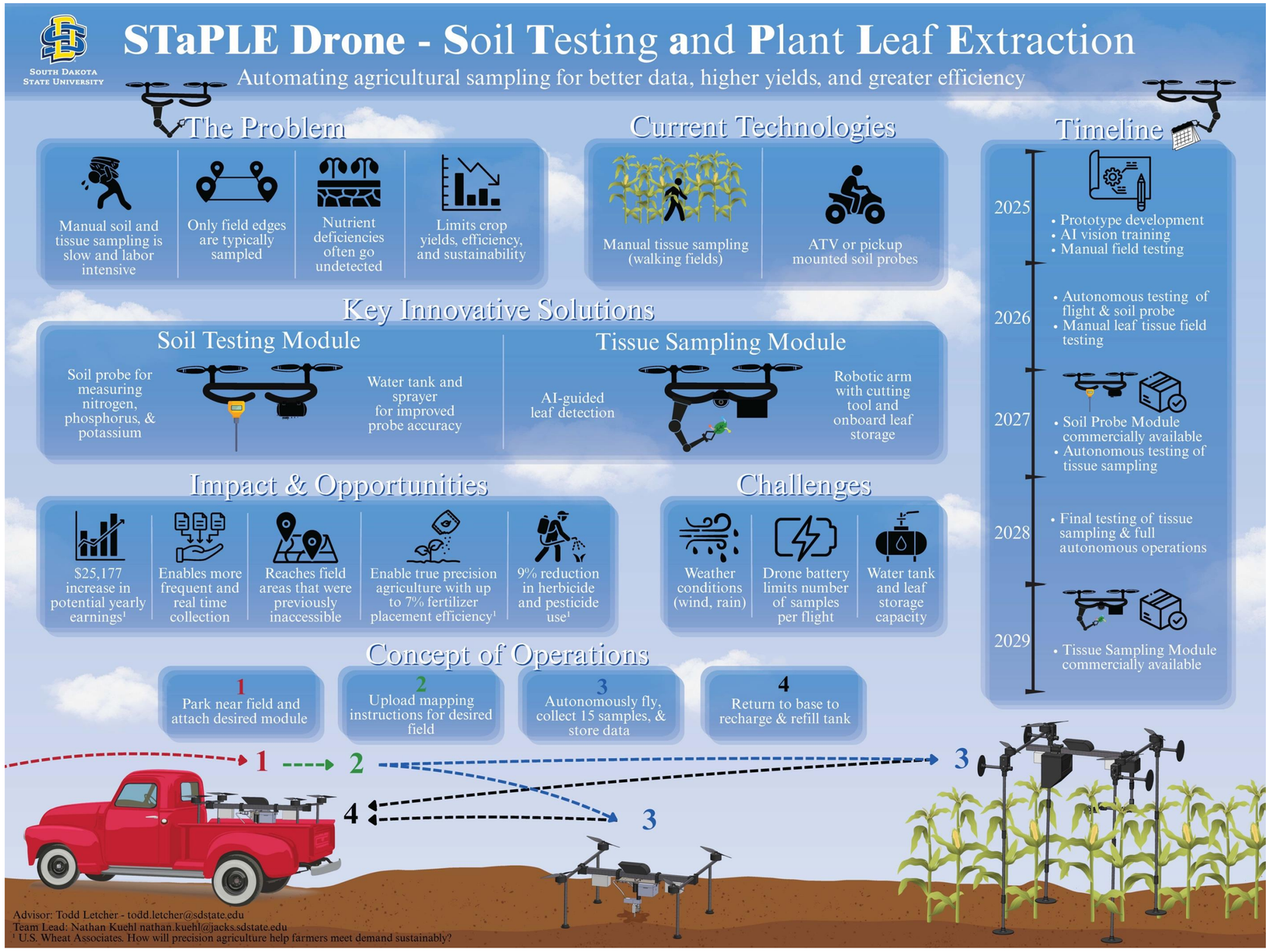
GATEWAYS TO BLUESKIES

South Dakota State University

"Soil Testing and Plant Leaf Extraction Drone (STaPLE)"



