisor. During development, the physical machine interface will likely be a touchscreen (Raybot screen can be used).

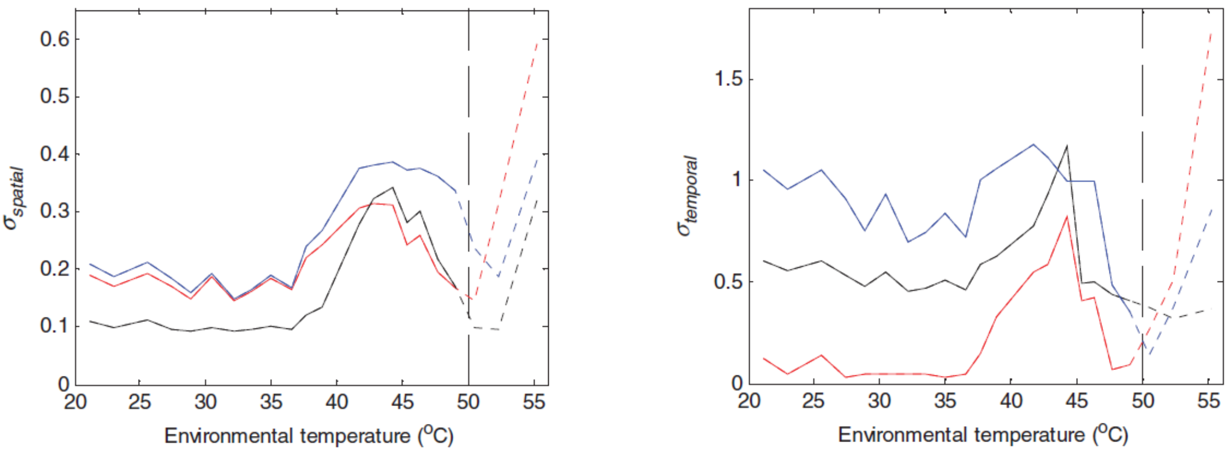
4.9 Interface

4.10 Cooling

Excessive heat will produce noises in the camera images so a cooling system is required to reduce the heat build up which is generated by the computer, camera and lights.



igure 6: Measurement of spatial noise (left) and temporal noise (right) for the uEye 1210-C CMOS camera. (Maximum specified oper 50°C.)



Measured Effects of Temperature on Illumination-Independent Camera Noise

Kenji Irie, Ian M. Woodhead

Alan E. McKinnon. Keith Unsworth

5. Quality Assurance

5.1 QA Outline

Cultivars: Strawberry characteristics including shape, colour and tolerance of different fruit characteristics (such as white tip and white shoulder) vary by cultivar so the System needs to be designed so that it is easy to switch between cultivars.

Grading Standard: The grading standard is a specific group of fruit characteristics that is the requirement for a particular market or customer. The primary grading standard tends to be size, shape and colour (taste, brix?) while ensuring compliance with customer's expectations for defects such as exclusion of rots, moulds, etc.

Packing Shed Management

While the operation and management of a packing shed vary considerably for purposes of this document the System will be designed with the following hierarchy:

> **Supervisor**: The Supervisor is the person who manages the packers at the benches that feed into the System. The Supervisor is responsible for examining rejected punnets and returning the rejected punnets to the relevant packer. The operator is also responsible for switching the System to the correct cultivar and grading standard at the start of each batch. The supervisor interface needs to take into account that the supervisor may have limited English language skills.
>
> **Technician**: The Technician is the person who will setup the initial cultivar and grading standards and who will be responsible for maintenance and troubleshooting. This person has excellent technical skills but may have limited produce knowledge (cultivars and grading standards).
>
> **Manager**: The Manager is responsible for sales and sets the grading standards. The Manager needs to be able to assess punnet statistics including statistical reports on punnets packed. The statistical information must be live and must be remotely accessible from a smart phone.

5.2 Interface - Supervisor

The System must have a simple supervisor interface such that:

1. A Supervisor with poor English language skills can intuitively use the System to select cultivar and grading standard.

2. The current cultivar and grading standard selection must be clearly visible at all times.

3. The number of rejected punnets by packer is clearly visible.

Mock-up of Supervisor interface showing current batch, button to start a new batch and performance of each packer:

