

Automating the California Strawberry Industry

John Lin, Ph.D.

Director of Automation Engineering

June 2023

CALIFORNIA
STRAWBERRY
COMMISSION

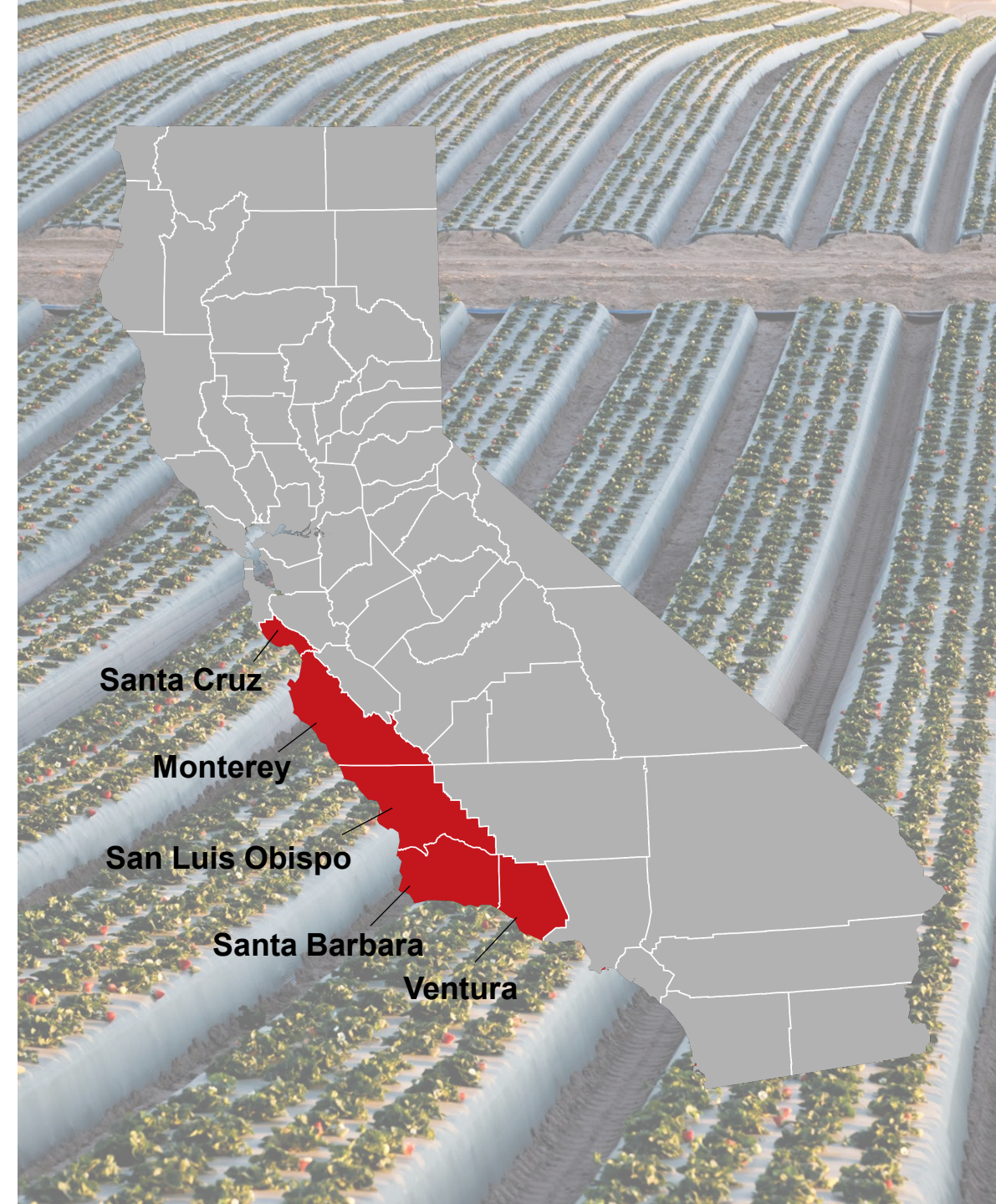
California Strawberries All Year Round

Fresh: 1.9 Billion Pounds

Frozen: 342 Million Pounds

Crop Value: \$3.0 Billion

Area: 37,552 Acres

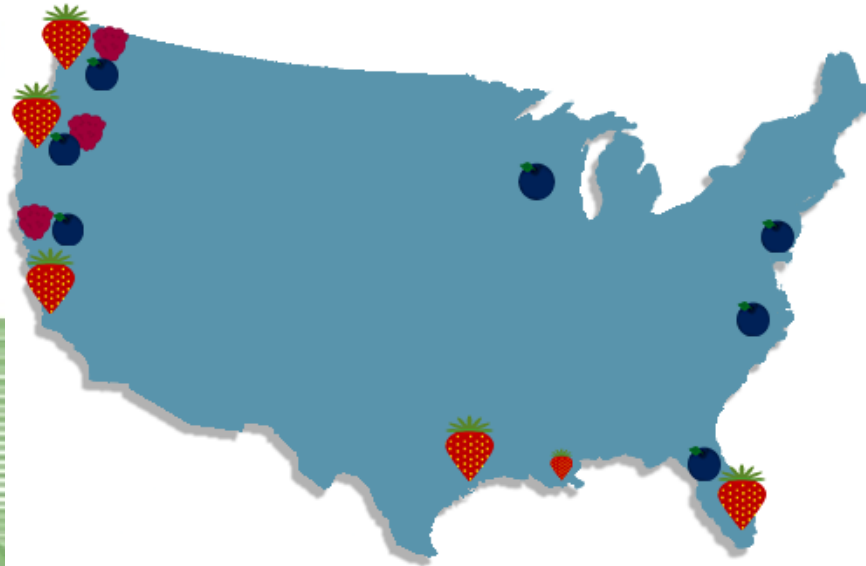


California Strawberries: Market Facts

USING LESS THAN 1% OF CALIFORNIA'S FARMLAND strawberries produce the fourth most valuable crop in California

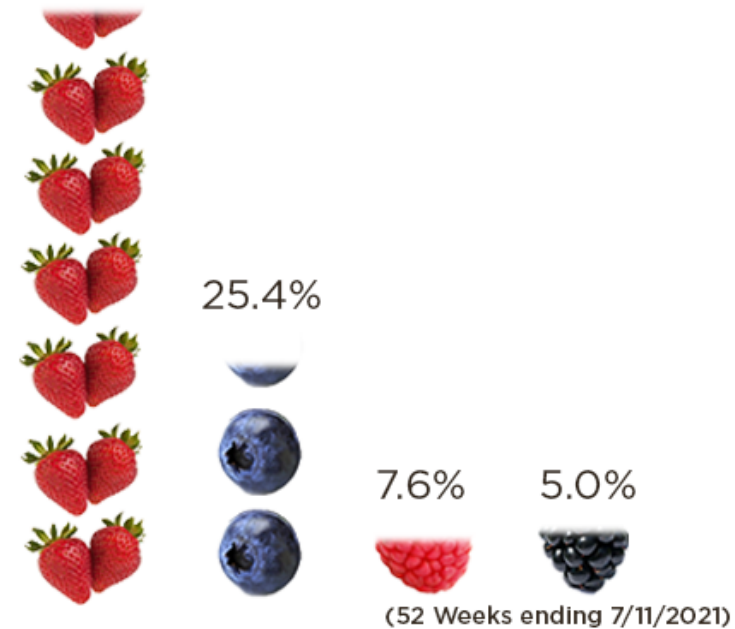


CALIFORNIA GROWS nearly 90% of all strawberries that are produced in the U.S.



(5 year average 2013 - 2017)

STRAWBERRIES account for 59.7% of berry pounds sales



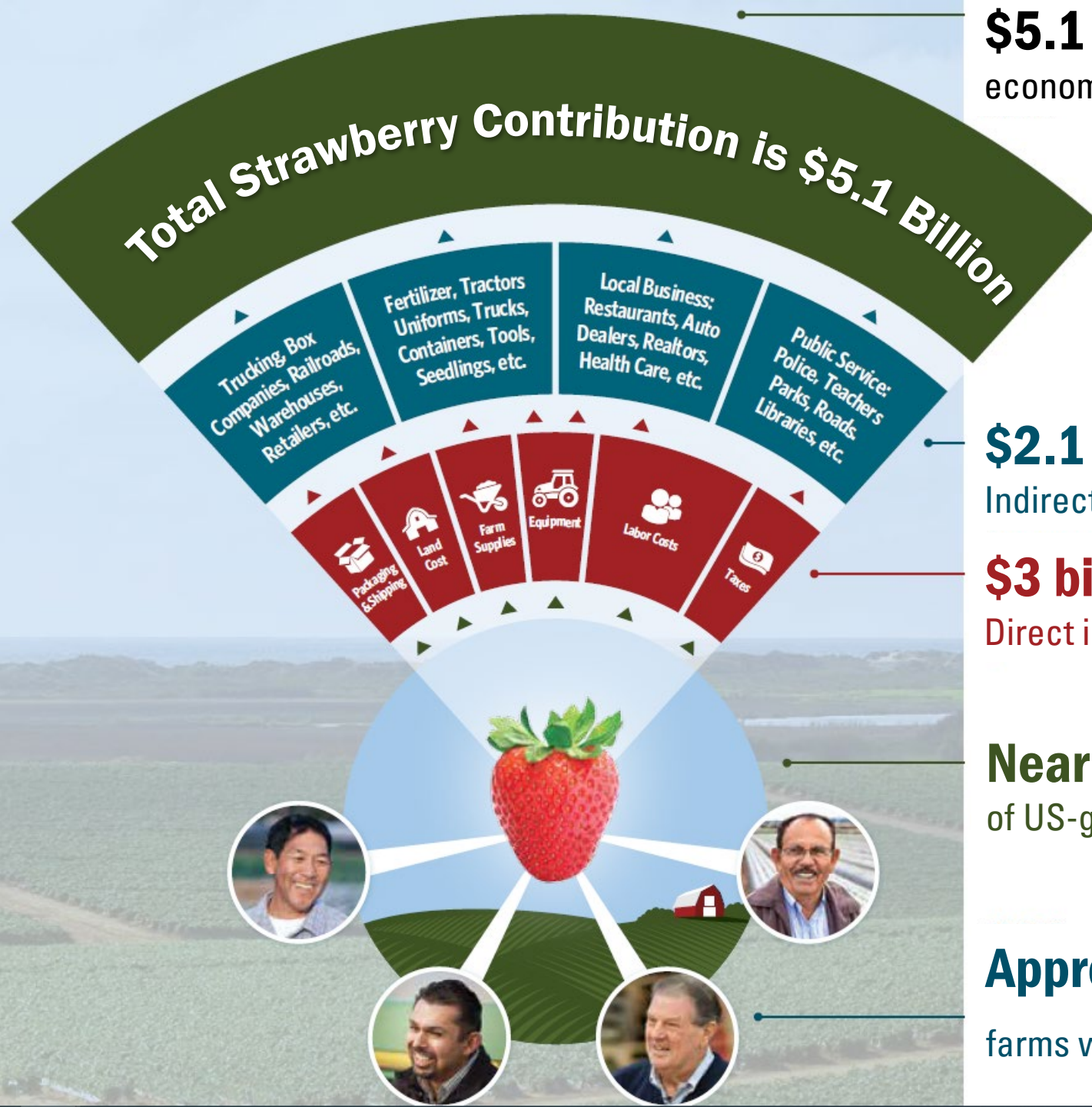
[CDFA Home](#) | [California Agricultural Production Statistics](#)