The South Dakota State University Presentation will begin at 9:40 AM Pacific Time.
View the 2025 Finalists' Infographics: **https://blueskies.nianet.org/finalists/**

STaPLE DRONE

Soil Testing and Plant Leaf Extraction Drone

South Dakota State University

Todd Letcher

Meet the Team

South Dakota State University

Nathan Kuehl
Team Lead

Laura Peterson
Systems Engineer

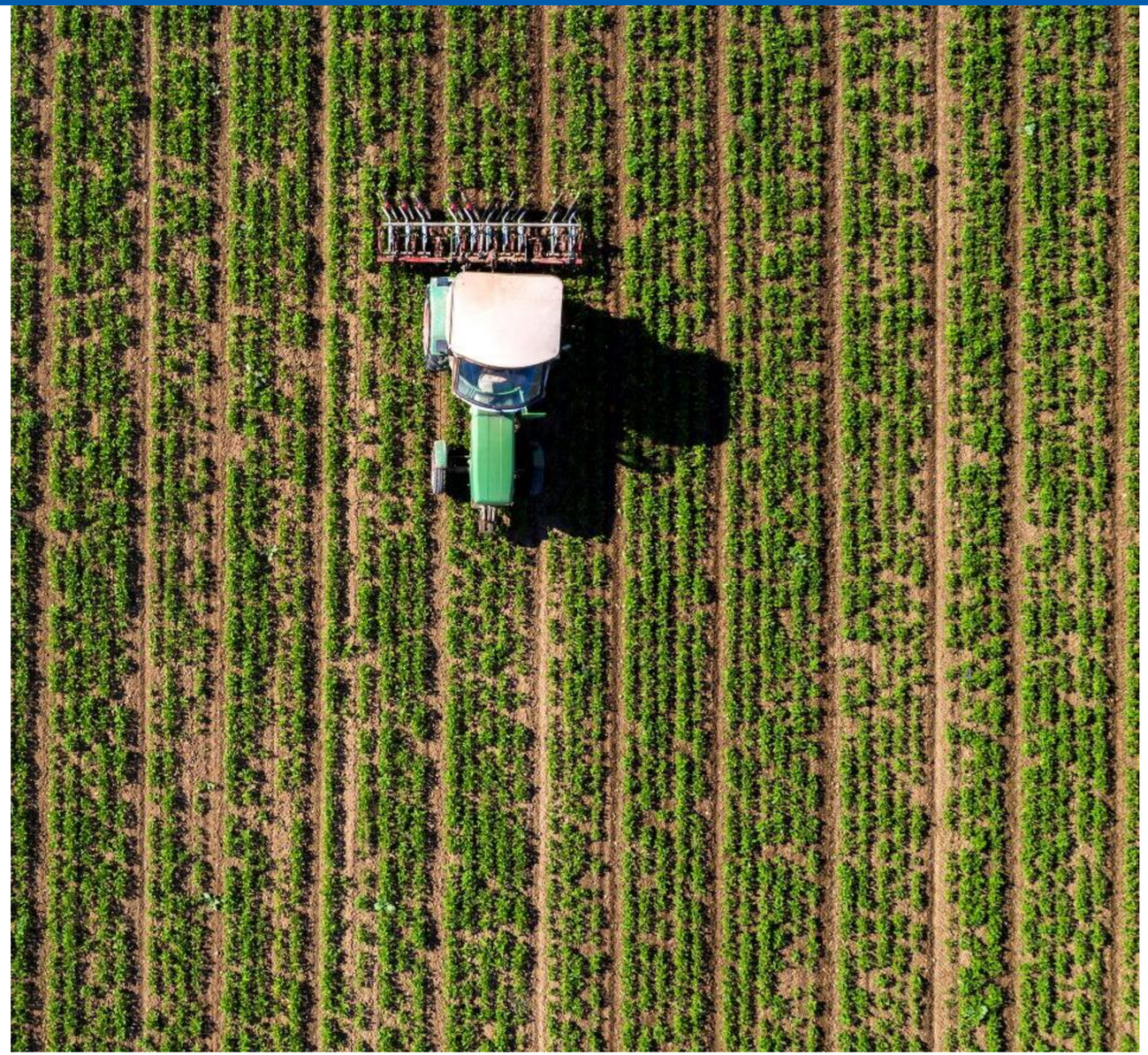
Keegan Visher
Tissue Extraction Lead

Nick Wolles
Soil Testing Lead

Allea Klauenberg
Graduate Advisor

Todd Letcher
Faculty Advisor

Situation Assessment



- Crop yield is one of the most critical and closely monitored metrics in agriculture

- Precision agriculture has changed the culture to allow more targeted applications of nutrients, pesticides, and herbicides

- Improvement lies in leveraging precision agriculture intelligently

- Farmers rely on low costs and high production of their crop

- Monitoring soil and crop nutrients is essential for improving crop yield

I-Corps Interview

Key challenges identified during 20+ interviews with agronomists and farmers across South Dakota and Minnesota

