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Foresight

Watching fruit grow.

Fruit Measurement Horticultural Device:
Developing Trust through Usability
across Complex Systems

A thesis submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy

Zené Krige

2024

Note for Examiners of Doctoral Theses

Explanation of Impacts on Research

The Doctoral Research Committee recognises the impacts of the pandemic, extreme weather events and/or university change processes, on research, particularly for doctoral candidates, and we appreciate the efforts made by supervisors and candidates to ensure timely completion of the doctoral thesis. We know that in some cases this has meant the project has needed to be changed in some way, including its final presentation. For students whose work has been impacted, we invite supervisors to provide a note for examiners explaining the circumstances.

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The three impacts noted above, provided a significant impact to Zené's health and wellbeing across the period of the research project. Her resolve to manage these external factors was undertaken with great fortitude. Of special note with regards to a significant impact, was the death of her life partner Daniel Harmsworth. This happened at a critical time during the write up of her exegesis, and had lasting affects that continue. In addition Zené managed the funeral arrangements along with supporting a grieving family that arrived from Australia. In addition she had to manage the posthumous estate (of which she is executor), and the ongoing obligations from this.

Signed, confirming this is a fair reflection of the impact of the pandemic, extreme weather events and/or university change processes on this research.

Student	Supervisor	Head of Academic Unit (or nominee)
		

College of Creative Arts | Toi Rauwhāangi
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Wellington, New Zealand

2024

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I wish to acknowledge my role as a researcher, my position as an immigrant to Aotearoa New Zealand, and my openness to a bi-cultural approach in which Māori and Western concepts of ethics and ways of seeing the world can coexist.

Special thank you goes to my supervisors, Associate Professor Rodney Adank, Professor Ian Yule, and Professor Vicki Karaminas. Rodney, thank you for believing in me before I believed in myself.

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To Daniel, thank you for being my rest

This thesis is dedicated to you. I will look for you in every season.

Related Publications and Awards

2021

- Massey Doctoral Scholarship - Funding Received 2021
- Ken and Elizabeth Powell Scholarship - Funding Received 2021
- Dick and Mary Earle Scholarship - Funding Received 2021
- PlantTech Doctoral Stipend for researchers - Funding Received 2021 - 2022

2022

- Digital Lives Symposium
- 3-Minute Thesis Massey Finalist

2023

- Human Factors and Ergonomics Society Conference in Arrowtown, New Zealand
6 June 2023 - Presenting on: Trust in the Age of Distrust: Human Factors and their
relationship to Technology Acceptance and Utilisation

2024

- DRS 2024 Conference Publication: Developing factors of trust for the design of
trustworthy Human-Product Interactions. <https://doi.org/10.21606/drs.2024.695>
Presented this paper at the conference on 26 June 2024

The role of PlantTech

This project was initiated in collaboration with PlantTech Research Institute in August of 2021.

I was fortunate to receive a great deal of support and guidance from staff who had a range of expertise within agriculture and technology. The Research Institute was interested in implementing design skillsets into their scientific and engineering-based expertise, exploring the value design can bring to communicating these emerging technologies and their surrounding services.

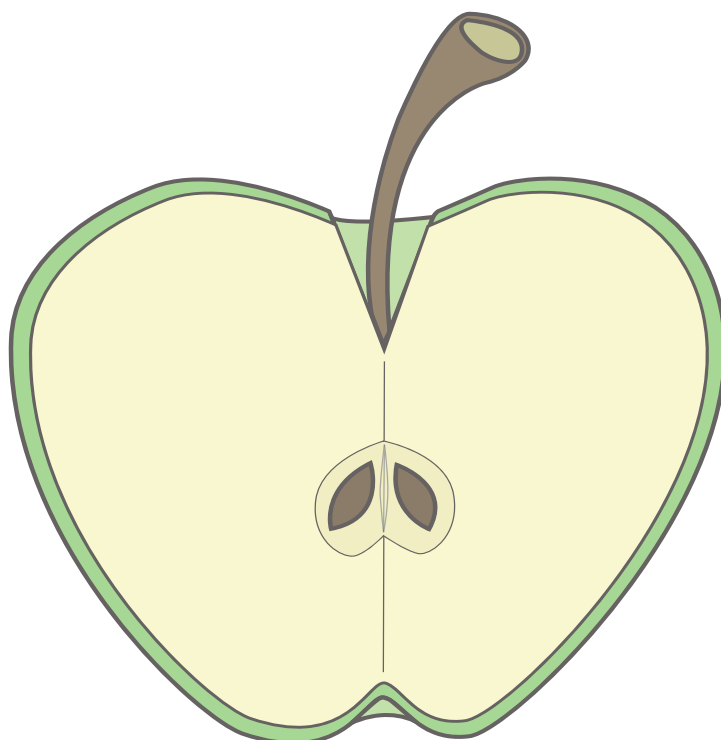
The receivership of PlantTech in November 2022 caused uncertainty for a number of months, over a critical growing season, and this change also disrupted many of the stakeholders involved in the initial aspects of the study. The stipend from PlantTech also ended at this point.

COVID-19 Impact Statement

COVID-19 lockdowns at the beginning of the study and the use of the level system heavily impacted the safe practices of meeting stakeholders. Mitigation strategies, such as the fruit study seen in Chapter 5, were used to enable research insights to be gained in a low-risk manner.

Personal Statement

The death of my life partner, Daniel on New Year's Day of 2024 also held a great deal of personal battle at the heights of the final sprint to complete the study.



Links to Relevant Works

This doctoral research consists of three parts: a creative practice component, a written thesis component and a presentation of work undertaken at examination.

Please see the following link for video content associated with this study:

https://drive.google.com/drive/folders/1u_H4NypdsnsAM9_kZ7jhFh0Y9ANlzWCD?usp=sharing

Statement of Original Authorship

Copyright notice/Declaration

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Abstract

The agricultural technology (ag-tech) sector aims to use emerging technologies to meet changing consumer demands. To do this, the design of an intuitive smart object needed to be developed, and appraised for the horticultural industry of New Zealand. Its subsequent data needed to be expressed in tangible ways that empower decision-making about orchard operations. An elevated user experience of the device, along with quality data driving the system, would provide a successful engagement with an intelligent product system that sustains trust in the interaction and purpose of the product and integrates trust as a value within the system to advance resilience in horticultural innovation.

Focusing on the task of fruit measurement, this project explores the conceptual design of a technology-driven device that can efficiently measure fruit size and count, throughout the season. The translation of this data in a format that enables stakeholders to analyse, query and act on it, seeks to inform and empower decision-making by the end users and stakeholders about the best time to harvest.

This allows for better management of resources and deployment of labour and equipment. The consequence is a more sustainable orchard operation with greater productivity and benefits to all stakeholders. The project investigates the interrelationships between stakeholders, their equipment and orchard systems to drive product innovation by strengthening foundations of trust and utility, developing confidence in product use, and demonstrating its role in providing critical data into a horticultural management system with an inanimate object (product) placed within the orchard environment.

This creative practice research project aims to address the opportunities that design can offer in bridging technological capability to usable products that can communicate trustworthy data clearly to end-users.

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Glossary

Foresight

“the ability to predict what will happen or be needed in the future”.- Oxford Dictionary

Anthropomorphism

“Anthropomorphism imbues non-human objects with human-like characteristics, alters people’s relationship with the objects, and shift people’s emotional and cognitive responses towards the objects.” (Echo Wen Wan and Rocky Peng Chen, 2021, p. 88)

Artificial Intelligence

“... a system’s ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation.” (Kaplan and Haenlein, 2019b, p.17)

Ground truthing

“Ground Truthing assesses the accuracy of remote sensing data by comparing it with physical measurements collected at the ground level.” - GIS Geography

Human-Centred Design

“A multidisciplinary approach incorporating human factors and ergonomic knowledge and techniques to make systems usable.” (Ngoc, Lasa and Iriarte, 2022, p.35)

Hyper-spectral Imaging

“A technique that analyzes a wide spectrum of light instead of just assigning primary colours (red, green, blue) to each pixel. The light striking each pixel is broken down into many different spectral bands to provide more information on what is imaged.” (Schneider and Feussner, 2017)

Industry 4.0

“Industry 4.0 defines a methodology to generate a transformation from machine-dominant manufacturing to digital manufacturing.” (Oztemel and Gursev. 2020, p.128)

Internet of Things

“a network that connects uniquely identifiable ‘Things’ to the Internet. The ‘Things’ have sensing/actuation and potential programmability capabilities. Through the exploitation of unique identification and sensing, information about the ‘Thing’ can be collected and the state of the ‘Thing’ can be changed from anywhere, anytime, by anything.” (R. Minerva et. Al, ‘Towards a definition of the Internet of Things (IoT)’ IEEE Internet Initiative, 2015, p.2)

LiDAR

“a detection system which works on the principle of radar, but uses light from a laser.” - Oxford Languages

Managed Retreat

“Managed retreat or managed relocation is the deliberate and coordinated decision to move structures and communities away from the increasing risks posed by rising sea levels, floods, and other risks such as landslides” (Climateandnature.org.nz, accessed August 2024)

Machine Learning

“Machine learning is a subfield of artificial intelligence, which is broadly defined as the capability of a machine to imitate intelligent human behavior.” (MIT Management, 2021)

Glossary

Monoculture

“The cultivation of a single crop in a given area.”
- Oxford Dictionary

More than Human

“A term used critically to remind human geographers that the non-human world not only exists but has causal powers and capacities of its own.” - Oxford Reference

NVIDIA

A company known for developing integrated circuits, which are used in everything from electronic game consoles to personal computers (PCs). The company is a leading manufacturer of high-end graphics processing units (GPUs). (NVIDIA.com, date accessed August 2024)

Parallax

“Stereographic parallax is the apparent shift in relative positions of features when it is viewed in different locations.”
-GIS Geography

Phenotyping

“Plant phenotyping is an emerging science that combines multiple methodologies and protocols to measure plant traits (e.g., growth, morphology, architecture, function, and composition) at multiple scales of organization.” (Carvalho et. al. , 2021)

Precision Agriculture “Precision Agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.” - (International Society for Precision Agriculture, 2021)

Photogrammetry “Photogrammetry uses photographs from at least two different vantage points. Similar to how your eyes work, it obtains depth and perspective because of separate points of observation.”-GIS Geography,

Proximal Sensing “Proximal sensing involves the use of sensors in close proximity to the plants, such as on a tractor or harvester or ground-based robot.” - Texas A&M Cotton Engineering

Trust “the attitude that an agent will help achieve an individual’s goals in a situation characterised by uncertainty and vulnerability” (Lee and See. 2004. p.54)

Remote Sensing “Remote sensing involves the use of sensors at a distance from the plants, such as on a satellite, a manned aircraft, or an unmanned aerial vehicle (UAVs) or drone. ” - Texas A&M Cotton Engineering

Abbreviations

ACT	- Affect Control Theory
Ag-Tech	- Agricultural Technology
A.I.	- Artificial Intelligence
ANT	- Actor Network Theory
BET	- Basic Emotion Theory
CASA	- Computers Are Social Actors
Co-bots	- Collaborative Robots
CPU	- Central Processing Unit
DFM	- Design for Manufacture
F.O.P.S	- Future Orchard Planting Systems
GPU	- Graphics Processing Unit
HCD	- Human Centred Design
HCI	- Human-Computer Interaction
HRI	- Human-Robot Interaction
ICT	- Information Communication Technology
IoT	- Internet of Things
ML	- Machine Learning
NZ	- New Zealand
RAAT	- Robotic and Autonomous Agricultural Technologies
ROI	- Return on Investment
RSE	- Recognised Seasonal Employee
STS	- Sociotechnical systems theory
TiA	- Trust in Automation
TAM	- Technology Acceptance Model
TAS	- Trustworthy Autonomous Systems
UTAUT	- Unified Theory of Acceptance and Use of Technology
XAI	- Explainable Artificial Intelligence

Positioning Statement

This project was situated in the overlap of design practice and technology to benefit the horticultural sector, with a scope focused on a New Zealand-based solution considering the measurement of fruit, particularly its sizing. Initiated for PlantTech Research Institute and working alongside a multi-disciplinary team of engineers and scientists informed the researcher and subsequent design to the current state of technological capabilities, and that which is emerging. This collaboration also enabled access to most of the major growing and packing companies of kiwifruit and apples on the North Island of New Zealand.

It was identified early on by the researcher and supervisor that a key factor within the project was the miscalibration of trust occurring as a result of a myriad of usability, data accessibility and communication for the fruit growing industry.

With a background in Industrial Design, the researcher brought a new perspective to the team and was able to identify opportunities for innovation within the complex ecosystems of orchards and packhouses, many of the insights expressed within this thesis. The traits of the researcher as being human-centric, insight-driven and sustainably minded in the design project complementarily paired with the context.

As the design component was experimental to PlantTech, the researcher operated individually on the project, receiving feedback and attending orchard walk-throughs and technology talks where appropriate with the wider team.

Acknowledging the need to learn through doing, the researcher set up a small field trial separately to mitigate disruption of access to this resource due to COVID-19 lockdowns and to collect data in the form of fruit size and count across multiple seasons, as well as usability data for informing potential pain points that could then be discussed with stakeholders. PlantTech went into receivership in November 2022, at which time the researcher needed to build new stakeholder relationships externally. Ensuring that a range of stakeholders such as individual growers through to large growing companies were represented was important, with communication happening primarily through orchard and innovation managers, as they are typically the first point of adoption for new innovation to the orchard.

The resulting outcome from the research offers a number of novel contributions to the current body of knowledge, including;

1. The creation of a product that acts as the first part of a wider system of products for better monitoring of orchards.
2. A Design criteria of factors when designing trust into objects.
3. The Trust within a Product Model of Experience framework enables the replication of designing products that effectively consider trust as part of the interconnective tissue between stakeholders.

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To measuring fruit

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Getting to the Core

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Figure 1: Apple Measurement, Photo by Author, 2021

Introduction

To measuring fruit

Traditional Industrial Design approaches developing usability, and utility, through modelling and prototyping heuristics, are central to establishing innovation in manufacturing sectors. This research project focuses on the horticultural sector, where technology-embedded products aim to collect various forms of data to inform orchard management decision-making, regarding the state of the crop.

Population and consumption pressures, along with the climate crisis and changing consumer preferences (Fruit and Vegetables – Your Dietary Essentials, 2020) are causing a shift in demand to higher quality, ethically sourced produce, placing pressure on land and farmers. Precision Agriculture provides innovative solutions to sustainable practice, enabled by data-driven technologies such as *Artificial Intelligence (A.I.)*.

Data generated in this manner seeks to enhance decision-making by stakeholders, optimise productivity and land use, and improve supply chain resilience and traceability (HortNZ, 2021). This improved value to horticultural production has the potential to provide New Zealand with a continued competitive edge in high-value export markets.

Current practices of fruit measurement use digital or manual devices and are often time and labour-intensive for seasonal workers. Being able to accurately measure fruit while on-tree can be challenging, with the quality of data collected being reliant on the skill and judgement of the individual. The measurement of fruit provides an indication of growth, identifies the ideal size based on fruit species and variants, and contributes to quality assessments and commercial sales. Fruit measurement processes are highly repetitive manual tasks, subject to human factor variables such as estimating the widest part of the fruit by eye. Orchard workers of different stature undertake the task, measuring in different heights of the tree, where fruit sizes would vary. Consequently, the data recorded may or may not be trusted by all the stakeholders operating within the orchard production system.

Within horticulture, the orchard environment requires continuous monitoring to assess optimal times for cropping. It is reliant on environmental factors such as weather, involves (and is sometimes constrained by) labour-intensive practices, and needs to be responsive to market trends. Having relevant environmental information, crop statistics, weather data, etc., is crucial to decision-making in the rapidly paced environment the orchards present.

Technology that enables forecasting and capturing of the current state of the orchard can greatly assist growers, orchard managers, and stakeholders in making the decisions they need for a successful season.

The potential for this project was identified as part of research being undertaken by PlantTech Research Institute, particularly Research Lead Professor Ian Yule, who saw an opportunity to engage with the issues of connecting to the *Agricultural Technology* (Ag-tech) sector from a different perspective; utilising design and the user-centred nature of its practice to create trustworthy systems and products.

1.1 Project Aim

This project seeks to design a fruit measurement device for the New Zealand horticultural industry. It focuses on measuring apples using a camera-based platform to collect insightful data throughout the growing season, translating these insights through a dashboard user interface. The project aims to inform design considerations through identifying factors of trust and integrating these factors into the product system.

1.2 Research Objectives

This design technology research proposed a new concept design for a fruit measurement system that provides clear and measurable benefits to stakeholders and enhances trust aspects of product and system experience. Understanding the emerging capabilities of machine learning and integrated technological influences of human-object and human-system interaction informed the investigation of how data can be visualised to be transparent, familiar and accessible for end users.

The project seeks to inform and empower decision-making by the end users and stakeholders about the best time to harvest, based on the progression of fruit development at a given time, historic growth data, and external factors such as weather.

This allows for better management of resources and deployment of labour and equipment. The consequence is a more sustainable orchard operation with greater productivity and benefits to all stakeholders.

This is achieved through a design discovery process, identifying key insights related to fruit measurement, integrating systems and related data, and developing an empathetic design solution across multiple modes of interaction and engagement.

1.3 Research Questions

What factors of trust are the most important in creating a successful fruit measurement product, and system interaction for end users?

How do factors of trust position themselves in relation to elevated usability approaches within industrial design?

What are the existing issues of trust and how do they operate between active agents?

What is the true nature of a fruit measurement device using embedded technologies?

What are the existing fruit measurement processes and their user experiences?

What is the true nature of the design of a technology-embedded fruit measurement product within an orchard context?

How is that products' subsequent data collected and visualised to inform the development of understanding and decision-making for end-users?

What methods of data visualisation are most appropriate for the horticultural sector in New Zealand?

Scope of Research

Design for...

The Horticulture Sector

Technology

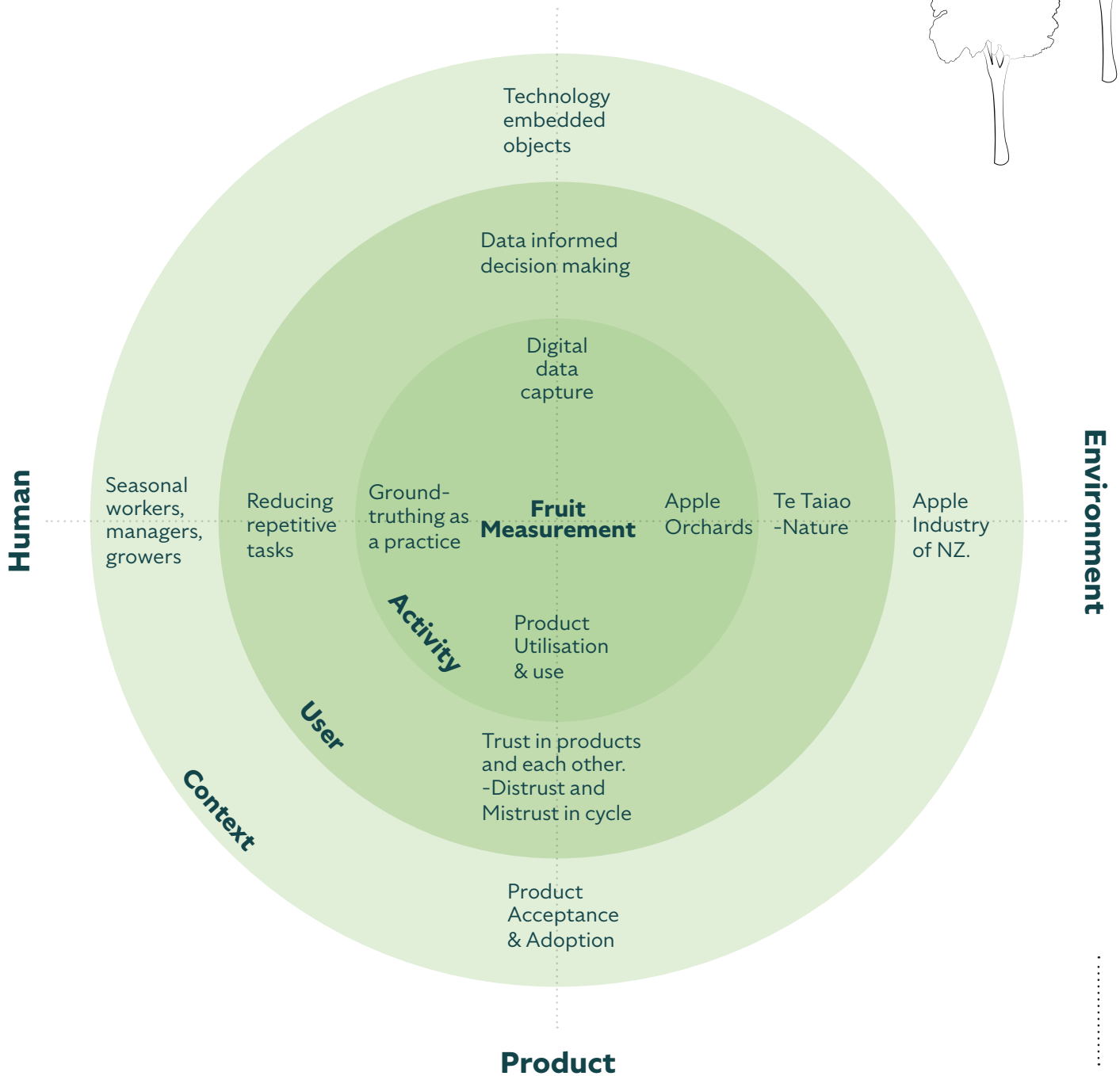


Figure 2: Scoping Diagram and Positional map, By author, 2023

1.4 Scope and Limitations

PlantTech utilised a range of technologies as part of their data collection and analysis processes. As part of the development strategy for this project, a number of feasible technologies were identified to assist in the scoping of the products' deliverables.

This project uses the terminology of a 'technology-embedded object', which utilises software with *Machine Learning* (ML) capabilities and uses Zed2i hardware for the camera. This hardware presents anthropomorphic characteristics in that it has two lenses that present as eyes. It is not a robot, as it is not self-acting and requires a human user to set operations. However, it uses product architecture similar in characteristics, semantics, and expectations to what users might assign to robots (Mondry and Cohn, 2021).

In the horticultural sector, technology-embedded products aim to collect various forms of data to inform orchard management's decision-making, regarding the state of the crop.

A technology-driven device that captures fruit count and size with accuracy would improve data quality. The translation of this data into a format that enables stakeholders to analyse, query, and act on the information presented holds many benefits for a time-sensitive industry. An elevated user experience of the device, along with quality data driving the system, would provide a successful engagement with an intelligent product system that integrates trust between stakeholders and contributes to resilience in horticultural production. Trust can be seen as a critical component to managing reliance for sustained product use.

1.5 Thesis Chapter Outline

This thesis contributes towards the partial fulfilment of a creative based doctoral study.

- 1.** Chapter 1 introduces the study, its driving forces and the key objectives and scope it sought to achieve.
- 2.** Chapter 2 addresses the context of the project, outlining the problem the project sought to investigate, the user group and the initial design methods of enquiry.
- 3.** Chapter 3 addresses the existing literature informing the project and identifies gaps in current research, as well as opportunities for innovation to the field of research. The subsection focuses on the literature around trust, and identifies the need for a framework for designing trustworthy products and the relationship between different actors involved when designing for trust.
- 4.** Chapter 4 addresses the methodology used in this study and discusses the design methods that have been used. This chapter also addresses the ethical considerations as part of this study.
- 5.** Chapter 5 addresses the findings from the 'Fruit Study', an immersive research approach which enabled a better understanding of current user experiences and growing practices.
- 6.** Chapter 6 captures the design process of the subsequent creative - practice from which 'Foresight' product and system was developed.
- 7.** Chapter 7 introduces 'Foresight' the final iteration of the design and discusses its features, benefits and implementation into orchard infrastructure.
- 8.** Chapter 8 produces an overview of the research and the gaps in the field of research the project fulfils. It reflects on the study as a whole as well as recommendations for other industries which may reflect on the subsequent framework.

References and Appendices are provided at the end of the thesis.



2.0

Context Review

Getting to the core

Figure 3: Apples in tree, Photograph by Author, January 2024

Situating the Study

The value of the New Zealand horticultural market was estimated at \$7.48 billion (HortNZ, 2024), of which \$4.67 billion came from exports. New Zealand grows over a hundred types of fruit and vegetables on almost 80,000 hectares of land and employs over 40,000 people throughout the horticultural sector. The sector exports to over 128 countries, including Australia, Japan, China and the United States. (Hort NZ Report, 2021) The New Zealand apple industry is the second largest exporter after the kiwifruit industry (AucklandNZ, 2023) and is an emerging international market for New Zealand with expanding orchard locations and apple varieties.

New Zealand is often described as a testbed for innovation due to its population size, and being a fairly accepting and technologically advanced nation. (Agritech Industry Transformation Plan, 2023) Many international markets see this as an ideal context in which to try ideas, and generally speaking, New Zealand welcomes this as it can create jobs and opportunities. The digital technology sector of New Zealand’s compound growth rate of 10.4% annually makes it our fastest-growing sector since 2016. “New Zealand is an ideal testbed for Information and Communications Technology (ICT) goods and services reflecting a population receptive to new technologies.” (International Trade Administration, 2023)

The seasonally-driven orchard environment hosts many labour-intensive practices, for which continuous monitoring of the crop is required to best inform orchard practices. Technology that enables forecasting and capturing the current state of the orchard can greatly assist in the decisions that farmers, orchard managers and stakeholders, need to make for a successful season. Current barriers include cloud connectivity, technology adoption rates and concerns around data ownership (Skilling, 2020)

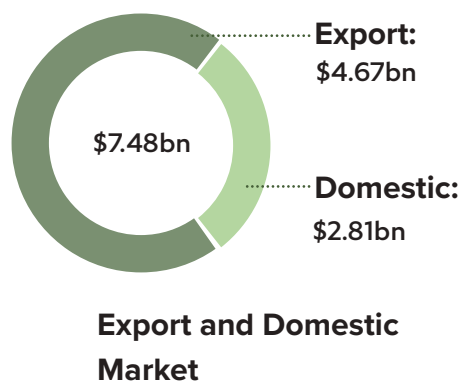
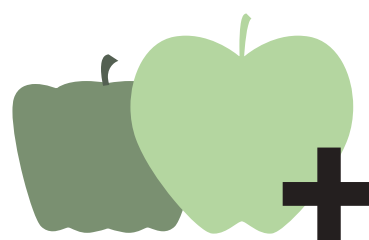
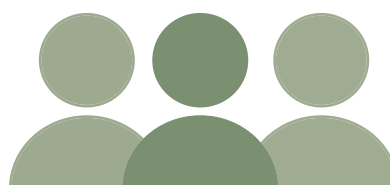


Fig. 4



100+
types of fruit and
vegetables grown in
New Zealand

Fig. 5



40,000+
employed in
horticultural industry

Fig. 6



\$7.48bn
Value of Horticulture
in New Zealand

Fig. 7

Global Apple Market

Import to New Zealand

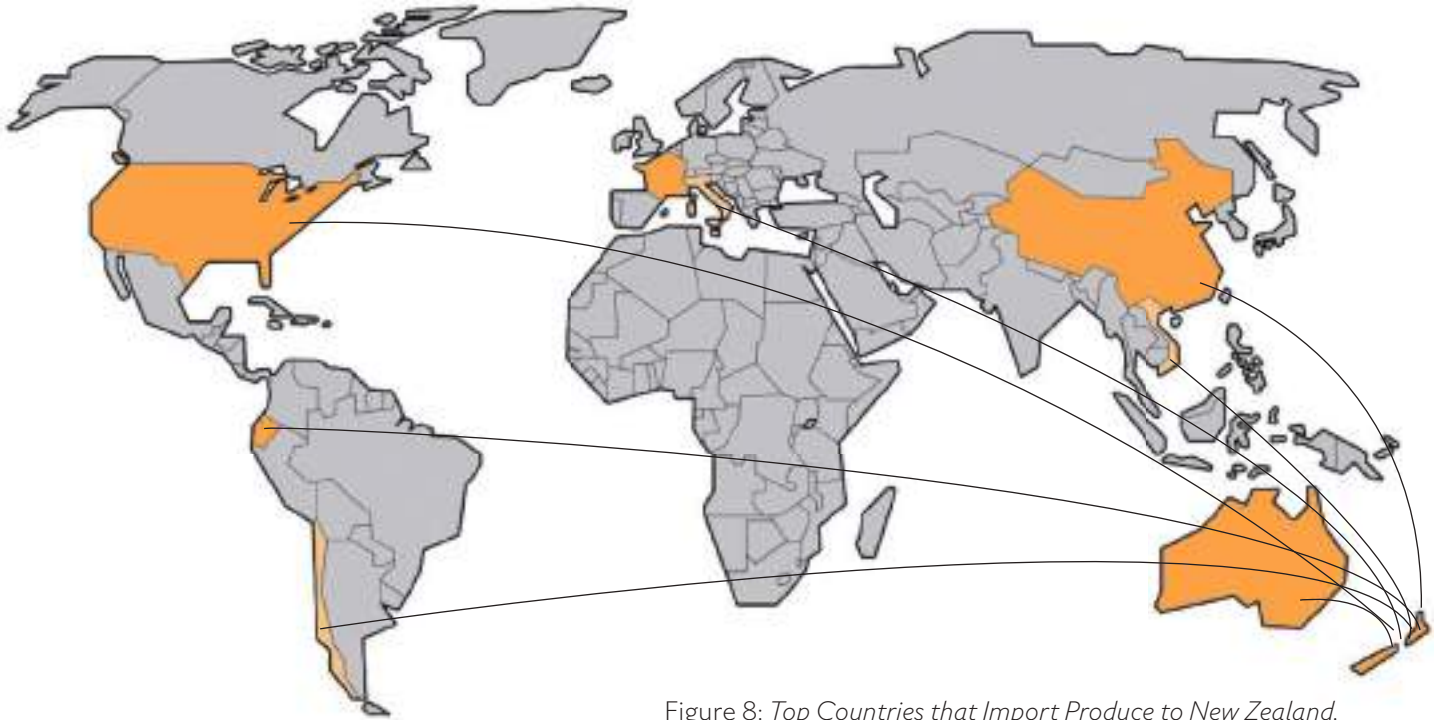


Figure 8: Top Countries that Import Produce to New Zealand, Drawn by Author, 2021



Showing New Zealand in relation to countries with similar production capabilities and varying landmass.

Fig. 9

Drawn by Author, based on the Dataset from: Food and Agriculture Organization of the United Nations (2023) – with major processing by Our World in Data. Our World in Data. <https://ourworldindata.org/grapher/apple-production>

Export from New Zealand



Figure 10: Top Countries that New Zealand Exports to, Drawn by Author, 2021

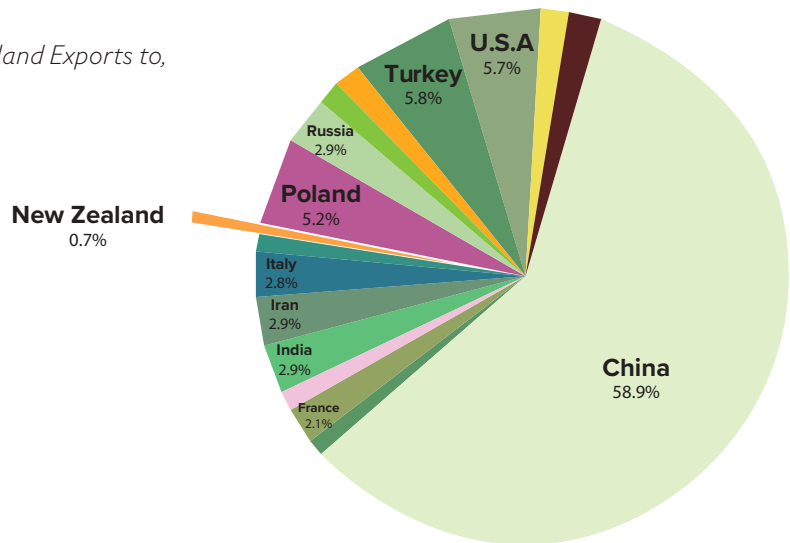


Fig. 11: Pie Chart showing percentage of New Zealand's contribution to Global Apple Production

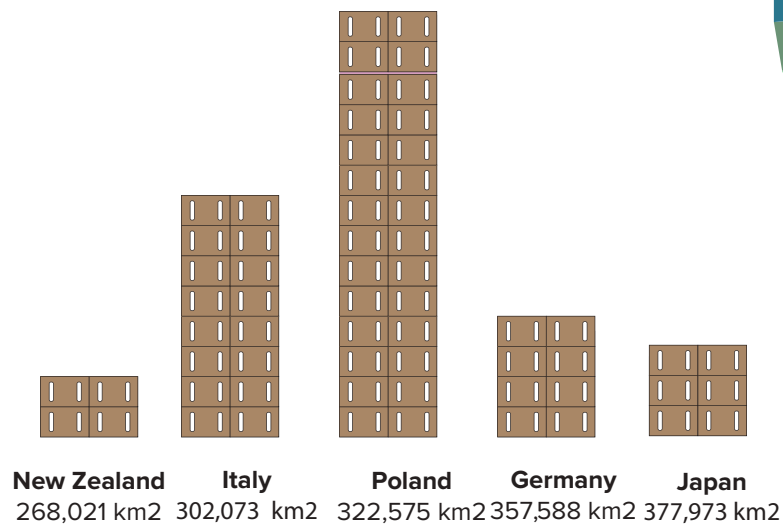
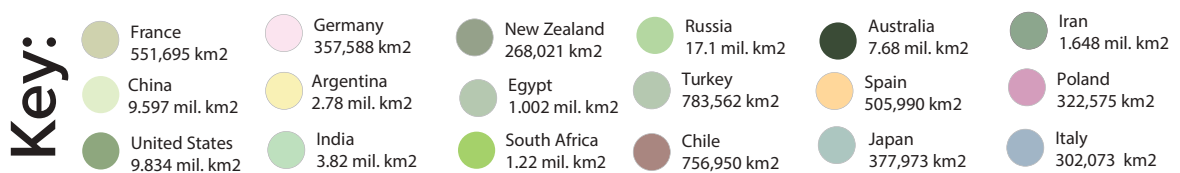


Fig. 12



2.1 Technology



Figure 13: Apple Studio Photo, Photograph by Author, January 2024

Precision Agriculture

Leveraging technological capabilities within products enables innovation and efficiencies replacing manual processes which may be subject to high levels of repetition and inaccuracies. *Jargon* (terminology used by specific professions) within technology can lead to confusion (Bullock et al., 2019; Rainer Rehak, 2021), mainly when terms are used interchangeably to refer to product performance. As technologies develop, their function becomes less transparent, furthering the potential of mis-calibrated expectations from users (Lyons, 2013).

Precision Agriculture seeks to find innovative solutions for sustainable practice, enhanced by technologies such as Artificial Intelligence, and Machine Learning.

Improved orchard data furthers supply chain resilience and improves traceability where a shift from volume to value (Our Land Report, 2021) is allowing New Zealand to have a competitive edge on the global stage.

Design acts as the facilitator of communication between the technological output and the practical application for the farmer. The solutions needed for this sector are not one-size-fits-all, but by increasing infrastructure to support integrated technologies in the field, there is a growing opportunity to understand how we can farm effectively, Interoperability, scalability, data privacy issues, and the changing labour force are key considerations that impact the way we design for this sector.

2.1.1 Industry 4.0

Industry 4.0 is a blanket term for the further connectivity and automation in current society and production industries. Initially suggested in Germany in 2011 (Oztemel & Gursev, 2020) it quickly spread as a concept interested in the integration of cloud based technologies to intelligent-objects. Liu et. al. (2017) reviews how the rise of Industry 4.0 has impacted agricultural practices. They critique the process of *Monoculture*; where the same produce is planted annually, leading to ecological decay over time, and the intensification of farming as not allowing the land enough time to regenerate. Ngoc, Lasa and Iriarte (2021) argue for the validity and implementation of *human-centred design* (HCD) into considerations of Industry 4.0. They argue that either humans must cooperate with systems or that systems need to acknowledge the competence level of the user. “the role of humans has changed and shifted from low-level operations – which can be dangerous, dirty, difficult and dull tasks to high expertise and safe tasks” (p. 37)

Automation and the incorporation of technology-embedded objects into the nature of work can create perceived challenges and barriers to trustworthy, collaborative work. The theme of automation replacing roles, and the shifting nature of human labour away from dull, dirty and dangerous work (Gavaghan, Knott, MacLaurin, 2021) means that tension arises in the openness to accept and adopt new technologies if there is a perception that they play a role in the eventual replacement of the human worker. A true collaboration between product and human worker requires the mitigation of communication styles and clear intentions expressed by both agents.

“Precision Agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.”

— International Society
for Precision Agriculture
(ISPA, 2021)

Please see Appendix A:
Technology Review

2.1.2 Internet of Things

The Internet of Things (IoT) is part of Industry 4.0. With the shift that New Zealand wishes to make from a volume to value paradigm, it is more important than ever that the narrative around the food that we produce, and consumers buy, address sustainable practices responsibly. The Internet of Things refers to objects that have programming potential and can interact via networks. Mishra et al., (2016) discuss the '4R' concept in precision agriculture, which suggests that identifying the right material, the right amount, the right location and the right time are key to creating more precise actions that will benefit the sector and environment. The authors suggest that advanced forecasting, traceability to show the journey from farm to fork, and combatting counterfeit and diversion attempts are all key benefits not discussed as prominently as the time and labour saving aspects of precision agriculture.

2.1.3 Proximal Sensing

Remote sensing refers to “collecting some property of an object using a device/sensor that is not in physical contact with the object” (Reddy 2021 p.254) This encompasses ground-based, air-based and satellite platforms. Whereas, proximal sensing collects data at close range in a non-physical capacity (Anderson et. al. 2021) The context of this project operates as a proximal sensing ground-based solution that operate up to a few metres away from the object. They can be static or moved around the orchard environment and have the benefit of being cheaper than many of the long-range sensing solutions. The use of various sensors, cameras and detectors can allow for key characteristics to be measured including numerical and /or image-based data.

2.1.4 Digital Crop Estimation

Digital Crop estimation is the process of capturing estimated data such as the count and size of a crop to assist decision-makers in better predicting yield and actions that may need to be undertaken as part of orchard operations. This process is done by farmers wanting to know more about their operations and is ideally done throughout the growing season to capture relevant information on growth patterns. Doing this over a series of years also allows for historical data to be collected for comparison.

This proposed design would utilise Digital Crop Estimation as a method of identifying fruit form and then calculating a numerical value based on the width of the pixels the algorithm defines as a fruit (Koirala et al., 2019; Gongal et al., 2018; Santos et al., 2020). This allows fruit size and fruit count to be measured, while fruit colour (also known as blush) can be visually analysed by the user by looking at the images.

Sensing technologies are constantly improving and expanding as componentry and systems become more accessible and connected. While there is a wealth of research that explores different sensor types, this has been omitted in this review.

2.2 Environment

New Zealand has a temperate climate (Palmer & Horne, 2021) with both coastal and inland areas being successful for growing fruit. Approximately 86% of New Zealand's apples are grown in the Hawkes Bay or Nelson region (Tupu. nz, 2024). As with many areas of land where intensive farming practices have occurred, we are turning to techniques such as Precision Agriculture to find out how we might better utilise the resources available in a sustainable manner, both in profitability and in meeting environmental standards.

2.2.1 Location

The majority of apples are grown in either Nelson or Hawkes Bay, but due to New Zealand's climate they can also be found in other key horticultural regions.

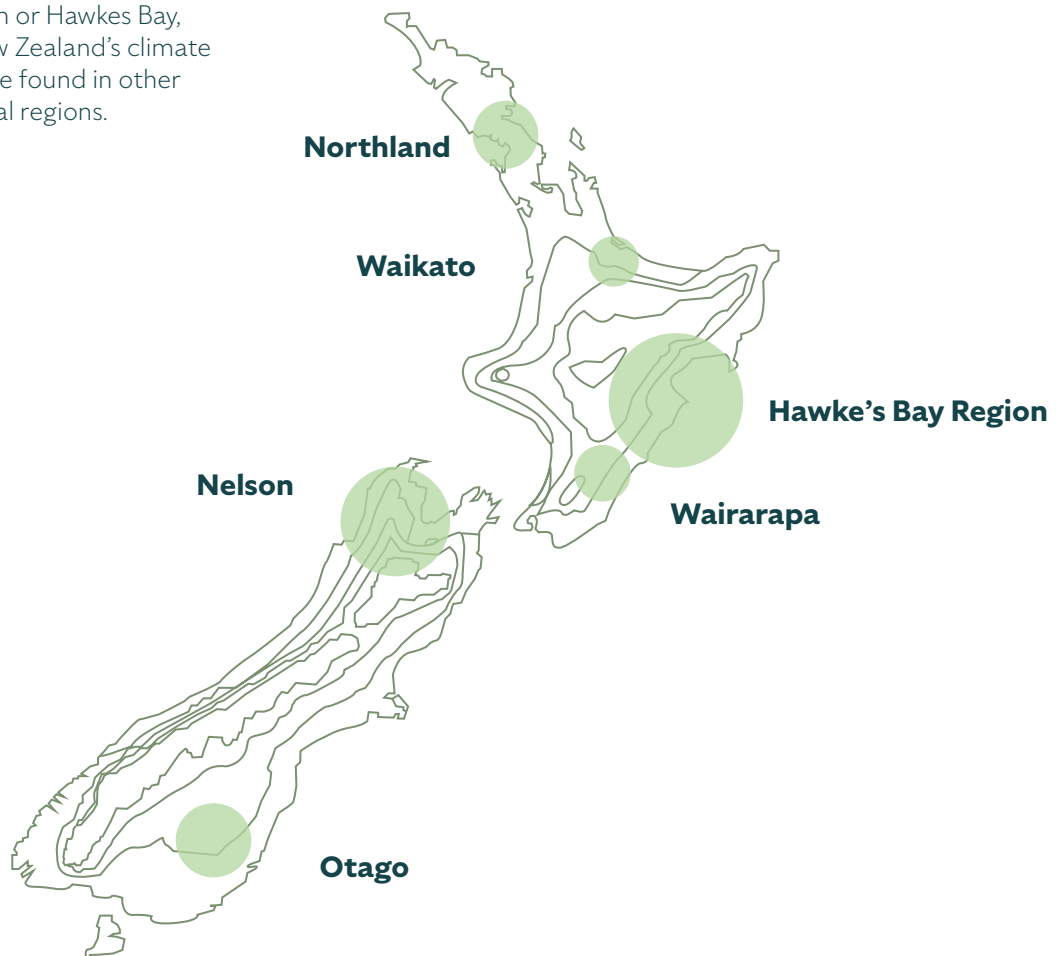


Figure 14: New Zealand Map showing estimated volume of apple production by region ,
Drawn by Author, October 2021

2.2.2 Why Apples?

An orchard manager and participant in the study identified that apples are typically harvested between February and May, depending on the growing location, species and weather fluctuations. Trees prefer full sun and require 2.5 cm of rainfall every 7-10 days in order to grow up to 1% a day. In 2023/2024 season, New Zealand exported approximately 480,000 tonnes of apples (Fresh Deciduous Fruit Semi-Annual, 2024). Orchards prefer flat or gently sloping land for machinery access, thrive with shelter in the form of windbreakers and need deep, free-draining soils. Setting up hail netting and frost fans are also common in colder areas and are becoming increasingly used as precautionary methods. (Tupu.nz, 2024)

The apple fruits shape, with a similar major and minor axis, colour and placement within a tree makes it the optimal fruit to focus on as part of the applications of this study.

6th

largest exporter globally of apples

2B

estimated \$2-billion-dollar industry by 2030

3rd

most produced fruit

83

million tonnes produced in 2017

1st

Ranked most competitive apple market globally (2018)



Estimating the widest part of the fruit can be challenging.

Figure 15: Apple Studio Image , Photograph by Author, January 2024

2.2.3 The apple market

The New Zealand apple and pear industry was voted the most competitive up-and-coming market by the World Apple Review (2016). The local shift in volume to value (NZTE, 2020) means that orchards are beginning to acknowledge the changing needs of their consumers who wish to consume ethically sourced, traceable food that is sustainably grown. A growing global population means that there is a need to establish maximised yields that can meet consumer demand in quantity and quality in the future.

2.2.4 What is being measured

Orchardists know a great deal about fruit production, and modern technologies have the potential to inform decision-making based on accurate real-time data and data history. Removing the reliance on tacit knowledge vested in individuals, allows rapid crop management decision-making and better forecasting of consequent yield. Data informing orchardists needs to be displayed in a manner meaningful to them, supporting trustworthy interaction across the system. A key aspect of critical data informing orchard management is fruit size.

2.2.6 Approaches

Different growing styles position the fruit in different locations within the tree, which is a critical design consideration as maximising how many fruit are seen via the camera is critical. For the sake of scaling to different styles, the design should be able to view both vertically and horizontally.

2.2.5 Morphometrics

Fruit size is a key commercial factor that orchards use to ensure that their yield can meet consumer demands for higher-quality produce. Different International markets seek different fruit sizes based on preference. Monitoring this can take significant time and labour, adding further stress to labour shortages. There are over 7,500 varieties of apples globally (Morgan & Richards, 2002), each having an ideal size before they are ready to be harvested.

The major and minor axis of apples tend to be similar in diameter, making them easier to measure. Referred to as morphometrics, one study by Christodoulou and Culham (2021), found that the timing of harvesting fruit, as well as good storage practices, can allow for staggered or planned harvests, enabling better distribution of labour and equipment. Apples grow different sizes throughout the height of the tree also.

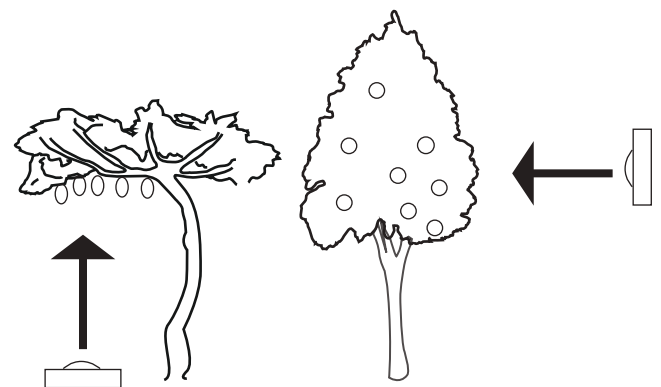


Figure 16: *Visual Approaches Explained*, Drawn by Author, 2021

2.3 Growing Styles

Traditional

Traditional trees typically refer to Central leader or Multi-leader branched trees, such as what we associate with tree shapes. This style is the most naturally formed and common style. Trees are often pruned for height and trying to promote light reaching the lower branches.



Fig.17

Future Orchard Processing System

F.O.P.S is a fairly new method of shaping the tree, promoting it in a similar way to what we might with grape wines to grow upwards and along wiring. This means the rows can be narrower to fit more trees in and light exposure means that fruit grow very successfully.



Fig.18

V trellis

These trellis' are splayed to allow two leaders from a tree to grow beside one another against wiring. Pruning in this method is quite intensive, but yield indicates that the space created in the centre enables successful growing.



Fig.19

Kiwifruit

Kiwifruit is grown along a grid trellis infrastructure to create a foliage canopy. The vines are secured along the wiring to assist in the shape of the growth and maximise leaf exposure to sunlight.



Fig.20

Profile View

Top View

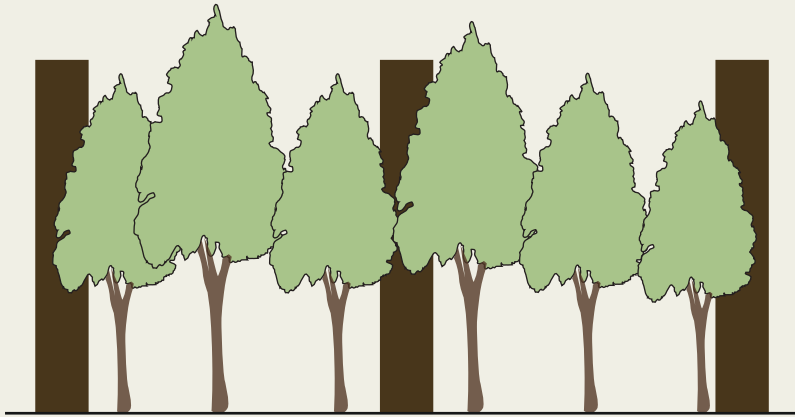
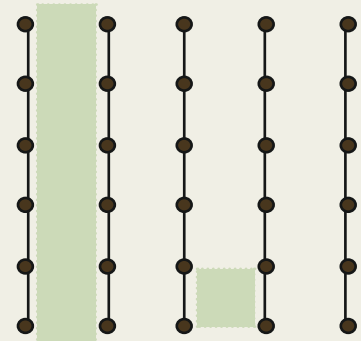


Fig.21



Row Bay

Fig.25

Narrower rows

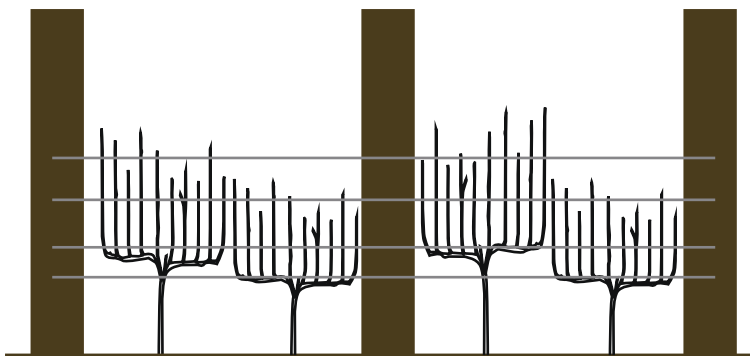
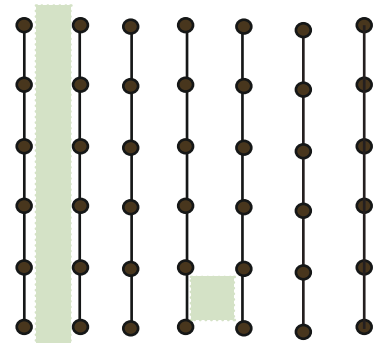


Fig.22

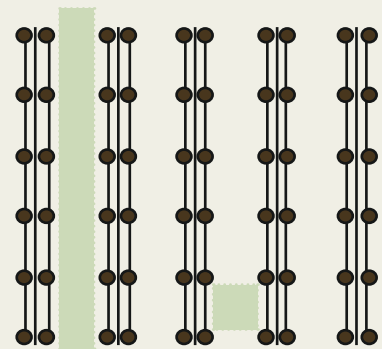


Row Bay

Fig.26



Fig.23



Row Bay

Fig.27

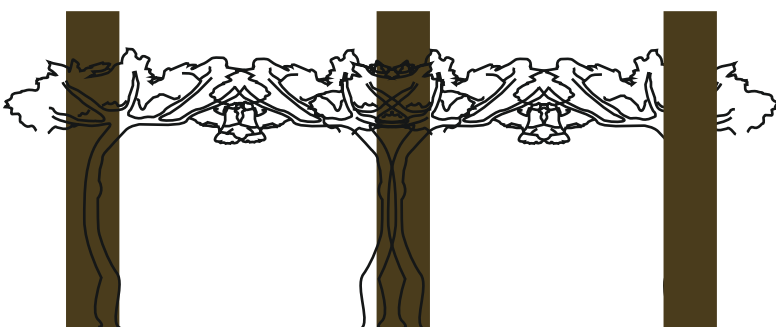
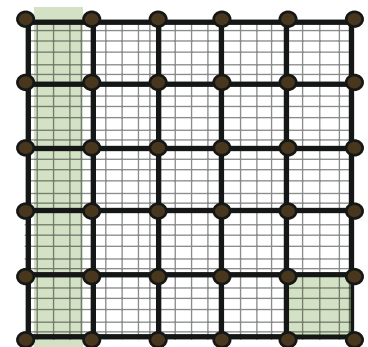


Fig.24



Row Bay

Fig.28

2.4 Precedent Analysis

Please see Appendix B:
Precedent Analysis

The following summary of existing in-orchard solutions to fruit measurement identified that many of the tasks require high levels of repetition, time for the user or are subjective when estimating the widest part of the fruit, leading to inaccuracies.

Perceptual Mapping

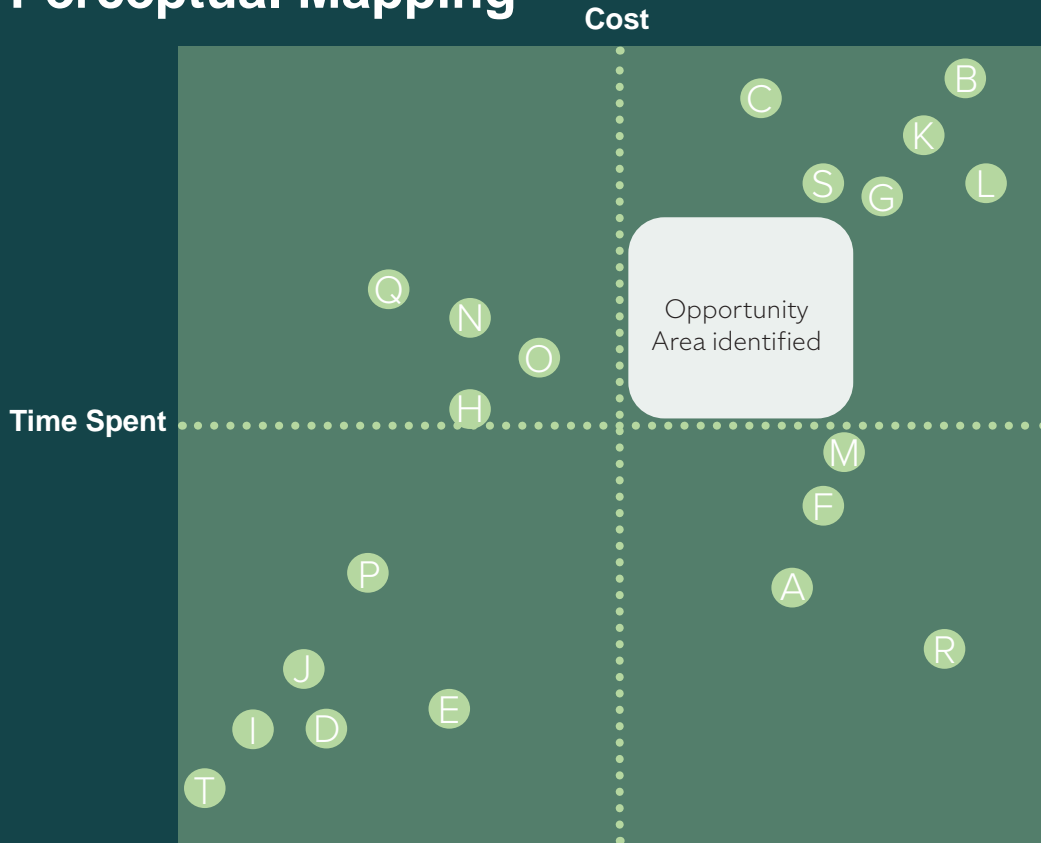


Fig. 49 Trend Map of cost versus time spent, by Author, 2022

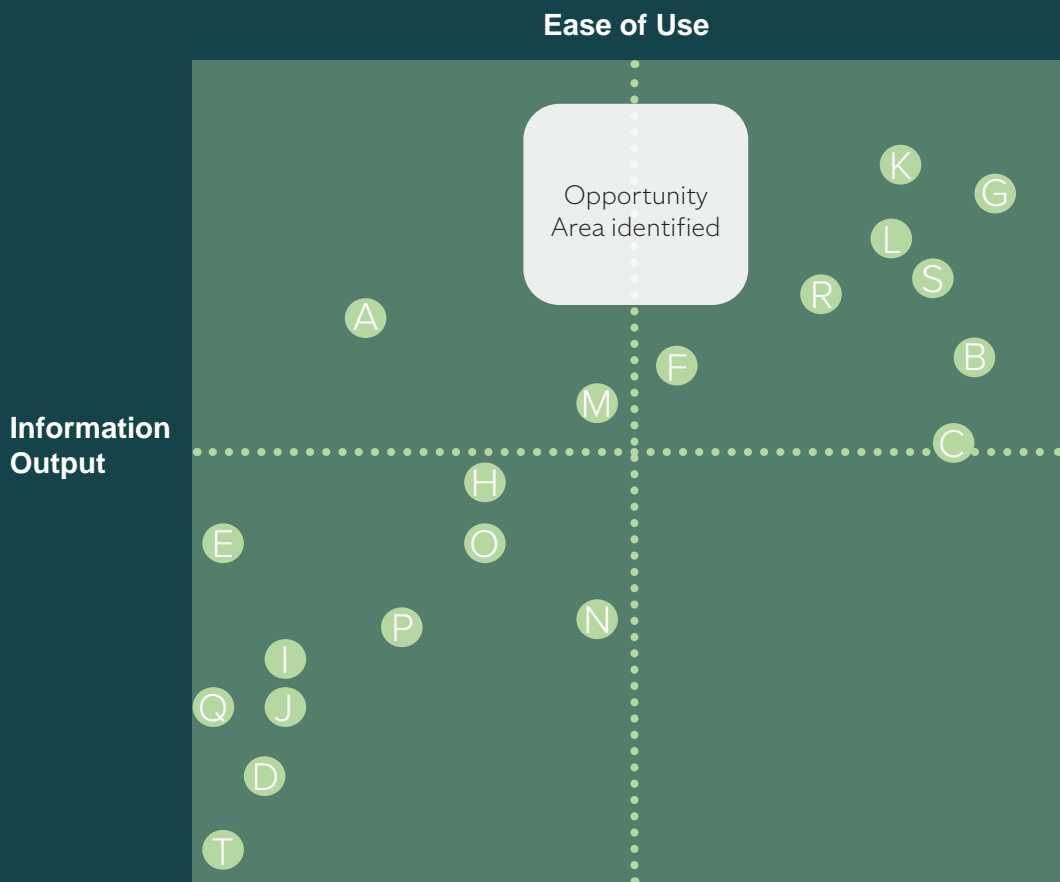


Fig. 50 Trend Map of Information Output versus Ease of Use, by Author, 2022

The above perceptual maps are a commonly used design method, and in this instance was used to understand the relative positioning of existing products and trends in relationship to each other, to best identify areas of opportunity for innovation.

What was identified was a product with high information output, moderate ease of use was ideal. The cost of a technology-embedded object like this could easily sit below many of its mobile platform competitors, as well as reducing the labour cost involved.

2.5 Case Studies

Case Studies have been conducted which explore companies, products and systems that operate in interesting ways with intelligent objects. These reviews seek to better understand the opportunities and mis-steps of others to better inform the design process.

**Please see Appendix C:
Case Studies**

Halter

Halter is a start-up company that looks at re-inventing the way dairy farms operate. The design of a halter which sits around the neck of the cow allows the farmer to move the herd with ease and virtual fencing.

This device allows the cow to be guided in the paddock, reducing the need for extensive fencing, saving the farmer time and money. It is reliant on cow behaviour being that the device can be fitted to a few and the rest will follow.



UBCO

UBCO has created one of the leading utility bikes worldwide, appropriate for a range of functions, but popular in the Agricultural sector. Released in 2018, UBCO gained popularity through its high-level of functionality, minimalist aesthetics, and sustainable approach to product design. A subscription-service also opens the market to a wider-range of customers.



Fig. 53

Farmbot

Open Source CNC Farming - The Farmbot is a kitset product designed for backyard, educational and research applications to allow everyday users to experiment and learn more about both robotics and growing food. The associated farmbot app allows for season planning, planting order and is completely customisable for different uses. This makes it a popular product option.



Fig. 54

John Deere

John Deere is a popular brand in the agricultural market that is best known for their tractors although they are exploring new innovations such as drone technology to ensure that their brand is keeping up with the trends and demands in agriculture. But with their new innovations, comes a new cost which is impacting heavily on the user. This case study looks at one of the key issues that many users have with John Deere and that is the serviceability of each product requires you to have a qualified John Deere repair man to have to do the job.

This means that farmers are not able to tinker or adjust any software on their tractor or they may be in violation of Intellectual Property conditions and in some cases such as in the United States, may face legal action. The loss that this can pose to farmers if the tractor is unable to operate during harvest and other important markers is immense.

Cropsy

Primarily focused on assisting the viticultural industry in mapping out vineyards. Using image sensing technology to assist growers in better decision-making. A recent startup which was introduced to the public at the 2021 Fieldays in June. Cropsy utilises a device which can be mounted on a tractor and records data along each row.

Current functions include counting bunches of grapes on vines, detecting disease and pest, assisting in the minimisation of crop loss and can estimate yields.



Fig. 55

2.6 Trends & Forecasts

- With 2021 as the International Year of Fruits and Vegetables, and acknowledged the ongoing need we have on a global scale to meet food demands in equitable and sustainable ways. New Zealand has a number of growing markets, with 42% of current horticultural exports being to Asian Countries. (FAO, 2020)
- By 2025, farms will require a Farm Environmental Plan to meet freshwater regulations. (Kiro, 2023)
- By 2028, there are expected to be many more distribution channels such as supermarkets with an increased demand for frozen and convenience meals. Methods of extending crop seasons will also begin to be more prominent as we try to meet food demands and work with climatic conditions. (Dalziel et. al., 2018)
- By 2050 it is estimated that there will be ten billion people, with shifting economic standings and changing consumer demands. To meet these demands, Agriculture is required to produce 50% more food than in 2012. (FAO, 2017)
- By 2100, sea-level increases are expected to cause major changes where certain fruit are grown most successfully (Young, 2020)

Managed Retreat

Two thirds of New Zealand's population is located in areas susceptible to flooding and rising sea levels (Ministry for Environment & Stats NZ, 2023) Managed retreat, also called planned relocation or te hekenga rauora (Arnold & Elias, 2023), takes a proactive approach to considerations of where we place our future orchards and related infrastructure. Hino et. al. (2017) compiled a set of case studies that reflect on approaches taken globally in response to climate change. Severe weather events are increasingly common, such as that of early 2023 in the Hawkes Bay region, with physical damage estimated to cost between \$9 -14.5 billion (The Treasury New Zealand, 2024.) These ongoing considerations will have increasing importance on the planned location and infrastructure of orchards.

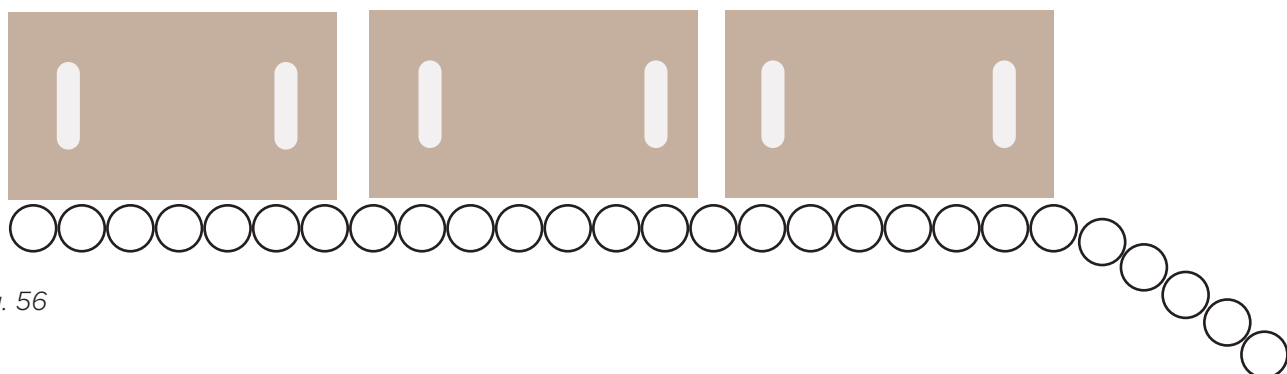


Fig. 56

2.7 The User Group

Introduction to the Users

There is a wide range of stakeholders involved in operations occurring in the horticultural sector and the activity of growing, maintaining, harvesting and processing apples. Their needs vary greatly as the nature of their involvement and related tasks are significantly different. Taking a staggered approach to address their needs was understood within the research scope as an essential part of the user investigations undertaken in this study.

A comprehensive diagram of stakeholders involved in this study is visualised below, with the dashed line symbolising the stakeholders engaged as part of this project.

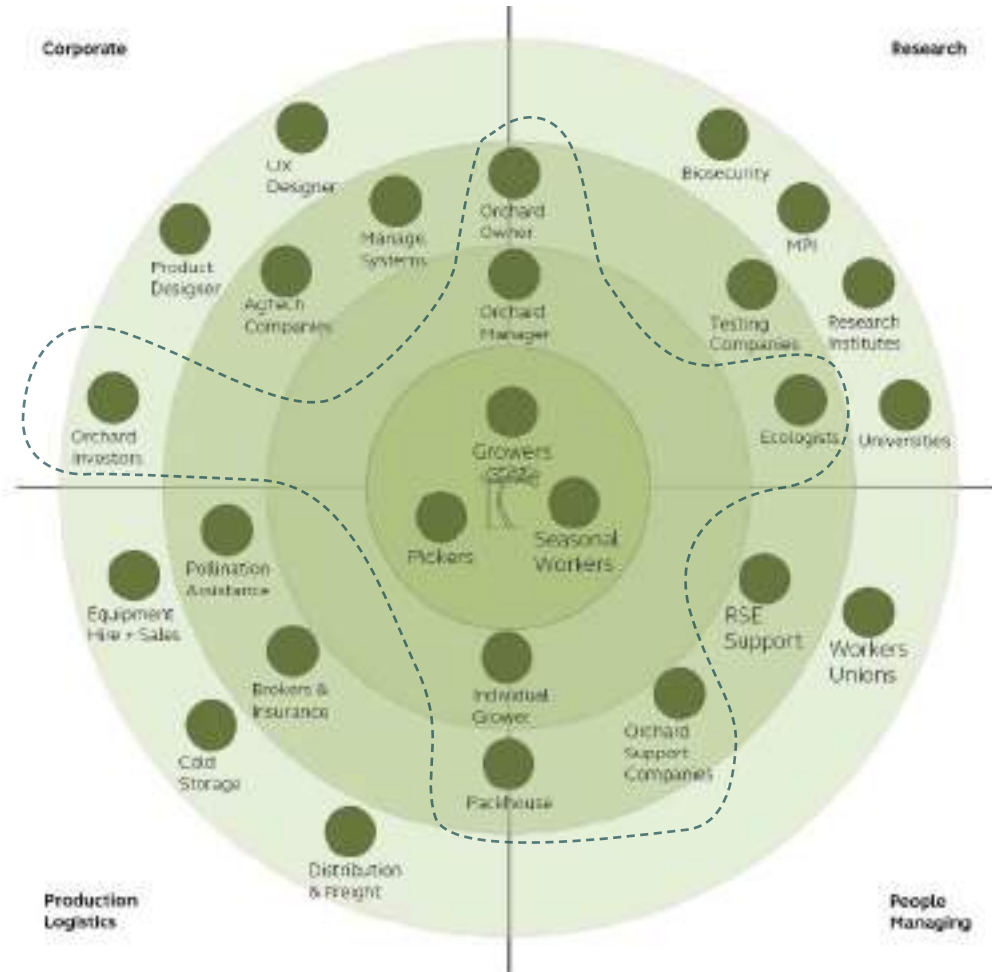


Figure 57: Stakeholder Map, drawn by Author, 2022

Please see Appendix D:
User Mapping

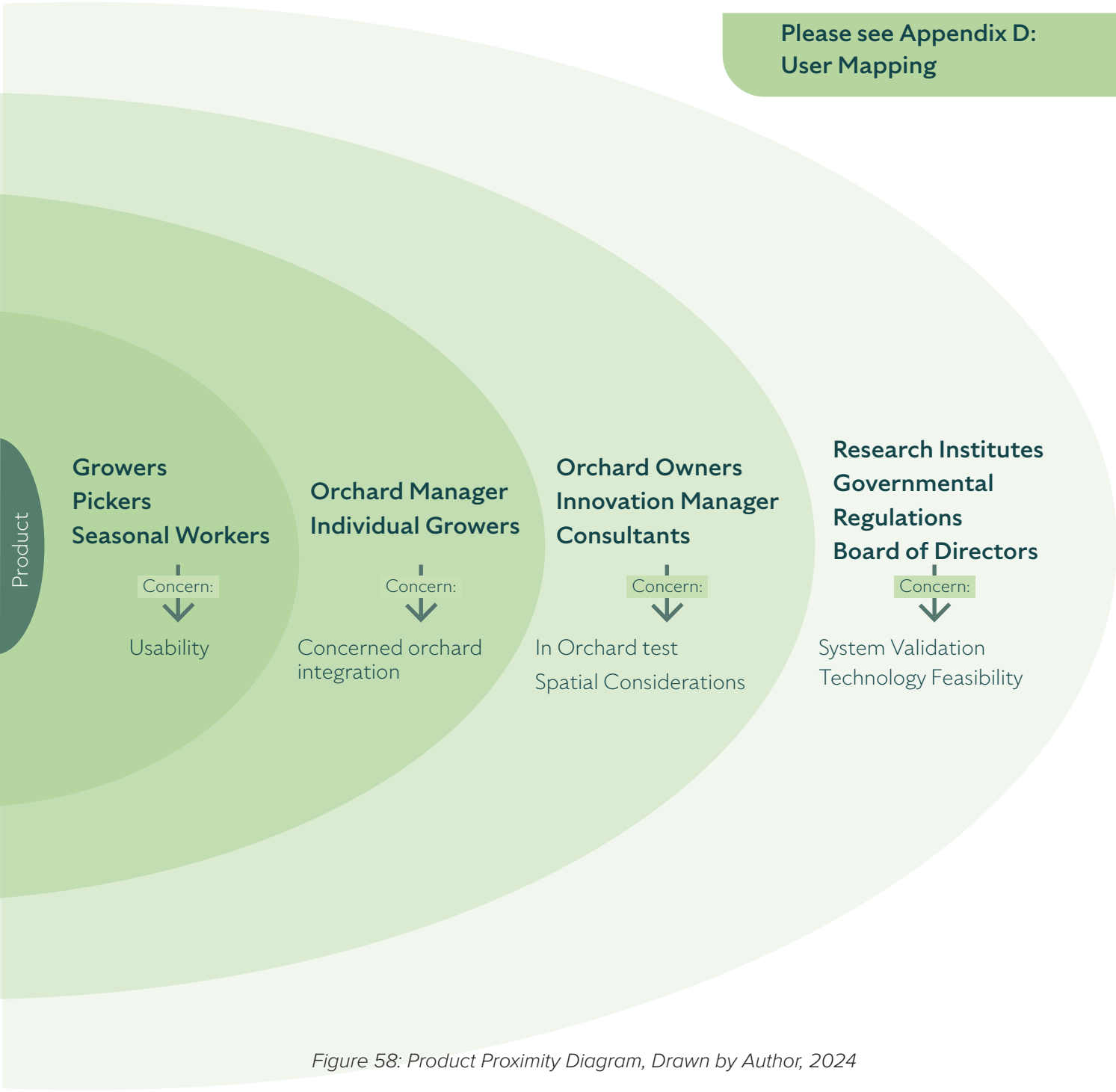


Figure 58: Product Proximity Diagram, Drawn by Author, 2024

2.7.1 Contexts, needs and backgrounds

This project communicated with fifteen horticultural companies, ten of whom gave feedback on the project as either comment, interviews or validation. The participants were a combination of growers, orchard managers and innovation managers to advise on the feasibility of the concept.

