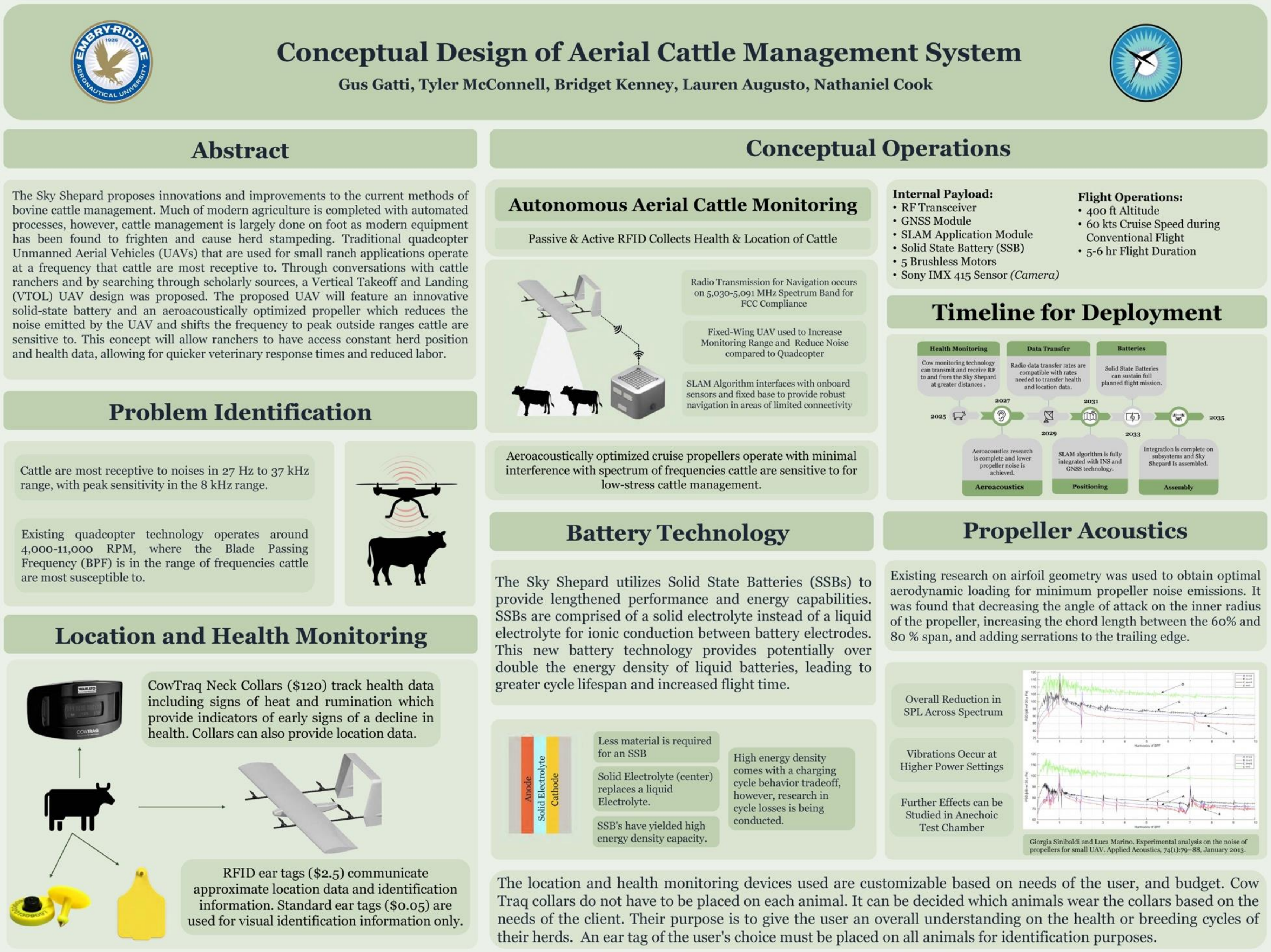
GATEWAYS TO BLUESKIES

Embry-Riddle Aeronautical University

“Sky Shepherd: Autonomous Aerial Cattle Monitoring”



The Embry-Riddle Aeronautical University Presentation will begin at 8:00 AM Pacific Time.
View the 2025 Finalists’ Infographics: https://blueskies.nianet.org/finalists/

COLLEGE OF ENGINEERING

SKY SHEPHERD:
Unmanned Aerial Cattle Surveillance

EMBRY-RIDDLE Aeronautical University

Introduction

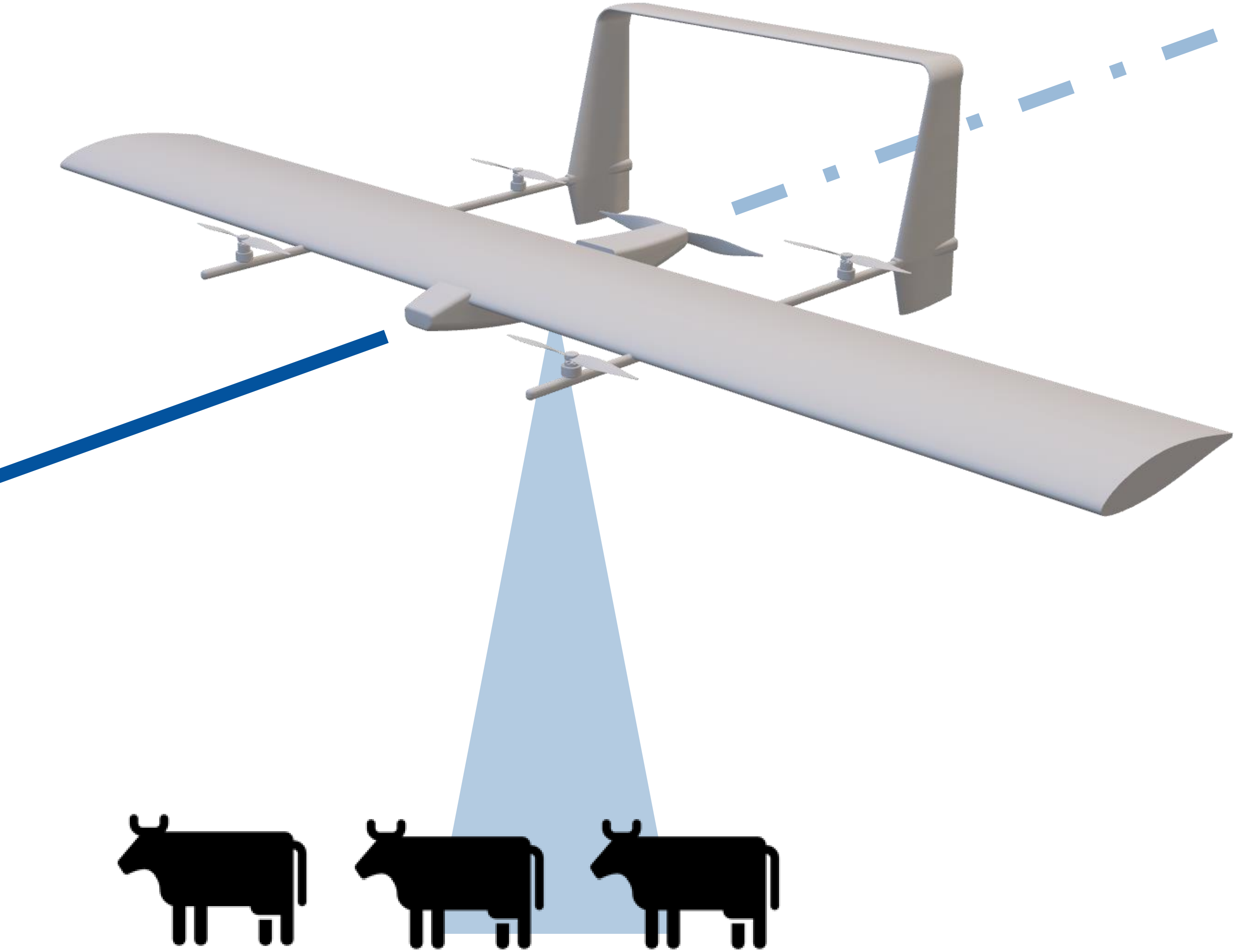
Tyler McConnell
Team Lead
Sophomore
Aerospace Engineering

Gus Gatti
Team Lead
Senior
Aerospace Engineering

Nathaniel Cook
Member
Sophomore
Aerospace Engineering

Bridget Kenney
Member
Sophomore
Aerospace Engineering

Proposal Overview



Problem Identification

Proposed Solution

Low-Stress Cattle Management

Product Innovations:

- *Aeroacoustically Optimized Propeller*
- *Cattle Monitoring Technology*
- *Navigation Algorithms*
- *Solid-State Battery Technology*

Budget and Timeline

Problem Identification

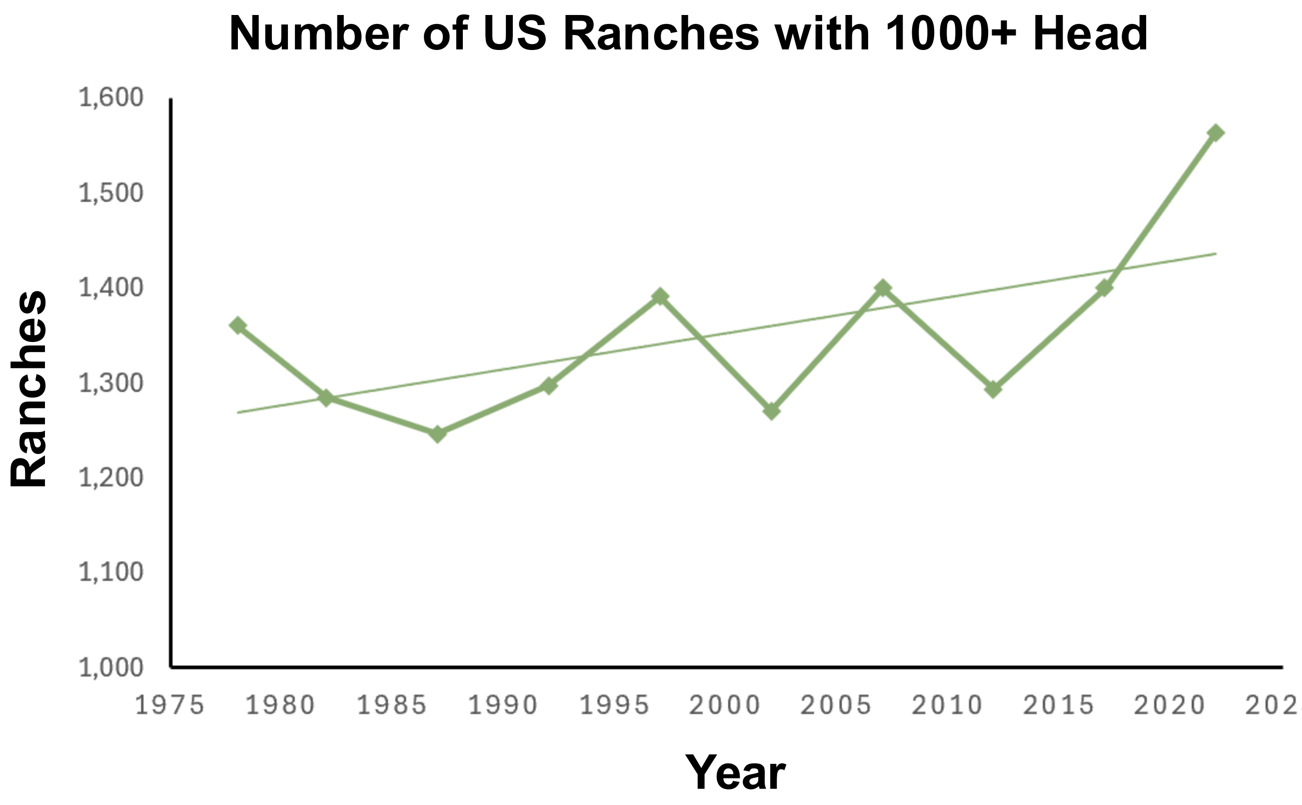
Increase in Ranch Size Since 1980

Larger ranch size leads to larger and more expensive cattle management.

