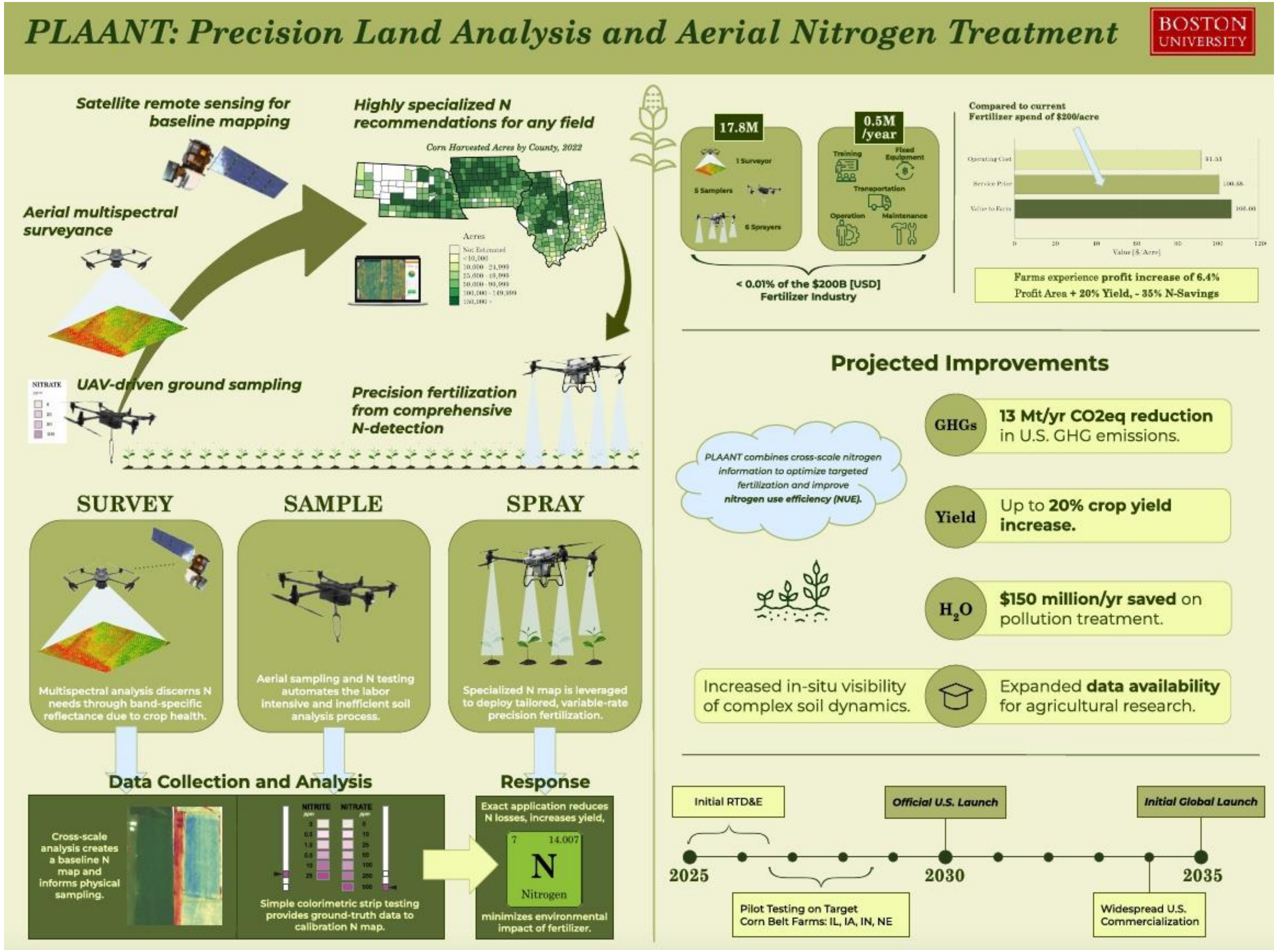
GATEWAYS TO BLUESKIES

Boston University

"PLAANT: Precision Land Analysis and Aerial Nitrogen Treatment"



The Boston University Presentation will begin at 9:35 AM Pacific Time.

View the 2025 Finalists' Infographics: https://blueskies.nianet.org/finalists/

PLAANT

Precision Land Analysis and
Aerial Nitrogen Treatment

BOSTON UNIVERSITY

Our Team

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Senior, Mechanical Engineering

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Advisor,
Adjunct Professor, Mechanical Engineering

*Aerospace Concentration
†Energy Technologies & Sustainability Concentration

Problem Area Comparison

1-3-9 Decision Matrix

Metrics:

Selected technical area

Technical Area:	*Opportunity*	*Cost*	*Scope*	*Technology*	*Environment*	*Future Trend*	*Total*
Cropland / Rangeland Surveyance + Conservation	3	3	9	3	3	9	30
Pest & Disease Management	3	9	9	3	9	9	42
Agriculture Inspection	3	3	3	3	1	3	16
Targeted Fertilizer Application	**3**	**9**	**9**	**3**	**9**	**9**	**42**
EAV's (Essential Agriculture Variables)	3	3	3	3	3	3	18
Autonomous Missions	3	3	1	3	1	3	14
Livestock Management	3	9	3	3	3	3	24
Improved Weather Accuracy	3	9	9	3	9	9	42

*PLAANT addresses the critical issue of **fertilizer resource management.***

Targeted Fertilizer Application

***Precision Agriculture (PA):** The use of advanced sensor and analysis tools to improve agricultural operations with data-driven insights.*

