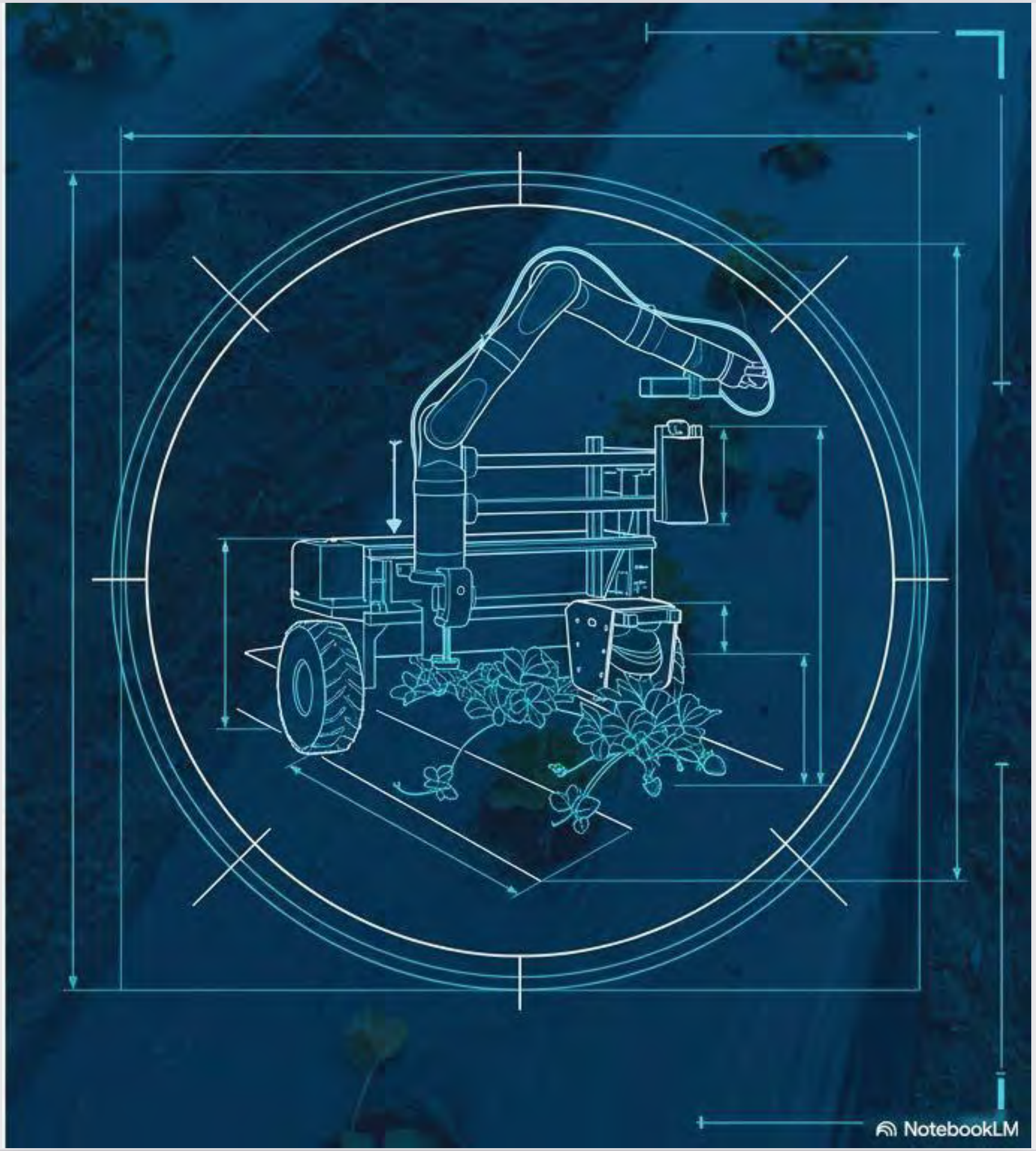
Automating Runner Cutting and Mite Application in Strawberry Fields

Reducing Labor and Improving Consistency in Strawberry Production

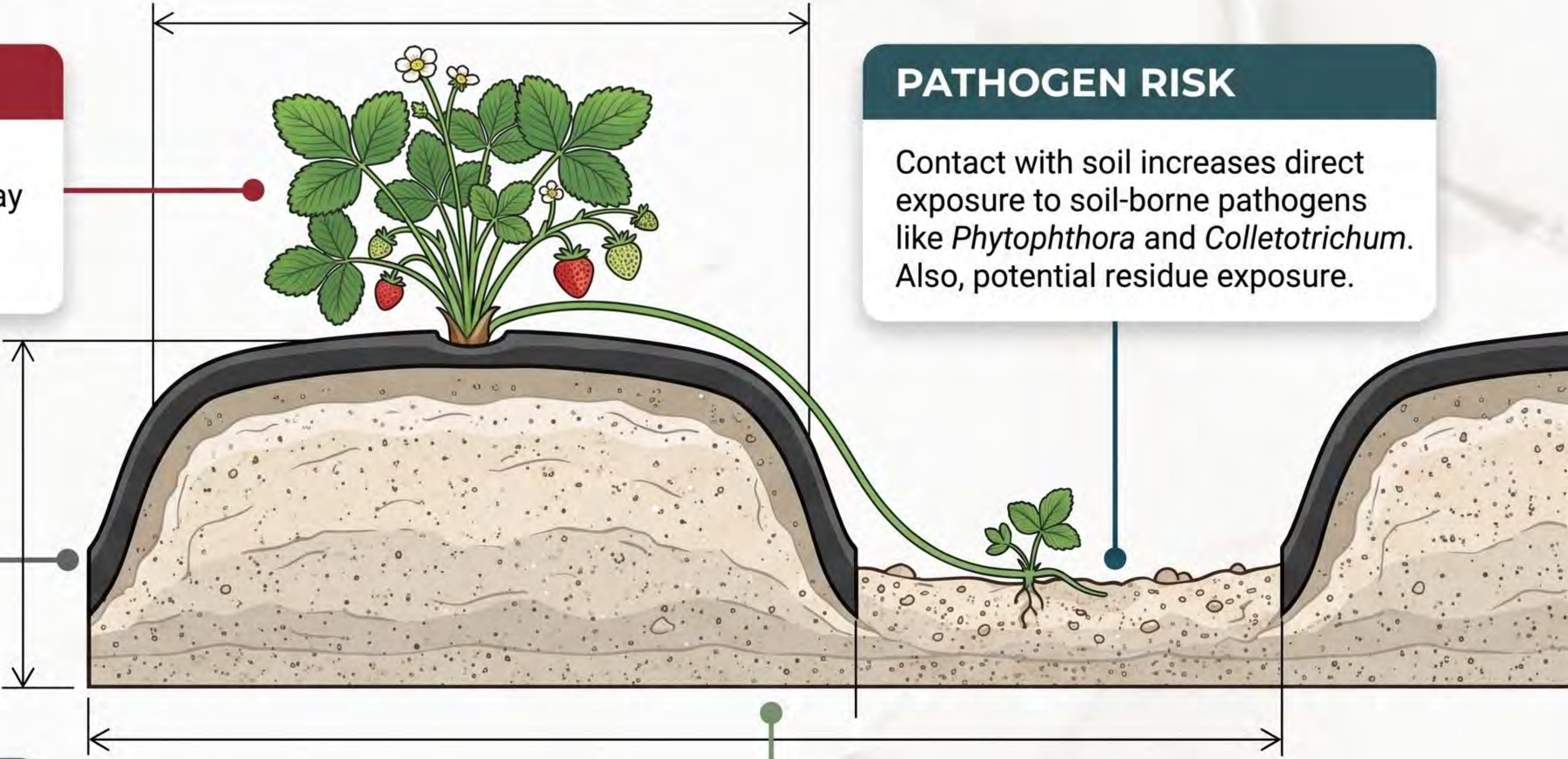
Dana Choi, UF/IFAS GCREC
Agricultural & Biological Engineering