Current methods of cattle identification rely on ground infrastructure*.

** ATV, by-foot, horse*

Duration between cattle identification trips can be long leading to delayed veterinary response.



Data via 2022 Census of Agriculture

Problem Identification

Existing Quadcopter Technology

Not applicable to large ranches. *Short range (under 1hr cruise)*, small tracking capacity. *(less than 40 subjects)*

Large noise emissions from 4 powerful motors and propellers.

Does not consider animal response to UAV, no implementation of Low-Stress Cattle Management.

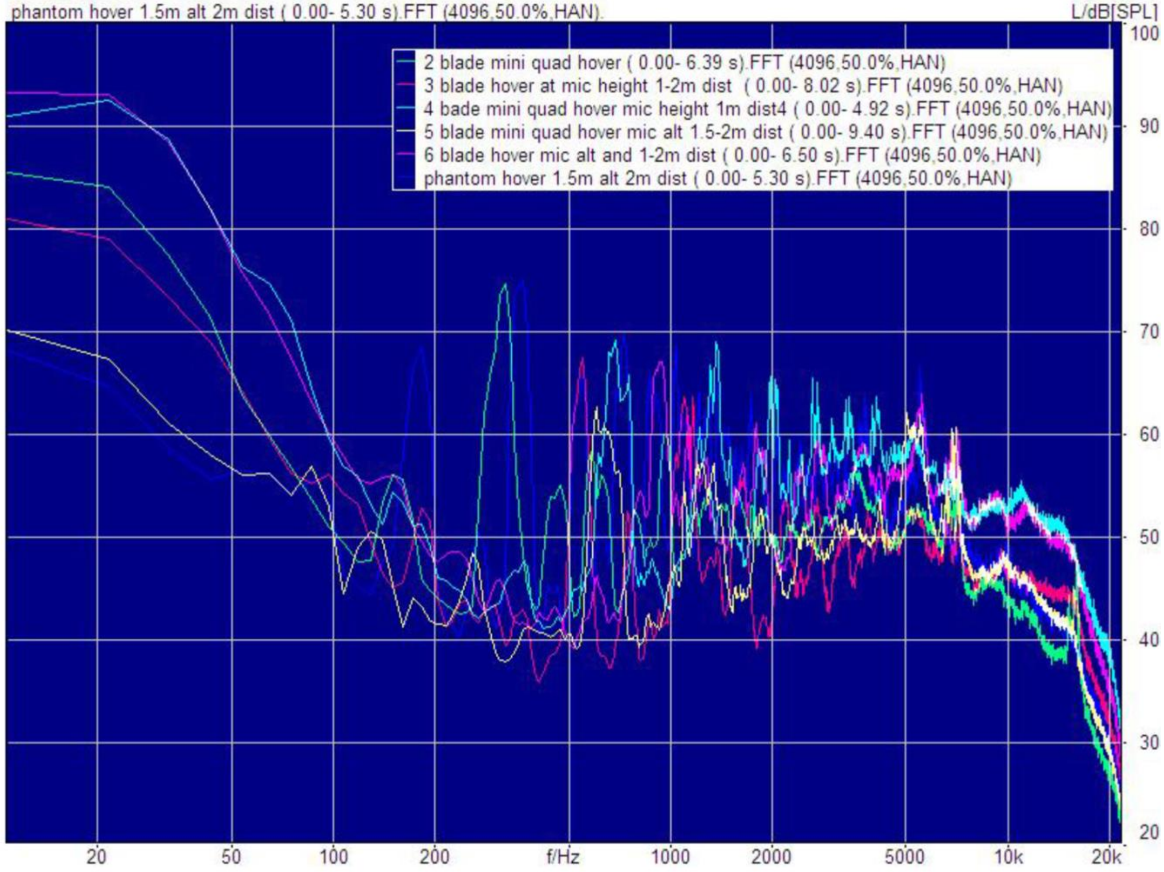
Photo via wildlifedrones.net

Problem Identification

Existing Quadcopter Technology

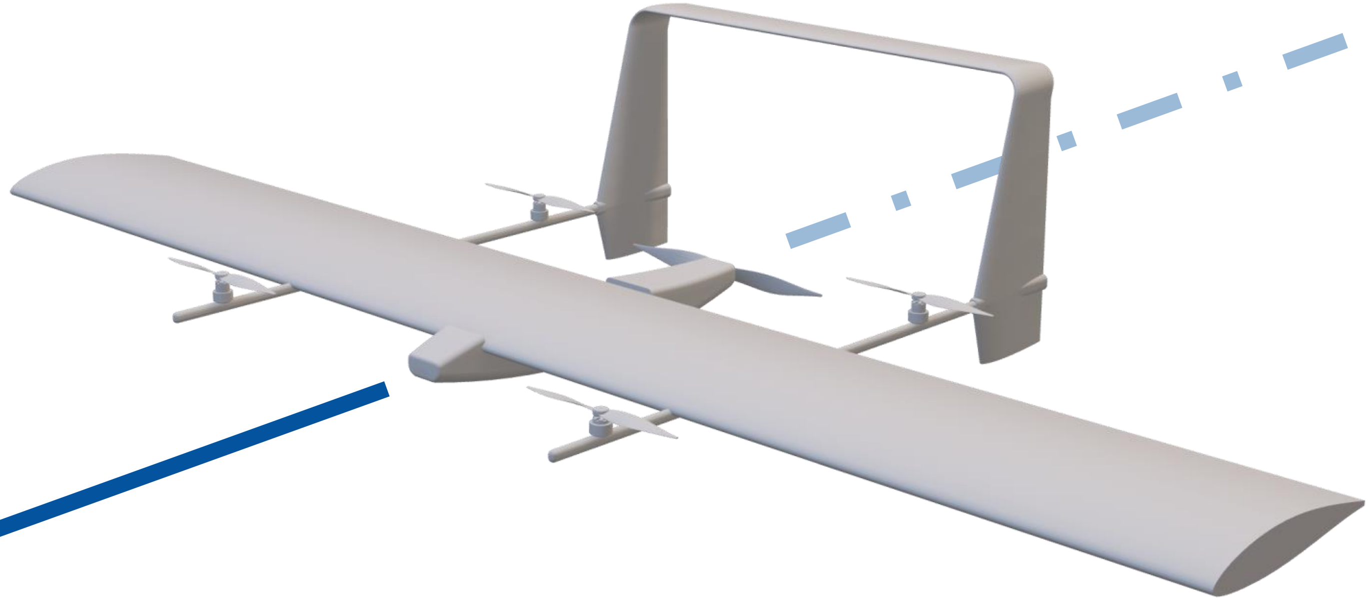
Cattle are receptive to frequencies between 27 Hz to 37 kHz with peak sensitivity at 8 kHz.

Small Consumer UAVs operate at 4,000-11,000 RPM corresponding to BPF of 400-550 Hz and harmonics in sensitive range.



Data via Kloet et al. 2024

Proposed Solution



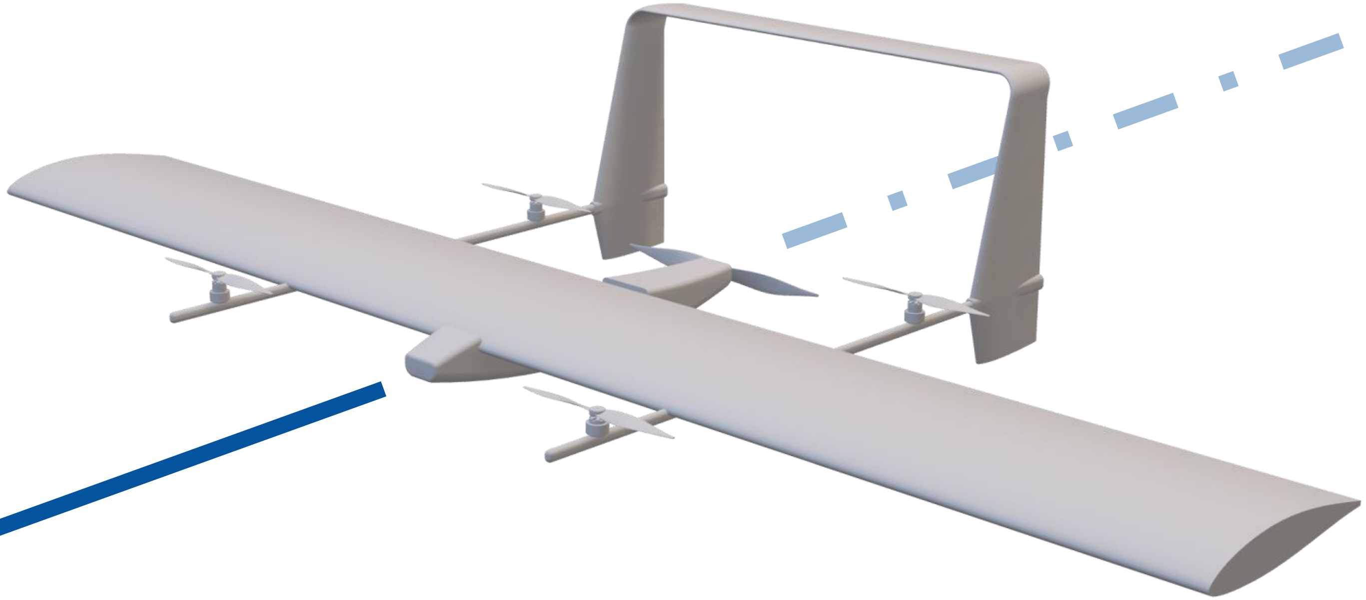
Sky Shepherd: Aerial Cattle Management

Reduce labor costs by eliminating the need for ranch hands to physically travel to locate herd.

Use AI mapping algorithms to identify herd location and report movements.

Monitor herd health in sensitive populations using e-collars to optimize treatment response time.

Proposed Solution



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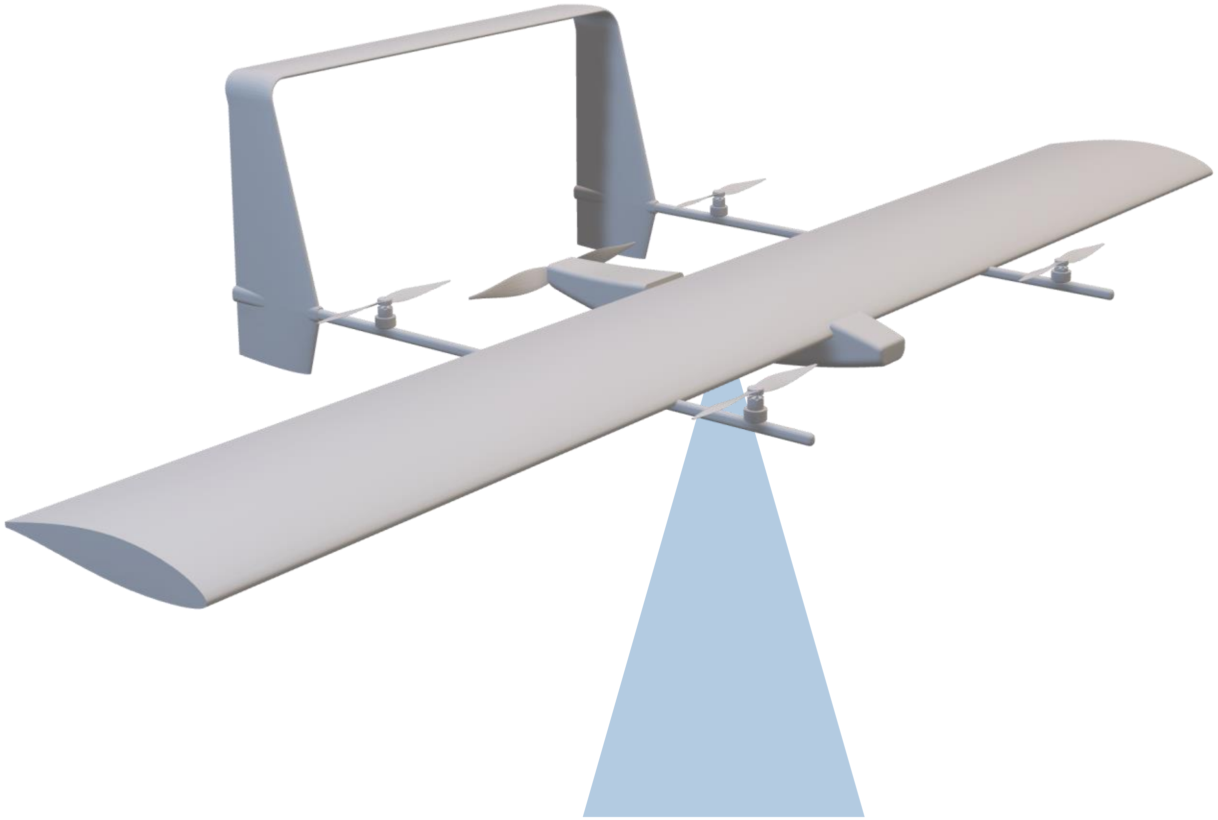