Technologies Utilized by *PLAANT*

- Ag modeling
- Multispectral surveying
- **Targeted Fertilization Application**

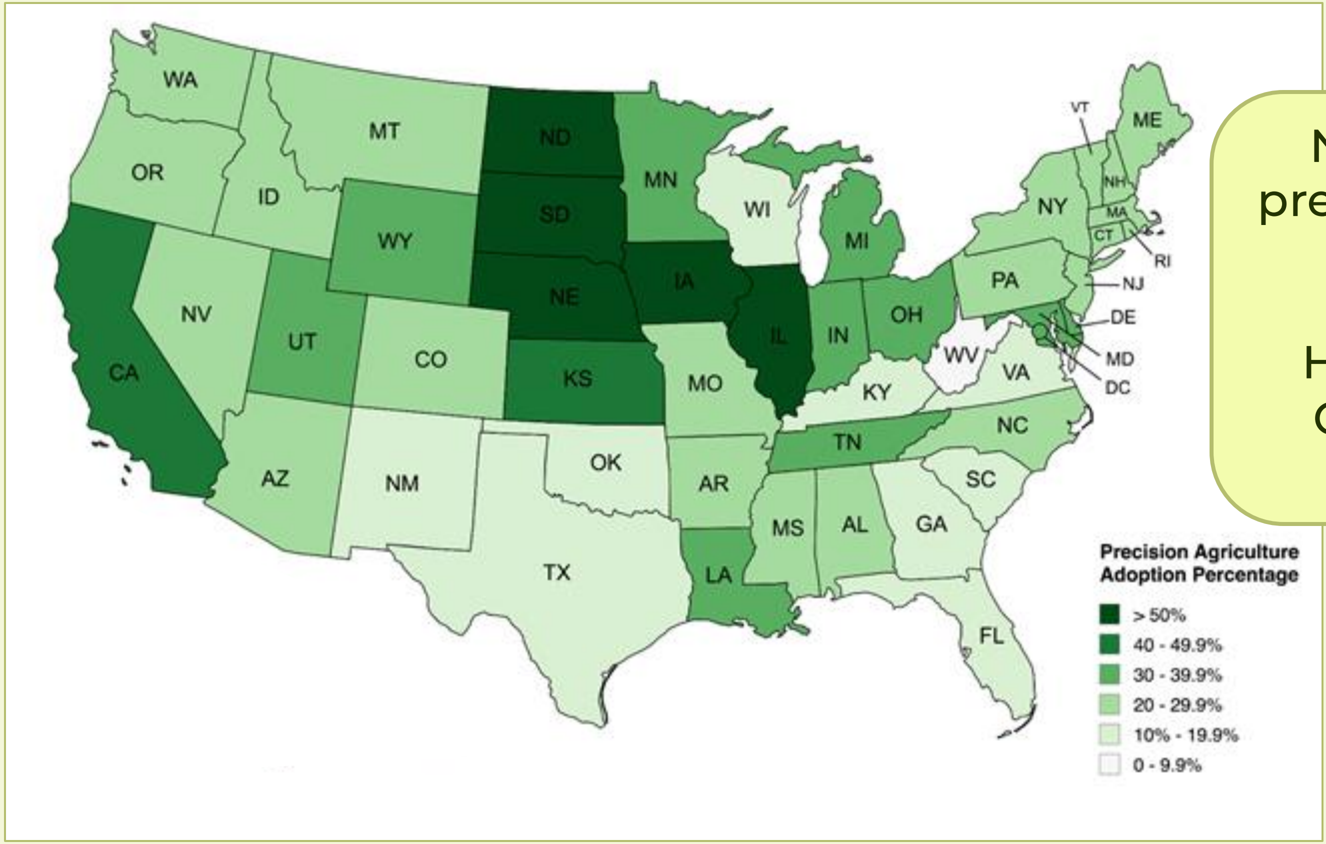
  Variable-rate fertilization

*Tailored application of fertilizer based on an area's **individually assessed need**.*

Nitrogen Fertilization

- Accounts for **over 50%** global fertilization consumption
- **~70%** of American farmland, **>97%** of planted corn acres
- **Peak uptake** in vegetative growth

Precision Agriculture Adoption in the U.S.



Nationwide **27%** precision agriculture adoption

High adoption in Corn Belt states **40-50+%**

Source: USDA 2023

Response to Problem Area: *PLAANT*

Assessed Need

- Nitrogen is a **key nutrient**, but **limiting factor**, for plant growth
- Inefficient fertilizer application → **runoff**, **GHG emissions**, and **$ losses**
- Current fertilizer technology outpaces nitrogen detection capabilities

Primary Use Cases

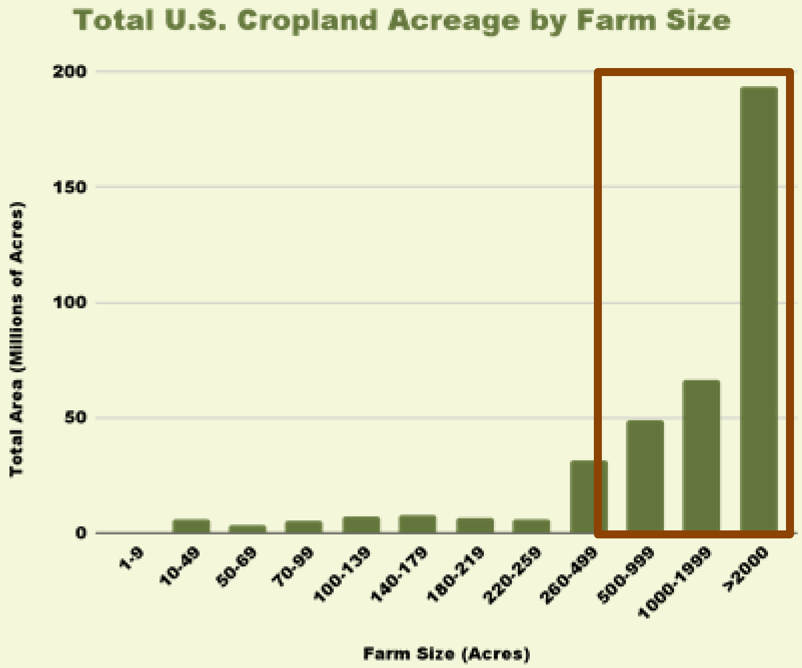
- **Real-time field monitoring** for targeted fertilizer application
- Precision Ag. system integration for **long-term management**

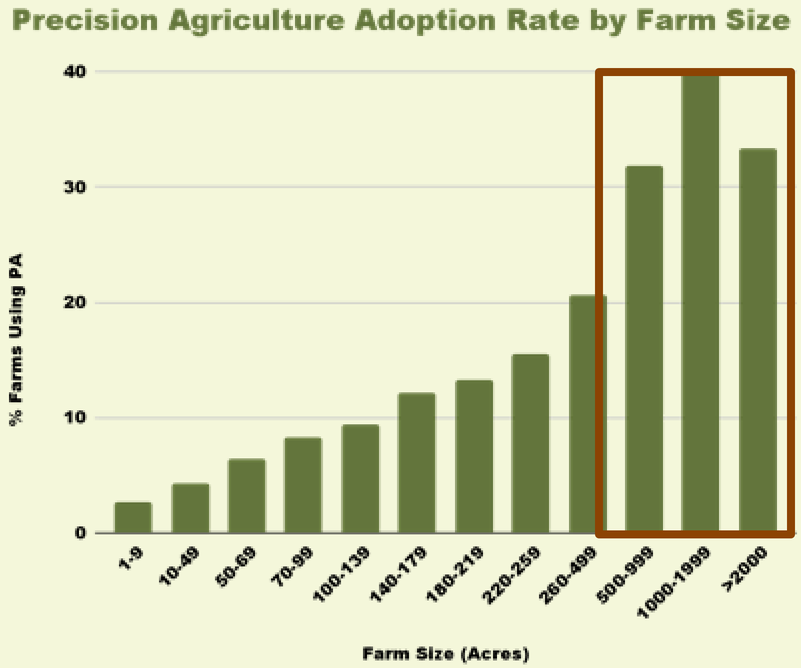
Target Audience

- Cropland containing corn, soybeans, cotton: **high-production** and **N needs**