- Labor intensive
  - Soil and leaf sampling.
- Real time data
  - Being able to track the nutrients in the plant throughout its growing season.
- Consistency
  - Soil samples should be a consistent 6 inches deep.
  - Leaf tissue samples should be taken from the same spots each year.
- Unable to enter fields
  - After lots of rain and when plants are fully grown.
- Chemical spraying drone battery life
  - This can range from 8 minutes to 20 minutes.

Current Methods

[1]

1

Manual Soil Testing

- Requires extracting a 6-inch soil core for laboratory nutrient analysis

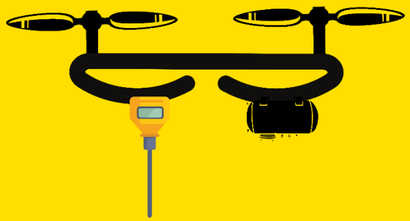
2

Manual Leaf Sampling

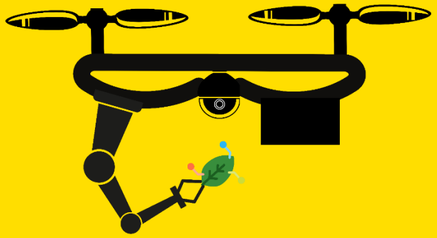
- Requires walking through fields to collect 10–15 leaf samples per zone for lab analysis

[2]

Design Solution



Two interchangeable modules integrate with an existing UAV platform to streamline soil and tissue sampling, reducing physical labor and improving efficiency.



1

Soil Testing Module

- Equipped with a soil probe designed to collect NPK, moisture, and PH levels of field soil