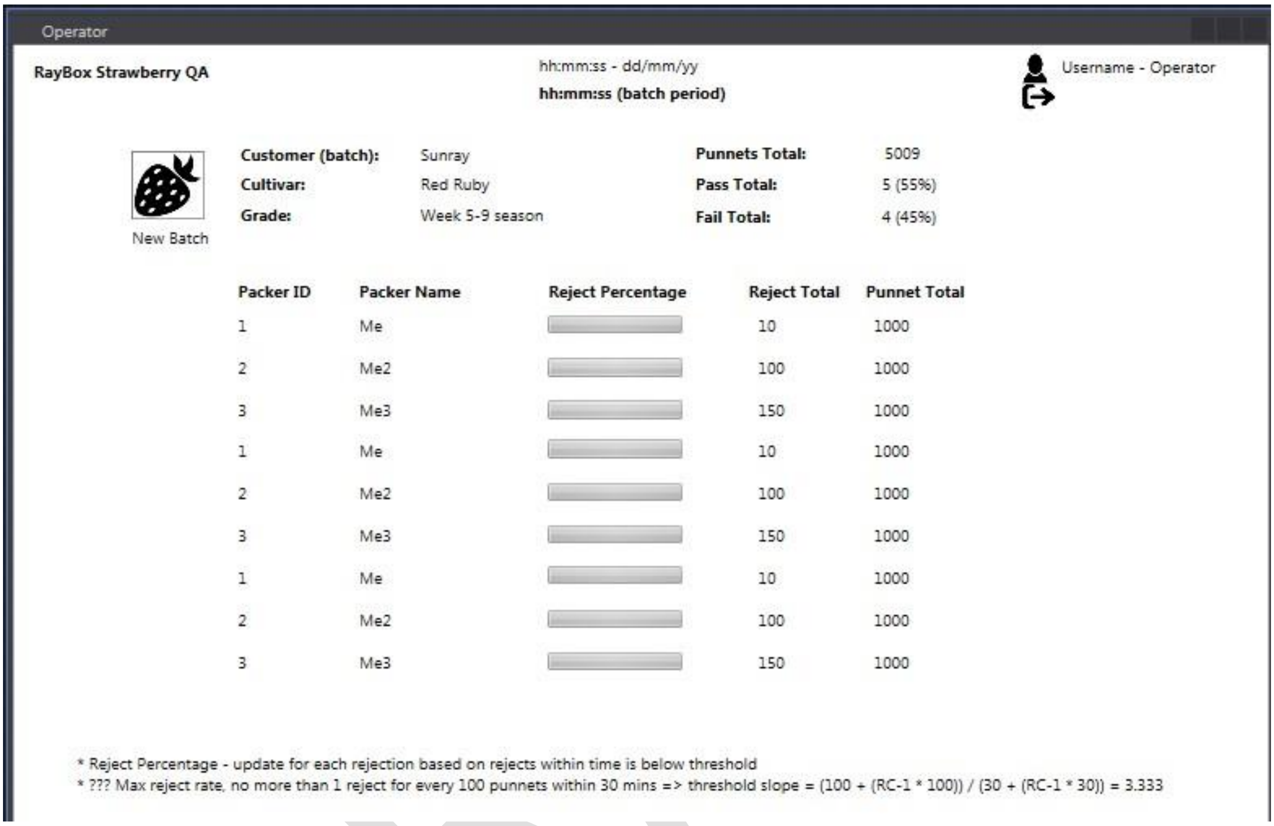


Figure 11: Supervisor interface.

5.3 Interface - Technician

The interface must have an advanced setup and diagnostics interface that is only accessible by a technician. This interface must provide:

1. Ability to add new cultivars and edit existing cultivars.
2. Ability to add new grading standards and edit existing standards.
3. Diagnostic information.
4. Have access restrictions such that only approved personnel can access the setup settings.

The following mock-ups show the initial screen for the Technician's Initial (top level), Settings and Diagnose screens.