California Agricultural Production Statistics

California's Top 10 Agricultural Commodities

California's agricultural abundance includes more than 400 commodities. Over a third of the country's vegetables and three-quarters of the country's fruits and nuts are grown in California. California's top 10 valued commodities for the 2021 crop year are:¹

- | | |
|---|-------------------------------|
| ➤ Dairy Products, Milk — \$7.57 billion | ➤ Pistachios — \$2.91 billion |
| ➤ Grapes — \$5.23 billion | ➤ Lettuce — \$2.03 billion |
| ➤ Almonds — \$5.03 billion | ➤ Tomatoes — \$1.18 billion |
| ➤ Cattle and Calves — \$3.11 billion | ➤ Walnuts — \$1.02 billion |
| ➤ Strawberries — \$3.02 billion | ➤ Rice — \$1.00 billion |



\$5.1 billion

economic contribution generated by California strawberry farmers

\$2.1 billion

Indirect impact of strawberry farmers

\$3 billion

Direct impact of strawberry farmers

Nearly 90%

of US-grown strawberries are from California

Approximately 250 family-owned strawberry farms with **70,000 jobs created**

University Network





About CA Strawberries ▾

Strawberry Health & Wellness ▾

Recipes ▾

Strawberry Farm Stories ▾

Blog

Search...



California Strawberries Healthy, Sustainable, and Delicious

Discover the care that goes into the land and people that produce the strawberries we all love.



 **Our Farmers**



 **Health &
Wellness**



 **Recipes**



 **The Best Summer
Cocktails**



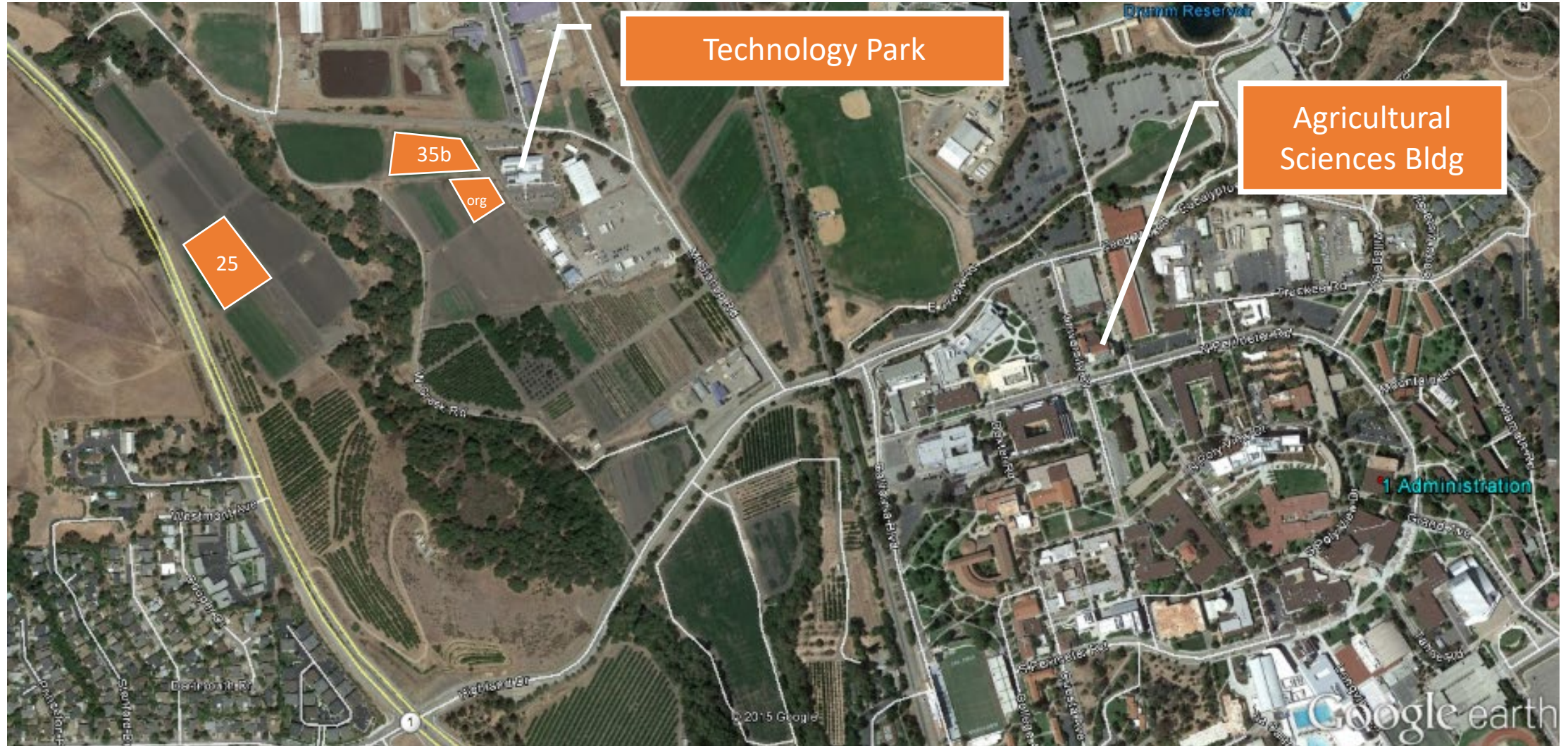
Pres. Jeff Armstrong

Chairman Victor Ramirez

CAL POLY
SAN LUIS OBISPO

California
STRAWBERRY
COMMISSION

Campus field research locations





Mission: Increase the sustainability of California Strawberry growing through research and education that is aligned with grower needs.