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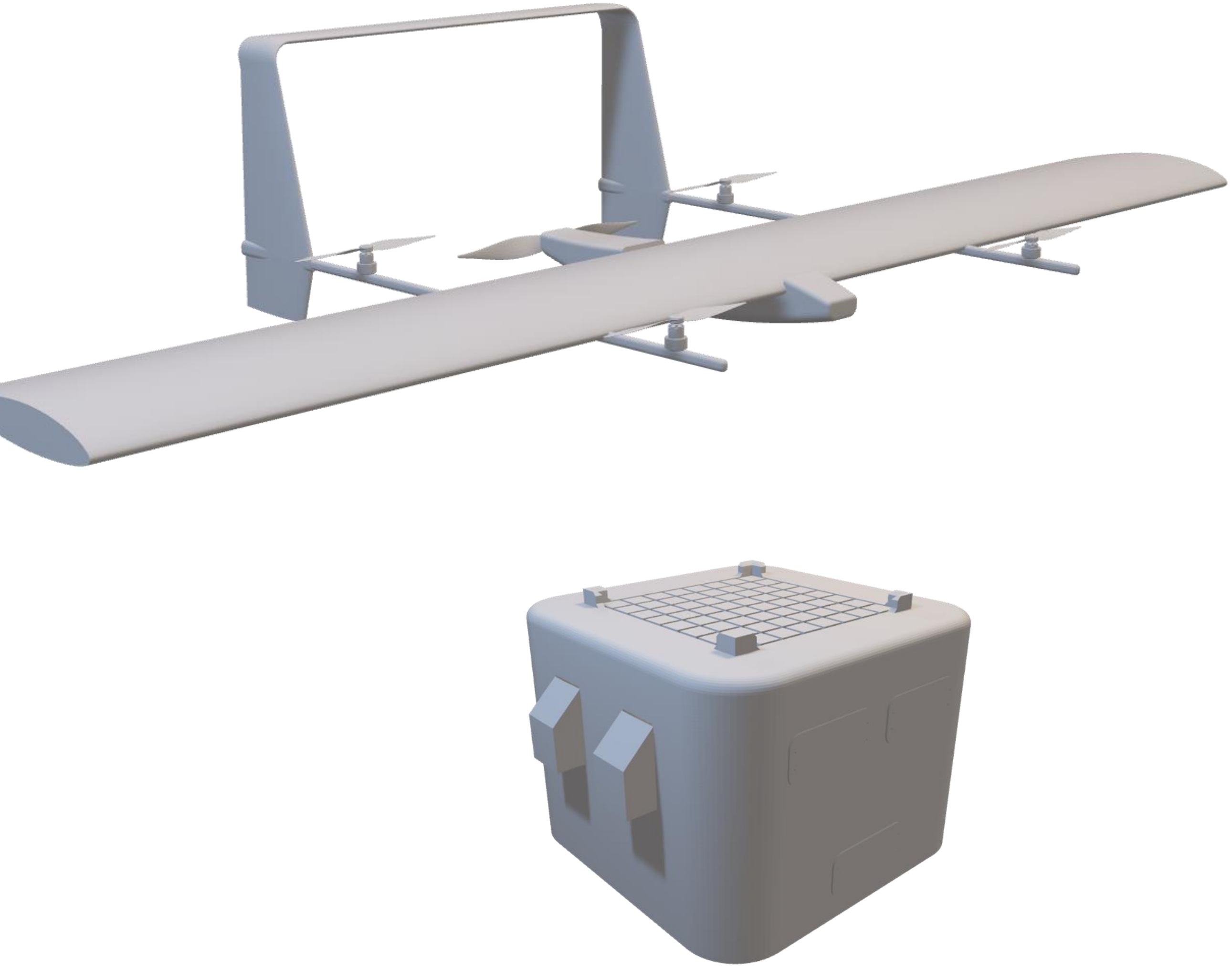
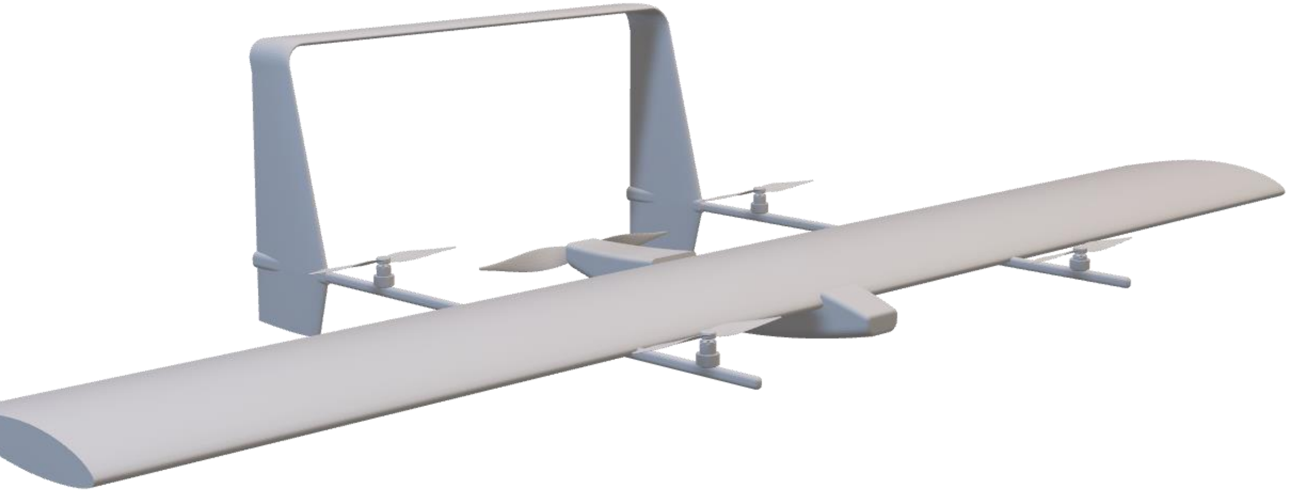
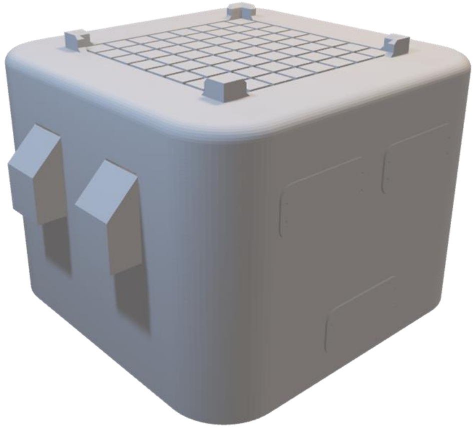


Sky Shepherd:
Aerial Cattle Management

- Fixed-Wing Autonomous UAV System
- Monitoring capability of 6,000 acres and 2,500 head
- VTOL capability from wireless charging pad

Sky Shepherd Charging





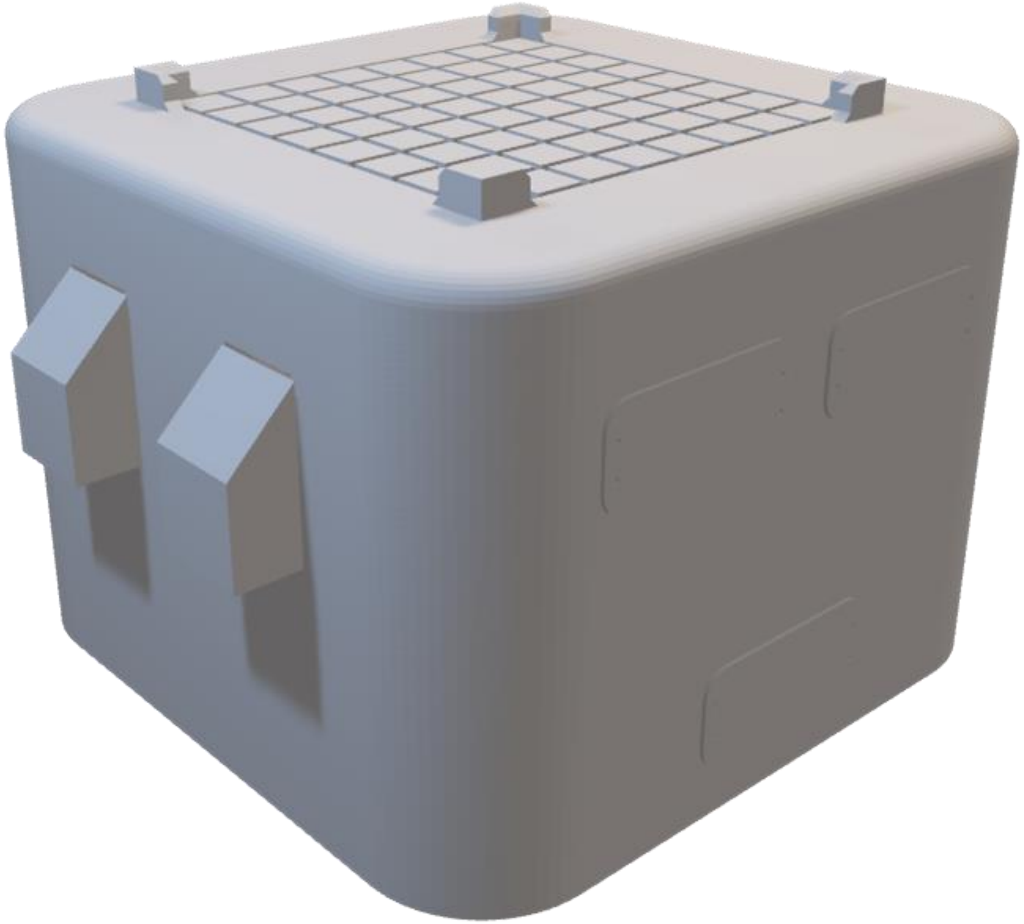
Logistics

Returns to the charging pad without any input from farmer.

Charging pad communicates approach and departure instructions to the UAV.

Quadcopter flight when approaching and departing charging pad.