The following is a summary of the primary users involved and the unique considerations that they brought to the design requirements and opportunities for meaningful integration of features into the design to benefit usability and cognition. It also identified the unique design communication that was required for each group to communicate the aspects of the design that they will find the most important to their appraisal.

2.7.2 Seasonal Workers

There is not as much clear data about local seasonal workers. They are more likely to make up part of the permanent workforce who support operations outside of the growing and harvesting season.

“The majority of people working in horticulture are paid an hourly rate. In harvesting, a piece rate was more common (43% of workers). In winter pruning there was an even split between the hourly rate and the piece rate. For all remaining seasonal tasks, the hourly rate was the most common.” (NZKGI, 2020, p.3) The concern with payment by piece, or by bin versus paying by the hour is that workers operate faster to try and make enough money, and take less care in the placement of apples into the bin.

Any damage to the surface of the fruit can cause it to rot, which can subsequently impact the rest of the bin, leading to a reduction in final yield. This is where the metaphor “one bad apple can spoil the barrel” is quite literal.

The nature of work is changing for workers in this industry, as is the amount of technological interactions required with new infrastructure and equipment. It also makes the orchard easier to pick, which enables a larger proportion of people to be recruited for the task.

The current tasks being undertaken in the lead-up to, during and post-harvest are highly repetitive and often rely on a subjective decision to be made based on the instructions given by orchard managers.

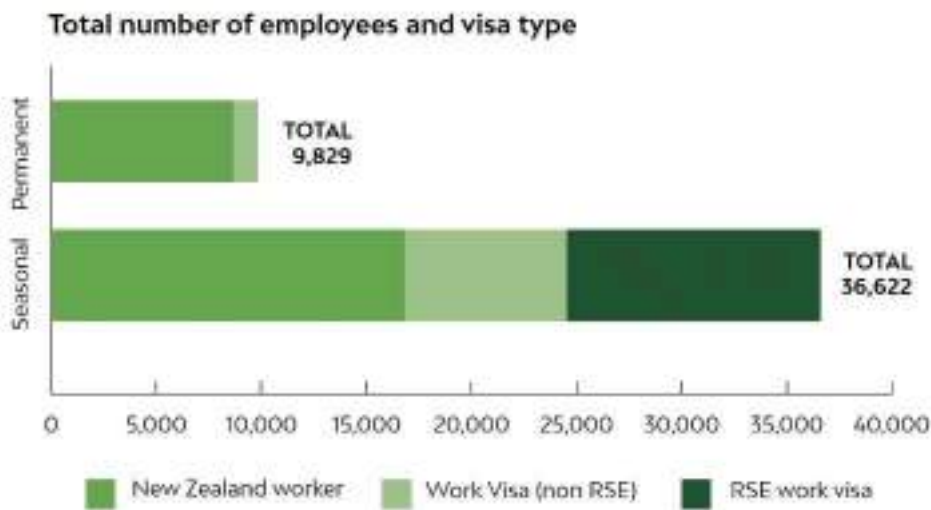


Figure 59: Total Number of Employees and Visa Type Chart, From Recognised Seasonal Worker Survey, 2020, page 3

“To harvest the 60 tonne per hectare apple crop, a worker must collectively climb the equivalent of 20 to 25 vertical kilometres, up and down ladders, carrying 20kg bags of apples.”

— Recognised Seasonal Worker Survey (2020, p.9)

2.7.3 RSE Workers

The *Recognised Seasonal Employee* (RSE) Scheme was established in 2007 in New Zealand to meet the demand for short-term workers to alleviate the labour shortages during the growing, harvesting and processing seasons in the horticultural industry. In 2020, RSE workers made up 33% of the seasonal workforce, “This industry is particularly reliant on Pacific Islanders to fulfil the physical demands of picking on ladders. Around 79% of all New Zealand’s apples and pears are picked by migrant workers.” (NZKGI, 2020, p.9) RSE workers from the Pacific come from locations such as Vanuatu (28,172), Tonga (14,294), Samoa (11,965), Solomon Islands (4,072), Kiribati (1,198), Tuvalu (682), Fiji (477), Papa New Guinea (386), and Nauru (57). (Nunns and Bedford, 2019, p.17) The scheme attempts to be a ‘triple win’; for employers in New Zealand, the seasonal workers and their communities. (Bedford and Bedford, 2023, p.44) There is a range of critiques on the scheme and its current practices, Dr Karanina Saunoamaali’i Sumeo, Equal Employment Opportunities Commissioner of the Human Rights Commission, expressed concern with the current treatment of workers under the Scheme (Royal Commission, 2022)

There has been a continuous rise in the number of RSE workers in recent years (Bedford, Bedford, Wall & Young, 2017; Gibson, McKenzie & Rohorua, 2014; Gibson & McKenzie, 2010).

Their incentives for travelling to New Zealand to work are typically to make a sufficient amount of money to support their families and communities, as well as improve their quality of life (Bong et al., 2023). They stay in New Zealand for between seven to nine months at a time with many returning year after year to undertake the work.

There is a need to acknowledge the unique cultural experiences and ways of interactions that are brought to the industry by RSE workers, and for a product to consider how it might be able to afford easy communication to users for whom English is not a primary language.

2.7.4 Orchard Managers

Orchard managers are concerned with the metrics and outcomes of the orchard, which they report further up the line to owners or directors of the orchard. They are also responsible for the relationships between staff, and the management of resources within the orchard. They are typically the user group who would be considering where to place these devices, and the ones most regularly involved in the checking of the data that would be coming through. This user group is typically the one who would be advising about the success of any new technological intervention, so ongoing use is reliant on the buy-in from this group.

Orchard managers may also be employed through external companies that bring in orchard services and technical systems that the orchard owners may choose to engage with. These managers benefit from having good working relationships with seasonal workers and unions to ensure there is sufficient labour capability to address the tasks throughout the growing season.

2.7.5 Orchard Owners

Orchard Owners have different levels of involvement based on the scale of the operation and the business models by which they operate. Typically, they will be the user group that is the most concerned about Return on Investment (ROI) in the introduction of any new technology, and the benefits and features will be critical to identify, to assist them in the appraisal of the design. They will be the most interested in the type of information being collected and how that can enable improved financial outcomes, which is what they can communicate to stakeholders, board members and/ or as part of any promotional releases.

Smaller scale orchard owners often also act as the orchard manager, and will be interested in the direct impact of a design intervention, or to ideally have a numeric value associated with the productivity of the orchard at a given time throughout the season.

2.7.6 Innovation/ Procurement Managers

Innovation and Procurement Managers are typically involved in larger operations that have an external-facing brand, where showing innovation and technological competence to end consumers is beneficial. They are interested in exploring methods of improving operations, yield, and communication, and will usually be the first group one interacts with when first bringing a new design intervention to larger-scale operations. They can set up and enable small-scale trialling to validate ideas, and usually with a good understanding of the iterative development of ideas. For this user group, a clear communication of points of difference, intended systems and price points will be critical in assisting their appraisal of the design and its implementation into their operations.

2.8 Trust in Context

Throughout the exploration of the context of this research project, a key theme that has presented itself is that of trust, or rather a mis-calibration of expectations between agents, leading to the disuse of products and technologies, as well as brand distrust.

The following section aims to explicitly state the critical trust issues within the experience of fruit measurement to which the resulting design seeks to respond.

1.

2.8.1 Trust Observation 1: Infrastructure

Ground truthing as an activity enables data that can confirm remote sensing technologies which are already commonly used as part of the product system. Ground truthing acts as the activity that helps calibrate the trust people have in larger-scale technologies.

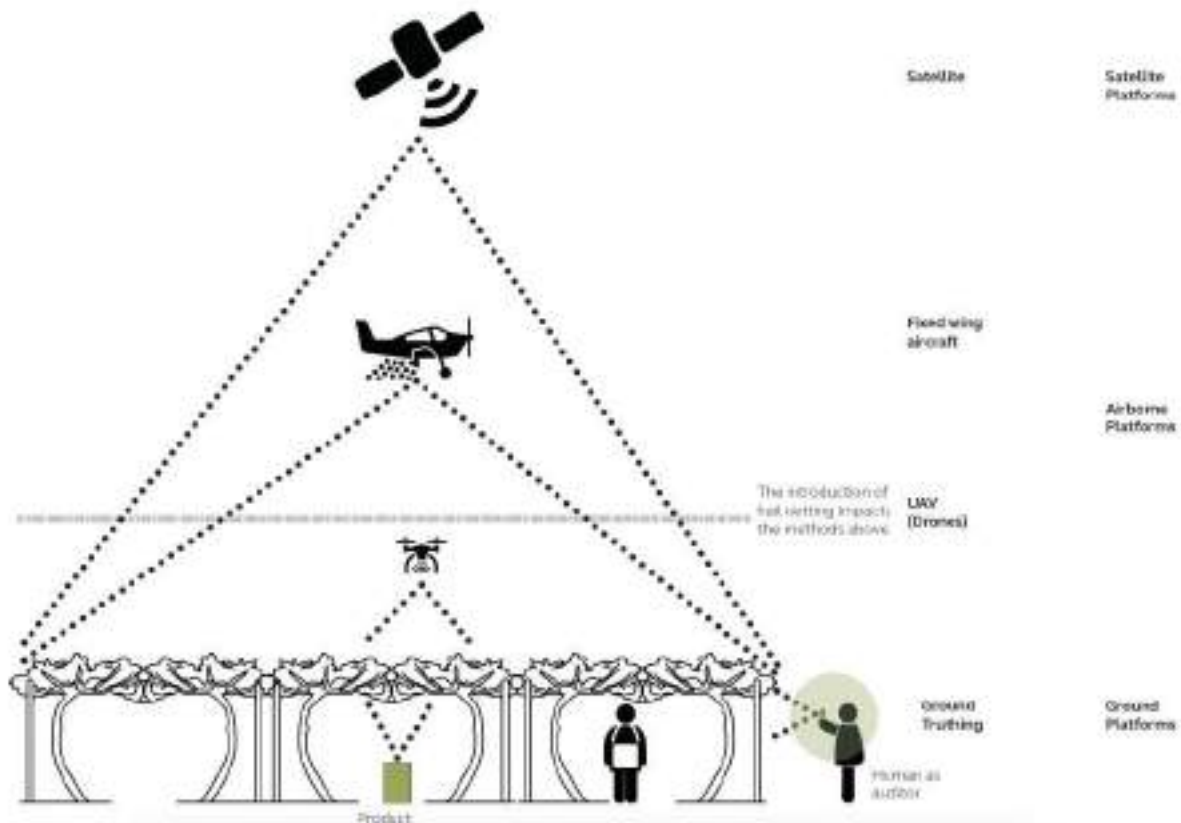


Figure 60: Technological platforms in relation to the orchard environment, Drawn by Author, May 2022

Ground truthing is a method of data collection which seeks to check the accuracy of data using remote techniques by going to the source. Remote sensing techniques such as satellite, *hyper-spectral* and *multi-spectral* scanning of canopies of trees are already being used to better understand about crop density and other factors.

Hail netting is increasingly used in response to climate change and the need to protect crops from frost and hail. (DiGiacomo et. al., 2023) The side effect of this is that some remote sensing techniques do not work as effectively with hail netting. There is a design opportunity to design a solution that exists below the hail netting and closer to the fruit to also assist in the ground truthing process.

“Ground truthing assesses the accuracy of remote sensing data by comparing it with physical measurements collected at the ground level.”

— GIS Geography

2.8.2 Trust observation 2: Lack of Collaboration

Both the kiwifruit and apple industries rely on confidentiality in the development of work that they are doing, meaning that innovation is not readily being shared between orchards and that there are a lot of people working on solving the same problem but not collaboratively doing this. Creating a device that gave users agency to generate their crop data readily enables them to make informed decisions for the next steps. Making the process of data collection more accessible, destigmatises its novelty.

2.

Interviews were conducted throughout the study to gain insights into user perceptions, attitudes and requirements. Semi-structured interviews allowed exploratory discussion while also being open about the design process and the stage the design was at to assist in appraisal. I found that many of the interviews would happen in the orchard environment, often while walking through rows. Participants often spoke to the environment around them and could point out examples.

Participants are committed to finding ways to maximise decision-making resources for themselves. The interview styles allowed for visual information to be responded to as drawings, prototypes or orchard-based observations. Availability for interaction fluctuated throughout the year due to the nature of the growing season.

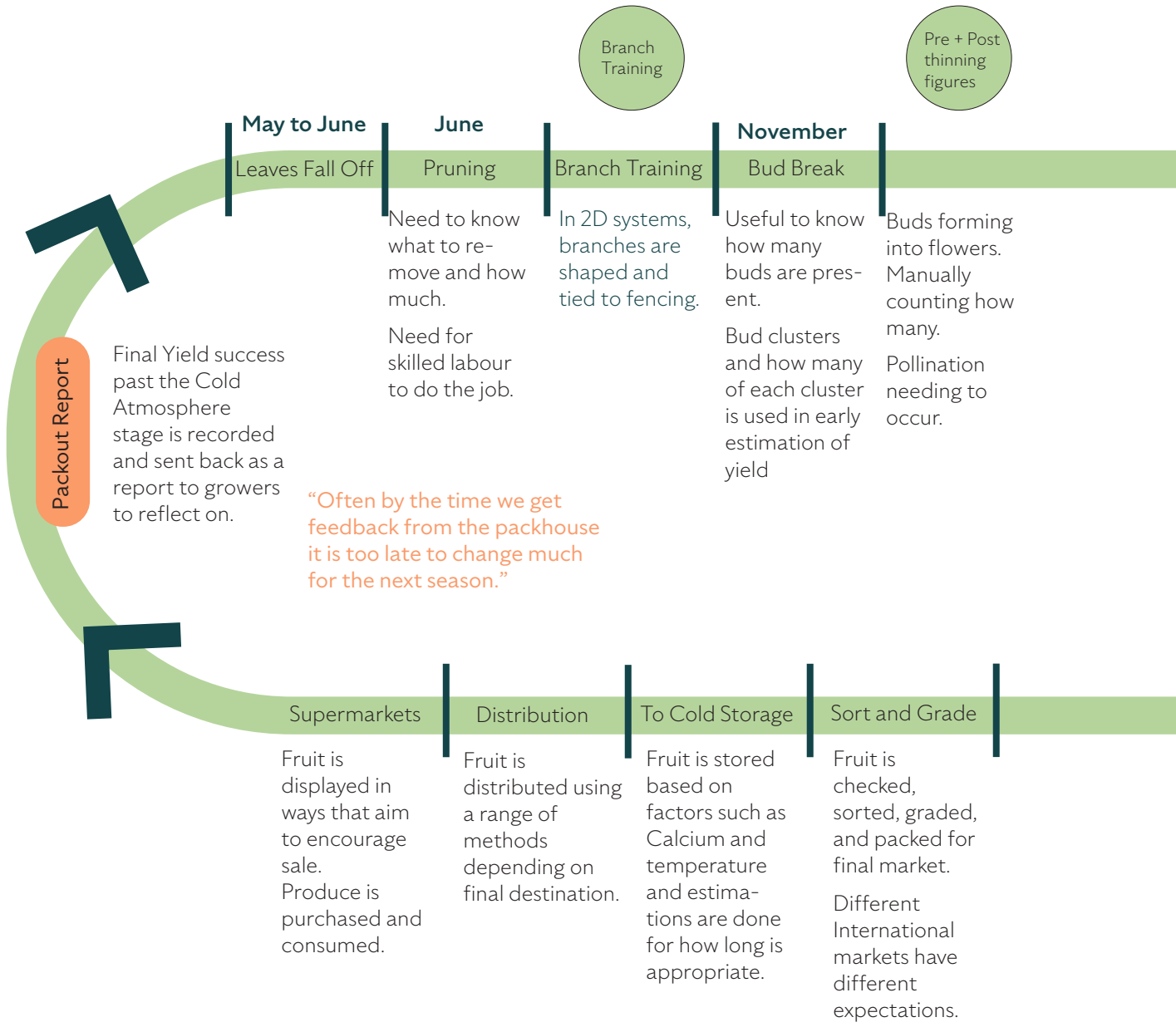
This project sought to connect with the stakeholders involved authentically. Meaningful engagement would mean continuing to engage with users throughout the project. Due to the speculative nature of the development of this project, and the lack of an effective network to build the relationship across seasons with seasonal workers, most feedback and development insights were built alongside orchard managers and owners.

The significance of trust was identified as part of the contextual review through the usability issues they are entwined with. That part of addressing the user experience through the design investigation is to address the breakdown of trust.

3.

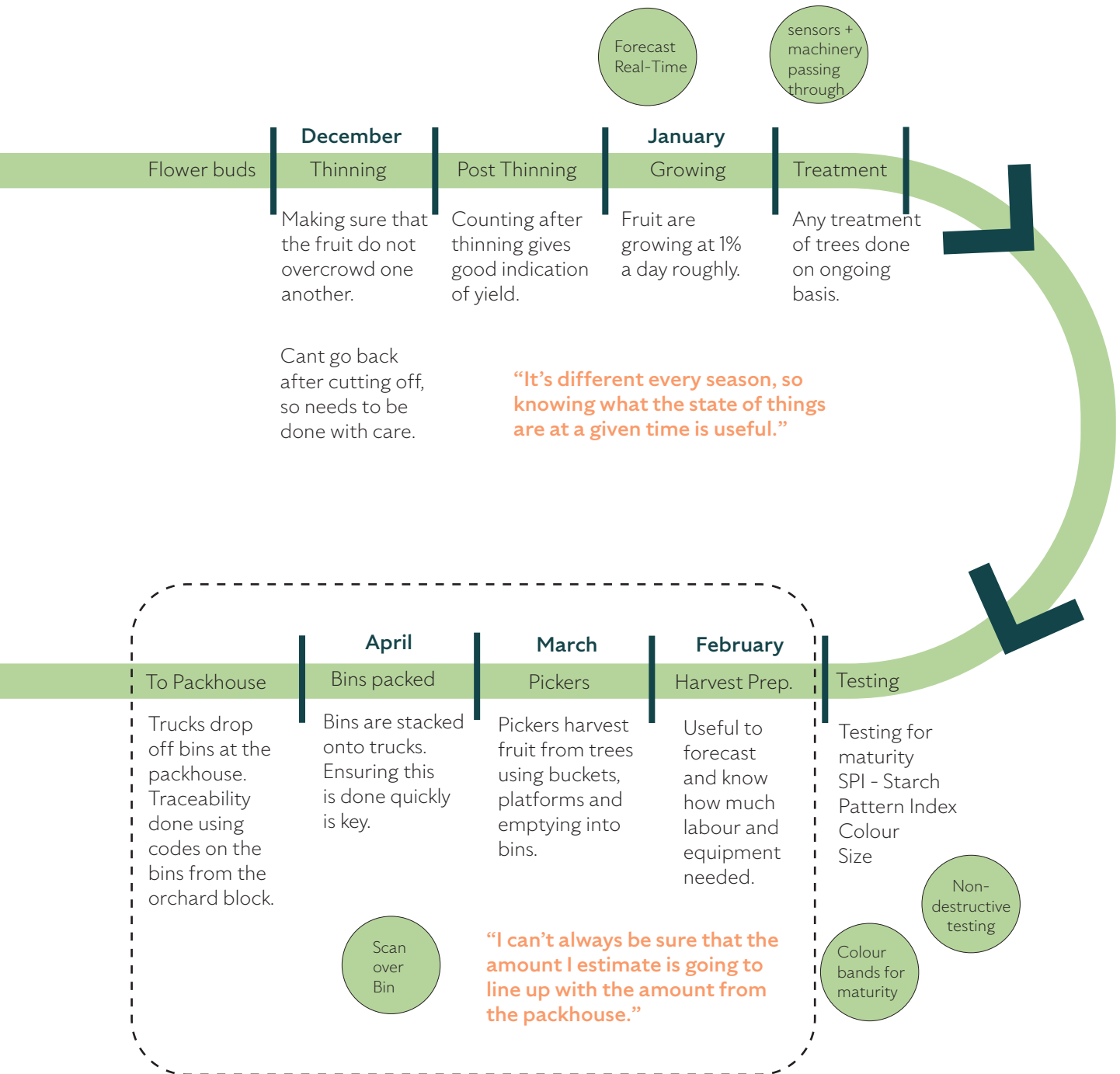
2.8.3 Trust Observation 3: System Distrust

Distrust being established between packhouses and orchards due to the packout report taking too long and orchards not getting the insights soon enough, or feeling that they are being shortchanged when the amount they are being paid for does not reflect the amount they estimate they sent to the packhouse. A simple solution is to provide the orchard with the harvesting data to enable better comparison and evidence of yield.



Design Themes

Figure 61: Annual Growth Cycle in Apple Production, Diagram by Author, July 2022



4.

2.8.4 Trust Observation 4: Usability Issue

The ergonomics of users doing current measurements is full of variations because finding the widest part of the fruit is subjective, and those measuring are different heights, and fruit vary in size throughout the tree. Creating a solution that captures data consistently and across multiple seasons can enable better accuracy and comparison to be established.

Mitutoyo Vernier Caliper



Fig. 62

Key Features

- Cost: \$204.80 on Trade Me
- Hardened Stainless Steel
- Made in Japan

User Experience

This set of calipers would be considered a good quality manual product and feels much more weighted than the digital example below. The length of the caliper means that you are also able to measure much larger items than the example below. The caliper set is narrow, meaning it can be gripped both delicately between the fingertips or grasped such as the views below.

The mechanism on which the thumb rests is fixed in place and narrow. The major drawback when opening as shown in the second illustration on the right below is that the edge comes in contact with the hand, meaning the user then shifts their hand before opening wider. This action is not ideal for repetitive tasks.

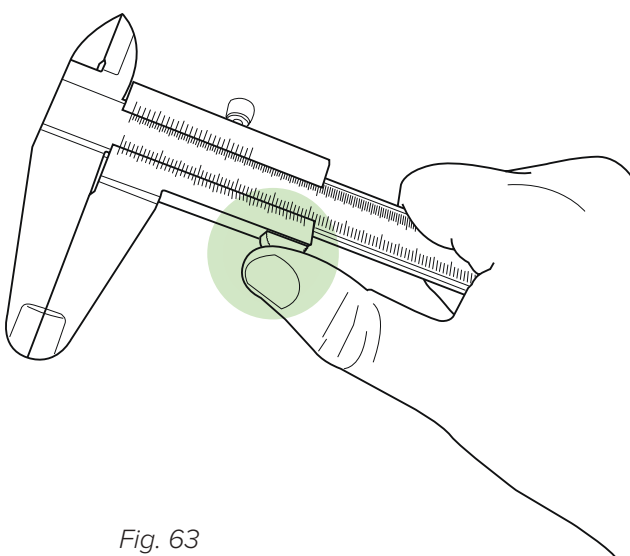
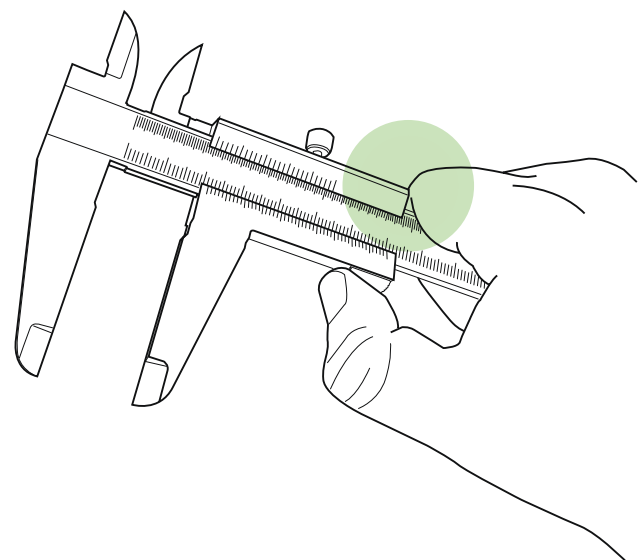


Fig. 63

Narrow wheel on which the thumb rests to adjust the calipers.



Edge coming in contact with the hand and requiring grip to be adjusted.

Whitworth Digital Caliper



Fig. 64

Key Features

Cost: \$23.95 on Save Barn
 Hardened Stainless Steel
 Made in Japan

User Experience

The overall caliper is not as weighted as the Mitutoyo example, and most of the weight is located at the front end of the caliper. The control wheel is loose and so spins by itself when not engaged with the track.

Immediately displays electronic measurement when moving. Has a series of buttons including on/off button, a zero button, and a mm/inch option button at the top. Please also see product autopsy video to better understand the componentry of the device.

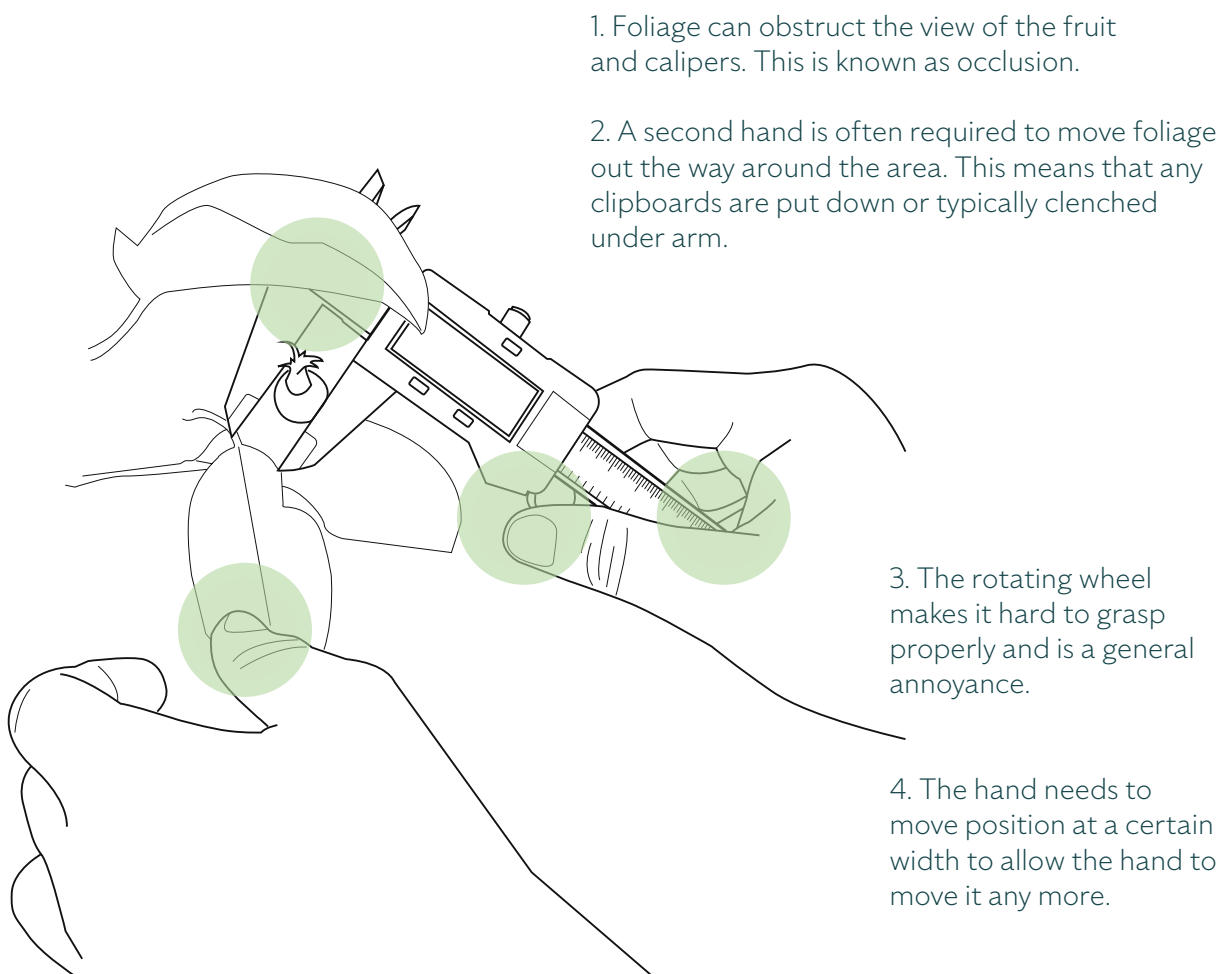


Fig. 65

1. Foliage can obstruct the view of the fruit and calipers. This is known as occlusion.

2. A second hand is often required to move foliage out the way around the area. This means that any clipboards are put down or typically clenched under arm.

3. The rotating wheel makes it hard to grasp properly and is a general annoyance.

4. The hand needs to move position at a certain width to allow the hand to move it any more.



Fig. 66



Fig. 67

Reach

It is important to note that the heights of the fruit tree will significantly impact the reach required. As seen above, a 10th percentile worker would need to reach outside of a comfortable range to reach fruit and also the neck needs to bend back to compensate for sight line. This is not a comfortable action to be doing repetitively. The 95th percentile male however is able to face directly ahead during the task.

Occlusion

Foliage covering the fruit and measuring device is called occlusion, which is the disruption of sight lines for the user. Currently the user may use a second hand to move the foliage out of the way when measuring. This can cause additional time and potential damage to surrounding fruit.

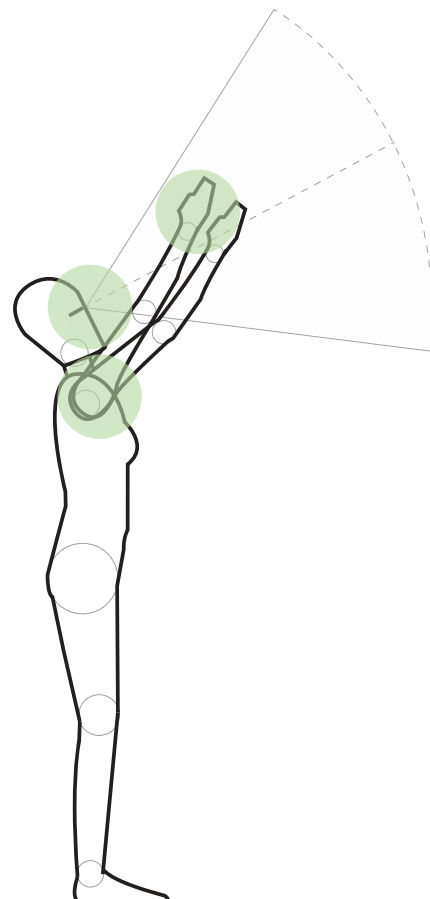
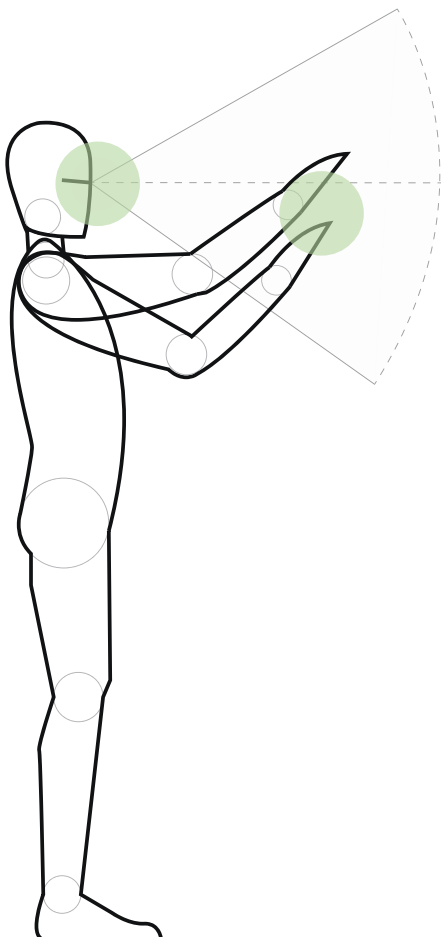


Fig. 68



Fig. 69

Posture

See above the height the shoulders need to reach for a 50th percentile female to measure fruit in the tree. This will become uncomfortable over time and cause strain. In the furthest to the right image we see a 10th percentile female reaching to measure fruit. The back, neck and shoulders need to compensate for reach and will lead to strain with repetition.



Fig. 70

Hands

The hands and wrists are needing to be twisted into a range of positions to measure around the fruit, especially if also trying to maintain sight of the measurement. The thumb is needing to make a repetitive motion of to and fro to adjust around the fruit and needs to do so carefully so as not to bruise the fruit. This is not a sustainable action over time.

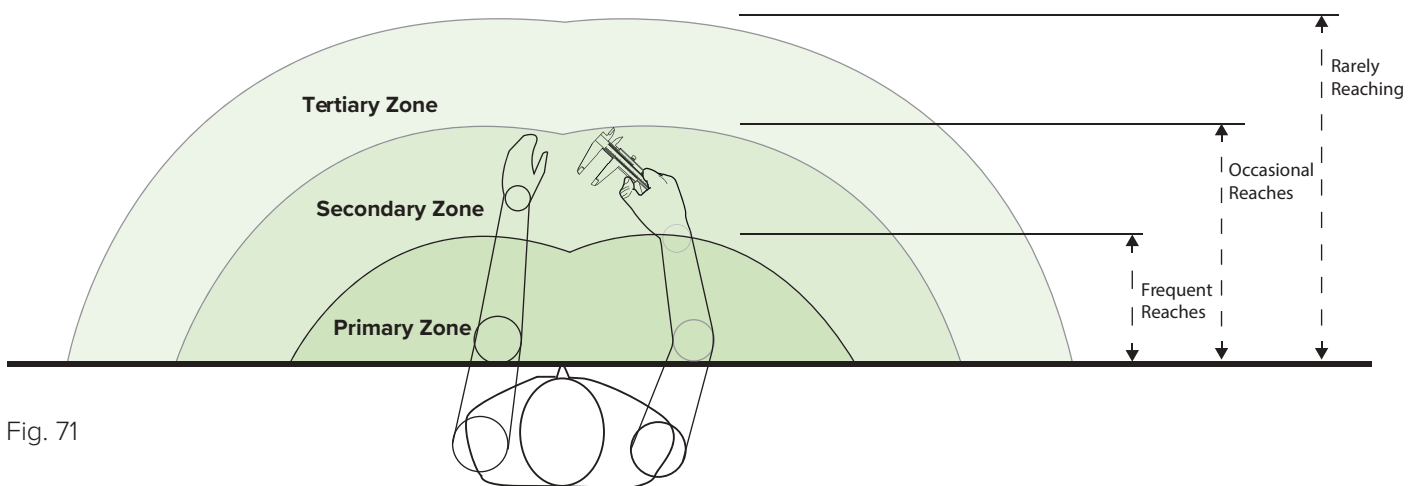


Fig. 71



The above model discusses the health of occupational reaches and is primarily focused on the arm reach distance being more at waist height. This emphasises that the range of movements at above the shoulder height is even more detrimental.

Most of the reaches are done within the Secondary zone, typically advised to be reserved for only occasional reaches. In most cases the user cannot get much closer to the tree because of environmental factors and sight lines. They are unlikely to operate within the tertiary zone commonly.

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STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Zenè Krige		
Name and title of main supervisor:	Associate Professor Rodney Adank		
In which chapter is the manuscript/published work?	Chapter 3: Literature Review		
Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work: ¹ Student is sole publisher.			
Please select one of the following three options:			
<input checked="" type="radio"/>	The manuscript/published work is published or in press Please provide the full reference of the research output: Krige, Z. (2024) Developing factors of trust for the design of trustworthy Human - Product interactions, in Gray, C., Ciliotta Chehade, E., Hekkert, P., Forlano, L., Ciuccarelli, P., Lloyd, P. (eds.), DRS2024: Boston, 23–28 June, Boston, USA. https://doi.org/10.21606/drs.2024.695		
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3.0

Literature Review

Getting to the core

This literature review identifies existing theoretical frameworks that assist in understanding the complex interrelationships of the psycho-social aspects of trust, the interactions between agents, and how these interactions are understood and accepted. A lack of frameworks that appropriately overlapped to address all aspects of this complex project was identified as a gap. Subsequently, a framework for this project was developed to map out the agents involved, and the types of trust being utilised, enabling a design criteria to be developed. Aspects of trust in autonomous systems are touched on alongside the cultural, philosophical, environmental and technological theories in which we ground our ways of seeing the world, as well as the methods design can utilise to increase trust, collaboration and interactions between humans and machines.

3.1 Product

The Product section consists of a number of facets of the visual expression of trust and interactive factors that the resulting product needed to consider and design toward.

3.1.1 Co-Bots

An area in which a lot of research emphasis has been placed is *Collaborative Robots* (co-bots), which are collaborative robots that work alongside humans to complete tasks. The nature of interactions can vary depending on the context, level of intelligence and control, which is also ultimately informed by trust. Human operators may assign more work to the automation system if they trust that it can effectively undertake the task.

The social nature in which humans interact with one another is often applied to their interaction with robots. De Melo et al. (2021) review humans' relationship with agents and the times when they may interact socially. In other words, "It is possible to take a psychology research paper about how people respond to other people, replace the word 'human' with the word 'computer' and get the same results." (Reeves & Nass, 1996, page 28)

Computers that displayed etiquette were seen to possess individualistic characteristics such as agreeableness and conscientiousness (Miller, 2002), making it easier for them to become part of a team or 'group'.

Humans tend to categorise agents (inanimate or animate) to help them better make sense of how to appraise the individual and the type of interactions, behaviours, attitudes and tone to take when communicating.

They are more likely to display trust in those they consider to be part of their 'group'.

These social identities are complicated to understand and may be interpreted differently by individuals based on previous experiences. However, the construction of machines that share familiarity or stereotypes is what Nass et al. (1995) suggest to be more successful.

Building on this, Christopher L. Nehaniv and Kerstin Dautenhahn (2007) discuss imitation and social learning between humans, animals and robots. They argue that this relationship between the 'teacher' and 'student' will be able to be reflected in the interactions that humans have with emerging technologies that can learn through imitation. They discuss object permanence and Piaget's (1954) analysis of children's ability to discern objects as physical entities. Jack Stilgoe (2020) expresses a critical view of the 'inevitability of technology' being integrated into our lived experience, regardless of our full consent or awareness of its expressions of intelligence. Rather than planning for a product technology to be meshed into an environment, we often retroactively need to make decisions as to why they have been implemented.

3.1.2 Explainable A.I.

The consequence of this study involved designing products and components to support the collection and aggregation of in-orchard data. This activity used image capture and analysis processes, and consequently, from a design perspective, it was important to understand how to best communicate these insights in an understandable and trustworthy manner to orchard decision-makers.

As a definition, Gunning et. al. (2019) states that *Explainable Artificial Intelligence* (XAI) aims to make the behaviour of intelligent objects and systems easier to understand and predict for users. They believe that the system should be able to “explain what it has done, what it is doing now, and what will happen next; and disclose the salient information it is acting on.” (p. 1)

The dialogue of XAI is often discussed in relation to science communication, as both seek to find ways of reaching audiences with information about technological findings. Bubela et. al. (2009) refers to the inappropriate hype given to aspects of science due to the way in which it is portrayed to the general community. The miscalibration of trust as a result of hype and omissions of context can lead to damaged trust. Further, they suggest that ‘Framing the Message’ is key when communicating scientific ideas. Wang et. al. (2019) generates a conceptual model of human-centred decision-theory XAI, which they hope will extend the usefulness of the system and the likelihood of adoption.

3.1.3 Data Visualisation

The social process of communication is full of “persuasive devices” that should recontextualise information to intended users. Estrada and Davis (2015) suggest that visual language is often at odds with scientific method, but is key in making information approachable. They discuss *User-Centred Design* as a tool for this communication, where design focusing on the needs and abilities of the user should dictate how information is relayed throughout the process using an interdisciplinary approach. They distinguish between visual thinking, visual learning and visual communication, and their role in our visual culture as a society. Baruch Fischhoff (2019) discuss the importance of not overwhelming the audience with the amount of information we give them. “Eager to share their knowledge, subject matter experts may drown decision-makers in facts that it would be nice to know.” (p. 7672)

Building on this, Dur (2014) speaks of the importance of visual language through the creation of infographics and other modes of visual representation. They define data visualisation as “visualisation of numeric values with charts, tables and graphics and as transformation of raw data information to visual presentations.” (p. 41) Dur investigates the increasing need for visual communication when working with data to make information as accessible as possible to the end user.

3.1.4 Science Communication

The use of jargon drastically impairs the ability to process new information, which results in greater resistance and lower support of the new information. Bullock et al. (2019)

In support of this, Nunes and Jannach (2017) suggest that transparency, improved decision-making, scrutability, debugging, and trust moderation are key factors. Doran, Shulz, and Besold (2017) refer to opaque, interpretable and comprehensible systems as varying degrees of user cognition. According to them, an explainable system encompasses confidence, trust, safety, ethics and fairness and should be used to measure the success of XAI, as it allows for reasoning to be shown and for the user to measure their response accordingly. “To achieve complete trustworthiness and an evaluation of the ethical and moral standards of a machine, detailed /explanations of A.I. decisions seem necessary.” (p. 1)

Similarly, Hoffman et. al. (2017) identify seven key factors to explanations; “Understandability, feeling of satisfaction, sufficiency of details, completeness, useful, accuracy and trustworthiness” (p.3) They believe an XAI system should help notify the user what method of trust to employ at different stages of operation, and should be measured throughout an interaction. “Minimally, a trust scale can ask two questions: Do you trust the machine’s outputs? (trust) and would you follow the machine’s advice? (reliance)”. (p. 20)

Interestingly, Michael F. Dahlstrom (2010) found that information placed at causal locations in the narrative resulted in greater acceptance than if the information was placed at lesser parts of the narrative. Causality can easily be manipulated, and people may engage with narratives in different ways. The value of understanding narrative is that we can better consider how design language and narrative can impact the success of our conveyance of information in design practice.

3.2 Anthropomorphism

Anthropomorphic characteristics not only come from visual form but can be reflected in language, sound, and behaviour. This adds to the experience an individual might have with an object and, in turn, the appraisal methods they employ to make their decisions on the object.

Wan and Chen (2021) reflect Nass's (1994) views, that human-object interaction is similar to human-human interaction. De Visser et. al. (2012) Discuss three key stages of trust being; formation, violation, and repair (p.332) Their findings include the use of the Godspeed Instrument (Bartneck, 2008), (Spatola, Kuhnlenz, Cheng, 2021) to assess humanness, likeability and perceived intelligence. They found that familiarity greatly plays a role in how users assess the reliability of a system or product. Similarly, Lee and Seppelt (2006) and Troshani et. al. (2021) outline the importance of familiarity when designing interactions between humans and systems.

As another key factor Spatola and Wudarczyk (2021) suggests that the more human a robot appears, the more "warmth" it possesses (sincerity, trustworthiness and morality) as active behaviours, while competence (ambition and confidence) is seen as passive behaviours. They refer to Haslam's taxonomy of dehumanisation (2006), which they theorise is key to social acceptance. Using a range of tests and scales such as the Implicit Association Test (IAT) (Greenwald et. al., 1998), and Robotic Social Attributes Scale, (Carpinella et. al., 2017), (Spatola, Kuhnlenz, Cheng, 2021), and also the Negative Attitude Toward Robots Scale (NARS) (Nomura et. al., 2006), they find that implicit versus explicit stimuli greatly impact on perception.

These frameworks are useful in navigating discourse around the perceptions of technology-embedded objects, with the most useful of the resources being Philips et. al. (2018), who created ABOT, an anthropomorphic database comparing different objects using a range of design criteria.

The object being a surrogate for human interaction is identified by Epley et.al. (cite) as sociality, as well as the concept of effecting, that is, attributing human traits to non-humans to better understand and connect with them. A critique of this is that we limit Artificial Intelligence when doing this. So then how do we adopt these technologies? Troshani et. al. (2021) discuss two technology adoption models; the Technology Adoption Model (TAM), and the Unified Theory of Acceptance and Use of Technology (UTAUT). Designing robots with human-like qualities can lengthen their use by the end user. Enhancing human-like qualities to be perceived as 'too human' can lead to discomfort or eeriness, also known as the "uncanny valley" (Mori, 1970)

Drawing similar discussion to previous authors, Spatola and Wykowska (2021) consider that we aim to understand complex technologies and the nature of robots by comparing them to our most extensive knowledge of behaviours and expectations – that of humans. Difficulty understanding robots often leads to ambivalence, which, from a design perspective, is a fatal position in ongoing use.

If trust is broken, Kim and Song (2021) discuss how anthropomorphism factors into the way an agent is perceived, and how it should apologise. They compare the Computers-Are-Social-Actors paradigm (Nass, 1994) to automation bias, written about by the likes of (Lee and See, 2004) They show that admitting a fault and asking how to improve helped rebuild trust. White and Remington (2019) found that personification is integral in the naming of objects, which in turn showed that naming an object led to higher levels of anthropomorphism.

In contrast, Russell & Norvig (2010) and Salles, Evers, and Farisco (2020) suggest that the addition of anthropomorphism in incorrect contexts can cause the mis-calibration of expectations and trust. As humans, we assign morals and social expectations to that which we deem human-like, these authors warn that by doing so, we delude people into thinking that Artificial Intelligence can make moral decisions, which holds many ethical and safety risks.

For this research's scope, anthropomorphism techniques were applied to facilitate the relationship between object, system and user. The importance of understanding how to design intelligent devices needs to consider their social limitations also.

“Anthropomorphism imbues non-human objects with human-like characteristics, alters people’s relationship with the objects, and shift people’s emotional and cognitive responses towards the objects.”

— Echo Wen Wan and Rocky Peng Chen (2021, p.88)

3.3 Experience

Creating elevated levels of usability through implementing theories and techniques of emotion and appraisal, enabled an understanding of what makes for higher satisfaction levels, with the goal of designing for continued use.

3.3.1 Defining Emotions

The original definition of emotion has long been disputed. Jesse Prinz (2006) refers to ‘the problems of parts’ and the ‘problems of plenty’, that is, the large array of definitions for emotion can make it difficult to grasp what emotion is. It is crucial to acknowledge the role that emotion and decision-making have in the way that humans interact with objects, systems and environments.

The term *Emotional Artificial Intelligence* was coined by McStay (2018), who suggests a set of guidelines as “emotional artificial intelligence has significant personal, interpersonal and societal implications” The authors comment that any research that operates in the space of human emotion and AI should be held to higher levels of scrutiny to ensure that the impacts it has both technically and socially is not detrimental. Failing to understand the emotion within its context allows for assumptions to be made that can lead to ethical missteps within the development and testing of an AI system.

“The definition of Arnold (1960 p.182) is therefore adopted for the current research: emotion is “the felt tendency toward anything intuitively appraised as good (beneficial), or away from anything intuitively appraised as bad (harmful)”

— Peter Desmet, *Designing Emotions*, (2007, p.11)

3.3.2 Appraisal Theory and Affect

Author of *Designing Emotion*, Pieter Desmet (2007), discusses the relationship between product design and evoked emotions. It has a specific focus on studying product appearance and how designers might impact or manipulate the emotions felt towards a particular object. The following definition of emotion is adopted for this project; “emotion is “the felt tendency toward anything intuitively appraised as good (beneficial), or away from anything intuitively appraised as bad (harmful)” - Arnold (1960, p.182)

A key definition for appraisal theory comes from Scarantino and de Souza (2018) connect evaluation and appraisal theory, the authors describe; “appraisal theory is concerned with developing “accounts of the structure of the processes that extract significance from stimuli and differentiate emotions from one another” (Luke Stark and Jesse Hoey, 2021, p.784) They refer to Rosalind Picard’s ‘Affective Computing’ (2000) in which she argued that emotion is a viable area of investigation for intelligent systems and the ‘datafication of human thinking’.

Alternatively, Agnes Moors et. al (2013) discuss the fundamental principles of appraisal theory and offer the following meaning; “The basic premise of appraisal theories is that emotions are adaptive responses which reflect appraisals of features of the environment that are significant for the organisms well-being.” (p. 119)

The emotion process is described as continuous and recursive and involves an interaction between the appraiser and the action. Comparatively, Lisa Feldman Barrett (2017) suggests that instead, “ we find that your emotions are not built-in but made from more basic parts. They are not universal but vary from culture to culture. They are not triggered: you create them.” (xii)

Similarly, L.S. Greenberg (2021) takes a clinical perspective of how humans experience emotion. She highlights the terms affect, feeling and emotion as having distinct differences, with appraisal theory being a central part of understanding how emotion is generated. Relating to both emotion and the ethics of its implementation into Artificial Intelligence, authors Luke Stark and Jesse Hoey (2021) address conceptual models and how this might impact decisions made within the development of Intelligent systems. They reference psychologist Jerome Kagan’s (1978) definition of affect: “a change in brain activity to select incentives”

3.4 Frameworks

The following section reviews a number of frameworks and models of cognition in relationship to emotion and appraisal theory, in an attempt to situate the theoretical underpinnings of the study effectively.

3.4.1 PrEmo Model

Affect is used to describe phenomena such as moods, emotions and sentiments. Desmet (2007) works through a number of descriptors for emotion and narrows this down to 14 key descriptors as part of the Product Emotion measurement instrument (PrEmo) model. This is laid out in a circumplex that defines emotion as either pleasant or unpleasant. One of the leading variables in how this model can be implemented is how these different emotions present themselves in different cultures. Product emotions are defined as personal, temporal and mixed.

3.4.2 Semantic Rating Scales

David V. Keyson (2008) discusses how we experience intelligent products. “The intelligent product may thus extend beyond a physical product and into the surrounding environment as products become more embedded in the user environment and able to communicate with each other” (p. 516) Keyson suggests systems should build trust over time.

3.4.3 Affect Control Theory (ACT)

Affect Control Theory (ACT) allows for the mapping of interactions and potential patterns in emotions. When ACT and Bayesian probabilistic decision theory are combined, the BayesACT model evaluates and predicts possible emotional outcomes from different situations, allowing intelligent systems to calibrate their responses to be appropriate according to the end consumer. (Sohn and Kwon, 2020) Computational Belief and Desire Theory of Emotions (CBDTE) was suggested by Reisenzein et al. (2013) who thinks that emotions are a result of evaluations and motivations.

3.4.4 Basic Emotion Theory (BET)

Silvan Tomkins and students Paul Ekman and Carrol E. Izard defined the Basic Emotion Theory (BET) in the 1970's. This model is popular in the discussion of how emotion might be integrated into systems and argues that human emotions are universal in the way that they are expressed, and identified through “biophysiological” processes. (Ekman and Scherer, 1984) Tomkins argues that there are primary programs in the human brain, and identifies the following 9; interest, enjoyment, surprise, fear, anger, distress, shame, contempt and disgust. In this view, emotions that are expressed outwardly are seen as the ‘true’ representation of inner states of emotion.

3.4.5 Basic Model of Emotions

The Basic model of emotions presents appraisal as central to the way we choose between products based on appearance and physical values.

The product appraisal types that are discussed are appealing-ness, motive compliance, legitimacy and novelty. Emotions are elicited by an appraisal. “An appraisal is a non-intellectual, automatic evaluation of the significance of a stimulus for one’s personal well-being ... Because appraisals mediate between products and emotions, different individuals who appraise the same product in different ways will feel different emotions.” (Schmidt et. al., 2010, p. 108)

3.4.6 Actor-Network Theory

The actor-network theory (ANT) Forlano (2017) and Lindley, Akmal and Coulton (2020) builds to support the interrelationships between networks and beings which it believes make up the ‘social’. It predominantly operates in the field of science and technology studies, supporting the idea of ‘hybrid configurations’ that emerge from these interactions. It builds on the thinking and concepts from sociotechnical systems theory (STS). Building on this, Adam Greenfield proposes that “human perception, scale, and desire are no longer the primary yardsticks of value.” (from Forlano, 2017)

3.4.7 Emotions Summary

Considering alternative ‘yardsticks of value’ then, frameworks of emotion and appraisal typically relate between the human and one agent, such as to the object or the contextual environment. For the nature of this project, it was needed to consider multi-agential interaction and the subsequent appraisal methods and factors for consideration. In the context of New Zealand, The New Zealand Algorithm Charter (StatsNZ, 2020) identifies transparency, accountability, and social licence as being crucial in building public trust. “Trust in data use is an important part of social licence, when people trust that their data will be used as they have agreed and accept that enough values will be created, they are more likely to be more comfortable with its use.” (Data Futures Partnership, 2017, p.5)

3.5 Trust

“The attitude that an agent will help achieve an individual’s goals in a situation characterised by uncertainty and vulnerability”

— Lee and See, 2004, p.54

Methods and approaches within design which integrate or consider trust, have tended to be narrow or prescriptive. This can be seen in investigations that focus on measurable factors such as reliance, transparency, or predictability (Lyons, 2017, Lee & Chiou, 2023).

These means of investigation have the unintended consequence of guiding design research into grooves of convenience, because they are easily measurable and familiar as part of our creative practice.

An example is where ‘reliance’ as a concept is attached to product performance, which omits the socio-cognitive aspects of reliance. It is here, where the divide between effective implementation of trust and design practice exists. This section seeks to address existing theories and frameworks of trust between agents to understand how we might design objects with ‘trust’ as the lens.

3.5.1 Interpersonal Trust

Also referred to as perceived trust or human-like, interpersonal trust identifies key characteristics in human-to-human trust. The key aspects of this model are ability/competence, integrity, and benevolence (Mayer et. al., 1995).

From the ‘Computers Are Social Actors’ Paradigm (Nass, 1994), humans are most likely to respond socially to technology first and change their approach or abandon interaction if trust has been mis-calibrated or broken. In business psychology, Vanessa Hall (2011) describes ‘pillars’ as expectations and needs, on which the overarching beam that is built is promises, when trust is broken, it is often at the foundational level in the mismanagement of needs or expectations.

Siau and Wang (2018) utilise the Human, Environment, Technology (HET) model, discussing its implementation throughout the relationship between the human operator and artificial intelligence systems. Toreini et. al (2020) discusses ‘The Chain of Trust’, which evaluates how trustworthy technologies are expressed throughout their implementation cycle, and then assesses this using the ABI+ model (Ability, benevolence, integrity and predictability), which was suggested by Mayer et.al. and Dietz and Den Hartog (2006). This builds on Mayer et al. (1995), the popular model of Ability, Benevolence and Integrity.

Alternatively, Bickmore and Cassell (2000) discuss intimacy, solidarity, closeness, familiarity, and affiliation as key in interpersonal relationships. In contrast, Rempel et al. (1985) provide an older definition of interpersonal trust, which is predictability, dependability, and faith, to measure trustworthiness.

The language used when describing interpersonal trust and relationships are oriented to the needs of the human and carries emotive expectations, unlike the functional criteria suggested by human-automation trust models.

More contemporarily, Schoeller et. al. (2021) propose a framework in which trust is modelled as a “sense of virtual control”. They identify three main brain functions as perception, cognition and action, all of which play into how we understand the world around us and react to it. “... trust is a measure of precision, or confidence, afforded by action plans that involve another (i.e. of the match between one’s actions- and their underlying intentions- and the predicted sensory consequences through another agent)” (p.6)

3.5.2 Technology Trusting Beliefs

Closely related to the following Human-Automation Trust, technology trusting beliefs often are the parts most applied to technology-embedded objects. A consequence of understanding this better is that we can understand the relationship between the technology and the designed object.

Foundationally, Lee and Moray (1992) suggest that performance, process and purpose, are the key characteristics which should be measured when theorising about trust in automation. Based on the work by Parasuraman et. al. (2000), “Performance information describes what automation does... Process information describes how the automation operates. Purpose...addresses the question of why the automation was developed.” (Lee & Seppelt, 2006, p.1621)

These three key pillars (purpose, process and performance), were suggested prior to the above ability, integrity and benevolence (Mayer et. al., 1995) and address a much more functional lens on the expressions of trust.

Additionally, Lyons (2013) suggests that transparency between technology-driven objects and humans is an effective way to facilitate interactions. Building on this, (Lyons, 2017) outline a number of theoretical models which include; Intentional Mode (Desai et. al., 2009), the Analytical Model (Cuevas et. al. 2007; Hancock et. al. 2011), and the Environmental model (Hancock et. al, 2011; Lee and See, 2004; Lyons, 2013)

3.5.3 Human Automation Trust

Trust in this context outlines the significance of the individual agents involved and has the consequence of suggesting that when designing, the interaction between human and machine is not one-directional.

Widely cited, Hoff and Bashir (2015) draw parallels to the framework set out by Marsh and Dibbens (2003), which highlights Dispositional Trust, Situational Trust and Learned Trust as key to how trust can be formed in the individual and their interaction with the automation system. Hoff and Bashir describe these three assets as the human operator, the environment, and the automated system.

Building on their earlier works, the authors, Lee and Chiou (2023) suggest that increasingly trusting automation relies on situation, semiotics, sequence and strategy to be considered within interactions. This is interesting because it is one of the first times where more than three facets have been used to express the 'pillars' of trust.

Importantly, Kohn et. al (2021) review different measurement techniques when evaluating levels of trust in automation. The authors discuss self-report, behavioural and physiological measures and frameworks of trust and suggest that although many researchers customise frameworks to suit their contexts, doing this without reference to existing frameworks, or using a single measure can lead to a lack of cohesive definition of what constitutes trust.

3.5.4 System Like Trust

This form of trust most informs the design of the visual aggregation of the data that is intending on being collected as part of this study.

In a foundational paper, Parasuraman et.al. (2000) refer to four stages of information-processing; information acquisition, information analysis, action selection automation, and action implementation Trust in this context outlines the significance of the social considerations that need to be responded to through the designs' form affordances and language. Lankton et. al. (2015) discuss social theory and refer to three factors that impact the trust that humans place in systems: reliability, functionality, and helpfulness. The authors explore social cognitive theories and affordance theory as factors that impact the interrelationships of humans and objects. They also make mention to the Actor-Network theory discussed earlier.

3.5.5 Technology Acceptance versus Adoption

The first important distinction to make is that to accept a new technology is not to adopt a new technology. In many articles, the terms are used interchangeably, which can lead to confusion when defining the stages of trust development. Chimento-Diaz et. al. (2022) define acceptances as “the intention to use a technology or the effective use of it.” While B.H. Hall and Khan (2002) defined adoption as “the choice to acquire and use a new invention or innovation.”

Acceptance refers to the initial state of decision-making, where appraisal methods such as Pieter Desmet’s Model of Product Emotions (Desmet, P.M.A, 2002), Affordance theories (Norman, 2007), or usability heuristics (Nielsen, 1994) might be used. Adoption is the beginning of an ongoing decision to have something as part of our lives.

When designing technology-embedded objects, it is important to understand what factors are important to their ongoing use. This can be based on the physical affordances (Norman, 2007) of the design but also extends to include the way it is marketed, describes itself and is communicated to the intended audience. As with all relationships, the trust and reliance we have on a product, system or automation is an ongoing journey of calibration to match our expectations to the context. These factors are critical to understanding how people may first accept and then adopt technologies, with common themes being intentions, behaviours and environmental factors.

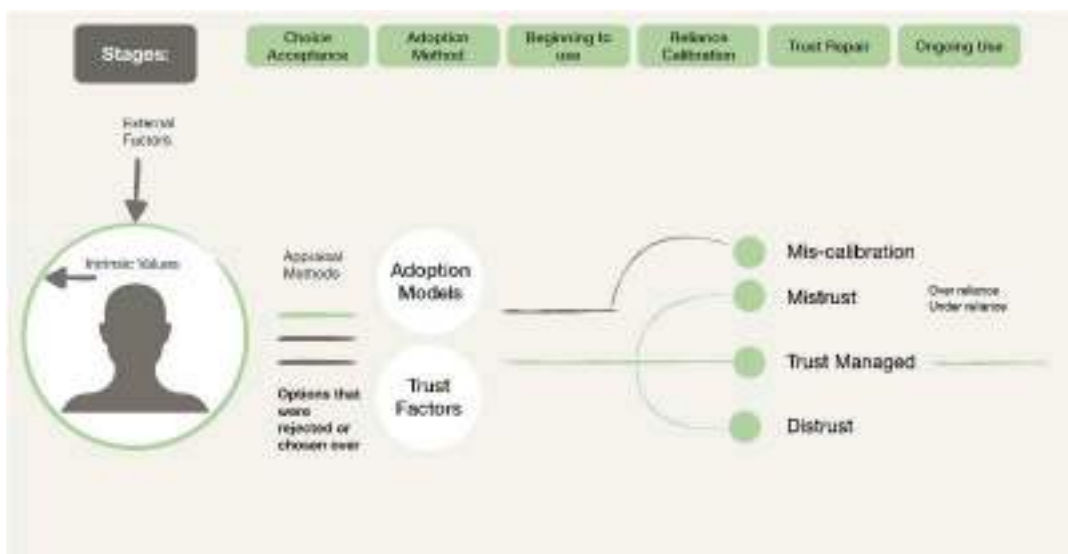


Figure 73: Author’s Translation of Technology Adoption Processes, Diagram by Author, July 2023

3.5.6 Hype and Technology Adoption

G.A Moore's Diffusion bell curve (Moore, 1991) discusses the notion of there being a range of adoption rates to new technologies and by proxy, technology-embedded objects.

There is also a distinct 'chasm' that needs to be crossed, which is where many technologies fall out of use. When aligned with Gartner's Cycle of Hype (Gartners, 2023), an annually released report on emerging technologies, there is a correlation between the success of the adoption and overcoming the initial expectations set out. Trust seeks to mitigate Hype and narratives of grand functionality, which leave the user less likely to engage with technologies that they feel are "over-selling" to them in the future (Stilgoe, 2020). The rate at which individuals accept new technologies depends on their contexts and previous experiences with technology.

Technology acceptance is the precursor to technology adoption, and it is important to understand which factors make for more effective engagement.

Kate Devitt discusses *Robotic and Autonomous Agricultural Technologies* (RAAT) through the context of social cognition. The level of partial autonomy we find in this sector requires consideration of the *human-robot interface (HRI)*. The adoption of technologies has three phases according to Devitt, 1) User adoption, in which consumers form an understanding of technologies and intend to use them, 2) Initial Use: in which calibration, personalisation and learning are essential, and 3) Post-adoptive use: in which the technology is regularly implemented into the routines in the orchard. Devitt suggests competency and integrity as the key factors required to build trust in RAAT.

The Unified Theory of Acceptance and Use of Technology (UTAUT) framework posed by (Venkatesh et. al., 2003; 2016) discusses the benefits of removing repetitive and potentially straining tasks from individuals and holds great promise in contrast with the challenges of adoption.

3.5.7 Misuse, disuse, mistrust & distrust

Once a decision has been made to accept a product and its embedded technology, we have to rely on the management of trust to allow for ongoing reliance and use, the crux of what we often hope to achieve as designers. Lee and See (2004) define the concept of misuse and disuse. *Misuse* refers to a system or technology being used inappropriately. *Disuse* refers to the avoidance or neglect of use. *Miscalibration* of trust can be due to the user's wariness or prior experiences with automation.

Miscalibration leads to disappointment, with hype playing a role in misaligning the expectations a user has a product.

Mistrust can refer to when an over or under-reliance takes place in a product. This is often where the words 'human error' get used as part of figuring out where to assign blame. *Distrust* is when the relationship has broken down to the point where repair strategies are needed to recover the relationship. Distrust can come from frustrations with product performance, unreliable communication and broken expectations.

When we need to repair trust with technology-embedded objects, it is similar to how we may look to repair trust between two people. Actions such as apologising, admitting fault and clarifying intentions are critical. By proving repeated reliance after the trust has been broken, it can slowly aim to rebuild trust. If a system can identify faults and offer support in fixing them proactively, this mitigates trust being broken in the first place. Sometimes, trust is just lost. (Esterwood and Robert, 2021)

3.5.8 Limitations of Existing Frameworks

While many frameworks were discussed that address trust in relationships that involve inter-human or human to automation, robotic, and technology trust, few match the context of design-specific factors of trust that can be implemented. As well as this, there is a marked lack of research about trust in the horticultural sector where factors such as culture, technological familiarity and hype should be explored. Throughout existing frameworks and literature on trust, authors often propose three key pillars for their frameworks, interestingly, the substance of these pillars vary between authors.

In reflection of this review, trends within each area show that scholarly emphasis was placed in research output in different 'waves'. The topic of trust, for example, was primarily written about as such: 1992 – 1996, 2004–2006, 2015, and emerging writings have begun again in 2021 and are currently at an all time high. The most recent rise may be due to the increasing concern of misinformation and disinformation throughout society and sectors. Considerations of the post-human, the trans-human and the future rights of intelligent objects act as an interesting discourse that will continue to gain relevancy to this area of research and will undoubtedly impact the way one designs for the constructed world.

If Aotearoa is seen as a test-bed for new technologies (AucklandNZ, 2023), then it makes sense to create a framework that considers the ways in which we can create beneficial, transparent and trustworthy interactions with each other, with systems and products, as well as the whenua (land).

3.6 Proposed Factors of Trust

The proposed factors of trust I am summarising in the following section are as a consequence of the reviewed literature, and was published for the DRS 2024 Conference:

Krige, Z. (2024) Developing factors of trust for the design of trustworthy Human - Product interactions. *in Gray, C., Ciliotta Chehade, E., Hekkert, P., Forlano, L., Ciuccarelli, P., Lloyd, P. (eds.), DRS2024: Boston, 23–28 June, Boston, USA.* <https://doi.org/10.21606/drs.2024.695>

Trust is an essential aspect of sustaining inter-relationship between agents. When designing products, we should be aware of how we can integrate features that promote trust in our products as the benefits of doing this include prolonging use and improving reliance on the product.

The initial hypothesis formed was that there is a disconnect between those in positions of decision-making power about which tools to implement and those required to use the tools, meaning that there is a misalignment of product expectations between stakeholders, leading to an increased likelihood of non-successful implementation. This is critical to better understand when designing for multiple sets of expectations and priorities.

The key factors of trust were developed based on their reoccurrence throughout the literature and their relevance to the horticultural industry, for which aspects of trust have not been readily researched yet and are key to building meaningful engagement.

A Likert chart was developed to measure the proposed factors of trust with individuals and the level of importance they place on each factor. It is important to note that trust is an ever-calibrating dynamic in a relationship, which is why reliability is suggested as a term for users in connection to trustworthiness as they are often closely related in the literature. Participants would be asked; “How important are these factors to you for products that you use as part of your work.” This assists in the contextualisation of what is being asked of the participant but still refers fairly broadly to the products they use in the sector.

A thematic analysis was undertaken to identify the most commonly reoccurring factors that enable trust building throughout approximately 110 research papers. Much of the seminal works were produced prior to the past ten years, so the preliminary search did not limit by date, but by citations and journal reputation. Distinctions were drawn between trust between robots, computers, physical objects, automation and Artificial Intelligence, as each of these offer inter-related yet specific lenses to the manner of interaction that is taking place. What was interesting was that there was a recurrence of similar themes despite this initial distinction.

Aspects such as intention and cultural alignment were omitted as they pose a non-linear measure and would be based on specific contexts, and vary based on the individual, their experiences and their location. These aspects are very important to measure however, and further research should explore both the wealth of resources already available and seek to further understand the role that culture plays in the expression of trust between individuals and the built environment and products.

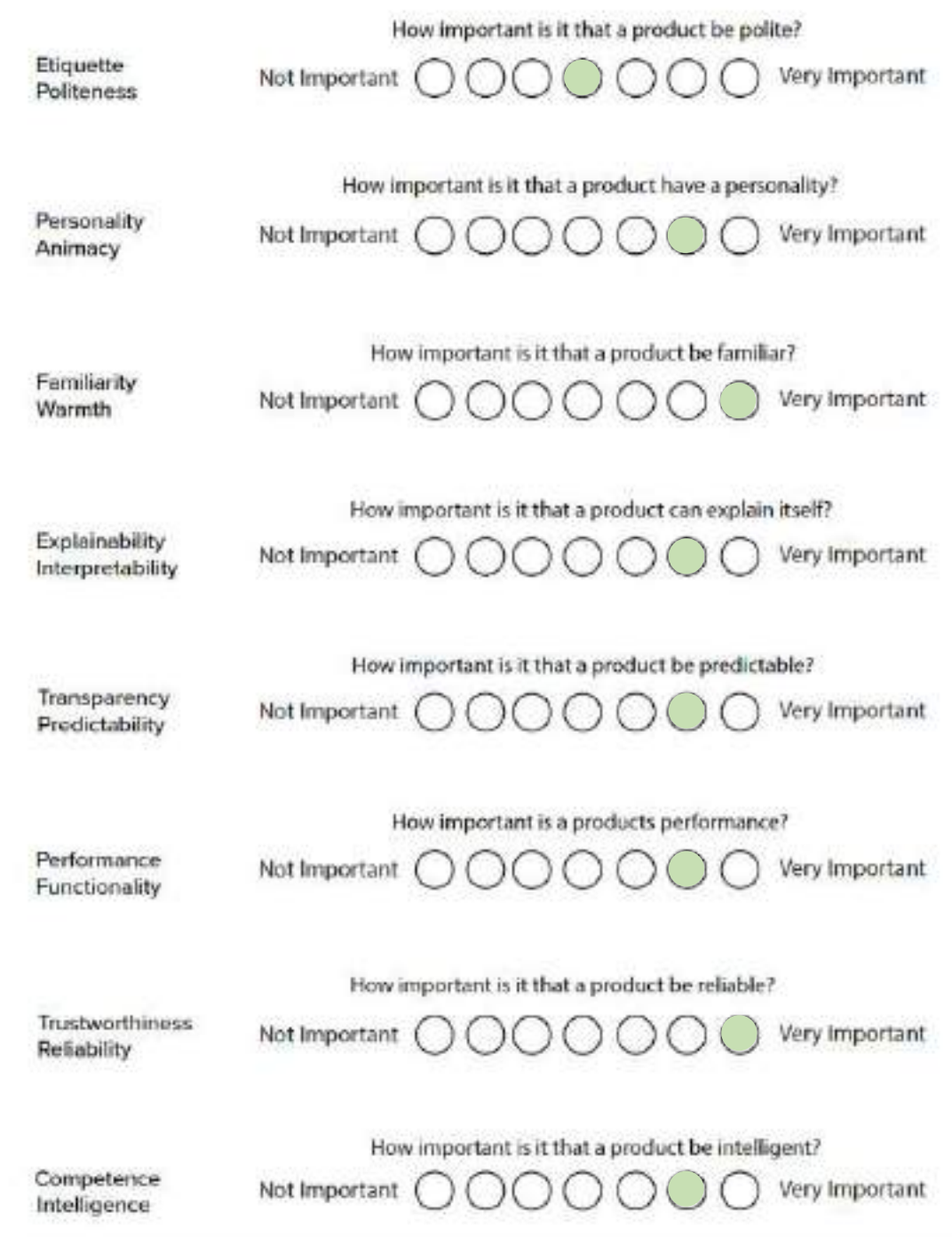


Figure 74: Likert Chart of Proposed Factors of Trust, created by Author, 2021

In order to further develop a design criteria that tests the active components of trust in the context of this study, the following factors need to be considered and weighed up by different user groups to understand their relationship and expectations on products and how we can best incorporate these into the designed outcome. A radar chart has been developed to help visualise what the result of this may look like.