Strawberry Center

Entomology

Pathology

Automation

Role In Automation



Fund

RFP / Internal Research



Facilitate

Define Targets / Farmer Surveys
/ Field Studies



Coordinate

Seminars / Field Days /
Introductory Meetings



Goal



Provide commercially
available solutions
within five years



Targets



Planting



Pruning



Pest Management

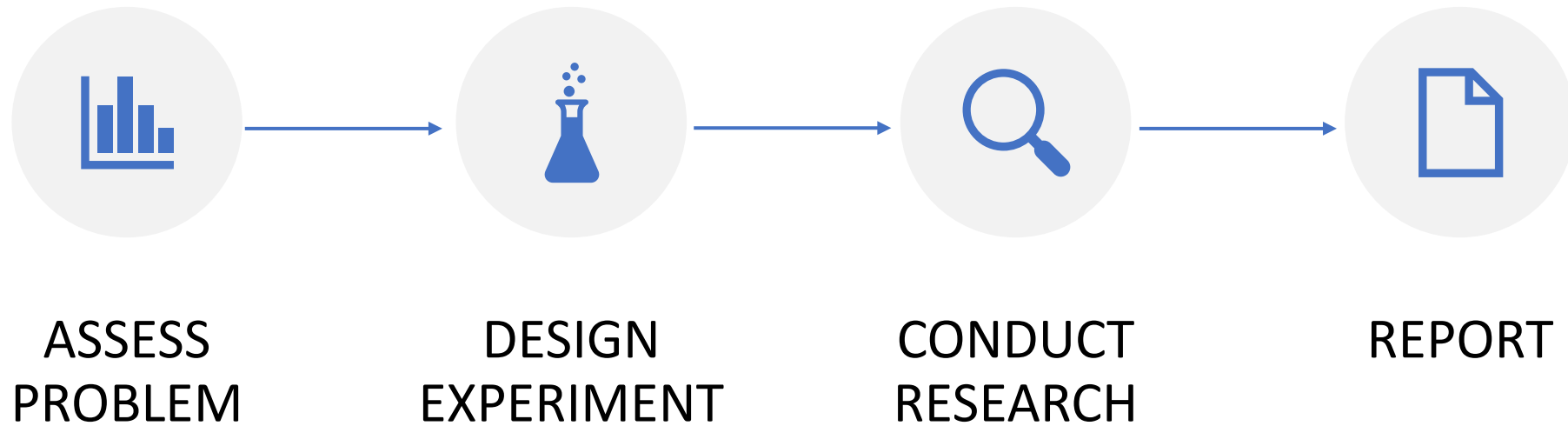


Picking



Processing

Conventional Approach



SBIR PROGRAM OUTPUTS

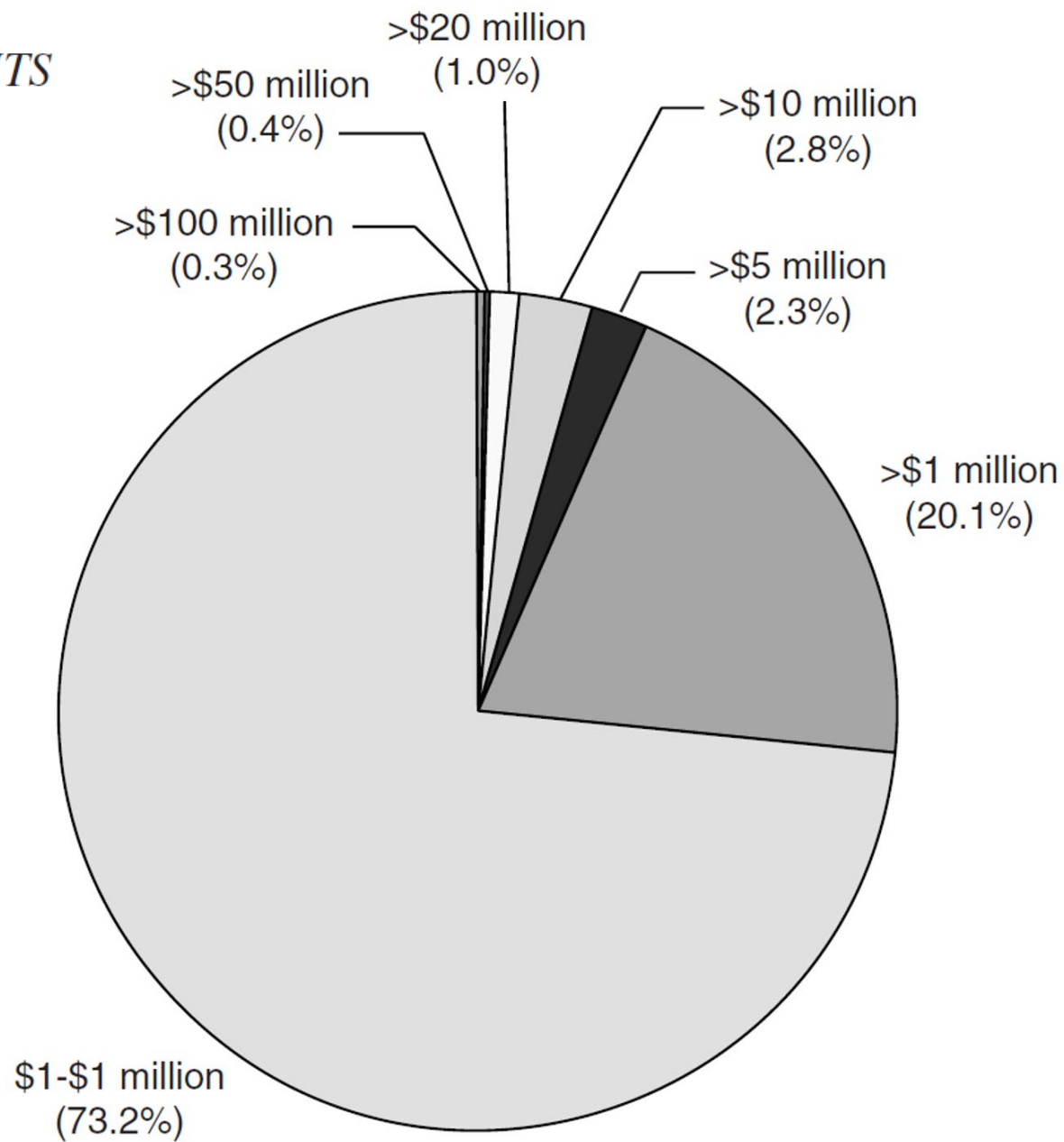
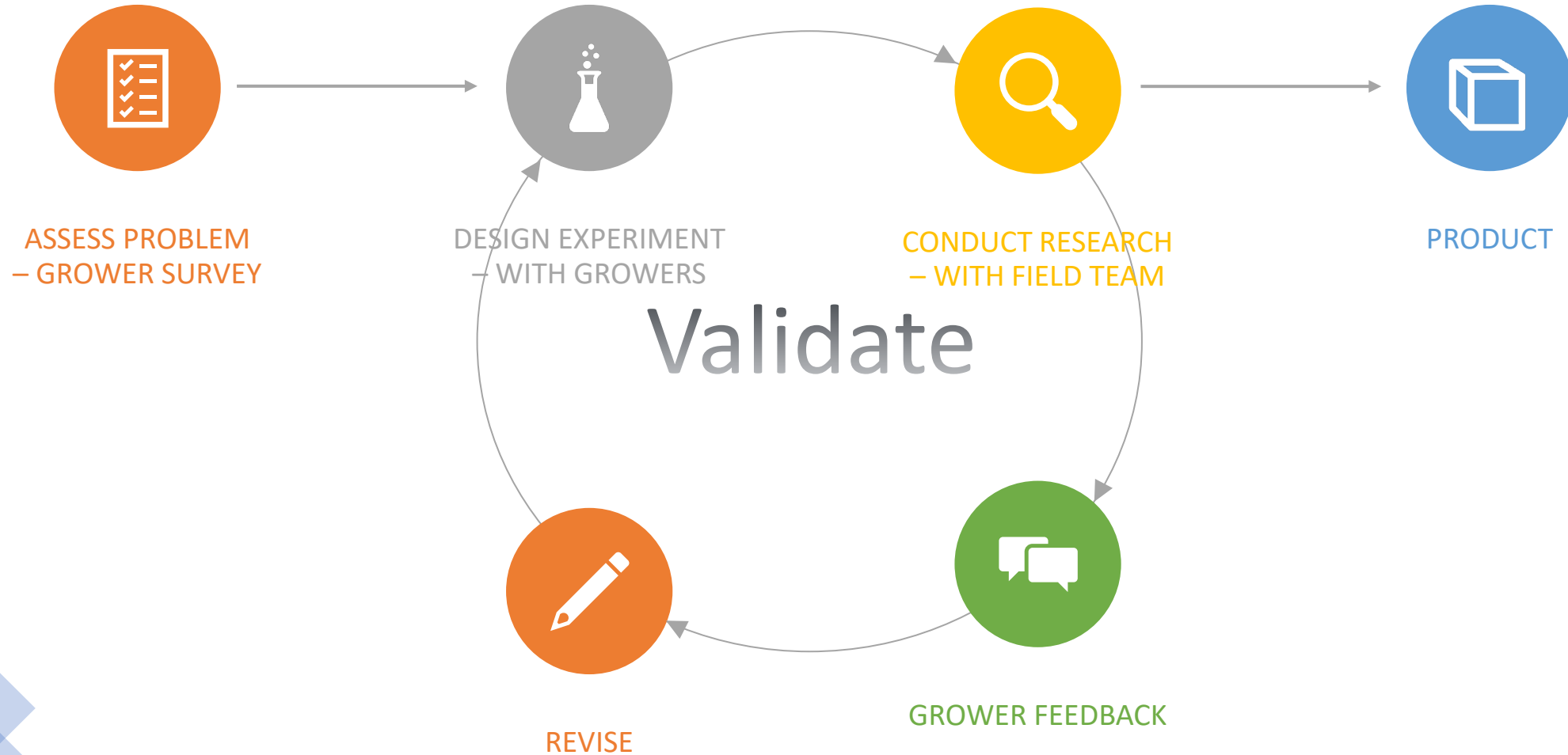


FIGURE 4-2 Distribution of projects with sales >\$0.

SOURCE: NRC Phase II Survey.

Strawberry Center Approach



Playbook



Listen to growers



**Products that meet
growers where they are**

Product Development Process

Exploration

UNIVERSITY
OF
CALIFORNIA

Application



Validation



Commercialization

2016



Automation



2018

Planting

Pruning

Pest Management

Picking

Processing



Bare Root Transplanting



Runner Detection



Bug Vacuum Optimization



Production Forecasting



Nutrient Delivery



Spray Rig Optimization



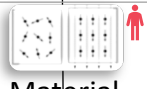
Machine Vision



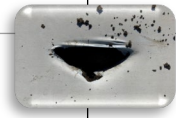
Path Planning



Precision Farming



Material Handling



Cross Hole Puncher



Runner Localization



Next-Gen Grow System



Bio-Kinematics



Adoption Economics

2020



Hoop House Remover



Runner Economics



Mite Counting



Time Motion Study



End Effector

2022



Runner Cutter



Lygus Monitoring



Harvester Economics

2024



UV-C Pest & Disease control

University research projects from 2016 to 2023

= Team of 1 to 5 students



CAL POLY

Strawberry Center

California Polytechnic State University, San Luis Obispo

Ag Sciences



California Polytechnic State University, San Luis Obispo

Ag Sciences

Ag Comm.

Automation
Summit

Mathematics

Biomechanics

Engineering



Home : Strawberry Automation Summit Held at Cal Poly

Strawberry Automation Summit Held at Cal Poly



OUR WORK

- [Presentations](#)
- [Research Posters](#)
- [Research Publications](#)
- [Outreach Publications](#)



CAL POLY **Department of Computer Science and Software Engineering**

CAL POLY **Mathematics Department** *College of Science & Mathematics*

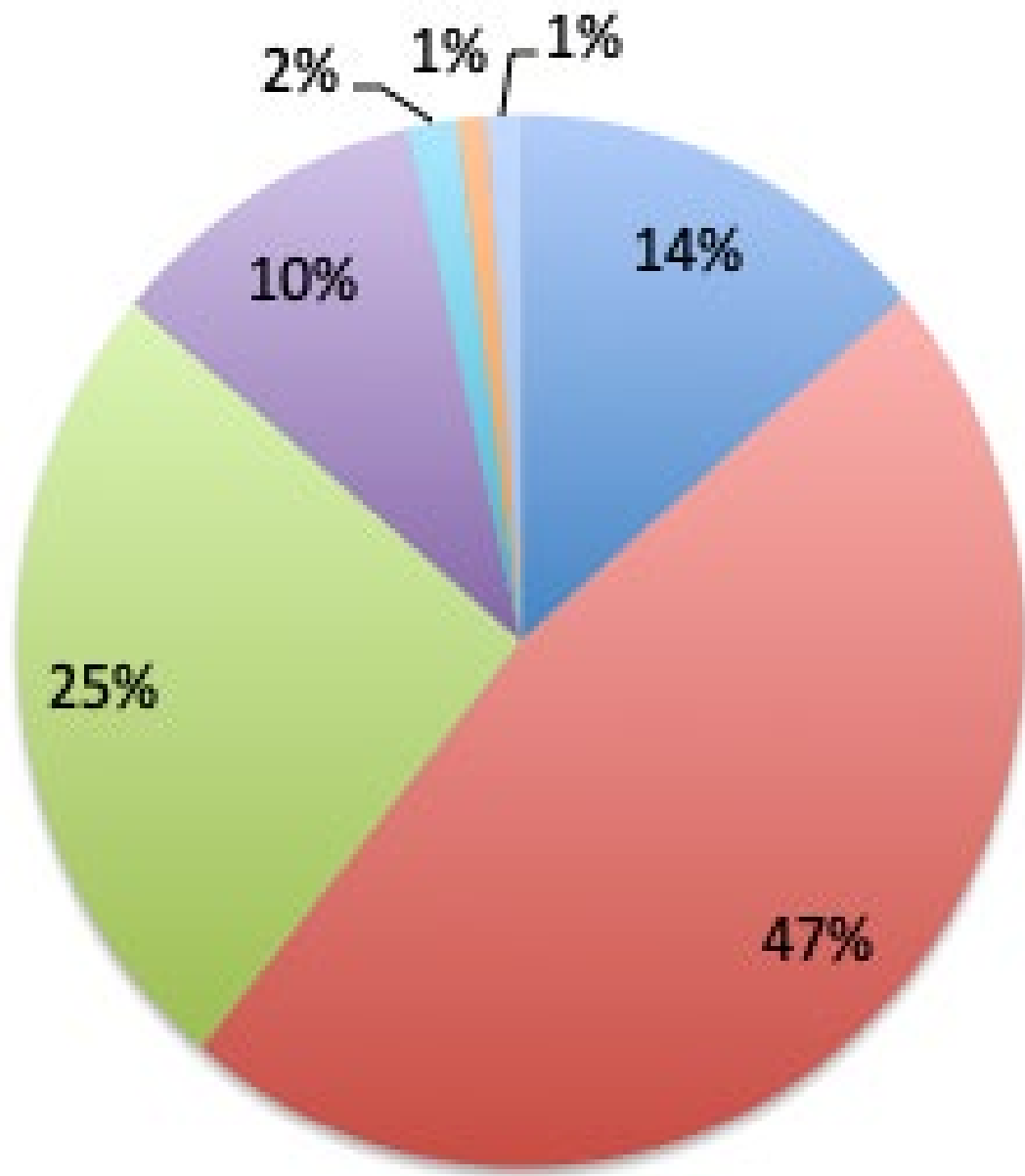
CAL POLY **Agribusiness Department** *College of Agriculture, Food & Environmental Sciences*

Home : 1st Annual Strawberry Automation Summit

1st Annual Strawberry Automation Summit

In January 2018 Professor Timothy Delbridge and Agribusiness students Drew Allen and Allison Deoudes participated in the 1st Annual Strawberry Automation Summit. The event featured presentations from engineers and business leaders at the forefront of automation and production technology in the strawberry industry. Drew and Allison are both working with Delbridge on strawberry industry research projects.

