Challenges and Opportunities for Spray Drones in Agriculture

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USDA

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Applications of UAS within Agriculture

- Remote Sensing
  - Acquiring information about fields, crops and animals using sUAS equipped with sensors (LIDAR, RGB, NIR, Red-Edge, Hyperspectral, Thermal)

- Aerial Application
  - Heavy Lift Aircraft (Typically 20-200 lbs. payload)
  - Crop Protectants (Fungicide, Herbicide, Insecticide, Biologicals)
  - Crop Production (Fertilizer and Seed)

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Aerial Application

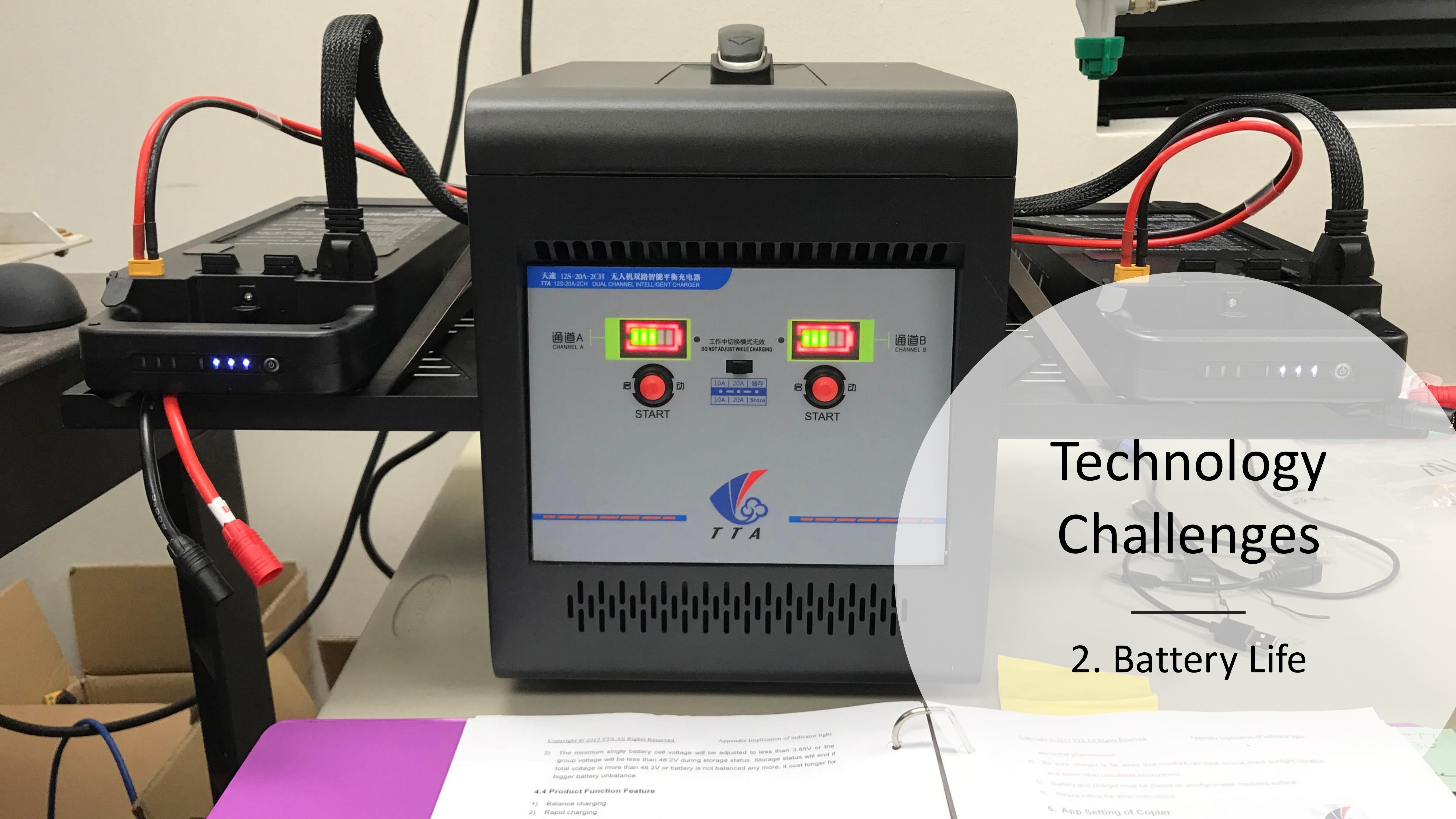

RESTRICTED

Technology Challenges

1. Payload

Technology Challenges

2. Battery Life

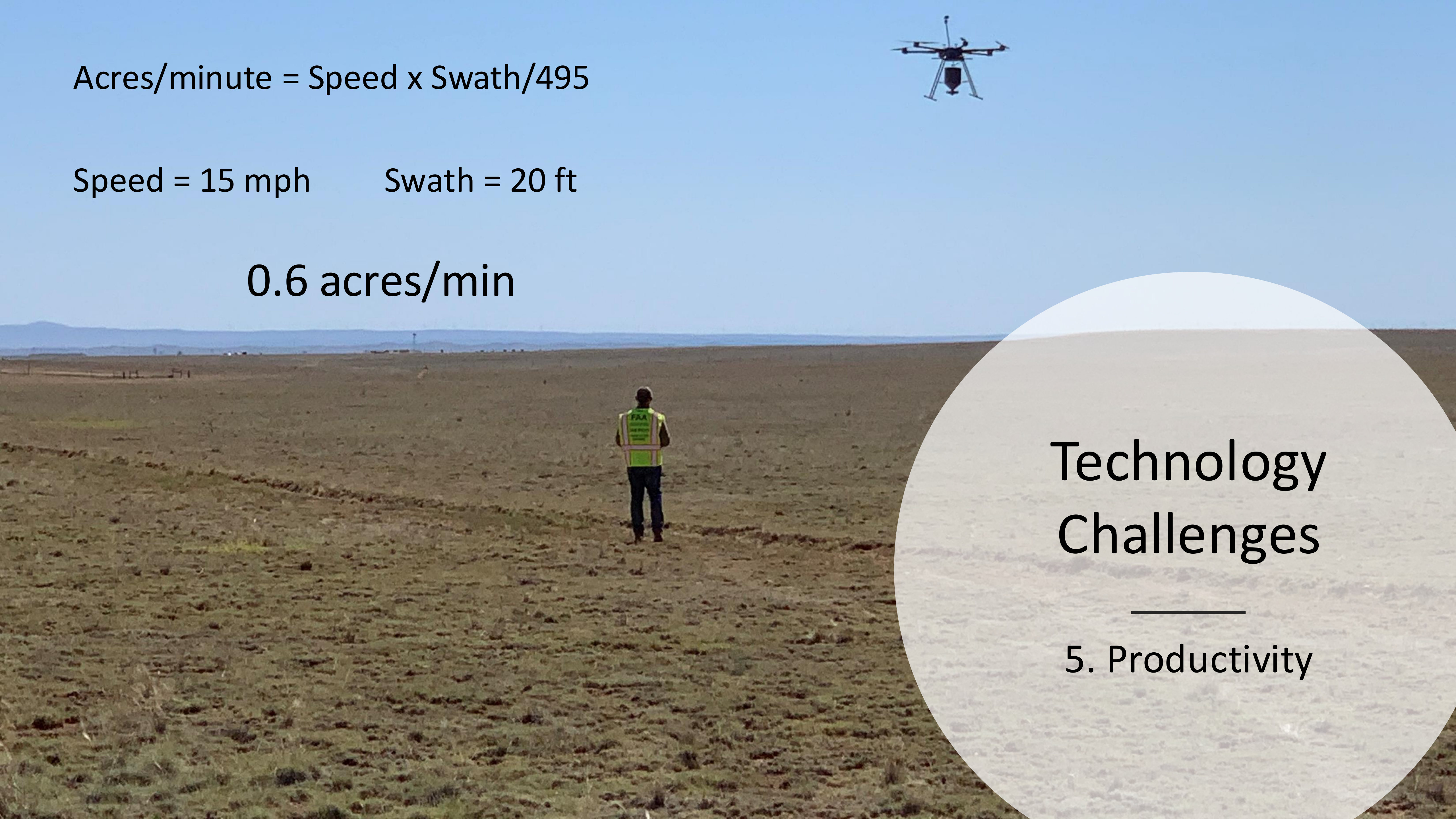


Technology Challenges

3. Swath

Technology Challenges