Home Base Functions



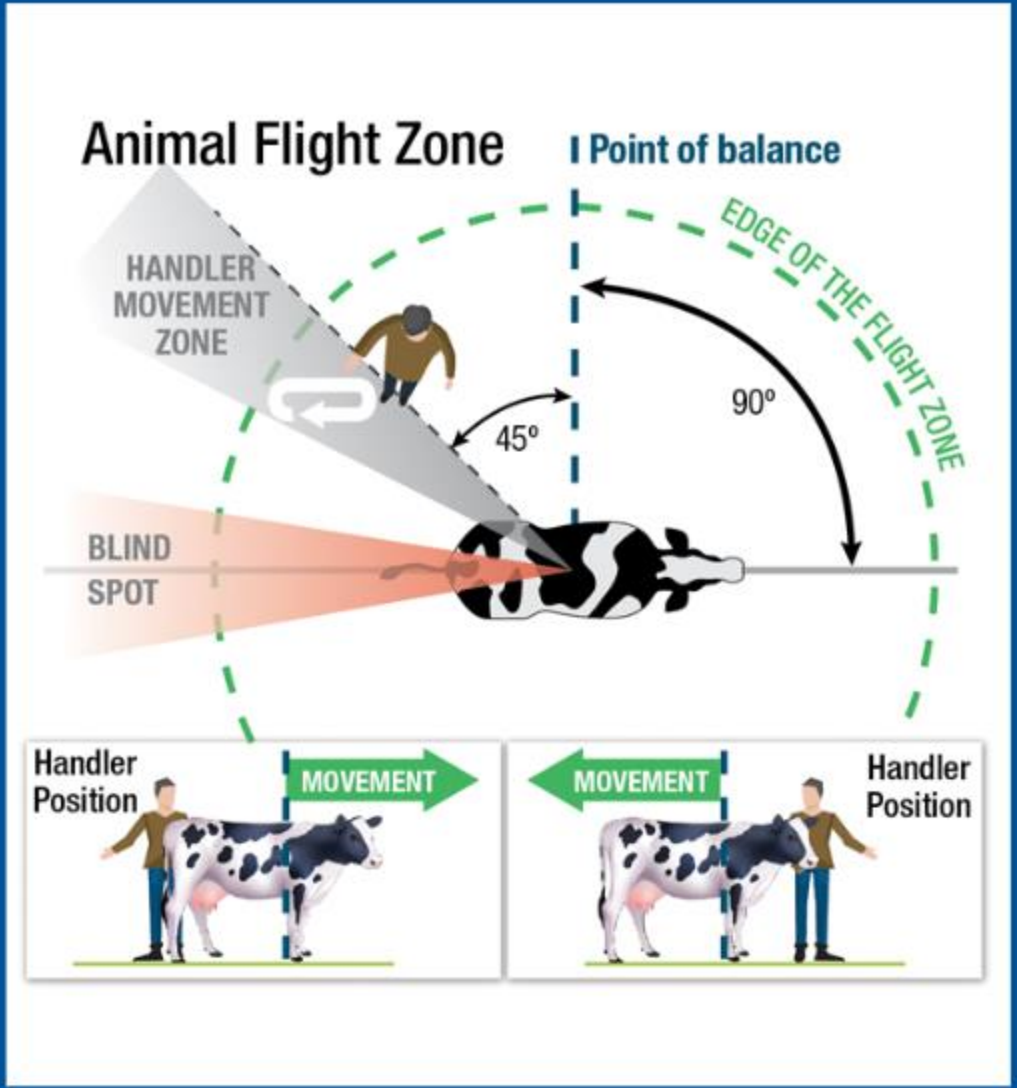
Logistics

Charging pad magnetically connects to the Sky Shepherd to ensure UAV safety and charging.

Main computing and communicating unit for the UAV.

Connects to power grid from farm/solar unit, and uses two backup batteries for emergency situations.

Low-Stress Cattle Management



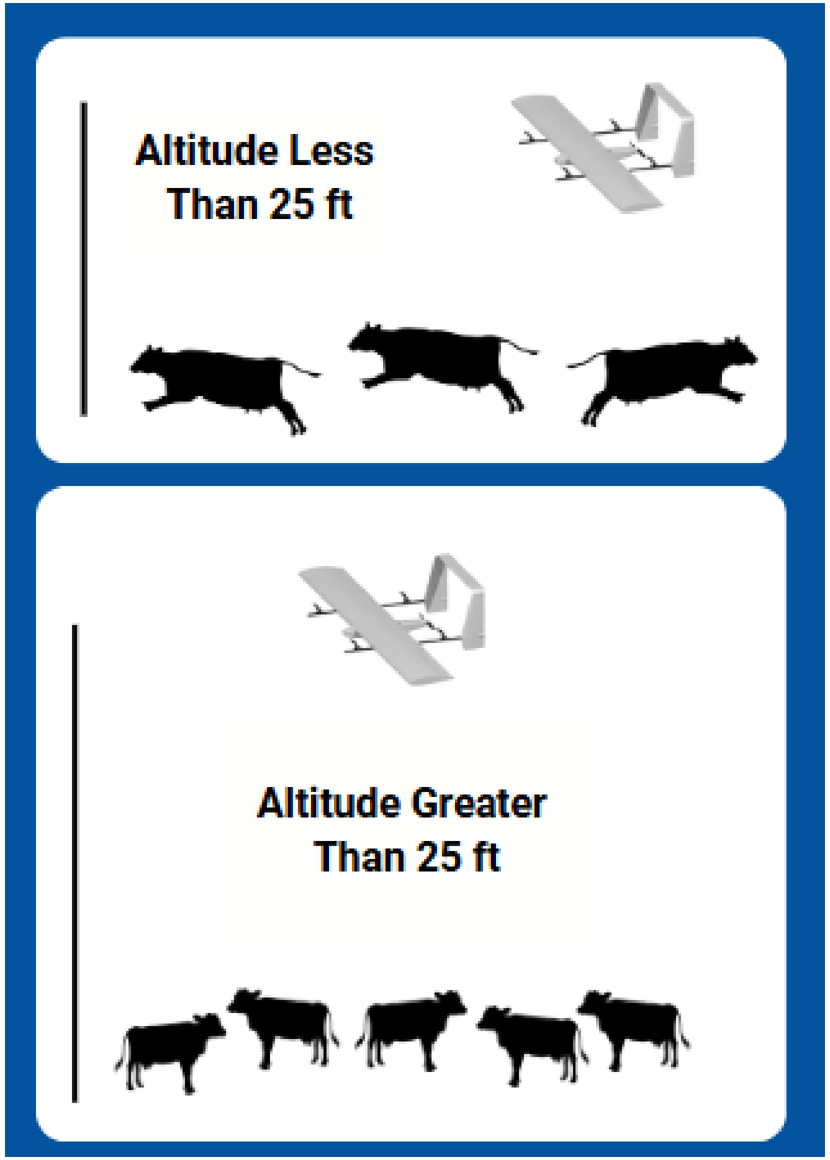
2 – D Cattle Management

Cattle Flight Zone is the reaction cattle has when a person or animal enters their vicinity.

Technique is used in herding to move cattle in a specific direction.

Elevated stress levels increase the radius of flight zone and make it more difficult to control the herds movements. [T. Grandin]

Low-Stress Cattle Management



3 – D Cattle Management

Research found that UAV's significantly increases the herds stress level when below 25 ft.

Changes with environment, proximity to calves and other animals, and general hormonal changes.

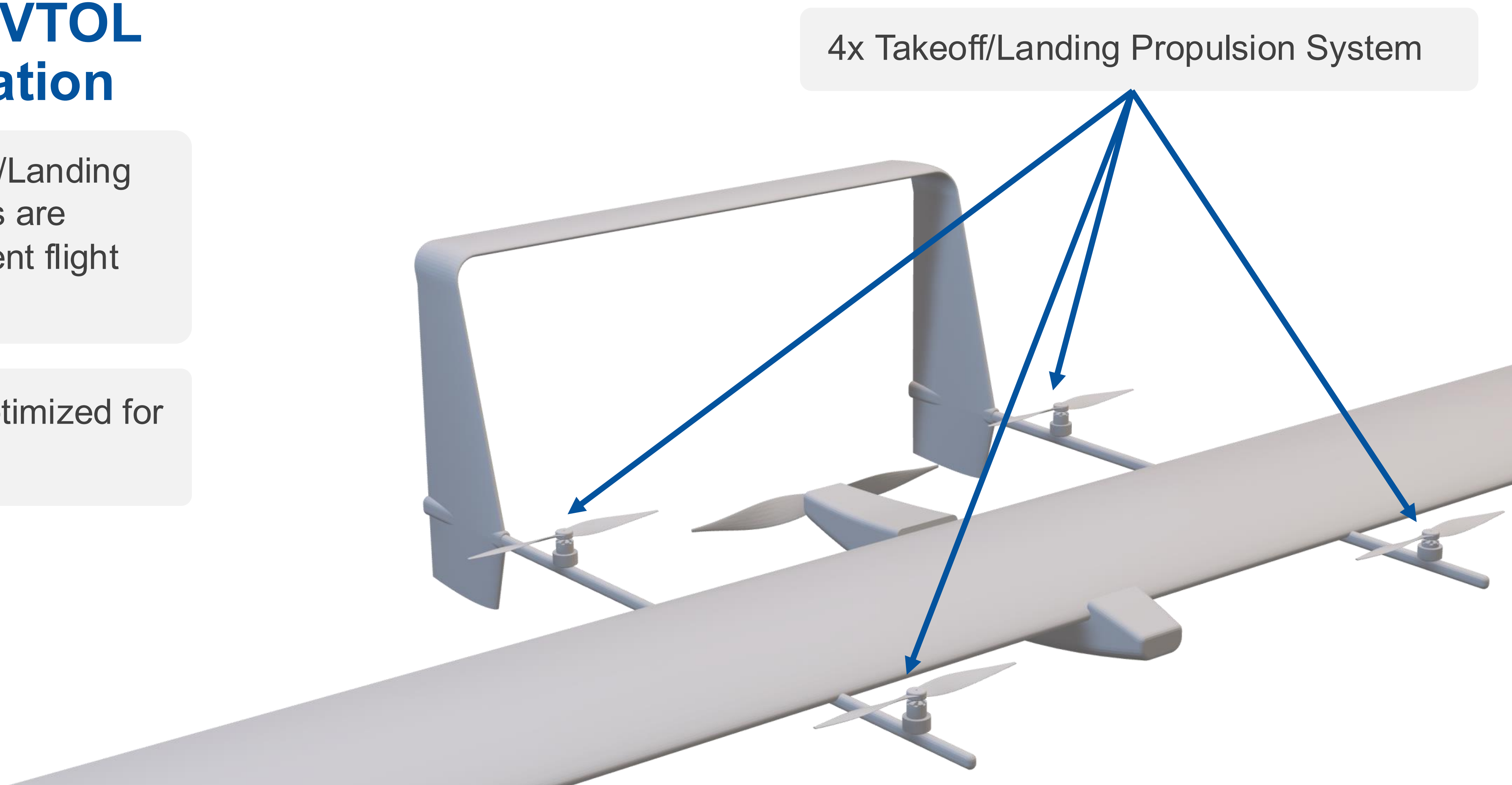
"Others will uncover new ways to utilize the technology to benefit both livestock and farmers." [M. Beverly]

Aeroacoustic Optimization

Benefit of VTOL Configuration

Cruise and Takeoff/Landing propulsion systems are designed for different flight conditions.

Takeoff/Landing optimized for high performance.