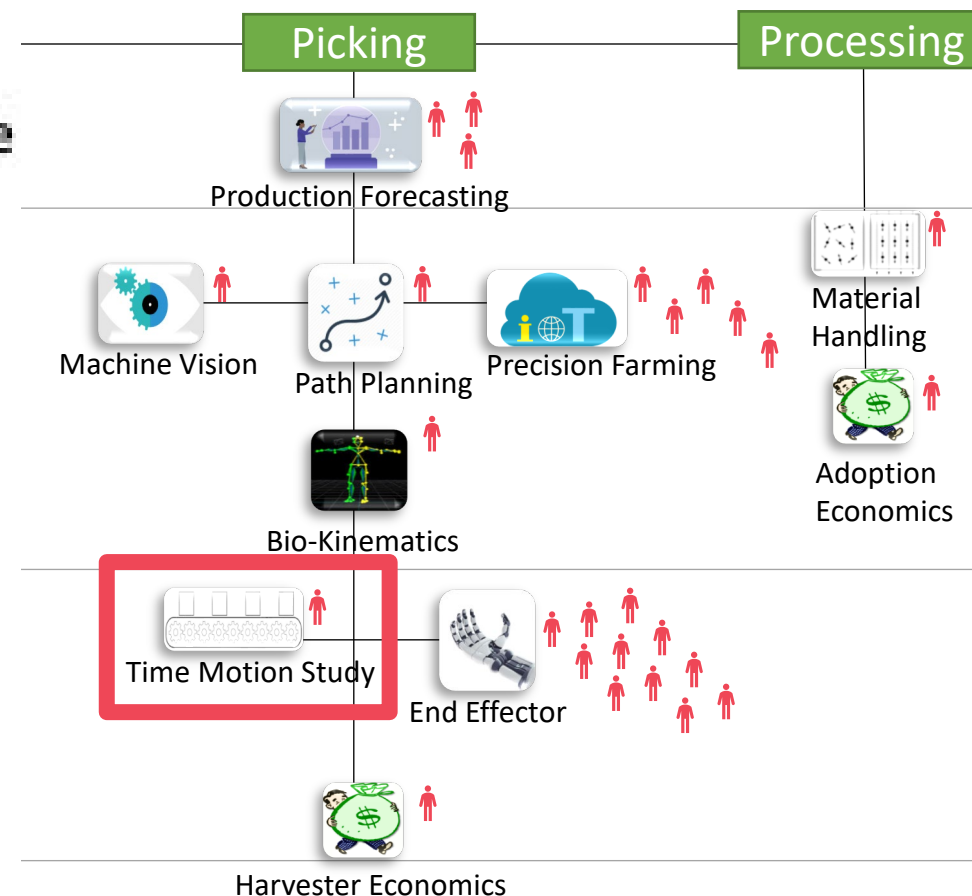
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- Tray Exchange
- Picking
- Packing
- Searching
- Quality Ass.
- Rest
- Move Rows