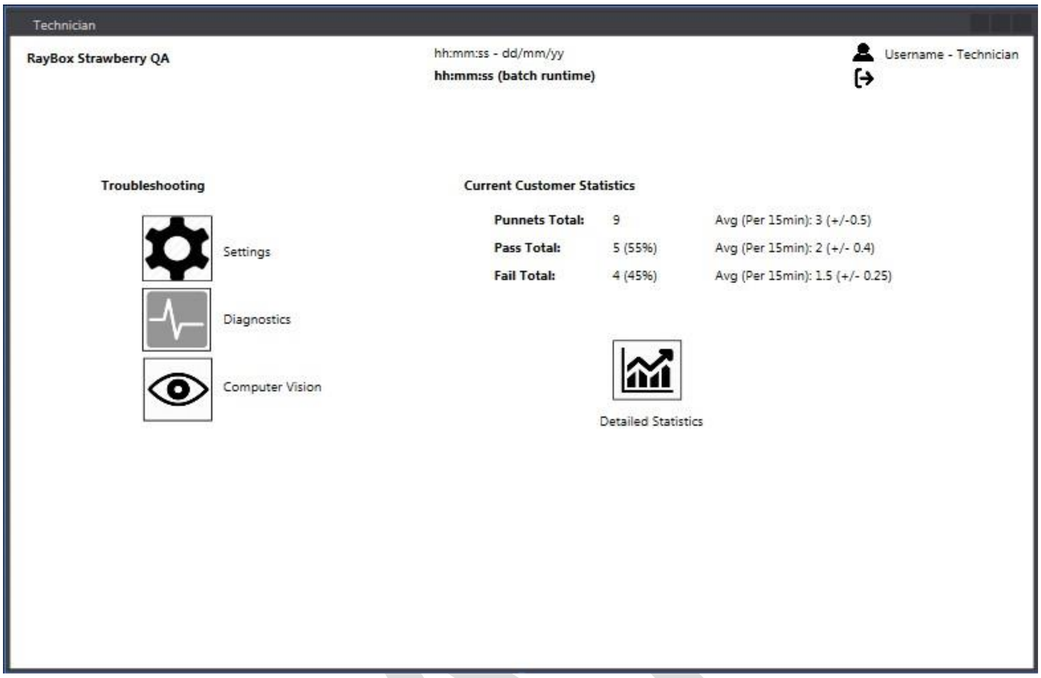


*Figure 12: **Initial** Technician screen with overview and access to more technical screens.*

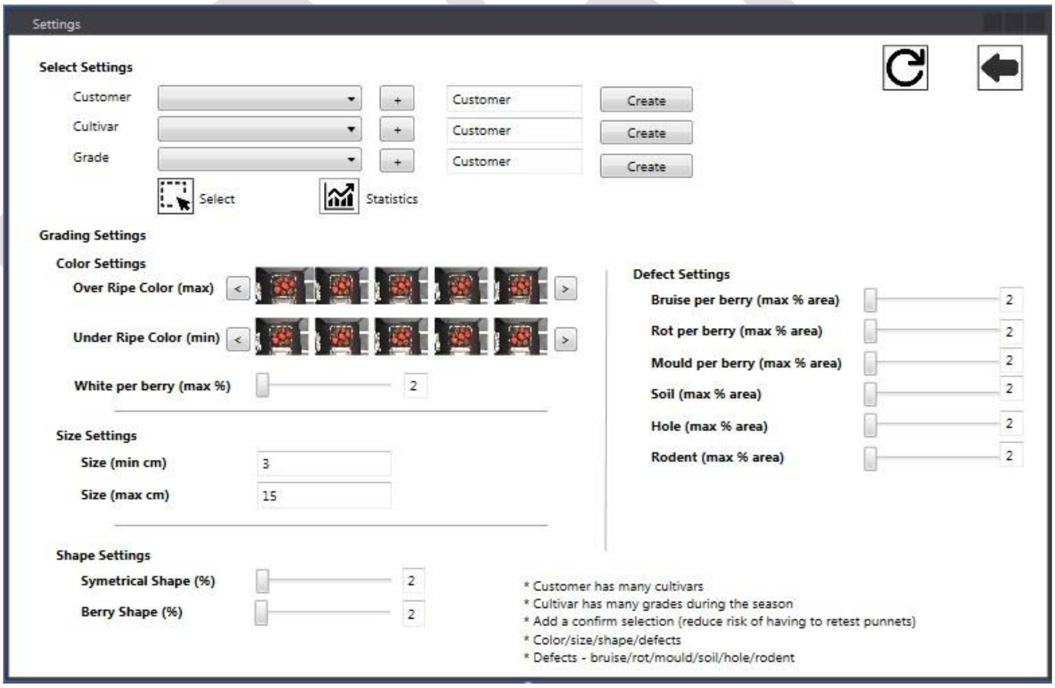


*Figure 13: Technician **Settings** screen: Setup of customer acceptance requirements.*