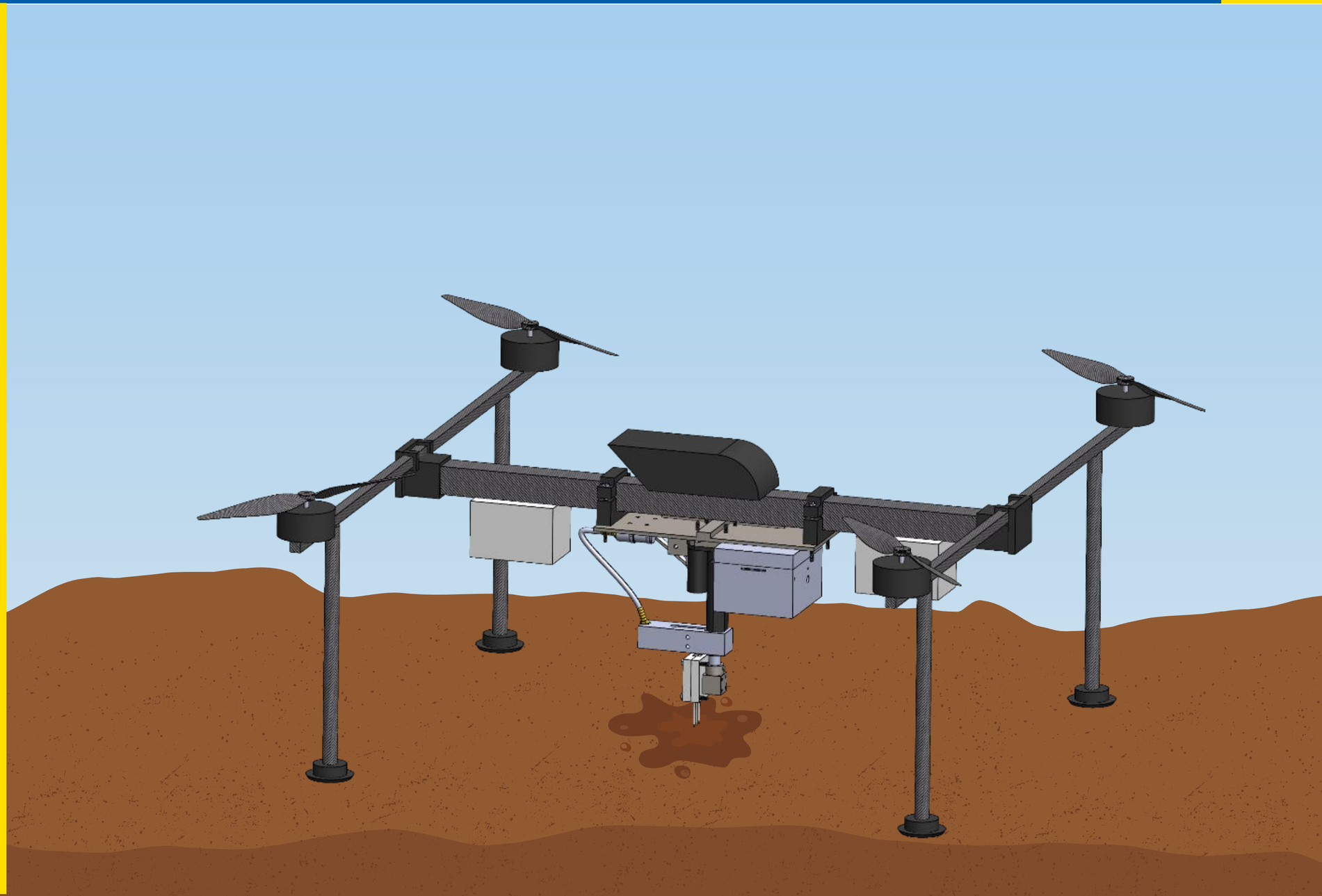
2

Tissue Sampling Module

- Equipped with an AI-guided mechanical arm that locates, cuts, and stores leaf samples for lab analysis

Soil Testing Module

- AeroFly UAV
- NPK soil sensor
  - Detects levels of nitrogen, phosphorus and potassium
- 2-quart water tank and pump
  - Wets soil to assist probe penetration and sensor sensitivity
- 6-inch linear actuator
  - Pushes probe to correct depth