*PLAANT combines cross-scale nitrogen information to optimize targeted fertilization and improve **nitrogen use efficiency (NUE).***

Primary Audience





*~ **80%** of cropland found on **> 400 acre farms***

*Among these farms, **Precision Agriculture Adoption = 20-40%***

Source: USDA 2024

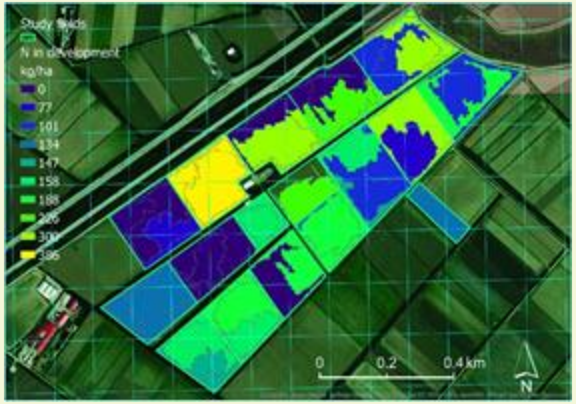
Challenges to Precise Nitrogen Application

Soil Nitrogen Dynamics

Spatially and Temporally Heterogeneous

Dependent on Exogenous Variables

[1]



Current Nitrogen Testing

Time and Labor Intensive

Long Lead Times

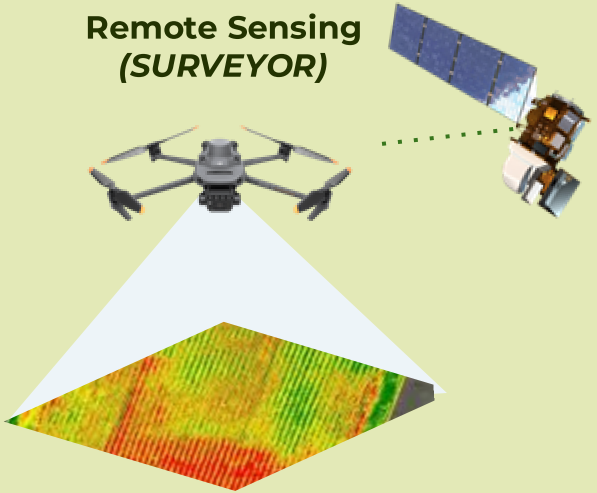
Low Adoption

[2]

[1] C. Karydas, M. Iatrou, G. Iatrou, and S. Mourelatos, "Management Zone Delineation for Site-Specific Fertilization in Rice Crop Using Multi-Temporal RapidEye Imagery," *Remote Sensing*, vol. 12, no. 16, p. 2604, Aug. 2020, doi: 10.3390/rs12162604.
[2] M. Hazard, "Img_0977 Xai tou soil sample Hafa Farm," Flickr, https://www.flickr.com/photos/88709139@N08/15569070266.

System Components

Remote Sensing
(SURVEYOR)