Aeroacoustic Optimization

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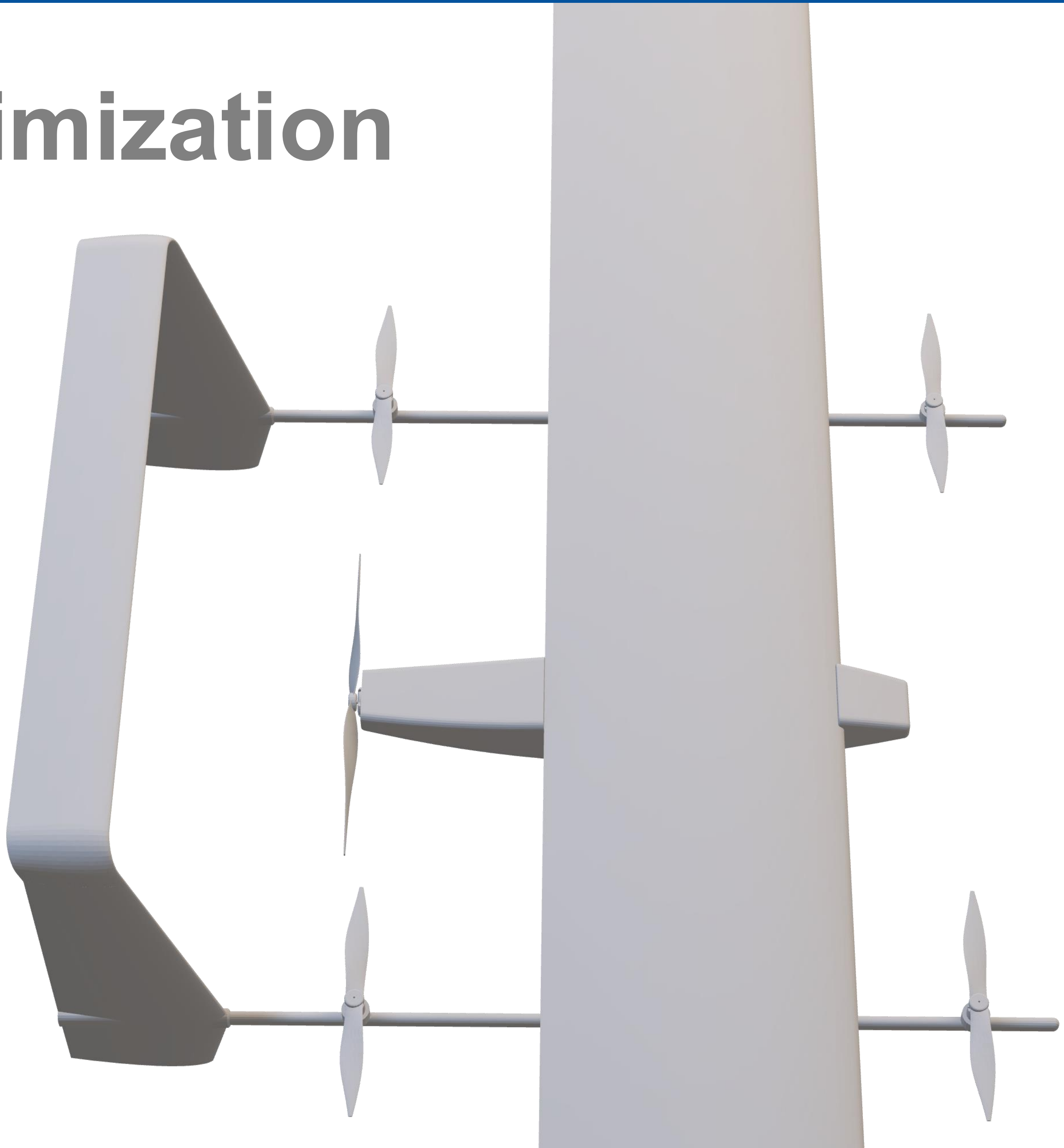
Cruise optimized for minimal SPL in cattle sensitive frequency range.



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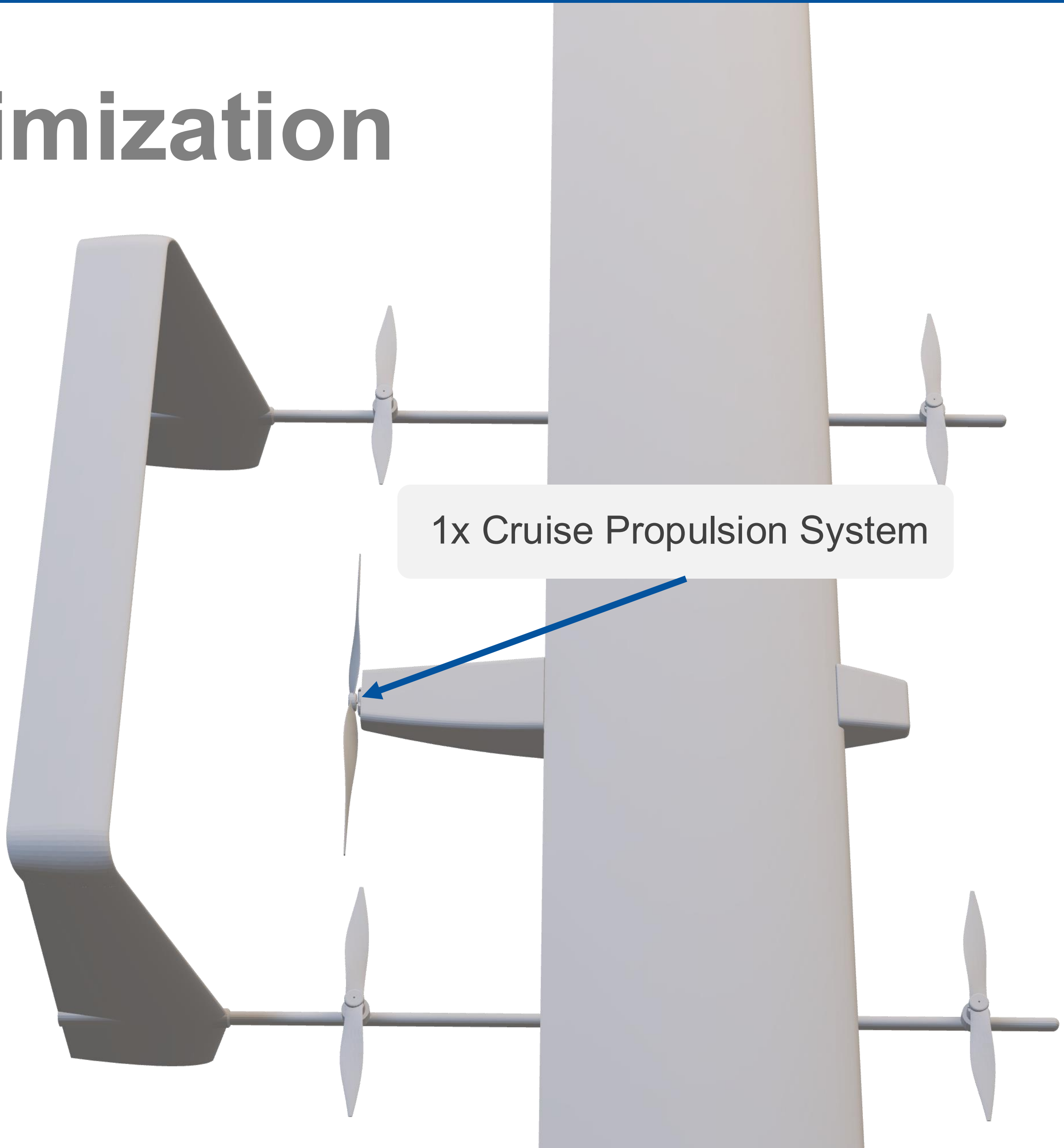


Aeroacoustic Optimization

Identified and Down-Selected Solutions

✗ Electric Ducted Fan (EDF)

- Higher BPF and lower SPL in broadband/tonal noise.

- Heavy, higher manufacturing complexity.

✓ Traditional Propeller

- Slightly elevated BPF SPL magnitude, can be decreased by lowering RPM.

- Weight efficient.

✗ Bio-Mimetic Propeller

- Increased acoustic reduction and thrust.

- Increased manufacturing complexity and cost.

Aeroacoustic Optimization

Methods of Propeller Sound Reduction

Increasing span and reducing RPM.

↓

Decreases magnitude and frequency of BPF.

Decreasing local angle of attack across spanwise portion of blade.

↓

Decreases magnitude of tonal/broadband noise, lower pressure gradient, lower thrust.

Increasing chord length toward tip of propeller.

↓

Larger area allows for decreased loading on propeller.

Conventional Propeller Geometry

Aeroacoustic Optimization

Existing Research Results and Application

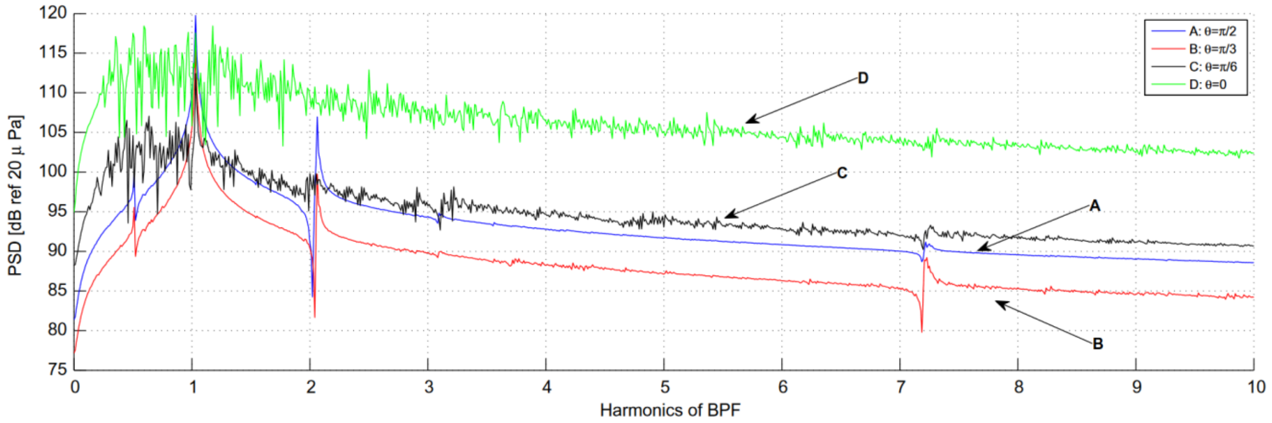
Chord Length increased between 60% and 80% spanwise radii.

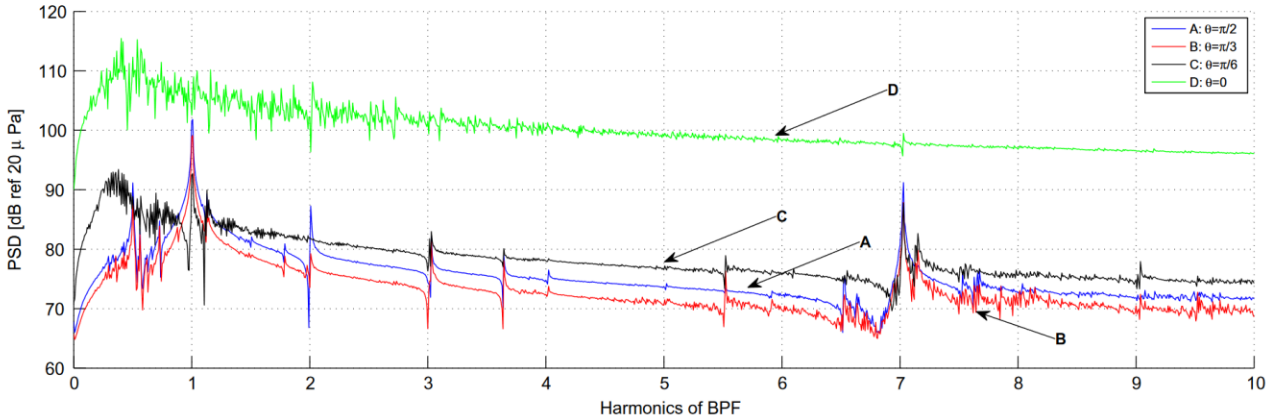
Angle of attack decreased overall, particularly at inner spanwise locations.

Geometry changes decrease SPL across most BPF harmonics by 5 dB.

Additional decreases in tonal/broadband noise by up to 12 dB in 8 kHz range.