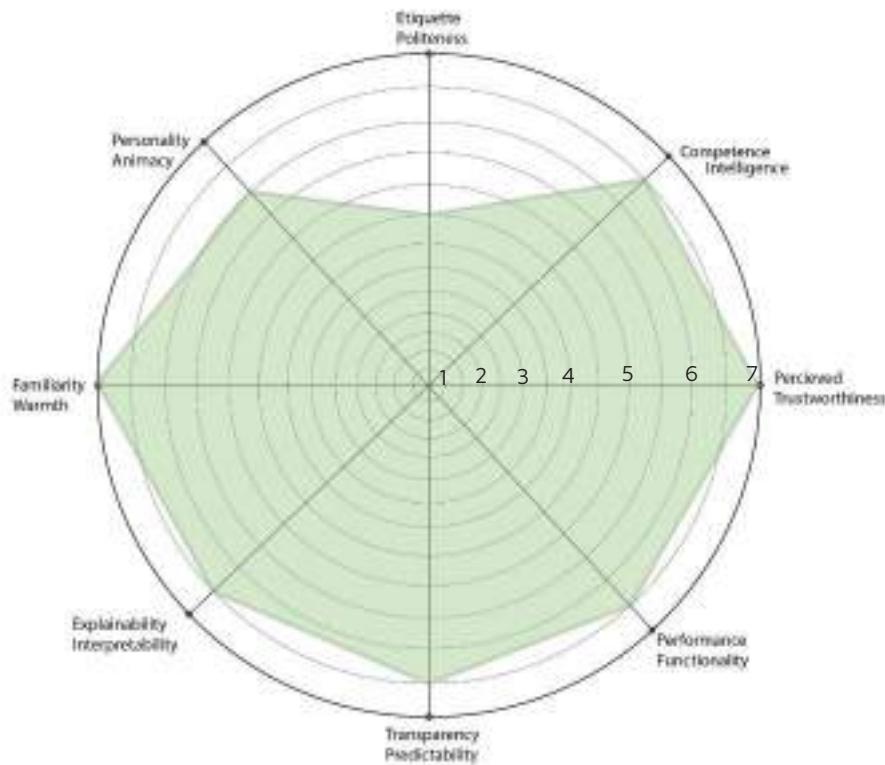


Figure 75: Radar Chart exploring Proposed Factors of Trust, created by Author, 2021

3.6.1 Familiarity and Warmth

Familiarity refers to how well we know or comprehend that which we are assessing for trustworthiness. It is the same as meeting a new person for the first time, and utilising appraisal theories to understand who they are and whether or not they pose a risk or benefit to you engaging with them. The more familiar we become with another agent, the more likely we are to develop friendship or ambivalence towards them being in our surroundings. We are also more likely to forgive them.

3.6.2 Performance and Functionality

The perceived utility of a product is vital when we decide whether or not this product is the best option for purchase to meet our wants or needs. We have an expectation of performance as intended and the expectation levels of users may differ based on a range of factors including the product price range and previous experience with a similar product. The mitigation of expectations that an individual has on a product is predominantly based on aspects of performance and then supported by other stimuli that impacts the user's appraisal of the product.

3.6.3 Personality and Animacy

The embodiment of personality into products is evident in design all around us, and a method in which we might make products more familiar, relatable and sociable. In products, personality can be imbued deliberately to further heighten the sense of connection we have with the product, even going so far to address anthropomorphism, the adding of biological creature- features into inanimate objects. Authors (De Visser et.al., 2012), (Spatola and Wudarczyk, 2021), (Salles et. al., 2020), (Troshani et. al., 2021), (Kim and Song, 2021) discuss anthropomorphism in its modern relationship to robots, computers and A.I. Masahiro Mori (1970) originally coined the ‘Uncanny Valley’ which is the point at which something becomes ‘too human’ and can cause an uncomfortable sensation and warns against this.

3.6.4 Explainability and Interpretability

The ability for a product to explain what it is doing and why is crucial to allow trust to be mitigated. We have all experienced the moment when a device randomly powers down or takes you to a page you didn’t want to be on. It can be frustrating and even dangerous. The ability for a product to communicate its function, and its intention is very important in helping to ensure that the user can remain in control and understand what has or is going to happen and why. The communication of pre or post-action may be through language, visual cues such as blinking lights or haptic feedback to name a few. This communication means that both the product and user are aware of what happens next and assists in fostering a collaborative interaction.

3.6.5 Etiquette and Politeness

The expression of social etiquette in intelligent products may be difficult to visualise until you imagine the opposite; a rude product. It is not until you consider what a rude product might act like that you realise that the language embedded into intelligent products are often set in a specific tone. We are surrounded by digital voices that we don’t notice until we look for them because they are a given part of using any system. When designing a product for the horticultural sector then, what tone should it have to help increase trust in it?

Parasuraman (2000) suggests the concept of politeness as important to the expectations we have of computers as social actors. Miller (2002) discusses the etiquette a computer should express towards humans to enhance the human-machine interaction and trust between the agents. The acknowledgement of different cultural backgrounds interacting with the device and how formality of language varies is a big factor, and then also extends to the local humour, tone or encouragements.

3.6.6 Transparency and Predictability

The predictability of a product is crucial in an environment where safety, time efficiency and accuracy are at the core of the products function. The product should be able to firstly explain why it is operating in this manner and then be transparent in its operations so that it can be understood what the process is behind the data to allow for faults to be better understood. An example in the apple growing industry is that an intelligent object might capture a series of images, and then process them. While processing them, it might estimate that a particular fruit size is the size of a basketball, distorting the data set. Now the user is needing to understand why this fault has happened, because they are looking at the same tree that was photographed and can clearly see there is not an apple of that size in the tree. If the system is transparent, this fault can be picked up quickly and the data point removed by the user. The device should be able to apologise and clarify for any errors so as to help manage the continued relationship between the user and the product.

3.6.7 Perceived Trustworthiness and Reliability

We want to know that the product we purchase is going to serve us well, possibly even for a long time. Reliability can be used to refer to the physical nature of the product as well as to the system in which it operates. The data collected should be accurate to help best inform the user and to make the product valuable to use over other methods. The physical product should be made and function in such a way that it can be seen as reliable and have faith placed in its ability to perform the task for the user when required. If trust is broken and the product is deemed to be unreliable, it is very unlikely to see continued use, especially in an industry where any time wasted can have dire consequences on their yield. Reliability also extends to the ecosystem around the product, to reflect on the products' makers and whether or not they can be appraised as being a reliable source from which to purchase the product and to possibly seek support the user if something goes wrong.

3.6.8 Competence and Intelligence

The overall competence of a product depends on the nature of the product. You may want a potato peeler to be intuitive to use, but you may have no expectations of intelligence beyond this. However, when an intelligent object such as a smartphone is being discussed, that same intuitive use becomes part of its overall perceived competence to undertake the task for you. The furthest extent of this is when a product becomes "too intelligent", resulting in the feeling of unease. For example, when something like Google's Home Assistant (Google 2024) starts listening even though we didn't ask them anything. While our expectation of competence might shift based on context, it is a given when designing intelligent objects and needs thoughtful integration.

3.6.9 Participant Responses

Looking at the results, you can see that there is very little correlation between role type and which factors were deemed the most beneficial. The sample size of participants was small, (ten) which also impacted the success in identifying any patterns. However, it was noted when relating the results to the participants' contributions to the personas, that their personality (extraversion versus introversion) and their level of openness to accepting a new technology played a significant role in how highly they rated each of the factors. This aspect of the research was not prioritised, however, would be beneficial to explore beyond this study.

Below is an example of the range of respondents:

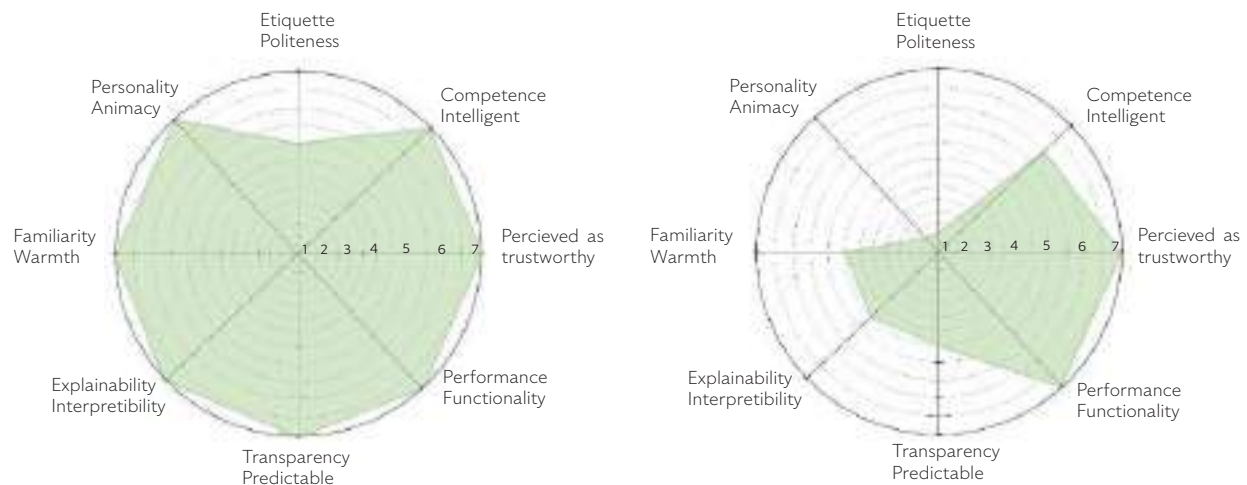


Figure 76: Summary Radar Charts from participants, Created by Author, 2024

While shaped for the horticultural industry, the ability to similarly experiment with these proposed factors in other industries should allow for interesting comparisons to be made between roles and act as guides by which we begin to create products that better consider how to imbue trustworthy characteristics.

Some recommendations when designing for trust as a result of this paper are as follows;

- Managing the expectations and deliverables
- To design for transparent and explainable actions
- Having clear intentions to ensure the user understands.
- Clear communication, including the removal of barriers of jargon and colloquial language.
- Take the time to critically engage with the context and attempt to align interests of the parties involved.

3.7 Discussion on Suggested Factors

The consequence of not understanding what makes for a trustworthy product is that we may continue to generate products which do not adequately mitigate our expectations at the start of the interaction. This has a knock-on effect for other products which might be encountered by the individual after this initial interaction and would be a contributing factor to discontinued use if reliance is broken.

The factors of trust were tested over the growing season across a range of stakeholders involved in the horticultural industry to understand the ratings of importance each of these factors have to different roles, and to identify the similarities and differences between expectations on products and how this shapes the considerations designers should factor in when integrating features and benefits. Often in the horticultural industry, Innovation Managers are responsible for investing in tools they think may benefit the orchard, but their experiences, technological competencies and interests may not align with the much more immediate, physical requirements of the seasonal worker needing to operate the design.

3.8 Resulting Design Criteria for Designing Trust

The resulting design criteria formed from these proposed factors add to the considerations which designers should employ when designing objects in socio-technological systems, particularly when aiming to heighten the sense of trust the individual has in the product. Please see Appendix ___ for full design criteria from research paper

- Etiquette and Politeness
- Familiarity and Warmth
- Personality and Animacy
- Explainability and Interpretability
- Transparency and Predictability
- Performance and Functionality
- Trustworthiness and Reliability
- Competence and Intelligence

Summary of Trust

When trust is understood as a fundamental part of relationship-building and interaction, we understand that the level of trust at any moment may be based on multiple factors. The human operator will be using techniques to appraise the right level of trust they should be placing in an object at a given time and context. Creating objects and systems that adhere to a set of design criteria is essential to build resilient objects that reduce the risk of a miscalibration of trust and encourage continued engagement with intelligent objects.

“One challenge to designing for appropriate trust is that trust has a strong emotional component and may respond to influences that would not be considered in the traditional information processing model that often underlies automation design.”

— (Lee & Seppelt, 2006, p.1621)



Fig. 77

Throughout the literature, a multitude of factors were suggested to be important to trust, importantly, between different types of stakeholders, but always with the inclusion of the human stakeholder. These key factors, although individually measured as part of the Likert chart, have similarities in their functional outputs to our perceptions.

An example of this is the figure above, where familiarity and personality create a warmth and social component which makes it easier to connect to. Predictability, transparency and explainability refers to the method of communication between agents. Reliability and functionality refer to the operation of the design. These key themes can be related back to Mayer et al (1995), where the factors of purpose, process and performance were suggested.

Taking a More-Than-Human approach to the consideration of stakeholders involved, there are a number of interactions taking place which creates opportunities for misunderstandings or distrust to occur. The reason for taking this approach is that it enables a more authentic consideration and inclusion of designing for the environment, a crucial part of this industry, while also acknowledging Te Ao Māori views of the land as sacred and with independent agency.

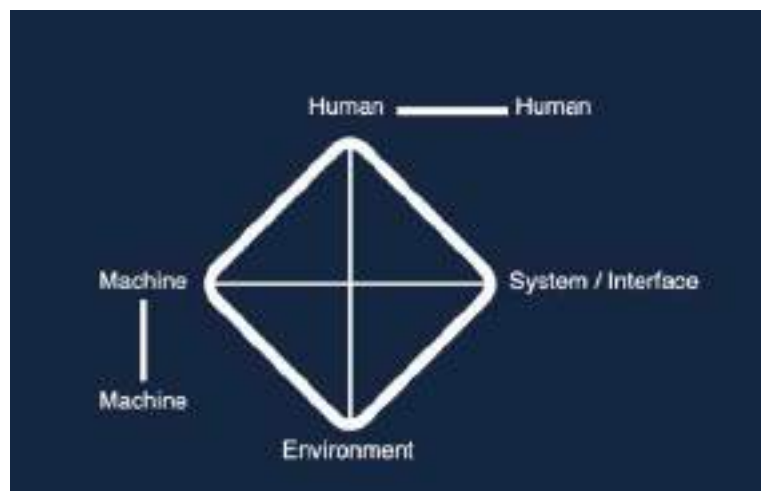


Fig. 78

Omissions

Although highly influential, trust in company brands was omitted for the scope of this project, as this is an extensive field of enquiry heavily impacted by the narrative surrounding their products or services, as well as advertising and marketing strategies.

Limitations

Only ten participants were involved in the initial testing of these factors, and the results suggest that overarching factors such as personality and openness to technology may be impacting the response mannerisms. To confirm this, a larger sample of data would need to be collected to assist in the shaping of these factors.

3.9 Research with, through and for design

Christopher Frayling discusses Research into, through and for art and design (1993) This approach used a number of design methods to investigate the subject matter in both direct and indirect contact.

As part of the secondary research it was identified that there was a gap within the literature of methods and approaches which enabled trust to be mapped and understood between multiple agents. The project saw research **into** trust, and realising that the success of the design relies on the success of other interactions taking place. The creative design investigation enabled research **through** making and using an iterative approach to learn from, and actively respond to new insights.

The outcome of this extends beyond a physical concept offering, to explain the approach developed **for** this project, which would have relevance to other practitioners in the future who consider how to design trust for multi-agent scenarios.

3.10 Trust within a Product Model of Experience

The 'Trust within a Product Model of Experience' framework posits trust as the connective thread between different agents in the framework. It suggests the forms of trust techniques and approaches that should be used between various agents, (for example, Human-Automation Trust between human and technology). In many ways, this proposed model outlines the primary observations from the literature review which investigated the primary factors and approaches of trust involved in the consideration when designing for trust.

To the right is a brief description of each agent;

The Human

Refers to the User (Operator) who use appraisal methods of experiences to moderate their responses to external factors. Users will have individual experiences, cultural backgrounds and contexts which impacts the values that they apply as well as the expectations they have of an experience.

The Product

The frameworks and factors of trust discussed as part of this framework creates a design criteria against which products and systems can be measured to identify whether or not they are defined as trustworthy. This will be tested and refined as part of the study.

The Context/ Environment

This project specifically applies this framework in the orchard environment, where Precision Agriculture operates to find sustainable and optimisation methods for the land. The ethical stewardship and relationship that users have with the environment begins to be considered and will be built upon with better understanding of perspectives from primary research.

The Technology

The framework acknowledges the need to better understand technology acceptance in the horticultural sector and which data methods are most appropriate for use when conveying large and complex datasets to the end users. Issues of Data Privacy, Ownership and Sovereignty is further discussed as part of the ethical discussion in this document.

The Experience

Beginning to think about traditional HCD, the decentering of the human and the focus on the experience allows for a very specific focus on what the key area for innovation. It also future-proofs the framework so that other actors that gain agency and or person-hood going forward can be afforded the same shared focus on experience that is mutually beneficial. By decentering the notion of 'human', I also invite dialogue about the responsibilities we have towards the environment and its ethical stewardship.

Trust within a Product Model of Experience

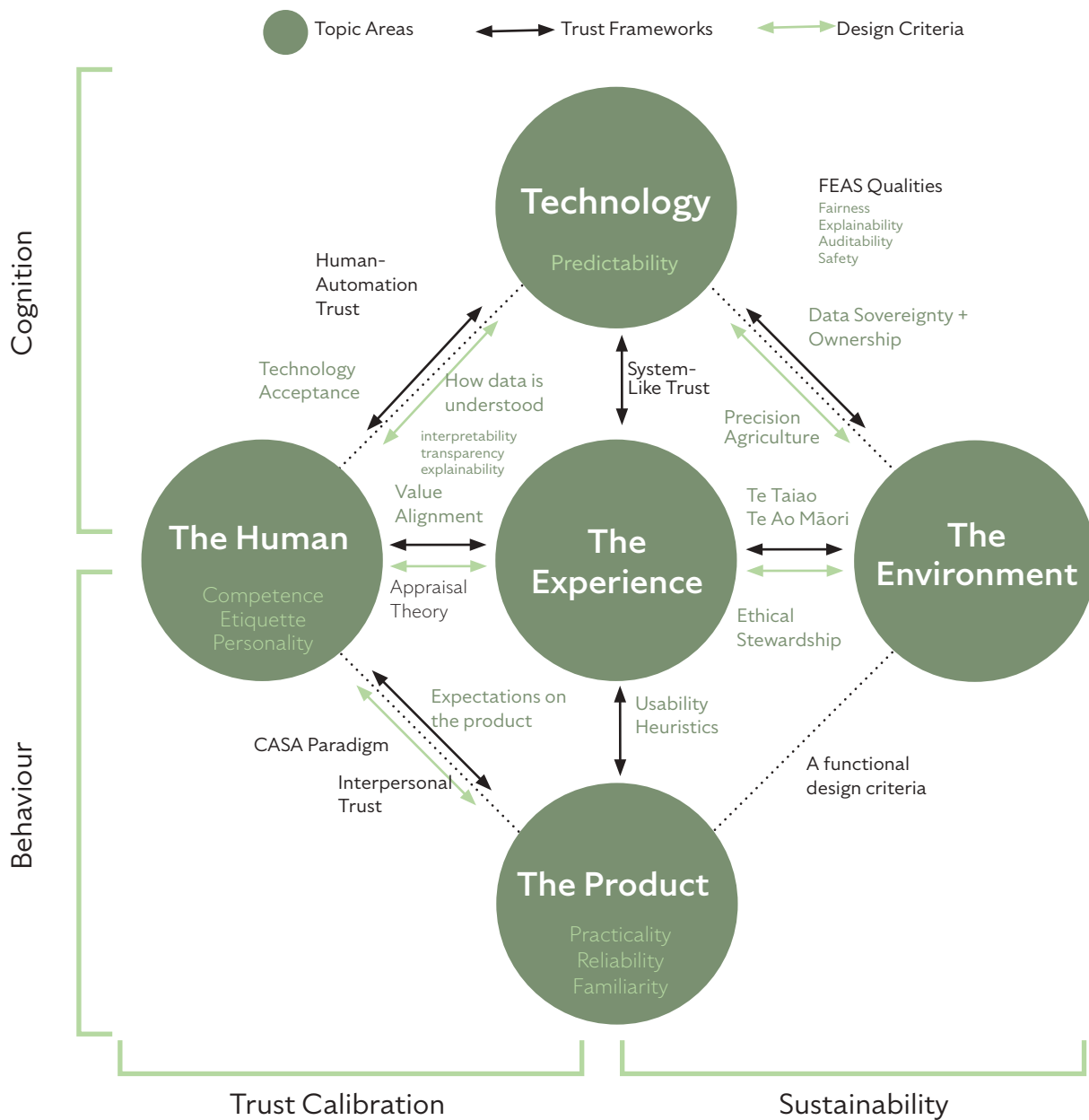


Figure 79: Trust within a Product Model of Experience - Full Version, Diagram by Author, 2022

Project Offered Framework

Human Centred Design, is a generalist approach to the societal and ecological concerns of our time, to which designers need to respond in an increasingly intentional manner. In the process of identifying the key users of this project, the consideration of *More-Than-Human* agents was critical to designing for Te Taiao, the natural environment around us, the emerging technologies being used and the objects that physically encompass these capabilities as well as human operators.

This project sought a framework to use as part of its theoretical foundation to understand how to promote ongoing usability and trust by a human user, of a technology-driven object, in the natural environment. A review of existing framework approaches found that some operated in trust, and some in product design, but minimal operated in the intersection of these two areas; part of the research gap that this project addresses. The synthesis of this research developed the framework in relation to the context of the study and key influencing factors, the core of which is the shared experience. This model would appear to have wider application.

4.0 Methodology

To measuring fruit

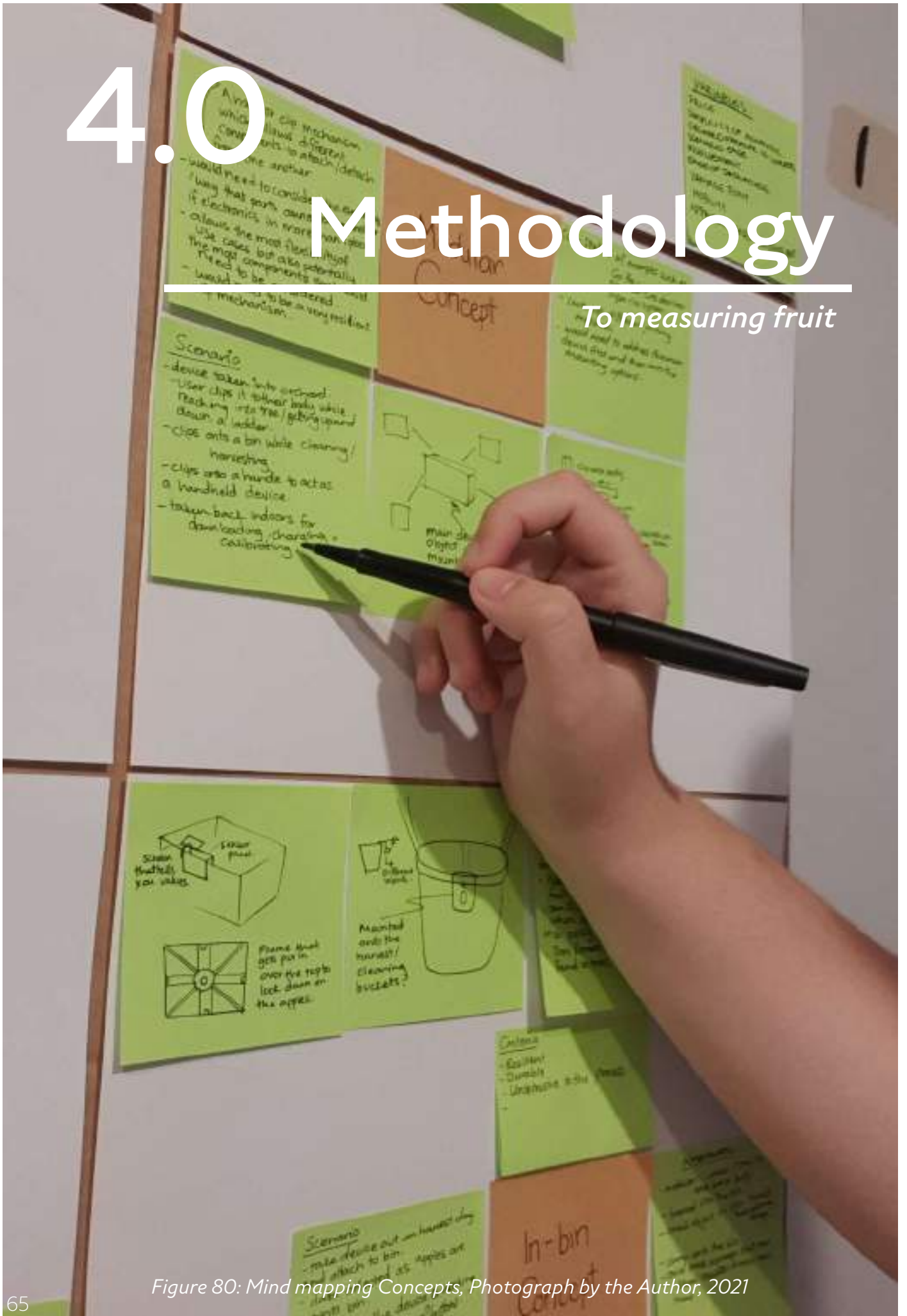


Figure 80: Mind mapping Concepts, Photograph by the Author, 2021

4.1 Mixed Method Approaches

4.1.1 Quantitative and Qualitative

Using a mixed methods approach, both qualitative and quantitative data was collected and produced, due to the data-driven nature of the project.

An example of quantitative research methods being utilised was during the Immersive Research data collection about fruit sizes, and the subsequent analysis of the data to reach new insights about the optimal harvest dates.

An example of qualitative research methods being utilised was a series of interviews that discuss current practices and opportunities for innovation with orchard managers and industry experts. The design investigation is part of the qualitative creative practice. The combination of these two approaches ensured that user insight can be supported by numerical data collected around task and growing outcomes in the orchard, which in turn, assists in validating the design decisions being made along the way.

4.1.2 Iterative Design Process

The iterative design process is a methodology of continued improvement, critique and refinement to resolve and develop a salient concept towards a commercial product outcome, or resolved design. This process is often intuitive to design processes where concepts are explored, tested and then iterated upon to improve the outcome. This process will be recorded through a concept log document.

4.1.3 Triple Diamond

The triple-diamond framework (Zendesk, 2020; TheyDo, 2022; Ulrich, 2023) is a process-based design method that leads the designer through divergent and convergent practices, building on the common double-diamond. The methods which will be implemented in this study will be spaced throughout the discovery, design and development process.

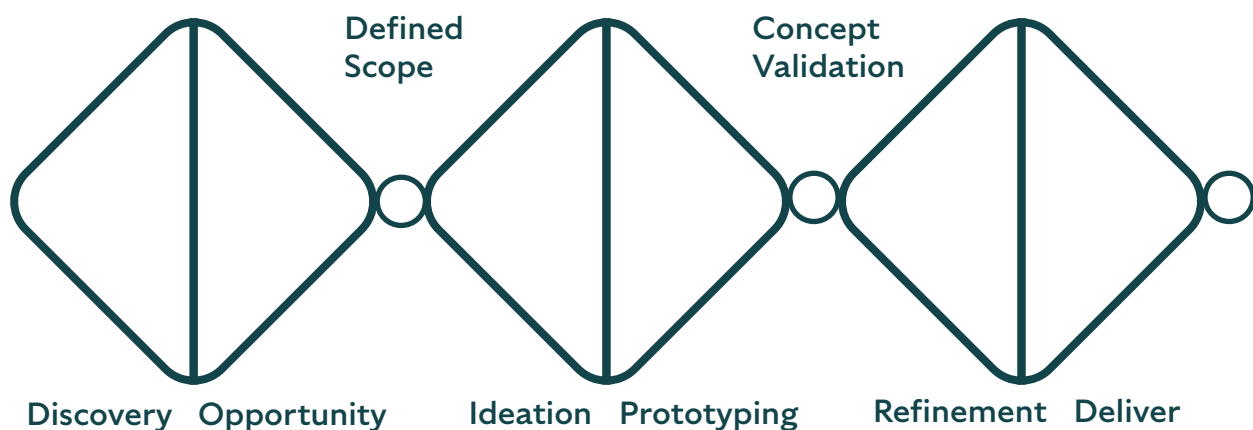


Figure 81: Triple Design Method Diagram, drawn by Author, from reference Bootcamp

4.2 Design Method Selection

Methods were selected based on their relevance to the project and how tangible their integration was around the busy user groups. The methods acknowledged the physical nature of growing fruit and sought to inform in ways that maximised insights being discovered and communicated back to users and stakeholders through anonymised data.

4.2.1 Immersive Research

Immersive research through growing and maintaining my own set of trees allowed me to learn, experiment and observe user experience as well as plant physiology that I had the agency to make changes to at no risk to an external stakeholder. The trees are located in Morrinsville, on my family lifestyle block, with moderate weather, and easy to access location. Four trees (an apple, a peach and two plum trees) were selected that best represented different challenges. The fruit study acted as an independent control, where I could test prototypes and ideas and gain comparative data to understand how effective a concept was at gathering quantitative data (in this instance, fruit size and quantity) I was also able to better understand how placement and labour involvement impacted on the success of each operation.

Please see Chapter 5: Fruit Study

4.2.2 Case Studies

Case Studies explore companies, products and systems that operate in interesting ways with intelligent objects and seek to better understand the opportunities and mis-steps of others to better inform the design process.

4.2.3 Perceptual Mapping

Perceptual mapping is used in two different ways; firstly, a trend map has been used to place existing products on a scale in terms of cost, agency and time-saving benefits. This method is useful to visualise gaps in the market where a potential product could have the most opportunity for innovation. Secondly, perceptions of anthropomorphism were considered to understand its relationship to camera lens layout that promotes ongoing, trusted use.

4.2.4 Interviews

This research method is valuable for gaining insights into previous product and system experiences, building relationships and trust by reciprocating knowledge and potential innovation with participants in the industry, in the form of new design concepts that attend to their issues and concerns.

Interviews were conducted in orchard and office environments with different user groups. Participants were invited to share their views on the current experience and products used. Consequently new concepts designs were presented for review and comment, and with physical prototypes, allowing feedback on design concepts to better understand how the product was understood and perceived.

4.2.5 Site Visits

Site visits were done in combination with informal interviews and observations. Initial contact was done through PlantTech Research Institute, and later through connections made in the industry. The ability to visit orchard environments was valuable to gain a better understanding of the task and surrounding contexts and infrastructure, the people and the way in which they would prefer a product to operate to meet their needs. The ability to speak directly to the context was useful for asking questions.

4.2.6 Observation - Photo Studies

Observation work was undertaken in two approaches, firstly, during the fruit growing season alongside stakeholders in orchard walk-throughs, and secondly through a visual analysis of a series of episodes from *Country Calender* (a staple of media coverage of technology and innovation across the horticulture and farming sectors for generations in New Zealand) to understand terminology and practices, while lockdown restrictions still limited access to orchards. Both of these methods were unobtrusive to orchard operations while gaining useful insight to existing infrastructure, equipment and practices. Observations were recorded either through image recording such as photograph or video, or by note-taking and sketching to map out the experiences.

4.2.7 Personas

Personas usefully anonymise the views, behaviours and experiences of interviewed participants to protect their privacy while communicating key design insights gained that inform what the project should be responding to, in order to meet user needs. Ensuring inclusive representation of individuals allowed for a variety of perspectives to be captured. To further protect identities, participants did not include pseudonym names or stock-images that can identify ethnicity or gender.

4.2.8 Semantic Differential - Likert Chart

This method was used to measure aspects such as the perceived trustworthiness, appearance or performance of a concept throughout the interview and development phase of the concept. This is an evaluative tool that allows for attitudes towards a topic to be weighed up so that the deeper meaning below can be understood. Much care went into this method to ensure that it effectively connected with the underlying topics and concerns that the user might have.

4.2.9 Journey Mapping

Journey mapping allowed for the graphic aggregation of a range of factors that impact user behaviour and tasks throughout the fruit measuring process. This visual documentation was analysed for opportunities for design intervention. Scenario mapping was also done as part of this method to capture current experiences and then identify what the ideal experience looks like, and the subsequent system that would enable this scenario and how the designed solution can best hold this system in place.

4.2.10 Task Analysis

Task analysis activities were built on the journey mapping method to capture considerations of specific insights from the current processes. This method captured areas for innovation from existing solutions and understanding the relationship between ergonomics and user difficulties. An example of this is that the widest part for measuring is subjective as it is estimated by eye, and that different user heights impact their reach when measuring in different parts of the tree, all leading to discrepancies in the outcome.

4.3 Assessment Criteria and Methodology

The creative direction of the project was driven by ongoing dialogue and feedback from stakeholders to help shape a design solution that addressed the needs they have. Using the Concept Scoring method of Ulrich and Eppinger (2020) in *Product Design and Development* allowed for a consistent means of measurement throughout the different decision-making stages of the project.

Overall, these methods present a range of exploratory means in which the user experience can be captured to allow for insights that inform design intervention for those measuring fruit in the orchard environment.

These methods provided a foundation of empathy and understanding of the current user experience of measuring fruit manually. Immersive methods enabled seasonal comparisons to reflect how actions taken have had a direct impact of the orchard yield.

Please see Appendix F: for a list of research methods used to address each Research Question.

The ethics application for this project was reviewed by the Human Ethics Panel of Massey and approved on 24 February 2022 for 3 years from approval date. Application Number: SOA 21/57

4.3.1 Data Management

The first step is awareness of the bias that can exist within an algorithm and dataset. As a researcher, I was wary of the impact that my world lens might have on the way in which I conducted my research so as to promote inclusivity, to ensure that my worldview was not the only one that is considered, and to not only employ binary outcomes such as “right or wrong”. When gathering data, it is important to identify outliers and patterns as the study progresses, as these outliers may have unique stories, reasons and intentions which allow me to better understand why the data is forming in the way it is. This means that I am less likely to be dismissive of aspects of the data after the fact. The data that I collect as part of this study should also not be used in another study without a clear acknowledgement of the context in which the data was collected, as this is often where bias has the most opportunity to mislead.

**Please see Appendix E:
for Ethics Documentation**

4.3.2 Collection Method

Data in the form of interviews, site visits and observations was collected as insights that enabled designerly reflection, analysis and response. The intentions were to contextualise the usability and system-based issues with the current task of fruit measurement and sought ways to respond to this. Data was recorded in a method preferred by the participant; such as audio, visual or analogue. All forms of recording and data intentions was listed as part of the information sheet and consent form so that participants could indicate which methods they are comfortable with. The data is stored on the Massey OneDrive of the researcher, with contact details being stored in a separate file location for the individuals in the study. This raw data will not be used as part of any other studies.

4.3.3 Confidentiality

All participant data is anonymised unless prior permission is given to utilise direct quotes, images, or recordings (both audio and visual) for use in publications such as the thesis. Personal data such as contact details for participants (in cases where the researcher has had to either contact via email, phone or in person) is kept separately from the research data and will not be published or shared by the researcher. Personas have assist in the protection of individual participants and their views, thoughts and concerns by pulling together the key insights gained from the participants rather than reflecting an individual.

4.3.4 Conflicts of Interest

No Conflicts of Interest were foreseen in this study as the relationship between Massey University, myself as a researcher and PlantTech Research Institute were well defined as part of the original agreement. Through the intervention of the Massey Intellectual Property Manager, IP rights from the research that continued transferred to the researcher and Massey University at the time of PlantTech's Receivership in November 2022.



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5.0

Fruit Study

Immersive Research

Figure 83: Image of Apple Measurement, Photograph by Author, 2024

The Immersive Research section of the study acted as a mitigation strategy in case of additional COVID-19 lock-downs, where access to orchards may be disrupted, but subsequently became an integral part of the data collection methodology throughout an otherwise tumultuous study. Three years of seasonal data allowed for comparison of different seasons, highlighting the fluctuation in crop, weather and demand for fruit, all of which are integral to the success of a yield and the likelihood of producing high-quality fruit, at quantities that enable them to be profitable for growers.

Purpose

This section of the research project gained an understanding of the fundamentals of growing a successful yield of fruit and gaining empathy for the user experience along the way. An immersive engagement, along with task analysis techniques were used to develop an understanding of the challenges of fruit measurement.

Method and Implementation

Tree branches were labelled to make it easier to navigate them. Five fruit were measured from each branch weekly. Typically, the smallest fruit, the largest and then fruit at random were selected. The branches were at different heights and sun directions within the tree to be able to measure differences in the tree as well. Current processes in the industry often meant that people are measuring a random fruit from a selected tree as they walked through the orchard.

Fruit Count

The fruit count is undertaken by manually counting the fruit on each branch. Challenges of occlusion (being hidden from sight) by leaves and other fruit, glare from the sun, and also the bunches that fruit grow in would make it harder to count. There would have been at least some human error in this process, additionally overlapping branches contributes to errors in accurate measurement. This problem is commonly solved through proper pruning.

Fruit Size

Fruit size data was collected for this study using callipers, the circumference estimated by eye (roughly the centre of the fruit). The size was then noted and written down onto a clipboard. This process was highly repetitive, switching hands and tasks constantly. To speed this process up, a research assistant assisted me by writing down the sizes as I read them out. In an orchard environment, dedicating two people to this process is not efficient.

Environmental Factors

Environmental factors such as temperature, wind, humidity, precipitation and UV Index were recorded as they reflect the conditions in which the fruit was growing. Often, it also explained fruit loss, damage or growth spurts. Heavy wind and rain cause fruit to fall, impacting fruit count, while defined cold and hot seasons saw good growth. Most unexplained changes to fruit counts or outliers can be explained by having the environmental log and the multiple data points in each tree.

Side View

Top View

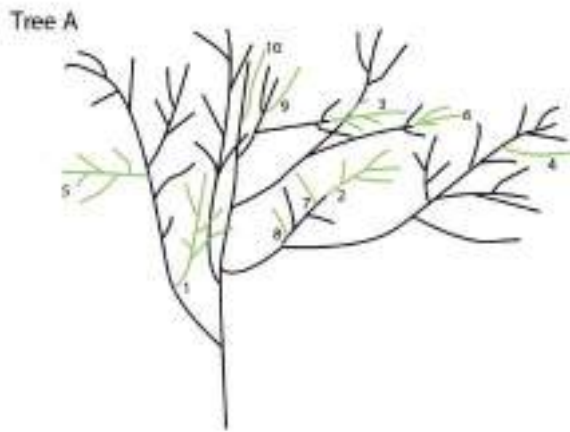


Figure 84

Figure 85

Side View

Top View

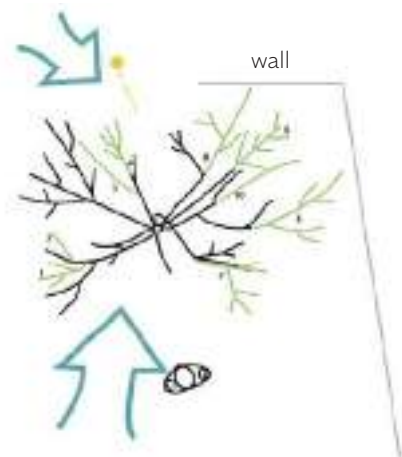


Figure 86

Figure 87



Figure 88

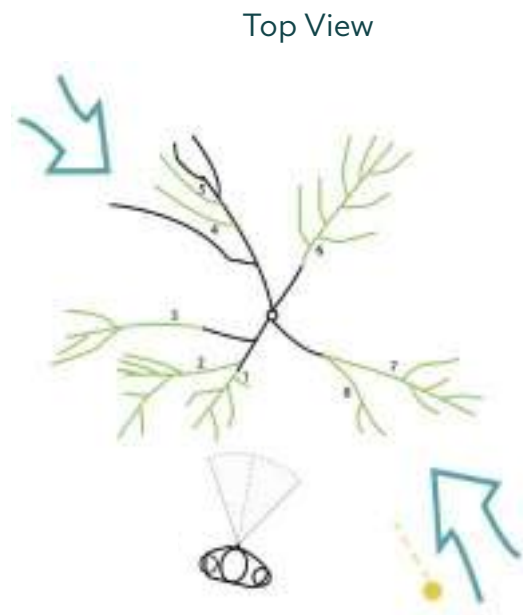


Figure 89



Figure 90



Figure 91



Figure 92: Protecting peaches from insect stings using Organza gift packets, Photograph by Author, 2022

The growing stage

Watering to ensure that trees had enough water during the hot and dry summer was key, this was typically done in the early evenings and in accordance with water restrictions. The fruit was measured using callipers once a week, typically on a Sunday and was done early morning or late evening to avoid the heat of the day. The growing stage encompassed a lot of the troubleshooting that had to happen when encountering a pest or disease impacting on the fruit. The fruit growth reflected the balance of the environment around it, with mild rain and hot days seeming to improve growth.

Harvesting stage

Each tree was ready for harvest at a different stage. The peach tree was first, mainly because the possums and disease meant there was only one, slightly unripe peach to be had. The harvesting process from Tree C happened before Tree D, both being harvested daily over the period of about two weeks.

This stage brought about a new type of task analysis, and that was understanding how one harvesting from higher up in the tree. It can be difficult to manoeuvre your body around the branches, and most movement results in a few fruit falling. The reach at any given time is significant, as you have to try to access all the fruit. Ripeness can be felt by the density of the fruit and a twisting motion with the wrist loosens the fruit. Holding a bucket that progressively gets heavier the more you pick and at great height is not a pleasant experience. This action daily resulted in stiff bodies, especially in the back and shoulders.

The harvesting numbers were recorded daily, and the fruit was counted into plastic containers, boxes and pallets as we distributed the fruit to friends and family.

Storing the fruit

The weight of the fruit means that those stacked at the bottom can be damaged if too much is added. Keeping the produce cool and out of sunlight can be a challenge, and it felt like a race against the clock to get the plums from this intermediate phase to those who might consume it. Much of the fruit damage can happen during this stage if it is not properly managed.

5.1 Trial 1: Kiwifruit Imagery Capture Test (2022)

Please see link in Preface to access Growth animations.

Purpose:

The purpose of this test was to identify the validity of capturing data in a regular scheduled interval and to assess how effective this information might be for data analysis and estimations of size and count of fruit while they are growing.

This study used a Go Pro Hero 9 as the method of image capture. The method of image capture varied slightly between each fruit tested, both in the way the camera was set up, but also the frequency at which imagery was captured. This is discussed further in the individual sections and then compared at the end.

The Go Pro was attached in ways that maximise the visibility of a particular patch of fruit growing and would map the change in the tree over the time that the tree was being studied. The decision-making process is outlined in the sections, with the author noting that there are certain factors such as bud placement, branch structure and placement that would impact the exact angle of best capture. All of the methods used to capture fruit data had some level of customisation to allow for the individual to adjust this.

The benefit of using a Go Pro is its robust, waterproof system and high quality imagery. The final product did not utilise a Go Pro, however the image quality should be held up as the minimal standard required to capture clear imagery of the fruit.

The limitation of the Go Pro is that it has a limited battery life which means that only a short amount of data can be captured each day - this resulted in the orchardist needing to replace the battery each day to ensure that the camera could operate. The placement of the camera box was marked against the post it was attached to. It was attached to a post instead of the tree to reduce the chance of damage to the tree as part of the initial test.

The travel direction of the sun dictated the direction in which the camera was set up, avoiding exposing the camera to too much morning glare. The data was only collected on workdays when the orchardist drove past the orchard on her way to work, but even this made for the interesting discovery that even capturing the data every few days was significant in showing growth patterns. The benefit to daily photography was that there was more data points to measure from.

Weather Event Acknowledgements:

It is important to note that approximately a week before this study began there was a severe cold snap across New Zealand, impacting most heavily on the kiwifruit industry, as most orchards would have been on the verge of bud break. The effects of this cold snap had long-term, varying impacts on the various crops, for example, the plums were already in bud break and after the cold snap followed by severe rain, many of the buds had fallen off, making for a smaller overall crop expected over the season.

Resulting Outcomes:

Over the course of the 3 weeks that data was collected, we can see (from the images below) that there was significant amounts of canopy growth. In this view we can also see that this farmer used hail netting over their crop, which is one of the main reasons they were successful after the aforementioned frost over many of their neighbouring kiwifruit orchards.



Fig. 93



Fig. 94

Both these photos were taken at approximately 7:30 in the morning, yet the cloud cover means that the amount of light in the images can vary greatly.

The primary potential that was identified by the PlantTech team had been the ability to even count fruit buds at this early stage - pre-thinning. This would require the system to be able to identify buds - which there are already a range of studies testing this capability with high levels of feasibility.



Fig. 95

From this test, I reflected on the factor that the time of day that the data is captured would impact on the amount of the light in the image, and also began doing research around studies which conducted image capture at night and their methodology.

5.2 Trial 2: Apple Imagery Capture Test (16 hour test)

To better understand the best time of day to capture fruit data, I undertook a cycle of photos across the span of a day, starting at 6 am until the sun was down by 10pm.

The findings from this show the variability of sunlight throughout the day as a major contributor to the amount of light in the scene, which can impact on the visibility, colour recognition and overall quality of the imagery.

A number of naturally occurring events such as cloud, wind, and retain can impact on the quality of the imagery captured. This can impact the occlusion of the actual lens as well as the amount of light and stillness of the subject matter.

This study and the amount of variation led me to explore night-time image capture with introduced and controlled lighting as a means of capturing more consistent data. In the next section I will discuss my exploration of this.



Fig. 96 Photo capture of the 16-hour Image Capture Investigation exploring time of day for photo capture, Photograph for Author, by Foresight, November 2022

5.3 Trial 3: Night Studies + Lighting studies



Fig. 97



Fig. 98

The Go Pro was mounted to a tripod, and a small flexible ring light was attached, of which the position could be manipulated. Below is data recording the best angles found for the light and camera placement.

On-tree Light Studies

Image #:	Distance x:	y:	Angle:	Details:
46	50	0		~400mm to fruit
47	100	0		
48	150	0		
49	50	-50		
50	100	-50		
51	150	+50		
52	50	+50		Towards trunk above camera
53	100	+50		Towards trunk above camera
54	150	-50	45	45 towards camera
55	50	0	45	45 away from camera up to tree
56	100	+50	-45	Behind camera to trunk -45

Table 1: On Tree Lighting Studies exploring distances from apple, February 2023



Figure 99: At Night Photography Attempt with Lighting - Apple Tree, Photograph by Author, November 2022



Fig. 100



Fig. 101



Figure 102: Series of Apple Tree Image Capture Adjusting Lighting to Reduce Glare, Photographs by Author, January 2023

Findings:

- Ideally, lighting is below or level to the camera, about 150-200 mm away from the camera and facing either directly upwards or at a 45° angle, in a cool tone.
- If the light came too close to the objects or camera the imagery would be over-saturated and not ideal for use.
- The distance from the camera to the fruit may vary in different orchard setups, so the camera needs to be able to adjust. The lighting should be adjustable, but favour the ideal range which allows for blue or cool lighting, as warm lighting distorted the colour and saturated the canopy too much.
- Continuous light in an evening setting draws insects to it, which may obscure the vision of the camera. The light would need to switch on briefly before the image is captured.

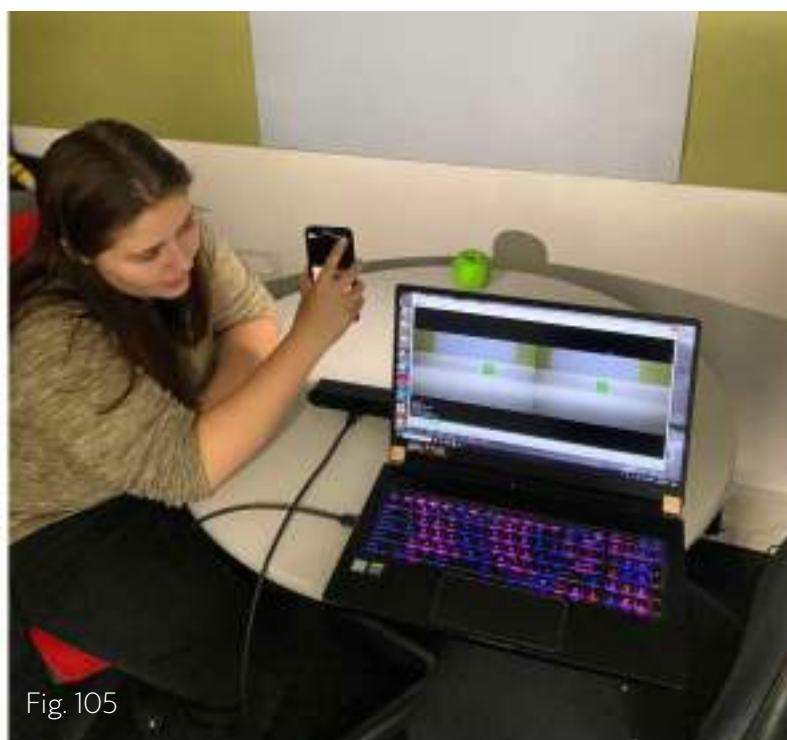
5.4 Trial 4: Lighting Studies

This study was done in a controlled room to expose controlled amounts and qualities of light to better understand the effectiveness of different means of illumination.

The model apple was used as a prop, and suspended from the ceiling using semi-reflective ribbon. The tie was made in a cross shape to support the apple prop but also create a central point of focus on the apple form to begin exploring the accuracy of size estimation.

This study was useful in trialling the distances and angles between the camera and lighting in a controlled environment.

The reflection of light back from the ceiling could have been considered a factor hence why the lighting test was also conducted outdoors.



Confirming Lighting position in a non-orchard setting with the Zed2i camera.

The below tables indicate the distances trialled as part of the investigation as to the ideal distance and light quality required when capturing the imagery.

Cool Light

Image #:	Distance x:	y:	Angle:	Details:
12	50	0	90	From apple centre
13	100	0	90	Distance from apple~200
14	150	0	90	
15	50	+50	90	
16	100	+50	90	
17	150	+50	90	
18	50	+100	90	
19	100	+100	90	
20	150	+100	90	
21	50	-50	90	
22	100	-50	90	
23	150	-50	90	
24	50	-100	90	
25	100	-100	90	
26	150	-100	90	

Table 2: Image Capture Results from White Light Tests, February 2023

Warm Light

Image #:	Distance x:	y:	Angle:	Details:
12	50	0	90	From apple centre
13	100	0	90	Distance from apple~200
14	150	0	90	
15	50	+50	90	
16	100	+50	90	
17	150	+50	90	
18	50	+100	90	
19	100	+100	90	
20	150	+100	90	
21	50	-50	90	
22	100	-50	90	
23	150	-50	90	
24	50	-100	90	
25	100	-100	90	
26	150	-100	90	

Table 3: Image Capture Results from Warm Light Tests, February 2023

5.5 Trial 5: Maturity Testing - 20 fruit sample

When picking the last of the apples of the season, a sample of 20 fruit was taken as is industry standard at random and these fruit were individually weighed and sized to capture an average of the end of the yield.



Figure 106: Photograph during Maturity Testing Process for the 2022-2023 Apple season, Photograph by Daniel Harmsworth for Author, February 2023



Figure 107: Photograph of Starch Maturity test results, Photograph by Author, February 2023

**Please see Appendix G:
Maturity Testing Resources**

5.6 Seasonal Observations

2021 to 2022 Season:

This season was the initial learning opportunity and in many ways setting up ad-hoc solutions to meet the challenges as they arose. A pro-active approach was taken in preparation for the following season. This included putting the following things in place;

- Capturing more information about the environment, including a small weather station at the location, as the local weather reported did not always reflect the actual weather outcome. Much more rain was predicted than there was.
- Measuring a larger sample size would help in reducing the amount of variation as there are more data-points.
- Treating the tree and soil below, before the fruit starts to form, and then pruning to ensure the trees are tidied to not have any overlapping branches.

2022 to 2023 Season:

Pruning

Pruning was undertaken in August of 2022 and took around four hours to complete.

The preparation for this included reading literature on recommended practices, speaking to experienced growers and enlisting the help of an experienced set of eyes to over see my work and given some advice.

I was warned about the fact that pruning can reduce yield for a year while the tree focuses on growth over producing fruit, but that it was also important to promote good sunlight exposure throughout the tree.

Treatment

Applied Copper spray to assist with the rising amounts of codling moth experienced. Tried to eradicate the earwigs (without killing the spiders and praying mantis - useful bugs)

Hand removed any curly leaf disease from the peach tree.

2023 to 2024 Season

From the model of this year, you can see that the overall crop count is well up, the weather was hot and dry, but the initial frost did not impact on the fruitlets as much as last year, allowing them to continue to grow.

The harsh pruning from the last season has also enabled the trees to push for vigour, and for more substantial foliage growth, ultimately impacting on the amount of nutrients that can be absorbed to enable larger fruit.

Pruning this year was kept to a minimum, learning from the failures from last year. The primary thing cut off were branches that would weigh down or be internal in the tree, as they offer little benefit.

Copper spray was applied before the fruit arrived.

Codling moth traps were put near the trees to try to capture any moths that may otherwise visit the tree.

The soil around the trees was shovelled around to disrupt any larvae or eggs that may have been laid. Positive predators, such as Praying mantis and spiders found elsewhere on the land were put onto the apple tree to help defend it. As a result, we had fewer aphids than any previous year.



Fig. 108



Fig. 109



Fig. 110



Fig. 111

Bio-security and Diseases:

The risk in measuring fruit using contact methods is that any disease or pest it may come in contact with can be spread to other locations. The protocols around this are often up to the discretion of the orchard manager.

5.7 Growth Comparative Results and Learnings across all seasons

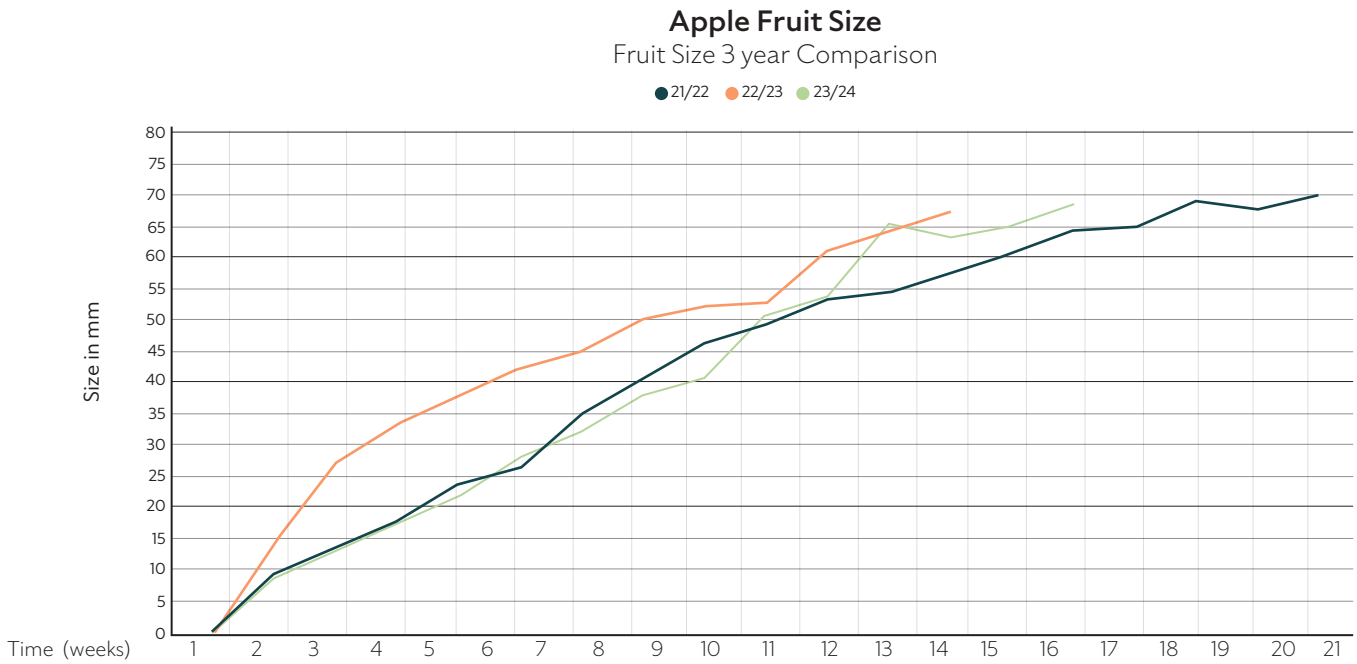


Figure 112: Chart showing Apple Fruit Size Comparison across three years, Diagram by Author, March 2024

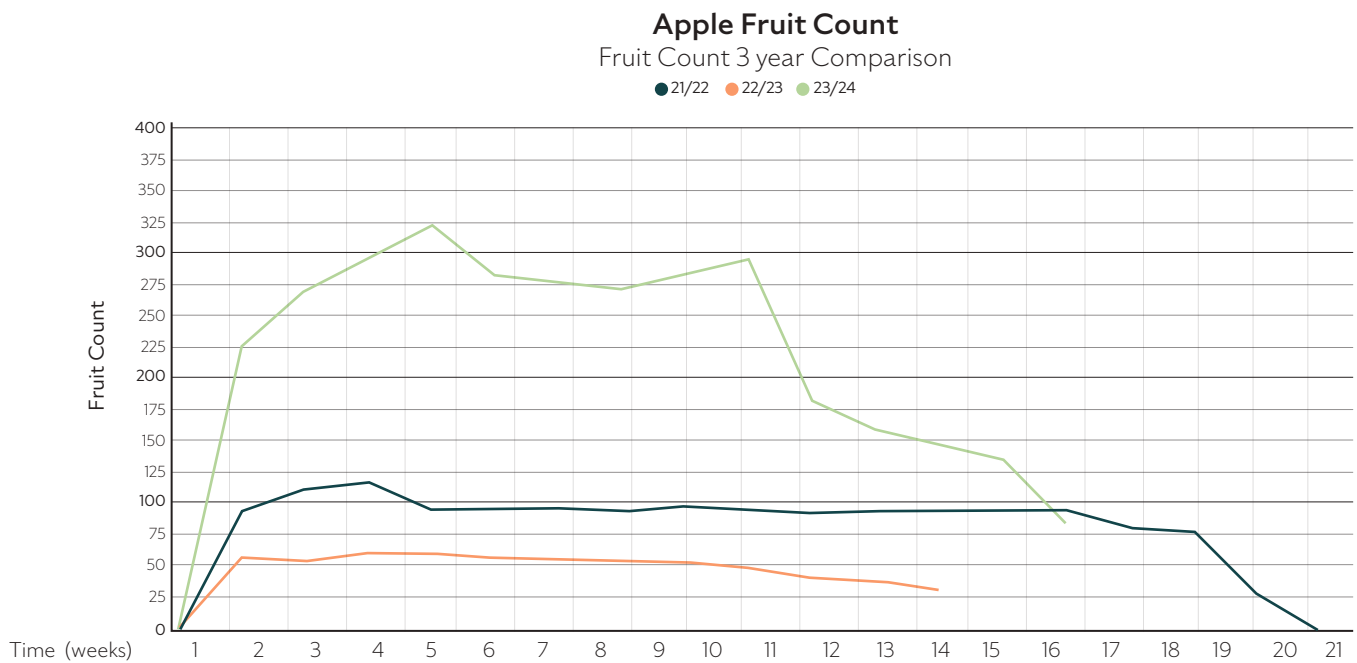


Figure 113: Chart showing Apple Fruit Count Comparison across three years, Diagram by Author, March 2024

The overall fruit count was highest in the 23-24 season, and lowest in the 22-23 season. The fruit size grew the most rapidly in the 22-23 season, however, the season was the shortest due to Cyclone Gabrielle, which was also reflected in the amount of fruit that was lost. The longest season was the 21-22 season, and overall yield was good that season considering no action had been taken such as

pruning or treating to support the success of the trees. The apple harvest from the 21-22 season is closely related to the 23-24 season. The excessive pruning in the 22-23 season would have impacted on the tree pushing to recover its cut-off branches rather than pushing for fruit quantity.

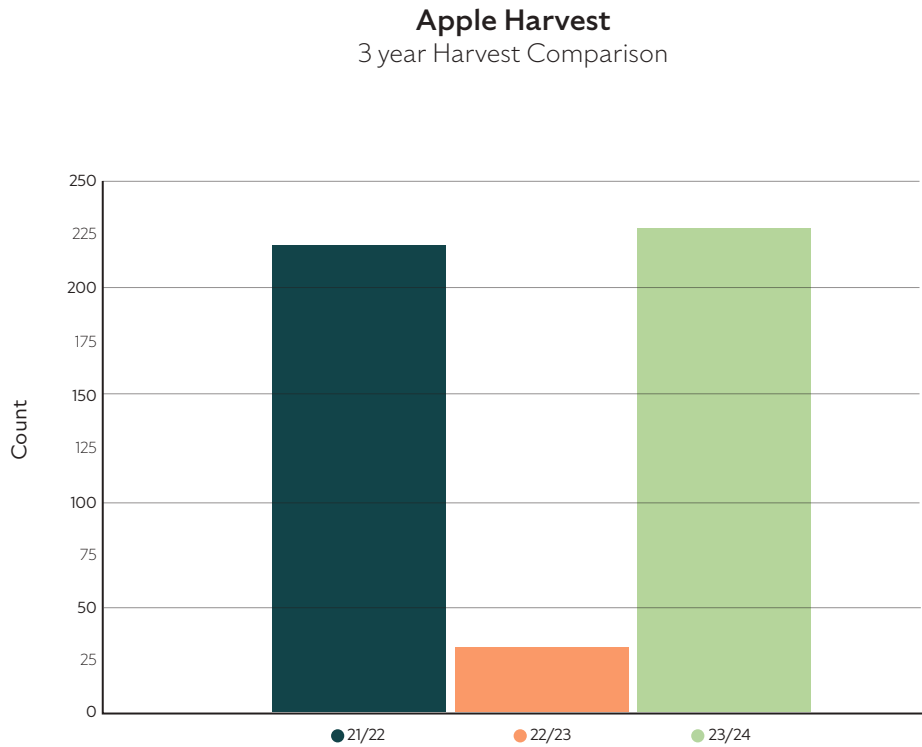


Figure 114: Chart showing Apple Yield Comparison across three years, Diagram by Author, March 2024

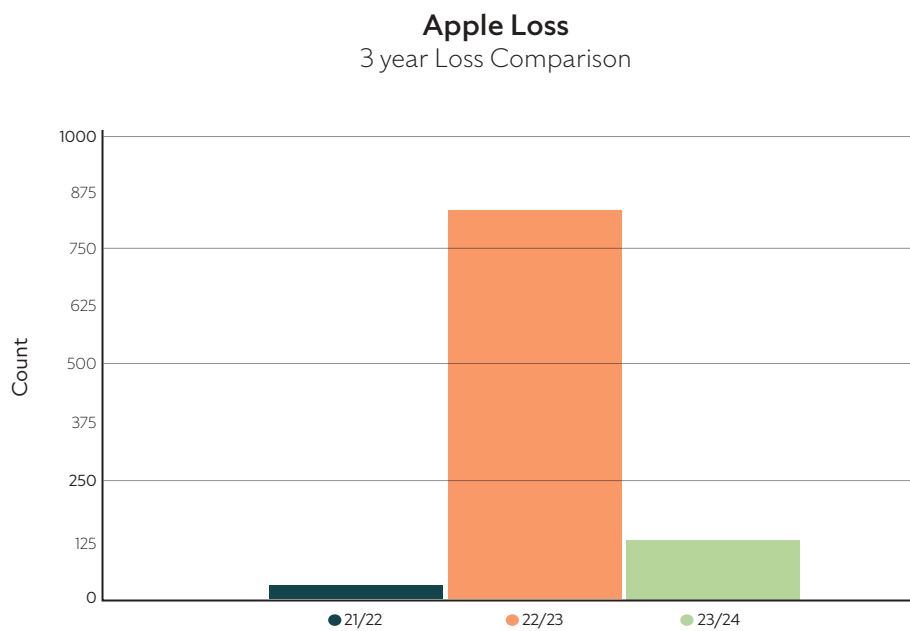


Figure 115: Chart showing Apple Fruit Loss Comparison across three years, Diagram by Author, March 2024

Fruit lost in the 22-23 season was mostly due to the extreme weather conditions in the lead up to, and subsequent to Cyclone Gabrielle, of which Morrinsville only caught the outskirts of the damage. In the 23-24 season, the majority of damage was caused by disease and pests, of which there was an abundance in the past year.

20 Fruit Test Results

Count	Size (mm) 2022-2023	Weight (g) 2022-2023	Size (mm) 2023-2024	Weight (g) 2023-2024
1	65.5	160	79	216
2	63.5	144	75	187
3	68.5	148	60	97
4	52	73	68	149
5	63.5	121	72	152
6	78.5	239	70	147
7	61.5	119	69	153
8	66	137	70	147
9	72	161	70	160
10	64	135	72	155
11	53.5	78	70	156
12	58	96	62	94
13	58	108	68	152
14	69.5	161	67	116
15	64.5	136	72	152
16	57	91	73	157
17	60	104	71	151
18	64.5	136	62	94
19	52	95	72	155
20	66	142	80	240
Avg.	62.9	129.2	70.1	151.5

Table 4: 20 Apple Fruit Maturity testing results for the 22/23 and 23/24 season, Table by Author, March 2024

Maturity Testing Results:

The following are the results from maturity testing that was undertaken over a series of 2 years which randomly select 20 apples and cut them open, applying an iodine solution and looking at the maturity markings to indicate the sugar content of the apple. This is another means of ensuring the quality of the produce, as size is by far not the only factor to consider for readiness for harvest. While not directly relevant to the project, immersing in this aspect of the quality assurance process was useful to understand as part of the user experience of manual measuring.

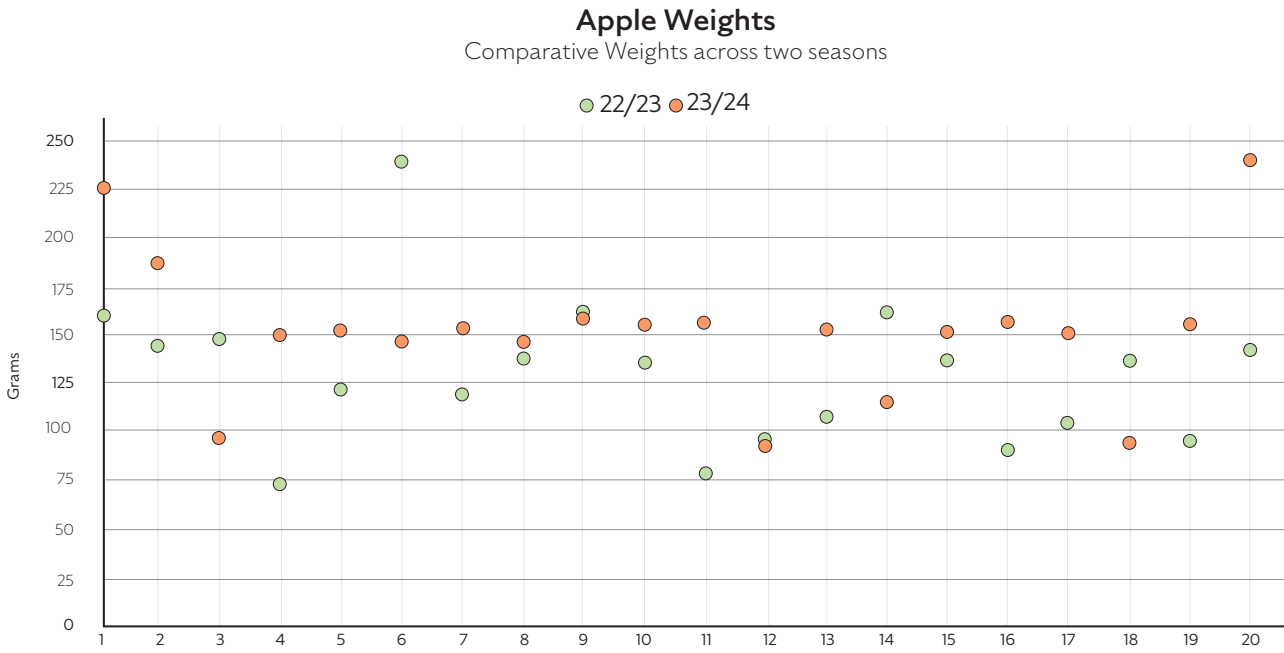


Figure 116: Comparative Weights from Maturity Testing across the two seasons, Diagram by Author, March 2024

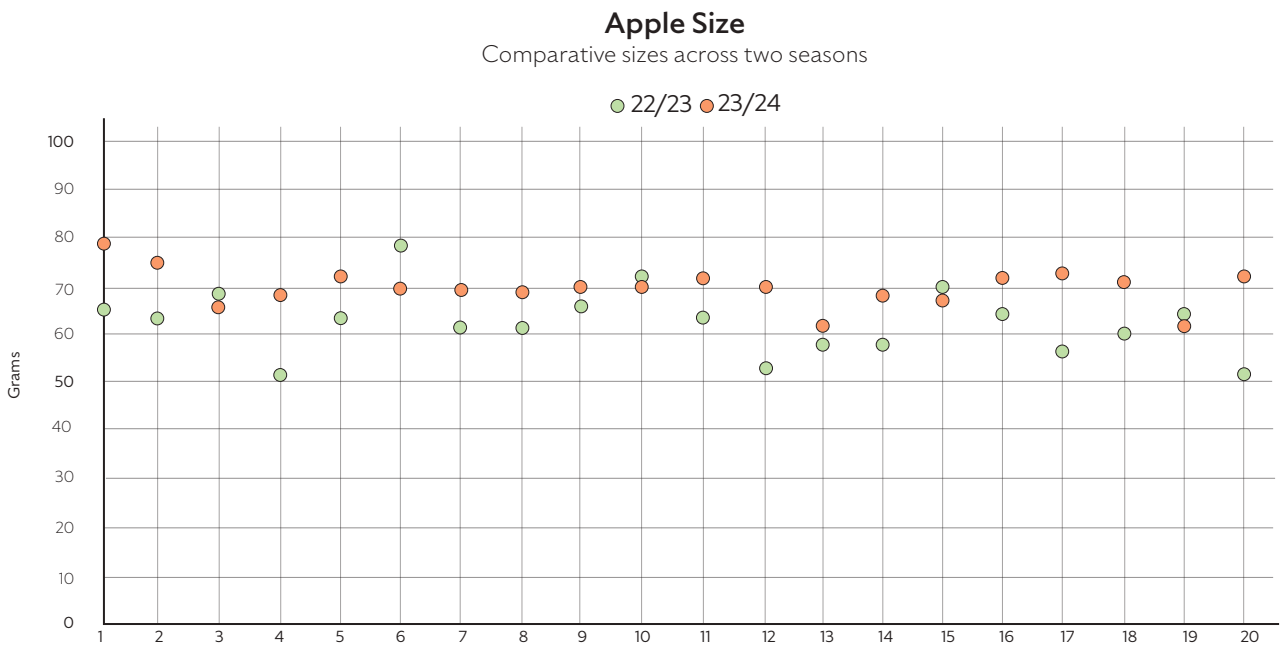


Figure 117: Comparative Fruit Size from Maturity testing across the two seasons, Diagram by Author, March 2024

The species of apples we grow is closest identified as Belle de BosKoop, a species typical used in desserts because of its sweetness. (Waimea Nurseries) with a height of 61mm and a width of 73.89 mm

This shows that the season of 2023-2024 was much more within the upper margin for acceptable width than the 2022-2023 season. The maturity studies did show that the apples from both seasons were at fairly similar levels of ripeness for picking.