The Hidden Cost of Runners

RESOURCE DRAIN

Runners divert water and essential nutrients (N, P, K) away from the mother plant and critical fruit development.



PATHOGEN RISK

Contact with soil increases direct exposure to soil-borne pathogens like *Phytophthora* and *Colletotrichum*. Also, potential residue exposure.

LABOR BOTTLENECK

Manual removal is slow, hand-pinching is highly labor-intensive, and increasingly cost-prohibitive in a competitive labor market.

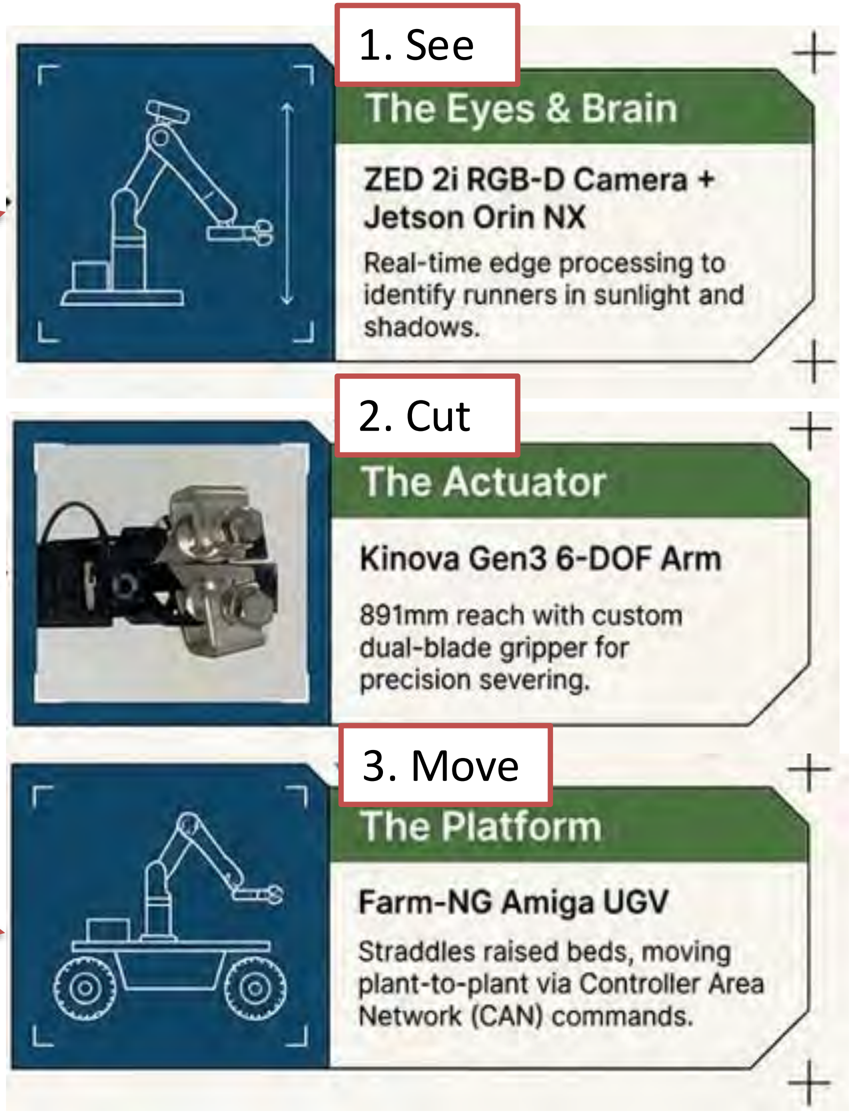
REDUCED CROP YIELD

Inconsistent runner management and competition reduce overall fruit size, quality, and marketable yield.

Flanages repact and covper siting reducement bontal-ioscucating competitints.

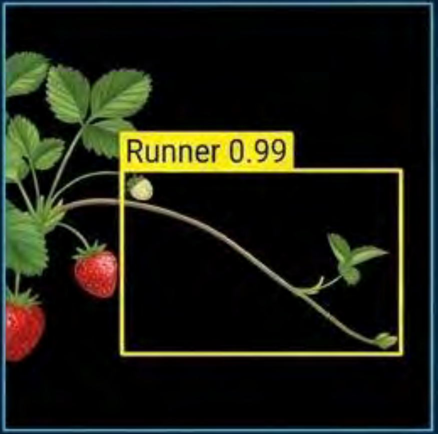
Meet the Autonomous Runner Cutter

Automates manual runner removal



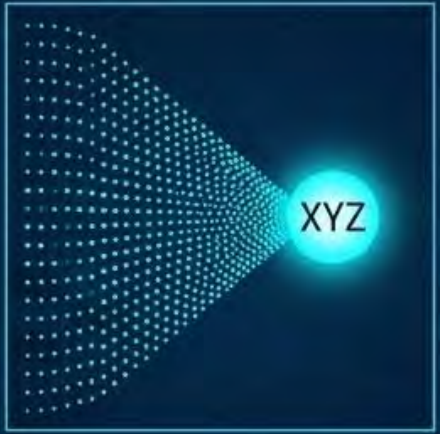
Autonomous Operational Workflow

Step 1: Perception



Capture RGB image. Apply YOLO deep learning model to mask the background and identify runner 2D pixel locations.