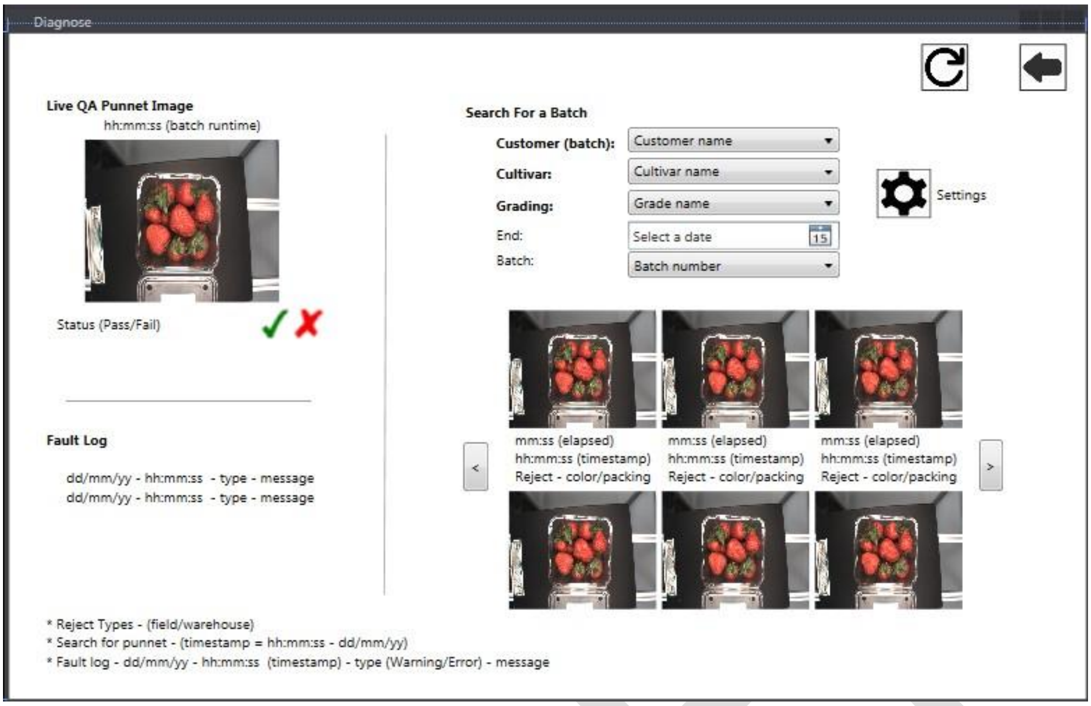


*Figure 14: Technician **Diagnose** screen for detail on faults and review of assured punnets.*

5.4 Interface - Management

The Management Interface must have the option to limit access to key personnel. This interface must provide:

1. Ability for the manager to view the quality control image of any punnet packed in the previous 3 weeks (selected by time scanned).

2. Graph showing the packing speed (punnets scanned per minute for the batch/day/week/month selected).

3. Graph showing the pass ratio (pass percentage per minute for the batch/day/week/month selected).

4. Histogram of rejection criteria for rejected punnets by day/week/month/batch.

5. Quality metrics by batch (between changes in cultivar and grading standard). Quality metrics to include:

   a) Estimated fruit pieces per punnet (average).

   b) Shape factor (metric of extent of misshapen fruit).

c) Estimated per cent green per punnet (average).

d) Seediness metric.

e) White shoulder metric.

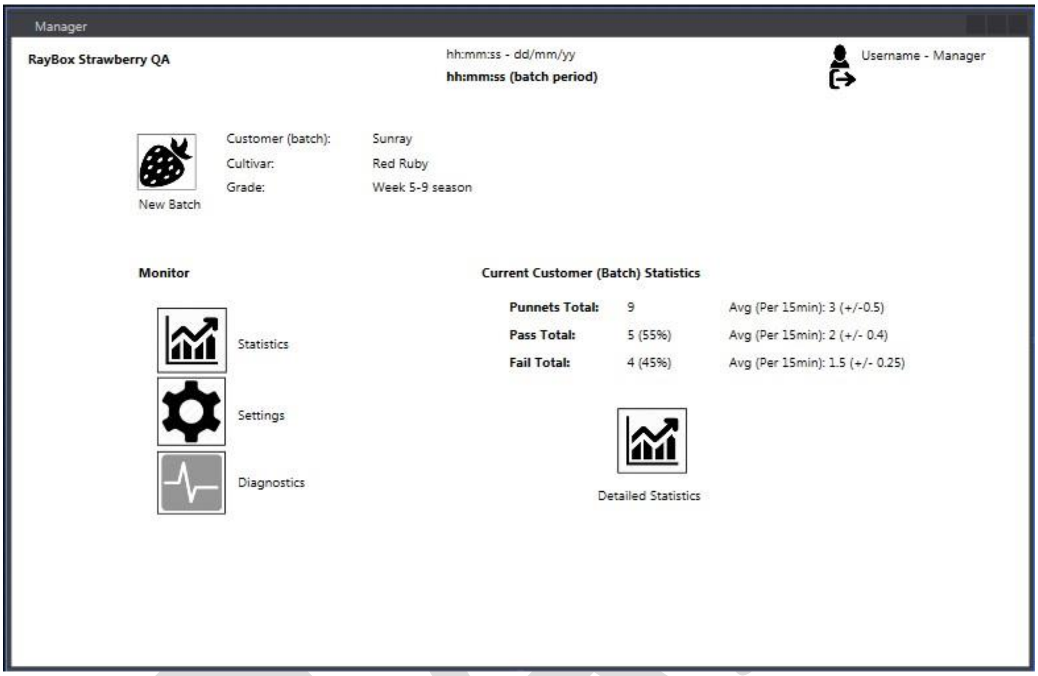
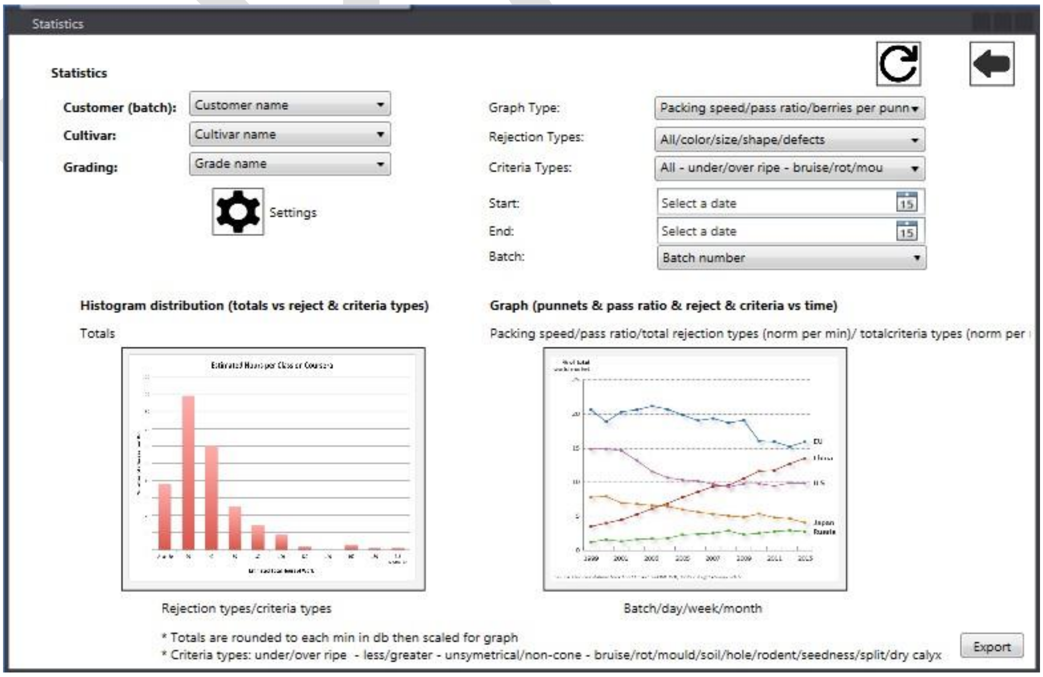