Colour Assessment:

The colour assessment is a difficult metric as it relies on the individual subjective assessment to make the decision opposed to a numeric output to help guide in the decision making. The blush of the apple was also dependent on the amount of sunlight it had been exposed to, meaning that one part of the tree may have apples with higher percentage of colour than the shaded side of the tree.

Harvest Totals:

Tree	21/22	22/23	23/24
Tree A	221	32	229
Tree B	1	0	10
Tree C	139	13	0
Tree D	2279	25	144

Table 5: Harvest Totals across the three seasons, Table by Author, 2024

Fruit Loss Totals:

Tree	21/22	22/23	23/24
Tree A	31	832	130
Tree B	42	3	418
Tree C	28	52	0
Tree D	1026	50	148

Table 6: Harvest Fruit Loss Totals across the three seasons, Table by Author, 2024

Time spent:

It took on average 1 to 1 and a half hours each week for two people to capture these data points, throughout the growing season, on four trees. In an entire orchard, this is likely to take up a considerable amount of time for just one task to be undertaken. The accuracy of this data is also dependent on the clear communication between orchard manager and staff, and the understanding of how to best find the widest part of the fruit.

Tree B and C are not apple trees, and had only minor counts across the years, and so was not visualised as part of this data.

Environmental Fluctuations:

Each year provided different environmental fluctuations and variables that made planning ahead very difficult. This is in keeping with the sentiments shared by growers around preparation and the active adaptation they need to do as part of their work.

Growth Patterns:

This study identified the importance of sunlight on the growth and blush development of fruit. The ratio of sunshine and rain impacted on the growth rate, and processes such as thinning and pruning impacted on the overall vigour of the tree growing. Cold snaps would occur with little notice, and minimal methods of protecting the crop at small scale, however it developed empathy in myself as researcher for growers who face this every season.

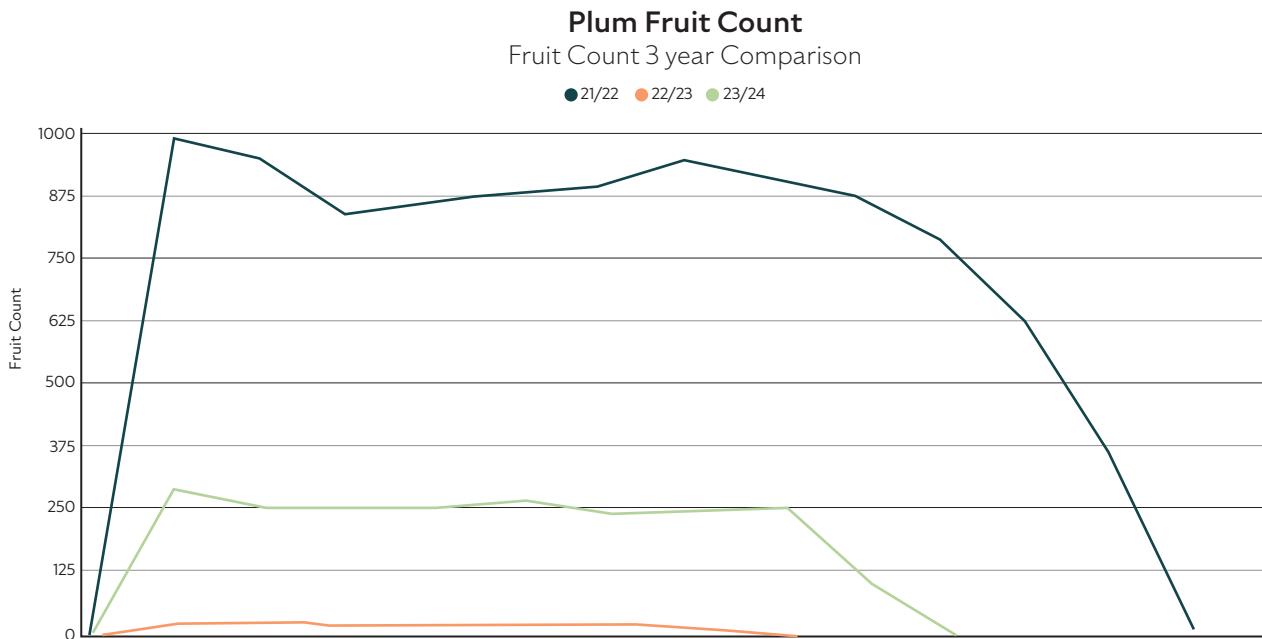


Figure 118: Chart showing three-year Fruit Count Comparison - Plum Tree, Diagram by Author, 2024

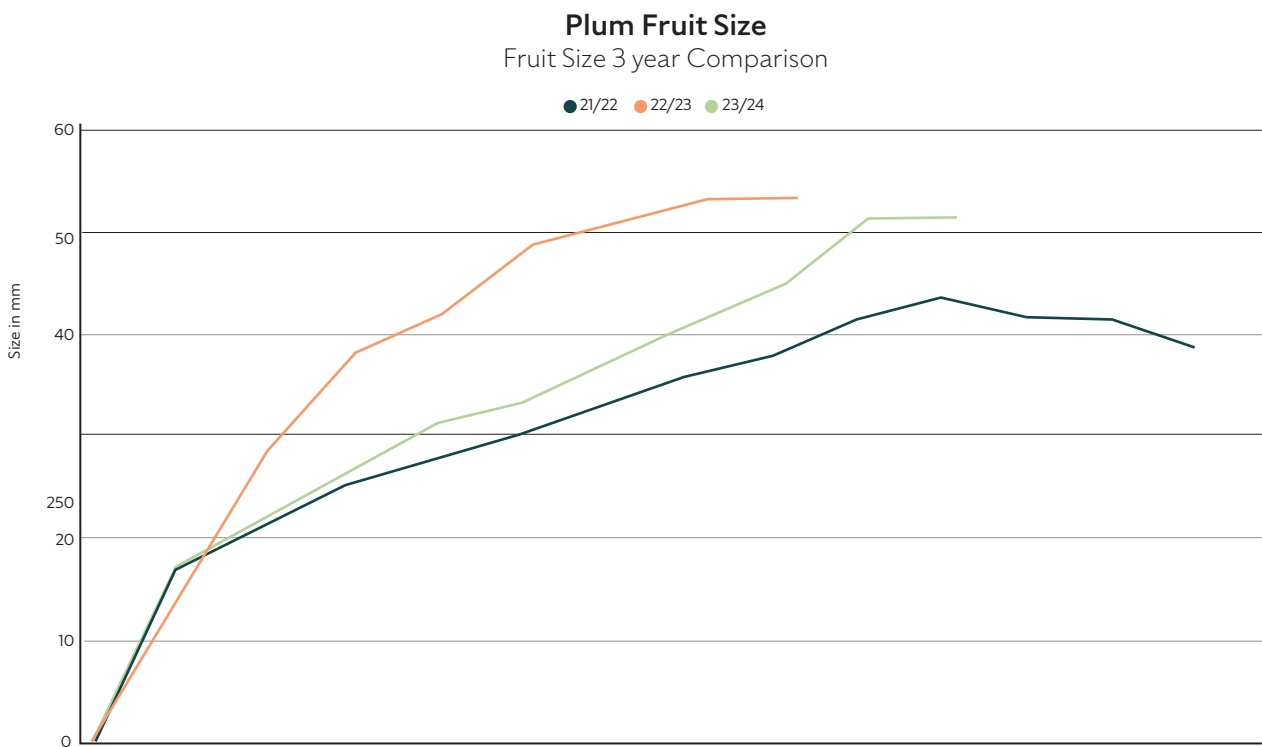


Figure 119: Chart showing three-year Fruit Size Comparison - Plum Tree, Diagram by Author, 2024

The Plum Tree (D) indicates that the 21-22 had the highest count, with 22-23 the lowest, most likely due to the severity of pruning. 21-22 was the longest season, with 22-23 being the shortest, while the fruit grew most rapidly that season. The harvest numbers were down tremendously from the first year of measuring.

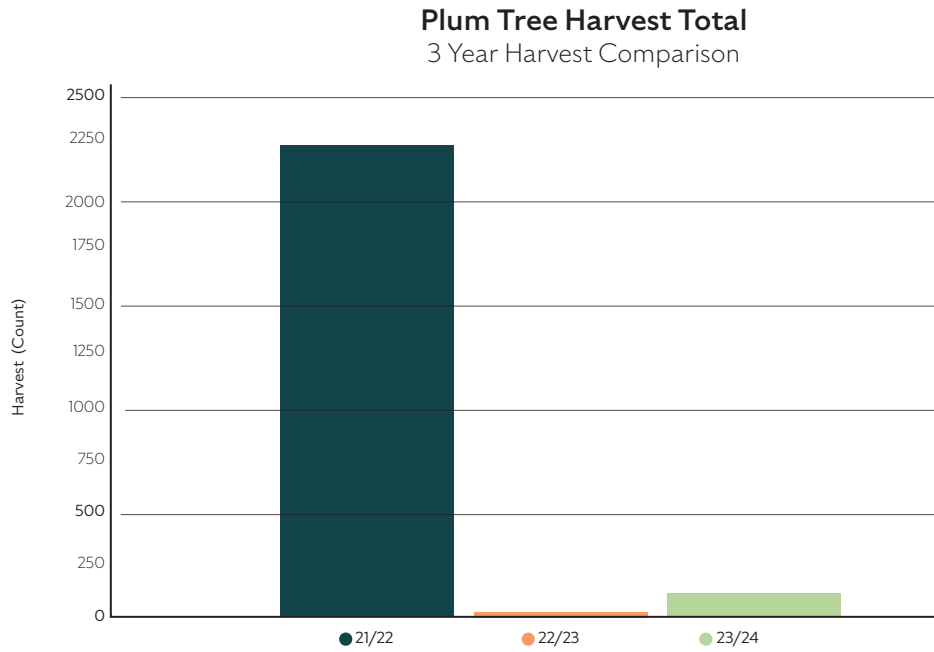


Figure 120: Chart showing Plum Yield Comparison across three years, Diagram by Author, March 2024

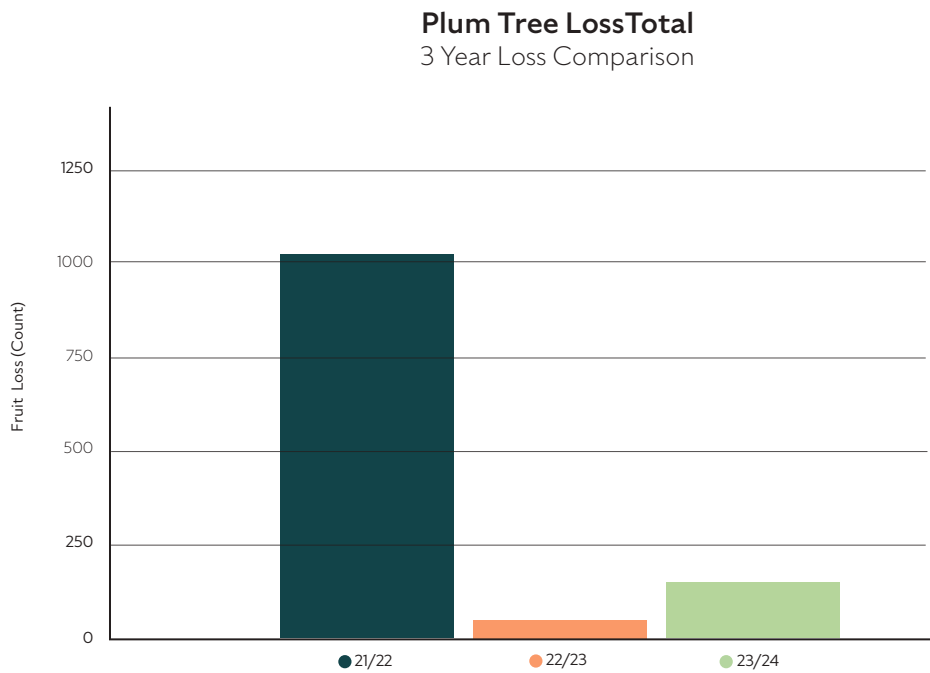


Figure 121: Chart showing Plum Fruit Loss Comparison across three years, Diagram by Author, March 2024

5.8 Also see Task Analysis for visual exploration of the usability issues outlined below;

Usability Feedback and Considerations

- Finding the widest part of the fruit
- Using callipers repetitively
- Dealing with sun glare
- Rain disrupting processes
- Repetitive nature of the overall task
- Recording of data process - clipboard and full hands
- Accidentally squishing fruit with calipers

Key Usability findings

- Callipers against the skin of the fruit is that it can spread disease from fruit to fruit or even to new trees.
- Digital callipers were of little use from the glare to the constant need to reset the figures while measuring. The larger the fruit, the more taxing the movement of the thumb to try and open wide enough to fit the size of the fruit. If you pushed too hard, it could leave marks on the fruit, and identifying the widest part was challenging.
- The clipboard, paper and pen were hard to manage in windy contexts or if doing the measuring by yourself.
- There was a dedicated bucket for any rotten or diseased fruit, stored far away from other plants and emptied into a designated compost or disposal bin.
- There was a large tub used during harvesting fruit that had handles to hold onto if up in the tree.



Figure 122: Image of Apples, Photograph by Author, March 2024

6.0

Design Process

From Insight to Foresight

Figure 123: Close-up detail of Prototypes, Photograph by Author, 2024

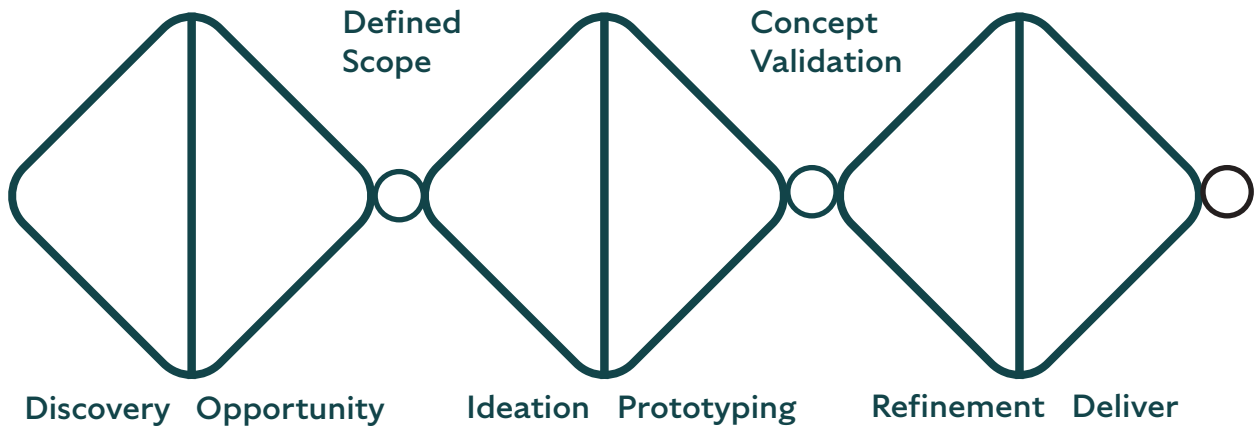


Figure 124: Triple Diamond Design Method, Drawn by Author, from reference Bootcamp

Introduction

This study hosted an extensive design process that sought to identify insights from current experiences, and to turn them into tangible features and benefits embedded in the product architecture, narrative and system.

The design process can be seen in the above triple diamond process, described in the methodology section of the thesis. It relied on mixed-method data collection techniques and needed to consider the seasonal nature of the horticultural industry.

6.1 Discovery Phase

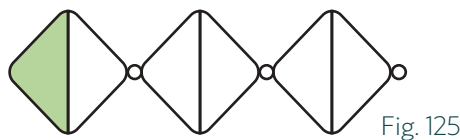


Fig. 125

The previous aspects of this thesis make up a large proportion of the discovery phase for this project. This phase included building connections with the industry and PlantTech team.

Starting at PlantTech, my first two months entailed attending many meetings with their shareholders and clients to introduce myself and learn about the state of the industry, the technology being used, and issues needing to be addressed.

One of the primary learnings was from the nature of the questions that were being asked and pick up key themes that I could go away and research.

One of the primary barriers I faced at the beginning of the study was the need to explain what design is, and what it can offer this field.

Most people were familiar with the concept of design, but when it became described as a physical object being designed it very quickly deviated to either an engineering-based conversation or system-based conversation. It was important to clarify this, to ensure that the expectations and understanding of everyone involved was aligned with the scope of the research.

Please see Appendix H: Concept Log

The primary way in which this was strengthened was the use of specific design terminology, and creating a shared terminology taught across different expertise in the team. It was rewarding to see the team begin to consider what the user experience of the technology they were developing might look like and how they might be able to communicate their intentions to me so that I could better translate it into design thinking or visuals.

Key issues and opportunities were identified through engagements with stakeholders alongside the team, and processed with supervisors to understand which topics were aligned with the scope and also the technologies that PlantTech were pursuing. The intentions at this stage was integrating aspects of the research being done within the team into a physically designed component. When it comes to the competitive, fast-paced Ag-tech industry, the need for a team with a diverse set of skills is critical.

I was able to access experts working at the leading edge of my topic area and learn rapidly what the constraints and potentials are as well as see areas in which innovation was occurring to identify where design could be most impactful.

We would have regular meetings where researchers would present their latest findings to the PlantTech team and we could discuss and inter-connect it with projects. This was a great way to rapidly learn about the state of innovation within Research Institutes in New Zealand, and how design might be able to act as a vehicle to better communicate these concepts between stakeholders.

6.2 Opportunity Phase

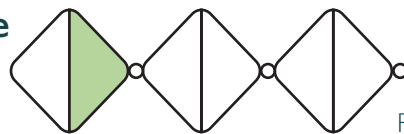


Fig. 126

Following on from the Discovery phase and equipped with understanding as to the context the design is needing to respond to, the next phase sought to generate initial approaches which could be assessed as means of improving fruit measurement experiences.

I spent a week focusing on the generation and thinking of different ways in which we could measure fruit. This was done in daily sessions as well as keeping note paper nearby to write and sketch on to add to the pile throughout the day while doing research.

By the end of the week, I had generated 287 note papers. I knew I needed to find a way to organise them, so I split them based on the different growing methods by drawing pictures of a standard spindle tree, a V trellis and a F.O.P.S. tree system and utilised this to organise the concepts with where they would operate in relation to the tree. This helped to refine the concept areas greatly.



Figure 127: 287 ways to measure fruit sorting cards, Photograph by Author, 2022



Figure 128: Card Sorting Activity for concepts, Photograph by Author, 2022

The concept areas were then organised into overarching categories and any duplicates of the same idea was removed. Twenty-five concept areas were identified, but with further generalisation of the concept areas meant that the concepts could be roughly placed in one of the following categories;

on tree, user interface design, in bin, or on body measurement concepts
 These categories were still very wide to allow for creative exploration within them. Concepts were then placed in relationship to criteria and growing styles, using a Differential scale.

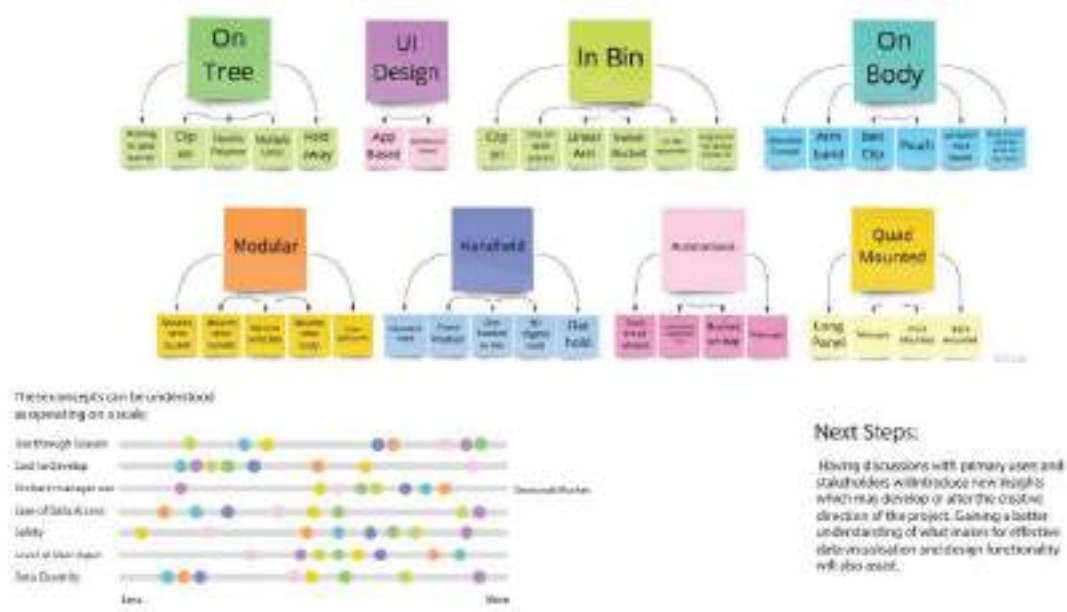
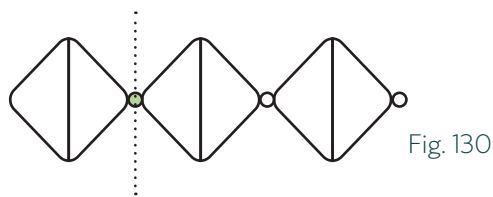


Figure 129: Concept areas defined, Diagram by Author, 2022

6.3 Chosen Concept



6.3.1 PlantTech Team Feedback

In a presentation to PlantTech on the 28th of July 2022, models, sketches and CAD explorations were presented to the full research staff for critical, technical feedback and guidance. The assessment criteria for making decisions had a few common themes such as accuracy, usability and time efficiency.

Key insights included;

- Not much mechanical movement - needs to be durable in that environment
- Static Ground monitor as a sort of standard
- Tree Limb is interesting but need to know if it is solving the problem people have in the orchard.
- Over/In Bin - An area that they see as having a lot of opportunities
- Liked bucket angled tipper
- Could we split bin in sizes?
- Liked QR Tree attachment idea - finding out where you are in the orchard
- Attachment to the weighing scale as useful - could be a fixture to the mobile caddy
- Wearables - Go Pro style, but not glasses
- Colour bands - Of big interest to everyone.
- Interest in picking platforms - Could help split fruit in Orchard already
- Hail netting attachment - could be expensive, but is the direction things are going in
- Mobile Quality Control Caddy
- Fly camera like in soccer
- Educational tool as interesting.

Please see Appendix I: Initial Concept Panels

The combination of sketch and CAD approaches meant that stakeholders who may not have engaged with design concept delivery before could be supported in the process.

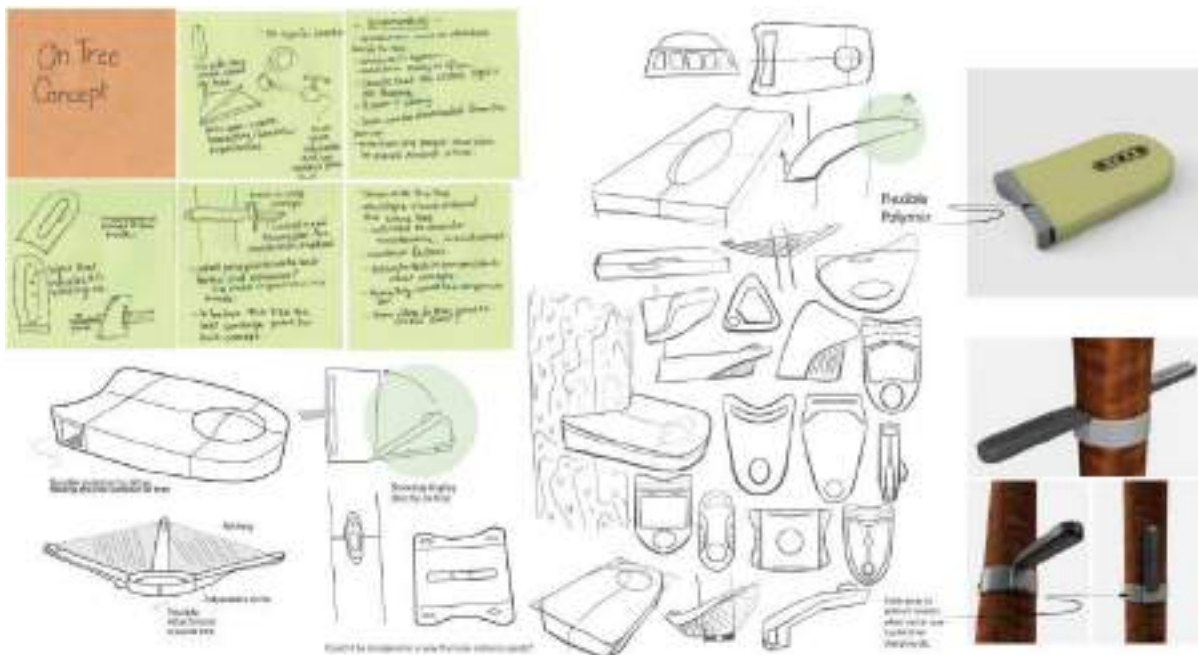


Figure 131: On Tree Initial Sketch ideas, Drawn by Author, 2022



Figure 132: Over bin Initial Sketch Ideas, Drawn by Author, 2022

6.3.2 Stakeholder Interview Feedback

As well as stakeholders in both the kiwifruit and apple industry in which great feedback was received. Stakeholders could see different concepts aligning more or less with their current operations and goals. These preferences were given a weighting with one being optimal and five being a potential, and stakeholders assigned this to the concepts.

6.3.3 Summary of concept preferences based on stakeholder feedback

PlantTech researchers were generally interested in the design process and enjoyed the wide range of ideas presented. Some immediately wanted to understand the technology that would make an idea work, but together we managed to assess the ideas for their feasibility, alignment with PlantTech research capabilities, and horticultural priorities.

6.3.4 Design Concept Area Decision and Justification

One of the big barriers encountered was that the chosen concepts all addressed different points of intervention that could be taken, and so trying to justify which one was the right one to take was complex.

I will now discuss the concepts in their ranked orders as per the weighting from stakeholder interviews and assessment;



Fig. 133

1. Colour bands

Creating colour bands to measure apple maturity based on blush offers practical testing of maturity that can be easy to carry along. The bands would have to show both foreground and background colour. The bands could also be designed as a promotional piece for PlantTech and can be made in batches for different species of apples. The project is a low-resolution concept in comparison to a colour sensor but could offer solutions more rapidly while they wait for long term applications to be made.



Fig. 134

2. Wearables

Wearables was cut out from the equation due to a range of usability issues that were raised including health and safety, and the fact that the lack of labour means that a concept which is reliant on a person being present may not be the best solution to the problem going forward.



Fig. 135

3. Testing Booth

This is looking at how we might optimise the fruit maturity testing process by creating a device which is able to capture a range of data about an apple including weight, size, and colour. The main critique of this concept was that it is only testing one fruit at a time, and that more value could come from measuring either all 20 fruit from a test at once, or going for the on/in bin concept area.

Fig. 136



4. On the tree

This concept is able to measure a large dataset about the fruit and tree health, but would need to be made affordable to be able to mass populate the orchard with devices to detect data throughout. The initial idea was validated with a phone mounted to the tree.

Fig. 137



5. On the Bin

This concept was already underway with competitors trialling it. This concept needed to be modular to meet the interests of stakeholders, who wanted to attach it to their picking platform. The concept deals with fruit that have already been picked.

Concept Assessment

Participant	On Bin	On Tree	Wearables	Colour band	Testing booth
1	4	3	2	5	1
2	1	3	2	4	5
3	2	1	4	3	5
4	2	1	3	4	5
5	3	2	4	1	5
6	3	1	4	2	5
7	1	2	5	4	3
8	1	3	5	4	2
	14	16	29	27	31

Table 7: Concept Area Weighting Results, Table by Author, 2024

Concepts were measured with 1 being highest and 5 the lowest, meaning the lowest result is the most preferred concept.

Based on the results of this weighting of the concepts, the following are the top three concepts; On-Tree, On-Bin, and colour bands. While the on-bin was the most preferred, most stakeholders wanted data earlier than the point of harvest, so creating a product solution which captured data throughout the season was most appropriate for this project, with the Over-Bin concept explored as an accessory.



Figure 138: Proposed Concept Intervention Diagram, Drawn by Author, 2024

6.3.5 Design Approach Justification

Currently, many growers distrust packhouses who collect the produce, sort and organise it to cool-stores, giving a report once the fruit have been sold and distributed back to the grower, which they are often being paid according to. The ability to empower the grower to collect data prior to the produce being sent to the packhouse will hold benefit in informing them about the state of their yield.

They may realise that the pack-house is not overcharging them, or they can query when figures are drastically different. The pack-out report also takes a long time to be sent back to the grower, so immediately having data about the state of the orchard means that the correct actions can be taken by the grower straight after the harvest season.

Implementing factors of trust into the design of the product, reduced the potential for distrust to occur in the first place.

6.4 Ideation Phase

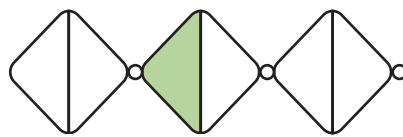


Fig. 139

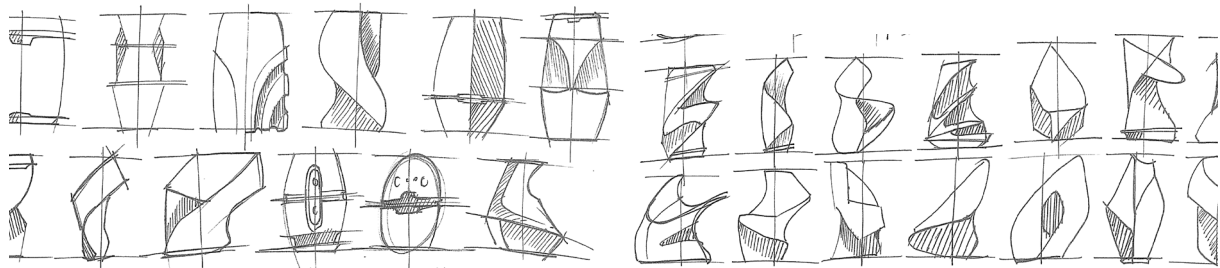


Fig. 140



Figure 141: Foam modelling exploration of handheld/ hybrid ideas, Photograph by Author, 2022

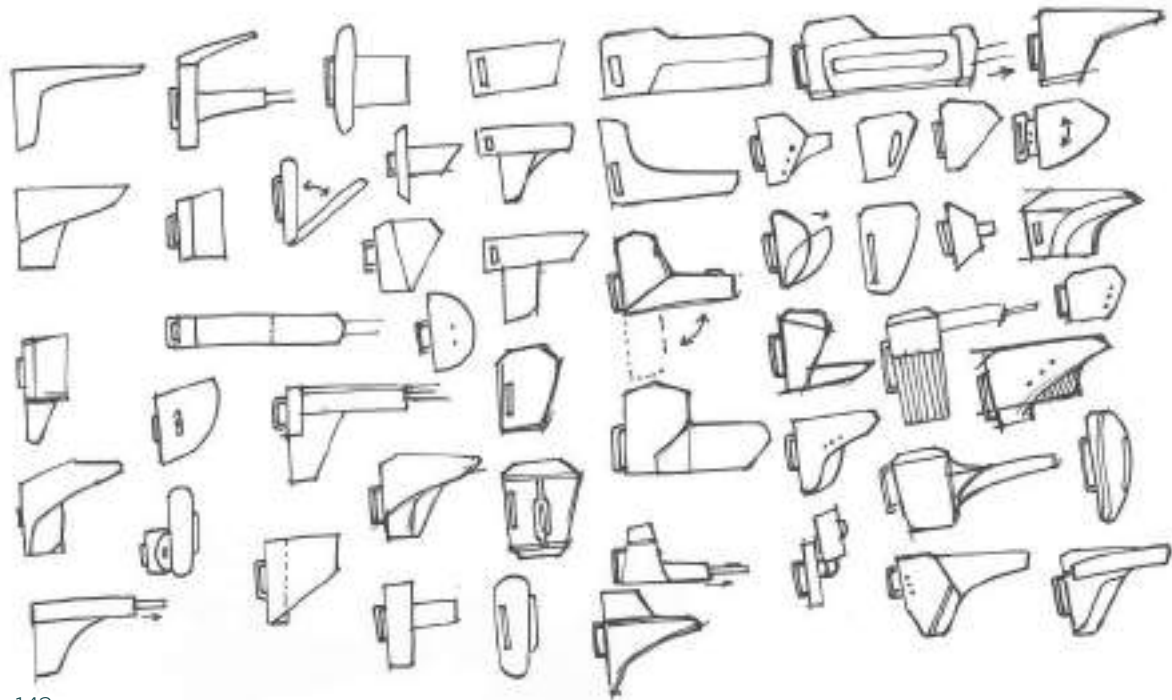


Fig. 142



Fig. 143



Fig. 144



Fig. 145

The growing styles of the trees impacted on the best vantage points to capture data from. The design needed to respond to being vertical and horizontal, a mounting system or a form needed to be established which could properly support the camera and its componentry in a secure manner.

The exploration led to experimenting with modular attachment methods and a rail system which enabled multiple attachment applications.



Fig. 146

The Image above shows the 3D printed prototype six months after it's deployment, having survived two cyclones and a very hot summer season.

Some initial prototypes used a Go Pro to test some of the feasibility and duration of camera operations and how the camera placement impacts on the quality of data being collected.

This unit also considered what battery housing size that would be required, and used a telescopic arm to change the distance of the camera away from the trunk, informed by earlier testing. Consistent data was captured using this prototype.

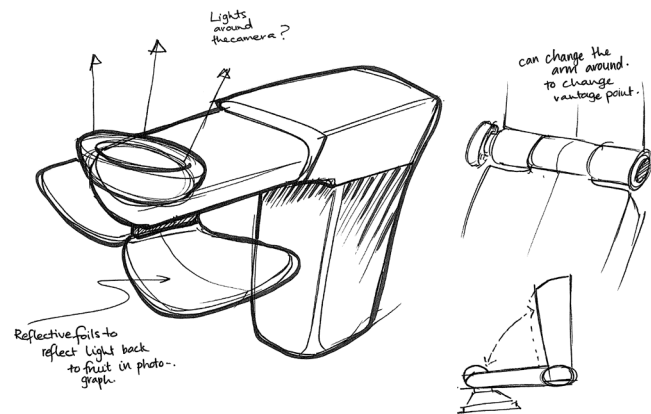


Fig. 147



Fig. 148



Fig. 149



Fig. 150

Fig 148

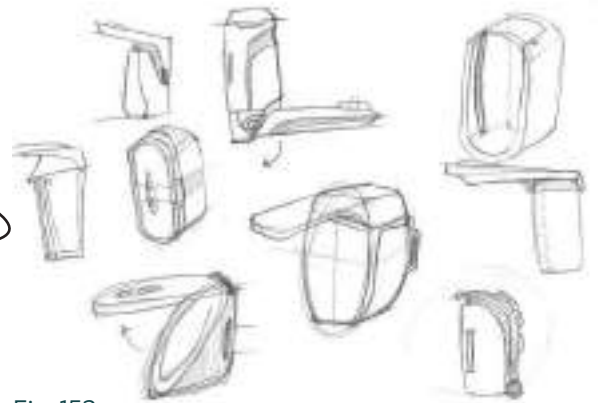
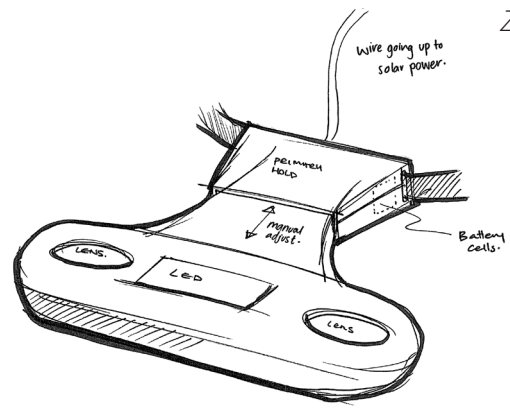


Fig. 152



Fig. 151

Two concerns arose from this prototype, the first was that using a rail system could result in matter falling into the rail grooves, impacting on the product performance, and the second was the consideration of any wires would mean that the ability to remove the rail and camera, and shift its positioning would expose cables to the elements. Therefore, a shape which was able to host all the components yet meet these multiple view perspectives was required.

Once it was established that a Zed2i camera would be used as part of this study, the challenge became how to enable the modularity for multiple viewing approaches, while maintaining stability, weight distribution, and visual proportion.



Fig. 153



Fig. 154



Fig. 155

This prototype was used as the proof of concept model for the Design Critique, discussed next.

The unit combined all the principles and learnings up to this point to enable stakeholder appraisal.

Usability of the form was also explored, as the almost square shape housed a lot of weight from components and was not well supported when horizontal against the tree.

Over Bin Development as an Accessory

This aspect of the project was left at this early conceptual stage as the amount of development made it a project offering in and of itself.

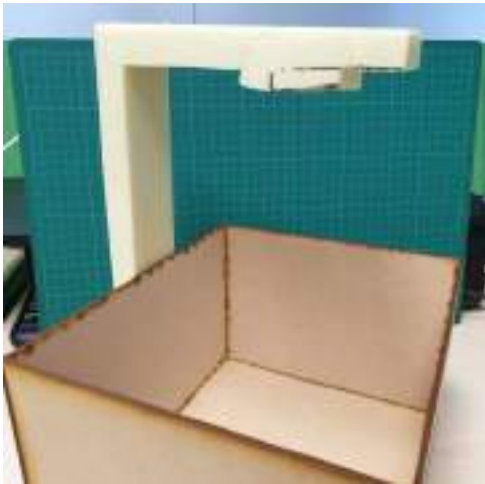


Fig. 156



Fig. 157

Through small-scale prototyping it was established that an arm would need to have minimal mechanical movement and be placed as centrally as possible over the bin.



Fig. 158



Fig. 159



Fig. 160

A unit which attaches onto the edge of the bin was also explored. The biggest risk was to the damage potentially caused in the process of taking the arm off once the bin is full. The apple skin is very sensitive, and any bruising at this stage would cause major damage.

A folding solution allows the part to be compact when not in use.



Fig. 161



Fig. 162

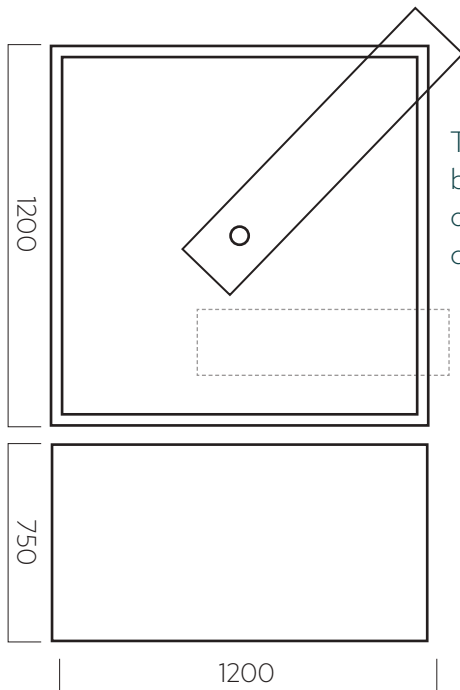


Fig. 163

Solar powered, allowing the camera unit to clip to the arm.

Folds away compactly.

Folded sheet metal for cost efficiencies. Wheeled for easy portability.



The arm would need to be located on a corner of the bin to enable centering the arm.

Fig. 164

Needs to consider head heights of workers.

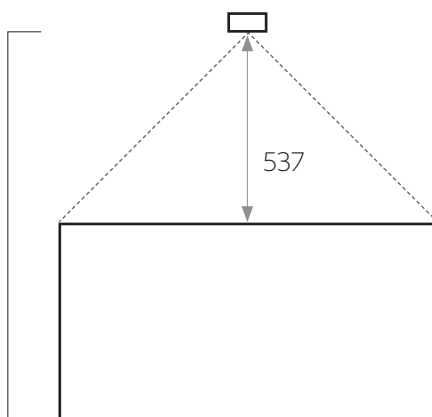


Fig. 165

Dimensions in mm

Fruit bins would have a edge markers (indicated as red pucks) that when disrupted waits a few seconds for the pickers to empty their buckets and then takes a photo. of the bin. The benefit is capturing more imagery throughout harvest, and circumnavigating the current practice where the tops of the bins are often 'tidied', which can be misleading.



Fig. 166

**Please see Appendix A:
Technology Review**

Zed 2i Camera:



Figure 167: Zed2i Camera, Photograph by Author, November 2022

A technology review was undertaken to identify cameras appropriate for the nature of the data capture that would enable imagery that captured depth, colour and had an open API to enable it to connect to software needed to automate the process of fruit size detection. The Zed2i is a versatile, IP66-rated (waterproof), stereo camera, which means that it can be plugged in, calibrated and set to operate in the orchard environment. The compact camera unit has a USB-C interface, and requires connection to NVIDIA for GPU or a 4GB RAM CPU processing system.

It can capture data up to ten metres away, and is appropriate for both static and dynamic image capture. It has an attractive price point in comparison to its competitors or any services which are reliant on a LiDAR unit, meaning that it is more appropriate for a use case where multiple devices would exist within the orchard, keeping individual units at an attractive price-point enables scaling as the device proves its utility to decision makers.

6.5 Prototyping Phase

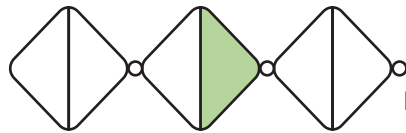


Fig. 168

6.5.1 Band Development



Fig. 169

The strap which attaches to the tree is a critical component for the design's functionality. Different existing methods were trialled to understand the nature of the attachment and its widths.



Fig. 170

Users indicated that they wanted to be able to replace the straps with ones they can source locally. Experimentation looked at protruding shapes which the band could pass through in different orientations.



Fig. 171

The ability to measure water strain was a potential benefit to be implemented into the strap, developed in concept to the right. Manual methods of measurement would not be accurate enough.



Fig. 172

Creating a binary code across a strip which could enable a sensor to read the code was considered as a more accurate means of measuring. This concept was ultimately ruled out of the scope of the project due to the complexity it added.



Figure 173: Foam Modelling concepts, Photograph by Author, 2023

6.5.2 Foam Modelling

Analogue means of prototyping and development were critical in the overall iterative process in which design principles of balance, line, proportion could be explored physically.

The relationship of the form around the uneven cylindrical tree trunk presented a number of challenges for the stability and balance of the device.

Modelling small scale forms enabled the exploration of proportion, curvature around tree and the modularity of the same shape to meet multiple vantage points.



Figure 174: Foam Modelling to trunk circumference, Photograph by Author, 2023

6.6 Design Critique

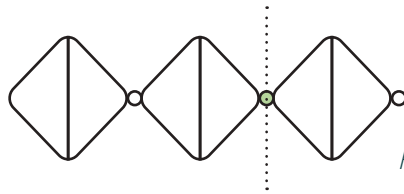


Fig. 175

The purpose of the Design Critique was to seek out external comments on the progression of the project in its aesthetic, function and narrative based considerations.

How people were selected:

A representation of voices was based on a number of factors, there is a primary focus on the merit of the designer in their career-based experience with designing products, and then also their relevant expertise and specialisation area. For example, a number of designers specialise in making products that focus on experience while there are some that focus on designing for manufacture. Their perspectives were different and both sets of feedback appreciated.

Everyone who wanted to attend or discuss the research was welcomed with food and reciprocal and open sharing.

The participant pool size was based on connections with relevant specialisations that were locally present and part of the network of the researcher and supervisors. The data took on a qualitative focus.

How information was recorded:

The conversations were recorded using voice recording and manual note taking as a means of capturing the information so that the discussion could be had without pauses. Permission was sought from everyone present before recording and the recordings were destroyed after the notes had been typed up.

In person Presentation - Groups

The relevant concepts that led to the current design, video showing the Zed 2i camera capability along with the packaged current design, was presented. The relevant research printed in booklets and across 5x A1 posters conveyed the design investigation progression and decision process. A feedback form encouraged aesthetic, usability and product narrative review.

This group presentation was useful as it allowed people to take the time to reflect on the design and build on the feedback from others to add their own and disagree or agree.

In Person presentations - one on one

Many of the one on one based critiques were hosted in the location of the designer, so a mobile version of the Critique was developed. This included the prototypes. This proved a useful activity, allowing individuals perspectives to be aired. The prototypes could be reviewed at the time and questions asked. This was a very useful activity and also meant that the individual's perspective alone could be given attention.

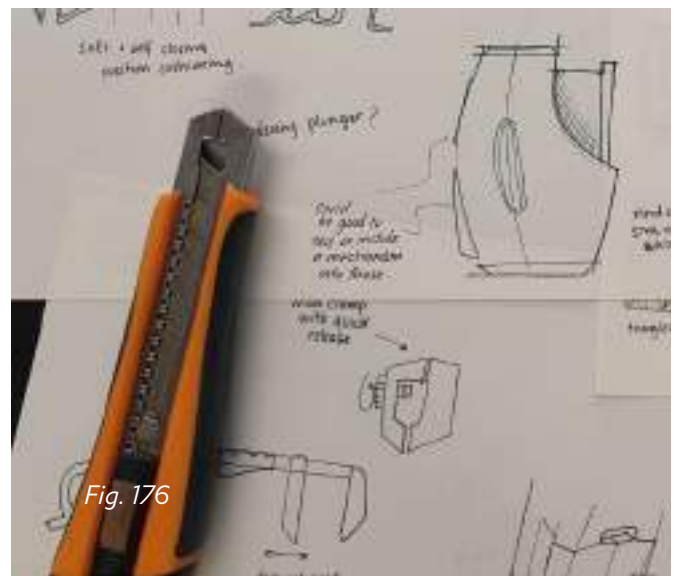


Fig. 176

Online Design Critiques

This needed some additional preparations. I recorded a video of me talking about the design, created a Miro board which hosted all of the information present at the Design Critique.

The thinking behind this would be that people can review the design work in their own time and give feedback. I then also reached out to them and offered them the opportunity to video chat to discuss the design project.

How this data was disseminated:

The observations from the different sessions were combined in a Miro board as stickies which allowed for them to be split based on the area of the feedback form that they would fall under; functional, aesthetic, narrative and system or gaps in the research. This was useful as it allowed me to overlay common repeated recommendations to understand where the most pressing factors lay. The recordings were listened to, notes captured and then the recordings removed as was stated at the time of recording.

The findings from each conversation was a rich set of insights and ways of thinking about the project inspired by every individual's way of making sense of a product which operated in a sector they have not necessarily worked in before.



Fig. 177

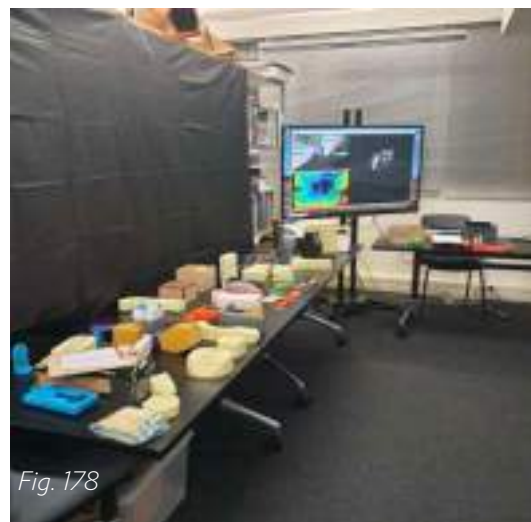


Fig. 178



Fig. 179





Figure 169

Please see Appendix L: Visual Analysis

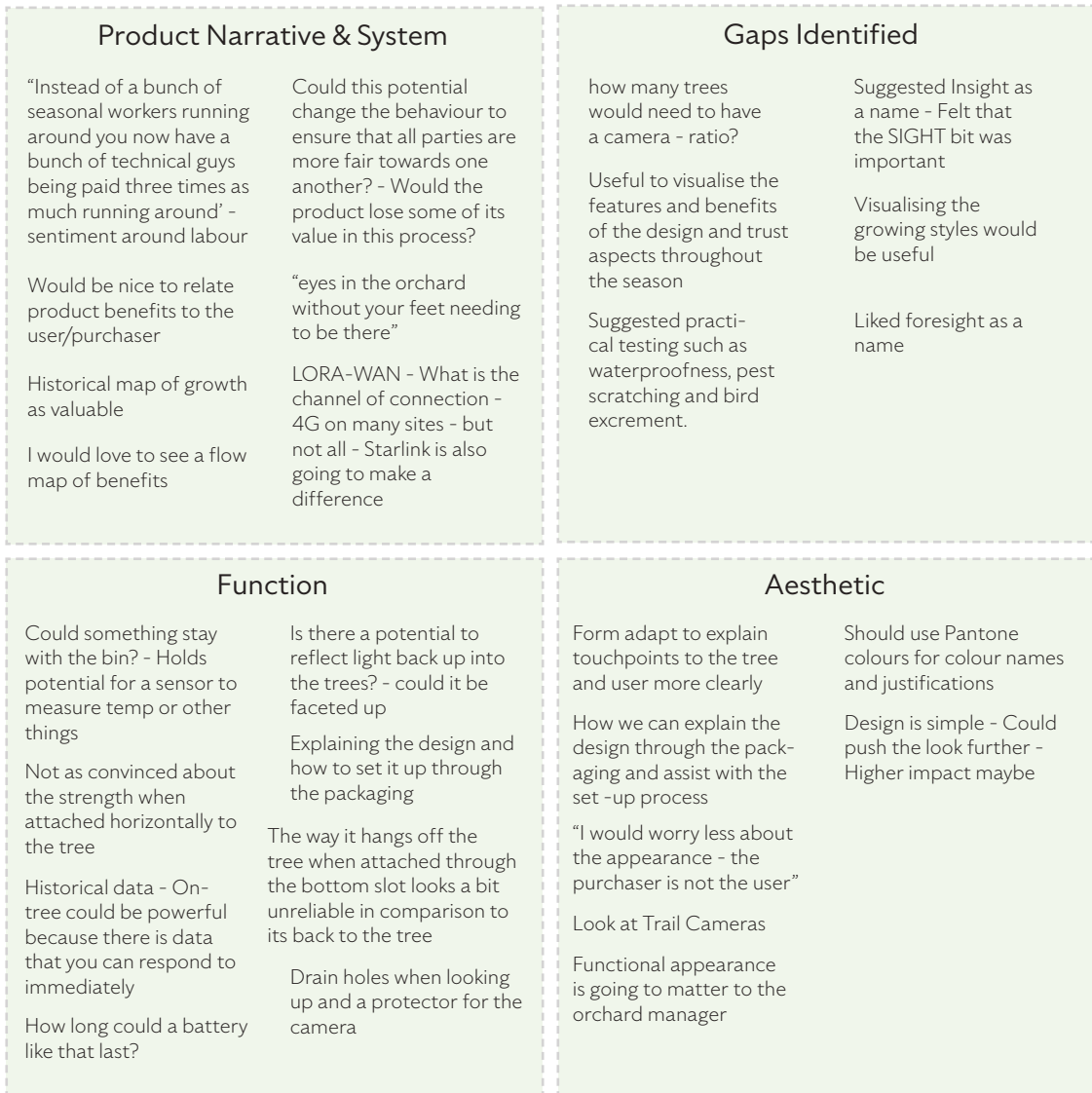


Figure 180: Diagram of Design Critique feedback, Drawn by Author, 2023

Through the repetition of the design content, the thinking was able to be more efficiently summarised. The extensive feedback from this process was valuable to the development of the product offering.

Please see Appendix J: Design Critique

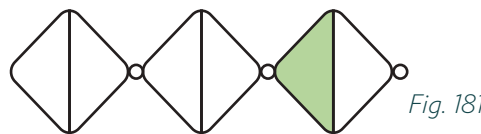
Concept Assessment

Participant	P1	P2	P3	P4	P5	
Feasibility	5	5	3	4	5	21 / 25
Practical	5	5	4	4	5	23 / 25
Perceived Reliability	3	4	3	4	3	17 / 25
Integration to operation	3	5	4	3	4	19 / 25
Alignment w. Industry	4	4	4	4	5	21 / 25
Feedback to users	1	4	4	3	3	15 / 25
Portability	1	4	4	4	4	17 / 25
Learning Curve for use	3	4	3	4	3	17 / 25
Perceived Accuracy	3	5	3	3	3	17 / 25
Ease of Use	4	5	4	4	4	21 / 25

5 best - 1 lowest

Table 8: Concept Design Critique Results, Table by Author, 2023

6.7 Refinement Phase



6.7.1 The need for form development

The design critique did an effective job of validating the system and principles of the design, with valuable insights into gaps that existed at that stage in the project. How the camera lenses were perceived was a re-occurring topic across stakeholder groups, requiring a review of the anthropomorphic qualities of the design.

As well as this, it was ensuring that the product form was communicating factors of reliability through its robustness, transparency through its indicator lighting, tactile feedback through its buttons and materiality, all while maintaining the camera a particular distance away from the tree trunk to enable best view of the growing fruit. This form-giving phase seeks to elevate the design concept to make the design visually distinctive, while integrating components in a streamlined manner.

Please see Appendix K:
Final Design Criteria

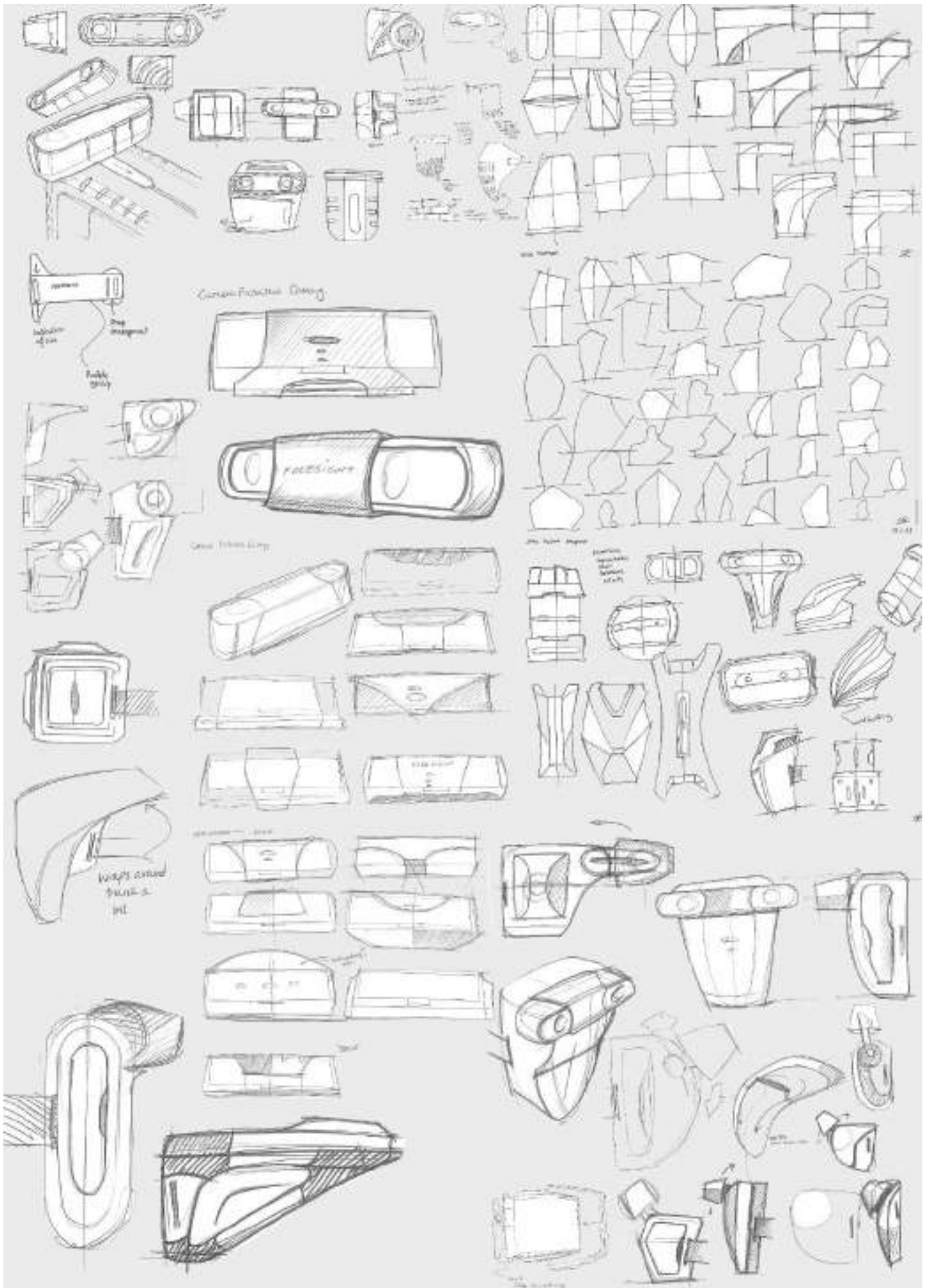


Figure 183: Developmental Sketches of Features and Details, Drawn by Author, April 2023



Figure 184: Laser-cut trials of Proportions based on CAD Drawings, Photograph by Author, 2023

6.7.2 How was the final visual direction selected

The form was not so much selected, as necessity dictated the development of the concept in the particular direction. There are multiple parts of the integrated product architecture that would not effectively work elsewhere, and these components became fixed parameters to design around, such as the band slots, the curving to better fit around a tree, and the design needing to work both horizontally and vertically.

It was observed that by turning the camera lengthways down the body it improved the sense of anthropomorphic “being watched” for stakeholders, and this significantly impacted the subsequent proportions of the design. The Zed2i camera has a cable mount that dictated a lot of the depth of the design, and then the battery capacity was calculated to last for a sustainable amount of time across different contexts.



Fig. 185

As part of the aesthetic development of the project, different approaches were taken to enable variation in how to consider the form. These descriptors considered factors that were desirable for users, and words commonly used when discussing the themes of the project.

Robust: The need to communicate the durability of the design through form expression.

Emotive: The ability to express personality, or not, and mediate this feeling and exchange between the design and viewer.

Sc-Fi Technology: Due to the design being technology-embedded, finding a visual narrative that conveys the ability of the product is useful. Many products are inspired by the creative works of film and literature in the science fiction category.

Organic: Drawing inspiration from nature, from flowing lines and textures, is a common foundation for the product form inspiration.

Minimalist: The reduction in visual clutter when looking at the form, truth to line and pure design principles is a hallmark of the notion that good design is invisible.

These categories are at odds with one another, offering varied approaches to how one might consider the form and how it may manifest itself in the context of this product. This line of enquiry sought to explore visual concepts within each of these categories, with the hopes of finding a balance between the different approaches that imbued these desirable traits into one cohesive form-language.

6.7.3 Anthropomorphism

One of the key design considerations relates back to the concept of anthropomorphism, where using a camera with two lenses gives the impressions of ‘eyes’. This presented a significant challenge to design around in relation to trying to ensure trustworthiness and adoption when the tone of the product could so easily become emotive. The product needing to be able to attach in two orientations also meant that the camera needed to be a particular distance away from the tree trunk, having a drastic impact on the proportions of the device.

One of the key developmental moments was when the camera was turned vertically, this disrupted the sense of ‘eyes’ and orchard manager stakeholders agreed that those operating in the orchard would be more likely to be at ease with this orientation.



Fig. 186

Please see Appendix M:
Form Development

6.7.4 Branding Review

A significant part of the visual feasibility of this project is in creating a cohesive narrative to users between the scenario being designed for and the features and benefits of the designed outcome. Creating a brand enabled the tone of the device and its supporting accessories to have a shared language in its communication.

The branding went through three iterations, the first was done alongside PlantTech to understand what a product as part of their entity would need to be marketed as.

The second was established post-PlantTech, and aimed at gaining initial validation from stakeholders as to the associations they had around the name, colourway and logo. From this, there were too many visual comparisons drawn to either existing brands or concerns around which aspects of the product it was emphasising, such as the idea of being watched. A more ambiguous form was needed.

The third and final iteration played with Logotype to accentuate the first letter of the brand name, Foresight, and used a leaf shape to create one of the stems. This simple but dynamic form is scalable, engaging in animations, and can be used by itself or alongside the name.

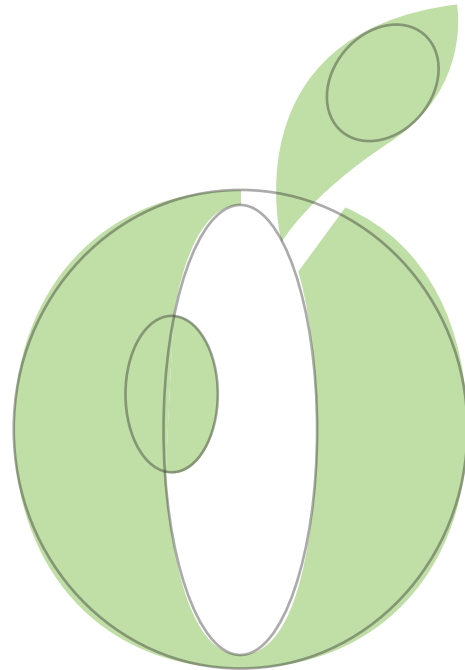


Fig. 187

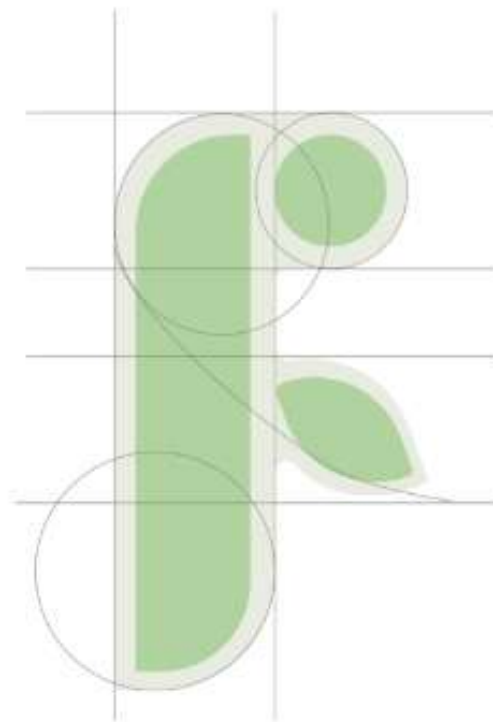


Fig. 188

Fig. 189



Fig. 190

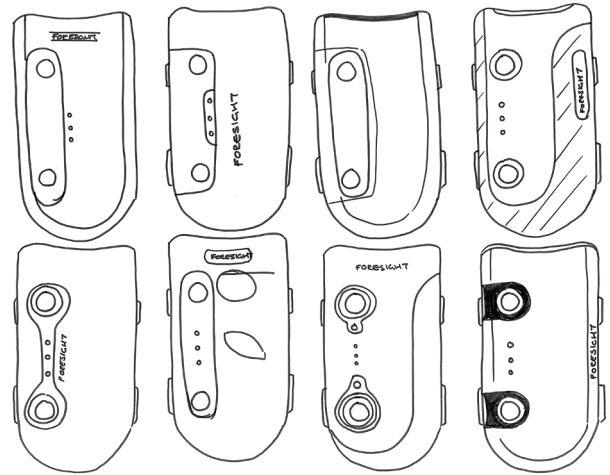


Fig. 191



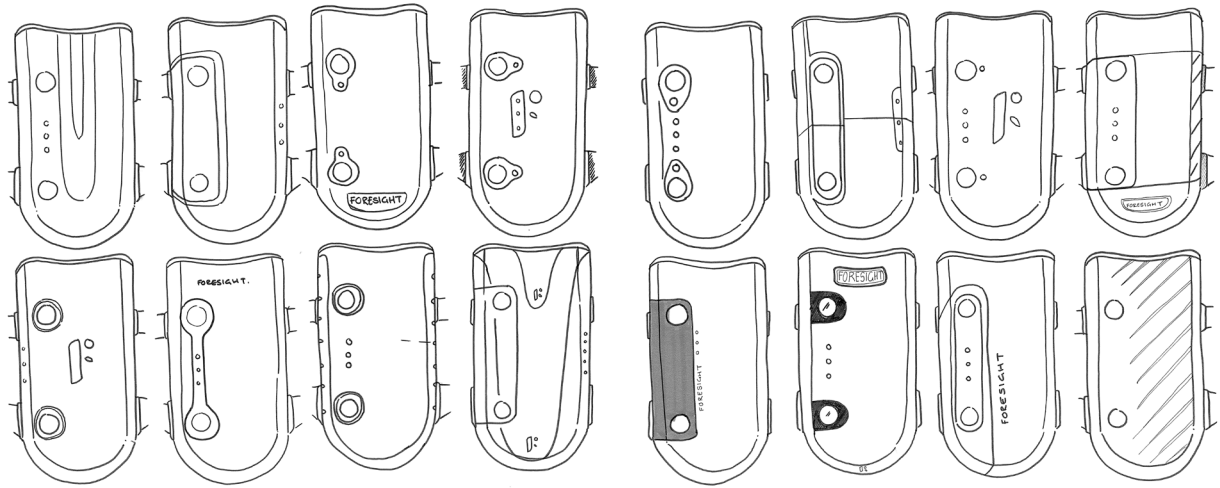
Fig. 192



6.7.5 The Design of accessories

Accessories to the design follow the same form language as the primary design unit with filleted chamfers rounding out forms on one primary edge, while the remaining lines remain angular. These accessories such as battery charger, tree strut, over bin arm, and solar panel, all seek to create visual cues as to the system surrounding the primary design solution, and would require further development.

Fig. 193



A critical part of the product system is the manner in which the data that is collected presents itself. The dashboard concept was developed in response to the understanding of what features and benefits the design has, and subsequently the type of data that these capabilities would be able to capture.

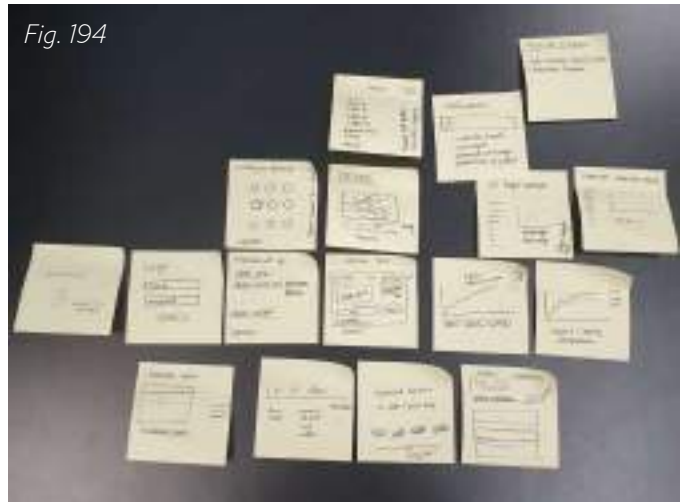


Fig. 194



Fig. 195

There was brief exploration of a variable direction band, but this did not hold the weight of the design sufficiently around smaller trunk circumferences, and could cause bending on younger trees. Therefore it was decided that the best course of action was for the band to pass through the body of the design, and that a strut be created as a method of supporting the weight if facing up into the tree.

6.7.6 Third to last version

This prototype sought to understand how to best built around the trunk circumference to better hold the device in place. Due to the variability of trunk sizes, the shape would need to be either flexible, or triangulated so it has more surface contact. When facing horizontally, this form did not have adequate stability.

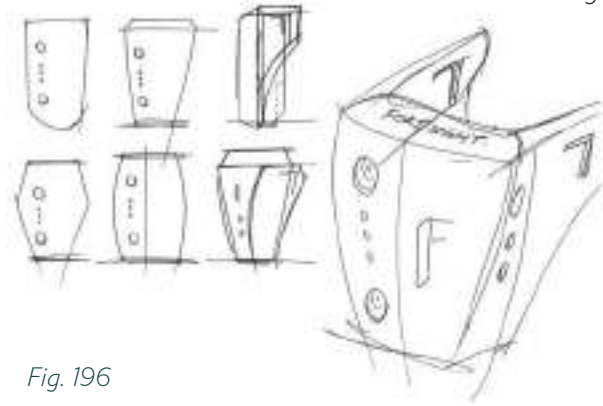


Fig. 196



Figure 197: Design detailing and incorporating the trunk circumference, Photograph by Author, 2023

6.7.7 Second to last version

This prototype sought to better curve around the tree while mindful of the placement of electronic components. It aimed to keep a slim profile to match the average trunk size, and looked at an alternative strapping method, which would have created too many additional usability steps.

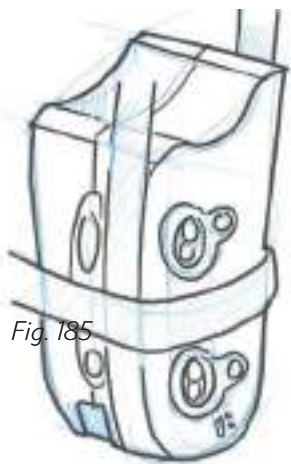
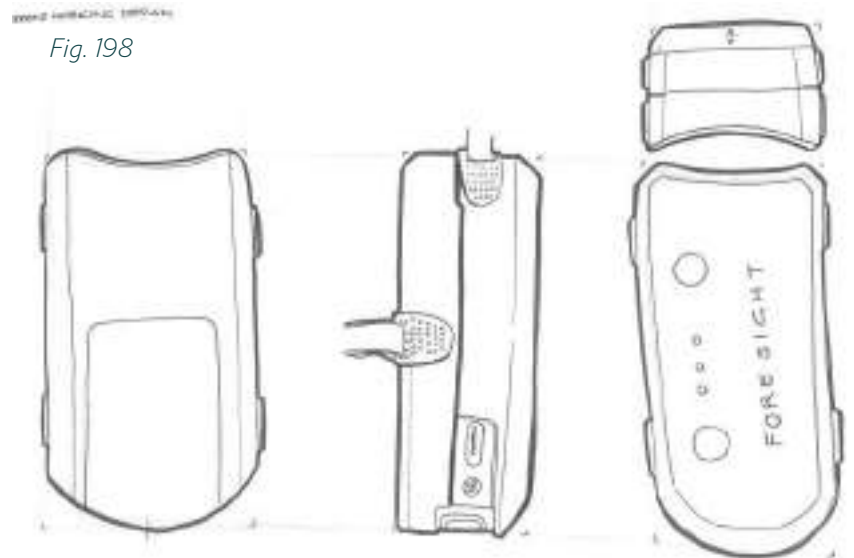
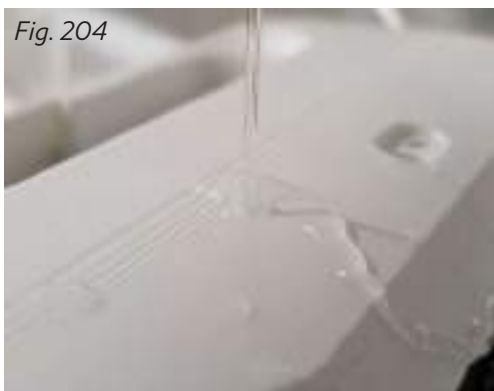


Fig. 199





Powering the Device

The length of product operation, power requirements and an understanding of the user experience around recharging the device, needed to be established prior to the development of the battery.