Step 2: 3D Localization



Retrieve corresponding distance values from 3D Point Cloud or Depth Image to extract precise (X, Y, Z) coordinates.

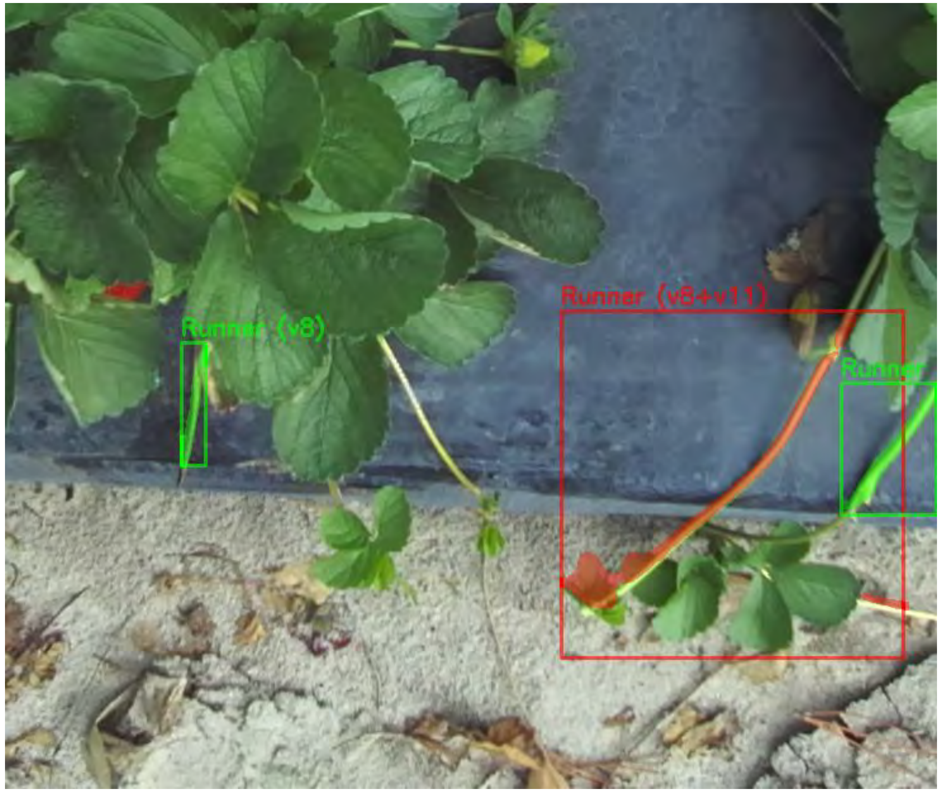
Step 3: Actuation

Verify coordinates are within the safe 891mm reach. Move robotic arm to intermediate waypoint, then execute the cut.

Step 4: Platform Advance

Scan unmasked FOV for remaining runners. Once clear, trigger CAN bus ‘velocity_twist’ command to advance the UGV to the next plant.

Detecting Where Runners Are



Human View VS AI View

System identifies runners (green) and selects a target to cut (red).

The Speed-Accuracy Tradeoff

- Faster → less accurate
  - Depth imaging is faster but contains larger errors
- More accurate → slower
  - Higher spatial fidelity (3D Clouds) provides superior accuracy for calibration but introduces processing delays.
- We chose accuracy to avoid damage
  - Point-cloud Imaging was selected for the final field prototype

Performance Summary

- Cutting success: ~84%
- Low bed damage
- ~33 sec per plant cycle
- Reliable actuation

Detection Results

IoU	Precision (%)		Recall (%)		F_1 score (%)	
	Full	Segment	Full	Segment	Full	Segment
0.5	43.3	76.7	24	43.4	31	55.4
0.3	53.3	86.7	29.6	49	38.1	62.7
0.1	76.7	86.7	42.6	49	54.8	62.7