4. Application Rate



Technology Challenges

5. Productivity

Acres/minute = Speed x Swath/495

Speed = 15 mph   Swath = 20 ft

0.6 acres/min

Technology Challenges

5. Productivity

0.6 acres/min

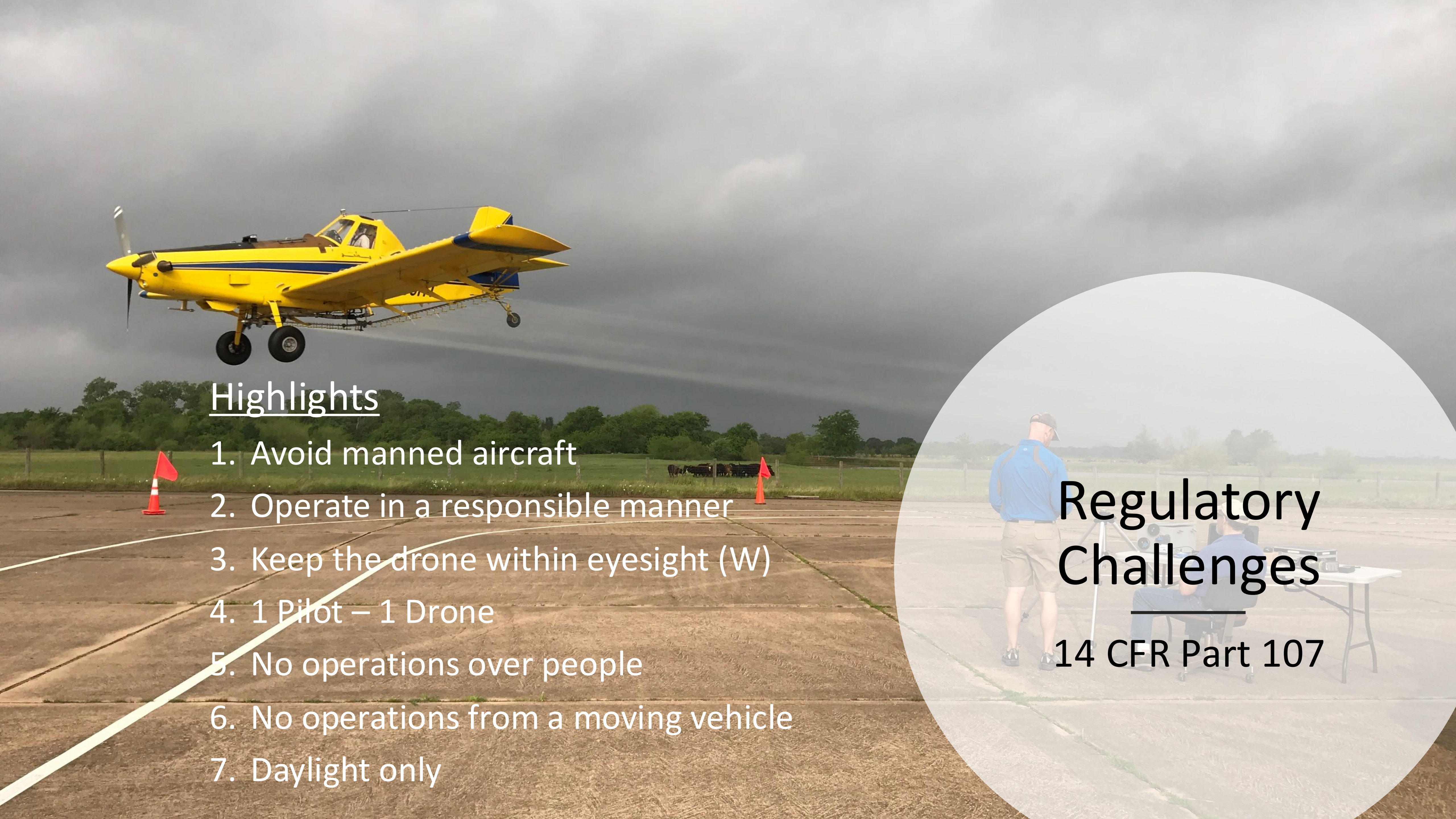
10 minutes/battery set

6.0 acres in 10 minutes

2 minute reload → 12 minute turnaround

30 acres/hr


Unmanned Aircraft Systems
Liquid Bait Application
Tank Mixture: 1 Sevin XLR Plus : 1 Water
USDA