*Figure 15: **Initial** Manager start screen with overview and access to more management screens.*



2. *Figure 16: Manager's **Statistics** screen.*

Manger also has access to settings and diagnostics as per Technician's requirements.

5.5 Per Cent Criteria

The technician interface must enable the technician to set the maximum (and minimum if appropriate) percentage of key characteristics for each cultivar and grading standard. Specifically, the System must be able to detect fruit that that do not meet the following criteria and eject punnets that do not meet these criteria:

a) Under-ripe.

b) Over-ripe.

c) Sizing.

d) White-tip.

e) Seediness (seed density).

f) White shoulder (the maximum extent of unripeness measured by seed rings).

g) Dry calyx.

h) Splits

i) Dry bruising.

j) White area (large single areas of under-ripeness on a fruit).

5.6 Always Reject Criteria

The System must be able to detect fruit and eject punnets containing fruit that has the following non-compliances:

a) Fruit that has been punctured.

b) Punnets containing any foreign objects including but not limited to soiling and insects.

c) Rots.

d) Moulds.

e) Wet bruising.

f) Pest damage.

g) Cuts.

Additionally, the System should reject punnets if the punnet markings are indistinct.

5.7 Misshapen fruit detection

The System must be able to detect misshapen fruit including a means of quantifying the extent misshapenness (a shape factor which measures deviation from standard vertically symmetric cone shape). The technician interface must allow the shape factor tolerance limits to be set for each cultivar and grading standard.

6. Packer Management

6.1 Packer Management Outline

The system will track the quality of packing for each packer including counting the number of punnets packed by each packer (according to punnet markings).

To achieve this a system for marking punnets that is easy for the machine vision system to track will be required. The system that is proposed is similar to the existing system using permanent marker pens but will only use a single colour markers as initial trials indicate that while the markings can be detected by the System, the System will not easily be able to reliably differentiate between colours due to the small size and translucency of the markings. To obtain the number of permutations of markings that are required the markings will be location dependent as follows:

- Each marking consist of one, two or three marks in a similar fashion to existing punnet markings made on the edges of a pile of punnets (as removed from the box).
- Marking can be on either of the long sides of the punnet (more control of background being the V-belt).
- Left, middle or right side of the long side (can be detected and provides more permutations).

This provides 364 unique markings (3^6/2) which is sufficient for a large packing shed while also allowing for some staff turnover.