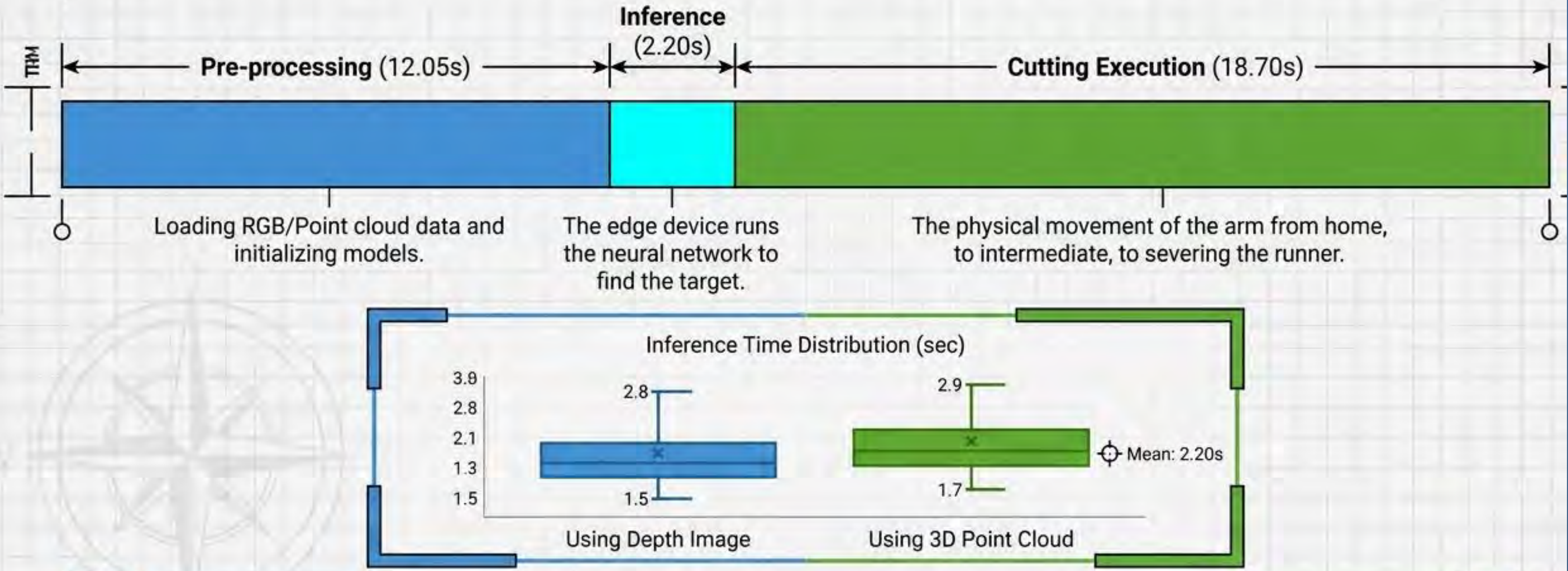
Mechanical Validation: The Blade Works

83.87%
Cutting Success

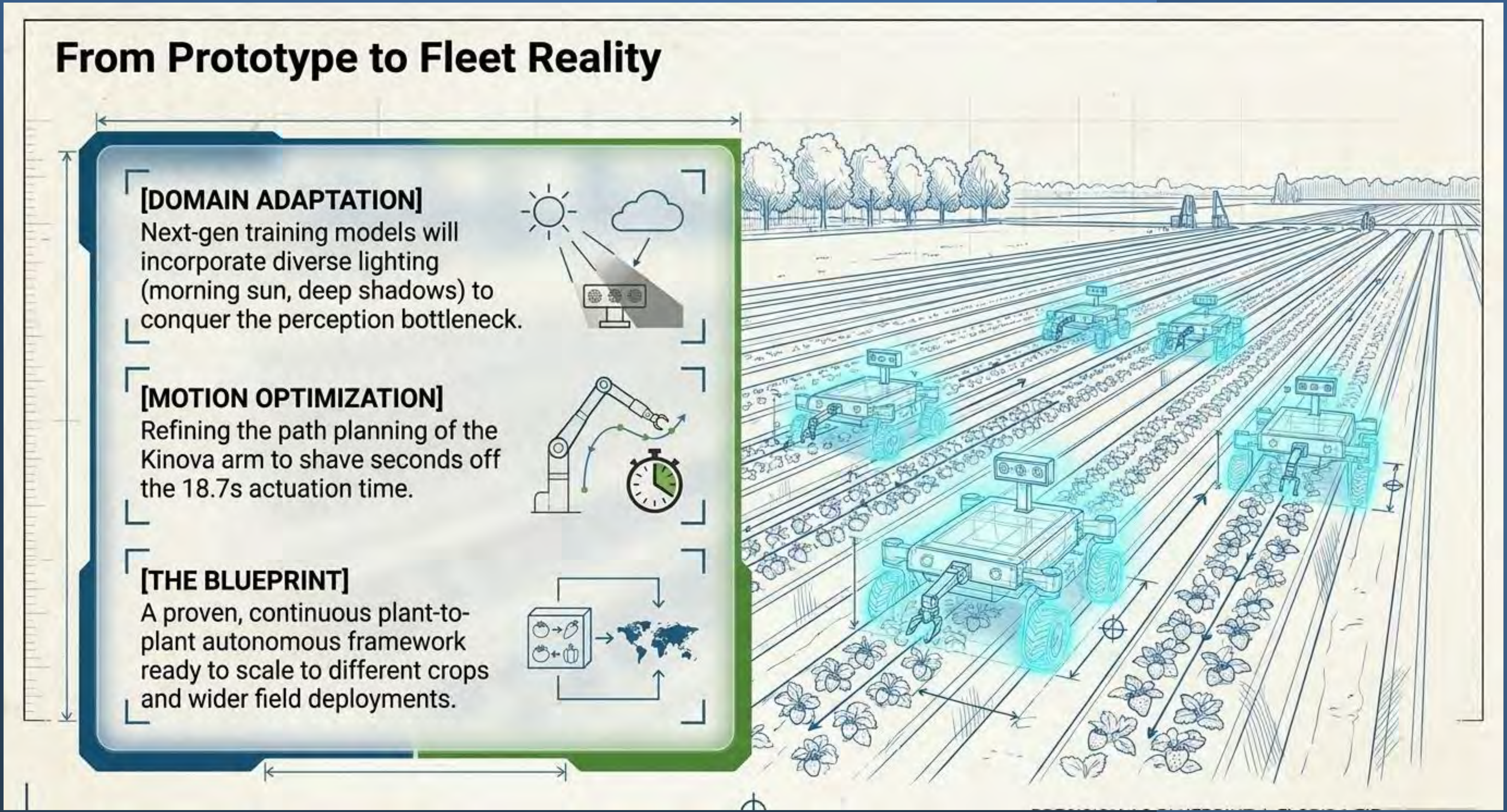
(When targets are detected)

- Out of 31 detected runners, the robotic arm successfully severed 26.
- Only 3 instances of bed damage recorded across all field operations.
- The mechanical actuation is reliable; the true challenge lies in perception.

Timing the Operation: The 33-Second Loop



Current speeds validate the autonomous pipeline. **Future software optimization will compress pre-processing, driving the 33-second loop** closer to human speeds.


From Prototype to Fleet Reality
[DOMAIN ADAPTATION]
Next-gen training models will incorporate diverse lighting (morning sun, deep shadows) to conquer the perception bottleneck.
[MOTION OPTIMIZATION]
Refining the path planning of the Kinova arm to shave seconds off the 18.7s actuation time.
[THE BLUEPRINT]
A proven, continuous plant-to-plant autonomous framework ready to scale to different crops and wider field deployments.

Simulation to Real Transformation for Runner Cutter

Objective:

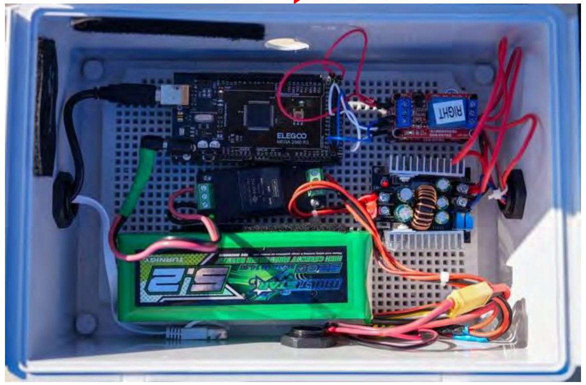
Develop a high-fidelity digital twin to train robotic systems for delicate maintenance tasks in commercial strawberry beds.

- Field evaluation of a robotic strawberry runner cutter at GCREC on February 5, 2026.
- Demonstrating delicate manipulation for clean cuts without damaging the underlying plastic mulch.