Conventional Propeller





Modified Geometry

Data via Sinbaldi et al. 2013

Aeroacoustic Optimization

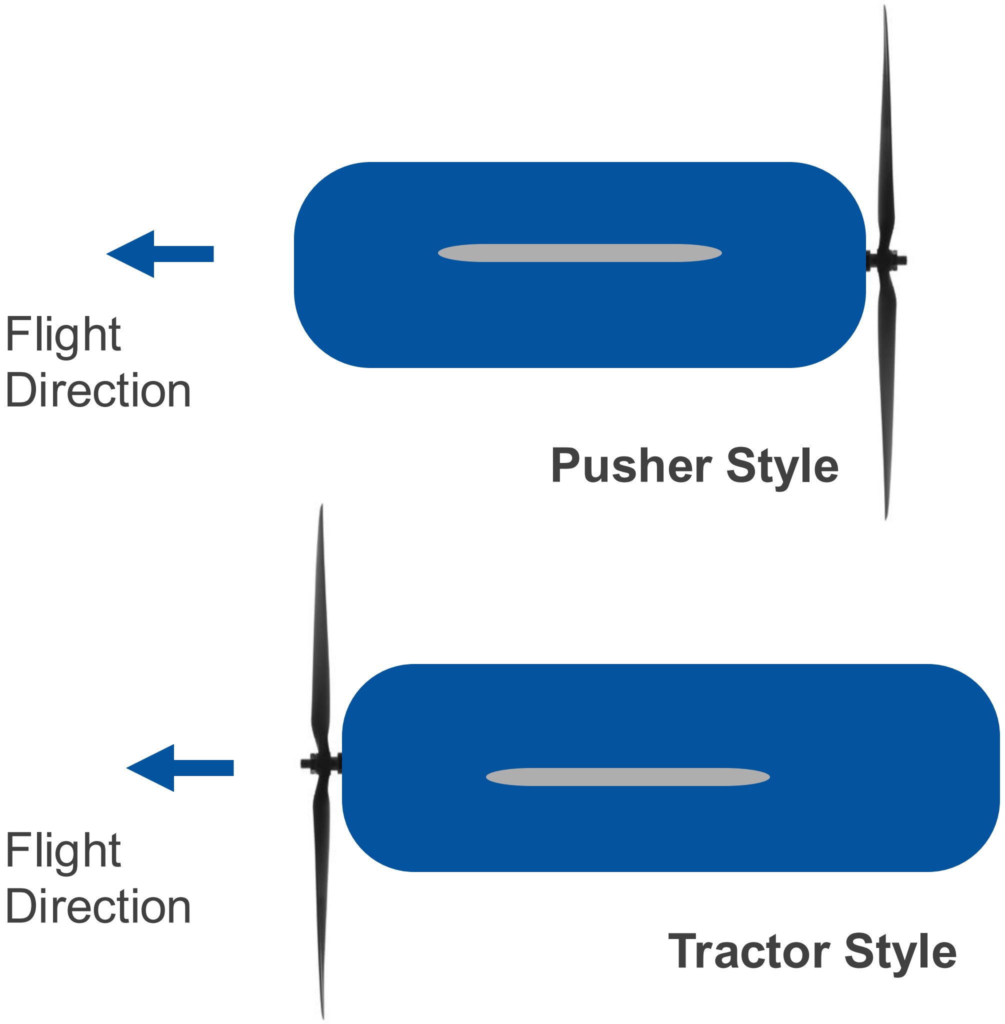
Tractor vs Pusher UAV Design

Tractor style propeller placement used due to heavier sensor payload in fuselage.

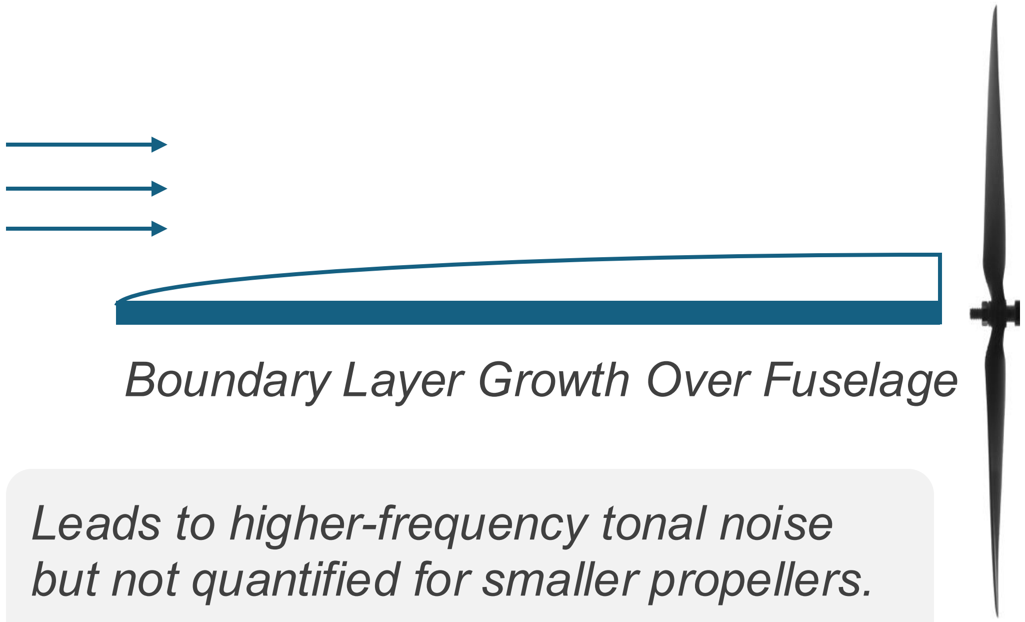
Balancing CG (Center of Gravity) is essential for aircraft stability.

Further aft CG allows for a smaller vertical stabilizer decreasing weight.

Turbulent wing wake and fuselage boundary layers cause inflow turbulence.



Aeroacoustic Optimization



Leads to higher-frequency tonal noise but not quantified for smaller propellers.

Schematic of Pusher-Style Inflow Testing Setup

UAV Scale Propellers with Turbulent Inflow

Gap in research for small-scale turbulent inflow aeroacoustic research.

Limited research into viscous effects from fuselage and wing interaction.

High-resolution studies (simulation and experimental tests) only performed on larger propellers; scaling effects and effects on pusher-style propulsion systems not extensively studied.

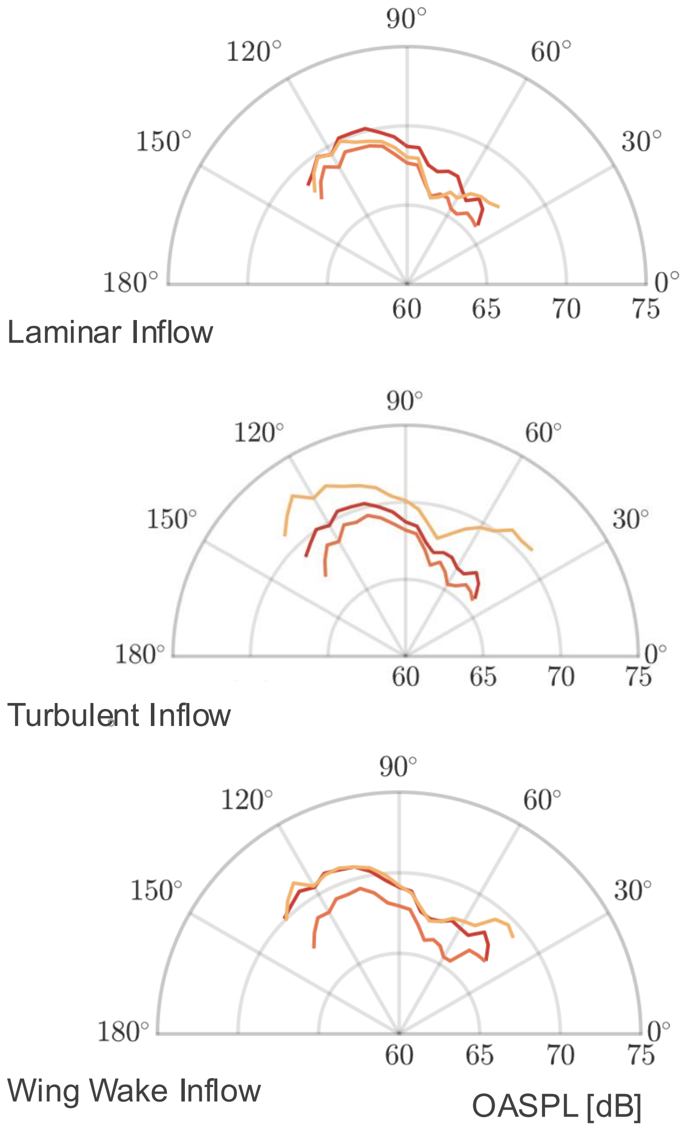
Aeroacoustic Optimization

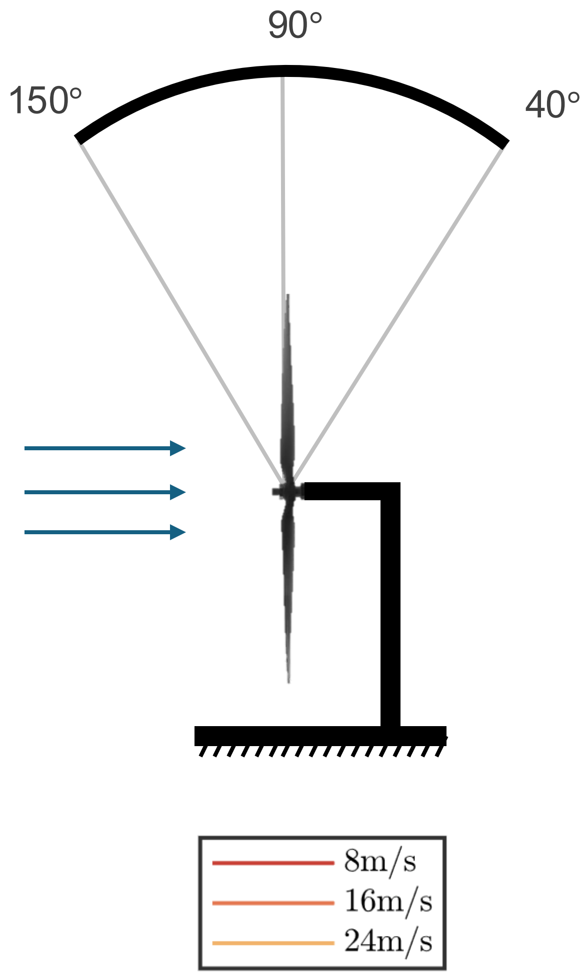
UAV Scale Propellers with Turbulent Inflow

Turbulent Inflow and wing wake interactions increase SPL.

Limited research into viscous effects from fuselage and wing interaction.