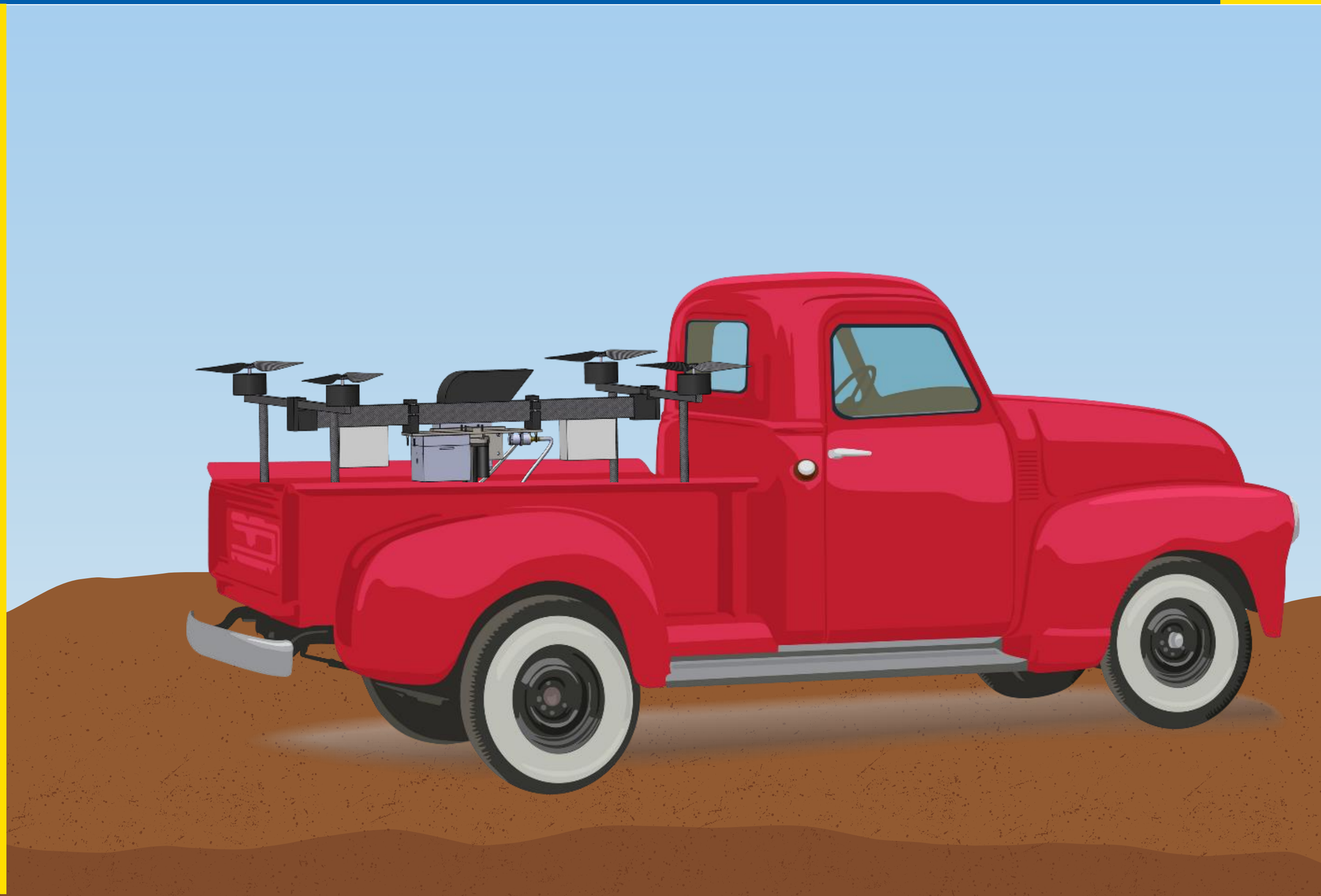


Tissue Sampling Module

- AeroFly UAV
- Robotic arm
  - 4 degree of freedom with gripper and leaf cutting attachment
- AI vision system
  - Finds and guides arm to topmost leaf
- Leaf storage bin
- Modular legs
  - Adjustable height to account for corn growth stages