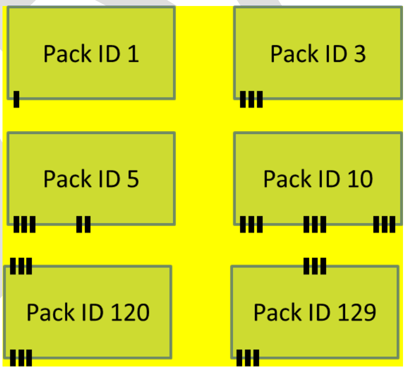


Figure 17: Example of easier to track punnet markings.

While the system cannot easily distinguish colour markings on the rim of the punnet, this does not exclude colours being used to assist with traceability. For example, for a consolidated distribution centre if different colours are used for different packing sheds, it will be possible to have traceability across multiple sheds.

6.2 Packer Management Requirements

The System must be able to:

a) Identify the punnet marking on each punnet with a very high degree of reliability.

b) Report on a daily or weekly basis by unique markings (packer ID) the following:

   a. Counts of rejected punnets according to packer ID.

   b. Counts punnets passed according to packer ID.

   c. Sort report based on count of rejected punnet or per cent punnets rejected.

7. High Level Design Requirements

7.1 Safe Operation

a. The System must be safe and simple to operate such that an unskilled operator can intuitively and quickly activate an emergency stop.

b. Signage that may impact on safety of operation must use clear unambiguous universally recognizable symbols.

7.2 Reliability

a. Failure mode and effects analysis is required to identify and mitigate likely failure modes.

b. Demonstrate Mean Time between Failure of better than 1,000.

7.3 Design Life

a. The design life for all components of the Harvester must be at least 5 years.

7.4 Servicability

a. An Manual is required for Supervisors who are the machine operators.

b. A Technical Guide is required for technicians.

c. An Owner's Manual is required for management staff.

d. The System must be able to be remotely accessed for monitoring, setup and other servicing that can be achieved remotely.

7.5 Maintenance - Keeping it working

Over time, light sources change their intensity and spectral distribution, lenses and physical reference standards gather dirt, and camera/lights may move and impact image quality. These changes affect the image and can cause the inspection algorithm to misclassify products; i.e., perfect products can fail because of imperfections in the inspection environment. So there must be a scheduled maintenance programme.

checking for dirt on the lenses and lights,

cleaning

tightening the mountings when necessary.

compares the live image with a reference image

lighting calibration check

dynamic real-time changes to the camera exposure, gain and RGB settings if lighting levels change?

7.6 Training

8. Compliance Requirements

As a minimum requirement, the QAS must:

8.1 Electromagnetic compliance

a. Demonstrate electromagnetic emissions compliance to the required standards for Australia.

8.2 Occupational Health & Safety

a. Pass a safety audit that compliance with occupational health and safety regulations.

8.3 Food safety

a. Adherence to DAFF (Department of Agriculture, Forestry & Fisheries) Guidelines for On-Farm Food Safety for Fresh Produce:

http://www.daff.gov.au/__data/assets/pdf_file/0003/183171/guidelines_onfarm_food_safety_fresh_produce_2004.pdf

b. Adherence to Coles, Woolworths, Costco and Aldi Produce Category Requirements.

http://www.wowlink.com.au/cmgt/wcm/connect/8bce5e004f02cc6a96a29f64aa8be21f/WQA_Category_ProduceJune09.pdf?MOD=AJPERES

8.4 Environmental ratings

a. All components must be rated to operate in the temperature range from 0°C to 40°C.

b. Components must be rated for a higher temperature range where they may be subject to other non-environmental sources of temperature extremes such as radiant heat or the build-up of heat inside an enclosure.

c. Electronic components in enclosures must be rated to operate at up to 60°C unless acceptable heat dissipation strategies are implemented that will keep the internal temperature to below the rated temperature when the outside temperature is 40°C.

8.5 Environmental testing

Compliance with the following tests is highly desirable. If budget limitations limit the scope of testing then alternative testing and or assessment of the expected reliability should be made:

a. Pass damp heat, steady state test to IEC 68-2-3, test Ca.

b. Pass damp heat, cyclic to IEC 68-2-30, test Db, variant 1.

c. Pass dry heat test according to IEC 68-2-2, test Bb.

d. Pass cold test shall be performed according to IEC 68-2-1, test Ab.

e. Pass thermal shock according to IEC 68-2-14, test Na.

f. Pass thermal cycling test according to IEC 68-2-14, test Nb.

9. Procurement

To facilitate continuous cost reduction, ease pressures on procurement, support and manufacturing the following guidelines to the design and sourcing of components have been adopted:

a. The supply risk of each component must be assessed and where there are no alternative suppliers with components that can directly replace the current supplier an assessment must be made of the supply risk that the single supplier poses. Appropriate measures must be taken to address the supply.

b. COTS (Commercial-Off-The-Shelf) components are preferred so as to reduce the time to market. It is highly desirable that custom components are kept to a minimum.

c. It is highly desirable that the number of individual suppliers of components or sub-assemblies are kept to a minimum.

a. Longest lead time for any component should be no more than 4 weeks.

b. Target cost of goods should be no more than $8000???