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Strawberry Center



UV-C Pest & Disease control

University research projects from 2016 to 2023

👤 = Team of 1 to 5 students

2016

Planting

Pruning

2018



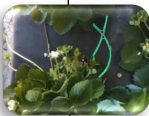
Bare Root Transplanting



Runner Detection

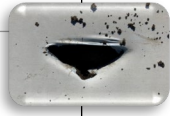


Nutrient Delivery



Runner Localization

2020



Cross Hole Puncher



Runner Economics

2022



Hoop House Remover



Runner Cutter

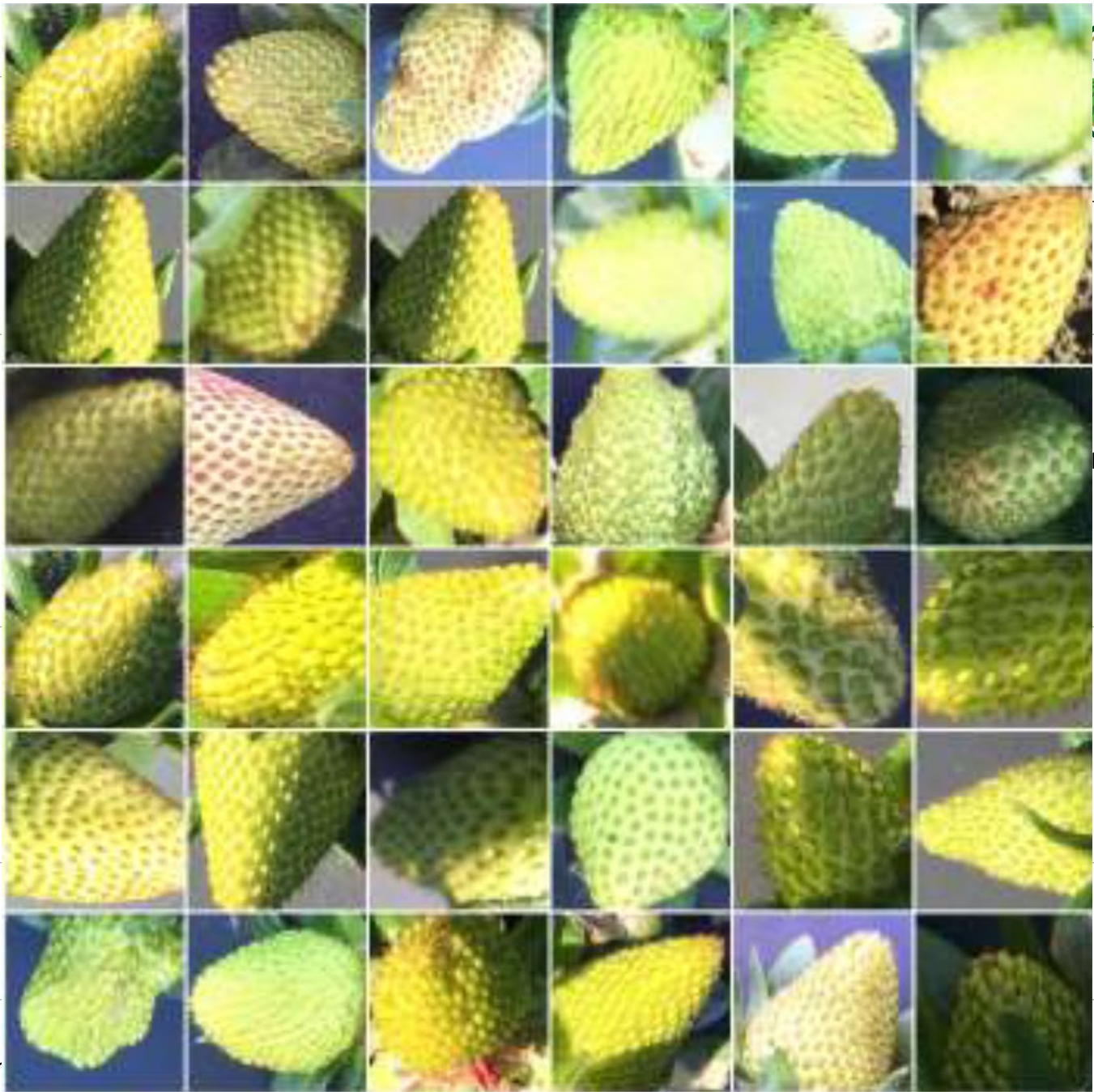
2024

University research projects from 2016 to 2023

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2016



2018

2020

2022

2024

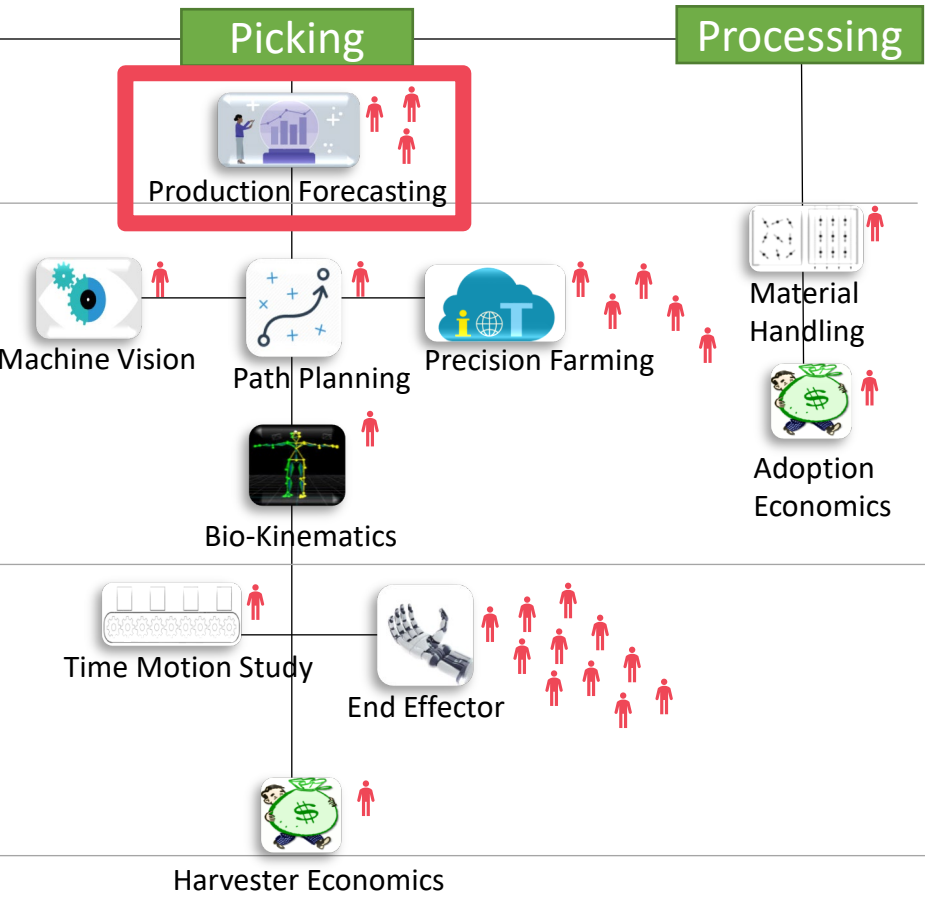
University r

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2016

Planting

Processing

2018

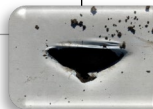


Bare Root Trans



Nutrient Deli

2020



Cross Hole Pur

2022



Hoop House Remover



Runner Economics



Runner Cutter



Lygus Monitoring



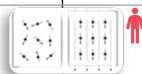
Harvester Economics



2024



UV-C Pest & Disease control



Material Handling



Adoption Economics

University research projects from 2016 to 2023

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2016



Planting

Pruning

Pest Management

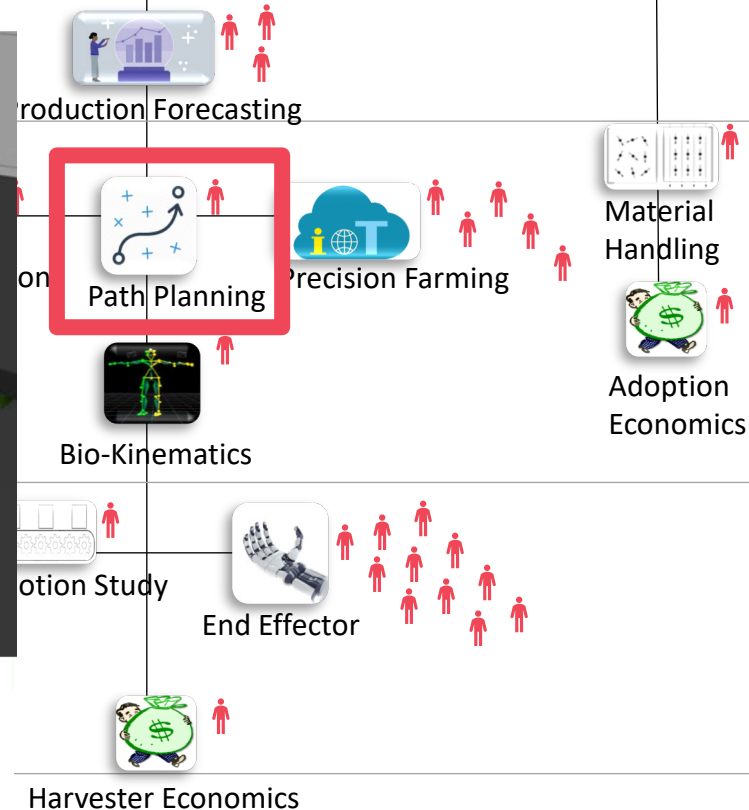
Picking

Processing

2018



2020



2022



2024



2016

Economic Feasibility of Strawberry Processing Mechanization

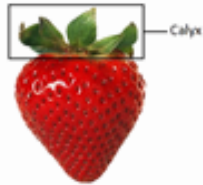
Drew Allen and Timothy Delbridge
Agribusiness Department

CAL POLY
College of Agriculture, Food
& Environmental Sciences

CAL POLY
Strawberry Center

Introduction

Strawberry processing is an important part of the industry but often goes unnoticed. In 2015, 627 million pounds of strawberries were processed, valued at \$276,330,000. Every strawberry that goes into the processing side of the industry must have the calyx removed. This removal process is currently done by hand, either in the field or processing facility.



Objectives

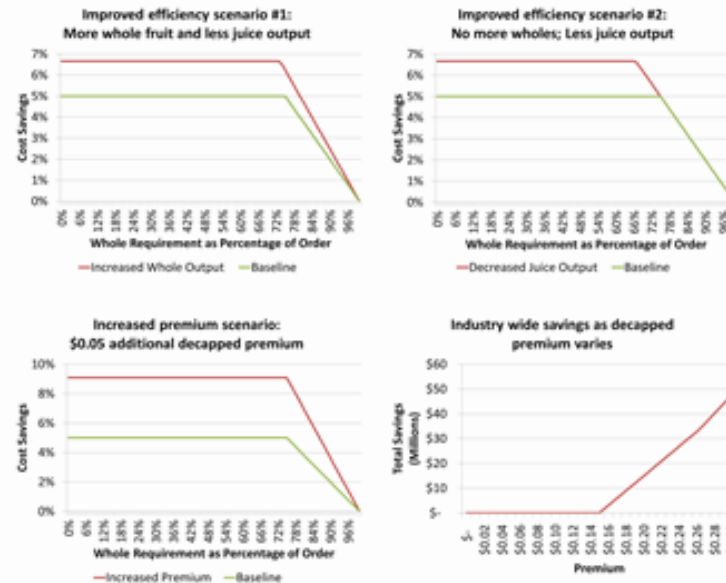
The objective of this project is to make a conclusion regarding the economic feasibility of a recently developed automated calyx removal machine. This machine uses a computer vision guided water knife to slice the calyx off the strawberry at a rate of 2,500 berries per minute.

Methods

We developed a linear programming model to identify the least cost strategy for decapping strawberries given the existence of the new technology subject to specified constraints. The model includes the option to purchase strawberries with the calyx, which will be sent through the automated calyx remover, or with the calyx previously removed. Strawberries purchased with the calyx previously removed are purchased at a premium but subject to less loss or fruit damage.

Results

Below are figures that show the results of the linear programming model and sensitivity analyses. These figures display how important individual parameters are to the total cost savings from implementing the robotic decapper. The baseline scenario reflects a required output of 50% wholes, 30% partials, and 20% juice with assumed costs of \$0.30 for capped strawberries and \$0.50 for decapped strawberries. These figures show the impact on cost savings from changing the assumed machine output efficiency and premiums for decapped fruit.



Conclusion

This analysis shows that the current output specifications of the robotic decapper do not make adoption feasible at current fruit prices. As can be seen in the results figures, the percentages of whole fruit and juice that are output from the machine create binding constraints depending on the order requirements. Premium also has a big impact on cost savings. The premium is much lower than normal in 2017, which causes the machine to be unprofitable. However, this is expected to rebound since many variables such as labor costs and yields cause the premium to shift.

This research points to three areas on which to focus moving forward.

1. Pre-sorting: Strawberries could be presorted so that only ideal size and conical shape are sent through the machine. This will increase the efficiency of the machine.
2. Partial Implementation: The machine could be implemented only at processors that have a relatively low whole requirements such as jam producers rather than industry wide. This will enable the machine output to meet a higher percentage of order specifications.
3. Machine Redesign: The machine could be redesigned to reduce processing speed and improve accuracy. This would allow the machine to meet more orders industry wide though the technical feasibility of redesign is uncertain.

2018

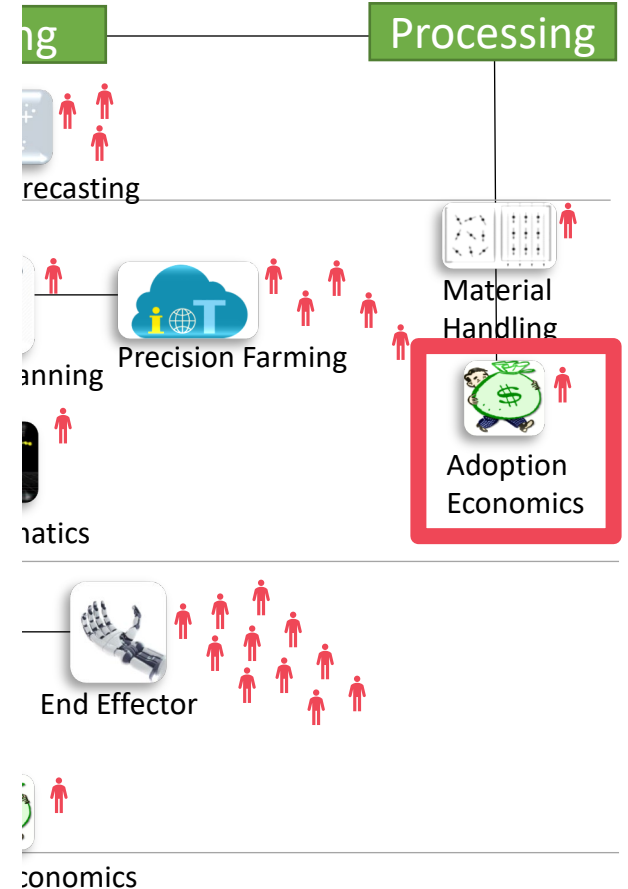
2020

2022

2024

University

= Team



2016



Automation



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Runner Cutter

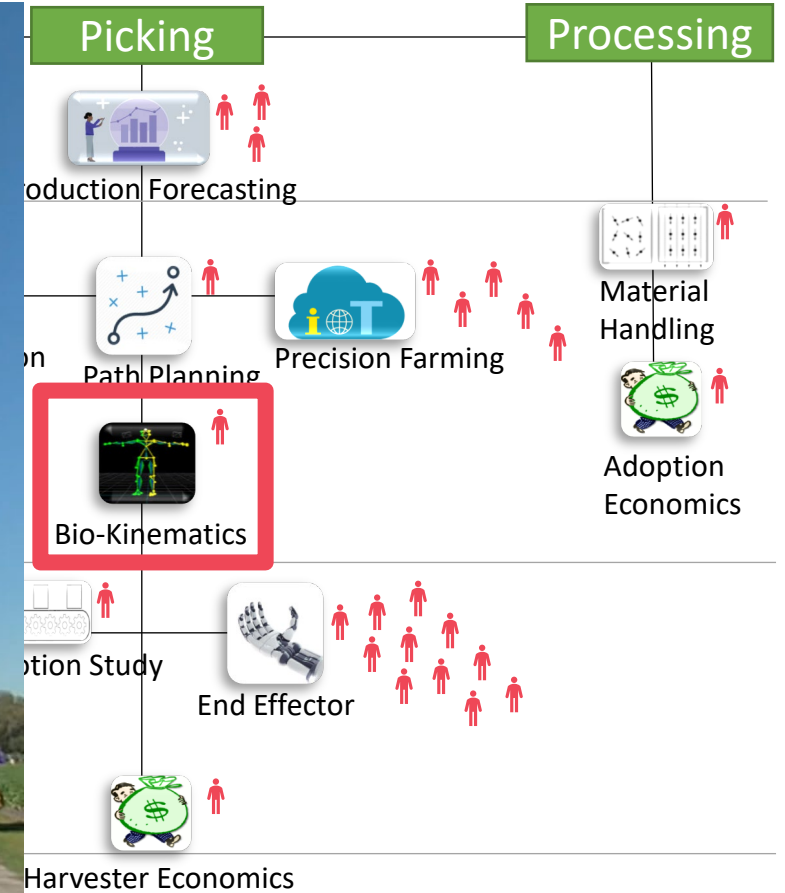


UV-C Pest & Disease control

2024

University research projects from 2016 to 2023

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Type to Save Image Here

Browse

Detect

Add Marker

Back

Next

Cross Hole Puncher



Hoop House Remover

Runner Economics



Runner Cutter

Mite Counting

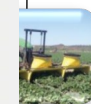


Lygus Monitoring



UV-C Pest & Disease control

Management



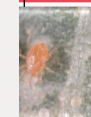
Optimization



Optimization



Grow System



Mite Counting



Lygus Monitoring



UV-C Pest & Disease control



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Picking



Production Forecasting



Machine Vision



Path Planning



Precision Farming



Bio-Kinematics



Time Motion Study

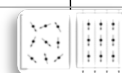


End Effector



Harvester Economics

Processing



Material Handling



Adoption Economics

2022

2024

University research projects from 2016 to 2023

👤 = Team of 1 to 5 students

Cancel

2018

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2020

2022

2024

University res

 = Team of 1

Automation



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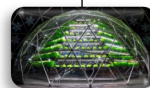
Pest Management