Connectivity Constraints – Base Station

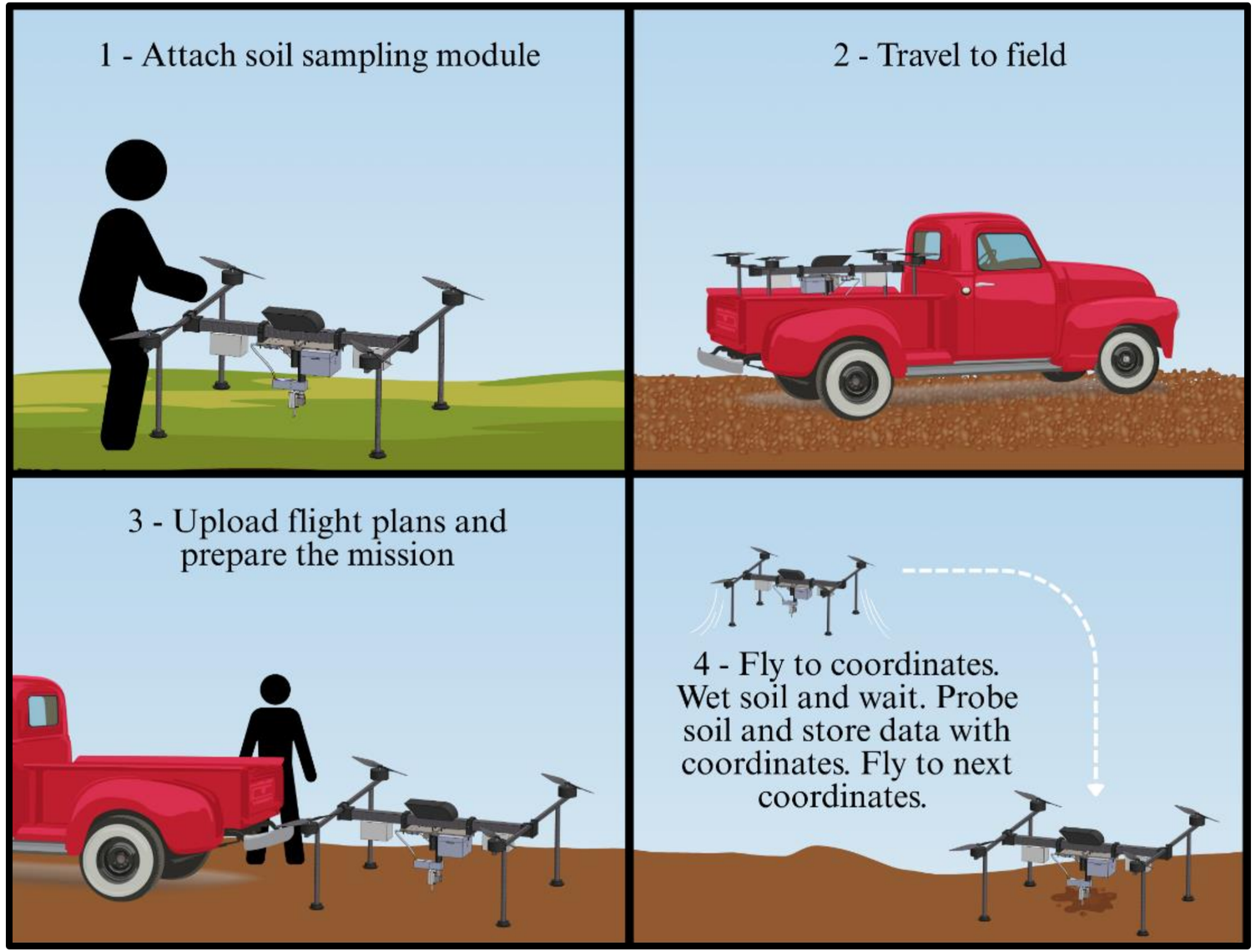
- Base station mounted to a truck bed or trailer
  - Takes advantage of preexisting farm vehicles
- Station powered by vehicle alternator or generator
- Uses RTK GPS
  - Centimeter level accuracy
- Onboard water tank for Soil Testing Module refills
- Clean and secure tissue sample storage