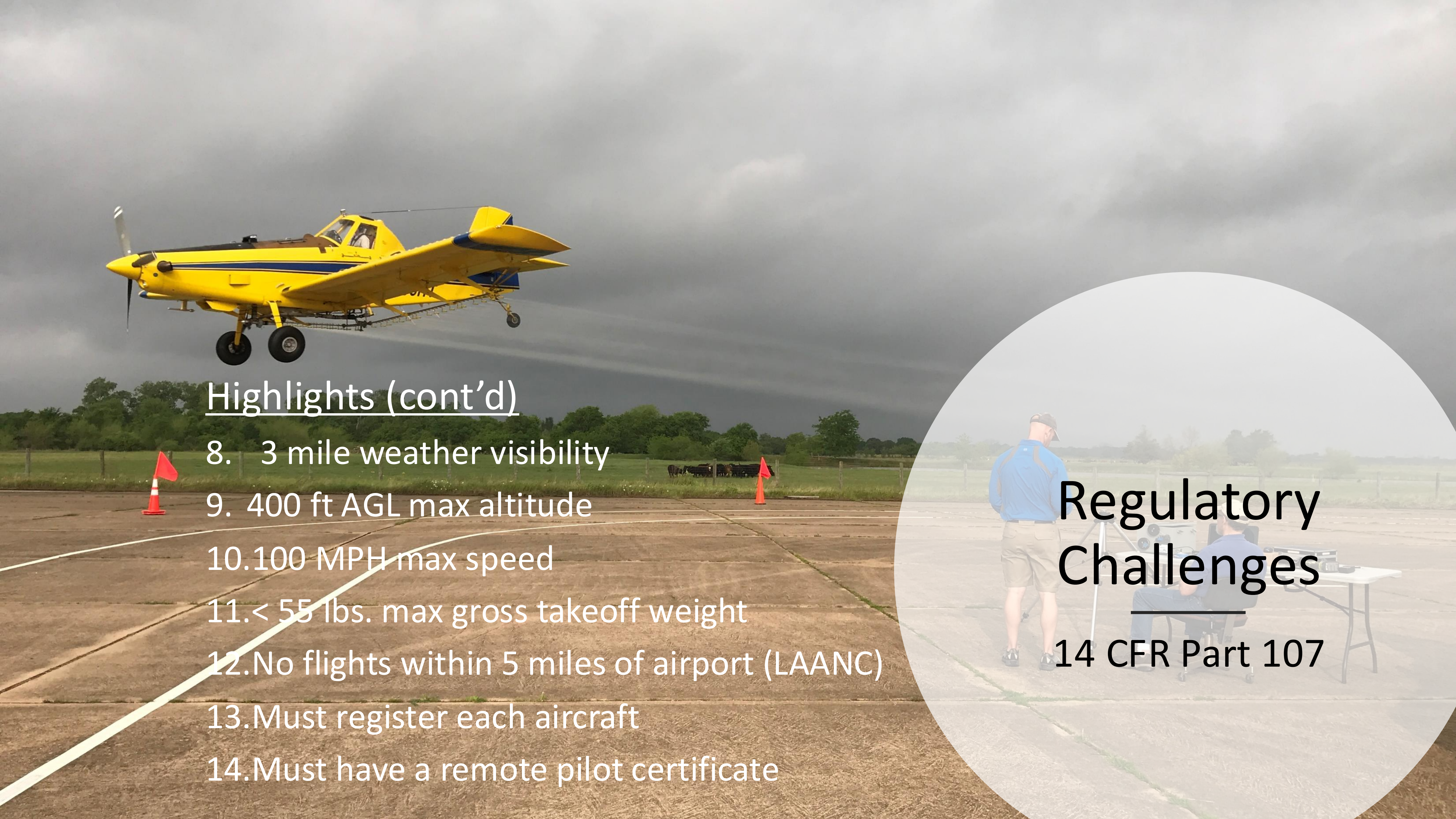


Regulatory Challenges

14 CFR Part 107

Highlights

1. Avoid manned aircraft
2. Operate in a responsible manner
3. Keep the drone within eyesight (W)
4. 1 Pilot – 1 Drone
5. No operations over people
6. No operations from a moving vehicle
7. Daylight only