10. Appendix A: Typical Customer Requirements

Basic Requirements:

1. Texture soft to firm
2. Brix >6
3. Fresh Produce - K: Size XXL: 14-18 pieces
4. Fruit colour bright red to deep red. >90% colour.
5. Calyx appearance to be green and fresh
6. 10 to 18 fruit in a 250 g punnet (XXL)

No major defects (defects that effect shelf life):

1. Wounds
2. Splits
3. Cuts
4. Cracks
5. Punctures
6. Rots
7. Moulds
8. Unhealed hail damage
9. Bird and insect damage
10. White Shoulder Greater than 2nd row of seeds
11. Soiling

<10% minor defects (not affecting shelf life)

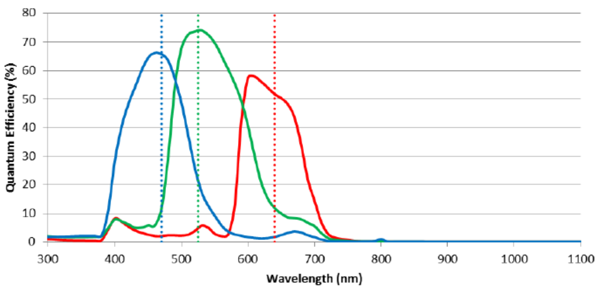
1. Healed weather mark
2. Skin marks
3. Superficial/dry bruising
4. White shoulder greater than 3rd row of seeds
5. Misshapen fruit
6. White tip

11. Appendix B: Camera Specifications

Imaging Performance (EMVA 1288)	See the Imaging Performance Specification, which includes quantum efficiency, saturation capacity (full well depth), read noise, dynamic range and signal to noise ratio.
A/D Converter	12-bit; 10- and 12-bit (BFLY-U3-23S6)
Video Data Output	8, 12, 16 and 24-bit digital data
Image Data Formats	Mono8, Mono12, Mono16, Raw8, Raw12, Raw16 (all models); RGB, YUV411, YUV422, YUV 444 (color models)
Partial Image Modes	Pixel binning, decimation, and region of interest (ROI) modes
Image Processing	Gamma, lookup table, hue, saturation, and sharpness
Shutter	Global shutter; Automatic/manual/one-push Up to 32 seconds
Gain	Automatic/manual/one-push -10.104 dB to 23.991 dB (BFLY-U3-03S2); 0 dB to 23.991 dB (BFLY-U3-05S2); -11 dB to 23.99 dB (BFLY-U3-13S2); -10.319 dB to 23.991 dB (BFLY-U3-20S4); 0 dB to 29.9 dB (BFLY-U3-23S6); -6.234 dB to 23.991 dB (BFLY-U3-50H5)
Gamma	0.50 to 3.99, programmable lookup table
White Balance	Automatic/manual/one-push
Color Processing	On-camera in YUV or RGB format, or on-PC in Raw format
Digital Interface	USB 3.0 interface with screw locks for camera control, data, and power
Transfer Rates	5 Gbit/s
GPIO	6-pin Hirose HR10A-7R-6PB GPIO connector for trigger, strobe, and power
External Trigger Modes	Standard, bulb, low smear, overlapped, multi shot
Image Buffer	16 MB frame buffer
Memory Channels	2 user configuration sets for custom camera settings
Flash Memory	1 MB non-volatile memory
Dimensions	29 mm x 29 mm x 30 mm excluding lens holder, without optics (metal case)
Mass	36 g (without optics)
Power Consumption	5-24 V via GPIO or 5 V via USB 3.0 interface, maximum <3 W
Machine Vision Standard	USB3 Vision
Camera Control	Via FlyCapture SDK or USB Vision third party software
Camera Updates	In-field firmware updates
Lens Mount	CS-mount; C-mount (BFLY-U3-23S6 and BFLY-U3-50H5)
Temperature	Operating: 0° to 45°C; Storage: -30° to 60°C
Humidity	Operating: 20 to 80% (no condensation); Storage: 20 to 95% (no condensation)
Compliance	CE, FCC, KCC, RoHS
Operating System	Windows, Linux (32- and 64-bit)
Warranty	3 years