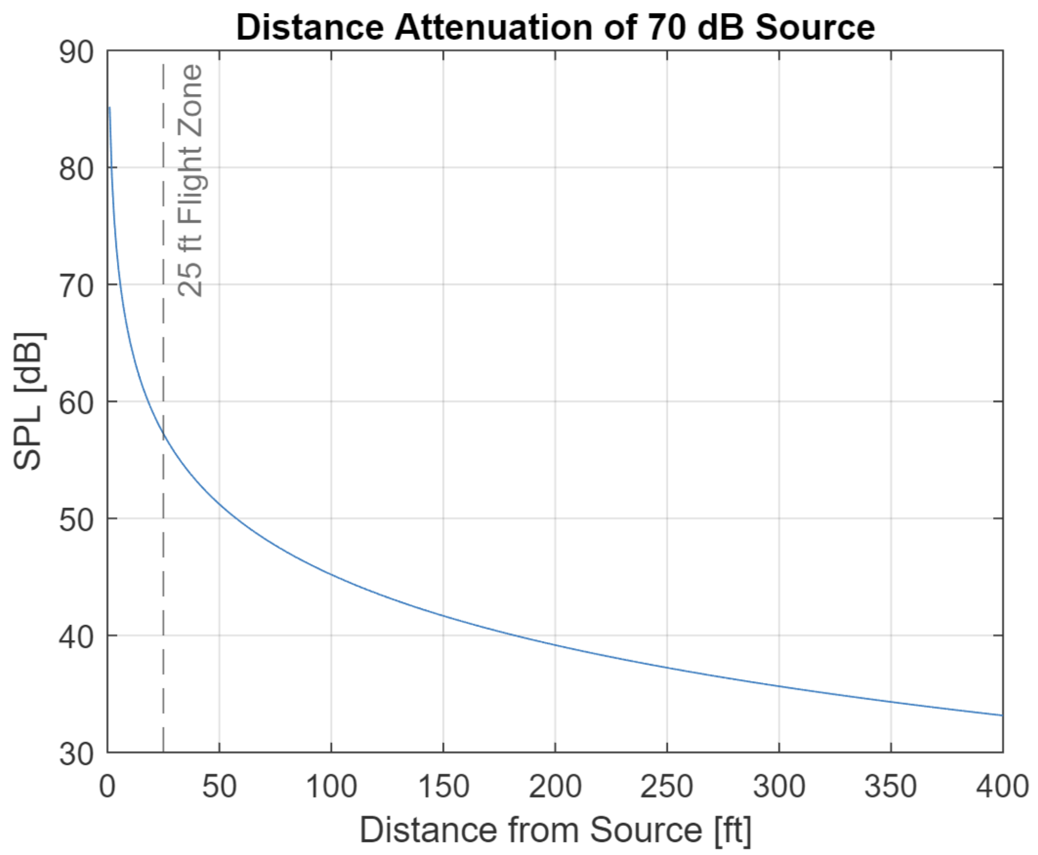
Frequency increases with turbulent and wing wake inflow, higher SPL in frequencies cattle are sensitive to.





Data via Jamaluddin et al. 2021

Aeroacoustic Optimization



Distance Attenuation of Turbulent Case

SPL decreases as distance from source increases.

For defined 3D flight zone minimum, SPL remains below 58 dB.

$$SPL_2 = SPL_1 - 20\log_{10}\left[\frac{R_2}{R_1}\right]$$

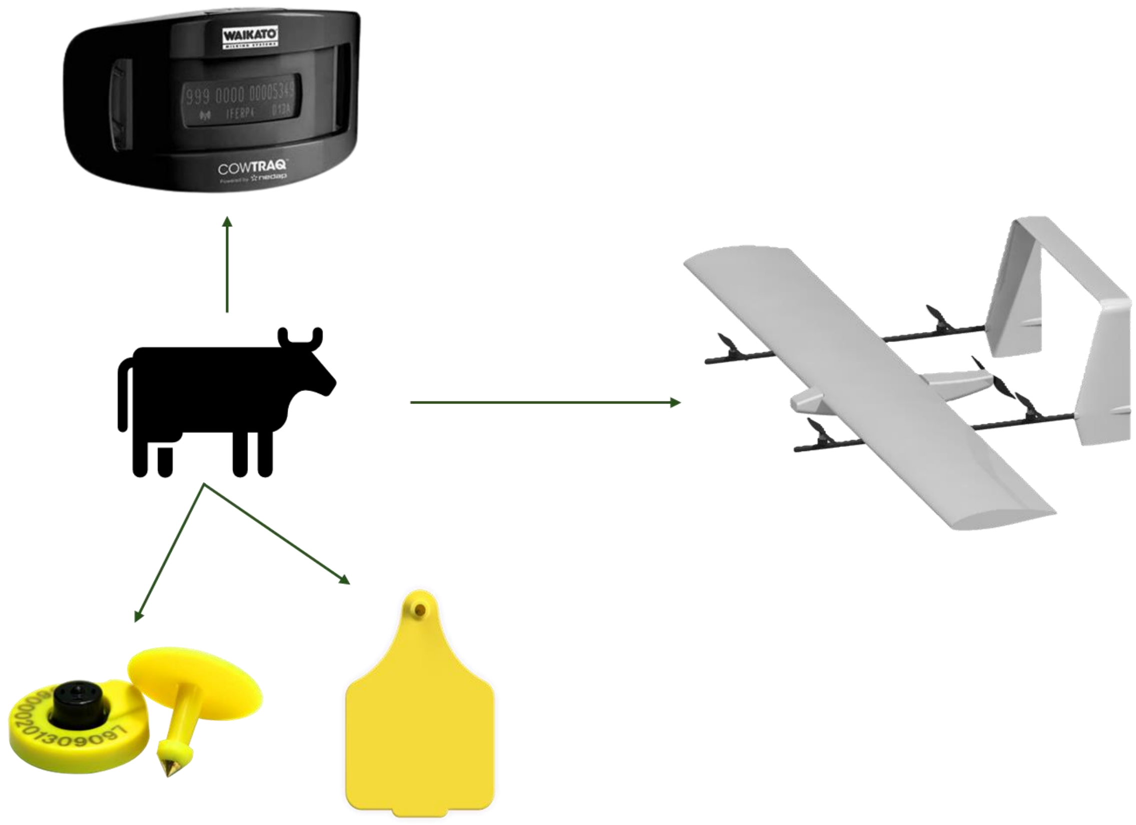
Cattle Monitoring

Monitoring and Tracking Capabilities

RFID ear tag required for all tracking subjects. Standard ear tag used to reduce cost.

Optional health-monitoring collar (CowTraq) for vulnerable populations.

Both CowTraq and ear tags communicate with UAV via RFID.



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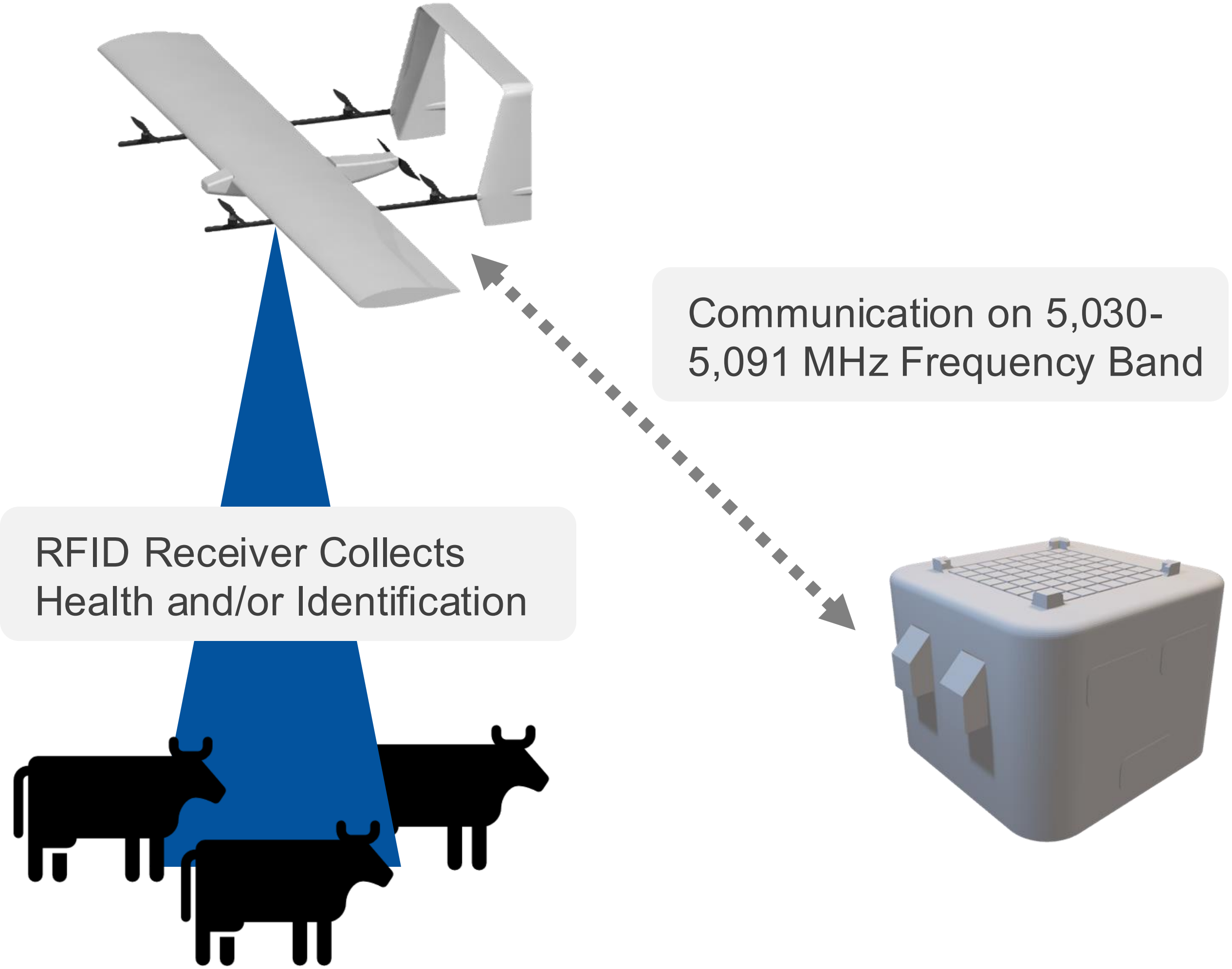


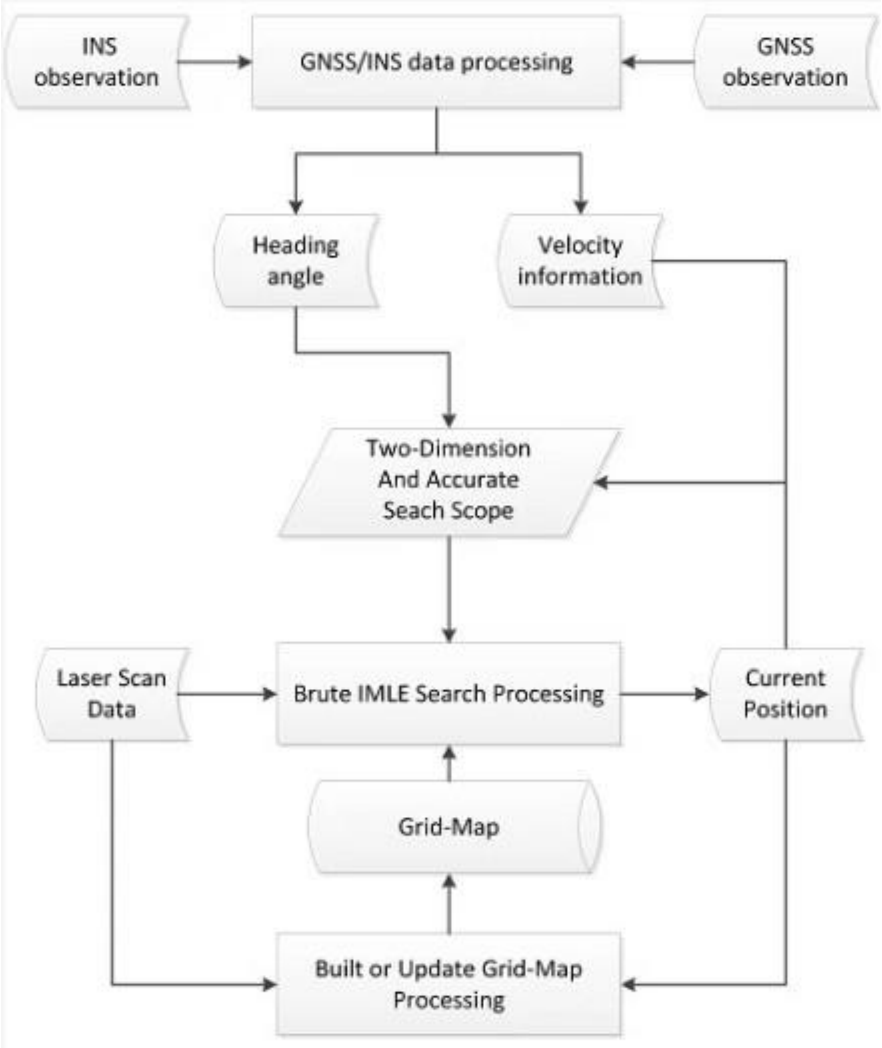
Monitoring and Tracking Capabilities

RFID position and health data is collected in the receiver field of view.