The scale is based on many standard Lithium batteries used for power tools, and is estimated to power for a minimum of two weeks, when daily snapshots are being taken. The pocket-size battery can then be taken indoors to charge.

A longer-term solution meant also factoring in solar power attachment to the device as an option.

Button

Button shape was developed to be distinctive from one another, so that rather than needing to communicate the word on the button, the shape communicates function. This navigates any language barriers, and the communication across distance in the orchard.

Waterproofing

One of the major challenges in the design development of this project was to consider how the design would respond to the environmental elements. Every feature needed to consider how the exterior would seal or is angled, to minimise the risk of water, sprays and insects entering the unit.

The front face is rounded to reduce water pooling, and the lens protector is angled to allow water to run off it. See Figure 204.

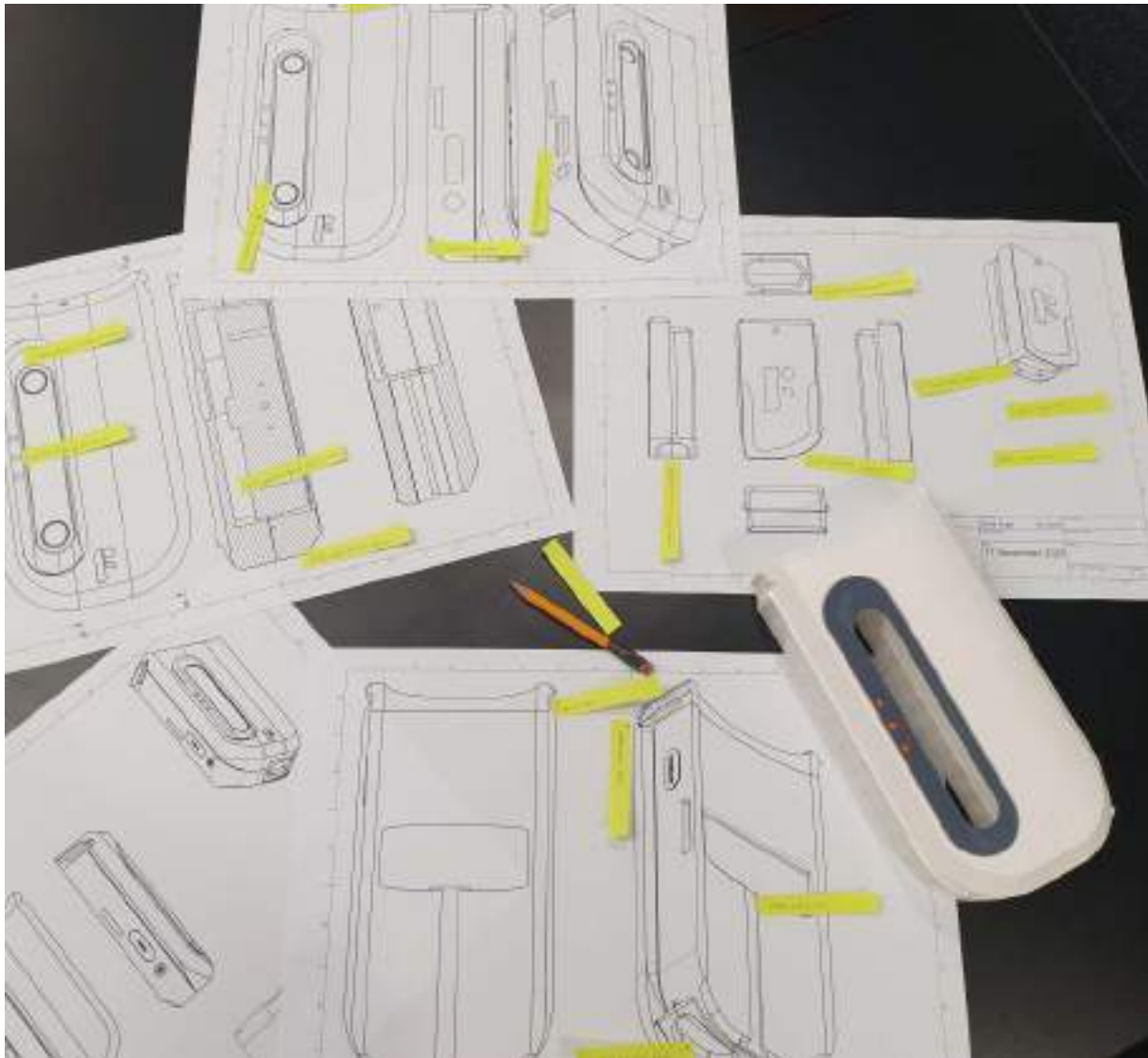
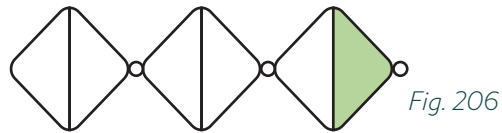


Figure 205: Revisions based on Technical drawings of components, Photograph by Author, 2023

The development of details enabled closer tolerances and fit to reduce the amount of material involved, and better its resistance to water entering the unit. Draft angles and curvature was added on all upward and forward facing components to enable rain to run off the device.

While early concepts explored texture to the design, it was found that it would hold too much dirt and grime, so it was subsequently made to have smooth faces where possible, and would require further development to include self-cleaning.

6.8 Deliver Phase



The use of a number of 3D printing techniques minimised the amount of material and cost involved in creating each prototype unit. Filament (the extruded material fed into the printer) was separated by plastic type when tidying each print so that this can be recycled afterwards.

The complex geometries of the front and back panel meant that a fine layer of PVA filament (similar to glue) was printed to maintain the surface finish of the design, and then this could be washed away in hot water. This is known as soluble support, and using it in combination with other support structures.

Assembly of the design saw an extensive amount of 3D printing iterations as tolerances (the gap or fit between two parts), component spatial affordances and wiring was streamlined to be as efficient as possible.



Fig. 210

View of internal electronic layout in the demonstration model.



Fig. 211

Haptic feedback of electronic lighting integrated to assist in prototyping the user feedback and experience.



Fig. 212

Assembly line of each component made for packaging.

6.9 Final User Validation

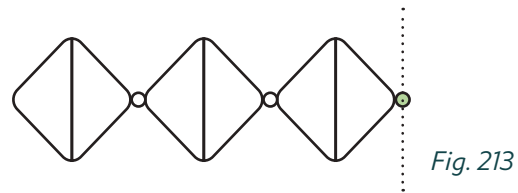


Fig. 213

Orchard Walk Through - F.O.P.S in Hawkes Bay November 2023

I was invited to attend a walk-through of orchard growing styles as part of an initiative by Plant and Food in the Hawkes Bay. While a lot of this day was focused around plant physiology, it was useful in confirming the feasibility of my design concept for this context, and then outlining thoughts on integrating with orchard infrastructure. The scale of measurement, the changing infrastructure, and the technological requirements were able to be better understood. I was fortunate to see the Green Atlas, a demonstration model of a quad-mounted crop data collection tool, understand the components involved, their product offering as a service. A significant benefit the Foresight product system has is its ability to capture information at night, which is something that none of the competitors can currently do.



Fig. 214



Fig. 215

Final interviews and site visits with stakeholders across four orchards resulted in the majority of feedback being that the next step would be to do a longer in-orchard trial.

“The ability to potentially know more about the whole season is very useful, and can change our practices for the better.”

“We could attach it at different heights in the tree.”

Informing decision-makers with up-to-date data is critical in allowing a proactive approach to fruit growing practices.

“It will be beneficial, because at the moment the people are our eyes, we come down once every 10 days and may miss something.”

“The accessories are what holds potential for us, we want to be able to buy into a system that gives us agency and works with our other equipment. This looks great.”

The system is designed to give agency to users to use what they already have locally to gain data. The scalability means that accessories and attachment can be created to suit even more applications in the future.

“So the next steps are to get our hands on a number of these and trial them for a season.”

“Generally people are aware that cameras are operating on orchards, they are here to protect us primarily, but I don’t think that concerns around cameras operating in the orchard are as warranted once they arrive here.”

Sentiments around the camera operating in the orchard environment. In terms of image capture. The re-occurring discussion was that we have a concept, now we need to see how it runs for a whole season in a functioning orchard environment.

“We don’t do any measuring, but maybe we should start if something like this is at an attractive enough price point and we could trial it.”

A final orchard visited for the first time to learn about their heritage varieties, and they expressed that learning about, and integrating technology into the future of their orchard is a must, especially if risk can be mitigated through a trial for them.

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Foresight

7.0

Watching Fruit grow

Figure: 216

Foresight

Watching fruit grow.

Brand Story

Foresight is dedicated to developing approachable, insight-led solutions for practical users. With a particular interest in how to create trustworthy, timely products, this project explores applications in the horticultural industry to empower growers to better understand their crops.

Product Story

Foresight collects in-orchard imagery, observing fruit size and count and measuring growth throughout the season. Generating data around cycles of growth allows orchardists to map the season and do historical comparison. In conjunction with weather, it can also be used to better understand when the right time to harvest might be.

Colour Palette

Figure 217



Space Cadet #172640	Atomic Tangerine #f79868	MSU Green #134449	Sprout #b0d29f	Alabaster #e9eae0	Raisin Black #212222
R: 22 G: 37 B: 63	R: 247 G: 152 B: 104	R: 19 G: 68 B: 73	R: 176 G: 209 B: 158	R: 232 G: 234 B: 224	R: 33 G: 34 B: 34

The colour palette for this project was selected based on research into existing products within this sector as well as its contrast for the written component of the research.

Key Phrases

Watching fruit grow.

Data-empowered decision making for users.

Intuitive user experiences for growers.

Built for growing environments.

Minimise labour, maximise insight

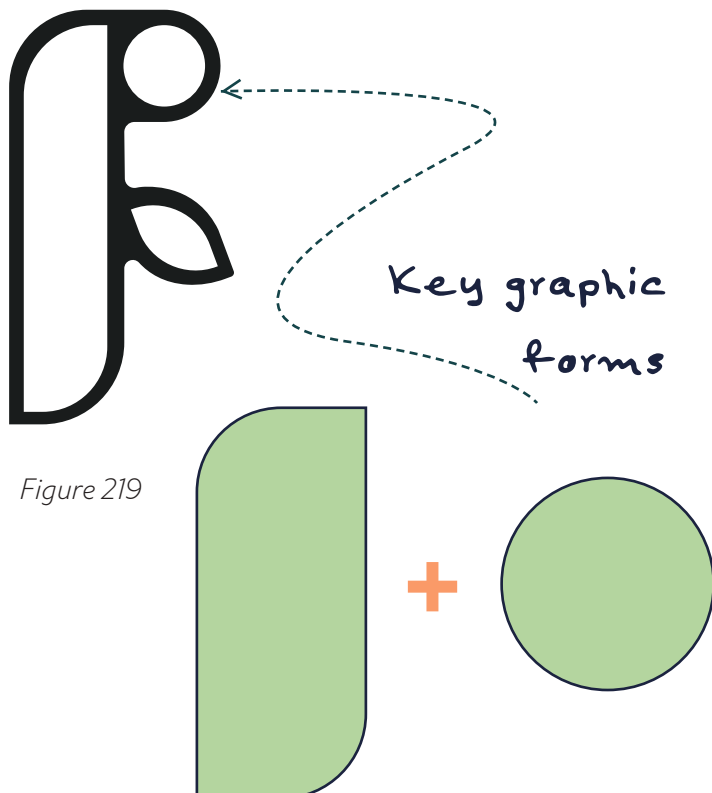


Figure 219

Figure 218

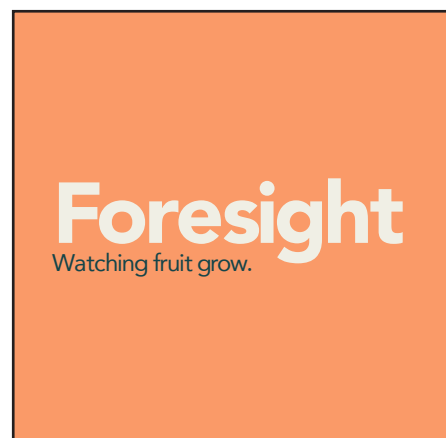




Figure 220



Figure 221

7.1 Product Architecture

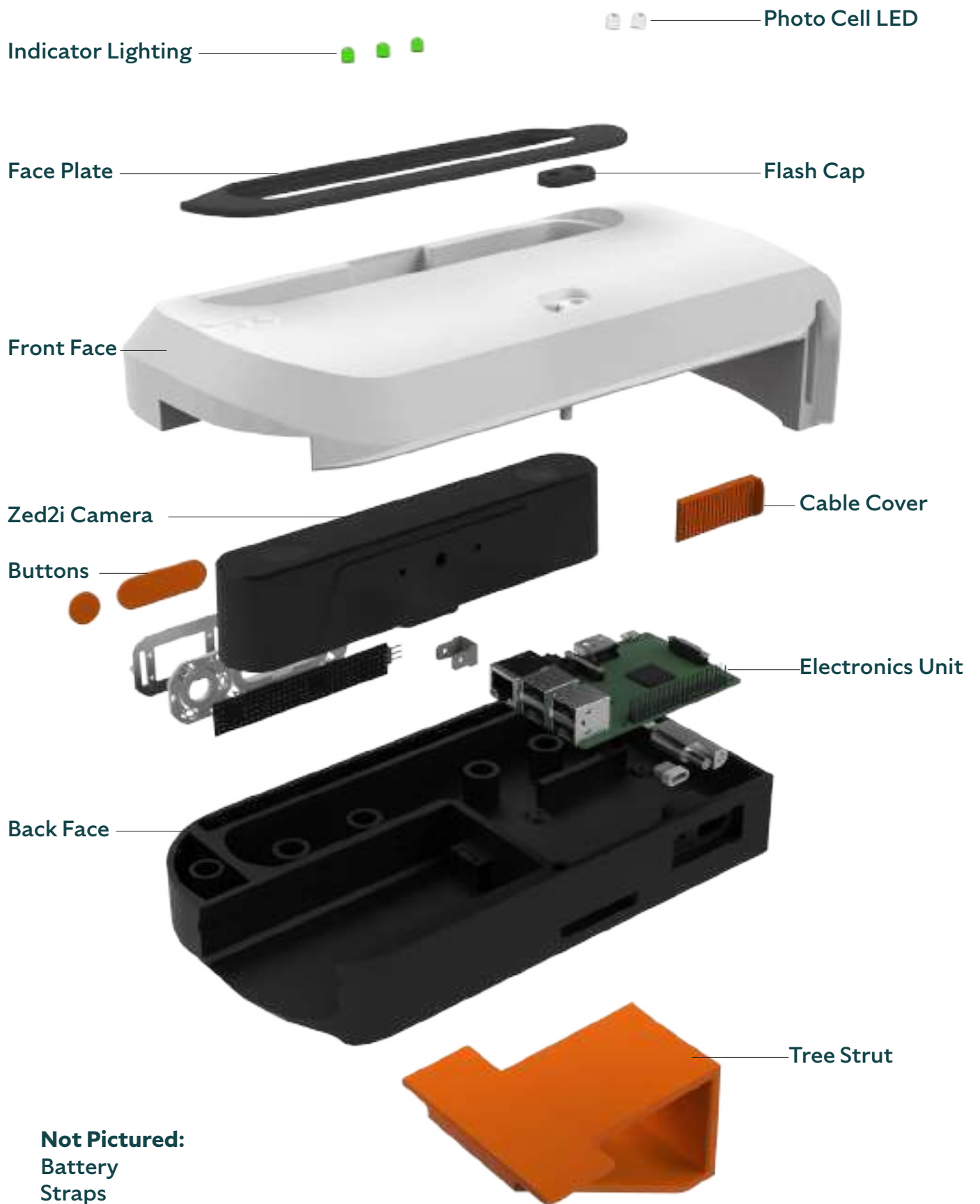


Figure 222

7.2 Packaging

The packaging insert holds components separate from one another to assist in the comprehension of components. A solid box allows for robust transportation, and the card colour creates contrast with the components while being modern, and natural. The packaging communicates key product slogans.



Figure 223

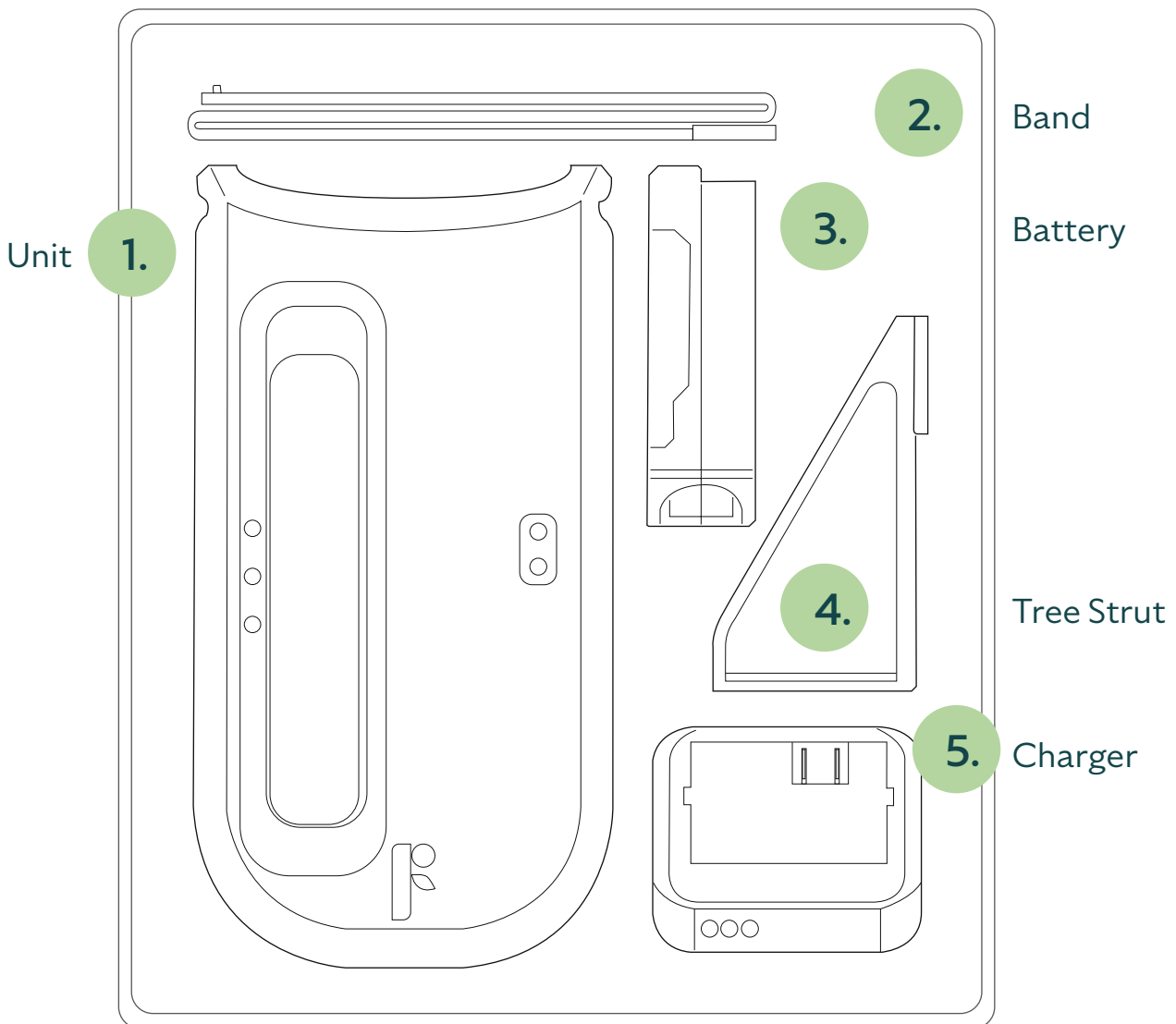


Figure 224: Diagram of Product Delivery inside Packaging, Drawn by Author, 2024



Fig. 225

The instructional booklet aims to guide the user through the familiarisation of the components, the set-up on the tree, and what the key operations are.

A QR code enables instructions to be viewed as a video, including the navigation of the associated dashboard.

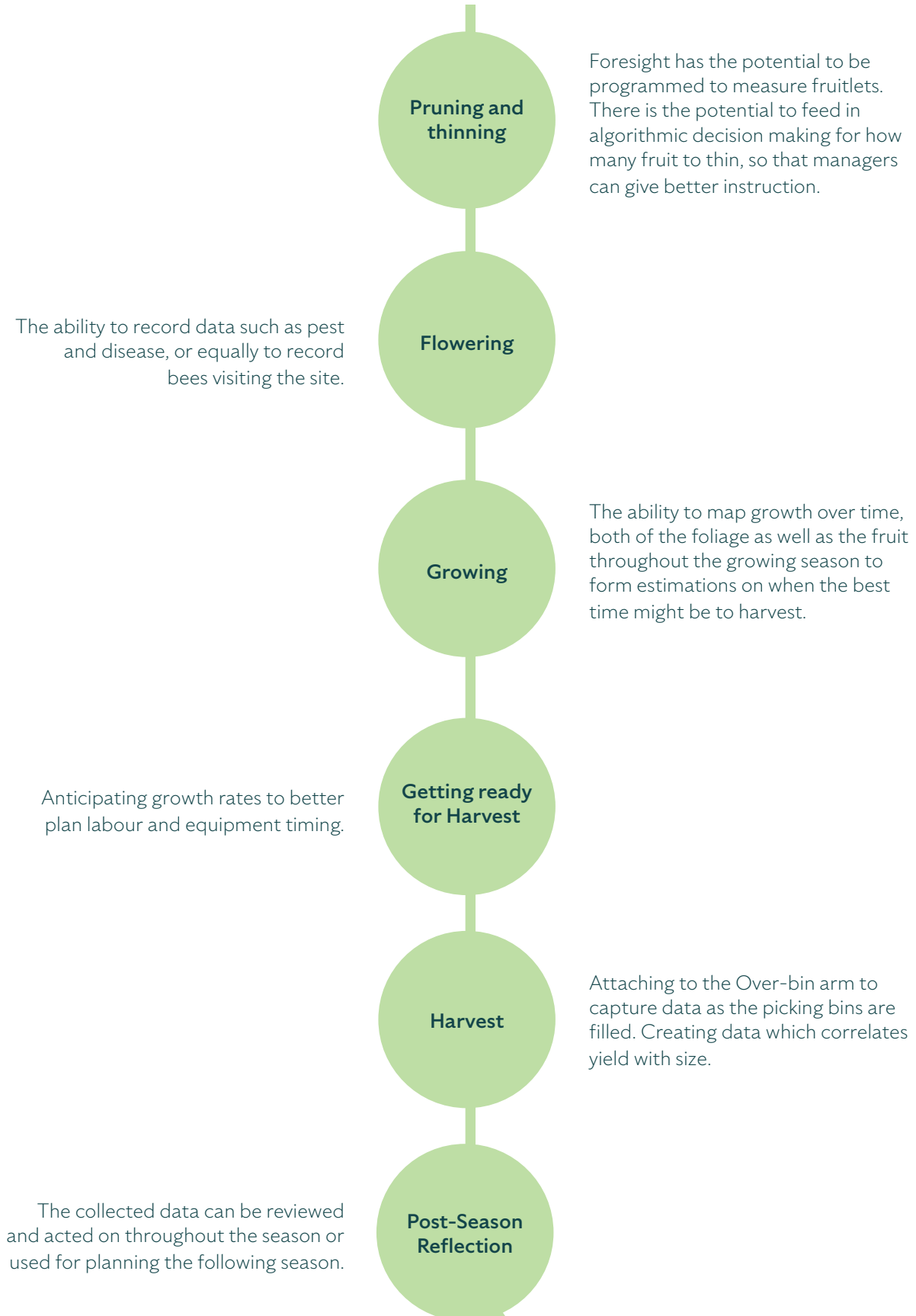
Instructional Booklet



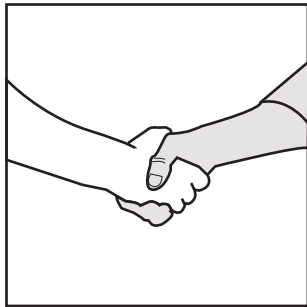
Figure 226: Layout of Instructional Booklet Layout, Drawn by Author, 2024

7.3 Potential Product Benefit

Across the seasonal duration of fruit growing and harvesting, Foresight delivers clear and perceivable benefits to stakeholder communities.

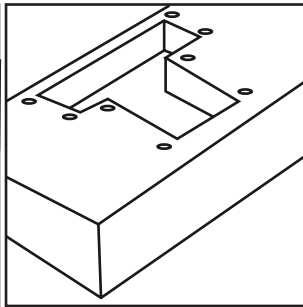


Ideal Scenario



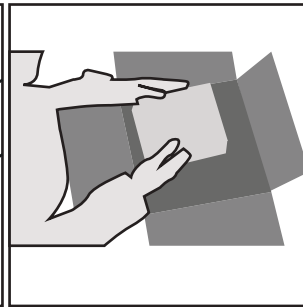
Procurement

System purchased by growers or innovation managers for larger companies.



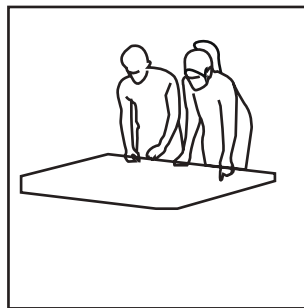
Production

Product bodies manufactured beforehand and coding is set-up to the size of the operation.



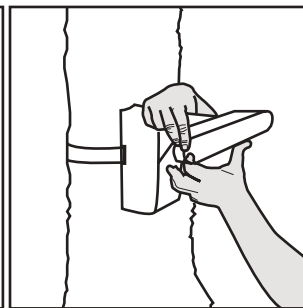
Unboxing

Foresight is shipped with an instructional booklet and resources to help in set-up.



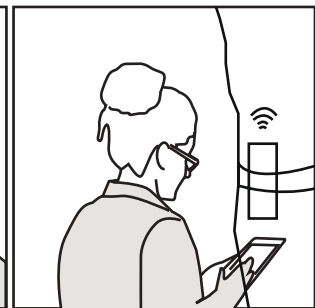
Planning

Staff review the orchard for best locations to place Foresight.



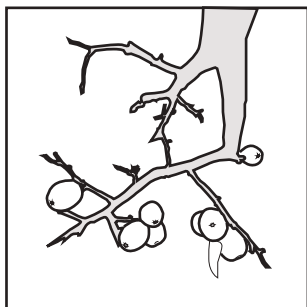
Set up

The on-tree sensor can be strapped to the tree and adjusted to capture the ideal vantage point.



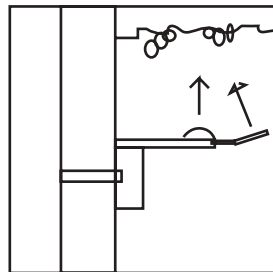
Connectivity

Device is turned on, and can be connected to the dashboard display and nearby units.



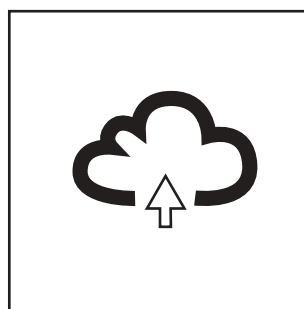
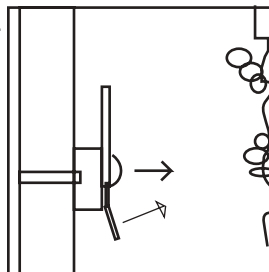
Data Capture

The camera and light turns on at set time to capture an image.



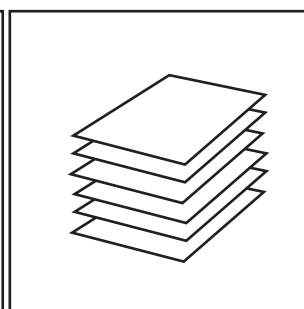
Camera looks to capture data at night with additional illumination.

Lights on - 10 seconds - Camera On - Photo taken
- Camera Off - 10 seconds - Lights Off



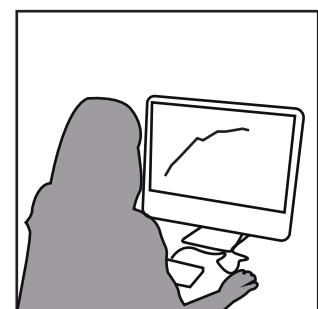
Data Upload

Data uploaded daily for data processing.



Data Processing

Data processed and translated to the dashboard or readable file



Insight Delivery

User views data on dashboard and can share with the wider team.

Figure 227

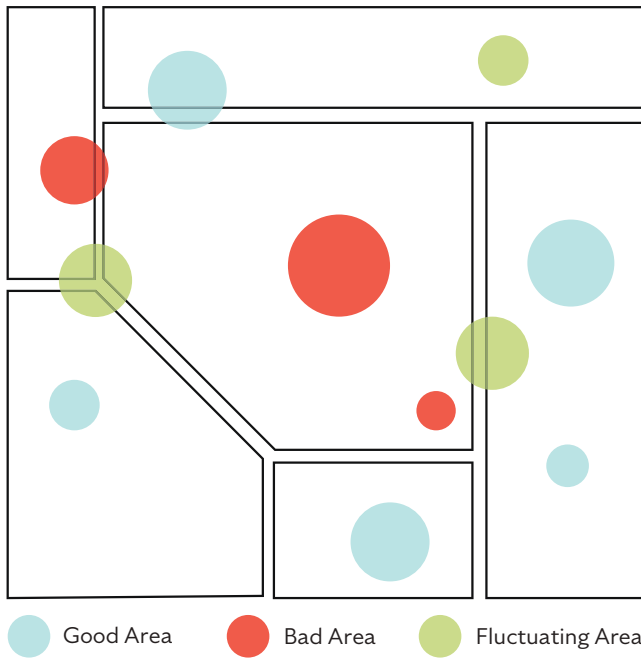


Figure 228

Orchard Variability

Orchards host a lot of variation across blocks in terms of terrain, soil condition and other factors which impact on the successful growth and subsequent yield of each area. These conditions mean that spreading Foresight devices into areas that are historically good, bad and fluctuating allows for a range of data to be captured, and for fluctuating areas to be monitored more closely.

In terms of scalability, the number of units will vary based on the level of adoption the stakeholders are willing to pursue. Starting with 3 to 5 per hectare as an estimate enables the benefits of the data capture to be measured. Having multiple units means that the price point needed to be considered to aid in the feasibility of the product system.



Figure 229: Illustration showing Foresight placement, Drawn by Author, 2024

7.4 Electronics



Fig. 230



Fig. 231

Electronics presented in the models produced give indication of the type of electronics that would be required to make the unit work.

The wiring and componentry choice would be optimised if undertaking batch production.

Please see Appendix N:
Technical Drawings

See Drive Link for Dashboard walk-through

7.5 Dashboard

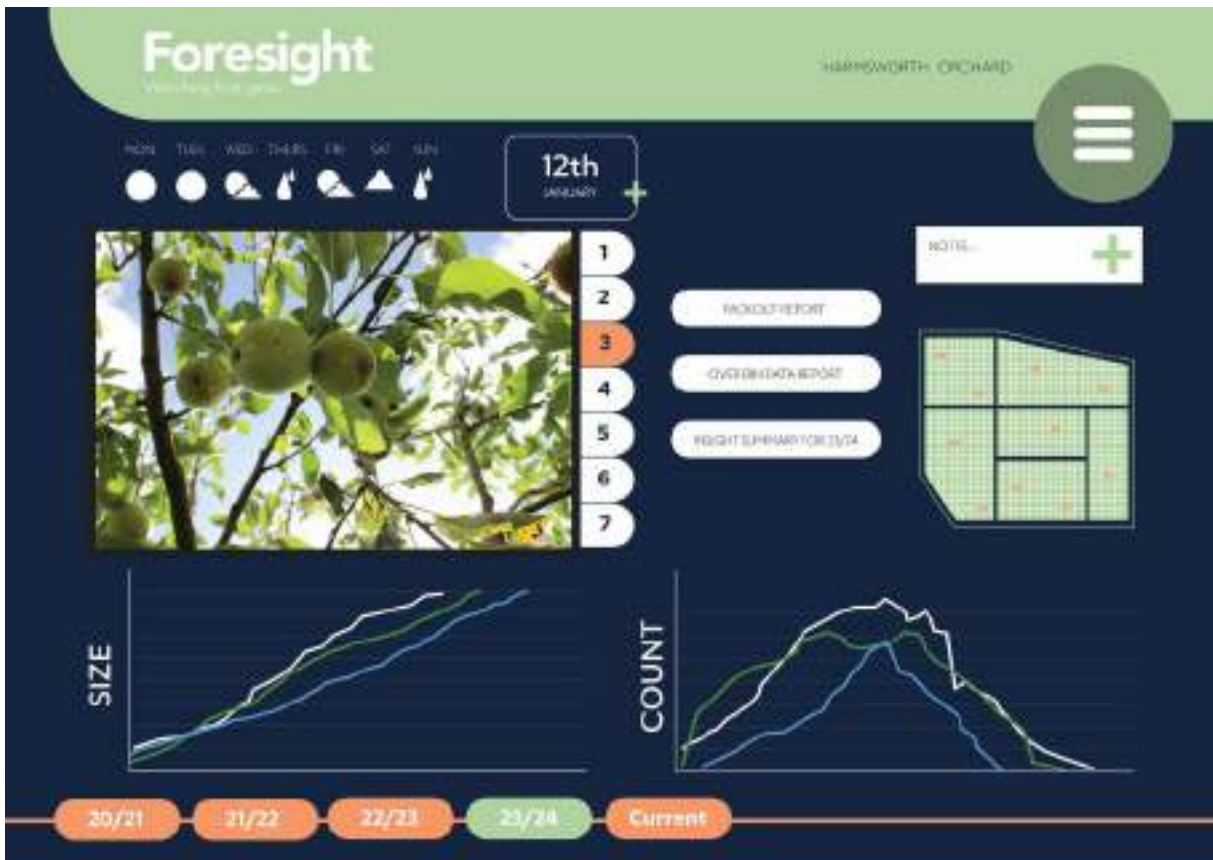


Fig. 232

The dashboard displays weekly views of each camera, as well as size and count data from this season compared to previous.

Data can be exported easily to be shared with other stakeholders, and enables open sharing with management systems.



Fig. 233

Notes enable any thoughts or tasks to be captured while using the dashboard.

Growth sequence can be dragged through to visually see the amount of change throughout the season.



Fig. 234

Manual data entry allows for users to capture any information they want manually into the system also.

An example of this is capturing Maturity test data and it being visualised to show a band of what is below, at or above the ideal.



Fig. 235

An outlook calendar can help the orchard manager navigate upcoming events, make notes on relevant actions and correlate their process with the success it produces in the growing.



Fig. 236

When initially setting up the dashboard, available units can be dragged and placed throughout the mapped orchard or the WLAN signal can be used to locate them.

7.6 Design Details

When facing upwards, the design would be re-inforced using the tree strut component to keep it level. The strut can also be left on the tree year round, marking the position and tree even if the camera is not present.



Fig. 237

A slider mechanism covers the solar panel charging port and a USB-C port which can be used to manually download data.



Fig. 238

The battery is an equivalent 18V battery, slotting into the body of the device. The battery lasts a number of weeks, and can be charged using the charging base indoors.



Fig. 239



Fig. 240

The straps pass through the body of the device to best secure it, with large gaps enabling a range of bands to be used.



Fig. 241

Curved on the top and back allows the design to better conform around the curved tree trunk.

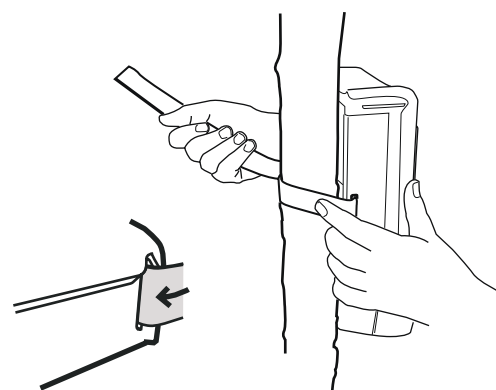


Fig. 242

A large white front surface is bee-friendly with accent colours of orange that highlights touch-points and makes removable parts, such as the battery easy to find within the orchard.

Users indicated that they want to be able to use any standard strapping that they have available. The slotting gap through the unit is big enough to allow a range of commonly used agricultural strapping to be used. For the purpose of the final concept, I have used the *Grunt Versa strap*, removing the branding only to not visually impede on the appraisal of the design. The band that measures trunk circumference would be a separate project which could integrate with this product.



Fig. 243

The battery hosts safety information on the back. The model sent to examiners does not represent the weight indication due to mitigating the risk of prototype being searched, and therefore altered if sent to examiners internationally.



Fig. 244

The battery charging unit is suggested as a single or multiple battery charging unit. Entailing LED lighting on the front to show charge levels.



Fig. 245



Fig. 246



Fig. 247

The buttons are two different shapes, enabling better communication across any language barriers and distance in the orchard.

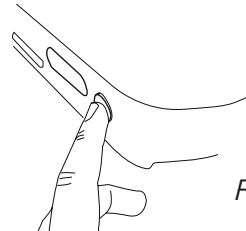


Fig. 248

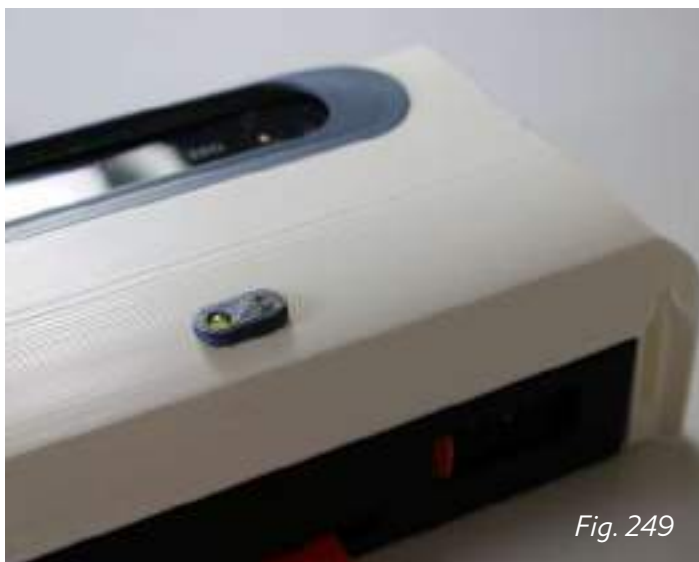


Fig. 249

A photocell and LED illuminates the tree canopy to enable night-time photography. It can run on a timer, with a photocell also measuring darkness and then the LED switches on for a few seconds, the Zed2i switches on, takes the photo, the light turns off, and the data is saved before the unit switches off.

A solar panel enables charging to the unit without the task of battery replacement. It is able to be mounted to orchard infrastructure.



Fig. 250

7.7 Features and Benefits

Insight

Design Response

Benefit

Capturing data throughout growing season

Designing a product that can adapt throughout the growing season.

The amount of data collected allows for a build up of historical data over time to allow for comparison.

Accommodating different growing styles

The ability for the device to be strapped to the tree either vertically or horizontally.

Allows for different growing styles, including kiwifruit to be catered for.

Reducing lighting variability in images

Trialling capturing data at night using controlled lighting.

The lighting and weather variations during the day does not impact on the quality of the imagery being collected.

White attracts bees

Making front shell of the design white.

Pollination is a vital part of the growing process and guiding bees is a useful feature.

Groundtruthing as a concept

Designing a product which acts as part of the groundtruthing process.

Integrates into current practices and reduces the level of repetitiveness. Works under hail netting.

Increased use in hail netting meaning innovation needs to operate below this.

Using integrated tech to measure fruit.

Using the Zed 2i camera

Stereoscopic vision accurate and affordable. Outdoor rated camera.

The product needs to clearly communicate process to the user.

Indicator lighting on the front showing operation.

Can see at a distance what functions are taking place.

Links to existing orchard management systems

Allows the data to be captured with systems they already have

Can see at a distance what functions are taking place.

The need to communicate function easily between staff

Buttons that are different shapes.

Having buttons that are different shapes allow for clearer communication on which one to press.

Needs to be resilient to the elements.

Using the Zed 2i camera which has an IP66 rating and waterproof connector

A design that is durable in the elements.

Capturing data in different sections of the orchard

Having multiple devices that can be placed throughout the orchard to compare different sections.

Understanding the performance of your historically good, bad, and variable sections.



Colourway



White
Bee-friendly



Orange
Touch-points



Grey
Accent

Fig. 252



Fig. 253



Fig. 254

8.0

Conclusion

From Insight to Foresight

Fig. 258

The early identification of trust as a concern in the processes of orchard management enabled a continuous investigation of the principles of trust, which informed the project and design development. The researchers' creative background enabled a designerly approach in addressing a repetitive, time-consuming and prone to variability task.

Stakeholders having their own data to compare to the pack-out report enables a decrease in distrust issues at the handover stage when fruit leaves the orchard to go to processing. The way Foresight is mounted means that the data captured is consistent, and nighttime photography being utilised in this application is novel, while also creating better control of the lighting conditions. Features and benefits have been incorporated in ways that reflect the insights from stakeholders, such as large, different-sized buttons that can be operated while wearing gloves, and mitigate miscommunication between orchard managers and workers.

This project had the privilege of being informed by knowledgeable voices in the areas of plant science, technology and design innovation, all of whom made the progression and development of meaningfully integrated features and benefits possible. A series of critiques throughout the project assisted in informing the design direction and detailing, as well as the narrative of the proposed system.

Foresight is a static fruit measuring device that seeks to respond to the problem of repetitive, manually intensive, yet often inaccurate collection of fruit data during the growing season. It seeks to understand growth patterns, enabling users to compare to previous seasons to better understand their orchard performance. Additionally, Foresight can be used to validate and augment other forms of data capture, such as satellite imagery used in predictive modelling for horticultural production. Foresight is attached to a tree trunk through a flexible and adaptable mounting system responsive to orchard design and tree shape. Image capture and subsequent data management within the product system enables reliable data comparison.

Creating a device that captures data throughout the season enables insights to be readily available for users and stakeholder interests. Data informs insights on the progress of a crop and the performance of individual orchard blocks. In addition, seasonal comparisons and impacts of weather can be factored into orchard decision-making. Operating below the hail netting level, Foresight data collection can also be used as a ground truthing strategy to larger scale data capture.

The scalability of the Foresight system means that users can trial with a minimal number of devices (three) and then scale as their confidence and trust in the system is supported through quality data streaming, robust design and visual communication through performance dashboards. This contrasts with some competitors who hire their system, require annual service fees, or purchase of a whole system to achieve functional performance. Giving the agency to users to collect their own orchard data and expanding the system as they require, enables users to learn from the system, collecting reliable data in a manner supporting productivity across orchard operations with a device they are in control of.

Having more readily available orchard-based data addresses the lack of collaboration, transparency and delay in information transfer across the industry stakeholder sectors, such as packhouses and orchard operations. The little reliable data that is currently present adversely affects innovation for this space, impacting quality management and affecting trust. Foresight's design

responds to this issue of trust between agents by seeking to empower the orchard-based decision-maker with information that they can compare to packhouse reports, informing their operations about grading and yield rates and optimising productivity for all. These comparisons allow for a better understanding of the gaps within orchard sector practices and have the potential to develop cross-sector communication, engendering trust.

Foresight utilises night-time photography as a means of further removing environmental variation and capturing data in a controlled manner. Excessive glare affects the accuracy required for fruit measurement, and being able to photograph at night with calibrated flash lighting mitigates the effects of daytime glare on data interpretation. The future possibilities of this would be to collect other forms of data around factors such as fruit colour more effectively.

The foundational framework produced as part of this study to map out the agents involved decentres the human as the primary agent to design for and argues that taking a More-Than-Human approach to design enables us to meet the obligations we have towards the environments we design for, and the technologically embedded objects and their operations as part of a broader team of active agents. The framework acknowledges Te Ao Māori ways of approaching non-human agents and their relationship to the natural world. This framework will have applications beyond this study when we consider how to design for trust between multiple agents and how we can provide benefits to all agents rather than only humans.

The research questions have been addressed using a mixed-method approach, all of which sought to best understand how an effective design of a fruit measurement device that promotes trust and ongoing utilisation should perform and appear.

Issues of trust were apparent at the initial stages of the project and introduced as an area of interest by the Research Director of PlantTech Research. It was introduced in the context review and elaborated upon in the literature review. Relevant research on current factors of trust commonly measures the interrelationship of two agents rather than multiple. However, within the environment of study multiple agents are at play and interact within the system. Trust Within a Product Model of Experience, developed within this study, allowed factors of trust and relationships affecting trust to surface and be explored through design. This model holds potential for further research and publishing in the future.

Usability issues and a lack of industry collaboration was identified as a concern in which a miscalibration of trust and product expectations develop. This could be mediated through intentional design to improve the experience and subsequent product interaction.

Understanding the current practices in fruit measurement and their limitation, which included unreliability, fruit damage, health and safety concerns, consistency and frequency, and potential disease transferal using physical instruments, provided a sound foundation to consider what the true nature of a fruit measurement device needed to be. The fundamental properties integrated into Foresight include noninvasive measurement, consistency, frequency, zero contact with fruit, and elimination of potential harm to orchard workers.

The true nature of the design of a technology-embedded product relies on broad stakeholder involvement informing the development of understanding and knowledge in relation to the functional and usability features of a product or system. The activities and mechanisms of design undertaken along this process included task analysis, journey mapping, site visits, interviews, design critiques and prototyping investigations, which are, to some degree, a type of immersive research where the end users become active agents in the process.

Understanding what data needed to be represented back to users through dashboards and product interaction was informed by interviews and design critiques with stakeholders and end users. The immersive fruit study provided confidence in decision-making with regard to assimilating research outcomes and allowed a knowledgeable and informed engagement with experts from the field. The triangulation of research and design practice activities contributed to confidence in the validation of Foresight by stakeholders and industry experts in review.

Data visualisation for the horticultural sector in this study was developed through interviews with stakeholders, creating a mock-up dashboard that allows for simple navigation and an indication of the type of data that would be visualised back to the user. This aspect was secondary to the product design but a critical part of the product system and communication of the data. The language that products and systems use should be adaptable to the different cultures into which they are deployed.

In the design investigation and concept phases of this project, several concepts fell outside of the scope of this project. One in particular, the concept of a band that can measure the trunk circumference and its fluctuations based on water strain, was explored. The technology requirements to make this idea viable are understood, but the development into a prototype was not further explored as it deviated from the primary scope of the project. The concept would be better served and developed at a future date. It would make a useful product extension to the foresight system potentially, adding tree hydration to the data sets would allow target watering and conservation of resources.

Growing fruit is a vital exercise in the pursuit of food production for consumption. Learning the processes involved in an immersive manner has given me a much greater appreciation for the processes involved.

The horticultural industry of New Zealand is a vibrant group of hardworking individuals who want to adapt, and being equipped with better data will enable more informed decisions about their crop management, productivity and environmental management.

Foresight takes over watching fruit grow, minimising labour and maximising insight.

Novel Contributions

This research offers at least three novel contributions to the current body of knowledge, including;

The creation of Foresight, a device that acts as the first part of a wider system of products for better monitoring of orchards. A Design criteria of factors when designing trust into objects, published and presented at the Design Research Society 2024 conference.

The Trust within a Product Model of Experience framework enables the replication of designing products that effectively consider trust as part of the interconnective tissue between stakeholders, and has application to other design-based enquiries beyond the horticultural sector.

Limitations

Taking a proactive approach to risk mitigation throughout the project made for the easier navigation of setbacks and losses that happened during the time that this project was underway. The fruit tree study had the benefit of collecting data throughout multiple seasons of the same trees, within controlled actions that could be recorded. The biggest variable and limitation was the weather, which saw the likes of Cyclone Gabrielle causing significant damage to the Apple Industry in 2023.

Due to the closure of PlantTech, many participants discontinued their engagement with the project, a limitation which was mitigated as much as possible through connecting with new participants.

The design for trust criteria that comes as a result of this review was generated with ten participants. What was interesting was that rather than a specific factor being most important, the overarching themes were the personality of the participant as introverted versus extroverted, and their level of openness to accept new technologies. This correlates with a number of other authors in this area. A larger sample size would be needed to better understand these responses.

The divergent nature of the initial concept exploration meant that many ideas that were also seen as highly feasible and interesting were placed outside the scope of this research project, however, can be developed as future projects or suggested as part of the Foresight product system.

Future Directions

The application of a device such as this in the orchard environment may have many other benefits to other research and activities occurring where sequential monitoring is required, both in the orchard and beyond.

Future works would include the exploration of components from the project, including the over-bin and band concepts as products that seek to expand the product capabilities and subsequent benefits to users.

The Zed2i camera was selected for its IP-66 rating, and plug-and-play capabilities allowing for rapid prototyping and validation of the concept. Future works could include exploring the option of licensing, at which point the involvement of software engineers and data analysts would greatly benefit the product and dictate its final visual expression. Future publishing has been identified as part of the continuing scholarly contribution to this field of research.

Foresight will be entered in a range of design competitions, furthering both its exposure, but also the importance of designing for an industry that wants to incorporate technology into its practice, in a useful and trustworthy way.



Figure 259: Zene in the orchard in Morrinsville,
Photograph by Wilma Joubert, 2021



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Figure: 260

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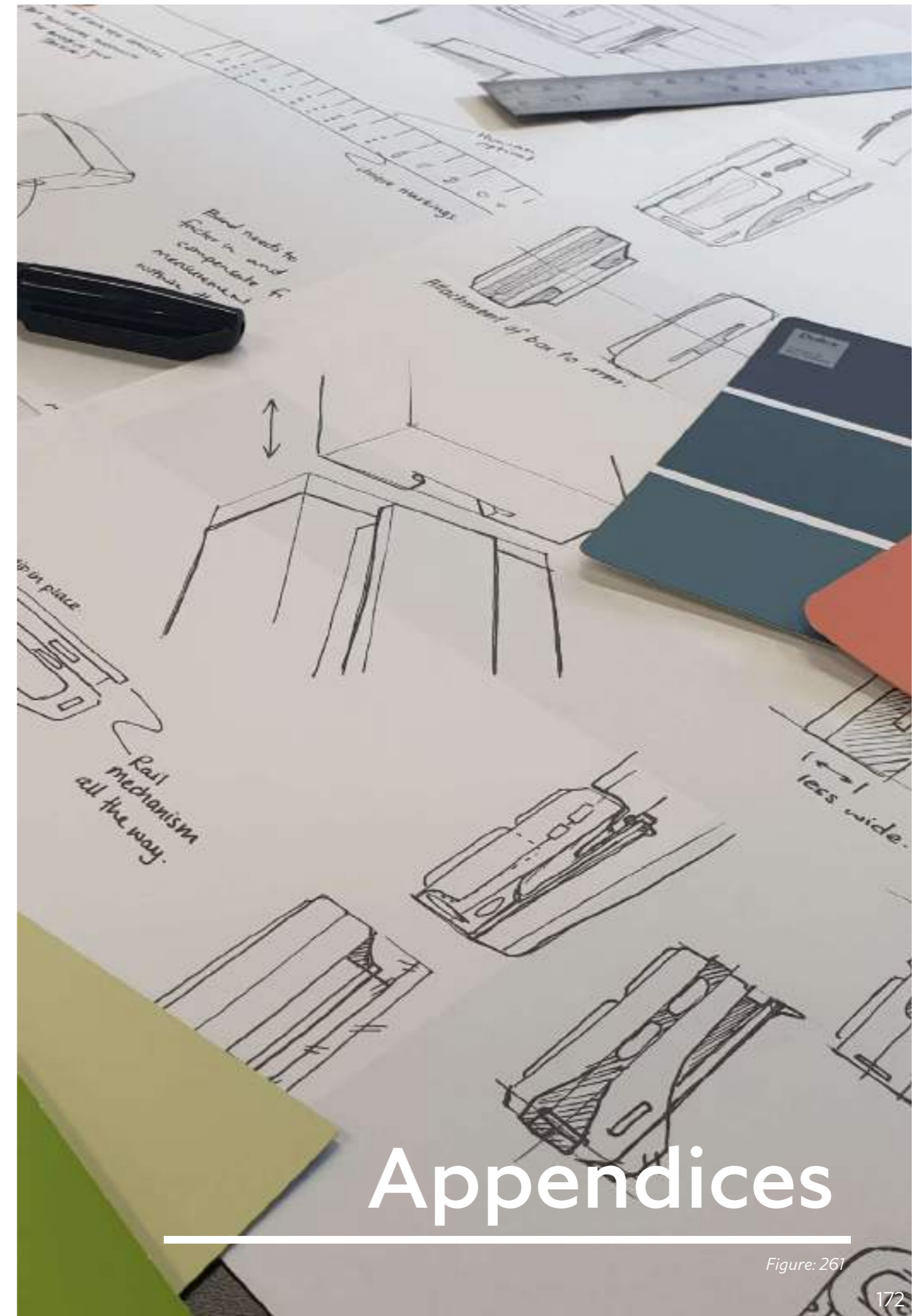


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Appendix A: Technology Review

The following areas were researched:

Digital Crop Estimation
Morphometrics
LiDAR - 3D Scanning
Colourimetry
Visible imaging
Visible and near-infrared
Spectroscopy
Hyperspectral imagery
Multispectral imagery
Fluorescence
Acoustic impulse techniques
Computed tomography (CT) scans
Magnetic resonance imaging (MRI)
Acoustical vibration technique
Electronic nose technique
ARCGIS - for mapping out the data
Solar Panels
Cellular Modems
LORA WAN
WIFI mesh network
Optical Quadrature - for understanding tree water strain
Capacitive Linear Encoder
Passive Linear Encoder
NVIDIA

Componentry

Sony Action Camera
GoPro
Apple iPhone cameras
Arduino
Raspberry Pi
App-based systems
IntelRealSense
Arducam
Zed 2i
Open CV - Learning/ About
Sensors
Motion detection
Light
Colour

Colour methods

CIELAB
RGB
CYMK

Digital Crop Estimation

Crop estimation is the process of capturing estimated data such as the count and size of a crop to assist decision-makers in better predicting yield and actions that may need to be undertaken as part of orchard operations. This process is done by farmers wanting to know more about their operations and is ideally done throughout the growing season to capture relevant information on growth. Doing this over a series of years also allows for historical data to be collected for comparison.

Morphometrics

Morphometrics can be seen equivalent to the Anthropometrics we often use when discussing human form, but refers to other organisms. Fruit have unique and individual forms and sizes, which can be indicators of quality, disease and overall health.

Types of data we want to collect:

- Fruit size - diameter
- Fruit Count
- Fruitlet Count (would be nice)
- Colour percentage of the fruit
- Tree Count
- Location in the orchard
- Time data captured

LiDAR

Light Detection ranging (LiDAR) is a remote sensing method which can collect three-dimensional measurements of space, starting in the 1960s and becoming increasingly utilised. Initial GPS systems aided greatly in proving the viability of the technology. The technique uses a laser light to measure the environment, and can also measure density among other factors. The main negative around this method is the cost associated with LiDAR does not align with the key requirements of the project at this stage.

<https://geoslam.com/what-is-lidar/>

<https://www.neonscience.org/resources/learning-hub/tutorials/lidar-basics>

<https://www.geospatialworld.net/prime/technology-and-innovation/what-is-lidar-technology-and-how-does-it-work/>

<https://www.grap.udl.cat/en/re-cerca/linies-de-recerca/detec-cio-de-fruits-i-estimacio-de-collita/>

Spectroscopy

“Spectroscopy is the study of the interaction of light and matter. Many types of spectroscopy rely on the ability of atoms and molecules to absorb or emit electromagnetic (EM) radiation. The absorption or emission of different forms of EM radiation is related to different types of transitions”. - Khan Academy

<https://www.khanacademy.org/science/ap-chemistry-beta/x2eef969c74e0d802:intermolecular-forces-and-properties/x2eef969c74e0d802:spectroscopy-and-the-electromagnetic-spectrum/v/introduction-to-spectroscopy>

Stereo Camera

In Comparison to LiDAR, Stereoscopic cameras are typically less expensive, as it relies on the concept of a left and right set of ‘eyes’ to allow the overlap to be measured as a means of measuring depth, which is a useful tool for three-dimensional data capture.

“Therefore, it is best to play to stereo vision’s strengths, as it will achieve excellent results when properly deployed in well-lit environments, used for applications such as bin-picking or autonomous cars. With no lasers or expensive lighting required, passive stereo vision can be much more affordable compared with 3D machine vision technologies.” Clearview

<https://www.clearview-imaging.com/en/blog/stereo-vision-for-3d-machine-vision-applications>

Spectrometry

In Comparison, Spectrometry is the practical application of measuring the spectrum of light that is interacting with matter, through factors such as transmittal, optical density and light absorbance.

<https://www.atascientific.com.au/spectrometry/>

Phenotyping

“the activity or process of determining, analyzing, or predicting all or part of an organism’s phenotype. Plant phenotyping, which is the assessment of expressed traits (as influenced by genetic make-up and changes in the environment), is a vital process in crop improvement programs.” - Mirriam Webster

<https://www.merriam-webster.com/dictionary/phenotyping#:~:text=%3A%20the%20activity%20or%20process%20of,process%20in%20crop%20improvement%20programs>

Hyperspectral Imagery

Building on Spectroscopy, Hyperspectral Imaging is an analytical technique collecting vast imagery of the same environment but at different wavelengths. It measures “a continuous spectrum of light for each pixel of the scene.” Nireos

These processes are continuously improving and their use are already widely understood as a key technique in better collecting and visualising data about the state of orchards.

Multispectral Imagery

Multispectral imaging captures light from a narrow range of wavelengths across the electromagnetic spectrum. Multispectral images are captured either with special cameras that separate these wavelengths using filters, or with instruments that are sensitive to particular wavelengths, including light from frequencies that are invisible to the human eye (infrared and ultra-violet, for example).

<https://photographycourse.net/multispectral-imaging-used-for/>

Thermal Imaging

It was defined that thermal imaging was out of the scope of this project, but was brought up as a potential a number of times at the start of the project.

ARCGIS

<https://www.arcgis.com/index.html>

Not in scope for this project but this is what is commonly used in orchard management to help map out the orchard and plan where things might go. This would also be able to map out things such as the results collected from the Orchard.

NVIDIA

NVIDIA is what the Zed 2i will be talking to when it comes to programming it to what we want it to do.

I will need a computer with NVIDIA to help Drive the Zed 2i while it is in prototype mode.

<https://www.nvidia.com/en-au/>
<https://www.nvidia.com/en-au/deep-learning-ai/industries/robotics/>

Zed 2i:

Description/ Definition:
A stereo AI-powered camera.
Cost: ~\$1,000

Functional Characteristics:
Stereoscopic Camera - uses 2 cameras to help detect distance - essentially acts like human eyes. This does play into the anthropomorphic aspects of the project which can actually enhance trust.

Benefits:
Wide Angle
IP-66 Rated Enclosure
Multiple Mounting Option
Built-in IMU, Barometer and Magnetometer
USB-C Connection
Has been tested in the Agriculture Space Environment Mapping
Spatial AI
Has been widely adapted and included into robotics projects
Works with OpenCV among many other popular means of coding and driving the programming behind the camera.

Limitations:
Uses an NVIDIA Driver
Will need to understand the powering mechanisms
How to charge the product and developments.

Use Cases:
Has been used in the horticultural/ agricultural context before.

Relevance to the project - How can we use it:
We can use it as the primary camera for image capture and analysis of the fruit.
The next section which tries to estimate size will need to be a bit more speculative as that is outside of the scope of my capabilities solely.

iPhone Camera

Description/ Definition:
A popular mobile phone/ tablet option as part of the mass-consumer market which has LIDAR integrated into its camera functionality (if Iphone 12 or newer)
Cost: ~\$2,000 minus accessories.

Benefits:
Incredibly accessible
Familiarity (see also the limitation of this)

Limitations:
The stigma’s around the phone being lost or stolen.
Misuse or incorrect use of a product for data capture based on the familiarity factors of the Iphone/ Ipad.
Cost and amount
Most solutions are app based in this space and can vary in cost.
Free apps which are inaccurate adds to the stigmas of using app-based solutions.
Data processing is happening by a third party/ cloud service, meaning that there can be a great delay between the two.

Use Cases:
Has been used in the horticultural/ agricultural context before and is being used increasingly as a means of data/ image capture.

Relevance to the project - How can we use it:
Can be used as a means of visual data capture - but would need to instruct the user about correct use during operation to capture consistent and usable data.

Go Pro

Description/ Definition:

A camera marketed as a multi-context/ adventure camera to capture high resolution imagery and video.

Cost: ~\$800 minus accessories.

The accessories are widely varying, and can range in cost. You would need a weather-proof casing ~\$100

Benefits:

Accessible

High levels of modularity to meet different contextual needs.

Limitations:

Terrible battery life

Water build up on the camera

Hard to adjust and modify the design factors around the camera when that is already the product/ system which is designed.

Use Cases:

Has been used in the horticultural/ agricultural context before and is used often as a means of capture away from smartphones.

Relevance to the project - How can we use it:

Can be used as a means of visual data capture - would need to have very specific camera set-up instructions and have external power supply permanently attached.

Matterport

https://www.crkennedy.co.nz/products/mc250/matterport-pro2-3d-camera?gclid=EAlaIQob-ChMI2Mqe5J2A_QIV2IJLBRIt_gvCEAMYASAAE-gLALFD_BwE

Description/ Definition:

A fully-enclosed unit which utilises camera and processing onboard. Typically used in the context of Interior /architectural mapping in home, commercial and industrial interiors. \

Cost: Not disclosed (expensive)

Benefits:

Able to capture data at a high resolution and export it to CAD for development.

Creates a 3D map which can be navigated through.

The way in which it is mounted and portable is an interesting factor which could be looked at. - The way it rotates around to scan at its own pace is cool.

Camera operated through an App on the phone

Limitations:

Not designed for exterior use

Not tested to understand how it might be used in the context of an outdoor project.

Use Cases:

There are no records where this is being used in an orchard environment

https://support.matterport.com/s/article/Scanning-Outside-Paths-to-Guest-Houses?language=en_US&ardId=kA05d000001DWyo-CAG#:~:text=The%20Matterport%20Pro%20and%20Pro2,devices%20when%20you%20move%20outside.

https://go.matterport.com/VT-EN.html?utm_source=google&utm_campaign=EN_APAC_NZ_Brand&utm_medium=ppc&utm_content=EN_APAC_NZ_Brand-matterport&utm_term=matterport&matchtype=p&device=c&gclid=CjwK-CAiAOJKfBhBIEiwAPhZXD9X55WxcCNHOT-geldFzujCFQmgr5mA7vvyovtvsWNVFlpLkRA-dUJcBoCxy8QAvD_BwE

<https://matterport.com/>

Raspberry Pi

“The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse.” - Raspberry Pi

An Example of a system used by hobbyists and professionals.

Raspberry Pi modules can be driven through most popular types of code and have a large community of users who share and contribute to the body of knowledge around it.

A range of sensors can interact with the modules and environment to capture data.

<https://www.raspberrypi.org/help/what-%20is-a-raspberry-pi/>

Arducam

An example of a more cost-effective camera alternative which can interact with most controller types. The lenses are often incorporated into the more expensive final products.

Small cameras which can be incorporated into the form of the product seamlessly.

This is possibly an option which can be reviewed later on.

<https://www.arducam.com/>

Optical Quadrature:

In essence, referring to a pattern on a band with a sensor facing it which tells you how much the trunk circumference is expanding or contracting over the course of the day so you know when the right time is to water the trees or stop.

Relevance to us - How can we use it:

I am going to attempt to simplify this by using easy visual means for orchard workers to look at the water strain based on the band which holds the product to the tree. The next step would be to have a sensor which then looks at this pattern and can record this for the orchard manager to know digitally as well.

Dendrometers - Tree Trunk Circumference

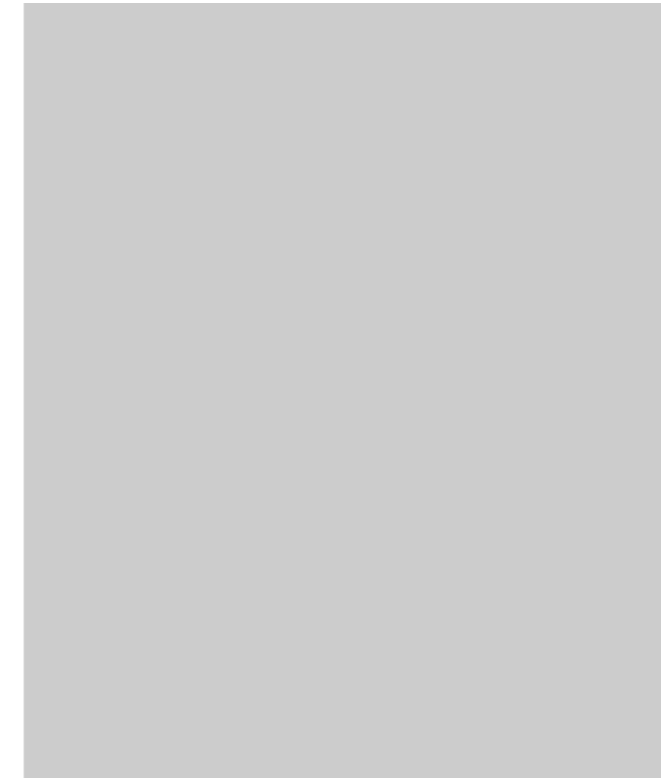
Dendrometers are commonly used as a means of understanding the physiology of a tree. Typically, the trunk of a tree can tell us a lot about the health of the rest of the tree such as the leaves and subsequent fruit.

Appendix B: Precedent Analysis

Table of Contents

- | | |
|--|--|
| 1. Pixofarm | 12. ARCore |
| 2. Fruitsize App | 13. CropVIEW |
| 3. Electronic Fruit Measurer - GUSS | 14. Perennial's Orchard Tool App |
| 4. EFM - GUSS - single unit | 15. Plantai |
| 5. Produce Measuring Gauge- Cranston | 16. WSU's Centre for Precision Agriculture |
| 6. Banana Calliper - QA Supplies | 17. Spectre by Hectre |
| 7. Citrus Produce Calipers - QA Supplies | 18. Harvest Quality Vision- CropTracker |
| 8. Flexible Banana Length Gauge | 19. Masser BT Calliper |
| 9. Fruit Sizer by Stelzner | 20. FruitVision System |
| 10. Fruit Ring Sizer | |
| 11. Clarifruit | |

PixoFarm Company



Source:

<https://pixofarm.com/>

What is interesting?

Utilises the capabilities of the modern smartphone to capture imagery of fruit to calculate the size of the fruit.

What is innovative?

- Predicted Diameter, production volume forecasting, Growth Rate Estimation, and Size Class Distribution
- The proposed convenience and speed of operating this system using a phone would make this an attractive system for some.

Who is the target user?

This system is aimed at the 'connected farmer' who likes the idea of utilising their cell phone for convenience. They will most likely need good coverage throughout the orchard to be able to capture and store data.

What benefit does it offer?

The ability for a compact and easy to access way to measure fruit. The system is presented in a manner that champions the idea of convenience.

How does it work?

Uses a reference sticker as a method of calibrating the size of the fruit. They do not specify how the product might work in remote locations or how instant the results are collected. While it can count the overall fruit from a distance, individual fruit sizes are done by focusing on only the fruit being measured.

What can be learnt from this?

The fruit measurement requires a reference sticker to be placed on the apple, which can cause damage to the fruit in the process of application and removal. In thick foliage it can also be a challenge to capture the fruit accurately.

Fruitsize App

CQU Sensors in Ag research group

What is innovative?

The app does not require 3G or above connection at the time of capturing the images, but does require a connection when uploading the images and other data to their website. Similar to the Pixofarm model, this concept uses a reference sticker on a background.

Who is the target user?

This app is similar to some of the other projects by the research institute and is focusing on post-harvest measurement, meaning that the technology can either be used by small-scale growers or selectively in packhouses.

What benefit does it offer?

The ability to use a fairly inexpensive phone by today's accounts to measure the size of the fruit. The reference sticker is not contacting the fruit. The app currently only operates on android phones and has a number of specifications about the ability of the camera required to undertake this task.

How does it work?

The user would place the fruit on the plain background with the reference sticker. The app allows you to capture an image which can be uploaded to the online database and data extracted from it.

What can be learnt from this?

The ability to utilise a cellphone to capture initial data may provide convenience and affordability, however the need to upload the data without any immediate feedback when holding the device can generate uncertainty.

Source:

<https://fruitmaps.com.au/static/app/apk/fruitsize%20app%20manual.pdf>

What is interesting?

This app-based fruit measurement solution was developed as part of the research from the CQ University Sensors in Ag Research Group which uses a reference image alongside programming based on the OpenCV software.

EFM (Electronic Fruit Measurer)

GUSS

Who is the target user?

This product is designed for post-harvest measuring and will most likely be used in the orchard or packhouse environment by a seasonal worker or orchard manager as a means of testing.

What benefit does it offer?

Range 12-100mm in diameter
1x 9V battery so that it can be operated remotely.
Measures in mm and inches
Storage - up to 12,000 fruit sizes.

How does it work?

The band around the fruit measures the diameter of the fruit after it has been harvested. While this is non destructive, it can cause bruising on the fruit which will impact its desirability and lifespan to the end consumer.

What can be learnt from this?

It is valuable to evaluate the products which exist within the industry currently as a standard for fruit measurement which is digital but not contactless. The buttons and screen interface are aimed at function, although the ease of reading is questionable. The sealed keypad is appropriate for workers who wear gloves while operating the device.

Source:

<https://freshproduceinstruments.com/electronic-fruit-sizer/>
<https://gasupplies.com/electronic-fruit-sizer-datalogger/>

What is interesting?

Price 600 Euro
This Electronic Fruit measurement unit is seen as one of the more popular devices on the market.

What is innovative?

With the extensive storage capabilities of the device, it is able to compare data from different years and orchards.
This can analyse the data for growth and distribution curves for fruit growth.
There is a calibrating disc included which needs to be done to ensure the device continues to receive accurate readings.

Produce Measuring Guage

Cranston



Source:

<https://qasupplies.com/produce-measuring-gauge/>

What is interesting?

Price \$35

This manual tool allows for quick one handed operation with simple product architecture and quick measuring motion. The device is lightweight and can fit in a pocket.

What is innovative?

This product assists in sizing and sorting as well as the quality inspections. The steel band has both inches and mm sizing, which is beneficial for a global market.

Who is the target user?

This design is made to allow for quick access in the field or in the packhouse, and can be used by harvesters and orchard managers to capture a quick and individual glimpse of what the size of a particular fruit might be.

What benefit does it offer?

The affordability and accessibility of such a product would make it an easy product to deploy without too much concern if it gets lost or broken.

How does it work?

A plastic casing with a steel band - the minimal manufactured parts make it easy to understand and do small repairs on. The simple parts also minimise wear areas and increases lifespan.

The measurements are both in inches and mm.

20 - 100mm diameter range

Accuracy is between 0.010 and 0.25mm

What can be learnt from this?