Concept of Operations – Soil Testing Module

Performs around 15 soil tests before returning to base to refill water tank and swap batteries

Sensor data and GPS location stored for every test performed

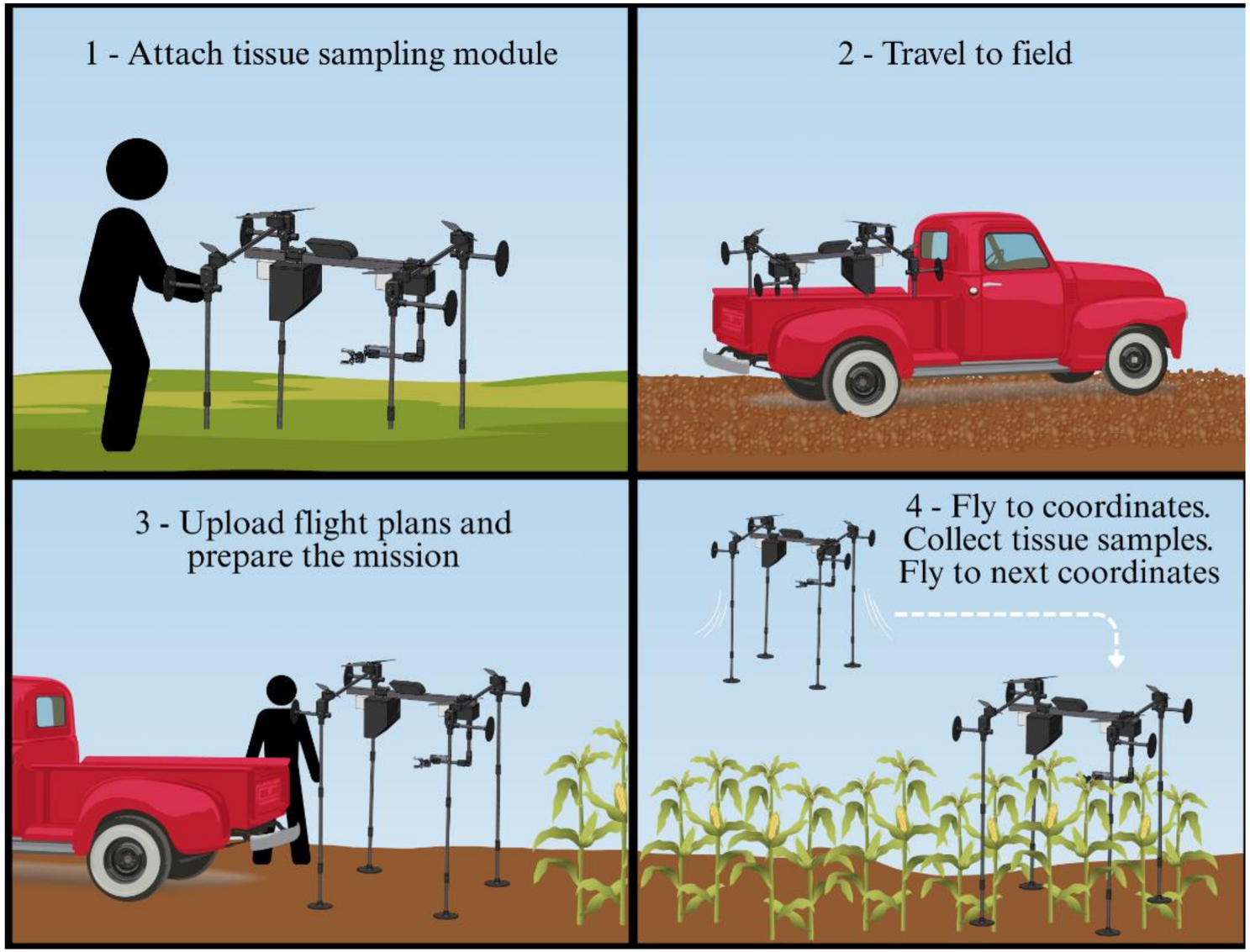


Concept of Operations – Tissue Sampling Module

Collects 10 to 15 samples per region before returning to base to empty bin and swap batteries