- High-fidelity digital twin simulations to develop robust robotic control

Variable Rate Dispensing of Predatory Mites

Edge computer, power supply and electronics box



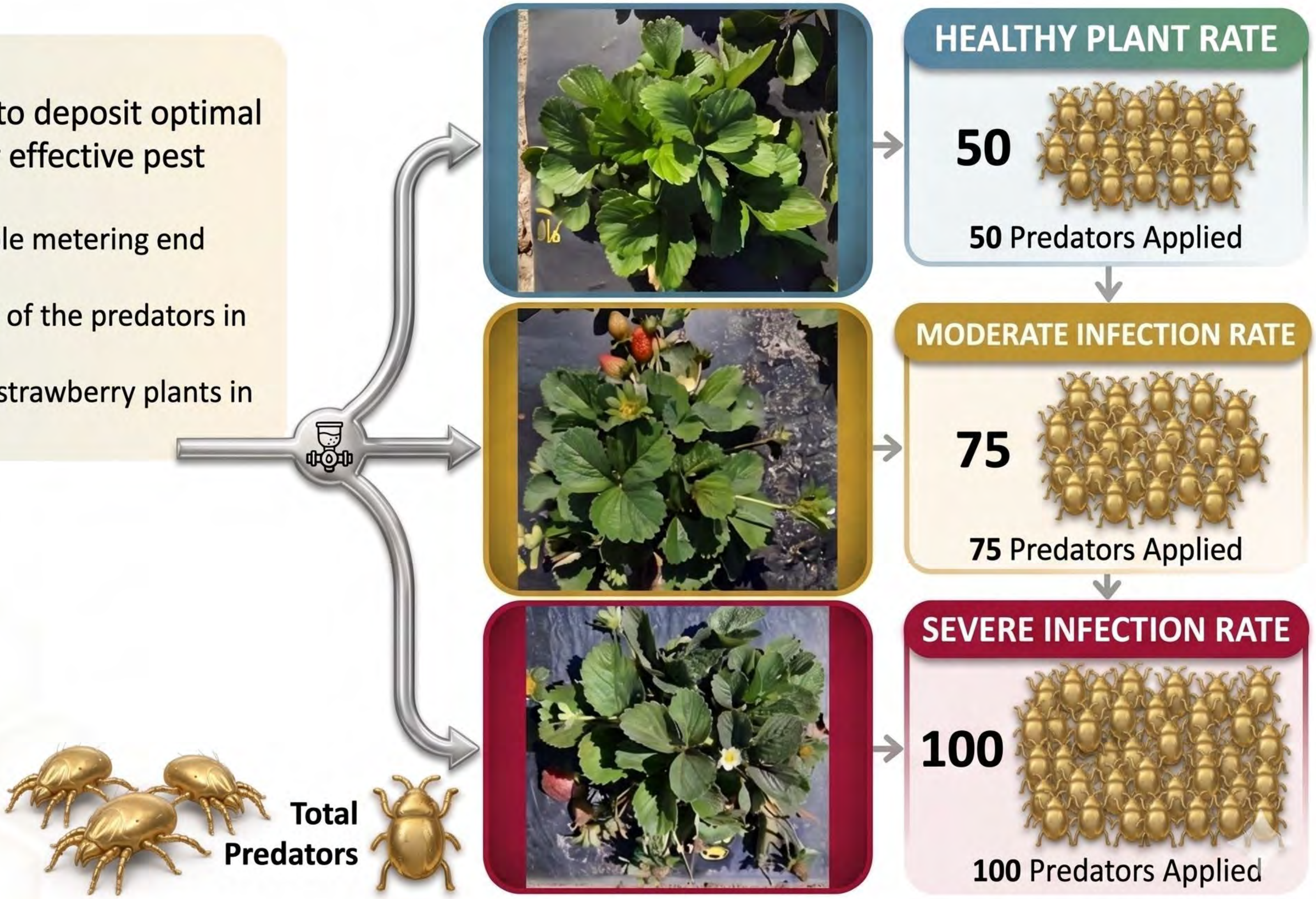
Electronics board

Flir Blackfly S cameras

Top view mite dispenser

Variable Rate Dispensing of Predatory Mites

- **Objective:**
- Develop a variable rate dispenser to deposit optimal number of biological predators for effective pest control.
    - Design, manufacture and assemble metering end effector,
    - Assess the mortality/survivability of the predators in the device,
    - Evaluate performance on indoor strawberry plants in controlled environment.



Engineering Methodology

Chili Thrip Damage Detection

Automated computer vision pipelines to identify early-stage silvering and leaf curling, distinguishing thrip-specific scarring | environmental stress.

End-Effector

High-precision metering components designed for gentle substrate handling to prevent mechanical injury.