Bug Vacuum Optimization



Spray Rig Optimization



Next-Gen Grow System



Mite Counting



Lygus Monitoring



UV-C Pest & Disease control

Picking



Production Forecasting



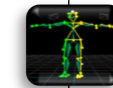
Machine Vision



Path Planning



Precision Farming



Bio-Kinematics



Time Motion Study

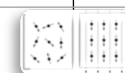


End Effector



Harvester Economics

Processing



Material
Handling



Adoption Economics

2016



Planting

Pruning

Pest Management

Picking

Processing

2018



Bare Root Transplanting



Nutrient Delivery

2020



Cross Hole Puncher

2022



Hoop House Remover

2024

University research projects from 20

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2016



Planting

Pruning

Pest Management

Picking

Processing

2018



Bare Root



Bug Vacuum Optimization



Production Forecasting



Material Handling

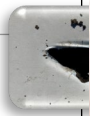


Adoption Economics

2020

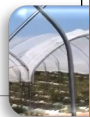


Nutrient



Cross Hol

2022



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2024

University research pro

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BRAE 419/422
SPRING 2019



2016



Automation



CAL POLY
Strawberry Center

Planting

Pruning

Pest Management

Picking

Processing

2018



Bare Root Transplanting



Runner Detection



Bug Vacuum Optimization



Production Forecasting

2020

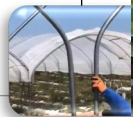


Nutrient Delivery



Cross Hole Pump

2022

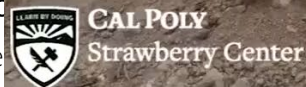


Hoop House

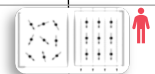
2024

University research project

👤 = Team of 1 to 5 students



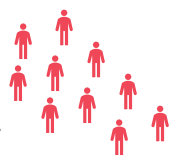
Precision Farming



Material Handling



Adoption Economics



2016



Planting

2018



Bare Root Transplanting



Nutrient Delivery

2020



Cross Hole Puncher


2022



Hoop House Remover

2024

University research projects from 2016 to 2024

 = Team of 1 to 5 students

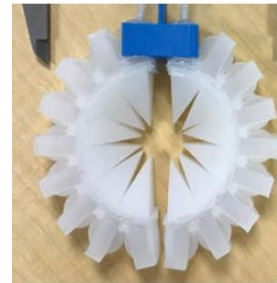


Automation Help Desk

- Professors
- Students
- Interns
- Engineering Staff



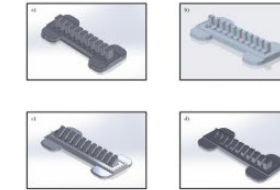
Strawberry Automation Research Award



Human Inspired Grasper



Lygus Vaccum Optimization



Very Berry Twisting Actuator



Automated Phenotyper



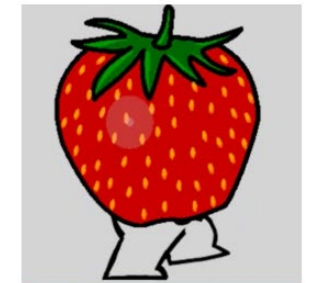
Wearable Spinal Support Device



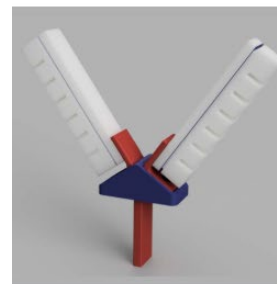
Texture Applications in Soft Grippers



PickMo - IOT Strawberry Harvest Aid



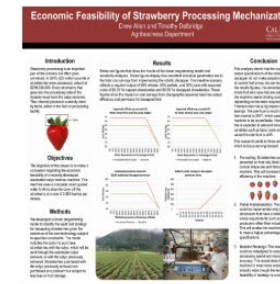
QuickPick - IOT Strawberry Harvest Aid



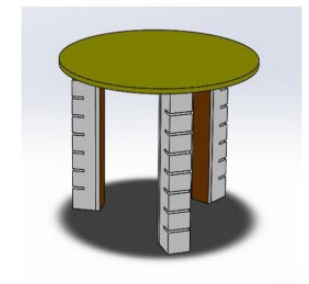
Haptic Sensing in Compliant Robotic Manipulators for Robust Grasping



Strawberry Bare Root Identification for Transplanter Applications



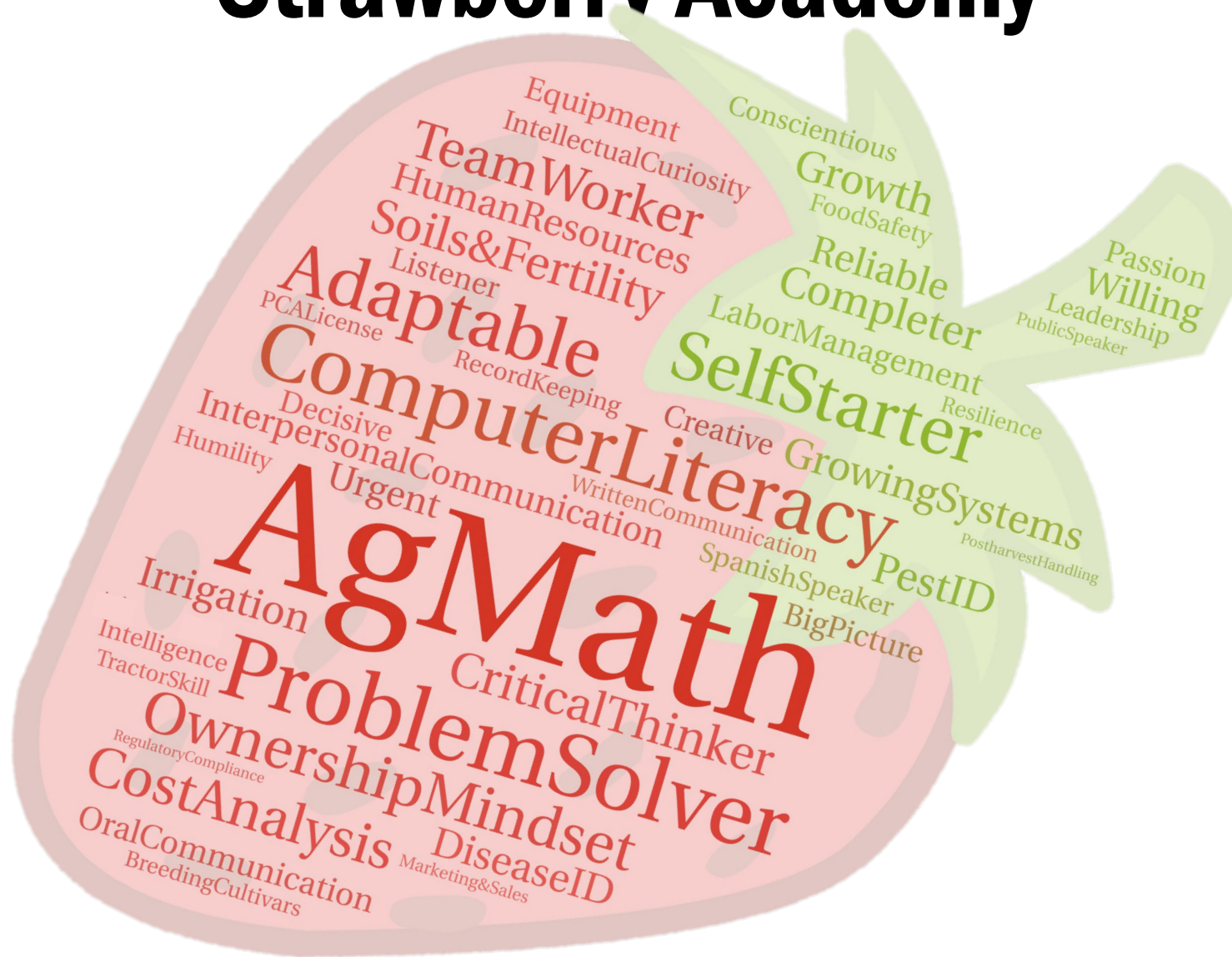
Economic Feasibility of Strawberry Processing Mechanization



Design of Two End Effectors of Farmer Behavior Inspired Strawberry Picking Methods