Highlights (cont'd)

8. 3 mile weather visibility
9. 400 ft AGL max altitude
10. 100 MPH max speed
11. < 55 lbs. max gross takeoff weight
12. No flights within 5 miles of airport (LAANC)
13. Must register each aircraft
14. Must have a remote pilot certificate

Regulatory Challenges

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14 CFR Part 107

Regulatory Challenges

14 CFR Part 137

These regulations govern Agricultural Aircraft in the United States and encompass the dispensing of pesticides.

Regulatory Challenges

EPA

Chemical Manufacturers will be working with the EPA to ensure current labels are appropriate for UAS aerial applications.


Opportunities
Invasive Species

Opportunities

Spot Spraying

Opportunities

Field Edges and Powerlines

Opportunities

Difficult Access

Opportunities

Difficult Access

Opportunities

Small Farms

Opportunities

Vineyards

Opportunities

Vineyards

Opportunities

Night Sprays to Protect Pollinators

Photo Credit: USDA-ARS

Opportunities

Vector Control

Photo Credit: Jose Ramirez

Opportunities

Spot Spraying

Opportunities

Spot Spraying

"Green-on-Green"

Opportunities

Spot Spraying

“Green-on-Green”

Spray Drift from Remotely Piloted Aerial Application Systems

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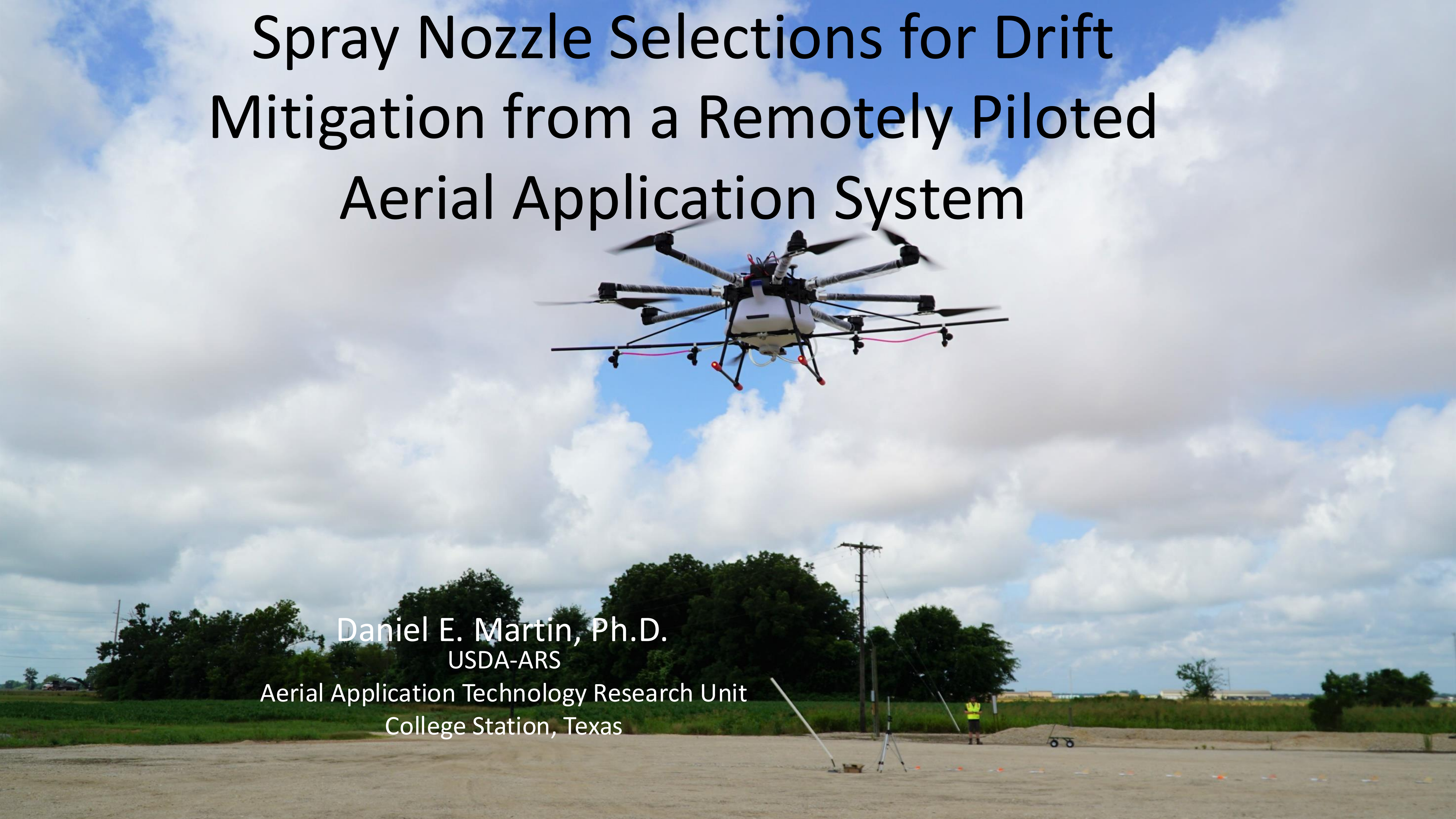
What is Spray Drift?