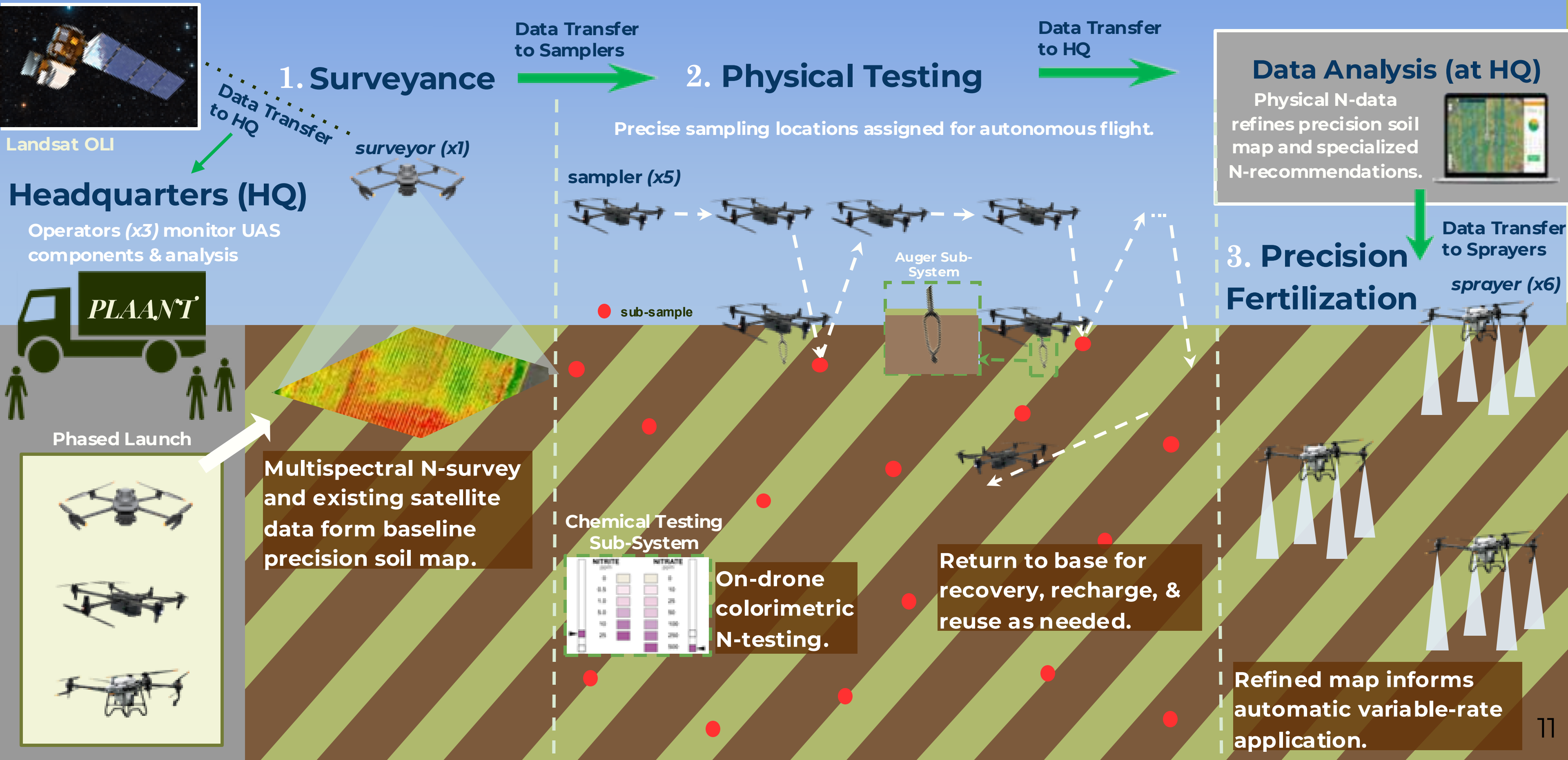


Automated Physical Testing
(SAMPLER)

Targeted Fertilizer Application
(SPRAYER)

*Phases integrate **existing** and **novel** precision agriculture tech. for **high modularity** and **solution flexibility.***

Concept of Operations (ConOps)



Headquarters (HQ)

Office

Fully equipped office for system planning, data processing, and PA model generation

Observation Deck

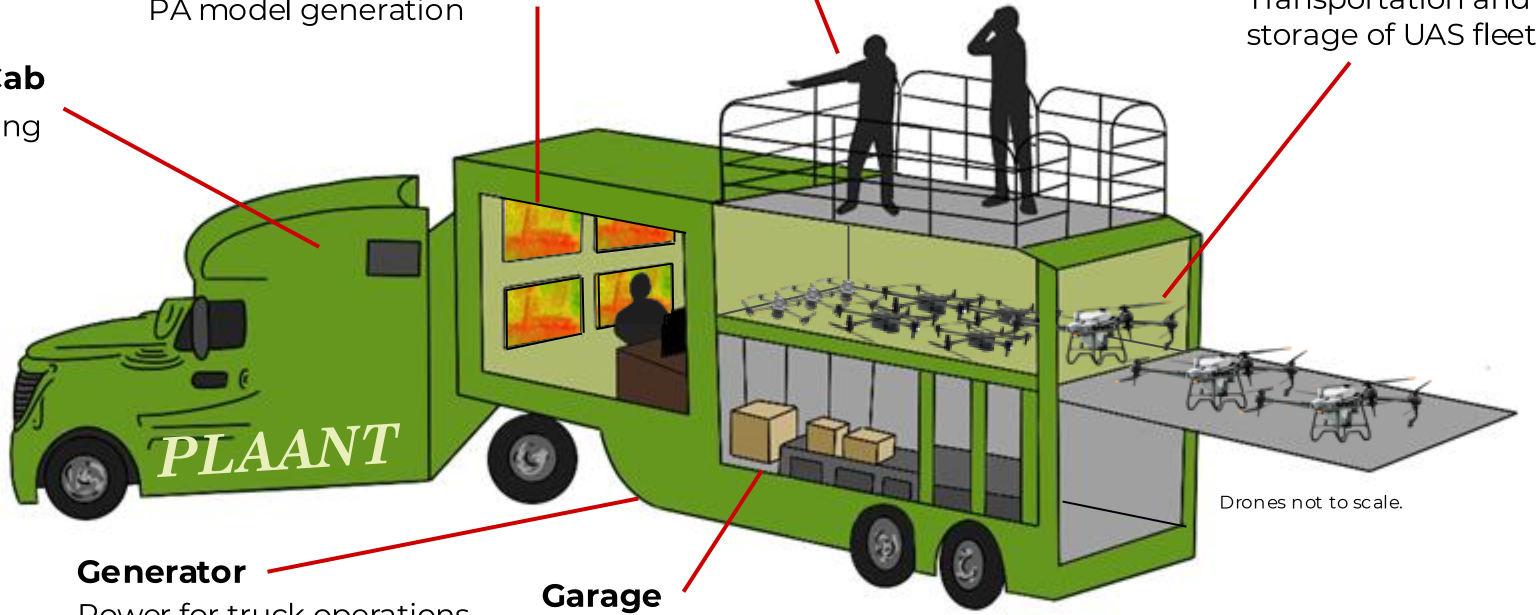
Improved vantage point for UAS monitoring within FAA regulations

Drone Bay

Transportation and storage of UAS fleet

Operator Cab

Operator living quarters



Drones not to scale.

Generator

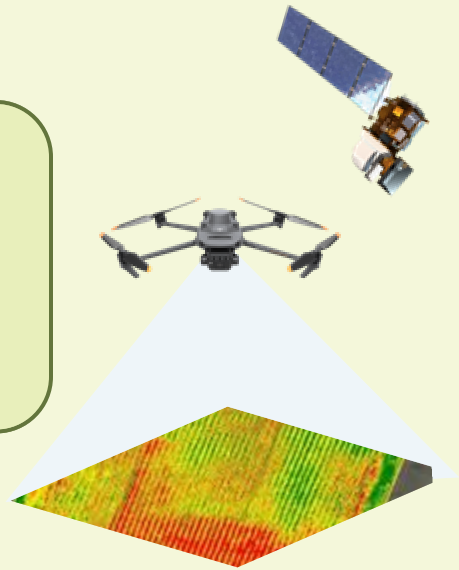
Power for truck operations

Garage

Fuel storage, sample archive, fertilizer stock

*Headquarters manages PLAANT operations from **centralized on-site location.***

1. Surveyance – Remote Sensing



Multispectral Analysis -

- N impacts crop vigor and band-specific reflectance
- Used to calculate and map vegetation indices
- Most applicable after crop emergence, critical uptake period, late season

Drone

- 1x per field, 5 acres/s
- Narrow swath, high res
- Real-time context
- Spatial baseline

Satellite

- Landsat OLI
- Wide swath, low res
- Consistent illumination
- Temporal baseline