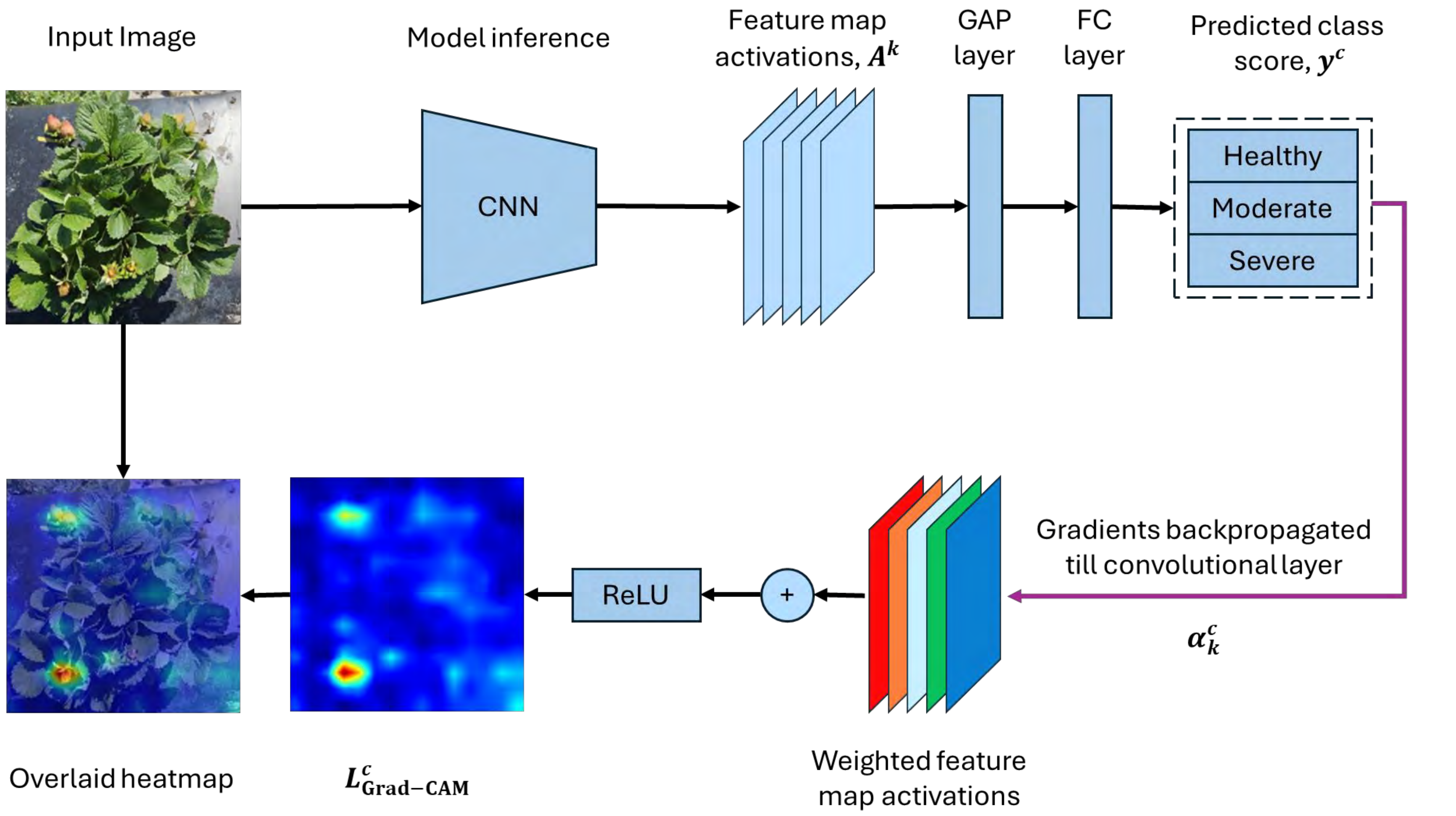
Vitality Testing

Standardized protocols to measure post-dispensing activity and reproductive health of predatory mites.

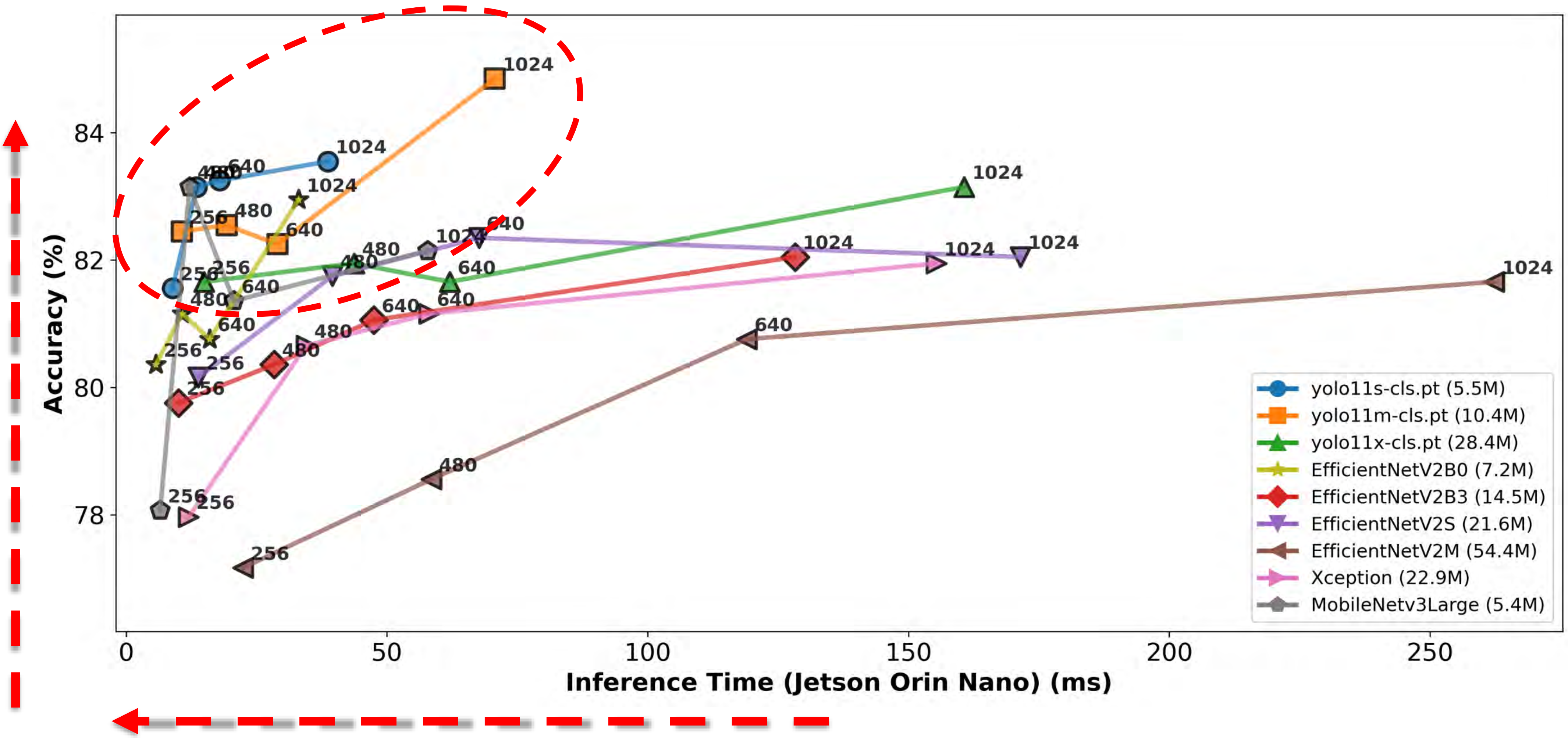
Field Evaluation

Real-world testing under typical open-field conditions at GCREC to calibrate release density with actual pest outbreaks.