Location of UAV is reported to base along with herd data at the reported position.

Defined map area is surveyed and results are summarized for end user.

GNSS/INS/SLAM Integration



Integration Capabilities

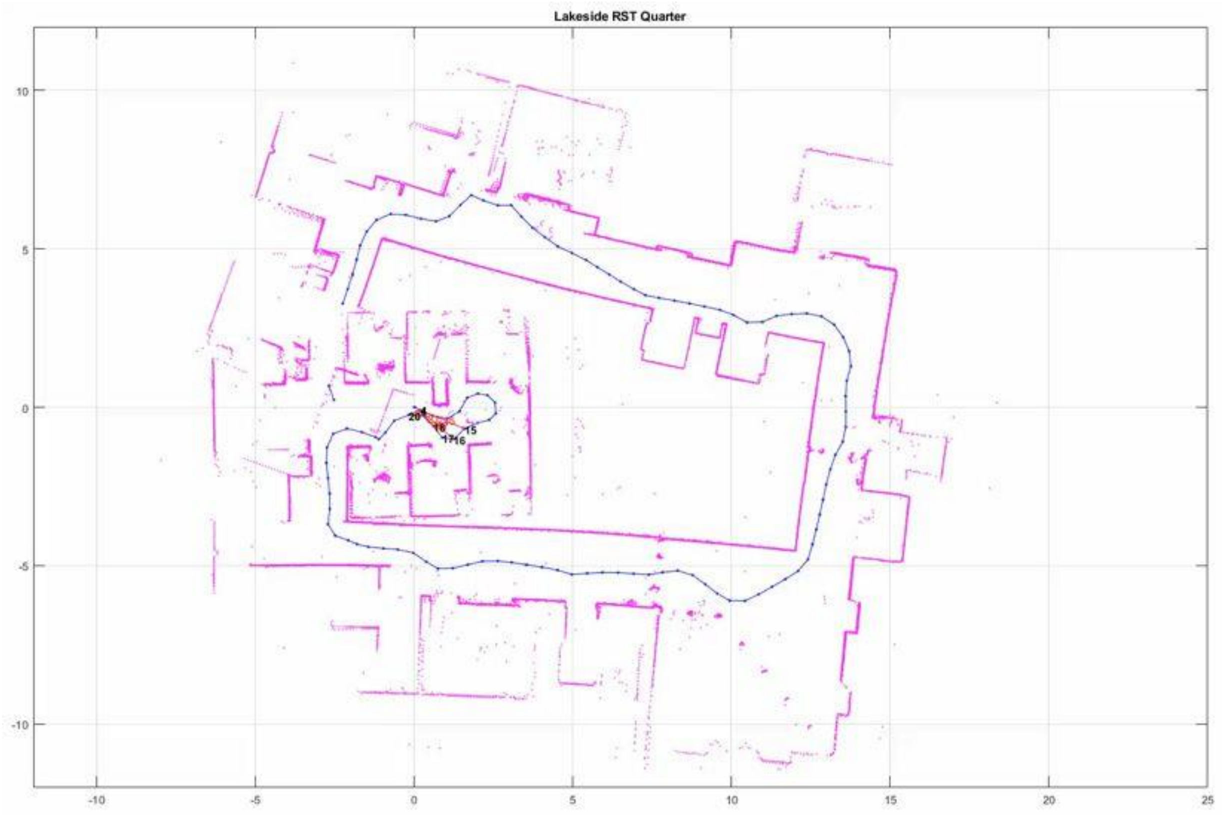
Tightly coupled integration offers navigation capabilities in remote areas without consistent satellite coverage.

INS/GNSS sensors used to gather positioning information then passed to the SLAM algorithm.

SLAM algorithm utilizes positioning information to map and continue traveling in designated area.

Flowchart via Qian et al. 2014

GNSS/INS/SLAM Integration



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Pose Graph via *Mathworks*

Battery Technology

Solid State Battery (SSB) vs. Liquid State Battery (LSB)

SSBs offer increased energy density capabilities.

SSBs utilize less materials than their LSB counterparts.

SSBs charge faster and more efficiently.

SSBs provide a more stable electrolyte composition, increasing safety.

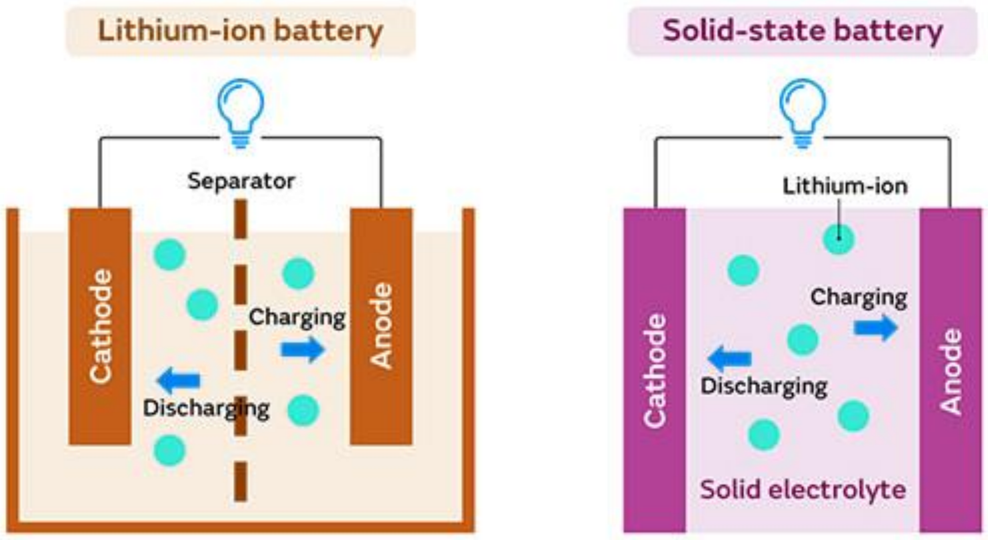


Image via everythingPE 2023

Budgeting for R&D

Software	Estimated Cost
Slam Algorithm Integration	$10,000
GNSS/INS Sensor Fusion	$6,000
Communication Protocol	$5,000
User Interface	$2,000
Total Cost of Software Development	$23,000

Testing	Estimated Cost
Wind Tunnel Testing (9 hours)	$9,900
ANSYS Discovery CFD simulations	$5,000
Battery Load	$5,000
Field Testing (Flight Trials)	$3,000
Testing Equipment	$1,000
Total Testing Cost	$23,900

Development of Software System and Experimental Testing

Software development was evaluated with two hours rates. $100/hour for complex development and $50/hour for UI development.

Physical testing includes rates from research allocated wind tunnels, software license, and battery testing materials.

Cost and Return on Investment

Internal Systems	Cost
4 Brushless 2,020Kv Motors (VTOL motors)	$180.00
1 Brushless 1,750Kv Motor (main power motor)	$43.00
Solid-State Battery	$720.18
RF Transceiver and Antenna	$70.00
GNSS module	$650.00
SONY IMX 415 Camera Sensor	$69.99
SLAM Application Module	$250.00
Total Cost	$1,983.17

Support Systems	Cost
CowTraq Neck Collars	$48,000.00
Electronic Ear Tags	$1,000.00
Landing Pad Computer System	$1,250.00
Skycharge Conductive Charger	$6,386.25
Internal Electronics of Landing Pad	$180.00
2 Landing Pad Batteries	$3,143.50
Total Cost	$59,959.75

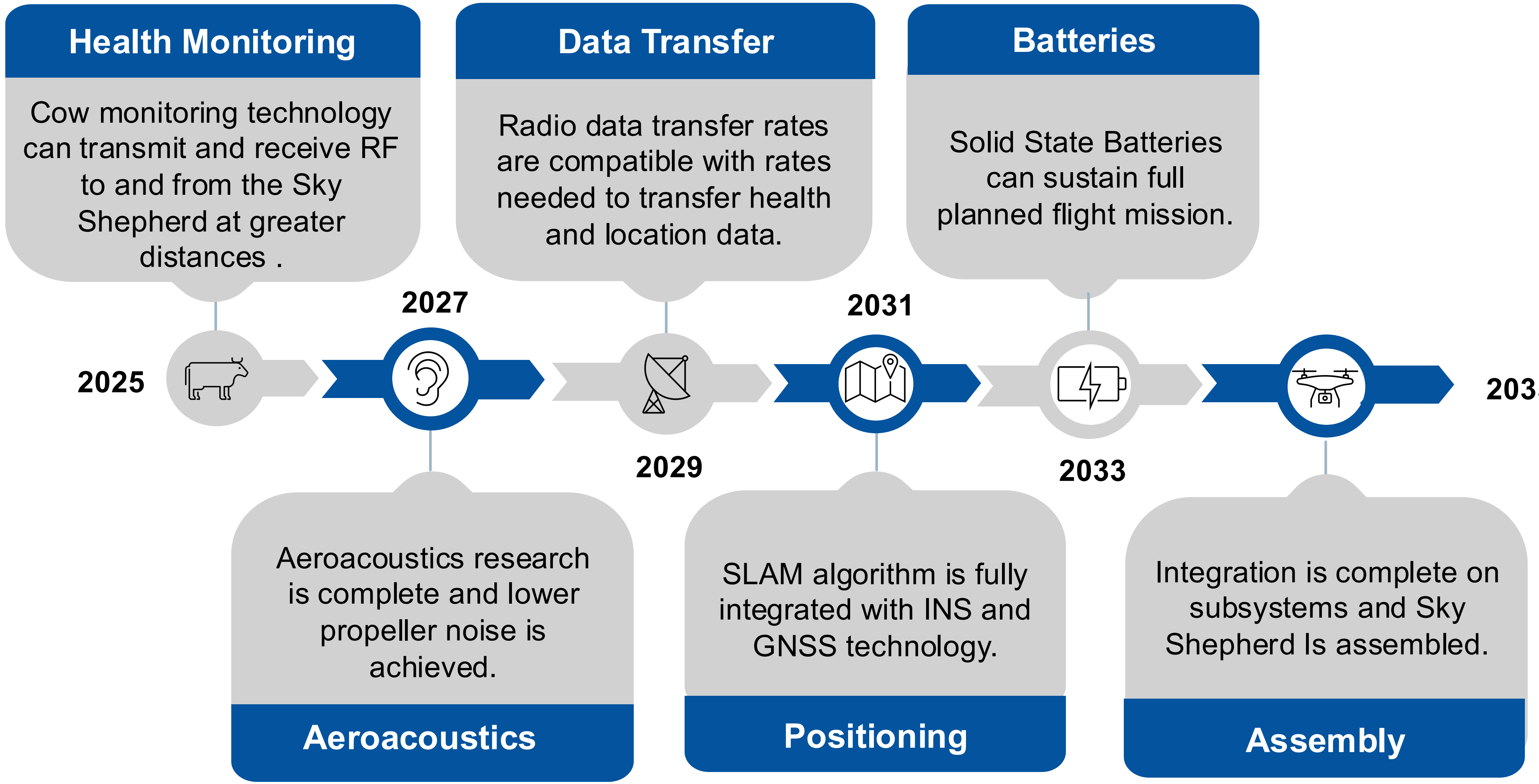
Hardware Costs

Prices of items with a tech readiness level of 9 were evaluated using their current prices.

Increased prices were used for items that still need to be researched. Such as the SSB.

The total cost of Sky Shepherd is $61,942.92. A rancher saving $1,200 a week will take roughly one year to have a positive annual ROI of 100%.

Deployment Timeline



QUESTIONS

COLLEGE OF ENGINEERING | DEPARTMENT OF ENGINEERING FUNDAMENTALS

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NASA'S
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2025 AgAir: Aviation Solutions for Agriculture Forum