*Forms **baseline** of precision map of N needs.*

Normalized Difference Vegetation Index

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

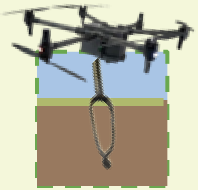
Normalized Difference Red Edge Index

$$NDRE = \frac{NIR - Red\ Edge}{NIR + Red\ Edge}$$

2. *Sampling* – Test Operations

Analysis at HQ

Collect Soil Sample



Automated sampling at 1-foot soil depth

5 Samplers per 400 Acre Segment, 8 hour cycle time

Store / Transmit Test Data

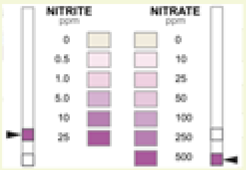
Homogenize Sample

Eject Excess Material

Mix with Water, Filter Particulates

Apply Sample to Test Strip

Analyze N Content

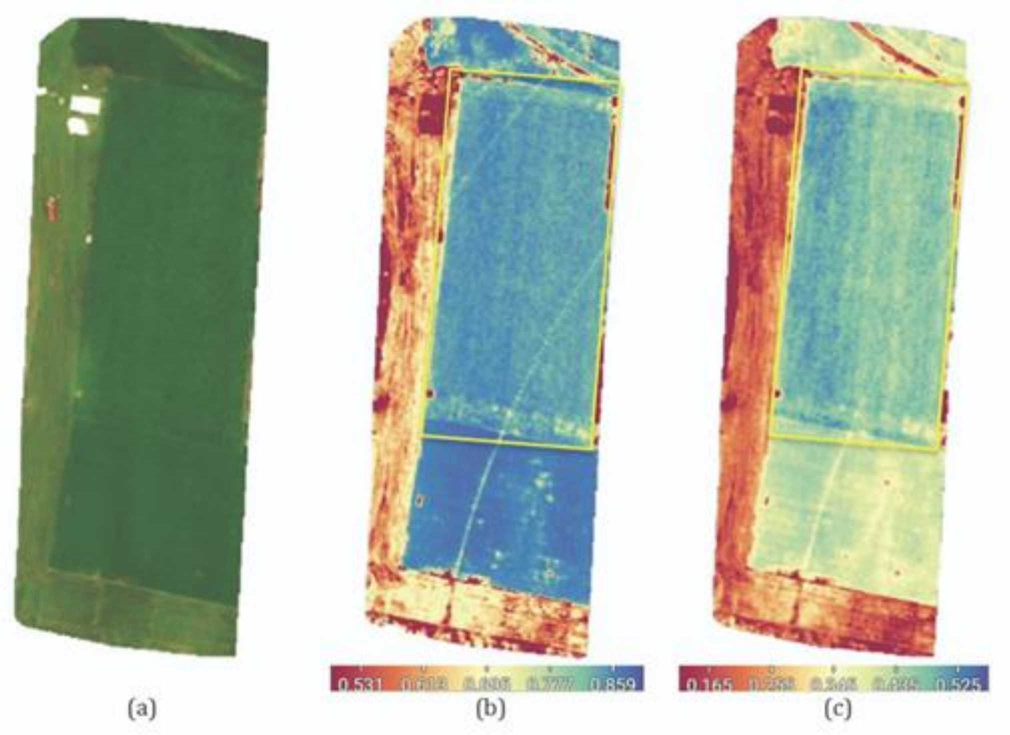


Retain Physical Sample for Archive

Streamlined real-time physical sampling and N-testing connects remote sensing and modeling with ***ground truth.***

Data Analysis and Precision Mapping

[1]



(a) Post-tassel corn field, (b) NDVI map, (c) NDRE map

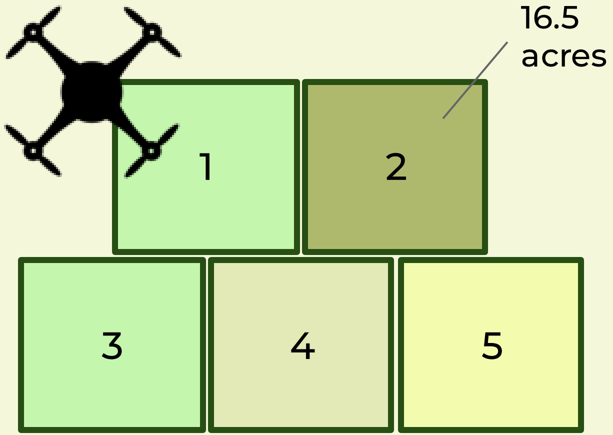
Mapping enhanced by indirect remote sensing analysis **AND** direct physical sampling information.

Outcome: *comprehensive map of N needs and health across field.*

[1] L. J. Thompson, Y. Shi, and R. B. Ferguson, “Getting Started with Drones in Agriculture,” *Nebraska Extension, University of Nebraska–Lincoln*

3. Spraying – Targeted Fertilizer Treatment

Fertilizer Application - leverages the informed N model for precise, targeted variable-rate treatment



Covers **16.5 acres/hr/drone**

6 Sprayer Drones per 400 acre segment, 4 hr cycle time

Critical Components of *PLAANT*

Component	Image	Purpose
Nitrate Test Strips		Rapid color-analysis soil test
Auger & Actuation		Soil drilling, sampling
Multispectral Camera		Detect growth activity
Additional Components	Modified Quadcopter, Auger-Actuation System, RTK Base Station, Color Spectrometer, Precision Agriculture Software	

Technology Readiness Levels (TRLs)

4

- 500 Wh/kg Lithium Ion Battery (for Surveyor, Sprayer)

6

- Miniaturized Auger and Actuation mechanism
- Auger-Drone System

9

- Miniaturized Nitrate Test Strips
- Multispectral Camera
- RTK Base Station
- Nano Color Spectrometer
- Soil Mapping Software
- Satellite Remote Sensing
- Sprayer Drone

Developed Auger-Drone System

NASA TRL Definitions

- **4** Validated in Lab
- **6** Tested in Relevant Environment
- **9** Proven, Commercially Available

*PLAANT leverages **mature** technology to **realistically improve NUE.***

[1] B. Tiede, et. al, "Battery Key Performance Projections based on Historical Trends and Chemistries," NASA Glenn Research Center
[2] Ackerman, Evan. "How to Dig a Hole with Two Drones and a Parachute." IEEE Spectrum