Methods: Grad-CAM Qualitative Analyses

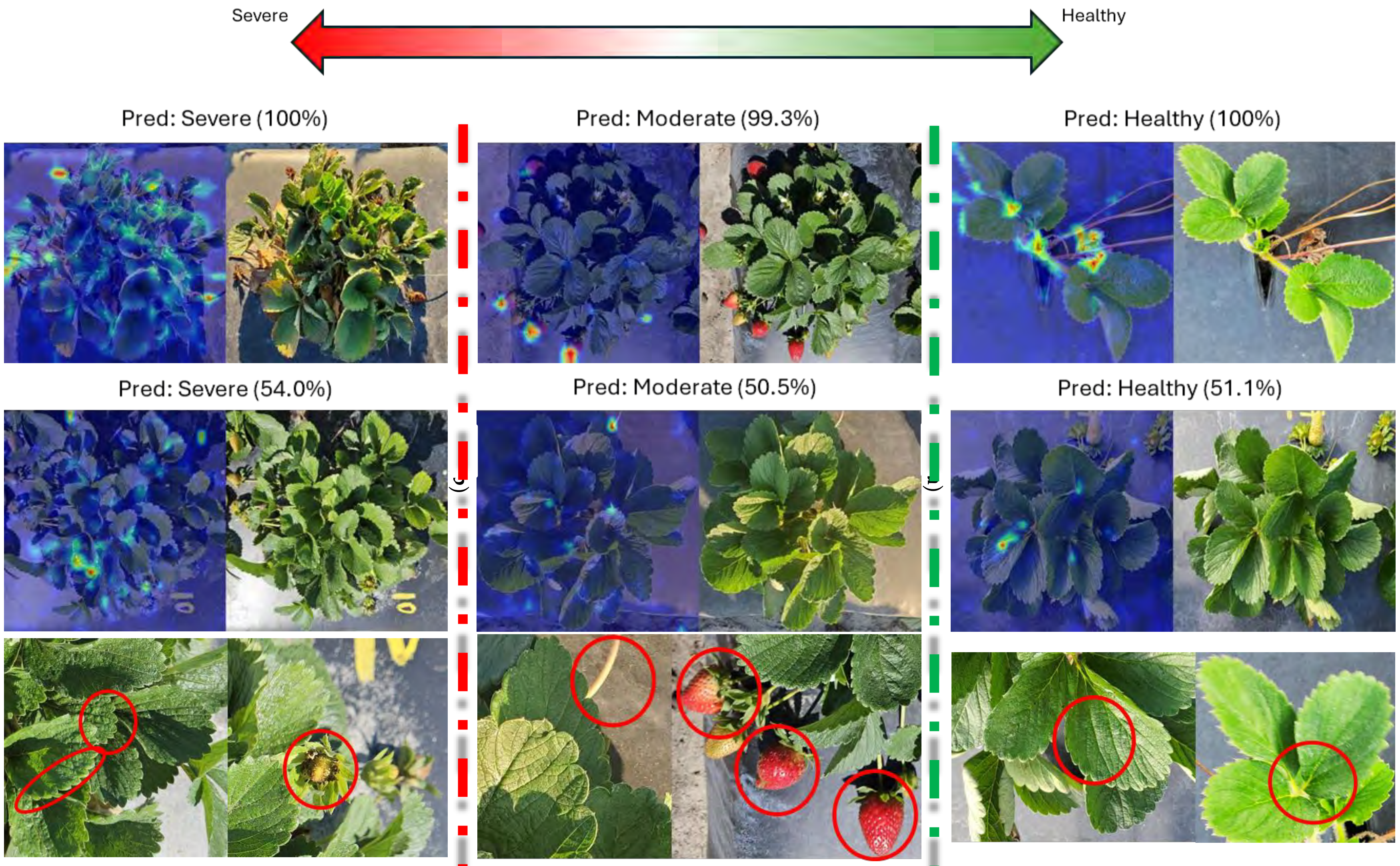


Results: Trade-offs



Peak accuracy:
85%
Peak Speed:
5.7 ms (176 images/s)

Results: Key Features for Model Prediction



Severe- Broad regions with Fruits and leaf edges

Moderate- localized regions with fruits, stems, and leaf edges

Healthy- localized regions with trifoliate intersection, stems, and leaf edges

Highlighted regions

- Leaf surface and veins
- Leaf edges,
- Fruits,
- Flowers
- Stems
- Background artifacts

Biologically relevant regions

- Leaf surface and veins
- Leaf edges,
- Fruits,
- Flowers

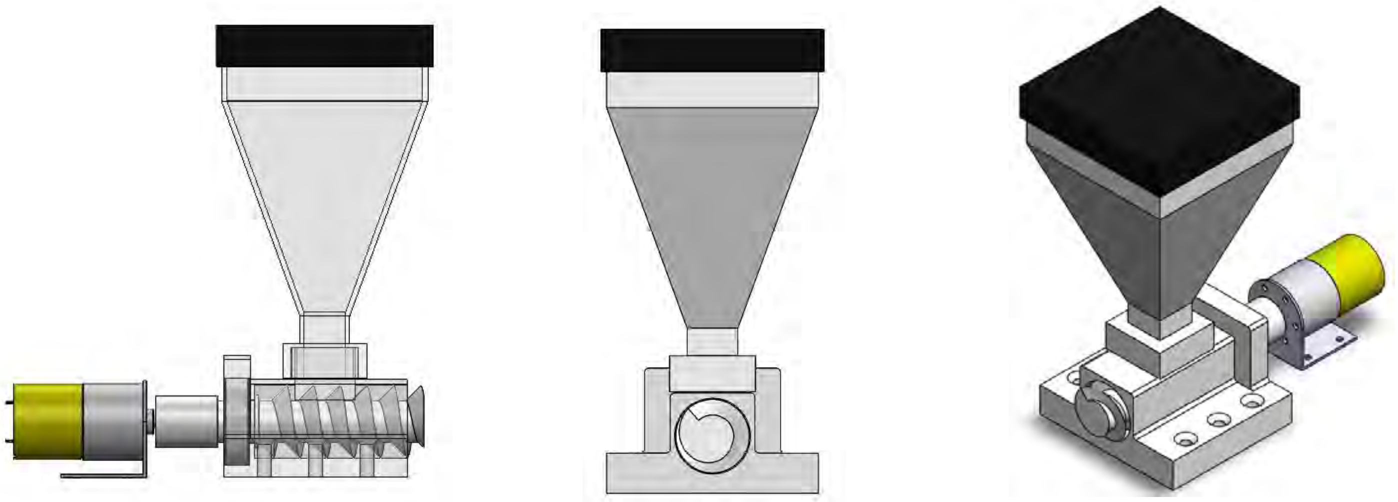
Sites of thrips aggregation

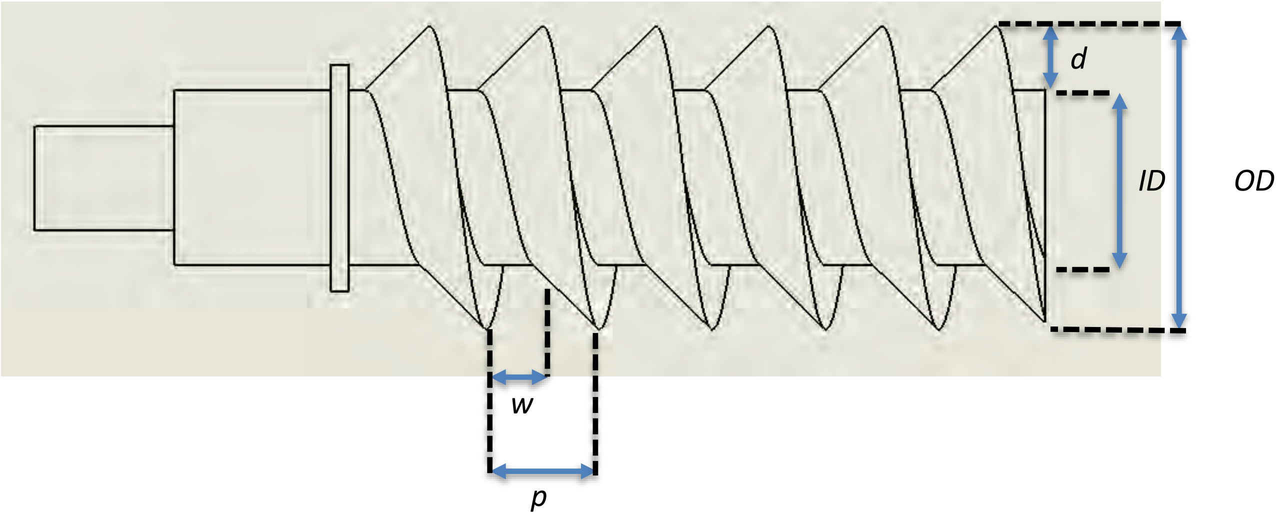
- Leaf surface and veins
- Fruits,
- Flowers