An affordable and low-tech solution would be an attractive way of solving this issue. The steel band mechanism would come in contact with fruit and cause bruising. The person will be estimating centre by eye, and with no way of recording the information, the size will be very much short-term data.

Banana Caliper

QA Supplies

Flexible Banana Length Gauge

QA Supplies



Source:

<https://qasupplies.com/flexible-banana-length-gauge/>

What is interesting?

\$15 USD - affordable

What is innovative?

A flexible form for measuring that which is non-linear makes good sense.

Who is the target user?

Those trying to measure bananas. This product could be used in the orchard or in packhouse environments.

What benefit does it offer?

A convenient way to measure a complex shape. It is cheap, meaning that multiple of the product can be placed around the environment. A simple product meaning that

it will need to be replaced rather than repaired.

How does it work?

The flexible product can be bent to measure around the outer edge of the banana.

Has measurements in both empiric and metric.

What can be learnt from this?

Different materials and their properties could also be beneficial to consider how to solace the problem of fruit measurement in simple ways.

Fruit Ring Sizer

Who is the target user?

Someone trying to measure fruit, most likely not multiple fruit as the time this product would take to use would be longer than others, and most likely used after the fruit has been harvested.

What benefit does it offer?

Inexpensive option for measuring fruit.

How does it work?

Relies on the user to try different ring sizes to find the one that fits the most comfortably around the fruit. This is a time-consuming and not very accurate solution.

What can be learnt from this?

Having fixed diameter things to test with will not be as accurate and most likely lead to time lost.

Source:

<https://www.virtualmarket.fruitlogistica.de/en/Fruit-rings-sizer.p1426379>

<https://www.trituroni.com/en/callipers-sizers/ring-sizers>

What is interesting?

Aluminium rings that range between 30 - 90mm. This product is made from fruit that is spherical or rounded on one axis.

Clarifruit

This product/system is developed for the post-harvest environment including in packhouses. It utilises a smartphone, which provides an initial idea of convenience

What benefit does it offer?

Clarifruit offers a number of ways in which to engage with the data that has been collected, including the front-end mobile app which gives basic information and summaries and is the tool used for measuring, while the Management Dashboard allows for greater insights, and then also furthered by an Analytical Platform that breaks down the figures further. This allows the user to interact with the information differently.

How does it work?

The more modern smartphone is able to capture an image at a resolution which allows the system to then interpret different aspects of the image to translate into numerical data such as size, and firmness based on light and pixels. See image sending technologies.

What can be learnt from this?

The initial convenience of a smartphone based system might not be as practical in a real-world setting. The system for this design is well thought out and having a summary of data easy to access is practical.

Source:

<https://www.clarifruit.com/>

<https://www.timesofisrael.com/fresh-fruit-and-vegetables-meet-a-suite-of-quality-assessing-software/>

What is interesting?

Clarifruit, alongside the application, has created a system which allows for the data collected to be analysed and for predictive modelling to indicate best next steps for individual growers of fruit and vegetables.

What is innovative?

Clarifruit is a smartphone based app which allows the user to use the camera to find out qualities such as size, stem colour, defects and firmness. It generates a quality Control Report after the measurements have been taken.

Who is the target user?

ARCore



Source:

<https://www.theverge.com/2018/6/22/17492846/google-augmented-reality-measure-app-arcore-tango-update>

What is interesting?

Google has implemented ARCore's capabilities into its Measure App to allow for ease of access to user groups.

What is innovative?

This system is not exclusive to measuring fruit, meaning that it can give you relatively accurate information about an individual fruit.

Who is the target user?

This app-based system currently operates on smartphones including Pixel and Samsung phones, with Apple looking to develop a measuring app which can incorporate this also. This would most likely have best relevance post-harvest and on an individual fruit at a time.

What benefit does it offer?

Highly accessible and low-cost, the app also offers the incentive of not only being developed to measure fruit.

How does it work?

The smartphone utilises its built in camera to capture and augmented reality capabilities to measure the relative width or length of an object, with the user most likely assisting in defining the start and end point of the measurement. This gives an indication of size rather than being pinpoint accurate.

What can be learnt from this?

As with looking at other products which measure irregular fruit such as bananas, we know that measuring in a linear manner is not always suitable. The ease of access to the app is a bonus.

CropVIEW

METOS



Source:

<https://metos.at/cropview/>
<http://staciemeteo.pl/produkt/cropview/>
<https://tillage-live.com/john-deere-and-pessi-announce-new-partnership/>

What is interesting?

CropVIEW systems allow for remote monitoring of crops, fruit and fields.

What is innovative?

This product presents quite a different approach to some of the other existing products which have the capability to measure fruit.

Who is the target user?

Orchards and farmers who are wanting to find out more about the state of their crops and be able to monitor them remotely.

What benefit does it offer?

It can be beneficial to compare images captured from the same fixed position to one another to understand the change over time.

How does it work?

Utilises optical high-resolution camera system which captures images of the monitored area and has the ability to identify individual fruit and from this image infer size. These cameras are placed in a fixed location, ideally not facing directly into sunlight.

What can be learnt from this?

The CropVIEW Tele uses one 10MP camera to focus on a particular area. The dual option incorporates Tele and Panoramic cameras which allows for different views at high quality for monitoring.

The idea of an adjustable angle for the camera is valid as this can suit different types of fruit being measured and how they grow.

Perrennia's Orchard Tool App



Source:

<https://www.goodfruit.com/new-apps-for-thinning-by-handheld/>

What is interesting?

This system is used alongside a set of digital calipers and holds the different fruit sizes and acts as a bit of a calculator to record the sizes and add them up to find a median. The associated app, Malusim, also has a carbohydrate thinning model and fruit growth rate model.

Developed at Cornell University.

Who is the target user?

Orchard workers who wish to measure fruit while attached to the tree and still growing.

What benefit does it offer?

Being able to record the sizes of individual fruit and offer some indication for processes such as thinning.

How does it work?

Digital Calipers are used to measure fruit size which is then typed in on the smartphone which records the size input and uses it to output a CSV file with the data. This is further developed and looking towards how using the smartphone camera can potentially speed up the process.

What can be learnt from this?

Having multiple objects needing to be handled in the process is not ideal from a user experience standpoint.

Spectre Hectre



Source:

<https://hectre.com/blog/method-for-fruit-size-estimation-during-harvest/>
<https://hectre.com/spectre/>

What is interesting?

The system is well presented and has a high level of accuracy. The visualisation of the data is very important and Hectre have managed to do this quite well. They also explain the technology behind their system clearly on their website.

What is innovative?

Fast and accurate data delivered from an iPad or phone. Can measure fruit size and colour.

Who is the target user?

This product is aimed at both the orchard and Packhouse environments to give an indication of the quality of the yield. Currently used primarily in the apple and citrus industries.

What benefit does it offer?

Offers 90% reduction in time spent measuring and a 100% sample size increase.

How does it work?

Simpler colour and environmental setups through the app. Uses the camera from the mobile device (computer vision) and machine learning to distinguish fruit from not fruit.

Fruit images are input into the system and it detects fruit contours and verifies this through the quantity of the data being collected.

What can be learnt from this?

The way in which the product and its function is communicated is often as important as the product itself. This particular example offers very similar functionality to the likes of Pixofarm, but the way in which it is explained is much more tangible and reliable.

Harvest Quality Vision CropTracker

How does it work?

Uses image-sensing technologies to capture images of the produce. This system presents itself in two methods; either in a on-demand tablet system or in a fixed portal installation which views from above in the likes of packhouses.

What can be learnt from this?

The different options depending on the environment is interesting, especially the fixed portal system which represents quite a different perspective than other existing products.

Source:

<https://www.croptracker.com/product/harvest-quality-vision.html>

What is interesting?

CropTracker is able to determine the colour and size of harvested fruit. This system is known within New Zealand already.

What is innovative?

Can measure a wide range of produce including; apples, avocados, beets, lemons, kiwis, peaches, mangoes, pears, oranges, tomatoes.

Who is the target user?

Designed for use in the orchard or packhouse environment to measure produce post-harvest.

What benefit does it offer?

- Highly accurate - within 3mm.
- Flexible payment solutions to suit different user needs.
- A wide range of compatible fruit and vegetables.

FruitVision System

Who is the target user?

Designed for farmers and orchard workers who need to gain information about the state of their crop to assist them in decision making.

What benefit does it offer?

Convenient mobility when it can be mounted to a quad bike and moved around the orchard environment.

How does it work?

The system uses image-sensing technology to capture images in the orchard and feedback data to the user about the state of the crop. It does not outline how it communicates the productivity of the orchard other than a heat map.

What can be learnt from this?

Intelligent Fruit Vision and Washington Tractor have teamed up on the development of this project. They report successful testing demonstrations in New Zealand in 2018.

The mobility of a solution like this is important to consider.

Source:

<http://www.intelligentfruitvision.com/>

What is interesting?

Fruit Vision system is a mounted unit which can capture data and analyse fruit crops to gain a comprehensive set of data about the health and size of the crop.

What is innovative?

This product offering is quite different to the other examples looked at, and can be mounted to the likes of a quad bike to move it around the orchard environment.

Appendix C: Case Study

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9. DJI	23. Naio Technologies
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Halter

Halter is a start-up company that looks at re-inventing the way dairy farms operate. The design of a halter which sits around the neck of the cow allows the farmer to move the herd with ease and virtual fencing.

SOURCE

<https://halterhq.com/>

RELEVANCE - what is interesting?

- This device allows the cow to be guided in the paddock, reducing the need for extensive fencing, saving the farmer time and money.
- It is reliant on cow behaviour being that the device can be fitted to a few and the rest will follow.
- The sensing technologies are sealed within an elastomeric band, making it highly resilient to the elements and for sitting on the cow.
- An example of what design + engineering can achieve for modern farming practises.

WHAT CAN WE LEARN FROM THIS?

Optimise Pasture Management - *Increasing utilisation by to 10%*

- Being more exact with the location of the cows optimises land use and allows the farmer to have control without the maintenance of traditional methods such as fences.

User Experience- *Time saving aspects for the human, minimal disruption for the cows.*

- Integrated technologies in compact units that offer minimal disruption to the cows wearing the halter, and means that the farmer is able to manage the herd from anywhere on the property.

"If you can find a tool that means you are going to look after your land better, look after your animals better, and through that, you make more money, why wouldn't you use it?" — Jay, Waikato dairy farmer

John Deere

John Deere is a popular brand in the agricultural market that is best known for their tractors. although they are exploring new innovations such as drone technology to ensure that their brand is keeping up with the trends and demands in agriculture. But with their new innovations, comes a new cost which is impacting heavily on the user.

SOURCE


<https://www.inc.com/erik-sherman/the-reason-farmers-hack-their-tractors-could-affect-your-company.html>

RELEVANCE - what is interesting?

This case study looks at one of the key issues that many users have with John Deere and that is the serviceability of each product requires you to have a qualified John Deere repairman to have to do the job. This means that farmers are not able to tinker or adjust any software on their tractor or they may be in violation of Intellectual Property conditions and in some cases such as in the United States, may face court. The loss that this can pose to farmers if the tractor is unable to operate during harvest and other important markers is immense.

WHAT CAN WE LEARN FROM THIS?

Creating accessible software, and acknowledging that farmers, particularly in New Zealand have a number 8 wire mentality and want to be able to understand the product as well as the potential of fixing it themselves is something that I will need to consider how to best implement.



UBCO

UBCO has created one of the leading utility bikes worldwide, appropriate for a range of functions, but popular in the Agricultural sector. Released in 2018, UBCO gained popularity through its high-level of functionality, minimalist aesthetics, and sustainable approach to product design. A subscription-service also opens the market to a wider-range of customers.

SOURCE

<https://www.ubcobikes.com/ubco-design-story/>
<https://www.ubcobikes.com/>

RELEVANCE - what is interesting?


- Ability to customise the ride experience with real-time data and associated app.
- Electric with a 120km range - Quiet, no gas, no emissions.
- Accessory Lugs allow for transportation
- All terrain suspension system and a vertical technology stack which includes vehicle hardware and electronics, firmware, software and cloud infrastructure.

WHAT CAN WE LEARN FROM THIS?

Subscription based option rather than purchasing the bike outright, this allows the customer to choose how they engage with the product and provide some financial flexibility.

Modularity - provides a brilliant way of replacing only that which is necessary and the exposed nature of the design.

Fleet design - This allows for the product to act as an individual or work alongside others and can give feedback through its data and AI collection for each bike.



FarmBot

Open Source CNC Farming - The Farmbot is a kitset product designed for backyard, educational and research applications to allow everyday users to experiment and learn more about both robotics and growing food. The associated farmbot app allows for season planning, planting order and is completely customisable for different uses. This makes it a popular product option.

SOURCE


<https://farm.bot/>

RELEVANCE - what is interesting?

- Kitset - Easy to manufacture and attractive to assemble and feel a sense of independence with the growing process.
- Open source software to make the product work as desired by the user, allowing for educational opportunities as well as innovation to be built on this framework.
- Bridging the gap between Robotics and farming, allowing for a digital experience with insights gained about the crop which can allow for decision making by the grower.
- App - The ability to map out planting and plan for a season is useful in the task of decision making on the part of the grower.

WHAT CAN WE LEARN FROM THIS?

The open Source community prides itself on the ability to share knowledge and resources freely, for this knowledge to be built upon and adapted, in the hopes that this elevated knowledge will then once again be further shared with others. Principles within this community are often kitset or modular to allow for easy assembly and adaptations.



Cropsy

Primarily focused on assisting the viticultural industry in mapping out vineyards. Using image sensing technology to assist growers in better decision-making. A recent startup which was introduced to the public at the 2021 Fielddays in June.

SOURCE

<https://www.cropsy.tech/>

<https://www.stuff.co.nz/business/innovation/125574396/ai-tech-cropsy-cultivates-data-to-help-wine-growers-make-better-decisions>


RELEVANCE - what is interesting?

- A New Zealand tech-startup always performs an interesting case study to look at its successes and the area of the market that their work caters to.
- Cropsy utilises a device which can be mounted on a tractor and records data along each row.
- The technology's capability can still be further developed and there are field tests being undertaken during the summer season of 2021 - 2022. - Further development of testing nutritional deficiencies, forecasting and more.
- Current functions include counting bunches of grapes on vines, detecting disease and pest, assisting in the minimisation of crop loss and can estimate yields.

WHAT CAN WE LEARN FROM THIS?

"And I guess our point of difference is that we are focused on something that delivers a solution to multiple challenges, it has to otherwise growers won't use it."

Mounting devices to existing tools being used in this environment may offer a practical way of minimising cost, and testing.



SCION

SCION is a New Zealand based research institute with a focus on innovation in the forestry sector.

SOURCE

<https://www.scionresearch.com/about-us/about-scion/corporate-publications/annual-reports/2019-annual-report/research-highlights/deep-learning-algorithm-can-identify-seedlings>

<https://www.scionresearch.com/about-us/about-scion/corporate-publications/scion-connections/past-issues-list/scion-connections-issue-35-march-2020/surveying-seedlings-for-precision-forestry>


<https://www.scionresearch.com/about-us/about-scion/corporate-publications/scion-connections/past-issues-list/issue-14-december-2016/mobile-scanner-game-changer-for-forestry-management>

RELEVANCE - what is interesting?

- One of their newer project has explored the use of an AI programme to assist in the identification of different types of seedlings in the forest. This project utilising aspects of deep learning and Unmanned Aerial Vehicles (drones)
- This new method of detection is proven to be approximately 94-98% effective and can rapidly detect seedlings within set-out test sites.
- They also utilise a handheld scanner in one of their older projects to capture data about the forest while the user walks through.

WHAT CAN WE LEARN FROM THIS?

It is valuable to see the investment that other New Zealand-based Research Institutes have in the exploration of emerging technologies such as deep Learning methods and the benefits which it has offered them thus far.



Robotics Plus

A technology company who looks at solving issues within the primary industries in New Zealand. It is a well regarded company with multiple awards and a keen desire to consider sustainable, innovative solutions. They have created a number of projects which address contemporary concerns in agriculture/ horticulture such as labour shortages, sustainability for growers, pollination gaps and yield security. The log scaling device also allows for a potentially dangerous task to be done without putting a human at risk while doing a repetitive task.

SOURCE


<https://www.roboticsplus.co.nz/>

RELEVANCE - what is interesting?

- A good example of a New Zealand company leading the way in innovative solutions to the current issues in primary industries
- A range of products within their portfolio is interesting to look at
- They are key stakeholders related to PlantTech, a good company to get in contact with.

WHAT CAN WE LEARN FROM THIS?

That there is a scope for innovation in this industry and that technology is leading the way as part of the solution to many of the big issues within this sector.



Blue Lab

BlueLab are a technology company who best describe their products as allowing controlled environment agriculture

SOURCE


https://bluelab.com/new_zealand/bluelab-peripod-m3
https://bluelab.com/new_zealand/
<https://resources.bluelab.com/brand-story>
'Grow Book - The User Guide, Better plants in the palm of your hand', BlueLab, March 2020, BlueLab.com

RELEVANCE - what is interesting?

- BlueLab meters look at what happens below the soil, which is vital to the health of the plant and cannot be seen visually.
- The user journey of these devices are not clearly stipulated, and there is not a clear indicator of what the output of this data is or how this might be recorded by the user observing it on the small screen.
- The devices measure a number of key factors that allow the user to make informed decisions, such as pH levels, conductivity, moisture meters, temperatures and multi-parameter goods. Alongside this, there is educational resources to assist the user within the system of products to understand what the value of this data might be for them.
- The system claims customisation of dosing and testing systems.

WHAT CAN WE LEARN FROM THIS?

The process of cleaning and calibrating the device occurs often, and the device is battery operated, which is not sustainable if you had multiple sets of the device. - Could the pens be made to be more robust to minimise damage?



Cucumber

A technology company which focuses on creating digital solutions for New Zealand's primary industry. With a user-centered focus to create systems and projects that require Visual communication around concepts or products. Most of their projects have an App Based output.

SOURCE


<https://www.cucumber.co.nz/>
<https://www.cucumber.co.nz/work/kiwicloud/>
<https://www.cucumber.co.nz/work/scion-biosecurityapp/>
<https://www.cucumber.co.nz/work/serena/>
<https://www.cucumber.co.nz/work/comvita/>

RELEVANCE - what is interesting?

- They cater to businesses within the primary sector, but who are in a variety of different specifications and have different requirements and user bases each who will have different expectations depending on the project.
- Cucumber has an emphasis on User experience design, usually through Visual Design.
- Some of their projects include app/ digital based solutions for KiwiCloud App (Plant & Food Research), SCION, Comvita, Tui, and Ports of Tauranga.

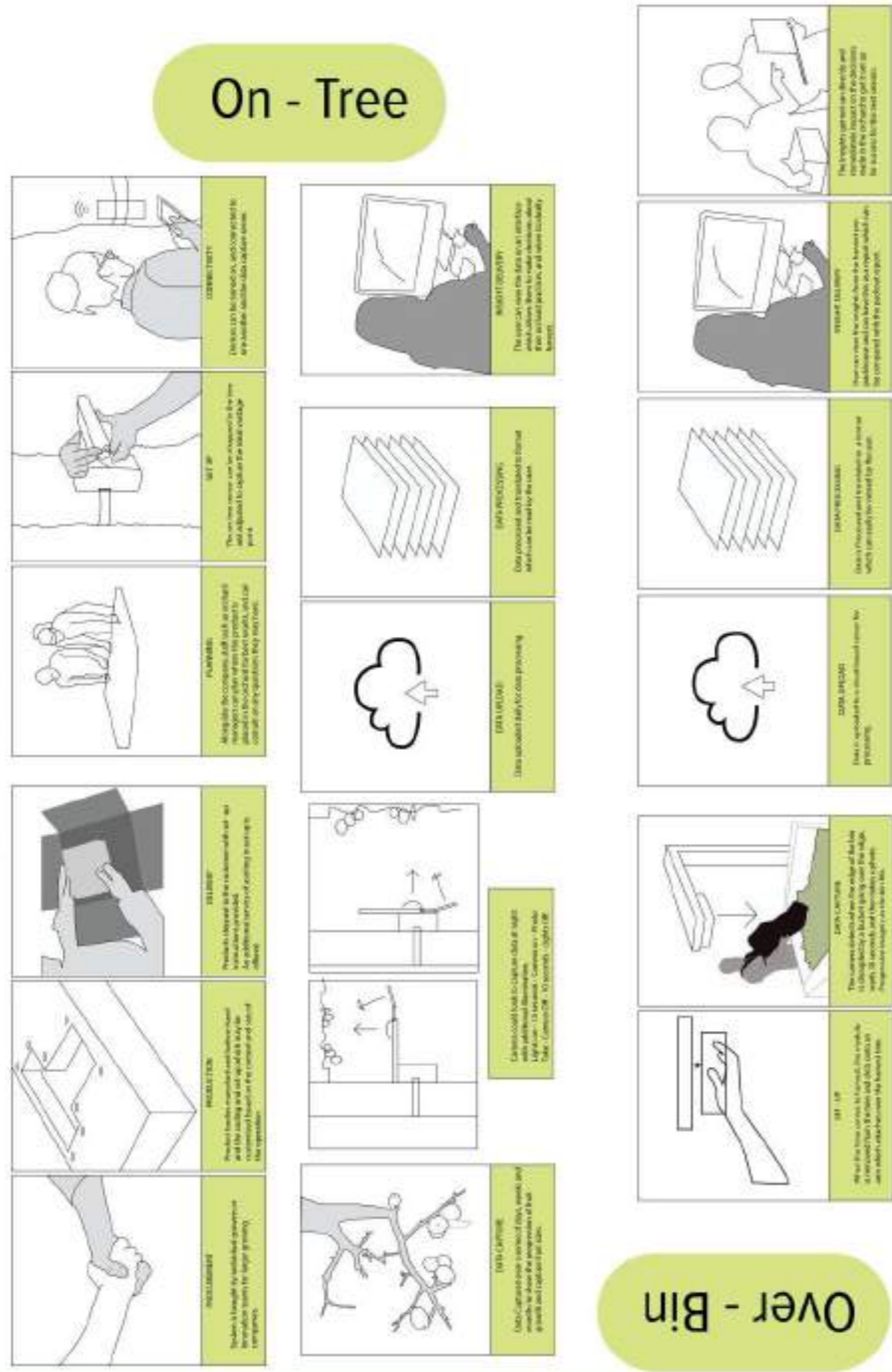
WHAT CAN WE LEARN FROM THIS?

There are a number of innovative companies operating within this space. Mandy Armstrong is from Cucumber and she is one of my mentors for my study, so it is also useful to gain a better understanding of the work that they do at Cucumber and how this aligns with what I am doing.



Appendix D: User Mapping

Ideal Scenario



Packhouse Journey

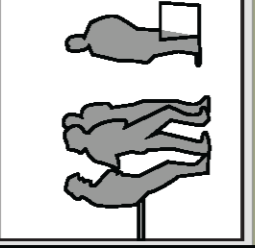
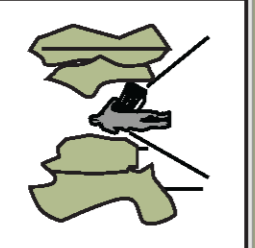
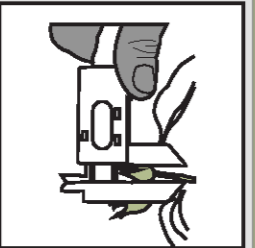
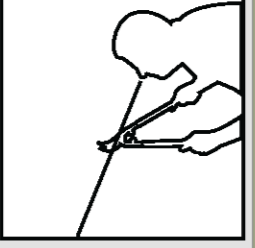
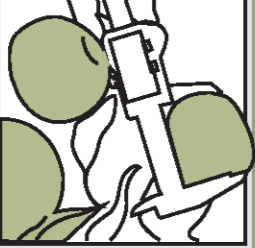
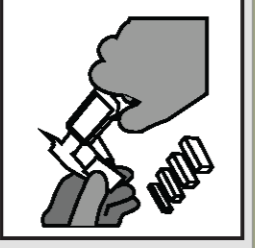
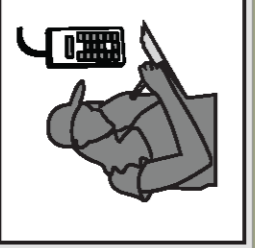
Key Stages & Opportunities

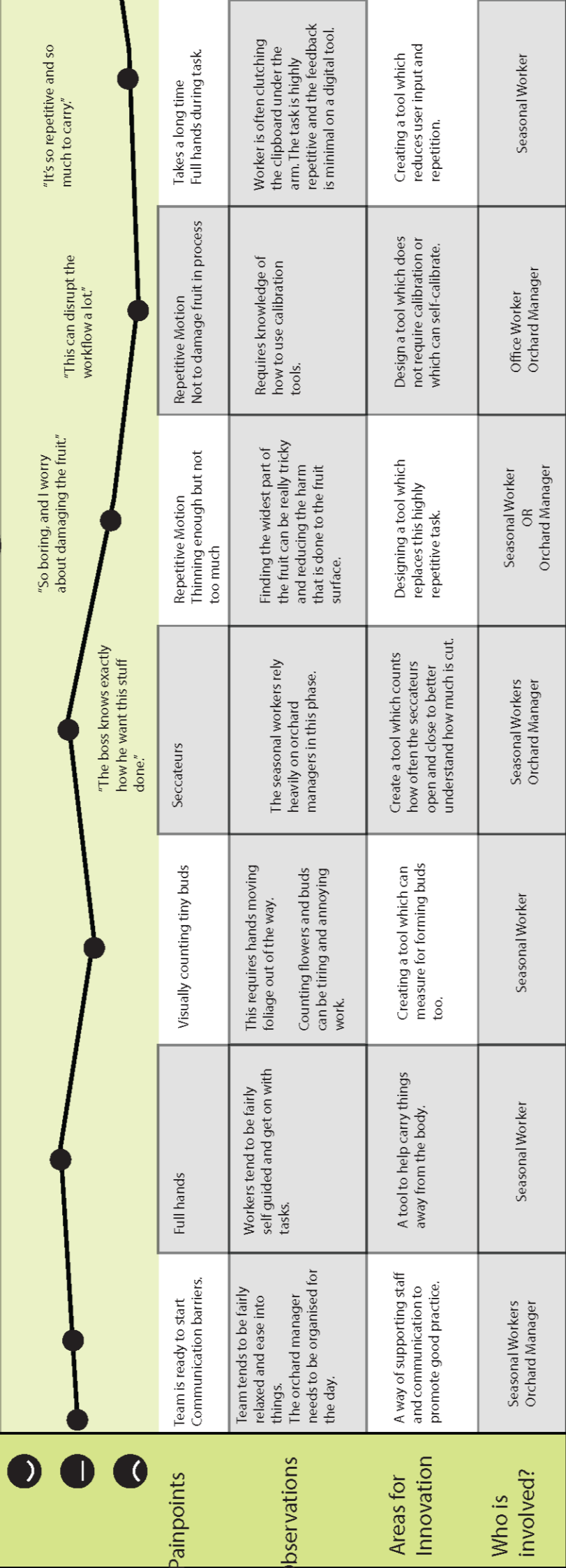
“People like to take photos to document things.”


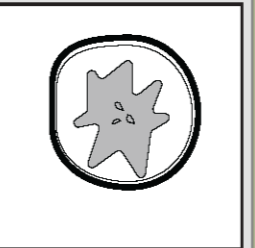
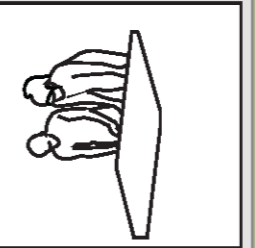
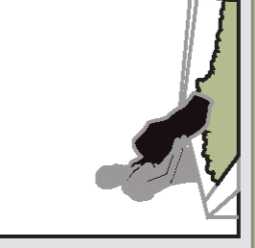
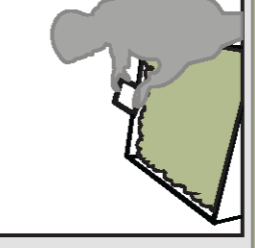
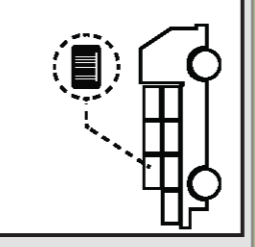

“You wouldn’t believe how difficult it is to put fruit in a box.”

Stage	Harvesting into Bin	Transport to packhouse	Unloaded into packhouse	Bins placing fruit down on conveyor	Manual Graders checking fruit	Quality Control Person	Rejected Fruit	Fruit Sorted by Class	Bins taken to Cold Storage	Bins taken to Distribution	Fruit being transported to supermarket	Insights back to Orchard Managers
Actions	Seasonal workers are hired to harvest fruit into bins that hold about 400 kg of fruit.	Truck moves bins (approx. 32 per truck) to the packhouse. The unique barcode shows where the fruit are from.	Bins are stacked on a truck, and taken to the packhouse, where forklifts shift them into bins.	Bins are emptied onto conveyors where fruit are split based on size, variety and class.	Manual Graders - Pull any visually defective fruit off the line. They log defect types on the system and then	Quality Control Checkers use a range of tools to closely evaluate fruit for	Rejected fruit may be disposed of or be sent to local markets.	Inspected and passed fruit are distributed into bins based on attributes.	Fruit are put into Cool storage until needed for sale.	Fruit go directly to distribution.	Fruit transported to stores for purchase.	A back-out report is sent to the orchard manager, to help them in decision making.
Touchpoints	Bucket Bin Ladders Monitor Devices	Truck Bins Forklift Scanners	Forklift Scanners Pallets Conveyor Belts	Bins Conveyors Forklifts Detection Equipment Flipping arm	Person with iPad Conveyor belt Handling fruit	Magnifying Glass iPad	Quality Control worker Conveyor Belt	Conveyor Belts Bins Detection Equipment	Forklifts Trucks C.A Container	Trucks Forklifts Distribution Center Conveyors Scanners	Trucks forklifts Pallets Store Storage	System Output Packout Report
Experience												
Painpoints	Placing fruit into the bin can cause damage to fruit. Bucket tipping can cause strain on body.	Ensuring that the fruit does not squash and damage. Time sensitive from orchard to packhouse.	Stacking the bins in large outdoor areas, a logistical challenge.	Any fruit that may have squashed leaks onto the conveyor, spoiling the fruit around it also.	Needing to detect fruit while moving rapidly. Needing to remove most, but not all, defective fruit.	Logging defects in system - can currently only log under 1 defect.	Defective fruit can cause whole shipments to be rejected by international markets.	Automating the process occurs due to lack of available labour.	The temperature of the pallet, and factors impact storability.	Delays in distribution channels can have major impacts on the successful delivery of fresh produce.	Ensuring that as much quality produce reaches the consumer is key.	The information is received after the season, and with year to year variation has little relevance at times.
Observations	Bins are central in the orchard rows and being worked around.	Trucks can often be seen lining up towards the packhouse due to the rate of harvesting happening at once.	Placement of bins may use RFID and visual cues to move the equipment around.	Debris from the fruit and branches can enter the conveyor. Manual removal needed.	The machine operates quickly, taking multiple photos and detecting defects with great accuracy.	It is their job to ensure that the manual graders are catching most of the defective fruit.	Defective fruit is sent down different conveyors than the accepted fruit.	Process moves quickly, with scanners throughout the process.	Logistics teams move the produce as quickly as possible to reduce spoiled produce.	Logistics teams move the produce as quickly as possible to reduce spoiled produce.	Fruit are displayed in store, out of the box into which they have been stacked.	A systems Manager needs to be able to help users if any issues are detected with the system.
Areas for Innovation	On/In Bin scanner Wave over scanner	Potentially a scanner above the truck.	-	Ways of reducing damage to the fruit at this stage of the tipping.	Labels are applied straight after by a rotating arm and rubber nub.	Equipment to help quality testing.	Potential to measure more information while the boxes are travelling on conveyors.	-	-	-	-	-
Who is involved?	Equipment Operator Orchard Manager	Equipment Operators	Packhouse manager Packhouse Staff Equipment Operator	Quality Control Graders Logistics Staff	Automation Quality Control Officer	Quality Control Packhouse Manager	Often Automated	Cold Store Manager Cold Store Staff Equipment Operators	Distribution Manager Logistics and Freight Equipment Operators	Distribution Manager Retail Staff	Packhouse Manager Quality Control Officer Send to Orchard Plan.	

Apple Growing and Harvesting Journey Map of a seasonal worker

Stage	Arriving to Work	Entering the Orchard	Monitoring flowers and buds	Thinning	Measuring fruit growth	Calibrating Equipment	Recording Information
Actions	The team meet for the morning to assign for tasks for the day. Orchard managers will go through the agenda and assign tasks as well as check in with staff.	Staff will collect the tools they need from the orchard office or nearby and enter the orchard to begin their tasks.	Staff will manually count flowers and buds as a means of estimating yield.	They will plan how many buds they want per branch and the seasonal worker will go out and use seccateurs to cut off anything extra	Once the fruit is set, they begin to grow around 1% a day. Weekly monitoring of fruit size, colour and condition is a time-consuming task.	Tools such as callipers, which are commonly used to measure need to be calibrated to ensure accuracy.	The information collected while measuring fruit is recorded manually or utilises a tool which can digitally record the information.
Touchpoints	Clipboards Printouts Equipment	Equipment Orchard Environment	Measuring Tool Clipboard Visual Counting	seccateurs	Callipers Clipboard or dig, tool pen	Calibration blocks Callipers	Clipboard + Pen Digital Record tool Callipers (bluetooth)
Experience							
Painpoints	Team is ready to start Communication barriers.	Full hands	Visually counting tiny buds	Seccateurs	Repetitive Motion Thinning enough but not too much	Repetitive Motion Not to damage fruit in process	Takes a long time Full hands during task.
Observations	Team tends to be fairly relaxed and ease into things. The orchard manager needs to be organised for the day.	Workers tend to be fairly self-guided and get on with tasks.	This requires hands moving foliage out of the way. Counting flowers and buds can be tiring and annoying work.	The seasonal workers rely heavily on orchard managers in this phase.	Finding the widest part of the fruit can be really tricky and reducing the harm that is done to the fruit surface.	Requires knowledge of how to use calibration tools.	Worker is often clutching the clipboard under the arm. The task is highly repetitive and the feedback is minimal on a digital tool.
Areas for Innovation	A way of supporting staff and communication to promote good practice.	A tool to help carry things away from the body.	Creating a tool which can measure for forming buds too.	Create a tool which counts how often the seccateurs open and close to better understand how much is cut.	Designing a tool which replaces this highly repetitive task.	Design a tool which does not require calibration or which can self-calibrate.	Creating a tool which reduces user input and repetition.
Who is involved?	Seasonal Workers Orchard Manager	Seasonal Worker	Seasonal Worker	Seasonal Workers Orchard Manager	Seasonal Worker OR Orchard Manager	Office Worker Orchard Manager	Seasonal Worker



Stage	Reviewing Insights	Maturity Testing	Harvest Planning	Harvesting into Bins	Capturing Data	Bins onto Trucks	Insights Reviewed
Actions	The data collected can be reviewed to help orchard managers have a dataset of fruit sizes to aid in their decision-making.	Once the fruit are at a size, colour and weight where they may be ready to pick, a 20 fruit sample is done to estimate the maturity of the fruit.	Orchard managers and species technicians may look at the information gained and walk through the orchard to plan where they will start to harvest from.	Pickers utilise a range of tools to pick fruit they deem to be ready for harvest. They may do multiple rounds of picking.	There are some pilot studies which use I pads to capture photos of the bin to try and estimate the yield at the end of the picking season.	Once the bin is full, it is loaded onto a truck to be taken to the packhouse (see this process on subsequent journey map)	Any remaining information about the season is reviewed (such as the possible scanning of bins) to help orchard managers decide on following steps.
Touch points	Computers Spreadsheets	Dendrometers Scales Iodine Sprays	Ground scans Data Sheets Satellite imagery	Bin Bucket	Tablet Bin	Bins Trucks Forklifts/Tractors	Computers Spreadsheets
Experience							
Painpoints	"It takes a few minutes to figure out what I am looking at."	"\$500+ a test, you better be ready."	"It is all about timing."	Heavy bags Rushing if paid by bag or bin	Photo not taken straight on - makes for inaccuracies	This process is time sensitive and needs good logistics management.	Lots of data, difficult to reference.
Observations	Often this section requires good understanding of statistics and specifics about the orchard.	This phase measures a range of factors including brix, weight, calcium, etc.	This can take some time + requires in-orchard understanding.	This is not always done very carefully.	This is an emerging part of the process that has lots of interest.	Any data prior to the packhouse report is useful for assisting in decision making.	Any data prior to the packhouse report is useful for assisting in decision making.
Areas for Innovation	Simplify Information Stream	Design a non-destructive measure of testing.	Creating a live dashboard of orchard performance.	Reducing damage to the fruit when emptying the buckets into the bin	Creating something that can capture data straight over the bin	Allowing for greater data sets and how this data is communicated.	Allowing for greater data sets and how this data is communicated.
Who is involved?	Orchard Manager	Quality Control Services/ Companies OR Orchard Manager	Species Technician Orchard Manager	Seasonal Pickers Equipment Operators	Seasonal Worker OR Orchard Manager	Equipment Operators	Orchard Manager Board/ Owner

Think and Feel:**Hear:**

- machinery operating
- Reversing trucks
- People talking and laughing + singing
- wind through the leaves and trees
- Birds
- Cars driving on gravel path
- Sprayers
- Orchard Managers giving guidance
- Different Languages

Say and Do:

- Giving instruction for new workers on how to do certain processes
- moving through the orchard, visually evaluating tree health and infrastructure.
- Heavy Physical Labour
- No pockets to put things into - Tuck tools into clothing
- Fiddly tools
- Using Phones to capture data

See:

- The scale of the orchard can be quite overwhelming
- Nervous to meet people with expertise
- Windy in rows- tied up hair
- Grass below feet.
- Thirsty
- Hot sun
- lots of activity in the orchard
- Leftover apples rejected on tree
- rotten apples under tree
- big wooden posts
- wires to train shape of tree
- signs at start of orchard
- row widths vary between orchards
- people working in orchard
- guys on coffee break
- gumboots and safety gear
- Reflective vests
- grass between rows
- gravel path
- harvest bins
- harvest platforms
- sprayers
- tractors
- lots of leaves
- hail netting
- Trees

Pains

- Usability of many of the products.
- Little data to make decisions from.
- Needing to train new people often.

Gains

- Rewarding nature of producing food
- Outdoor and stimulating work
- Undertsanding about the labour, and skills required to grow food.

Empathy Map

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- machinery operating
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Participant 1

Business Owner
Passionate about innovation in the AgTech Sector.

Experience

Started developing the system when there weren't really any local competitors, allowing them to develop over the past 2 decades

Their "Why"

Created a system when they identified that there was a gap in the amount of data people had about their orchards and felt that technology could help solve this.

Motivations+Goals

- To offer innovative products and systems to consumers.
- To ensure validation, testing and trust in the system to promote ongoing use.

Primary Tasks

- Managing company, interests and new innovations to implement into the existing systems.
- To manage the relationship that the company has with stakeholders.

Working with:



Product Expectations

Expects a high-level of usability in the products delivering.

Wants to have a reliable system.

Data Driven and Analytical.

Engineer so excited by visuals of new concepts, but analytical in personality so is likely to scrutinise for value. Has worked in industry for many years, so has seen many of the trends that have come and gone.

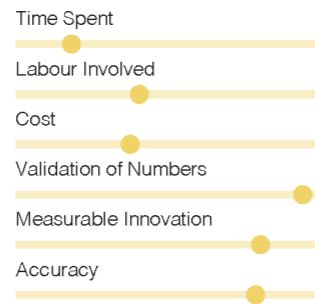
Is optimistic for a technology/ automation-filled future in the packhouse industry.

Has a number of systems that are suited to different parts of the growing, packing, and storing processes as well as one that span across the process to deliver insights.

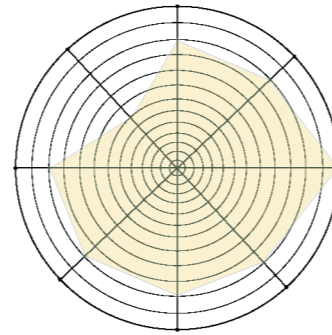
Time constrained.

"There are so many facets that make up part of our decision-making... it can also have knock on effects."

Priorities



Trust Factors



Technology Confidence



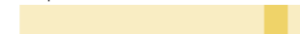
Interface Navigation



Personality



Experience



Frustrations + Painpoints

Wanting to make the system more approachable for those with low levels of technology competence and acceptance.

Quality Control and Inventory management.

Wanting to identify opportunities to meet further needs of user groups and ways of improving the system.



Participant 3

Individual Grower and Manager

Dedicated to being an Organic Kiwifruit farmer and cares about the legacy of the orchard.

Experience

Been working in orchards since 17, with 40 years of experience.

Their "Why"

Passionate about the land and growing the best possible harvest each year.

Motivations + Goals

- Aims to have the best possible yield.
- Believes in organic growing even if it takes a bit longer.
- Wants to be successful and up to date in kiwifruit innovations but doesn't always know where to start.

Primary Tasks

- Managing the orchard
- Making key decisions throughout the season about actions in the orchard.
- Tracking changes and yield counts in the orchard to inform choices.

Working with:



Tools Using



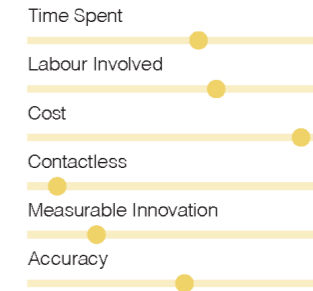
Product Expectations

- Cost efficient
- Time Saving
- Practical
- Happy for it to be something that could hold their smartphone.
- Familiar and simple products.
- Less technological, but wanting to utilise it if it offers benefits.
- Needs to be explainable and show clear benefits.

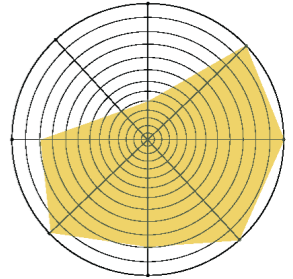
Frustrations + Painpoints

- The cost of current tests that measure things like sugar levels, yield etc. without clear insights.
- Getting the timing just right.
- "We are all winging it."
- Cost limiting how often testing occurs.

Priorities



Trust Factors



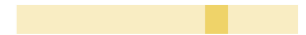
Technology Confidence



Interface Navigation



Personality



Experience



"We are all winging it... it changes so much from season to season"



Participant 2

Business Analyst

Driven to bridge the gap between technology and people.

Experience

Has developed their work as a business analyst over time and always had interest in the AgTech sector and applying their knowledge and expertise there.

Their "Why"

Passionate about the system and thinks that it could make the lives easier for a lot of people.

Motivations + Goals

- Creating a successful system that integrates into current operations.
- Ensuring the gap between the system and the users is bridged through engagement and testing.

Primary Tasks

- Communicating the system to new users, troubleshooting any issues as they arise, and managing the relationships that people have with the system and the business.
- Identifying opportunities for innovation in the system.

Working with:



Product Expectations

Efficient
Time saving
Trustworthy engagement
Validation of data
Easy to Use
Simple User Interface

Much of their work focuses on helping to make the system easier to understand for users and to make sure that any faults are picked up early and fixed.

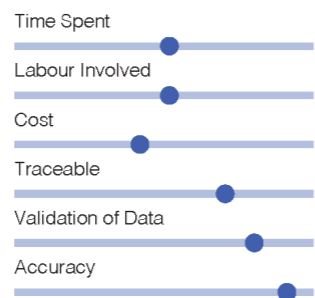
Creating a simple user interface can help make it easier to navigate for anyone

Very familiar with the processes involved in packhouses and how their systems work alongside this.

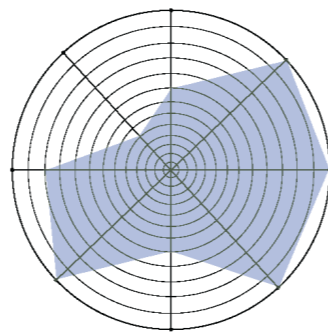
Frustrations + Painpoints

Laggards - Individuals who are particularly against the introduction of technology.

Priorities



Trust Factors



Technology Confidence



Interface Navigation



Personality



Experience



"You wouldn't believe how difficult it is to put fruit in a box"



Participant 4

Grower Services Rep.

Working alongside growers, packhouses and stakeholders to implement orchard management systems that help with efficiency.

Experience

Immigrated to New Zealand, and saw a massive shift in terms of attitudes and practices. Believes technology holds the answer but is not confident with it.

Their "Why"

Wanting to use orchard management systems to help growers in their work. Likes innovative thinking and applying it to their work.

Motivations+Goals

- Encouraging people to capture data as they can to help make informed decisions.
- To help growers see the value in using orchard management systems.

Primary Tasks

- Bridging the gap between growers and packhouses to facilitate orchard operations.
- Going out to sites and assisting in services such as data collection.

Working with:



Product Expectations

- Responsive
- A productivity rather than management solution is needed.
- Easy to communicate
- Continuous monitoring throughout the season will allow for the best tracking.
- Historical Data will have benefits.
- Thinks that a multi-faceted approach will be useful.
- Visualising the data will have many benefits.
- There is a need for measuring tools.
- Getting the timing right is crucial for efficient farming.

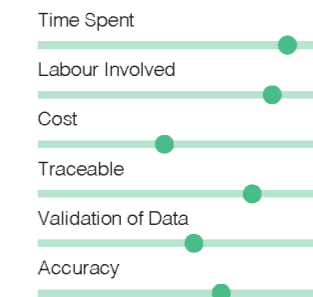
Frustrations + Painpoints

Technology adoption and acceptance can be improved by making familiar, explainable products.

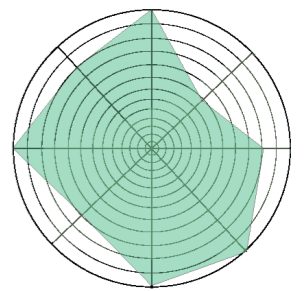
Being able to explain the technologies that are involved to users and stakeholders.

Concerned about Nutrient Loss and how we might be able to measure this.

Priorities



Trust Factors



Technology Confidence



Interface Navigation



Personality



Experience



"I'm generally checking how new technologies work for others to know what we should be implementing"

Often undertaking the task of measuring on behalf of other companies and groups.

Enjoys creating relationships with companies and fostering innovative practice.



Participant 5

Technical Board of Company

Wanting to deliver measurable innovation for the orchards they work with.

Experience

Most have been in the industry for around 20 years, but their engagement with the orchard versus system varies based on their roles.

Their "Why"

Wanting to maximise efficiency and promote advanced practices to the orchards they work with, and deliver benefits of yield increase to their stakeholders.

Motivations+Goals

- Finding solutions alongside and for growers that could better their outputs.
- Finding cost-effective partnerships for their company to convey these technologies.

Primary Tasks

- Managing orchard practices and equipment, providing suggestions for next steps based on data and expertise.
- Connect with Industry Partners to better capabilities.

Working with:



Product Expectations

A younger company open and excited for new innovative technologies and incorporating them into their practice.

Needing data that can be incorporated into existing dashboards for users.

Think that there is great value in utilising technologies and being able to map out the change in the orchard environment throughout the season and yearly so that they can have comparative data that informs changes in the orchard and to compare which practices are more effective than others.

Wants a system that is clear to understand and can easily be translated to an end user.

Opportunity for collaboration and working alongside to be able to speak to a range of users and contacts.

Frustrations + Painpoints

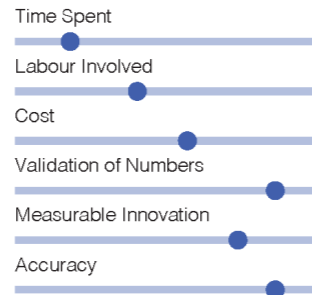
The inability to map out a range of things in one place.

Water is an increasingly important factor. The lack of customisation of systems to meet their specific datasets and needs.

The lack of historical mapping of the same sites.

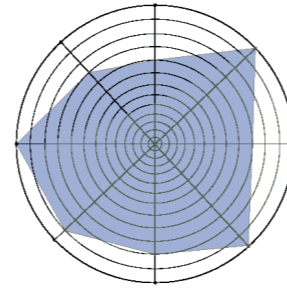
Ensuring that data is understood easily.

Priorities



"We want to better understand orchards to help us prepare for the future of an industry which is seeing great deals of change."

Trust Factors



Technology Confidence



Interface Navigation



Personality



Experience



Participant 7

Pipfruit Division Head

Working for a progressive company hoping to adopt new technologies and invest in progressive methods.

Experience

Has previously invested in new technologies and applied it to orchard practices.

Their "Why"

Maximising yield and orchard operations to ensure a successful season while also ensuring that they have a competitive edge in the pipfruit industry.

Motivations+Goals

- Focused on maximising yield and using tools that can assist them to do this in a practical manner.

Primary Tasks

- Procuring new innovation to implement and test in operations.
- Monitoring overall results and yield to inform operations.
- Working with support companies and groups to build relationships.

Working with:



Product Expectations

Interested in understanding year on year variability

Adapted Vertigation - weekly to fortnightly at start but then down to daily.

Fruitlet test - done in Early December - this could be a good time to measure.

Agri-chemical checks

Ground trthing
Constantly cutting new wood which takes away from the apples

End January - Fruit weight - calcium on size

Fortnight before harvest as a final check.

Frustrations + Painpoints

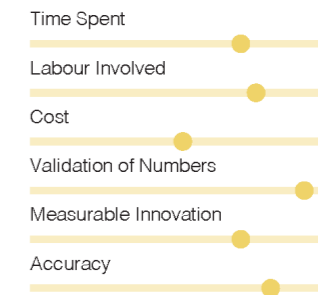
Interested in Calcium and how this impacts storage.

Fruit measurement as important.

Interested in Calcium and how this impacts storage.

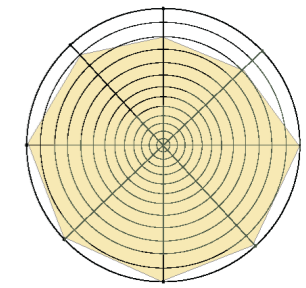
Fruit measurement as important.
Interested in trunk circumference.

Priorities

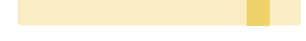


"I enjoy trying new tools to try and make the most of our orchard... it's expensive at times but the benefits outweigh the risk thus far."

Trust Factors



Technology Confidence



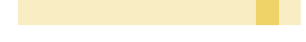
Interface Navigation



Personality



Experience



Participant 6

Packhouse Worker

Working in a range of roles within the packhouse to pack, organise and communicate between groups.

Experience

Worked in the packhouse after immigrating to New Zealand and has been working for 5 years.

Their "Why"

Passionate about getting the perfect box of fruit out and enjoys the physical, and unique challenges that comes from working with fruit.

Motivations+Goals

- Motivated to provide for their family, and to work their way up in the packhouse through showing care in their work.
- Detail- oriented so enjoy looking for defects.
- Money to support family.

Primary Tasks

- Packing boxes of kiwifruit based on size.
- Cleaning their station, defect detection.
- Stacking the completed boxes onto a pallet beside conveyor.
- Communicating with others and supervisor.

Working with:



Product Expectations

Is moving around a lot unless at a designated station - needs something portable.

Needs something that can verify what is being looked at easily.

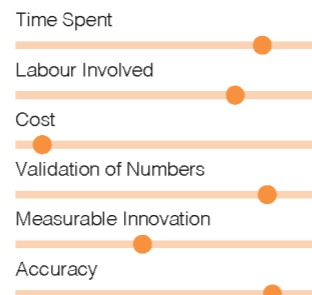
Want something light that can be out the way until needed.

Something that is secure when moving above the conveyors.

Something easy to use, speedy, and which confirms actions.

Only needing to be charged every so often or can grab another one and keep working.

Priorities



"It is a big operation... we often don't have enough hands on deck to support us."

- The speed of needing to enter details is slower than their brain is moving.
- Can only log 1 defect per defective fruit.
- Protective equipment all day can be tiring and annoying.

Environment

Incredibly Loud - Machinery and Music.

Already using tablets, computers, scanners and scientific equipment.

Everyone with designated roles and posts.

A busy, things moving environment.

A lot of fruit passing manual and electronic checks before getting packed.

Technology Confidence



Interface Navigation



Personality



Experience



Participant 8

Global Variety Technician

Commercialisation company specialising in the generation of new fruit. A company built as a venture from an existing initiative.

Experience

Over 25 years of experience and operates as a network of experts in the apple sector.

Their "Why"

Dedicated to innovation and developing new variations of apples to international markets that meet consumer preferences.

Motivations+Goals

- Concerned about calcium levels and its correlation between leaf and fruit.
- Getting insights at the right time throughout the growing phase.
- Brix and Starch factors.

Primary Tasks

- Working alongside growers and labs to develop new varieties of fruit.
- Understanding what international consumer desires are and addressing these in new variations.

Working with:



Product Expectations

Ground trthing - checking in orchard.

Not always sure of the maturity areas.

Timing as crucial.
Turn around of satellite plane imagery data - returned within a week would be useful.

Designing a fool-proof device or system

Year to year variability

Dashboard that tells you where things are at.
Mechanism to include/ exclude technologies.

Resolved some background interference with apples

Fruit quality prediction

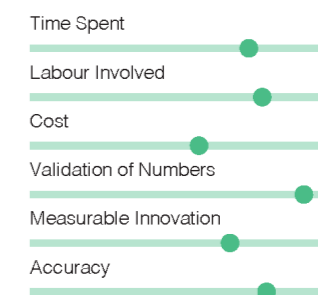
Frustrations + Painpoints

Can we confirm the work done by remote sensing using ground platforms?

Picked up issues of internal browning in Nelson.

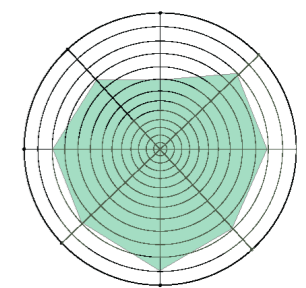
Currently packhouse insights are not beneficial enough as it comes at the end of the season and variations year by year means that the data is often not relevant anyways.

Priorities



"Every year we get a surprise because January was hot or cold. It's always down to some old guy saying 'Oh, this tracks like the summer of '96 or something.'"

Trust Factors



Technology Confidence



Interface Navigation



Personality



Experience



212



Participant 9

Technical Manager

Working with a range of produce and a large, diverse workforce. The participant is eager to implement innovation into the orchard to deliver benefits.

Experience

A family business with a long and proud legacy, learnt over time and about the same piece of land so has a good understanding of the sector and trends

Their "Why"

Creating a good quality, organic product, keeping the legacy alive and maximising the yield for stakeholders.

Motivations+Goals

- Community driven
- Approachable and Friendly - passionate about innovation in the apple sector.
- Maximising yield and operating in a sustainable manner.

Primary Tasks

- Building relationships with technical firms that could benefit them.
- Understanding the current yield and what the issues might be that impacts the yield throughout the season.

Working with:



Product Expectations

Bigger sustainability emphasis Family + Community Sense

<800 staff

Part of the RSE Scheme

Measuring 2 days a week each week with a team. Using digital calipers

Using as a reporting tool

Every week is 1% aimed growth increase.

Starch tests Pressure tests

Opportunities for harvest strategy and Planning

2700 fruit approx measured over the 2 days.

Being able to predict forward would be very useful to give any indication of next steps.

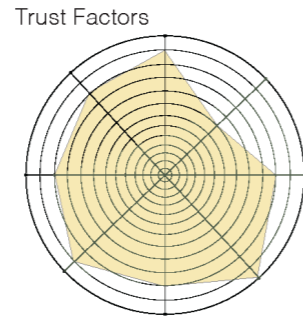
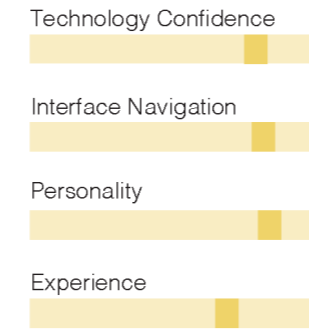
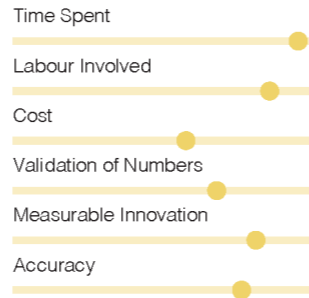
Terminal size Distribution of size Count Rolling bigger number for export guys

Very Friendly and approachable.

20 fruit sample test colour, pressure, Brix, starch

Timeliness. - when the right time is to measure

Priorities



Frustrations + Painpoints

Work with Crop Tracker HQV Scanning bins for size by waving phone over it Lidar phone being used.

Conscious of sustainability impact

AFS - Cumbersome - System in its infancy still and uploading slow. Smart Phone

Motivations+Goals

- Getting a visual tool to help them understand the insights from data and implement that into current practices.
- To reduced variation within the crop.

Primary Tasks

- Finding new innovations that can be implemented into operations.
- Working with staff to understand what is needed to help solve issues in the chain of operations.

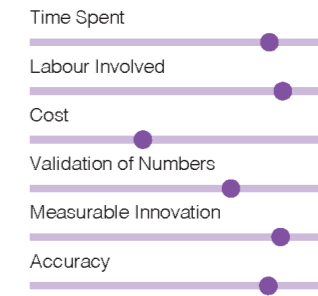
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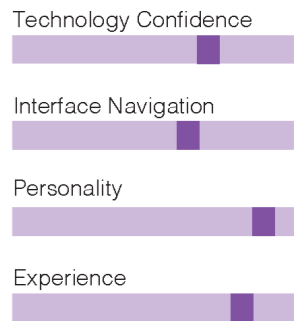
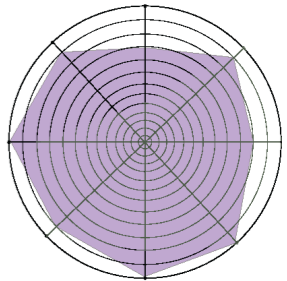
Product Expectations

Envy, Jazz and Rockit as main variations of apples they grow. -Requiring good insights within a reasonable amount of time. -Discussed the need to be able to identify colour. -interested in colour, starch pattern index (SPI), pressure, brix. -Willing to spend a sizeable amount on the right system. Currently using weight as a proxy for size. -Counting fruitlets would be useful for them pre and post thinning. -Key for colour and size. - Water usage, sustainability, crop estimation, inventory management, orchard management system is important for them.

Priorities



Trust Factors



"We need practical solutions that we can implement and test in a cyclical way, most development happens during the growing season."

Frustrations + Painpoints

-Discussions on the current practices and the concerns around meeting objectives. -Biggest risk is labour management. -Variation between apple variations, but also at different heights in the tree. -tried many systems with little return so they are interested in the point of difference they can have.



Participant 11

Innovation Manager

Interested in furthering the technological advancement of the sector and employing techniques to better their understanding of yield.

Experience

12years of understanding in the industry with a background in Engineering. Interested in how the system works, and how it can be implemented into current practices.

Their "Why"

Practical problem solving needs to be implemented soon to help compete against other markets that are technologically well-advanced. Cares about the logistics and getting the job done.



Participant 10

Orchard Manager

Knowledgeable and interested in bettering the quality of the yield and the information they can use to inform operations.

Experience

Has worked in the sector for some years, works directly with orchard managers and growers. Is after a practical solution.

Their "Why"

Passionate about the apple sector and producing good quality food.

Motivations+Goals

- Maximising yield and using tools to help inform decisions that have to be made about operations and logistics.
- Wanting to get accurate readings and some prediction ahead.

Primary Tasks

- Working with growers to understand the harvest and make decisions along the way.
- Working alongside others to find innovative solutions to integrate and test in the orchard.

Working with:



Product Expectations

Stores quite long - into next January Depending on block weather

Calcium at fruitlet stage - impacts where to stack in cool store

Most useful: Sizing Scanning

Earlier we know the better.

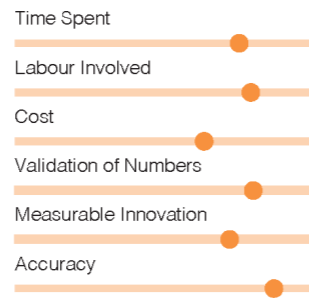
People with callipers.

Getting fruit size is vital

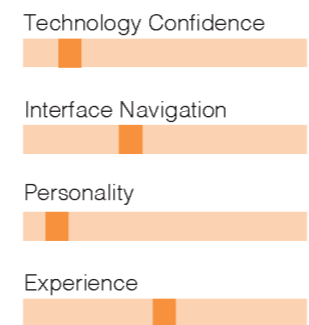
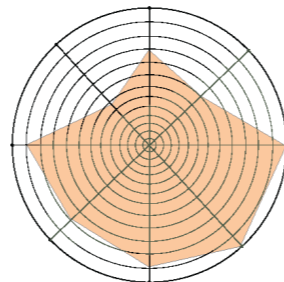
Blocks that range - generally they know their good and bad blocks, and the unpredictable ones are the struggle.

0.7 MSE value is good for them - "better than the sample accuracy we often have."

Priorities



Trust Factors



Frustrations + Painpoints

Concerned about data security.

Wanting to provide measurable innovation in comparison to competitor companies in the same area.

Concerned about storing fruit - ensuring that the harvest reaches an end market.

"Would be nice to have a bit of notice."

Motivations+Goals

- Motivated to reducing variability in the crop.
- Working with others to solve issues in a practical manner.
- Motivated to educating new workers about best practice and passing on skills.

Primary Tasks

- Identifying new areas of research and development to test for implementation.
- Practical problem solving and communications with industry partners.

Working with:



Product Expectations

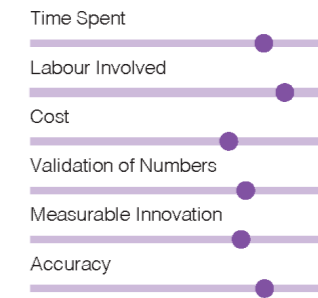
For a product to be clear and concise with what it is doing and how to function.

Interested in SPI, Starch, Brix, colour and size. Growing multi-leader trees and not planning on shifting to FOPS. Would be useful to know the final average count not the export count, so measurement pre - packhouse is useful.

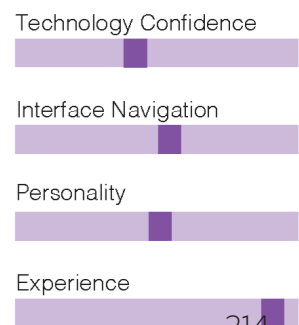
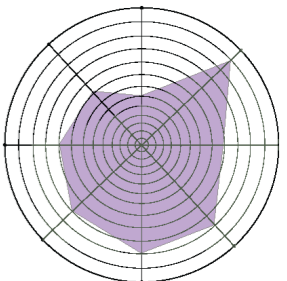
Utilises a secondary company to come in and do their measurement for them.

Interested in understanding the physiology of the fruit.

Priorities



Trust Factors



"We need people to be able to pick up a device and be able to use it. The time to learn a device's functions is not a luxury we have... it needs to explain itself as we go."

Frustrations + Painpoints

The inability to pass on knowledge to staff that they know they will be able to retain for a long time.

Having tried many new solutions which in the long run hold very little benefit.



Participant 12

R&D Manager

Has tried many different systems and finally settled on a method of data collection that suits their needs.

Experience

Has worked in the sector for a number of decades alongside others and is very experienced, but also, very concerned about the lack of new long-term staff to retain the knowledge built up.

Their "Why"

Passionate about growing good food and utilising all the insights available to make informed decisions. Has used new technologies as they have emerged over time.



Participant 13

Seasonal Worker

Joined the working team on the orchard and is learning on the job how to maintain the orchard and support harvesting.

Experience

This is their first growing season and they are anxious to do a good job and to learn about the processes.

Their "Why"

They are home for the summer from University and figured it would be nice to spend time outdoors during the nice weather.

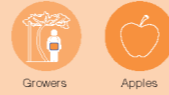
Motivations+Goals

- They wanted a job that allows them to make money over the summer holidays.
- They want to enjoy their time in nice weather and get out of the house.

Primary Tasks

- Receiving instructions from Manager and going into the orchard to execute the tasks.
- Pruning, measuring, pest removal, and then moving onto assisting with picking the fruit.

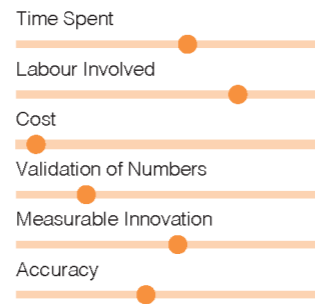
Working with:



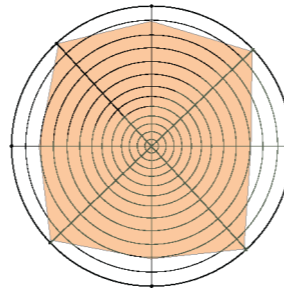
Product Expectations

- The product needs to not take up hand-space while doing daily operations.
- Needs to be fool-proof as they were struggling with even basic tools due to unfamiliarity.
- Reducing repetitive tasks where possible is useful.
- Screen or material glare from products can be really annoying.
- Products that can explain what they are doing and give you options is useful.
- Product needs to be easy enough to move - lots of heavy things in the orchard so reducing this would be useful.

Priorities



Trust Factors



Technology Confidence



Interface Navigation



Personality



Experience



Frustrations + Painpoints

The fruit bin bags can be quite heavy but are pretty comfortable.

Frustrating when you need to pick carefully but are being paid by the bin, while also reducing the damage done to the fruit in the process.

"It's hard work in the orchard, fulfilling, but hard. If a tool can speed up or make the process more comfortable that would be great!"



Participant 14

Seasonal Worker

A seasoned worker who comes back every year. Enjoys the physical nature of the job. Family-focused and enjoys the social nature of teamwork.

Experience

Has worked as a seasonal worker for the past 10 years, returning to the same orchard for the past 7 years due to the positive working culture and infrastructure at the orchard.

Their "Why"

They are family-focused, and enjoy the support they can offer their extended family by doing this. Out of season they work as a Freelance Carpenter.

Motivations+Goals

- Driven to support their family.
- Enjoys the physical nature of the role.
- Paid by the hour so aims to minimise damage and pick carefully.

Primary Tasks

- Works with the orchard manager to perform maintenance tasks.
- Support new workers to learn skills.
- Prioritising picking and setting up the orchard tools for harvest.

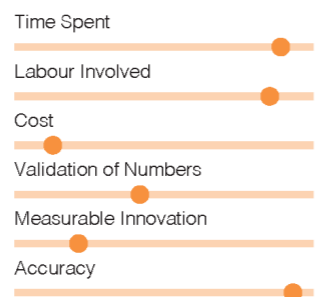
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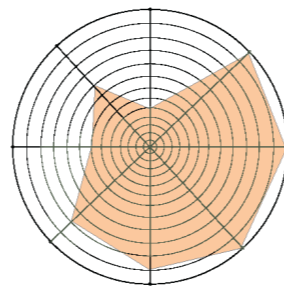
Product Expectations

- A practical, easy to understand solution.
- A product which is durable and won't break easily.
- A product which works with large hands.
- Clear information they can report back to their manager.
- Easy attachments and troubleshooting.
- Easy to spot so they can direct younger staff from a distance.
- Needs to be situated in a way that reduces it needing to be carried in a hand.

Priorities



Trust Factors



Technology Confidence



Interface Navigation



Personality



Experience



Frustrations + Painpoints

Products that pinch the skin when they fold up.
Products that have too many steps involved (as it often becomes their job to set up any new tools)
Instructions that are embedded in the tool or on a clear - image based form (rather than thick user manuals)

"Practical, accurate, and durable. If it's too complicated I probably won't use it."

Appendix E: Ethics Protocol

Data Management

Algorithm Bias is problematic in its ability to discriminate based on the data sets that already exist in our world. The reason the existing datasets hold consequences is that many of them are built on systems that are unjust, unequal and driven by the views of programmers and those who create the data sets and their parameters, sometimes unknowingly. Identifying who a system benefits, aspects of ownership and privileges should allow for a better understanding of assigning roles and responsibility when needing to resolve issues, rather than passing along blame.

The first step is awareness of the bias that can exist within an algorithm and dataset. I as a researcher need to be wary of the impact that my world lens might have on the way in which I conduct my research so as to promote inclusivity, to ensure that my worldview is not the only one that is considered, and to not only employ binary outcomes such as “right or wrong”. When gathering data, it is important to identify outliers and patterns as the study progresses as these outliers may have unique stories, reasons and intentions which allow me to better understand why the data is forming in the way it is. This means that I am less likely to be dismissive of aspects of the data after the fact. The data that I collect as part of this study should also not be used in another study without a clear acknowledgement of the context in which the data was collected, as this is often where bias has the most opportunity to mislead.

Te Tiriti + Data Sovereignty

Inclusive research that allows voluntary participation of individuals working in the horticulture space can allow for great insights and will be reciprocated by providing shared knowledge of how technology could benefit current practices and user experiences in the orchard environment.

Since a large percentage of seasonal workers are of Māori or Pasifika ethnicity, it is important to acknowledge traditional knowledge and connection to the land. Understanding worker rights, migrant fears and inequalities that might make participants feel obligated to answer in particular ways need to be acknowledged, as well as fear of repercussions from employers because of the answers given. Breaking down the stigmas and formalities of institutions will assist in making the participant feel at ease with how any information is being collected, being open to them sharing knowledge from their perspective and also ensuring that the outcome of the study does not have any repercussions for employees through the strict management of data and anonymity of responses.

Confidentiality

All participant data is anonymised unless prior permission is given to utilise direct quotes, images, or recordings (both audio and visual) for use in publications such as the thesis.

Personal data such as contact details for participants (in cases where the researcher has had to either contact via email, phone or in person) will be kept separately from the research data and will not be published or shared by the researcher. Personas will assist in the protection of individual participants and their views, thoughts and concerns by pulling together the key insights gained from the participants rather than reflecting an individual. If a participant wants further clarification than what has been outlined on the information sheet they can contact me directly, or raise any concerns with my supervisors.

Data

Recording of the data will be done using a range of methods based on the context and preference of the participant. Data will be recorded using methods such as notebooks for writing notes or drawings, a phone or digital camera for recording images, audio, and/or visuals, computer for recording any large amounts of data such as in-field sensor readings (if appropriate for later parts of the study). All of these forms of recording will be listed in the information sheet and consent form so that participants can indicate which methods they are comfortable with, while also having the option to opt-out of any questions. The data will be stored on the Massey OneDrive of the researcher, with contact details being stored in a separate file location to the individuals in the study. This raw data will not be used as part of any other studies. The data will be retained for a further 5 years after the completion of the study and disposed of by the supervisors of the study. Any recordings of a participant can be disclosed to them at any time they might request it.

Conflicts of Interest

No Conflicts of Interest were foreseen in this study as the relationship between Massey University, myself as a researcher and PlantTech were well defined as part of the original agreement. Through intervention of the Massey Intellectual Property Manager, IP rights from the research that continued transferred to the researcher and Massey to the researcher and Massey University at the time of PlantTech’s liquidation.