Drone Sizing Analysis

Characteristic	Surveyor	Soil Sampler	Sprayer
Gross Weight [lb]	1.90 [1]	108 [2]	163 [2]
Frame Dimensions [ft] (L x W x D)	0.40 x 0.40 x 0.10	3.0 x 3.0 x 0.43	4.5 x 4.5 x 0.60
Payload [lb]	0.24 [3]	20 [4]	70 [5]
Battery [Wh/kg]	150 [6]	–	150 [6]
Gas Fuel (per Flight) [lb]	–	0.3 [7]	–
Lift/Drag	4.23	4.22	1.02
Drone Service Life [year]	2	5	5

[1] “DJI Mavic 3 pro - Specs - DJI.” *DJI Official*

[2] “T30 - Specifications - DJI.” *DJI Official*

[3] Fawcett, Dominic, et al. “Multi-scale evaluation of drone-based multispectral surface reflectance and vegetation indices in operational conditions.” *Remote Sensing.*

[4] “Cuav New VT240 Pro Vtol.” *World Drone Market.*

[5] “DJI Agras FAQ.” *Agri Spray Drones.*

[6] B. Tiede, C. O’Meara and R. Jansen, "Battery Key Performance Projections based on Historical Trends and Chemistries," *2022 ITEC.*

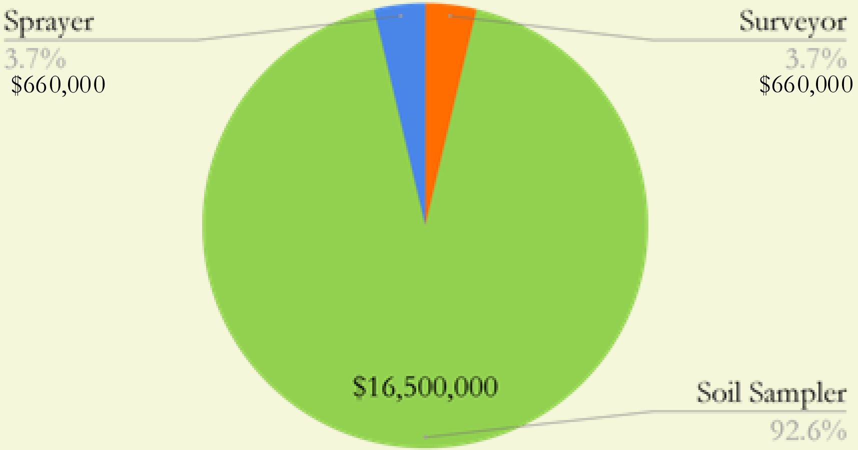
[7] “Energy Density.” *Beloit Education.*

Risk Analysis and Abatement

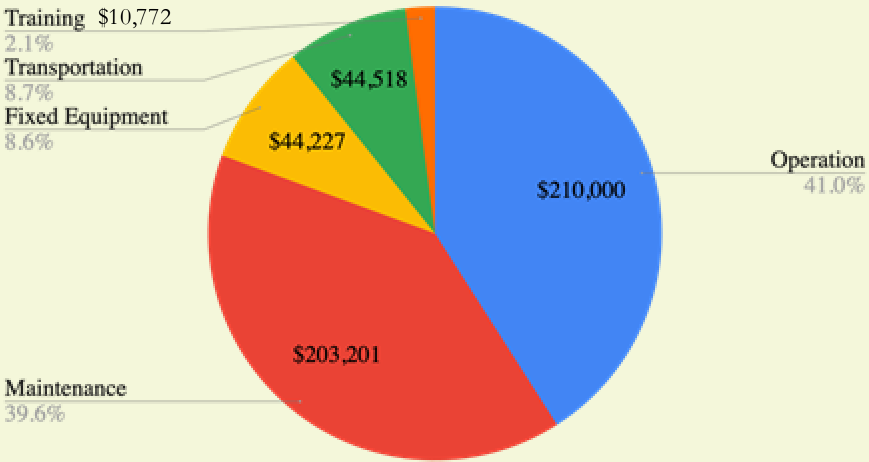
Auger Obstruction	Landing Instability	Inaccurate Recommendation
Ejectable Auger	Slow Landing/Takeoff	15 Samples/20 Acres
Closed-loop Force Feedback at Actuator	Large Drone Weight/Crop Strength Ratio, Soil Anchors, Rotor Guards	Bi-weekly Servicing in Growing Season

Cost Breakdown

Non-Recurring Cost Breakdown [$]
Total: $17,820,000



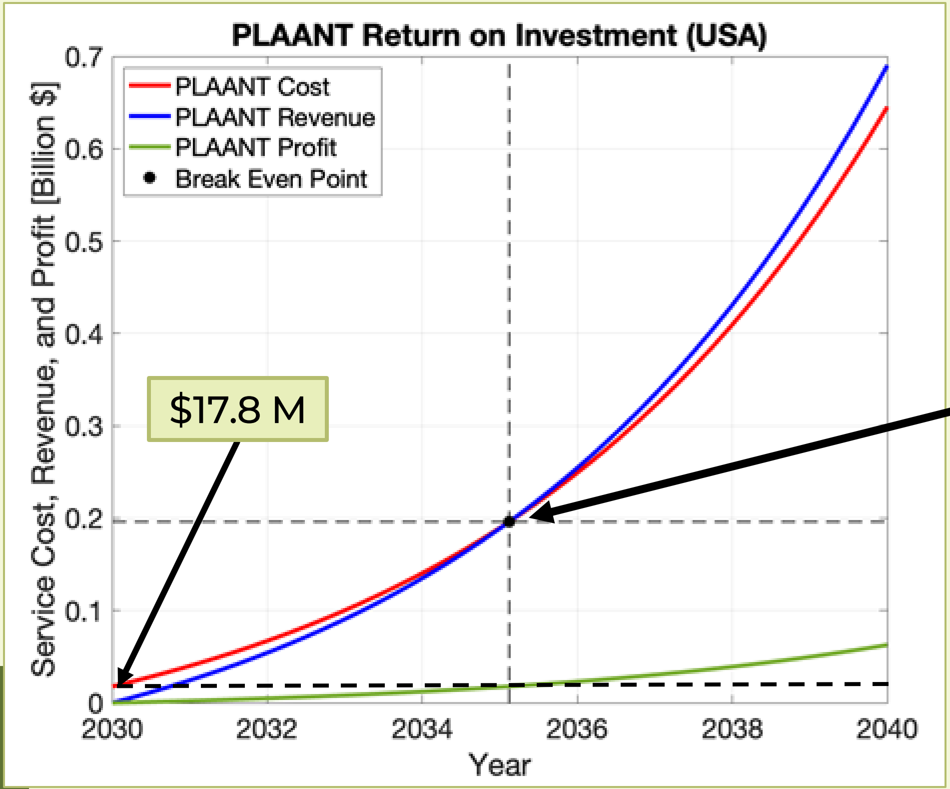
Recurring Cost Breakdown [$/year] (5600 Acres/Year)
Total: $512,718/year