Strawberry Academy



Learn

- Production practices
- ID pests & diseases

Do

- Plant
- Design experiments
- Collect data

Teach

- Mentor
- Presentations



CAL POLY
Strawberry Center

ANNUAL FIELD DAY

Thursday, July 28, 2022



ATTENDEES

445



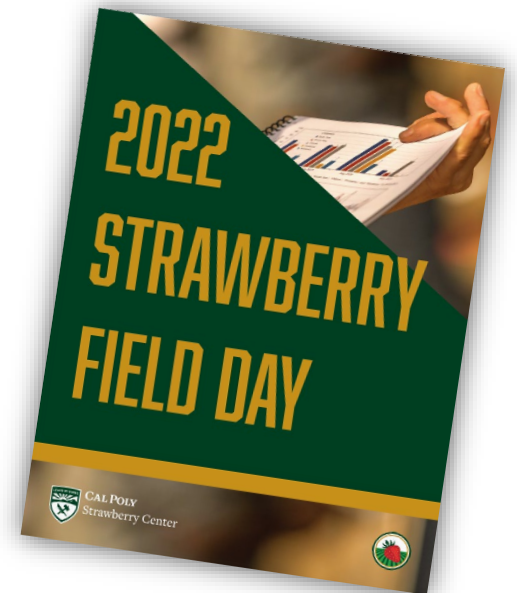
SPONSORS

40



CASH DONATIONS

\$69,700



Product Development Process

Exploration

**UNIVERSITY
OF
CALIFORNIA**

Application



CAL POLY
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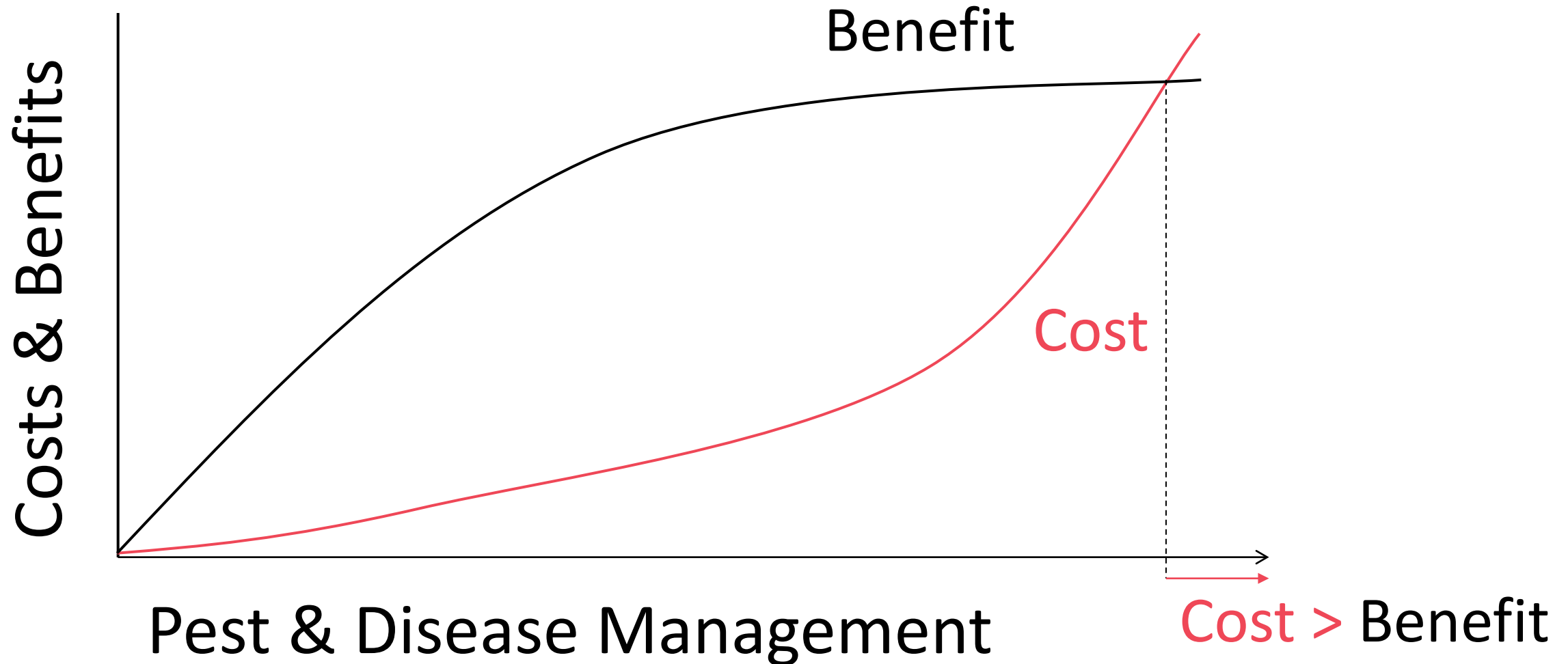
Validation