24/02/2022

Dear: Zene Krige

Re: Ethics Application - SOA 21/57 - Fruit Measurement Agricultural Robotics: Developing Usability across complex systems

Thank you for the above application that was considered by the Massey University Human Ethics Committee.

Human Ethics Southern A Committee at their meeting held on **Tuesday, 8 February 2022**

On behalf of the Committee I am pleased to advise you that the ethics of your application are approved.

Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and Director (Research Ethics)



Fruit Measurement Agricultural Robotics: Developing Usability across Complex Systems

INFORMATION SHEET

Project Description and Invitation

The purpose of this project is to design a fruit measurement device which can assist in decision-making with regards to crop development and harvesting. The project explores how we talk about new technologies and the interactions we have with these objects. For those working in the orchard, the project seeks to make the task of measuring fruit size an easier and safer task, reducing the amount of time spent and allowing for greater accuracy in the information being collected. This project will be done in collaboration with PlantTech, a research institute dedicated to innovation in the AgTech sector.

Participant Identification and Recruitment

You are invited to participate in this research as your experience and knowledge in this area would greatly benefit the project. Participation should not pose any discomfort or risks. It is completely voluntary, and if you change your mind you can withdraw from participation at any time. If you are uncomfortable in anyway please indicate this to the researcher.

Project Procedures

The researcher will have compiled a number of questions prior to meeting, these are not strict talking points, any additional insights, observations or knowledge that you would be willing to share with the researcher is welcome and appreciated. You are not obligated to answer questions you are uncomfortable with, or wish not to discuss. Please also feel free to ask questions. Participants interested in continued engagement will be sent follow up questions as the project progresses.

You have been invited to attend one of the following activities, the duration of these are listed below.

60 – 90 minutes – Interviews and Focus Groups

10-30 minutes – Observation, in-orchard interviews, and survey.

Data Management

The information collected from this research will be used to inform the development of ideas and approaches for new designs and improvements on the current systems in place for fruit measurement. Your responses will be collected anonymously and none of your



Researcher Introduction

Researcher Name: Zene Krige
PhD Candidate – School of Design

responses, imagery or quotes will be shared with third parties or published without your prior consent. The method used for preserving confidentiality will be through the development of personas; anonymised representation of users and their needs collected, this protects the identity of all participants.

If you are interested in the outcome of the project, it is your right to receive a summary of the project. Email hello@zene.design to request this at the completion of the study (around July 2024)

Participants Rights

You are under no obligation to accept this invitation, if you decide to participate, you have the right to:

- Decline to answer any particular question
- Withdraw from the study at any time
- Ask questions about the study at any time during participation
- Provide information on the understanding that your name will not be used unless you give permission to the researcher
- Be given access to a summary of the project findings when it is concluded in July 2024.
- You can ask for the recorder to be turned off at any time during the interview.

Project Contacts

Researcher Name: Zene Krige
Email: hello@zene.design
Contact number: 021 123 1122

Supervisor Details:

Rodney Adank
Associate Professor, Industrial Design
College of Creative Arts
r.p.adank@massey.ac.nz
+64 (0)4 801 5799 ext 60634; 021 423 615
Massey University
James Coe Industrial Design Centre
Buckle Street, Wellington

Please feel free to contact either myself and/or my supervisor if you have any questions or concerns about this project.

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 21/57. If you have any concerns about the conduct of this research, please contact: Dr Negar Partow, Chair, Massey University Human Ethics Committee: Southern A, telephone 04 801 5799 x 63363, email humanethicsoutha@massey.ac.nz

Research Ethics Office, Research and Enterprise
Massey University, Private Bag 11 222, Palmerston North, 4442, New Zealand T 06 951 6841; 06 95106840
E humanethics@massey.ac.nz; animalethics@massey.ac.nz; gtc@massey.ac.nz

Fruit Measurement Agricultural Robotics: Developing Usability across complex Systems

FOCUS GROUP PARTICIPANT CONSENT FORM

I have read, or have had read to me in my first language, and I understand the Information Sheet attached. I have had the details of the study explained to me, my questions have been answered to my satisfaction, and I understand that I may ask further questions at any time. I have been given sufficient time to consider whether to participate in this study and I understand participation is voluntary and that I may withdraw from the study at any time.

1. I understand that I have an obligation to respect the privacy of the other members of the group by not disclosing any personal information that they share during our discussion.
2. I understand that all the information I provide will be kept confidential to the extent permitted by law, and the names of all people in the study will be kept confidential by the researcher.

Note: There are limits on confidentiality as there are no formal sanctions on other group participants from disclosing your involvement, identity or what you say to others in the focus group. There are risks in taking part in focus group research and taking part assumes that you are willing to assume those risks.

3. I agree to participate in the focus group under the conditions set out in the Information Sheet attached.

Declaration by Participant:

Signature: _____ Date: _____

Full Name - printed _____

Fruit Measurement Horticultural Devices: Developing Usability across complex Systems

Participant Consent Form - Individual

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time. I have been given sufficient time to consider whether to participate in this study and I understand participation is voluntary and that I may withdraw from the study at any time.

Please indicate your agreement or disagreement to the following statements.

I agree to the interview being sound recorded.

<input type="checkbox"/>	Yes
<input type="checkbox"/>	No

I agree to the interview being image recorded.

<input type="checkbox"/>	Yes
<input type="checkbox"/>	No

I wish to have a copy of my recordings returned to me.

<input type="checkbox"/>	Yes
<input type="checkbox"/>	No

I agree to participate in this study under the conditions set out in the Information Sheet.

<input type="checkbox"/>	Yes
<input type="checkbox"/>	No

English is my first language.

<input type="checkbox"/>	Yes
<input type="checkbox"/>	No

If you feel you are not confident to share your knowledge in English, please nominate someone who you are comfortable with and who would be willing to translate for you.

Their Name: _____ Signature: _____

Participant Details:

Signature: _____ Date: _____

Full Name - printed _____

Appendix F: Methods answering Research Questions

1. What factors of trust are the most important in creating reliable product and system interactions for end users?

- Literature Review
- Contextual Review
- Semantic differential
- Interviews
- Personas

1.5 What are the existing issues of trust and how do they operate between active agents?

- Interviews
- Literature Review
- Perception Mapping
- Task Analysis
- Journey Mapping - Scenario Mapping
- Personas

2. What is the true nature of a fruit measurement device?

- Precedent Analysis
- Visual Analysis
- Case Studies
- Site Visits
- Observations/Photo Studies

2.5 What are the existing fruit measurement processes and their user experiences?

- Task Analysis
- Ergonomic Analysis
- Journey Mapping
- Personas
- Site Visits
- Observations and Photo Studies
- Interviews
- Immersive Research

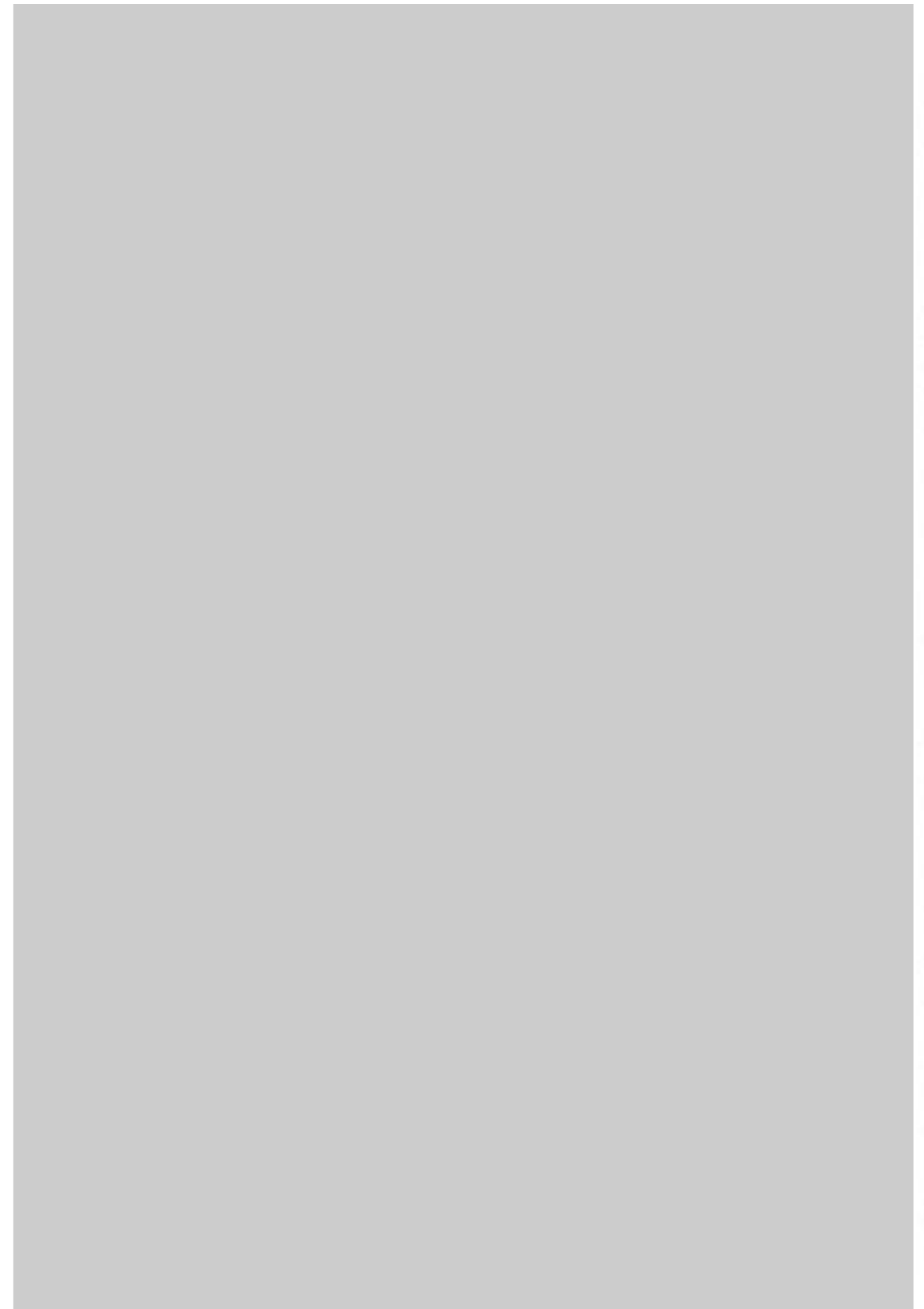
3. How is that products' subsequent data collected and visualised to inform the development of understanding and decision-making for end-users?

- Case Studies
- Visual Analysis
- Immersive Research
- Task Analysis
- Interviews

3.5 What methods of data visualisation are most appropriate for the horticultural sector in New Zealand?

- Visual Analysis
- Interviews
- Observation
- User Testing
- Personas
- Perceptual Mapping

Appendix G: Maturity Measure Sheet



Appendix H: Concept Log

1. Blue One



What was being tested?

This concept was designed to hold a Samsung Galaxy Note 9 and look up at the tree to understand the initial idea and its feasibility.

Components:

- Body 1 - to hold the phone - 3D printed
- Lid - with acrylic lining to keep water out - 3D printed
- Hose clamp - to attach around the tree

Observations:

- The hose clamp took a long time to attach using a screwdriver and would not be practical as a final means of attachment.
- If a phone were to be used it would need to be fully waterproof.
- The clear cover distorts the image captured by the phone. This would need to be reviewed.
- The hose clamp attachment area worked well.

Next Steps:

- Move away from the use of the phone as it is unlikely to be the final mode of capture.
- Find ways of stabilising against the tree
- Could be interesting to capture information about the tree from the band going around the trunk.

2. Kiwifruit Test Mount



What was being tested?

A mount was designed for the kiwifruit environment and allows a Go Pro to be attached and held in place. The camera was set to capture an image per day and managed by a fellow researcher who lived in the area.

Components:

- Go Pro camera in protective casing
- 3D printed arm - 2 parts - the main section and a lid
- Hoseclamp.

Observations:

- In order to not damage the kiwifruit tree, this concept was attached around an infrastructure post and set to capture imagery of a cluster of emerging fruit.
- The hose clamp is not practical
- The arm is short and could be made longer
- Keeping the device in the same place even when handling the camera is crucial.

Next steps:

- Improve the sturdiness of the device
- Find ways of better supporting the camera
- Find a way to power the camera for longer than just a few hours.

5.Box Concept



What was being tested?

Creating a box that is able to hold a battery, with wiring holes from the battery to the camera, and a telescoping arm to allow for adjustable length and reach. The band passes through the body of the container.

Components:

- Body - 3D printed white - two sections, one holding a specific power bank and the other allowing the strap to pass through without the battery being exposed to moisture.
- Lid - 3D printed black - holds the arm while fitting onto the main body, with holes that allow for cables to pass through.
- Arm - 3D printed white - has a hole that allows Go Pro to hook into it.
- Grunt Versa Strap - Orange
- Go pro Camera in protective case

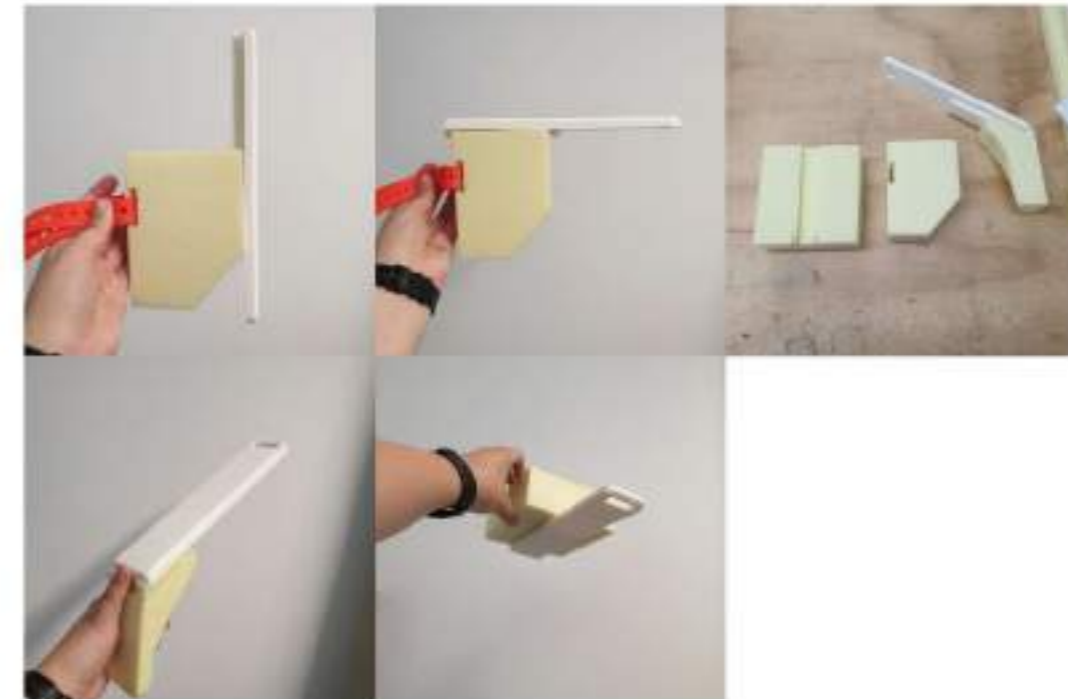
Observations:

- Black and white contrast well with each other and in the tree, and white is one of the colours which can attract bees, so there is a lot of benefit to using it.
- A zip tie had to be used to keep the 'lid' of the box securely on due to the tolerances not being tight enough.
- The Go Pro was not stable facing away from the lid, but when turned around, the slight rise between the arm and the lid allows it to be much more stable.

Next steps:

Minimise battery space, better the balance of the device, find a way of reducing the size, and reflect on the technologies that might be needed in the final design.

16. Proof of modularity concept



What was being tested?

The versatility of the rail system was tested using foam modelling to represent the ability to attach the same component (white) to a number of different objects with different intended functions, such as on-tree, on a handle and over-bin. This is a simple way in which we can introduce scalability into the product architecture.

Components:

- On-Tree foam block - showing the white section attached vertically and horizontally
- Handle Foam Block - Showing the white section slotting into a handle component
- Over Bin Block - showing the white section hanging in place.
- Grunt Band for attaching to tree (Orange)
- White - 3D printed railing section which symbolises the camera fixture.

Observations:

The system is simple but could allow for a lot of opportunities to be developed and for the product to scale to meet different user needs.

The same white section needs to be designed to work well in each use case.

Next Steps:

Identify which cameras are likely to be used and bring this into the form consideration.

16. Zed2i System attempt



What was being tested?

How we might incorporate our thinking from the previous concept into a concept which now utilises the Zed 2i camera. The Zed2i camera is represented by the part with the two dots on it.

Components:

- Zed2i Camera copy - 3D printed in grey
- On Tree Casing - 3D printed in Grey
- Rail arm - 3D printed in Grey
- In Box Unit - 3D printed in grey - Considering how the camera might be placed over a bin unit.
- Grunt Versa Strap - Black.

Observations:

The relationship between the rail mechanism and the camera feel disjointed and flimsy.

The mechanisms need to have a way of stopping the railing from passing all the way through.

The over-bin unit looks impractical and bears little relationship to other parts of the system.

Next Steps:

Develop the form of the concept and explore the railing mechanism further as well as alternatives to it.

38. Multi-Directional Attachment Idea



What was being tested?

This concept was looking at simply creating two holes through the body to allow for attachment in a horizontal or vertical position.

Components:

- Camera
- Battery
- Indicator Lights

Observations:

This concept solves the problem of multi-directional attachment, and the distance of the camera away from the trunk.

This concept felt like there was not enough material at the bottom and towards the back of the device to support a balanced attachment against the tree.

Next steps:

Possibly explore how this idea could be better balanced.

39. Strap Mechanisms - Test



What was being tested?

Focusing on the band attachment section and its usability, these prototypes were trialling ideas to see what was the most practical and give some direction for future prototyping.

Components:

- Measuring tape
- Green 3D printed parts

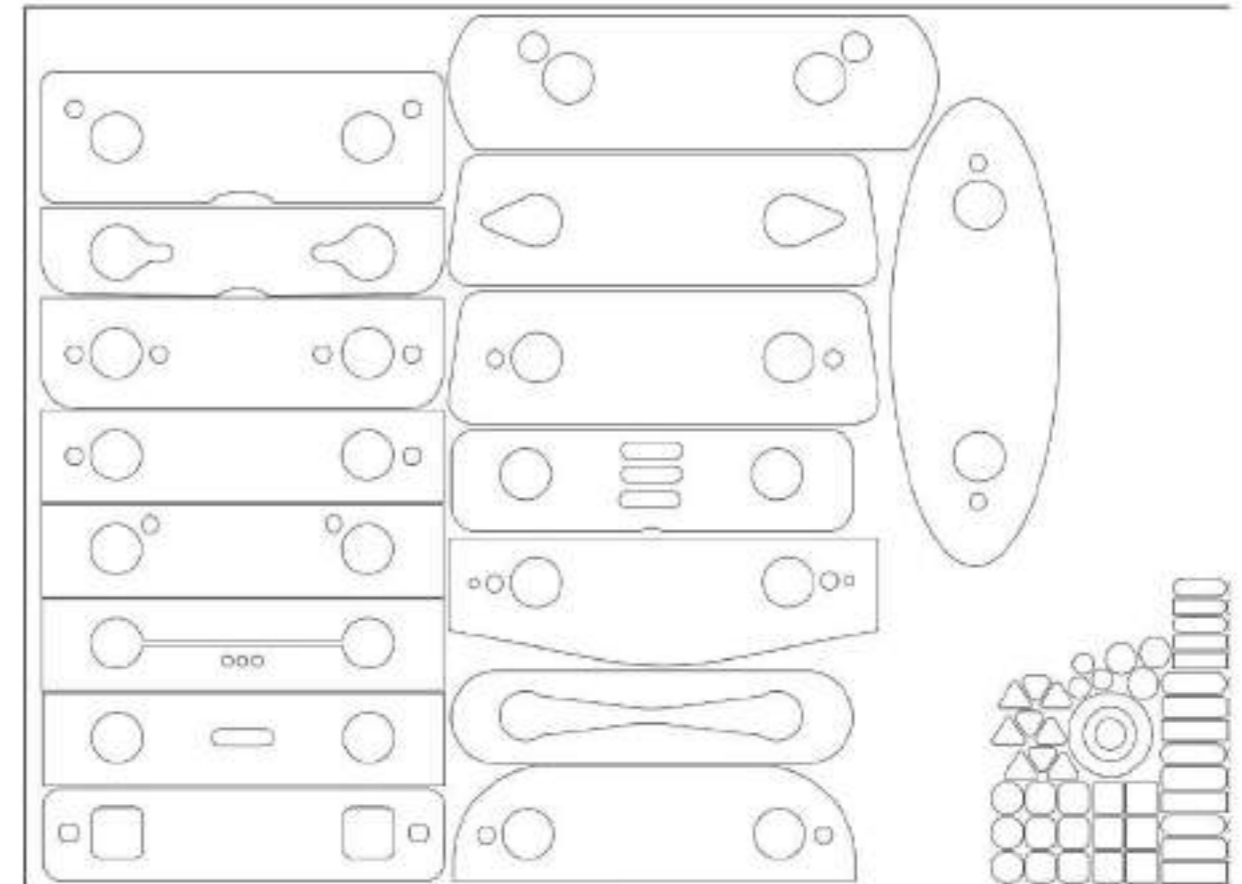
Observations:

- Having a solid area for holding onto speeds up the process.
- The pinch idea (bottom right) actually held the best, but was hardest to set up, the top right was most usable, the top left was most fidgety due to the bad tolerances between objects.

Next steps:

- Find a more accurate and secure way of attaching
- Test with a weight or object on the other side.

48. Anthropomorphic Faceplates



What was being tested?

These face plates were lasercut to understand the different faces that can be created through the use of form and line. The eyes from the Zed 2i camera means that there is the unintended consequence of a character being shaped, so the ability to manage this perception is vital.

Components:

- Lasercut out of MDF

Observations:

A Number of students looked at these and managed to give some feedback - I think it would be interesting to test this with different generations as the connections made were with characters from animated movies.

Next Steps:

Find ways of implementing this information into the design of the object,

51. Science-Fiction Inspired.



What was being tested?

This concept was testing a different approach to thinking about the form and looking at how the form could be compacted down a great deal. This concept also tests the alternative camera layout to see how it impacts the aspects of anthropomorphism.

Components:

- Over Bin arm - With a hinge to help stabilize the arm when opened.
- On Tree Mount allowing for vertical and horizontal attachment.
- Compact Device that can flick out to lengthen distance from tree trunk when looking up into the tree.
- Battery inserts into the body of the device in a way that reduces change of water damage.
- Indicator lighting showing battery level.
- Rubberised around the camera to protect it.
- Buttons in different shapes to assist in the communication of use.

Observations:

- The Button shapes being different can help ease the communication of use between previous and new user scenarios. It can also bridge language barriers, which is a common occurrence in the orchard environment.
- By having the camera lenses in this orientation, it means that the aspects of character is much less visible.

Next Steps:

Further explore this concept

59. Minimalist Slim



What was being tested?

This concept was looking at applying much of the understanding and observations prior into one model to test a number of factors. The form sought to sit down and around the trunk circumference if made from a slightly flexible material.

Components:

- Solar Panel on the back of the arm
- Arm that slots into place
- Device.

Observations:

The arm slotting in could save a lot of space when disassembled. Need to consider how the arm would be made and out of what to promote stability.

Next Steps:

Explore this concept further.

Appendix I: Initial Concept Presentation

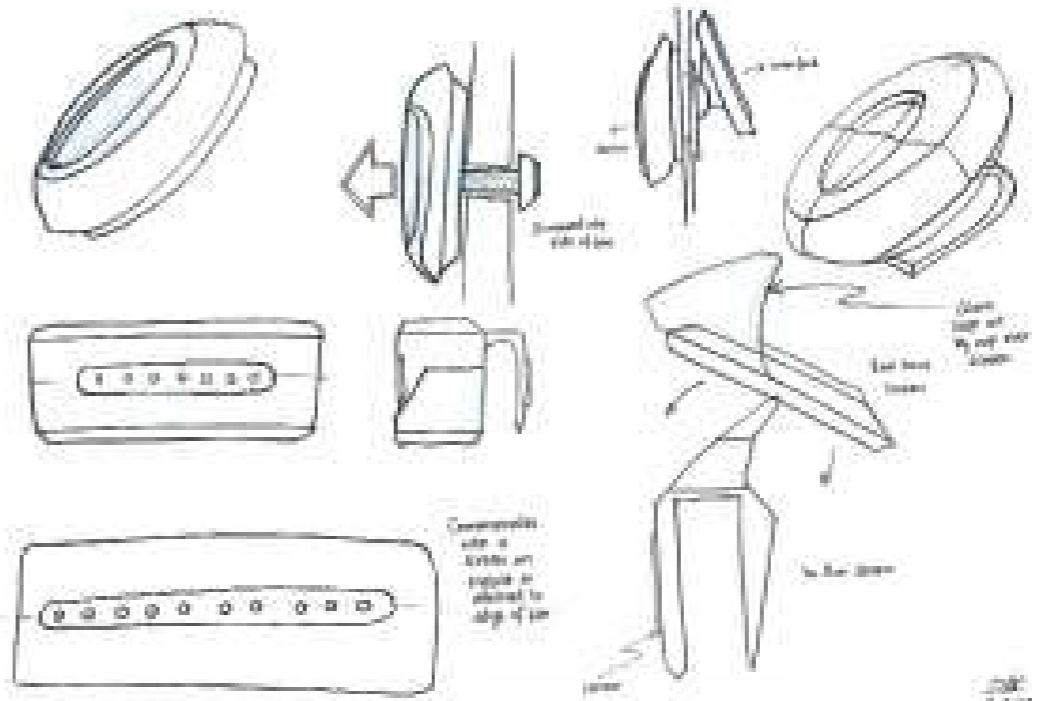
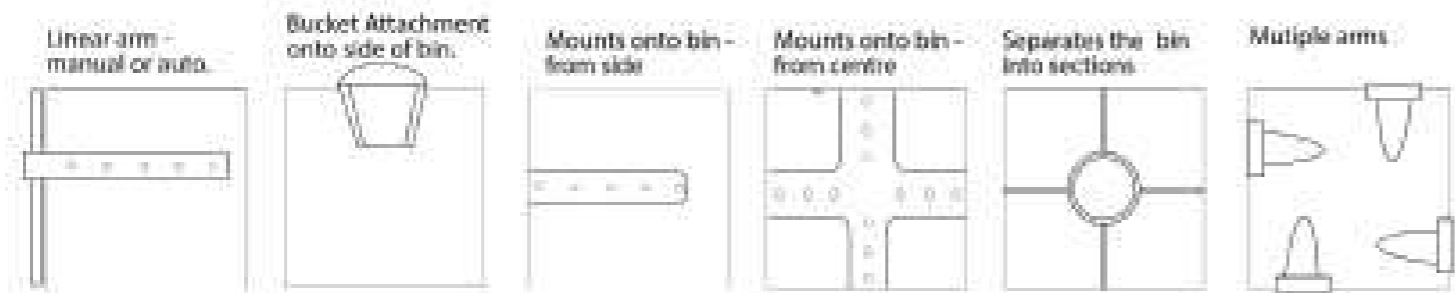
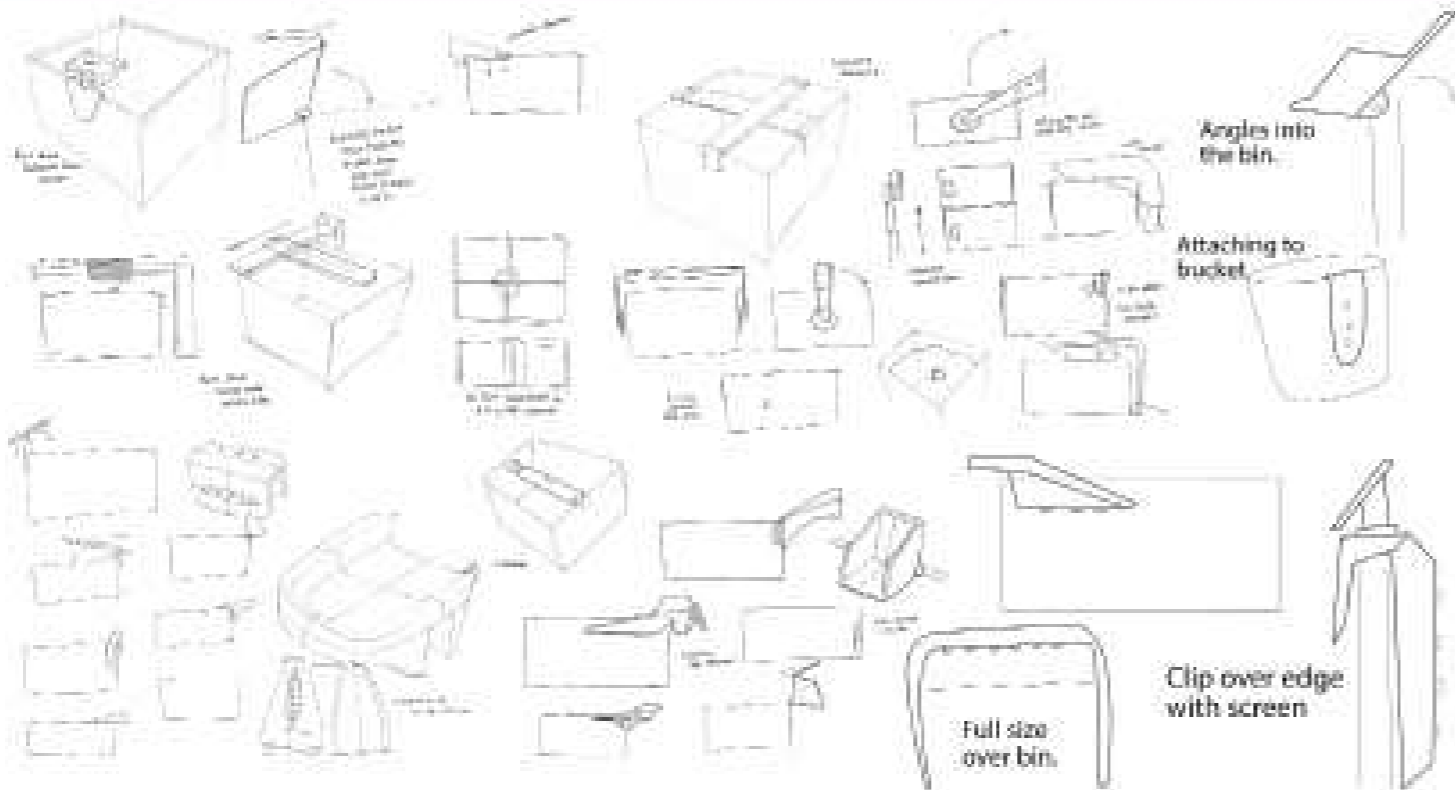
On/In Bin



This concept looks at measuring fruit once they have been picked and placed into a harvesting bin. These sensors would capture the fruit as it enters or lays in the bin. The concepts either attach to the bin or stand beside it.

The design should not hinder the operations of those emptying buckets into it. Timing becomes an important factor once the fruit is picked, and care needs to be taken to reduce any damage done during this stage.

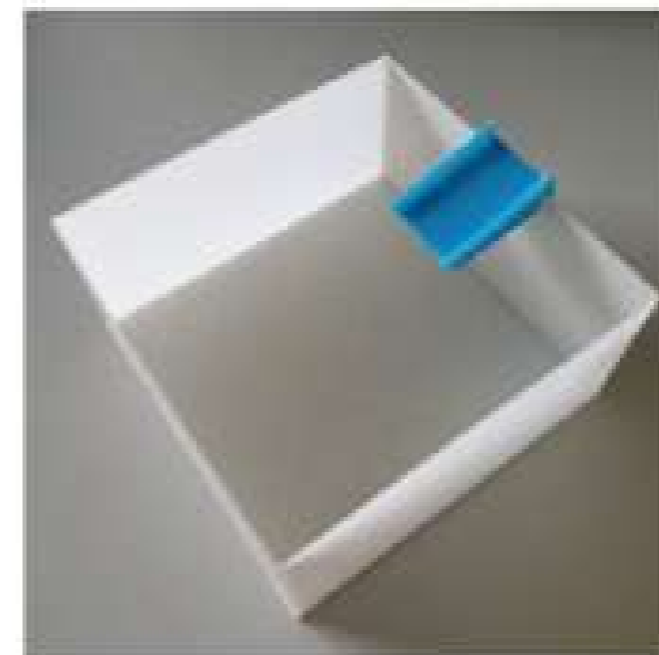
Near real-time feedback may be displayed on a screen to show how the sizes are progressing, and which may help ensure that the bins are packed with relatively similar sizes to assist in yield estimations and operations in the packhouse.



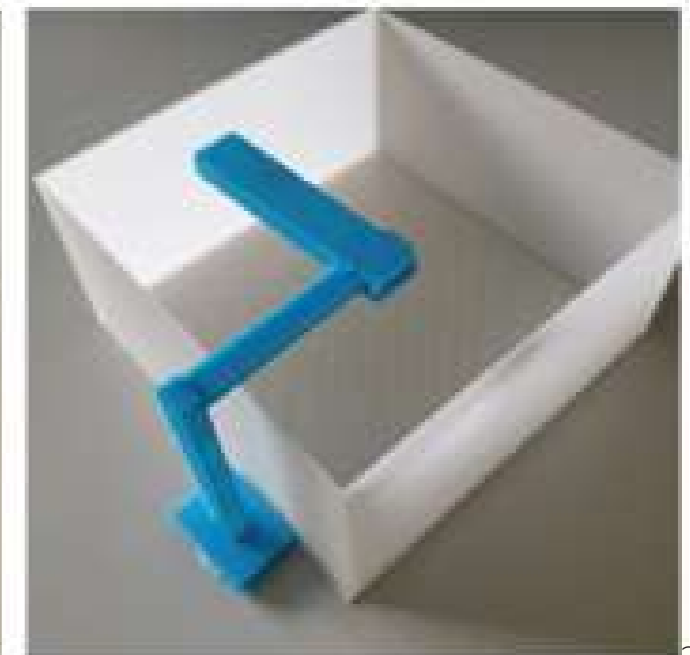
Screen attached to sensor that sits on the side of the bin



Sensor that sits on the side of the bin, data sent to dashboard



Ramp shape allows buckets to be rested on it and for the apples to roll in.



Free standing scanner arm that moves across length of bin.

Handheld



Handheld concepts are currently the most popular manner of collecting data in the orchard due to its mobility and ease of accessing fruit.

The way in which devices are charged, stored on the body and calibrated need further consideration based on current user practice.

The manner in which this device operates and moves will have a great impact on its overall functionality and effectiveness at measuring fruit.



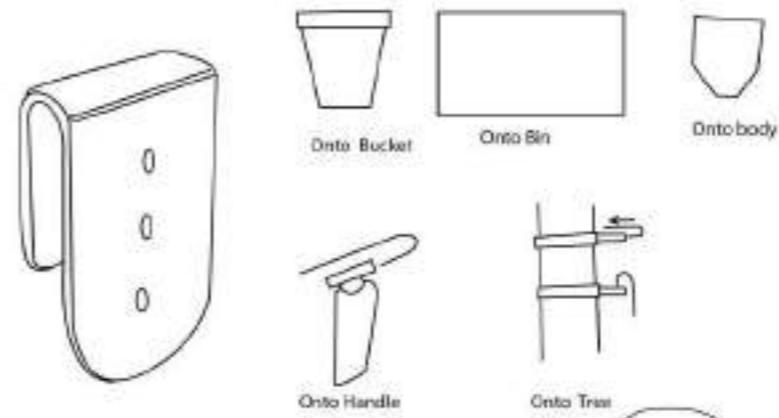
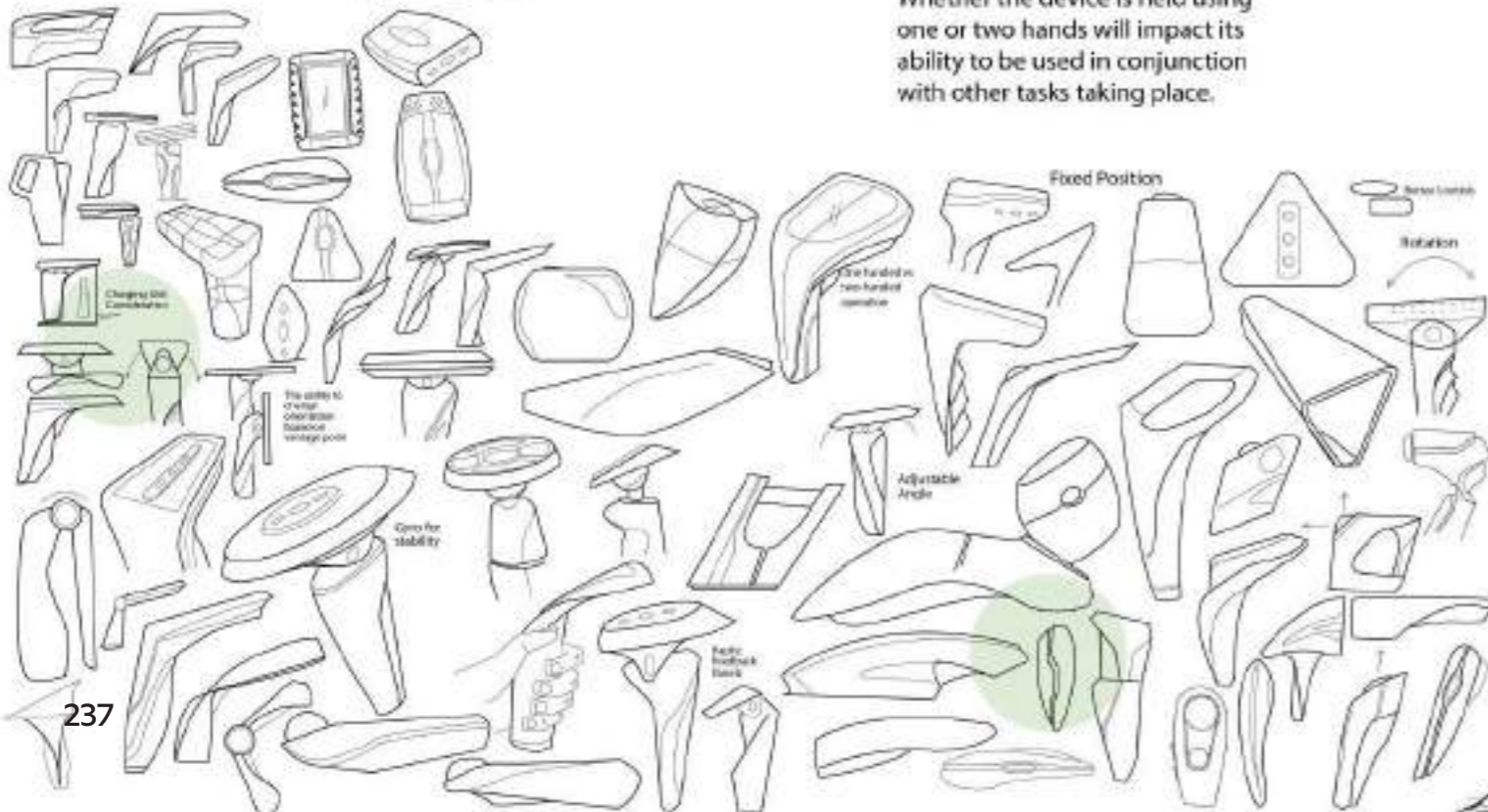
Some basic prototyping was undertaken to explore how we might approach such a device and the way in which body behaviour impacts the design.



Consideration of heights at which measurement might take place.

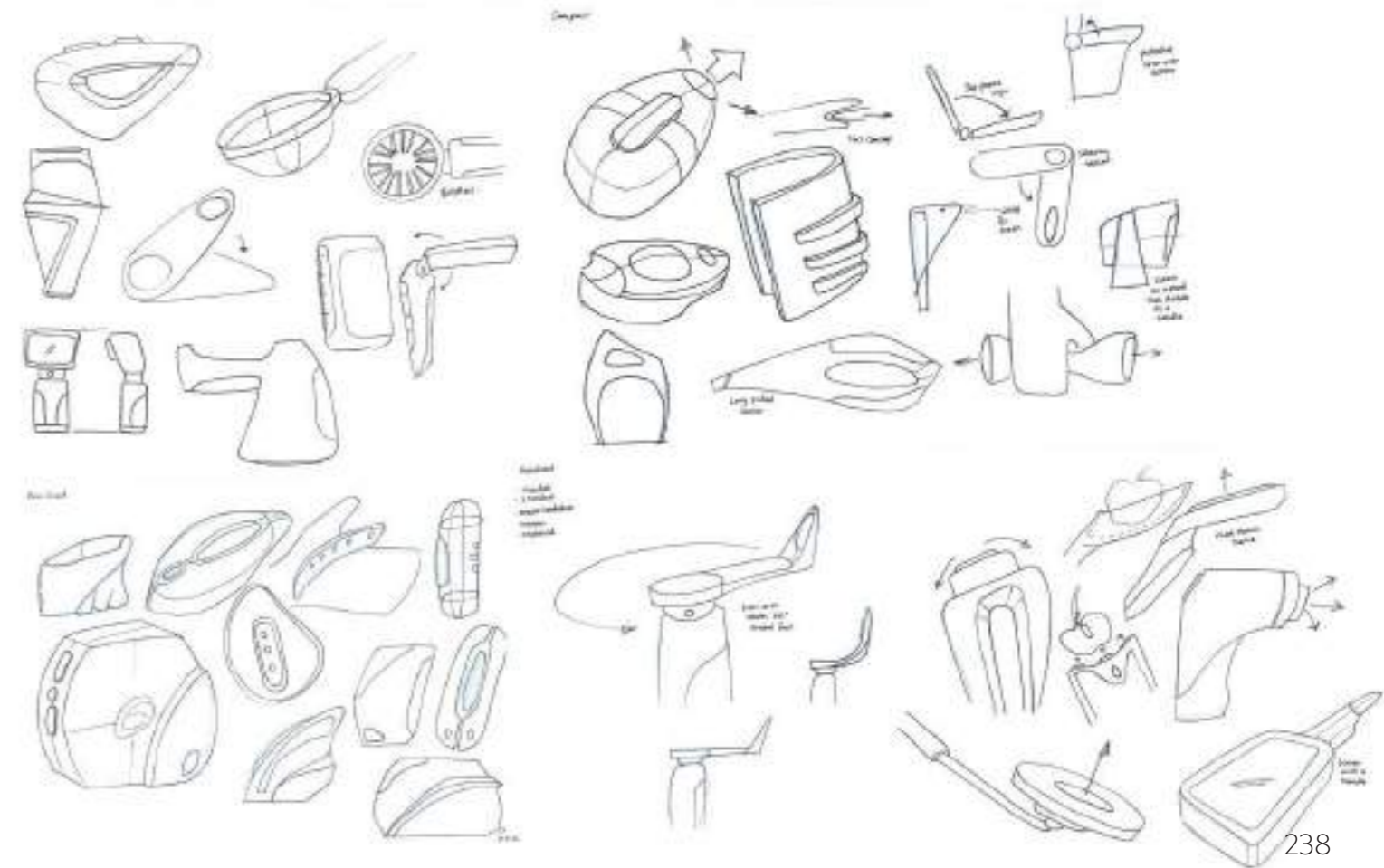
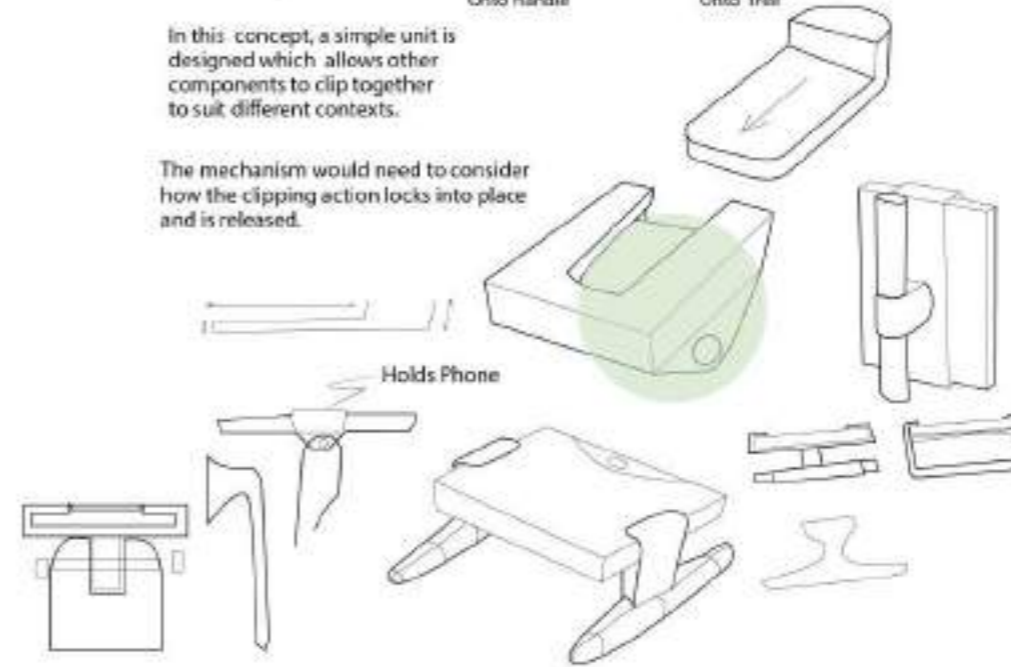
Consideration of hand and body position.

Whether the device is held using one or two hands will impact its ability to be used in conjunction with other tasks taking place.



In this concept, a simple unit is designed which allows other components to clip together to suit different contexts.

The mechanism would need to consider how the clipping action locks into place and is released.



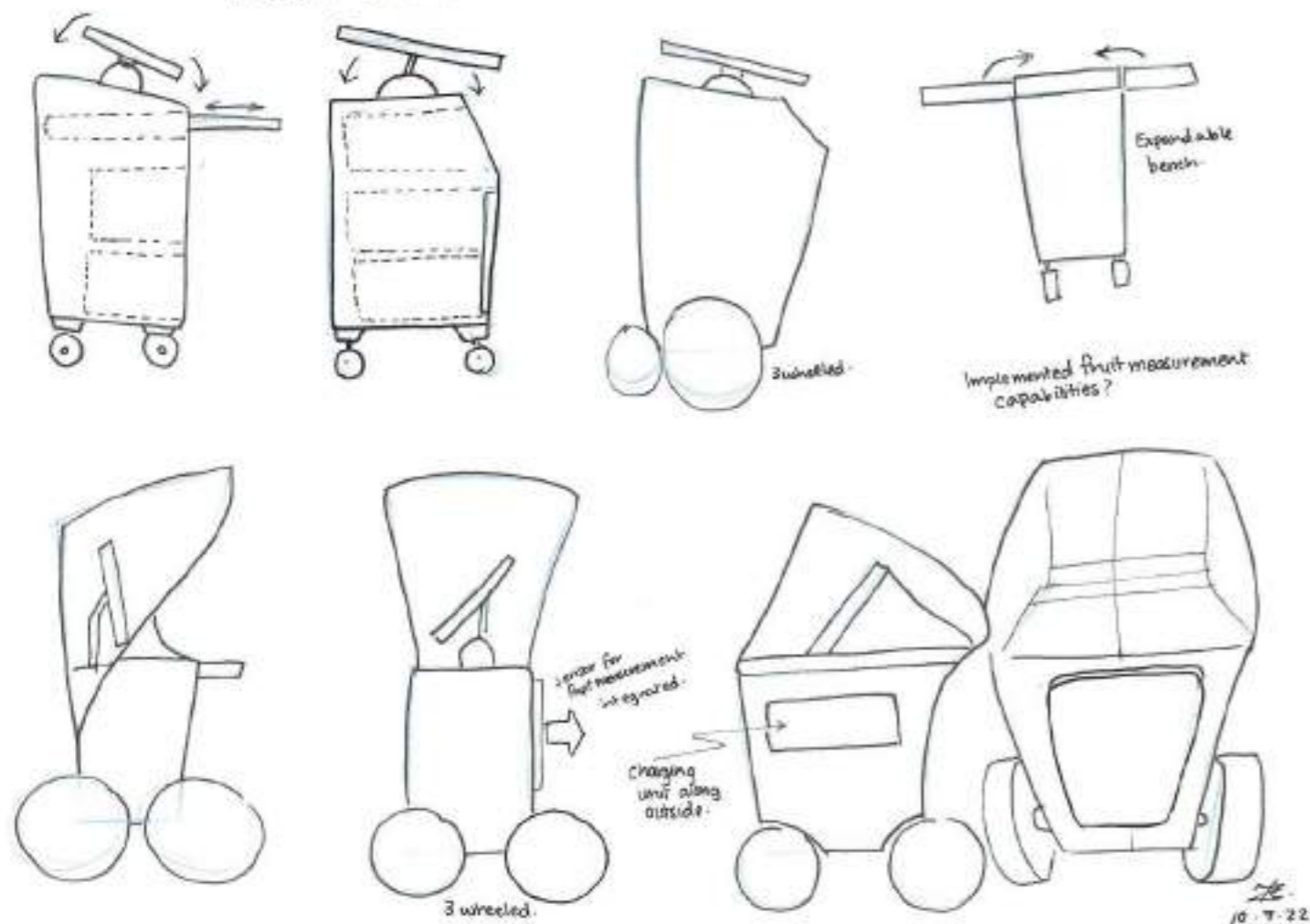
Mobile Quality Control Caddy



Based on a set of insights gained, there is need in the packhouse environment for a Mobile Quality Control device. With a different set of wheels and terrain capabilities, this concept area may be useful both in the packhouse and orchard environment.

Creating a modular, mobile platform means that instead of the workers carrying heavy boxes from the conveyor to the table, the table goes to the conveyor. In orchard, this means that tests can be conducted out in orchard rather than the backwards and forwards to the office.

Mobile Caddy Idea. In Packhouse versus In Orchard.

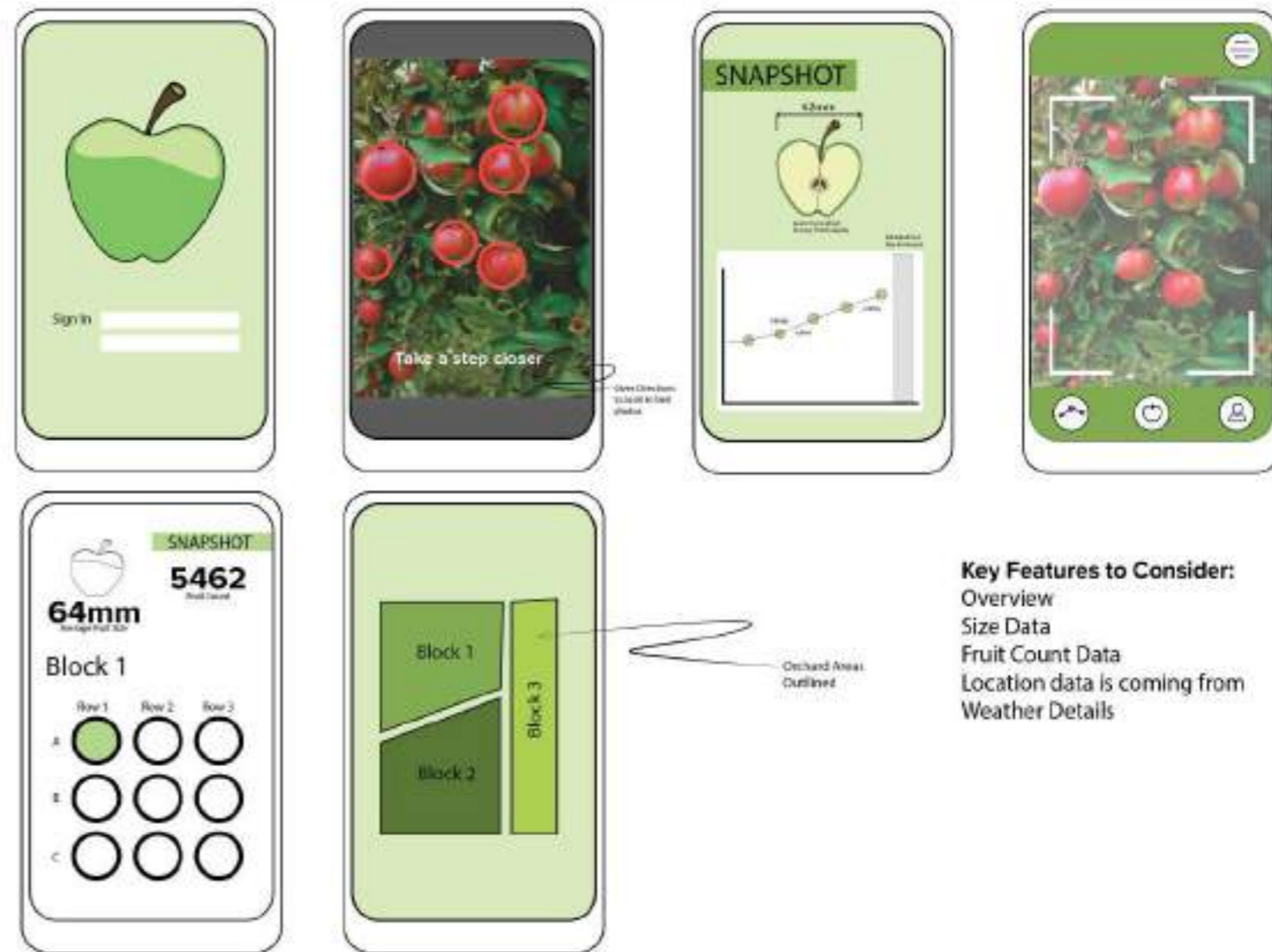


Interface Design

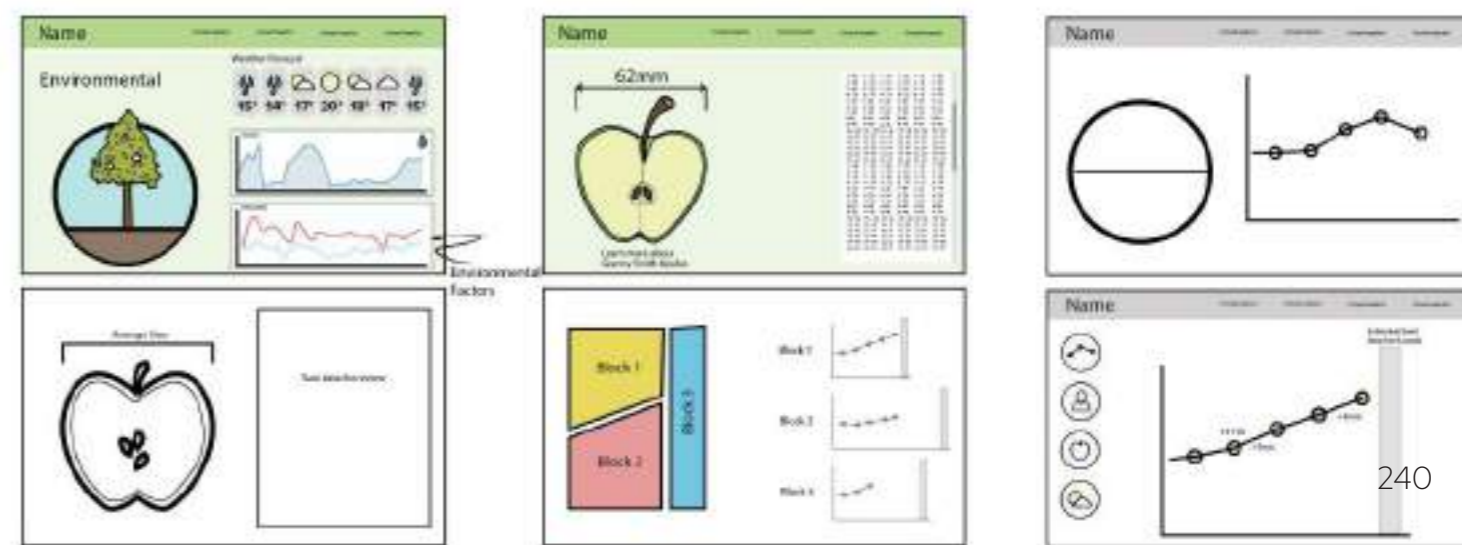


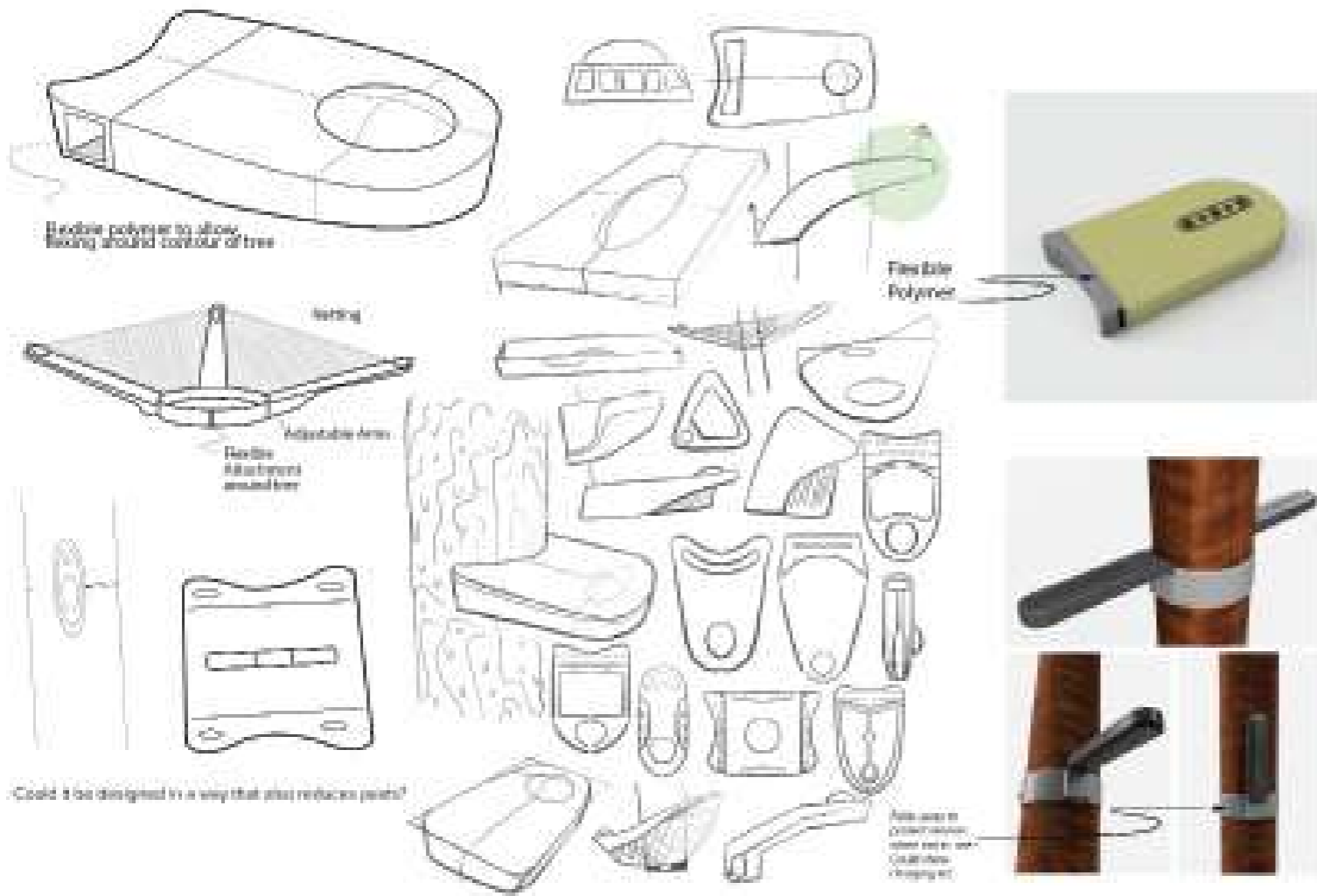
An interface such as via an app or dashboard offers the ability to clearly communicate key data and acts as a map for historical data. The system may be able to give some indication of predicted time for harvest based on the current patterns of growth, helping orchard managers decide when the right time is to harvest.

The layout of the dashboard can hold a wealth of information and make the complex information easier to consume. The ability for the dashboard to be customised to suit the needs of the individual grower is also important.



- Key Features to Consider:**
- Overview
 - Size Data
 - Fruit Count Data
 - Location data is coming from Weather Details





flexible polymer to allow flexing around contour of tree

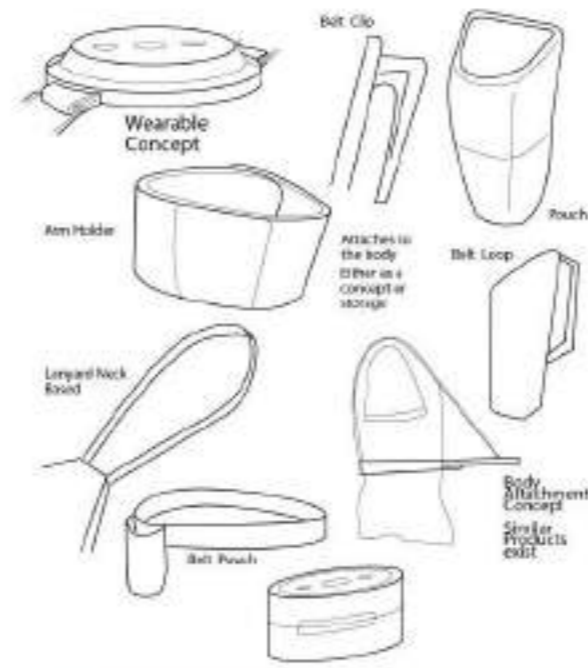
flexing

flexible arms

flexible attachment around tree

Could it be designed in a way that also reduces pests?

Note used to connect device to tree via hose clamp



The design opportunities in this concept area may be the easiest to grasp because of its relationship to the human body.

The refinement of which body area to design for will need to be discussed based on the type of fruit being viewed and their growing style to calibrate the best vantage point.



In traditional tree growing, the ability to spread adult branches is often done using techniques such as large sections of timber; this does not securely stay in the tree.

The manner in which the concept is secured to the tree will need to factor in growth of the tree over time, and either be manually loosened or be able to stretch.

In the prototype below, I have designed it so as to be able to house a smartphone so that I can test it during dry days. Attached to a branch using a hose clamp.



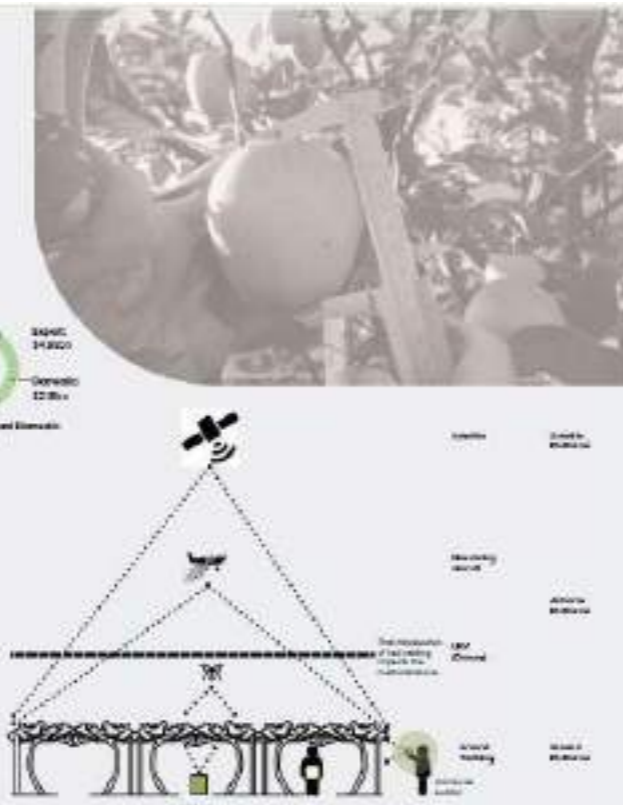
Appendix J: Design Critique Panels & Feedback

Fruit Measuring Horticultural Devices: Developing Usability across Complex Systems



This design technology research project seeks to understand the foundations of trust, and how it impacts the relationships we have with intelligent objects. It aims to explore this through the design of a fruit measurement system. The design seeks to inform and empower decision-making by the end users and stakeholders about the best time to harvest, based on the progression of fruit development, historic growth data and external factors such as weather.

This allows for better management of resources, deployment of labour and equipment. The consequence being a more sustainable orchard operation with greater productivity and benefits to all stakeholders. This will be achieved through a design discovery process identifying key insights related to fruit measurement, the integration of systems and related data to develop an empathetic design solution, across multiple modes of interaction and engagement.



User Experience

Reach
It's important to measure the height of the fruit trees and adjust the height of the device accordingly.

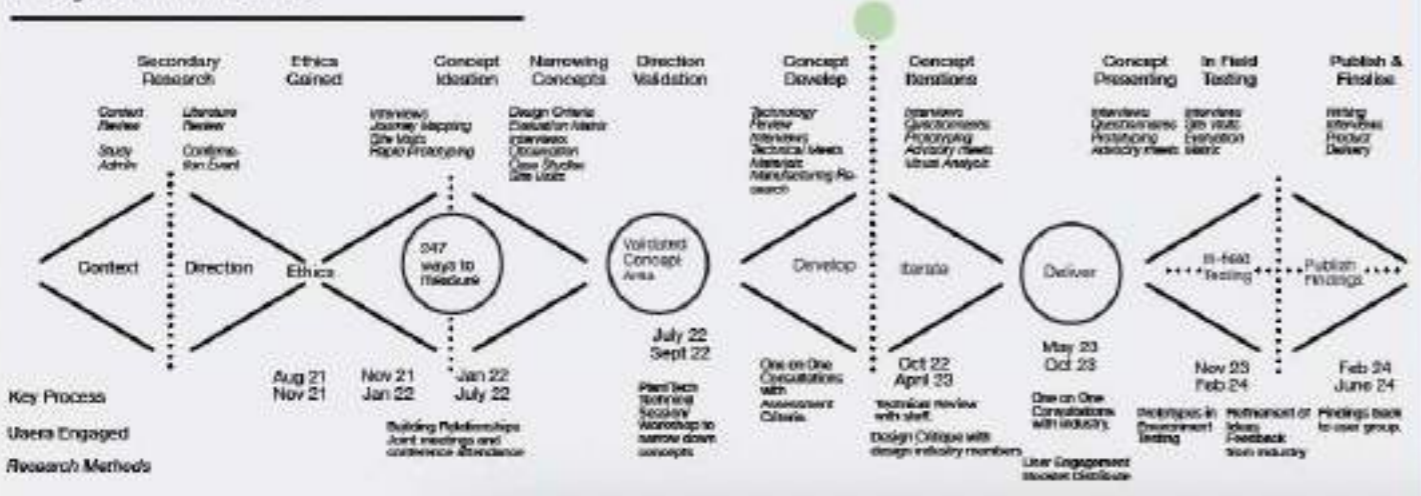
Obstruction
The device must be able to measure the height of the fruit trees, which is the display of light trees for the user.

Posture
How should the height of the device be used to measure fruit in the trees?

Hands
The device must be able to measure the height of the fruit trees, which is the display of light trees for the user.

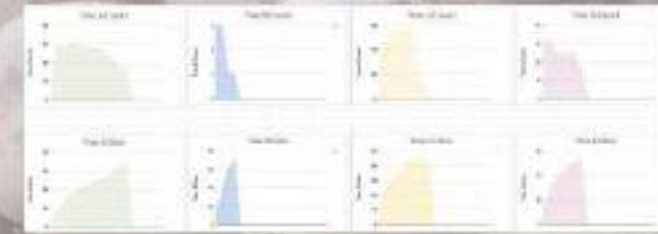
1. The device must be able to measure the height of the fruit trees, which is the display of light trees for the user.
2. The device must be able to measure the height of the fruit trees, which is the display of light trees for the user.
3. The device must be able to measure the height of the fruit trees, which is the display of light trees for the user.
4. The device must be able to measure the height of the fruit trees, which is the display of light trees for the user.

Project Timeline



Fruit Study

The fruit study offers a micro-view into orchard operations and allows for close testing and monitoring of selected trees.



Occurring in Morrinsville, it allows for seasonal comparison between years of the study. Monitoring weather and actions in the orchard and their consequence to fruit growth.

Night Photography



Night photography allows for the amount of light in a scene to be controlled.

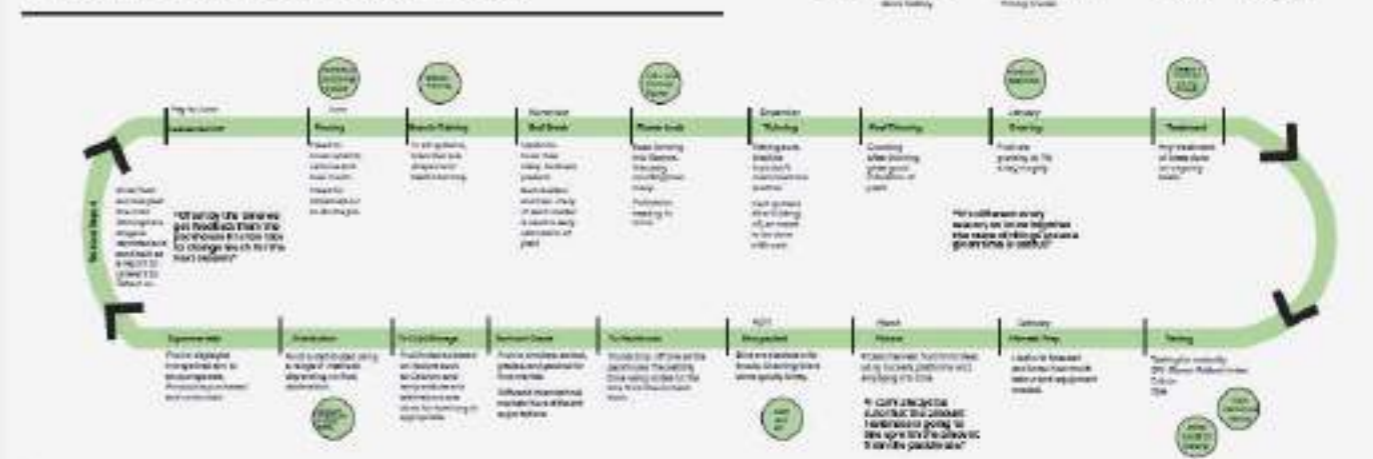
Practical Testing



Harvest

Maturity Testing of 20 apples

Intervention Opportunities



Personas

A sample of personas generated from user engagement and anonymised.