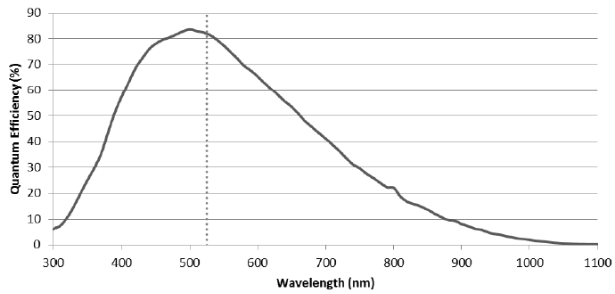
Measurement	Video Mode 0	Video Mode 7
Frame Rate (FPS)	41 FPS	32 FPS
Pixel Clock (MHz)	37.5	37.5
ADC (Bits)	10-bit	12-bit
Quantum Efficiency Blue (% at 470 nm)	65	66
Quantum Efficiency Green (% at 525 nm)	74	74
Quantum Efficiency Red (% at 640 nm)	51	52
Temporal Dark Noise (Read Noise) (e-)	13.77	6.89
Signal to Noise Ratio Maximum (dB)	45.21	45.23
Signal to Noise Ratio Maximum (Bits)	7.51	7.51
Absolute Sensitivity Threshold (γ)	20.26	10.42
Saturation Capacity (Well Depth) (e-)	33158	33368
Dynamic Range (dB)	67.33	73.09
Dynamic Range (Bits)	11.18	12.14
Gain (e-/ADU)	0.52	0.53

BFLY-U3-23S6C



Measurement	Video Mode 0	Video Mode 7
Frame Rate (FPS)	41 FPS	32 FPS
Pixel Clock (MHz)	37.5	37.5
ADC (Bits)	10-bit	12-bit
Quantum Efficiency (% at 525 nm)	81	82
Temporal Dark Noise (Read Noise) (e-)	14.25	6.97
Signal to Noise Ratio Maximum (dB)	45.25	45.27
Signal to Noise Ratio Maximum (Bits)	7.52	7.52
Absolute Sensitivity Threshold (γ)	18.61	9.36
Saturation Capacity (Well Depth) (e-)	33489	33676
Dynamic Range (dB)	67.12	73.08
Dynamic Range (Bits)	11.15	12.14
Gain (e-/ADU)	0.53	0.53

BFLY-U3-23S6M



12. Appendix C: Hardware Budget

Estimates ONLY	Quantity	Total Cost	Pending Cost	Notes
Vision components				
Polarising sheets	4x50x50cm	$575.60	$575.60	Urgent
Cameras	4 but have 1	$2,857.14	$2,142.86	
Lenses	4 but have 1	$2,248.40	$1,686.30	
Filter-infrared	2 but have 1	$351.00	$351.00	
polarising filters on lens	4 but have 1	$357.00	$357.00	
Mechanical				
Materials - frame and cladding	1	$340.00	$540.00	
Hinges, brackets, bolts, ..	1	$150.00	$150.00	
Teflon - belt guide	2	$22.00	$80.00	
Laser cutting	1	$160.00	$200.00	
Powder coating	1	$65.00	$80.00	
Bearings & housings	10	$440.00	$440.00	
Shaft coupling	1	$70.00	$70.00	
Drive chains	2	$40.00	$40.00	
Sprockets	4	$80.00	$80.00	
Drive motor and controller	1 but have 1	$1,740.00		
Pulleys	4	$283.00	$283.00	
V-belts	2	$125.00	$125.00	
Lens cleaning mechanism	1	$90.00	$90.00	
Paint, cables and sundries	1	$200.00	$200.00	
Sensors & Actuators				
Sick VTF180-2P41112P	5 but have 5	$715.00		from wrap machines
WLL180T-P434	1	$234.00	$234.00	
Emergency stop	1	$30.00	$30.00	
USB to Digital interface (PhidgetInterfaceKit 0/16/16)	1 but have 1	$135.00		
Relays 24V heady Duty 20A	2 but have 2	$10.00		
IT				
Computer	1 but have 1	$1,560.00		Raybot PC
Touchscreen	1 but have 1	$550.00		Raybot screen
Halcon runtime	1 but have 1	$1,460.00		
UPS	1	$200.00	$200.00	
Halcon runtime license	1	$1,580.00		
Pneumatic				
Ejector nozzle, valve, hose, connectors and flow controller)	1	$353.50	$353.50	
	TOTAL	**$17,021.64**	**$8,308.26**	

Note: White text on black indicates estimates ONLY with no quote.

Bill of Outstanding Materials

Item	Quantity	Status
Bearings	10	BSC delivered
Plummer block	10	BSC delivered
M10 x 150 + nuts	6	need 2 more
15 mm shaft	1000 mm	
Teflon		BSC delivered
Motor	100-250 rpm	
Sprockets ½” - 15	3	
Taper lock to 15mm for sprockets	4	
½” chain	3m	
1/2” chain connecting link	2	
25x25 square	2x1500, 2x920, 4x620, 5x390mm	
30x30 square	500mm	
2mm plate	200x1000mm	