Methods: Auger Design Considerations

Auger Dimensions

Property	Value	Consideration
Auger pitch, *p*	**13 mm**	**Greater than sum of bran/vermiculite width and length (3.13 + 2.15 mm).**
Flight strip depth, *d*	**7.35 mm**	**Greater than maximum vermiculite dimension (3.13 mm)**
Fight strip width, *w*	**5.65 mm**	**Greater than the maximum vermiculite dimension (3.13 mm)**
Auger ID	20 mm	Greater than drive shaft diameter (6 mm)
Auger OD	34.7 mm	Less than 5 times the ID
Auger housing clearance	0.55 mm	Smaller than the min width of bran (0.71)
Hopper angle	70 degrees	Greater than the angle of repose of bran (30 to 45 degrees)
Auger material	3D printing PETG plastic	Rapid prototyping and finetuning





CEMA Screw Conveyor Engineering Guide Roberts (1999)
ASABE standard EP 389
Maleki et al. 2006

Methods: Dosage Calibration and Dilution

Calibration using vermiculite, microcontroller and 12V 100 RPM DC motor

Time of rotation (s)	Target mite count	Measured Volume (mL)	Measured Mass (g)
0.5	Healthy (50)	2.08 ± 0.59	0.29 ± 0.08
0.75	Moderate (75)	2.86 ± 1.32	0.4 ± 0.18
1	Severe (100)	3.72 ± 0.76	0.52 ± 0.10

Original mite concentration , $C_{stock} = 50 \text{ mites/mL}$

Desired mite concentration, $C_{desired} = \frac{100}{3.72} \text{ mites/mL},$

Desired volume, $V_{desired}$

Stock volume for dilution, $V_{stock} = \frac{(C_{desired} * V_{desired})}{C_{stock}}$

Extra vermiculite to add = $V_{desired} - V_{stock}$

Natural Enemies

Home Depot

The end effector calibration directs the vehicle speed- Assuming the average plant diameter of 12 inches, maximum vehicle speed will be **12 in/s (0.3 m/s)**

Methodology: Indoor Experiment

- 3 runs (randomized pot positions)
- 20 Potted Plants
- 15-inch spacing (length)
- 12-inch spacing (width)
- Vehicle speed 40 ft/min (0.2 m/s)

Evaluation Metrics

- Case A- Identified and fully sprayed (within 80% of plant area)
- Case B- Plant Identified and partially sprayed (on plant but not completely within 80% of area)
- Case C- Plant Identified but target missed
- Case D- Plant not identified (so not sprayed)
- Case E- False positive target is sprayed

$$Precision = \frac{Success}{Success + Failure} = \frac{Case\ A + Case\ B}{Case\ A + Case\ B + Case\ C + Case\ E}$$

$$Recall = \frac{Success}{No\ of\ Plants} = \frac{Case\ A + Case\ B}{No\ of\ plants}$$

Partel et al. 2019

Results- Indoor Testing

Metric	Description	Value
Prototype Precision	Total number of targets sprayed/ total number of successfully sprays	100%
Prototype Recall	Total number of targets sprayed/ total number of targets	96.7%
Fully Sprayed Targets (FST %)	Percentage of fully sprayed targets: case A/ No. of targets	88.3%
Half Sprayed Targets (HST %)	Percentage of half sprayed targets: case B/ No. of targets	8.3%
Missed Spray Targets (MST %)	Percentage of missed spraying targets: case C/ No. of targets	0
Missed Targets (MT %)	Percentage of missed targets: case D/ No. of targets	3.3%

Outcome	Cause of Failure			
	Vehicle Alignment	Plant Tracking Model	Plant Morphology	NA
YES	0	0	0	53
PARTIAL	2	0	3	0
NO	0	2	0	0

Methodology: Outdoor Experiment

- 2 runs on 2 strawberry beds (585 plants)
- Morning and Evening
- 15-inch spacing (length)
- 12-inch spacing (width)
- Vehicle speed 40 ft/min (0.2 m/s)

Results- Outdoor Testing

Metric	Description	Value
Prototype Precision	Total number of targets sprayed/ total number of successfully sprays	95.0%
Prototype Recall	Total number of targets sprayed/ total number of targets	96.4%
Fully Sprayed Targets (FST %)	Percentage of fully sprayed targets: case A/ No. of targets	86.6%
Half Sprayed Targets (HST %)	Percentage of half sprayed targets: case B/ No. of targets	9.7%
Missed Spray Targets (MST %)	Percentage of missed spraying targets: case C/ No. of targets	3.5%
Missed Targets (MT %)	Percentage of missed targets: case D/ No. of targets	0.2%

Outcome	Cause of Failure					
	Vehicle Alignment	Prototype Design	Plant Tracking Model	Vehicle Speed	Environmental Conditions	NA
YES	0	0	0	0	0	499
PARTIAL	5	0	1	1	49	0
NO	1	14	1	0	5	0
WEED	0	0	0	0	0	9

Red values indicate suboptimal performance

Key Takeaways

- **Robotic runner cutting is field-feasible**
- **Variable-rate biocontrol enables plant-level precision application**
- **Vision remains the primary bottleneck in real environments**
- **Integrated multi-module platform is the next step**

Acknowledgement

Key Personnel

Co-Principal Investigators

Dr. Kevin Wang
Dr. Sriyanka Lahiri
Dr. Vance Whitaker

Lead Researchers

Dr. Md Didarul Islam
Mr. Uchechukwu Ilodibe

Funding Sources

Core Funding

Grant awards from FSREF (Florida Strawberry Research and Education Foundation) to fund these studies

Federal Grant

USDA NIFA AFRI (National Institute of Food and Agriculture)

Questions?

Dr. Dana (Daeun) Choi | Agricultural & Biological Engineering

GCREC, UF/IFAS | dana.choi@ufl.edu