Labor cost *= Biggest factor in Maintenance & Operation*

Non-Recurring *attributed to singular RTD&E expenses*

PLAANT ROI at Full Projected U.S. Deployment

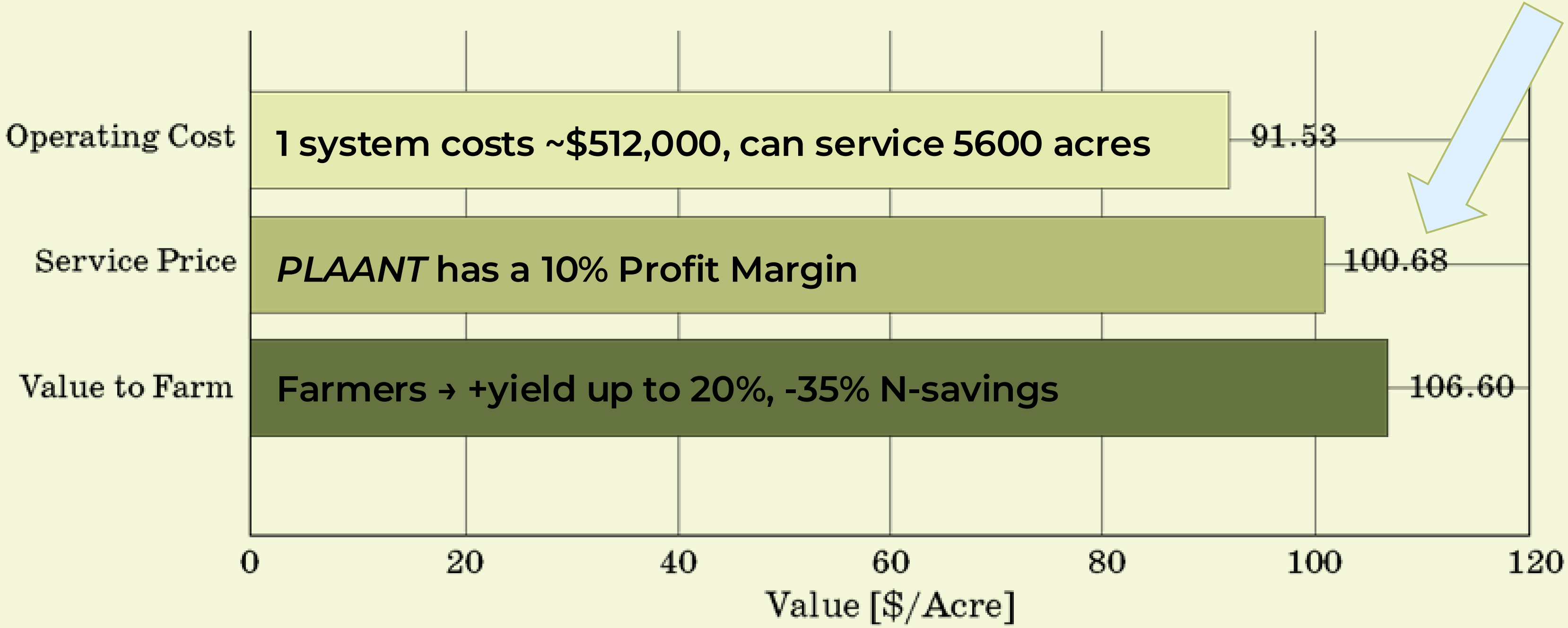


Non Recurring Cost: *$17.8M*
Initial Profit Margin: *10%*
US Launch: 2030

Break Even Point:
- 2035
- 0.45% Cropland Adoption
- ~1.35 M acres serviced
- *$16.2 M* increase in Yield
- *4.4 M (lb)* Nitrogen saved

Value to Farmers

Compared to current
Fertilizer spend of ~$200/acre



PLAANT is Affordable → Farms experience ***6.4% return on investment***

Increased Profit Area → ***+ 20% Yield, - 35% N-Savings***

Derived Value

Environmental Impact

Greenhouse Gas Emissions

N-fertilizer production and use cause **5% of global GHG emissions**

13 Mt/yr CO_2eq reduction in U.S. GHG emissions

Water Pollution

Water eutrophication from nitrogen, phosphorus fertilizers costs **$2.4 billion/yr** in U.S.

$150 million/yr savings on water eutrophication in U.S.

Extended Impact

Expanded **data availability** for agricultural research

Increased visibility of complex soil dynamics

Implementation Barriers and Considerations

Regulatory Compliance

- Waiver 107.35 (1 Operator → 3 Drones)
- Part 137 and Part 135 → Proper disposal of soil sample
- EPA regulations
- Farmer data privacy

Training Needs

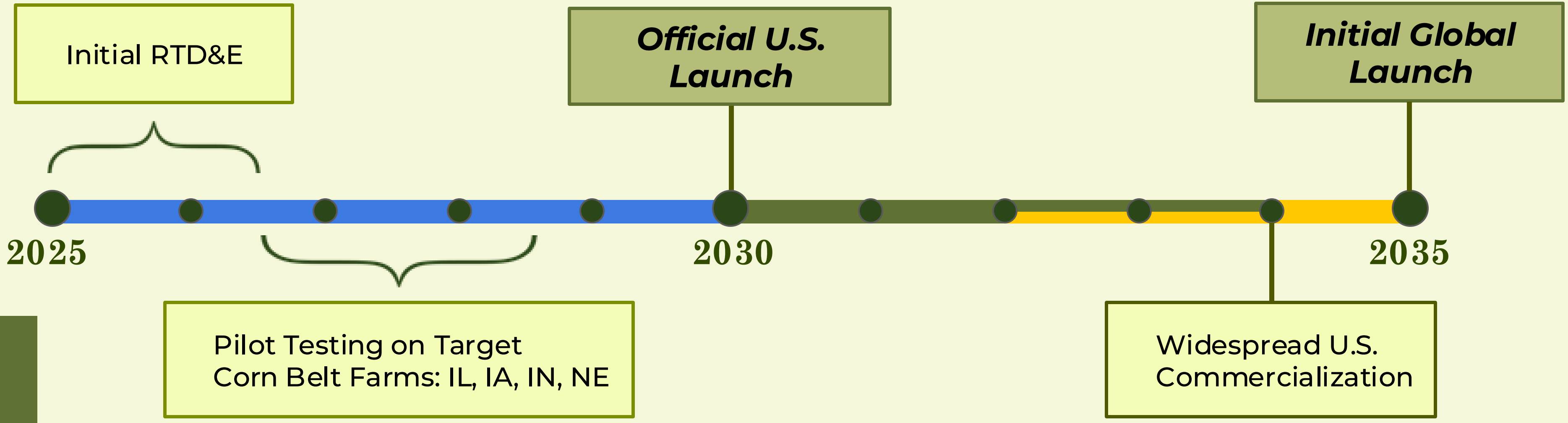
- FAA Part 107 for UAV Pilot Certification
- Specialized training for *PLAANT* system operators
- USDA support (e.g. *Environmental Quality Incentives Program, TSP)*