- Tissue labs require 10-15 simples per test

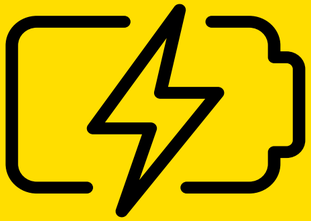
GPS location stored for every leaf collected



Operation Constraints

Precipitiation and winds greater then 15 mph

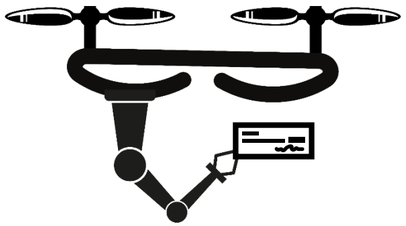
Operating temperature of batteries (20°-100° F)



Drone battery limits number of samples per flight

Water tank and leaf storage capacity

Return on Investment



The use of precision ag has shown:

- 4% yield increase
- 7% fertilizer efficiency improvement
- 9% reduction in herbicide and pesticide use

For a 1,000-acre corn field:

- At 177.3 bu/acre*$3.55/bu = 629,415 baseline revenue
- A 4% yield increase = **$25,177/year**

Module cost estimate: $5,000 - $10,000 per module
ROI timeline: System pays for itself in **< 1 year**

[3,4]

Timeline to Commercialization

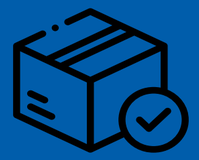
2025
- Prototype development
- AI vision training
- Manual field testing

2026
- Autonomous testing of flight & soil probe
- Manual leaf tissue field testing

2027
- Soil Probe Module commercially available
- Autonomous testing of tissue sampling

2028
- Final testing of tissue sampling & full autonomous operations

2029
- Tissue Sampling Module commercially available



Subsystem	2025 TRL	2026 TRL	2027 TRL	2028 TRL
AeroFly UAV Platform	9	9	9	9
Soil Probe Module	4	6	9	9
Tissue Sampling Module	2	4	6	9
Arm with Gripper/Cutter	4	5	6	9
Machine Vision with AI	2	4	6	9
Automated Cutting	3	5	9	9
Sample Storage Box	5	9	9	9

Component TRL level by year

Prototypes

Soil Testing Module

Soil Testing Module on AeroFly UAV

Tissue Sampling Module

Tissue Sampling Module on Aerofly UAV

Soil Testing Prototype Test

Tissue Sampling Prototype Test

References

[1] EnviroTech Engineering. “Soil Assessment and Soil Management.” https://www.envirotecheng.com/soil-assessment-and-soil-management/

[2] “Use Tissue Samples to Better Manage Crop Nutrients.” *Successful Farming*. https://www.agriculture.com/crops/use-tissue-samples-to-better-manage-crop-nutrients

[3] S. Mercer and R. Loos, “How will precision agriculture help farmers meet demand sustainably?,” U.S. Wheat Associates, https://www.uswheat.org/wheatletter/how-will-precision-agriculture-help-farmers-meet-food-demand-sustainably/

[4] “USDA Agricultural Projections to 2030 Interagency Agricultural Projections Committee USDA Long-Term Projections,” 2021. Available: https://www.usda.gov/sites/default/files/documents/USDA-Agricultural-Projections-to-2030.pdf

THANK YOU

Questions?

NASA'S GATEWAYS TO BLUESKIES

2025 AgAir: Aviation Solutions for Agriculture Forum

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