Participant 1
Name: [Anonymised]
Role: [Anonymised]
Key Characteristics: [Anonymised]

Participant 2
Name: [Anonymised]
Role: [Anonymised]
Key Characteristics: [Anonymised]

Participant 3
Name: [Anonymised]
Role: [Anonymised]
Key Characteristics: [Anonymised]

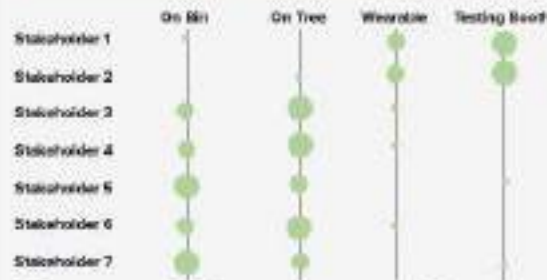
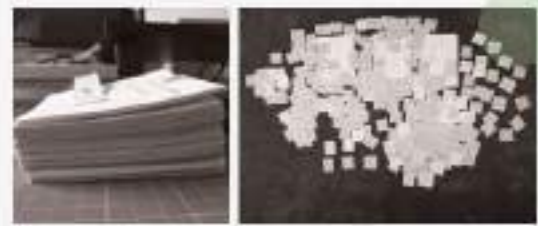
Participant 4
Name: [Anonymised]
Role: [Anonymised]
Key Characteristics: [Anonymised]

Participant 5
Name: [Anonymised]
Role: [Anonymised]
Key Characteristics: [Anonymised]

Participant 6
Name: [Anonymised]
Role: [Anonymised]
Key Characteristics: [Anonymised]



Concept Ideation



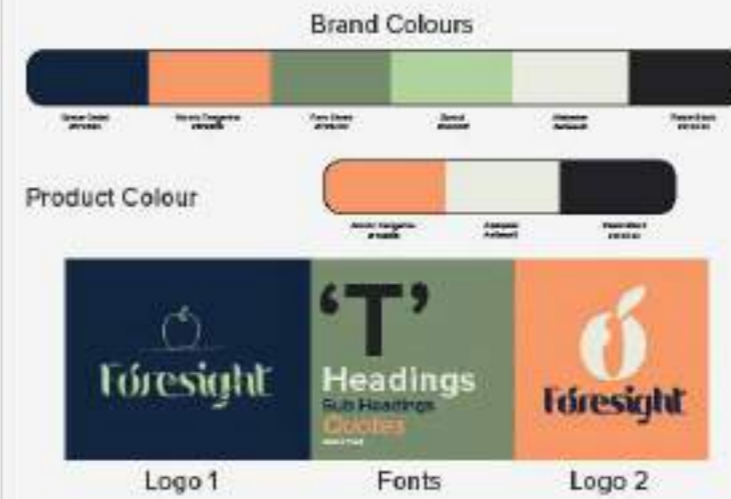
Concept Development



Prototyping



Foresight



The Technology



The scalability of using this system means that you could rent or own multiple devices based on your orchard size at a cost-point lower than current leading smart phones.

Zed2i is a Stereo Camera which harnesses AI capability to assist in depth perception and processing. IP66 rated, the camera is appropriate for the orchard environment.

Use SLAM technology to build a 3D map of the surroundings. Fruit size and count can be inferred from this and monitored throughout the growing season.



The System



Foresight is a product which utilises the power of the Zed2i stereoscopic camera to capture imagery of fruit in the canopy as they grow, allowing for monitoring of size and count across a sample of trees. This product acts as a method of ground truthing, reducing labour and time involved in the monitoring process.

These insights equip orchard managers with data to make decisions with, and simplify the process for seasonal workers. This design-focused product seeks to improve the user experience of measuring fruit in a manner that is time efficient, minimises labour and maximises insight.

Strapped to the tree, the Zed2i captures high-resolution 3D footage when water sprays cross. Users bring with a sensor to report.

Alabaster #01560
Atomic Tangerine #173056
Raisin Black #21222

Right, Front, Left, Back

Buttons: Best slot through back.
 Zed2i is inserted from the side.
 Battery inserts from the side.
 Band can be slot through the bottom.

Packaging includes an instructional booklet and separated components to allow ease of navigation.

Device slots into the arm to sit over the bin.
 Felt cover on sections which may come in contact with fruit.
 Device slots into the arm to sit over the bin.

When ready to harvest, Foresight can be slot into an arm attached over the harvest bin, capturing images as workers empty fruit into the bins, creating a dataset before the produce heads to the pack house.

Using the edge of the bin as an image trigger, it waits 30 seconds to take a photo.

Foresight
Wishing fruit grow.

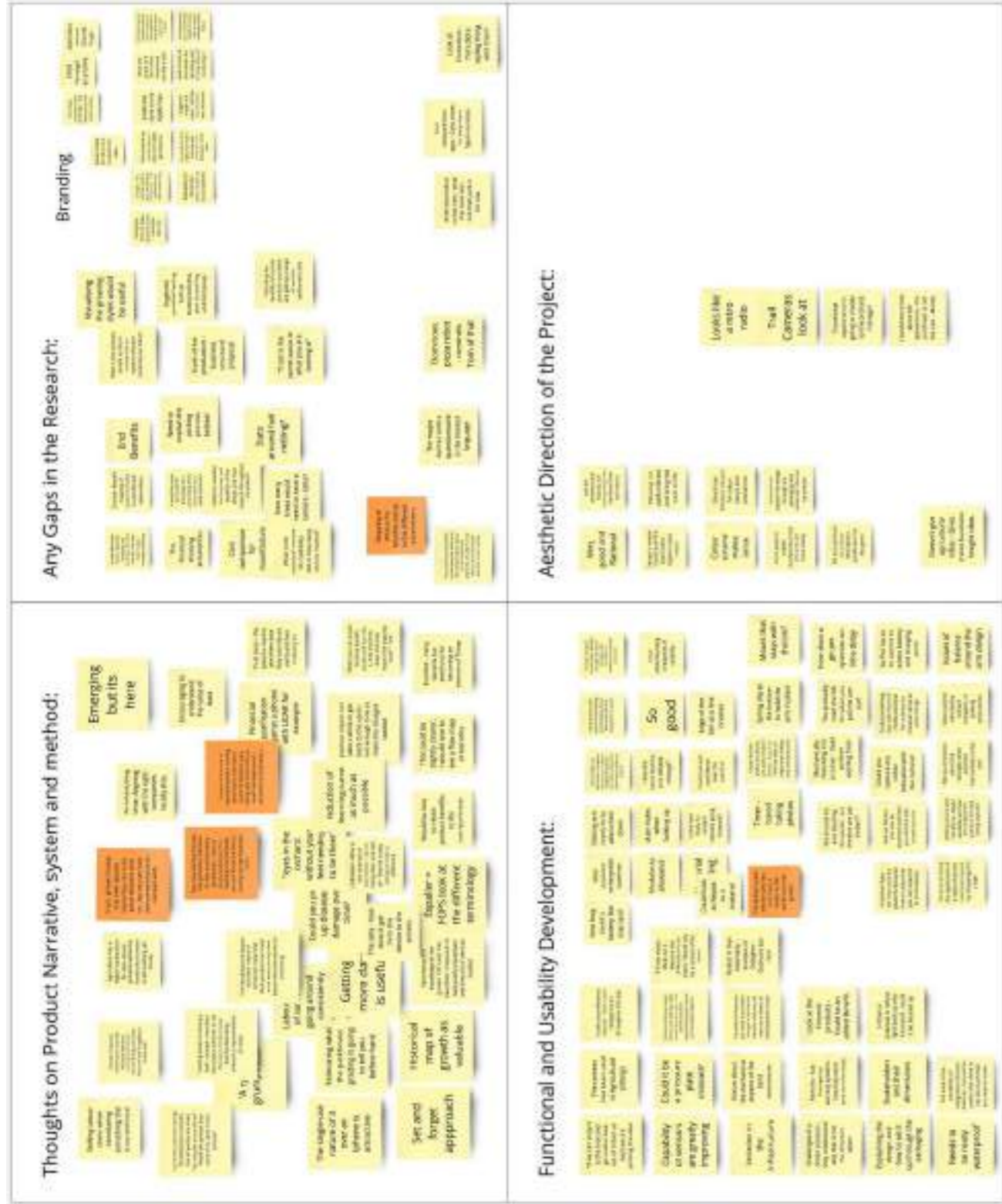
Feedback form used as part of the Design Critique.

Design Critique of:
Horticultural Fruit Measuring Devices:
Developing Usability across Complex Systems

Please rate your perceptions of the final design:
 5 meaning low, needing re-consideration
 3 is acceptable, but not great
 1 being excellent with minor developments

Functional and Usability Development	Feasibility	5	4	3	2	1
	Practicality	5	4	3	2	1
	Perceived Reliability	5	4	3	2	1
	Integration into Systems	5	4	3	2	1
	Alignment with Industry	5	4	3	2	1
	Feedback to Users	5	4	3	2	1
	Portability	5	4	3	2	1
	Learning Curve for Use	5	4	3	2	1
	Perceived Accuracy	5	4	3	2	1
	Handling, Time Spent	5	4	3	2	1
Aesthetic direction of the project	Thoughts on Product narrative, system and method:					
	Any gaps in the Project:					

Feedback from the Design Critique was broken down into post-it notes on Miro, to group together similar parts for feedback and assist in the prioritising of tasks to begin to address the design opportunities, identified gaps and narrative flow.



Appendix K:

Final Design Criteria

Trust Attributes

- Competent - ability
- Useful - helpfulness
- Engaging
- Respectful
- Likeability
- Perceived intelligence
- Perceived Trustworthiness
- Familiarity - Warmth
- Etiquette - Politeness
- Predictable actions
- Collaborative behaviour
- Transparency - Predictability
- Performance - Functionality
- Competence - Intelligence
- Personality - Amiability
- Explainability - Interpretability

Feedback to the User

- Near Real-Time updating
- Using the likes of a Dashboard to collect and communicate the data

Mobility

- Easy to Transport
- Easy charging

Accuracy

- Easy calibration
- Reliability associated with accuracy

Communication

- Communication via a dashboard/ interface
- Clarity & Concise
- Needs to communicate data from device to server

Intelligible

- Transparent Operations
- Clear option selection

Integration

- Easy integration into current practices
- Dashboard can integrate into existing management systems
- Integrated technologies are explainable
- Connected to existing operations
- Suitable for both 2D and 3D growing systems

Functional Aspects

- Durable material
- Environmental Durability
- Easy Cleaning
- No pinch points
- Mechanically sound
- Robust
- Efficient time and performance
- Effectiveness - getting the job done
- Materiality - Needs to be able to survive at least 1 spray season, (In case it gets left up)

On Tree

- Needs to be placed in line with the direction of the sun to avoid glare. - Requires sundial.
- Band needs to securely fasten to the tree - without suffocating it.
- Needs to have some way of showing the user what stage of the process it is in.
- Needs to be sustainably charged or have battery
- Needs to be able to shift from a vertical to horizontal viewing position for different growing styles
- Would be nice to capture information about the trunk circumference
- Aesthetically, needs to look robust;
- Needs to afford nighttime Photography through the addition of a ring light.
- Needs to have drain holes or ways of ensuring that water is not collecting on the surface of the design.

On Bin

- Needs to be easy to assemble
- Needs to be sturdy
- Needs to be lightweight
- Felt around any areas that may come in contact with fruit
- Needs to minimise potential pinch points in the design
- Needs to securely hold the camera in place
- Should be mounted to a corner to allow for more accurate centering.

Colour

- Colours that stand out from the environment
- Colours that are accessible and inclusive.
- Colours that attract bees

Non obtrusive/ Non contact

- The device should be able to work without coming in contact with the fruit.

User friendly

- No training is required prior to operation
- Reduce accidental activation
- Can be used with gloves on
- Clear interface
- Simple to set up

Inclusive Design

- Human considerations -for example, left and right-handedness
- Function needs to be communicated with consideration to language barriers.
- Needs to be easy to use by seasonal workers or those with little orchard and technical device experience.

Scalable

- Can purchase more devices to scale to different business needs

Minimal learning curve for use

- The device should be able to be used by anyone and indicate stages

Manufacturability

- Manufactured using means that are appropriate for functional aspects while also being cost and performance conscious.
- Allow for easy assembly and disassembly for replacement parts rather than whole unit disposal and replacement systems
- Should seek to use sustainable materials or means of manufacture where possible.

Self-reporting issues

- If the system picks up any issues with how the device is operating, this is reported to the user immediately via a notification on the appropriate interface

Fail-safes

- Device can be turned off rapidly, or have a release mechanism if it can impact the health and safety of any individual in the orchard.

Backups

- The device creates a backup of the data in each operating cycle and retains this data until successfully transferred to the cloud or alternative connection route.

Secure connection

- Data collected by the device cannot be accessed by third parties remotely and

cannot change the operations of the device without prior consent from the operator.

- If the connection is disrupted, data is still stored on the device and can be uploaded once the connection is restored.

Adaptive/ Personalised systems

- The system should be able to be personalised to suit the needs of the individual grower.

Haptic feedback

- The device should communicate actions through light.

Human control sense

- The human operator should be in control of the operations of the device and able to change their mind at any time during operation.

Storage

- Can be stored when not in use in a compact manner.

Packaging

- Durable packaging as it is likely to be re-used in the off season
- Packaging needs to assist in explaining the functionality of the device and how to set it up

Marketing and Brand

- Attractive Price point
- Should be recognisable in form and presentation - including branding
- Needs to reliably communicate the scalability of the concept

Accessories

- Solar Panel unit to give the alternative option of charging.
- Batteries need to be easy to remove from the housing and built for longevity
- Batteries need to be able to charge in an unobtrusive manner in the office.

Appendix L: Visual Analysis

Usability	Fruit Growers	Form	System
Gardena Tru-test Fiskars Dyson Braun	Rockit Bostock Zespri Cropsy	Husqvarna Clearpath Robotics Gallagher Saia Agrobotics	iRobot Good Nature Nespresso Go Pro Fitbit
Familiarity	Interface eg.	Colour	Functionality
John Deere Bosch Ryobi STIHL Nylex	Pixofarm Spectre Green Atlas Plantai Crop Tracker Clarifruit	Halter UBCO Kubota SAM Machinery	Robotics Plus Farmbot BlueLab Strella
Consistency	Personality		
Kaercher Makita De Walt Tesla	Alessi Boston Dynamics ANKI Postmates vs Starship		

Fiskars

Context:
Fiskars offers a range of products for garden and in home contexts which are thoughtfully designed to consider ergonomics and the user experience.

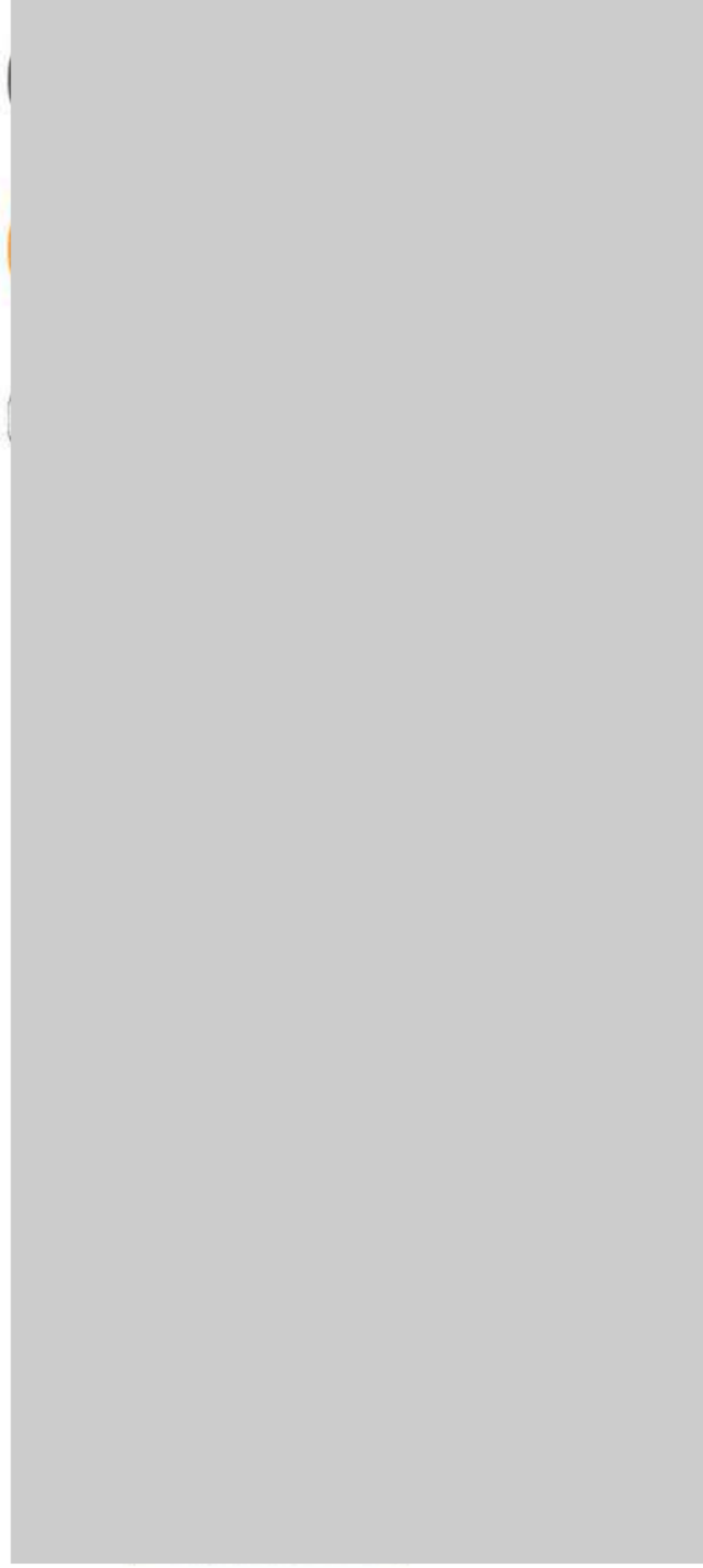
What can we learn from this?
Fiskars is often held up as a good example of designing for different abilities, such as left and right handedness and this is important when designing products for everyone.

Colour
Fiskars uses Orange and black across their various product ranges, unique at the time of their launch. Colour is used to highlight key touchpoints and informs how to use the product.

Form
As with most tools, durable functionality is key, and the form suggests easy navigation, with ergonomic form to the handles assisting in proper use.

Materiality
Handles are made from a durable matte plastic, contrasting with the metallic tool mechanisms. Components are combined but visually separate, allowing for easy repair and maintenance.

Proportions
Handles are longer to accommodate for reach as part of certain tasks. Many tools can also shift left and right handedness. Locking mechanisms consider finger reach ergonomics.



RYOBI

Context:

Ryobi is a company which creates gardening and construction tools. They service general public and commercial needs, with a comprehensive system that can run off a shared battery configuration.

What can we learn from this?

Creating a recognisable product range means that it can be clearly recognised as different from competitors and associated with a particular brand.

Colour

Ryobi is well known for its distinctive colour palette that is consistent across the product range. The colours are familiar to customers, and make the tools easy to find.

Form

The form suggests durability through its angular part lines and changing materiality. Functionally-driven, the form suggests a rugged design fit for purpose.

Pattern

Part lines and colour accentuate patterns across the body of the products which helps to also inform the way in which to hold and use the product.

Repetition

Repetition occurs across the product range, and within the product features and lines repeat, such as strokes and bevels that visually tie aspects together.

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Nylex

Context

Nylex is an Australian based company started by a Plastics manufacturer. They are a major competitor in garden equipment and watering tools for the domestic setting.

What can we learn from this?

Nylex is a less-known product range but which has high levels of usability while being visually clean and appropriate for a modern garden. Form and colour helps to tie the products in the range together.

Form

Geometric forms with rounded edges makes it easier to clean, and more approachable. Function is integrated into the body of the form.

Colour

Mostly white and black with blue as an accent colour throughout the product range. The blue highlights key visual features and touchpoints.

Proportions

Driven by usability, the proportions factor in hands and aims to develop balance and symmetry across the body.

Line

Geometric lines that have been rounded and softened, emphasised by colour and part lines.

Tesla

Context:

Tesla is a technological automotive and clean energy company. Known for being started by Elon Musk, the company brought a lot of hype and design around electric vehicles to the mass market.

What can we learn from this?

Tesla as a company uses colours in keeping with modern minimalist aesthetics, it is understated in line and form, yet proportionally is attention grabbing and bold. It aims to be part of everyday life while being functionally different.

Colour

Tesla uses muted colours such as greys and white, in keeping with a lot of the minimalist aesthetic which is seen in technological driven companies.

Line

Part lines are highlighted through the use of colour, and are generally fairly subtle, suggesting a level of modesty and familiarity to other products on the market.

Form

A lot of organic and flowing forms are used, except in the case of the Cyber truck where they experimented with form expression in an angular manner.

Proportions

Many of the products are elongated, occupying space in a way that gives the product a presence, without over exaggerated visual tools.



© 2020 ROCKIT APPLES

Rockit Apples

Context

Rockit is an apple growing company based in New Zealand and America who invested heavily in the design and brand story of their company, winning a few awards, showing the benefit that design can have to the horticultural industry.

What can we learn from this?

Using bold, clear language and graphic elements can make it a lot easier to capture engagements and highlight the memorable parts of that which your brand delivers.

Colour

Bold colours that feel natural and related to apples are used, often to contrast the images or graphics that is being used alongside it.

Language

The language used on the website is bold and decisive, using smaller text to go into more detail, using a more passive voice to describe aspects of their services and product.

Hierarchy

Bold and large font used as the key sentences and statements, capturing the eye and ensuring that the most memorable parts are easy to access.

Icons and Representation

Graphics used are approachable and universal of the core ideas, such as the lightning bolt symbolise strength, the heart symbolising health and love.

Bostock Brothers

Context

The Bostock Brothers is a brand which started from the sons of the owner of Bostock, an apple company in the Hawkes Bay. They specialise in free range chickens who live on the apple orchards, creating a highly family driven and sustainable story.

What can we learn from this?

Creating a brand which feels open and warm can often take away a lot of the stigmas associated with brands that may provide a similar product or service.

Colour

They utilise a range of different greens, from a dark green to a fresh green, appropriate with the colours of nature part of many of their images.

Language

The language that they use is informal and approachable, furthering their identity as a trusted, local family driven company.

Font

The fonts are bold to capture attention, with the Bostock Brothers logo being reminiscent of old deli signs, and family-legacy brands.

Imagery

The imagery on the website and Instagram capture both the product and the environment from which it came and the people involved. It tells a warm narrative that people feel is transparent.

Zespri

Context

Zespri is a co-operative of growers in New Zealand working with the kiwifruit industry to create quality produce for local and international markets.

What can I learn from this?

Relating to benefits from a product or service goes beyond only the technical, and often also ties in the emotional connection that people have with their decisions.

Colour

A lot of fresh colours are used, typical of brands working in the horticultural industry. Bolder colours are used to highlight key navigations on the website or key facts and features they want known.

Imagery

The imagery focuses on the story of growing kiwifruit, the environment and the colour differences in the kiwifruit, all adding to a sense of health which comes with the marketing for the fruit.

Font

Similar to Bostock Brothers, Zespri uses bold fonts that are slightly misaligned and look like legacy farm signs from years past.

Language

The language used is emotive, leading a narrative of health for the consumer, and the health of the environment from which the produce comes.

Cropsy

Context

Cropsy is a startup company in New Zealand who creates image-sensing based devices which can measure fruit data. Recently started.

What can we learn from this?

There is value in understanding the existing competitors and what they are offering. The value of design will be in creating developed products that meet the technical needs as well as the human factor based needs.

Form

The form of the device is simple and function-driven, with minimal design factors included, as the focus is on collecting the data and not in a fully fledged product yet.

Colour

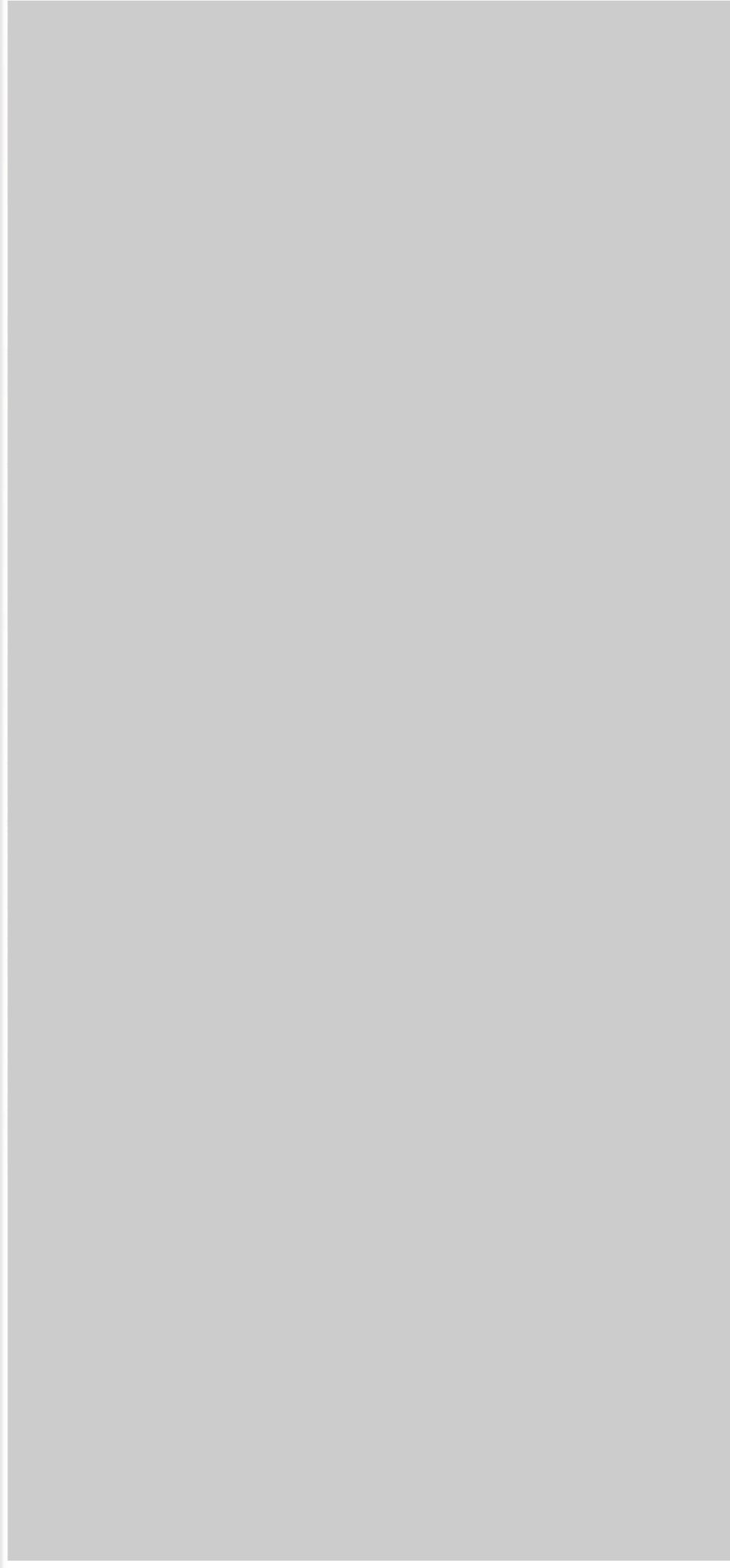
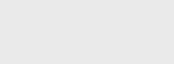
Colour in their website interface uses green and blue, natural colours that relate to the context in which the product and system operates.

Language

The language aims to inspire the customer using words such as 'transform'.

Interface

The interface is still in trialing mode as they aim to further the accuracy of its fruit sizing and counting algorithms.



Pixofarm

Context

Pixofarm is an app-based design solution for fruit measurement from Canada which seeks to count and estimate fruit size. It aims to offer a fairly accurate results, but is still in its infancy.

What can we learn from this?

The language and imagery used is important in signifying the success of a system over another competitor, however using language that is too assertive can make people skeptical.

Colour

The brand uses a teal green as its primary colours as well as general greens to suggest the environment it is used in. Red from apples and fruit are used in contrast.

Imagery

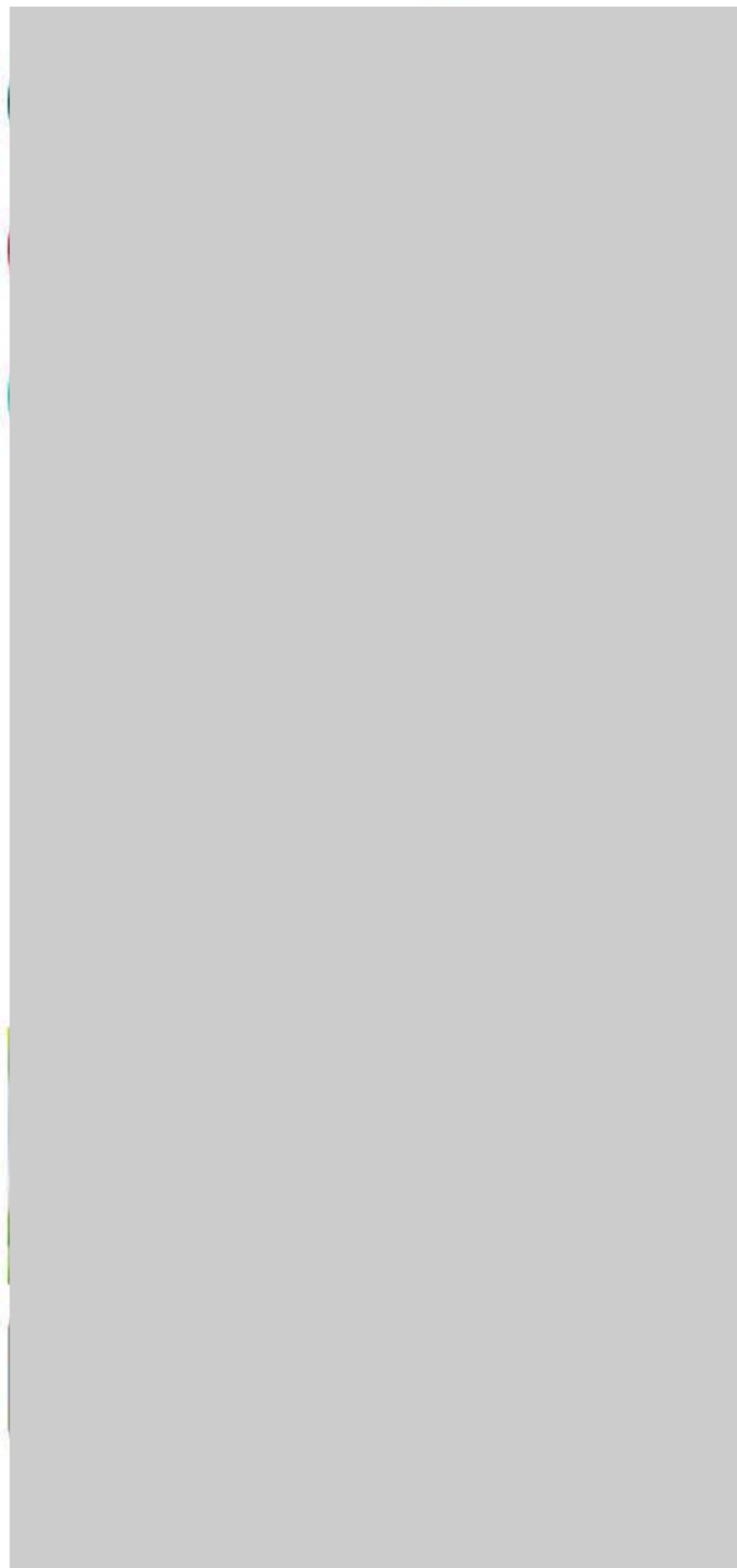
Imagery aims to help explain how the system works, and simple graphics such as fruit trees help to contextualize the app when away from demonstrations of function.

Hierarchy

Font, line and colour are used in different ways to suggest hierarchy on different parts of the app. This helps clarify navigation and highlight the key insights that might be gained from the app and its service.

Language

The language is assertive and promising, using words such as precise and exact can add to the feeling of accuracy that the system might have without providing the statistics of accuracy.



Hectre

Context

Hectre is a company which specialises in using machine learning to better the accuracy that can be collected in the horticulture industry in practises such as fruit sizing.

Colour

Using a bright red, and fairly muted colours otherwise stands out from many of the other competitors. The red is bright and urgent.

Interface

The interface can be used across mobile devices such as phone, tablet and computer, allowing for easy access to the service.

Hierarchy

The use of colour is assertive and generally highlights the sections which should be focused on, as well as the use of larger text and familiar formatting

Imagery

The imagery would be collected by the user, and the results from each scan is dependent on how successfully they have captured the image.



What can we learn from this?

Being able to use a system across different devices is a practical asset, and then being able to assess the data collected easily to get insights is crucial.

Green Atlas

Context

Green Atlas is focused on developing crop management systems for the horticulture industry and using tools that are mounted onto off-loaders to collect data from the orchard and translate this into tangible insights.

Colour

Colour is used to relate the system back to its natural context using a muted green, and then using contrasting colours in maps to help the user identify aspects of interest.

Imagery

The use of CAD renders is unique to many of the competitors and can suggest that some of the technology is still in its infancy, however, it creates a cohesive set of imagery across the site.

Language

The language used is clear and simple to navigate, it is inviting, using words such as Discover and Explore.

Iconic Representation

The representations of data have been simplified to aid in the understanding of the complex data that is being collected.

What can we learn from this?

The use of CAD can be both cohesive, and deceptive, so it needs to be used appropriately. The use of inviting words can make people excited to navigate an interface or website to learn about your product or service.

ANKI

Context

Vector by ANKI is a tabletop companion robot designed for all ages which can interact with its environment, and make sounds and faces that give it personable qualities.

What can we learn from this?

Materiality can lend a lot to the overall feeling from a product even without colour changes, and that anthropomorphism can be emphasised through changing of expressions to make the product appear more sentient.

Form

While a lot of it is driven by function, the form creates a spider-like product with a face which can tilt, and a set of arms which can lift and interact.

Colour

While mostly black, the surfaces are added to through the use of different materials to create texture and surface finishes, and suggest robustness.

Proportions

The product is a very compact unit, made to be unobtrusive on the desk when not in use. The digital eyes are large, creating a 'cute' factor.

Anthropomorphism

The spider-like qualities of the device and the way in which it moves is inspired by principles of anthropomorphism to create a companion which can be seen as being alive.

Good Nature

Context

Good Nature is a new Zealand based company seeking to find more humane ways in which to trap predators such as rats, stoats and possums.

What can we learn from this?

Creating a system which allows for parts to be replenished adds to the longevity of use for the product. Creating bold, simple shapes can be effective for making the product easy to navigate, especially when assisted by colour.

Proportions

The devices are designed with the size of the pest they address in mind. The sections are based on functional aspects, and could generally be split into thirds.

Colour

The products use off-white, black and orange primarily. Black and white alternate between products, and the orange is used to highlight the key touchpoints that are part of the device.

System

Additional parts such as the canisters and bait can be purchased from stores to replenish, while the body is a set unit that you only need one of for each pest type.

Form

The form is function-driven, with fairly geometric lines throughout. The form is also based on what is ergonomically easy to carry, and the right size for the pest being addressed.

Gallaghers

Context

Gallaghers is a New Zealand based company with strong family heritage at the core of its branding. The impact of this branding has been developed and fostered over many years.

What can we learn from this?
Product narratives and legacies are built over time, and creating memorable products are about the experience it creates as much as visual aspects.

Colour

Using a vibrant orange and dark grey, the products are generally easy to distinguish from competitors, except for some who use very similar colours to try and buy into the trust that Gallaghers has built over time.

Form

Simple geometries that are function-driven, with rounded edges and part lines that are accentuated by colour use. Ribbing on edges gives a sense of durability.

Proportions

Interfaces have considered ergonomic requirements, as has the key touchpoints and dials to help with product navigation. The products occupy space and stand out from their environment.

Materiality

A combination of plastic and rubber polymers have been used to create textural difference and a sense of durability around the body.

Halter

Context

Halter is a Agri-tech company recently started in the Waikato, New Zealand with the primary technology of cattle guidance systems using an app.

What can we learn from this?

As an emerging company, the use of minimalist colours ties the brand more to technology-driven than the traditionally agricultural. Materiality and its processes are vital to the overall perception of a product and its usability.

Colour

The halter is all black, making it fairly unobtrusive. The website uses a teal colour alongside its graphics which softens the overall minimalist perception.

Materiality

The halter is made from a combination of plastic and silicone polymers to allow for rigidity in sections and flexibility in others.

System & Interface

The system and interface uses a teal colour, and simple graphic icons to explain the functions of the technology inside the product. The app is made to be minimalist and practical.

Form

The form is function driven, with a sleek and flexible section over the neck to accommodate different cows, and then rigid on the sides where the components are kept.

Strella

Context
Strella is a startup company which creates sensor-driven products which detect ethylene levels as the fruit ripens.

What can we learn from this?
Products which are functionally-driven but lack any user navigation cues can be difficult to understand and interact with, making this product feel like it is an 'expert's device', rather than the lay grower or packer. This can be problematic for ongoing use.

Colour

The company uses a vivid green/yellow as their primary product colour, while the logo has a bright and leaf green.

Form

All the sensor casings are very geometric and box-like, with simple rounded edges. The overall appearance is quite minimalist, but does not aid user interactions.

Proportions

The sensors are the size of about 2 apples in width, small in the overall scale of things, meaning it can be hard to know their location or fix them to places.

Brand Placement

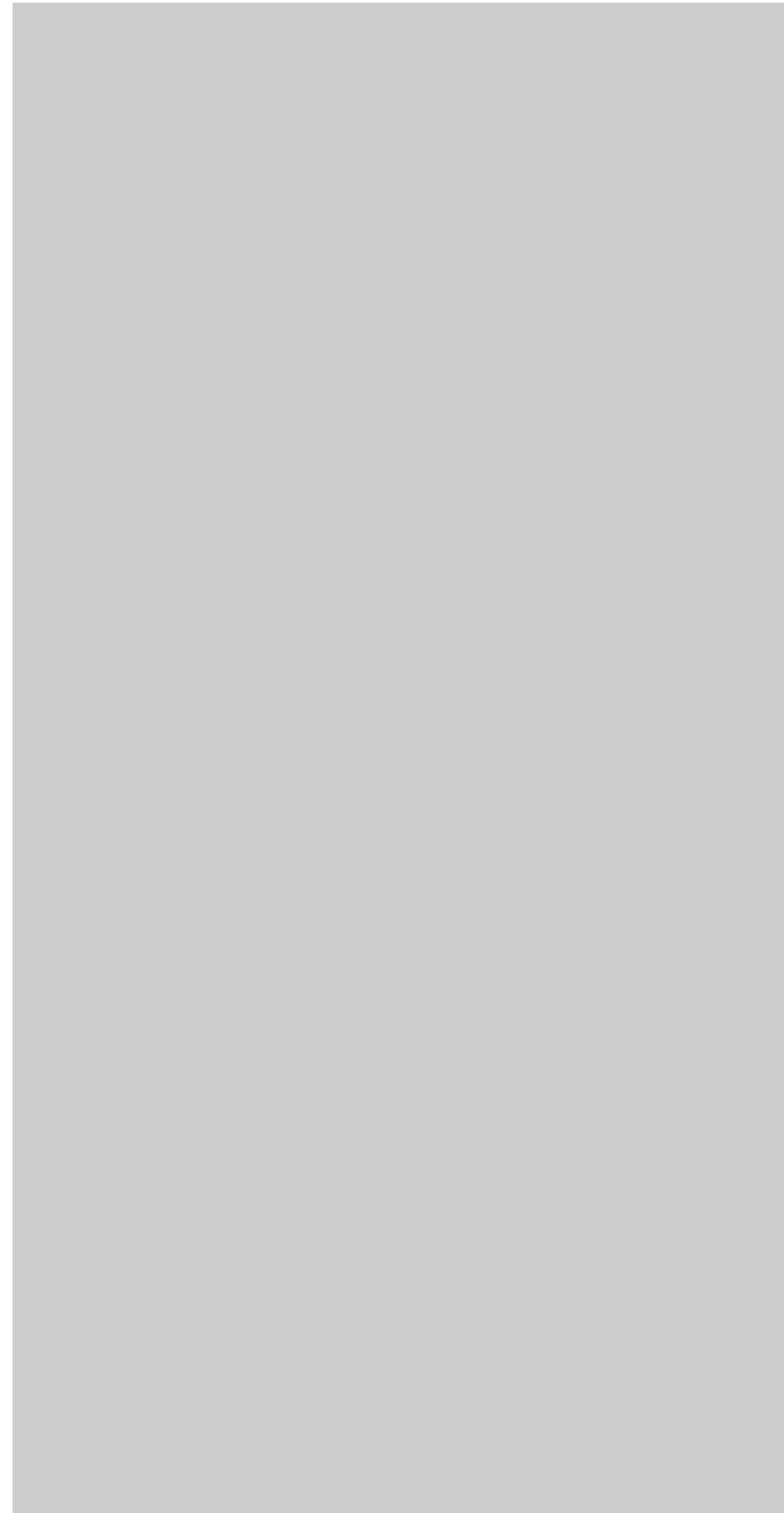
In all shown cases, the brand placement is large across the majority of the face of the product. It is fairly deliberate and clear.

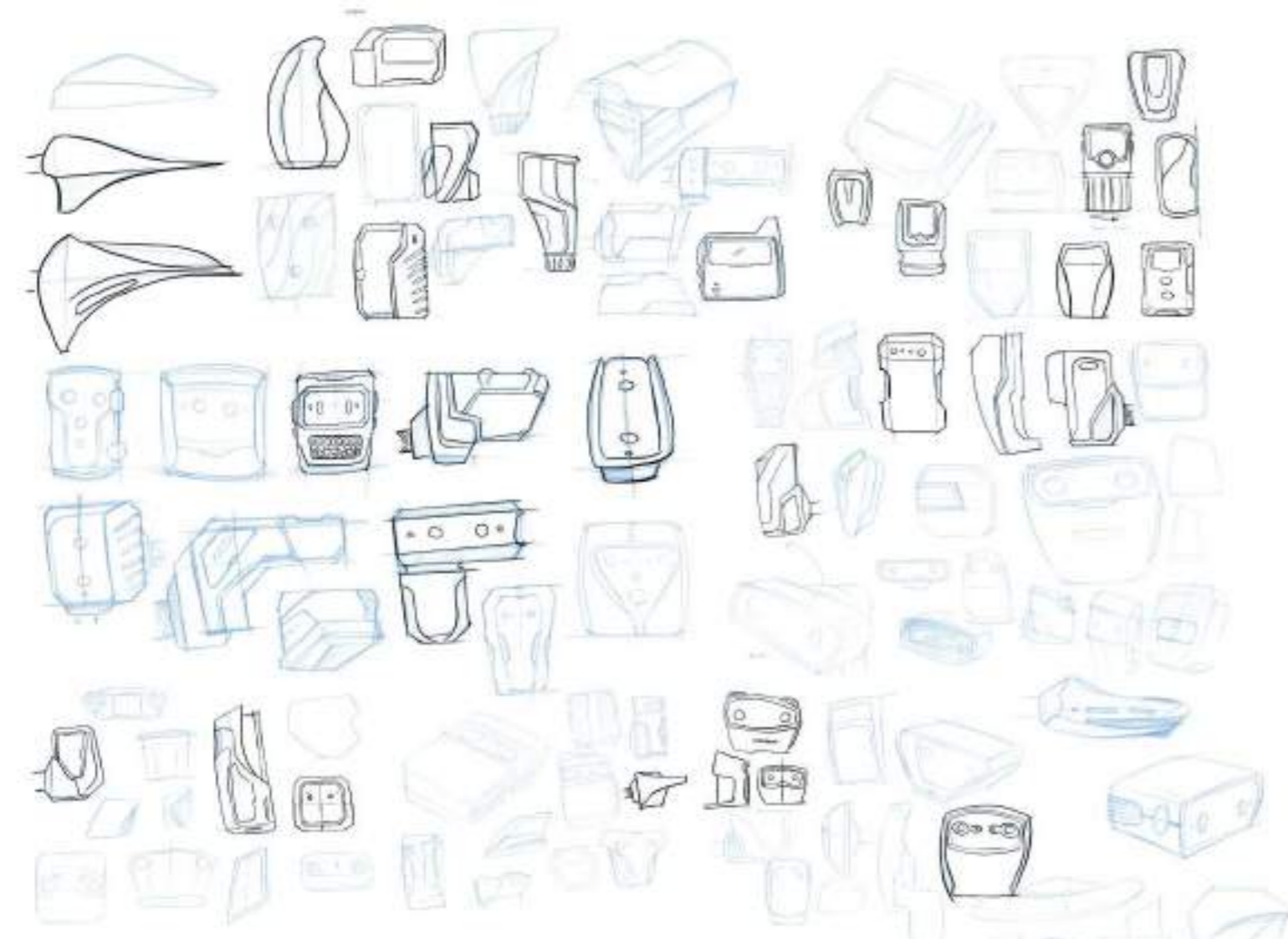
Conclusion

Key Insights from the Visual Analysis Exercise

- Minimalist, unifying colours
- Materiality and its processes are vital to the overall perception of a product and its usability.
- Name and brand placement as important.
- Creating longevity through adjusting with the needs of your customer base, and empowering them to be able to make the changes or easy repairs when needed is essential.
- Unobtrusive to the environment or operations taking place.
- Clear form which is still familiar even when the main colour is different.
- Product narratives and legacies are built over time, and creating memorable products are about the experience it creates as much as visual aspects.
- Creating a recognisable product range - different from competitors and associated with specific values.
- Scalability within a brand addresses different needs while also allowing for the longevity of the company.
- Form and colour helps to tie the products in the range together.
- Creating a memorable colour palette to tie aspects of a brand and product range together is really important.
- Understanding the market who will be purchasing into the product and their needs can be the crucial factor when deciding between two alternatives.
- Materiality can lend a lot to the overall feeling from a product even without colour changes, and that anthropomorphism can be emphasised through changing of expressions to make the product appear more sentient.
- Highlighting key touchpoints is useful in the usability of a product, as well as utilising colour to guide the ergonomics for best use of the product.
- Anthropomorphism has a fine line of interesting and unsettling, however there are many connections that can be made in the narrative between the robot and the animal they are likened to.
- Creating products which appear friendly can be done in both subtle and emphasised ways, and it is a fine line before the product may be inappropriate for its context.
- The use of CAD can be both cohesive, and deceptive, so it needs to be used appropriately.
- The use of inviting words can make people excited to navigate an interface or website to learn about your product or service.
- Form is an important part of product navigation and usability, and can set the tone for the product as being friendly, aggressive, etc.
- Benefits from a product or service goes beyond only the technical, and often also ties in the emotional connection that people have with their agency.
- Creating a brand which feels open and warm can often take away a lot of the stigmas associated.
- Using bold, clear language and graphic elements can make it a lot easier to capture engagement and highlight memorable parts of the brand.
- Creating a familiar product range through its visual nature is important in creating memorable products.
- Colour will be important to stand out from the existing solutions.
- There is value in understanding the existing competitors and what they are offering. The value of design will be in creating developed products that meet the technical needs as well as the human factor based needs.
- The language and imagery used is important in signifying the success of a system over another competitor, however using language that is too assertive can make people skeptical.
- Being able to use a system across different devices is a practical asset, and then being able to assess the data collected easily to get insights is crucial.
- Designing for different abilities, such as left and right handedness and other forms of inclusivity.
- When designing products that require high levels of durability, materiality will be key in ensuring that the body of the device is able to cope in the outdoor environment.
- Products which are functionally-driven but lack any user navigation cues can be difficult to understand and interact with, making this product feel like it is an 'expert's device', rather than the lay grower or packer. This can be problematic for ongoing use.
- Products which are intuitively integrated into our everyday operations make for less disruptive use, and promotes ongoing interaction with the product.
- Creating a system which allows for parts to be replenished adds to the longevity of use for the product.
- Creating bold, simple shapes can be effective for making the product easy to navigate, especially when assisted by colour.
- Reviewing the fundamental ideas of the brand, such as luxury and success and then finding ways of visually expressing this in the product and its advertising.
- Creating a modular system means that a product regardless of its own performance can be optimised to be easy to use in different contexts.
- Aspects of trust in Internet of Things products mean that sensitive data needs to be carefully protected to maintain the trust of the individual and the integrity of the product name.
- The intersection of engineering and design can be dealt with in varying degrees. Having a cohesive visual language across products in vital.
- The ability to customise a product to your specific needs is crucial to the ongoing use of the product.
- There is a trade-off when needing to design a product of which you might need a bulk amount, that you either make them as recyclable as possible or you make them last. The price range of these products might also be indicative of the expected range of my product.
- Dieter Rams created a series of principles that he believes makes for successful products which has been popularised in the discussion of products.
- Functional systems such as the clicking mechanism being standardised and in a different colour is useful for colour navigation.
- Creating a consistent visual makes the brand easier to differentiate and buy into.

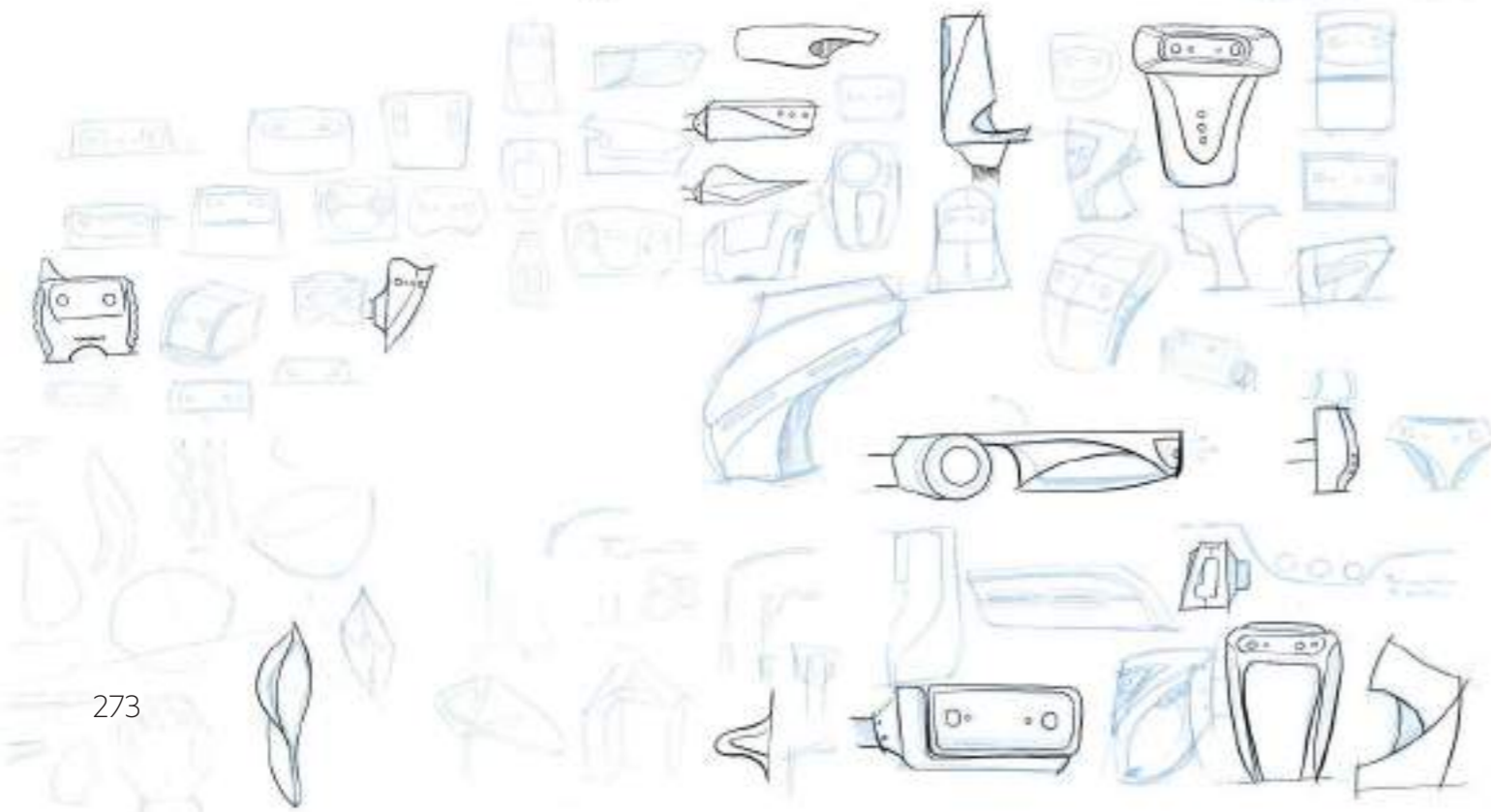
Examples of Data Visualisation pieces that were annotated to identify relevant parts to the research project.





Form Development

Approaches:
Robust | Emotive | Sci-fi | Organic | Minimalist



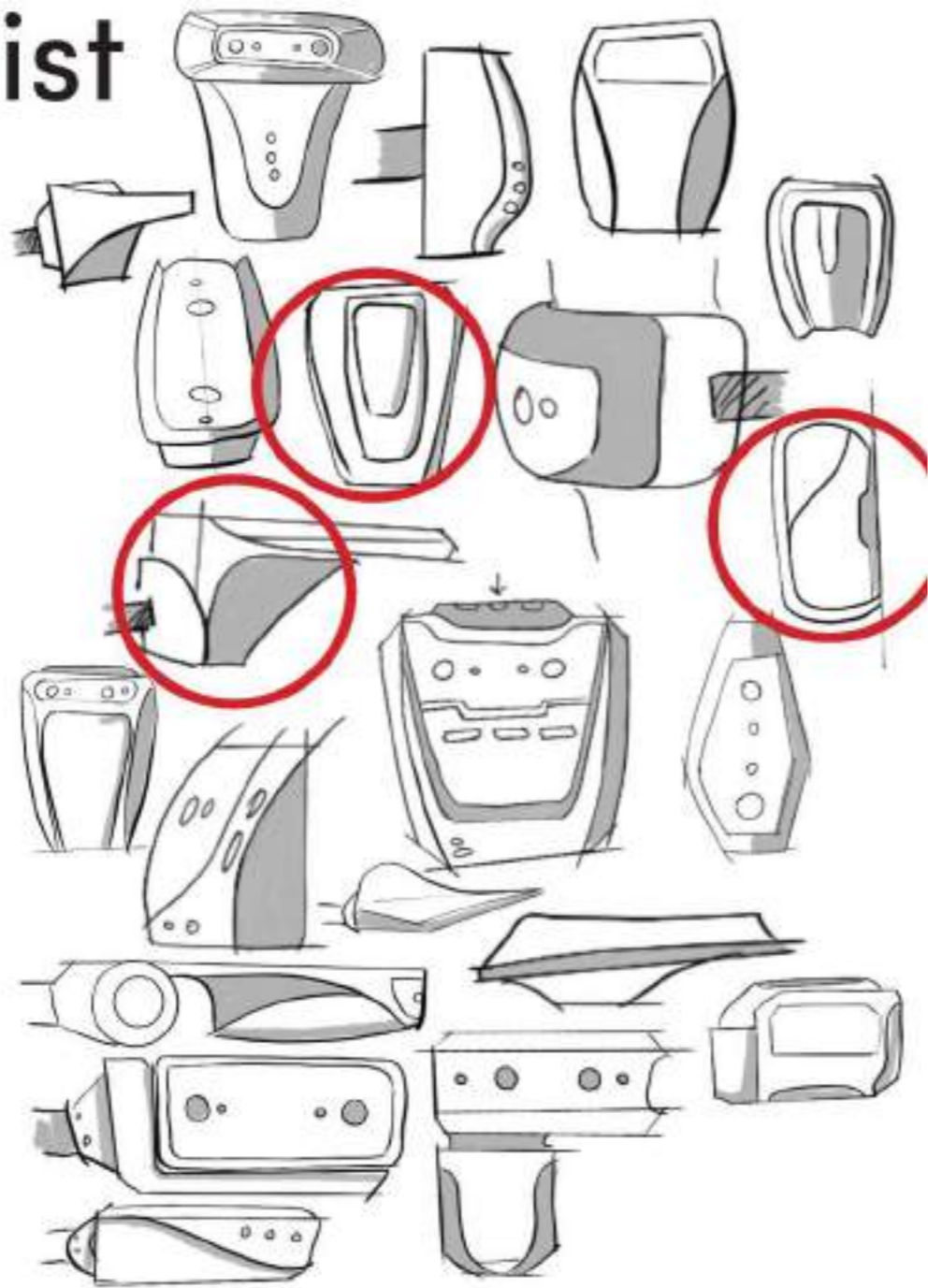
Robust

This approach seeks to develop a sense of robust and reliable form factor into the design. It seeks to explore utility and materiality as well as features that could improve the user experience.

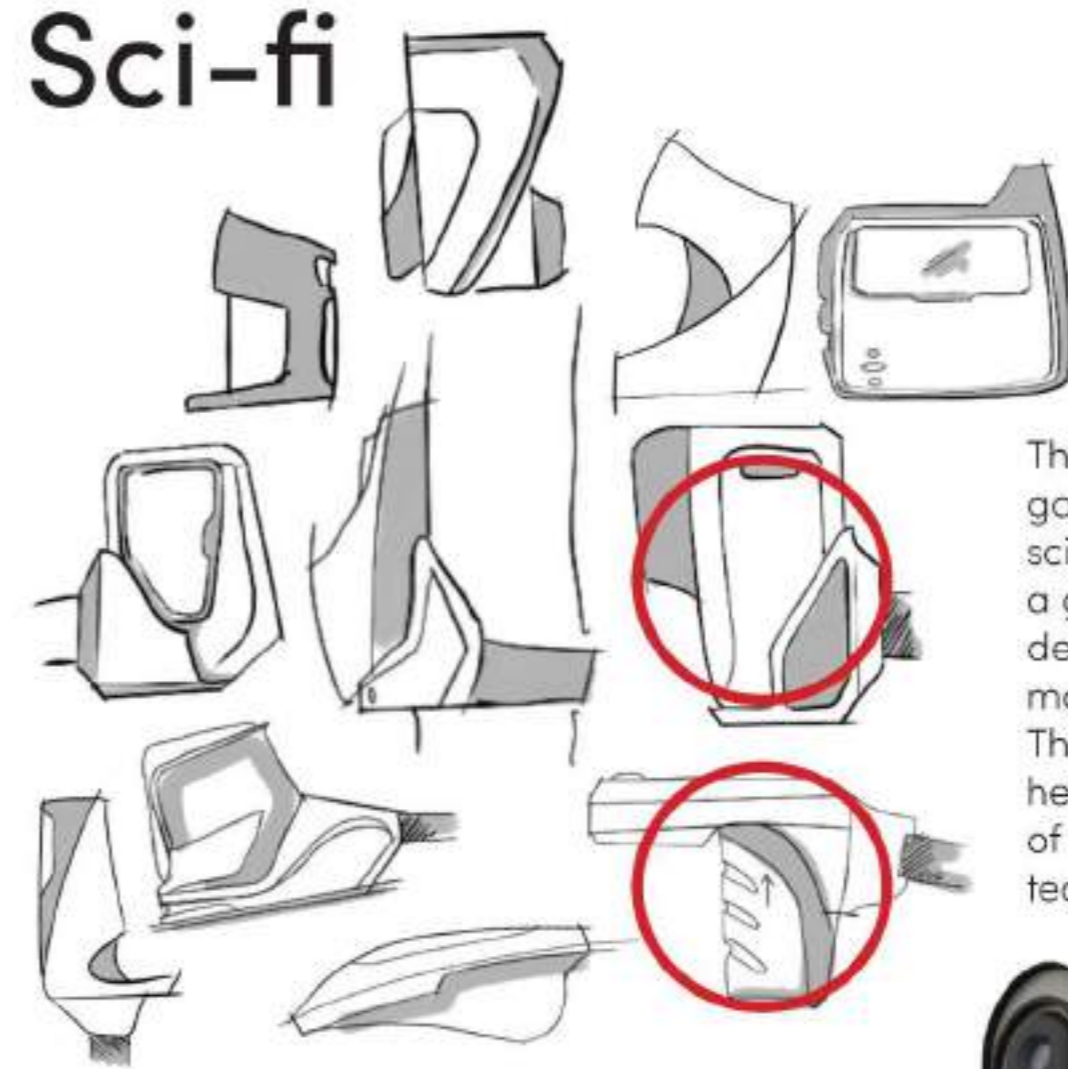


Minimalist

This approach seeks to design a form that seeks simple line and details to create a modern, sleek tool.



Sci-fi

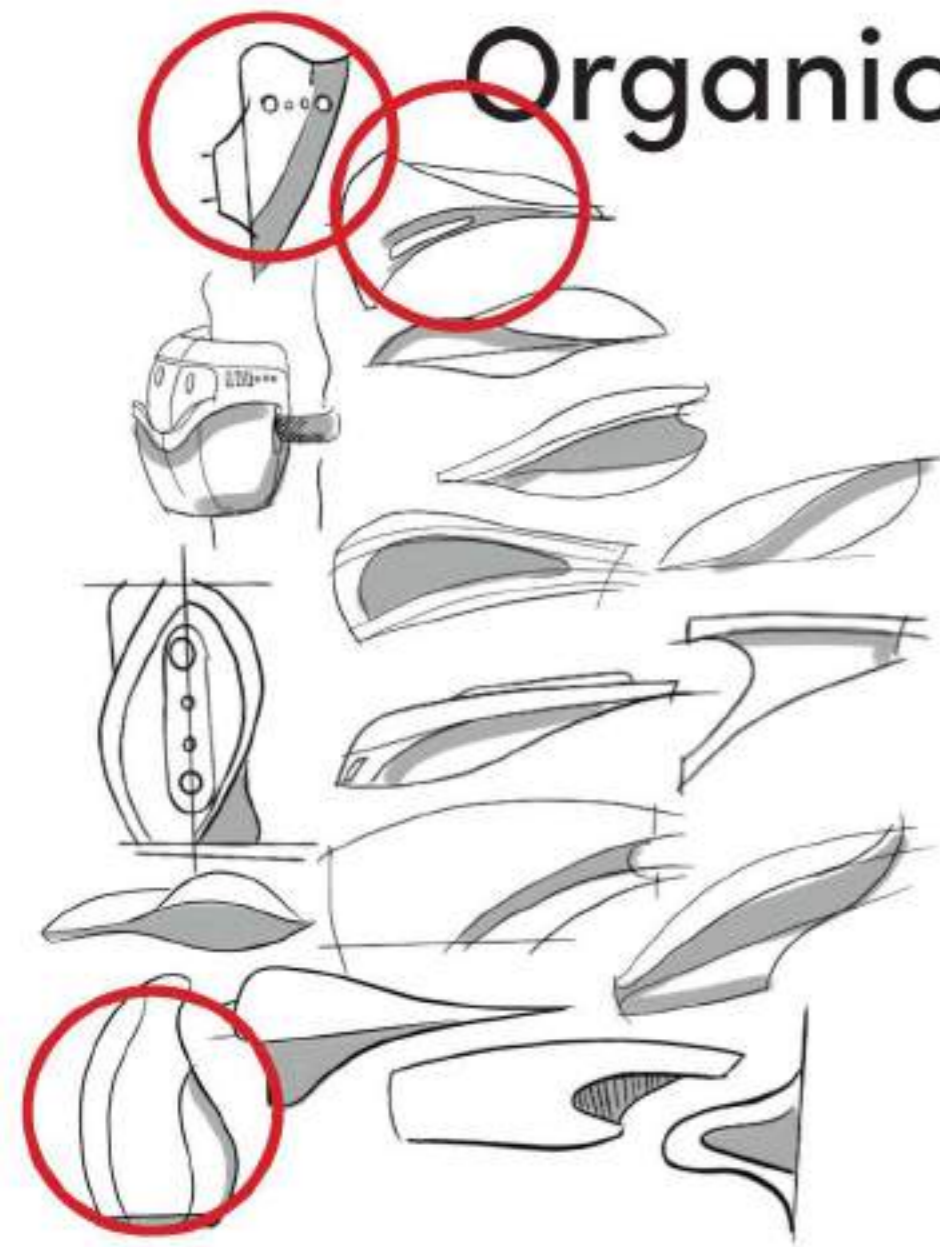


This approach seeks to gain inspiration from science-fiction and offer a great deal of surface detailing and is the maximalist approach. This approach also heightens the sense of the tool being technologically-driven.



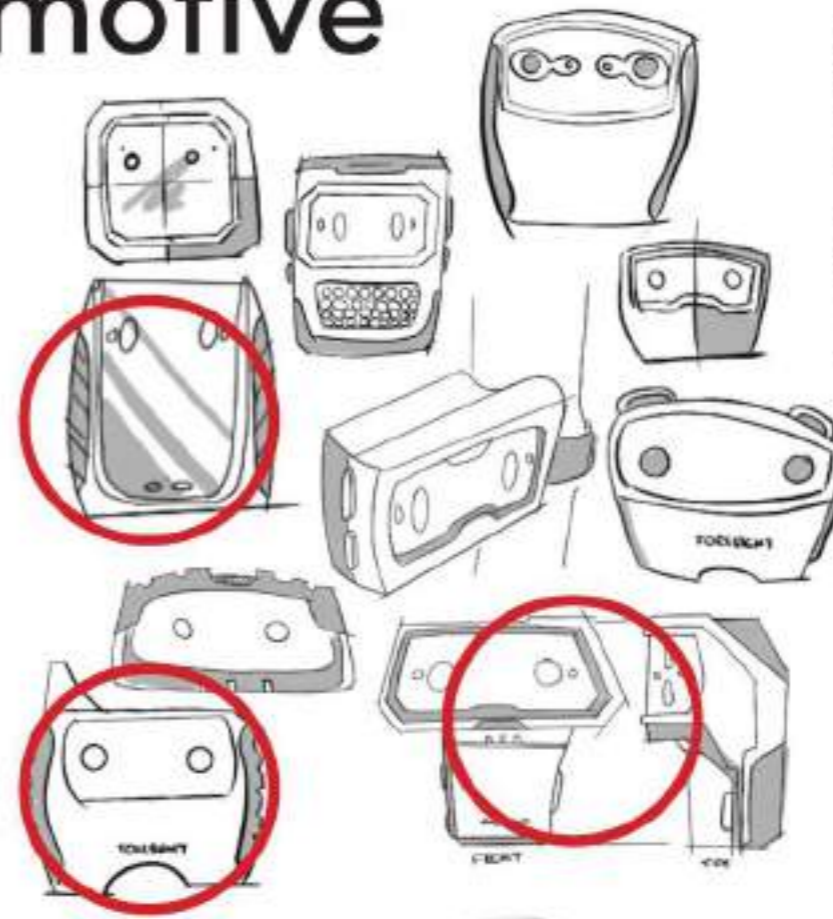
Organic

This approach seeks to find inspiration within nature and reflect it through organic line, texture and integration of the tool to the tree.

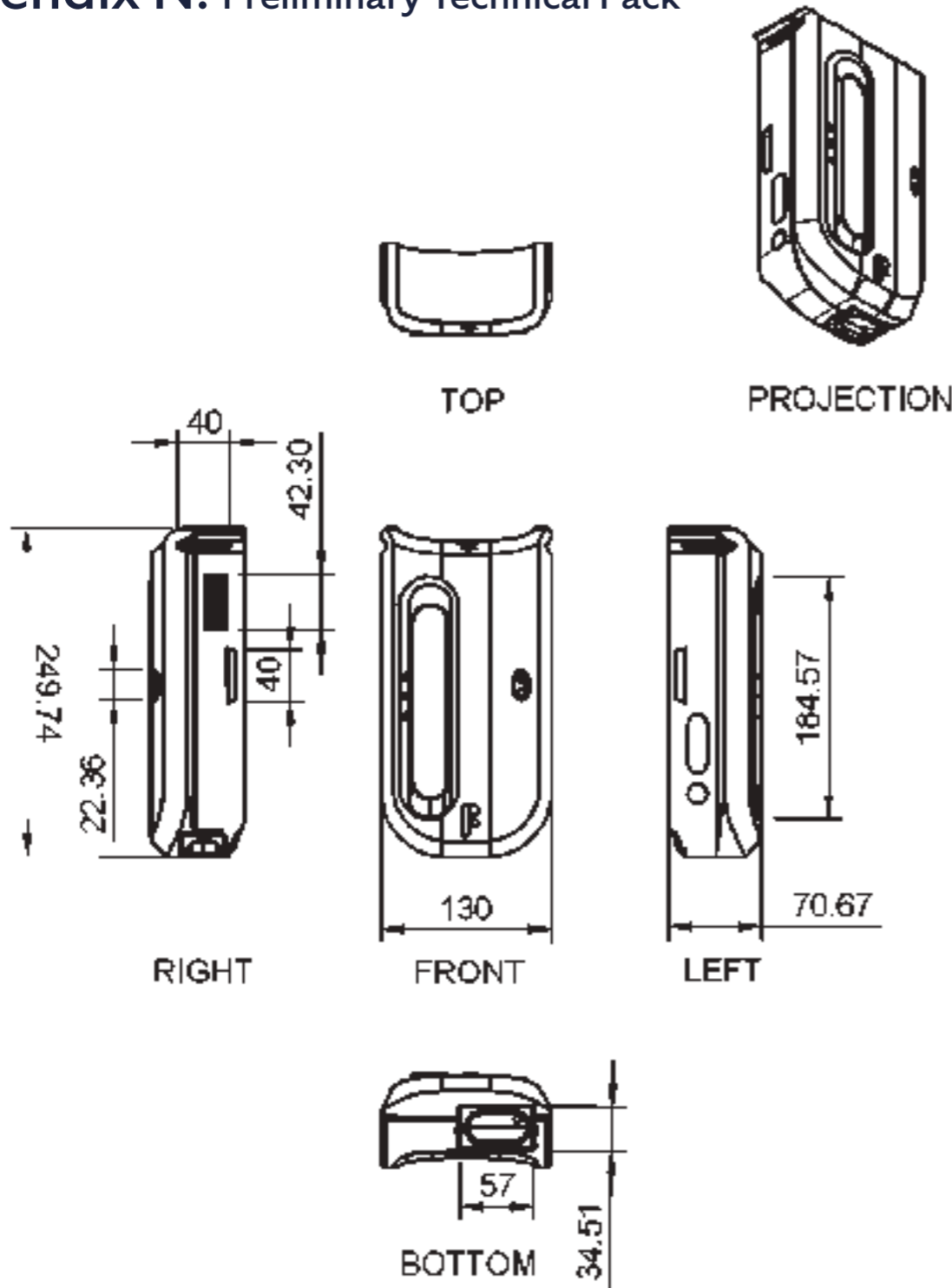


Emotive

This approach seeks to explore how emotion can be conveyed through the 'face' of the tool and how the creation of a character could lead to a sense of familiarity and willingness to cooperate with the design.



Appendix N: Preliminary Technical Pack



A-A (1:2)

B-B (1:2)

8	Battery Connector	
7	Flash Cap v3	
6	ZED 21 Lens Protector v2	
5	ZED 21 v1	
4	Lower Body And Electronics v20	
3	Tree Strut v2	
2	Indicator Lighting	
1	Battery	
Item	Part Name	Description

Created by	Zene Krige	15/09/24	Approved by	Ryan Greer	15/09/2024
Document type	Dimensioned View Foresight		Document status	1	
Rev	Date of issue	Sheet	DWG No		
		1/2	1		

Created by	Zene Krige	15/09/24	Approved by	Ryan Greer	15/09/2024
Document type	Section View		Document status	2	
Rev	Date of issue	Sheet	DWG No		
		1/2	1		