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COMMISSION

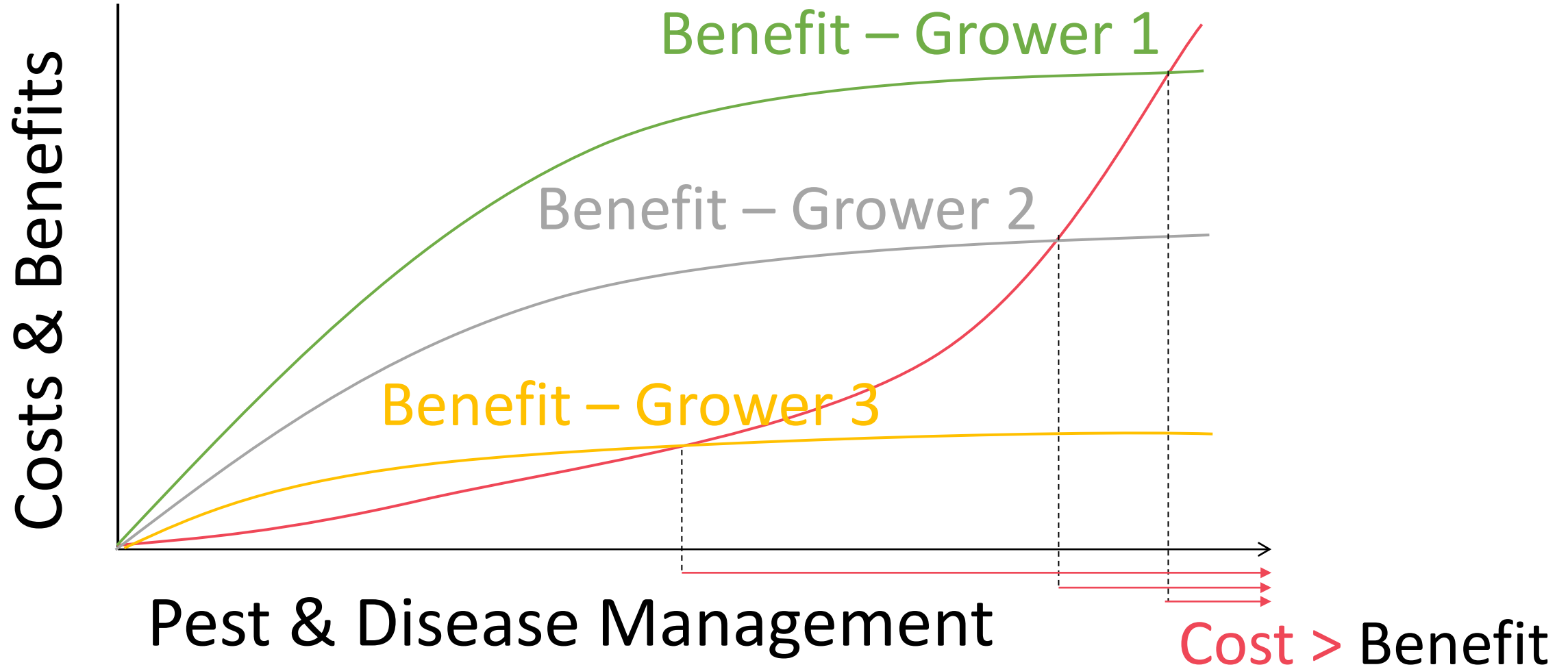
Commercialization



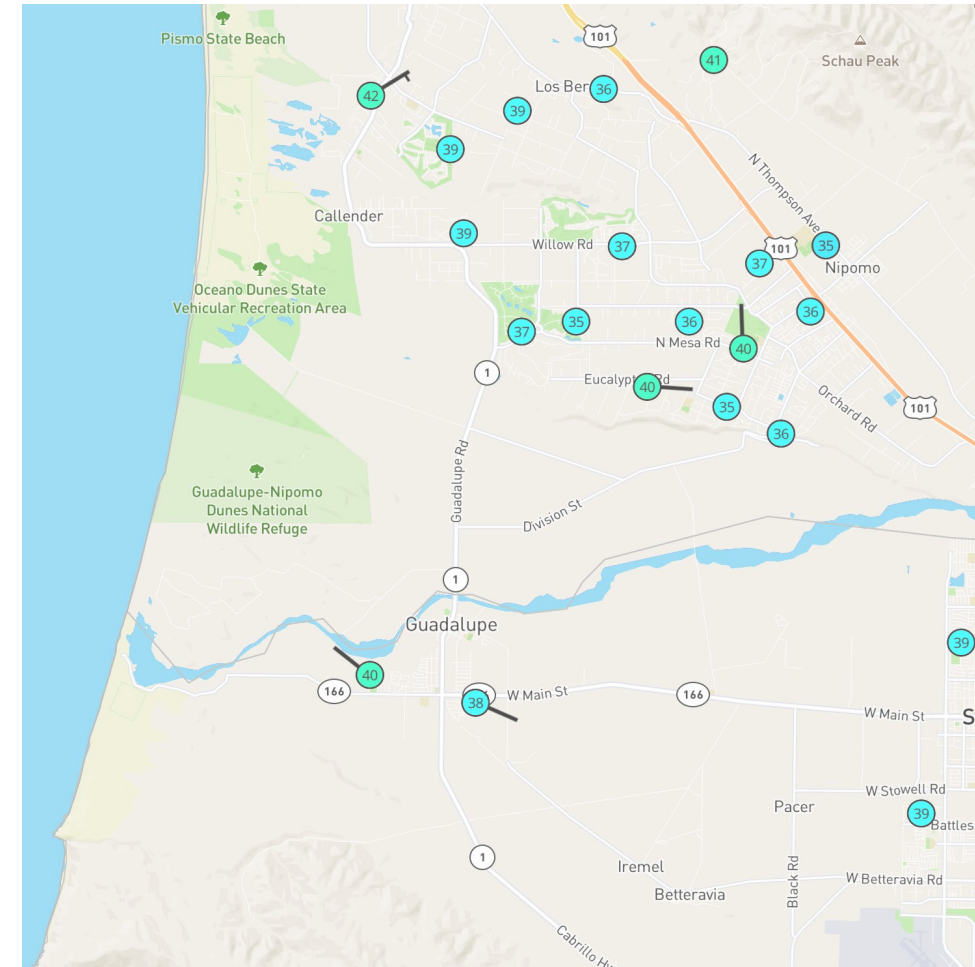
Industry Analysis



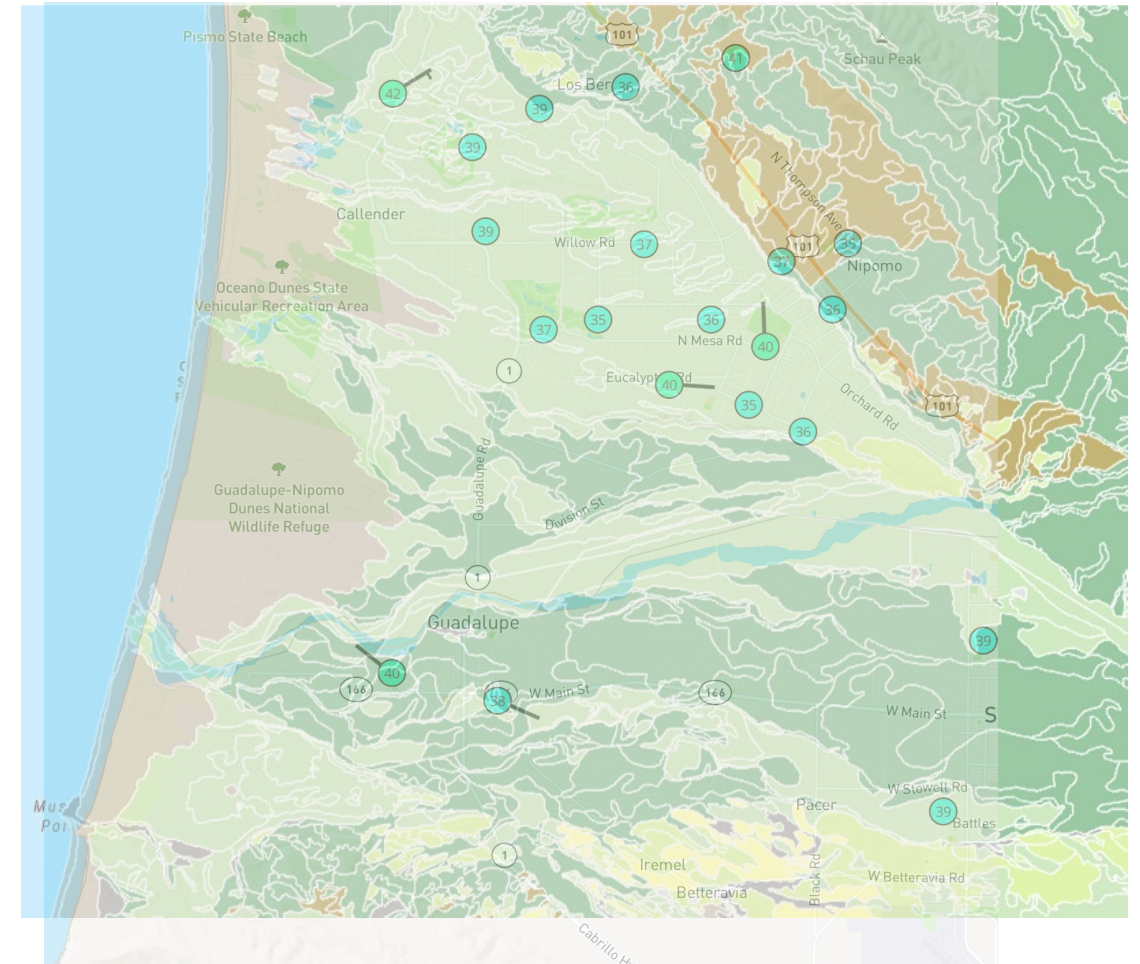
Industry Analysis



Field Infrastructure – Microclimate



Field Infrastructure – Soil Type



Field Infrastructure – Inclination



Field Infrastructure

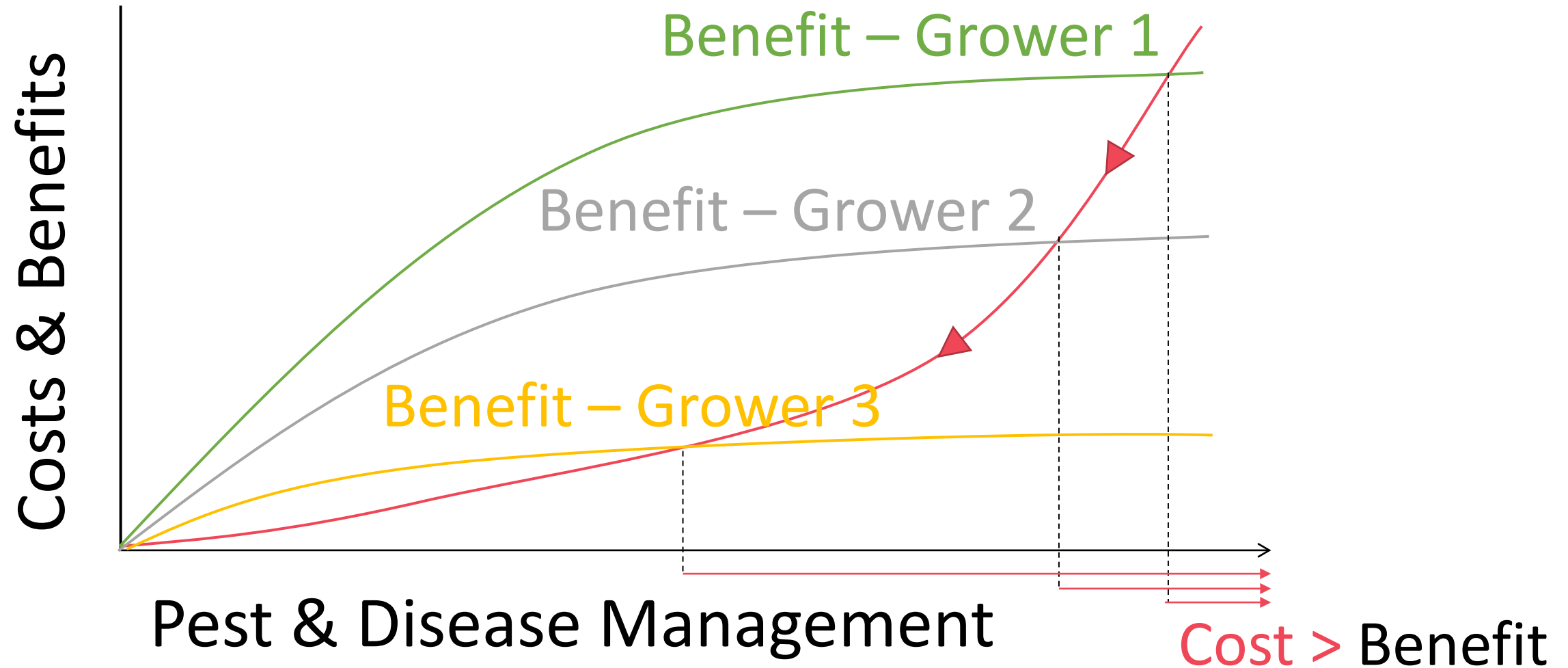


**Challenges: Tall rows, sprinklers,
drainage ditches**



**Challenges: Steep hill, security,
drainage ditches**

Economies Of Scale



Automation Projects 2016-2023



Green = Available & Red = Pending

Non-Chemical Pest & Disease Control



Optimized
Bug Vacuum



Weed / Runner
Mechanical Removal



Cost Effective
UVC

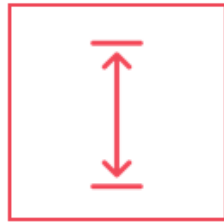
Enhanced Pest & Disease Control



Optimized
Spray Rig



Lygus Bug
Monitor



Equipment
Operator Aid

Workforce Efficiency & Safety



Decapper



Cross Hole
Puncher / Burner



Hoop House
Arch Remover

Lygus Bug Vacuum



Lygus Bug Vacuum



Plastic Mulch Hole Burner



Plastic Mulch Hole Burner



Plastic Mulch Cross Hatching



Plastic Mulch Cross Hatching



Hoop Arch Removal



Hoop Arch Removal



Strawberry Processing - Decapping




Strawberry Processing - Decapping



Journal Publications Trade Magazines

Awards

International Journal of Fruit Science



Taylor & Francis
Taylor & Francis Group



A BETTER BUG VAC

University of California is improving equipment for vacuuming lygus bugs off strawberries. The designs are free, and growers are building their own.

is double barrel vacuum removes lygus in a southern district growing region. Photos: California Strawberry Commission

Crystal Nay
Western Editor

For the better part of a decade, there has been some version in the market of a bug vacuum for use against lygus in California strawberries. Within five years of its commercial availability, about 90% of strawberry growers adopted the vacuum into their operations, seeing it as a valuable tool not only for a more sustainable control approach, but also in situations where pesticides were not allowed or had run out. That same figure still seems true today.

Lygus bugs are a problem in strawberry, causing misshapen fruit, or "catfacing," by feeding on the seeds during fruit development. Based on research conducted by the California Strawberry Commission and the Cal Poly Strawberry Center, lygus damage is estimated at \$100-200 million annually in decreased fruit yields – a hefty figure for the more than 4,600 organic and 36,400 conventional strawberry acres in the state.

How the bug vacuum has reduced those economic loss figures is still unknown, as a large-scale study to assess these figures has not yet been conducted. There are, however, predictions based on smaller plots.

"We expect the lygus population to decrease by about a third," said John Lin, production automation manager for both the California Strawberry Commission and the Cal Poly Strawberry Center. "We don't know yet if that will have a direct translation into a third decrease in damage, but we expect the population to be suppressed by a third based on preliminary results."

Two districts, two models

Across California's strawberry acreage are two growing districts – the northern and the southern – that feature two different growing systems, each with a tractor-mounted vacuum designed for that region's production system. For the four-row system in the southern district, there is a double-barrel bug vacuum, which recently underwent some design changes to improve airflow.

A straight tube design took the place of narrow ducting, which allowed for more efficient fans and maintenance of the 50-mile-per-hour airspeed within the vacuum. The change improved airspeed by 20% by allowing air to flow out of

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Thank you,

Julie Henderson, DPR Director
February 23, 2022

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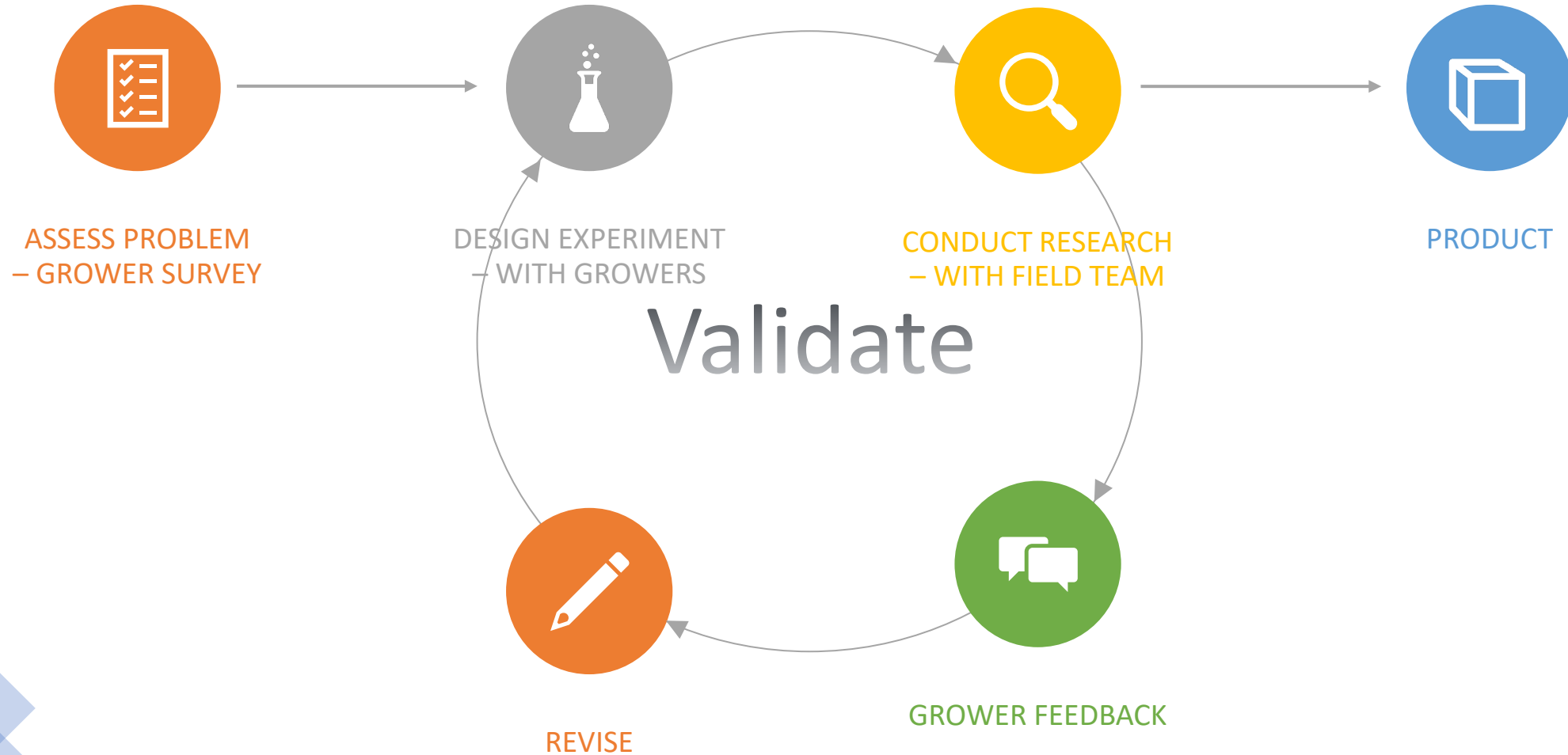


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