Adoption Challenges

- < 50% of farms use PA due to service cost, data unfamiliarity
- PA market growth → offered by 20-50% service providers
- Product diffusion into market

10 Year *PLAANT* Deployment

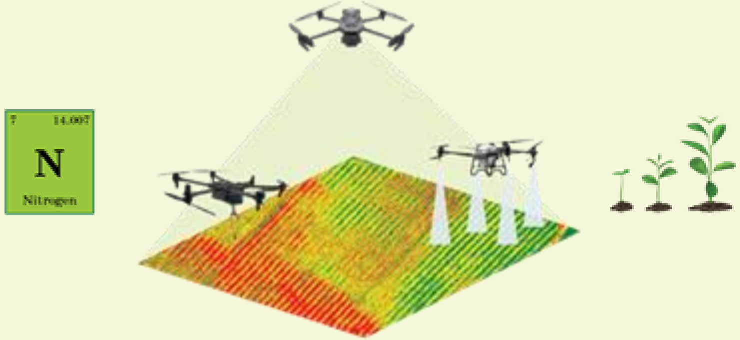
- **Phase 1: R&D + Early Rollout**
- **Phase 2: Full U.S. Deployment**
- **Phase 3: Initial Global Deployment**



Additional Considerations

Technology Improvements

- Testing for **different nutrients** and **N-types**
- Assimilation with Satellite NO_x data to address U.N. Sustainable Development Goals
- Further **IoT and ML integration** to improve modeling & simulation capabilities



Full Global Rollout

- Adaptation for **varying global regions**
- Application towards **region specific crops**

Consulted Experts

Prof. Sheng Wang
NASA Acres, UIUC

Advised On: **Cross-scale soil sampling and data assimilation for increased NUE**

Prof. Raj Khosla
KSU Agronomy

Advised On: **Precision Ag UAS for Nutrient Management, N management in Midwest**

Prof. Kenneth Sebesta
BU Mechanical Engineering
Advised On: **Drone Hardware**

Prof. Xia Zhu-Barker
UW-M Soil Science
Advised On: **Soil Sampling, N Dynamics**

Prof. Hemendra Kumar
UMD Precision Ag Specialist
Advised On: **UAS, Remote Sensing**

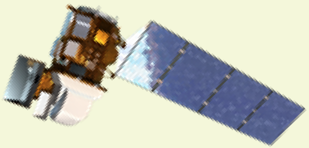
Prof. Mark Friedl
BU Earth & Environment
Advised On: **Environment Impact**

Miguel Oliveras
NRCS TSP Coordinator, Central Region
Advised On: **TSP Integration & Gov. Programs**

Prof. Michael Dietze
BU Earth & Environment
Advised On: **Soil Nutrients**

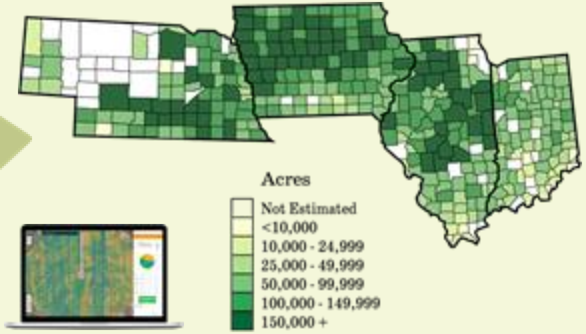
PLAANT System Overview

Satellite remote sensing
for baseline mapping

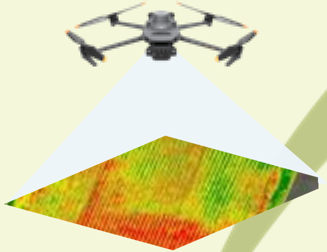


Highly specialized crop N for each
field in primary target area

Corn Harvested Acres by County, 2022

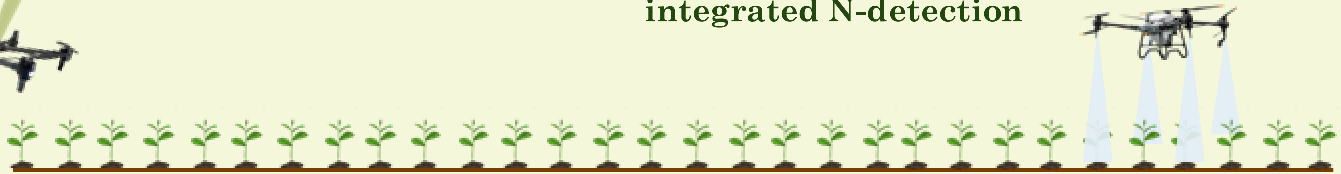


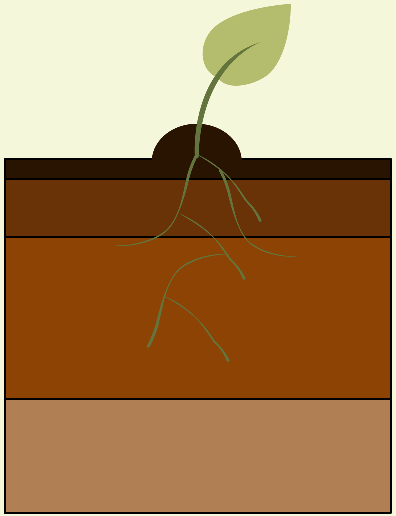
Aerial multispectral
surveyance



UAV-driven ground sampling

Automated precision
fertilizer response from
integrated N-detection





Thanks!

Any questions?

NASA'S

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2025 AgAir: Aviation Solutions for Agriculture Forum