The movement of spray droplets through the air at the time of application, or soon thereafter, from the target site to any non- or off-target site, excluding pesticide movements by erosion, migration, volatility, or windblown soil particles after application. (EPA)

Why Mitigate Spray Drift?

- Wastes product.
- Increases input costs.
- Causes unintentional damages.
- It’s illegal.

Spray Nozzle Selections for Drift Mitigation from a Remotely Piloted Aerial Application System



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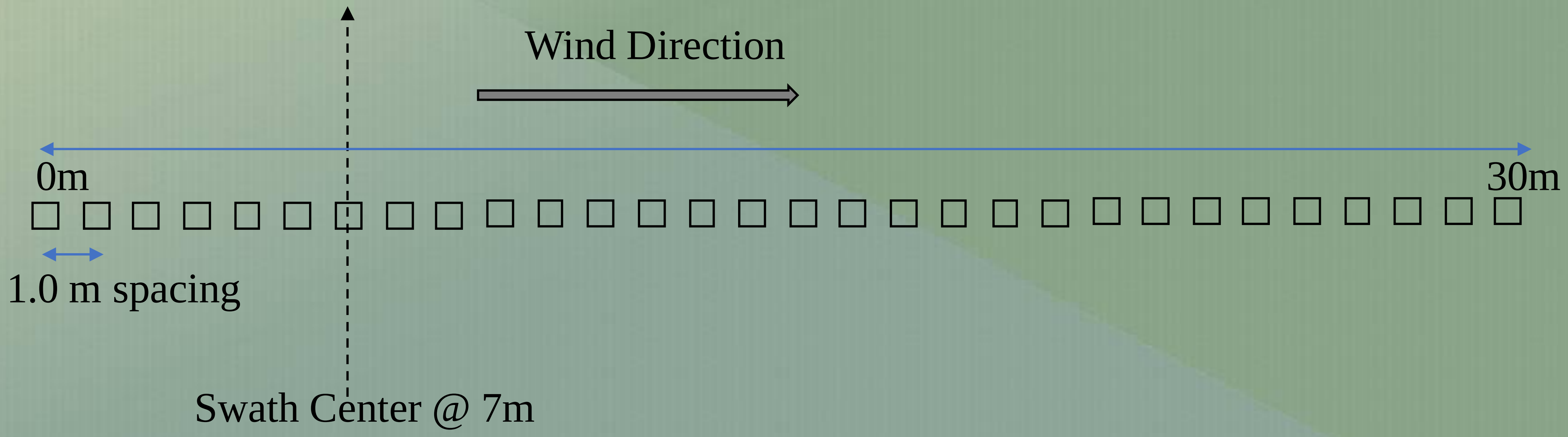
Objectives

- Characterize the differences in spray drift resulting from RPAAS applications of a fine, medium and coarse spray.
  - HSE V8A Pro
  - Water/Dye
  - 10 ft. Application Height
  - 7 mph Ground Speed
  - XR 110-01 Fine
  - TT 110-01 Medium
  - TTI 110-01 Coarse
  - 24 psi

Study Layout



Field Layout

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Weather Station

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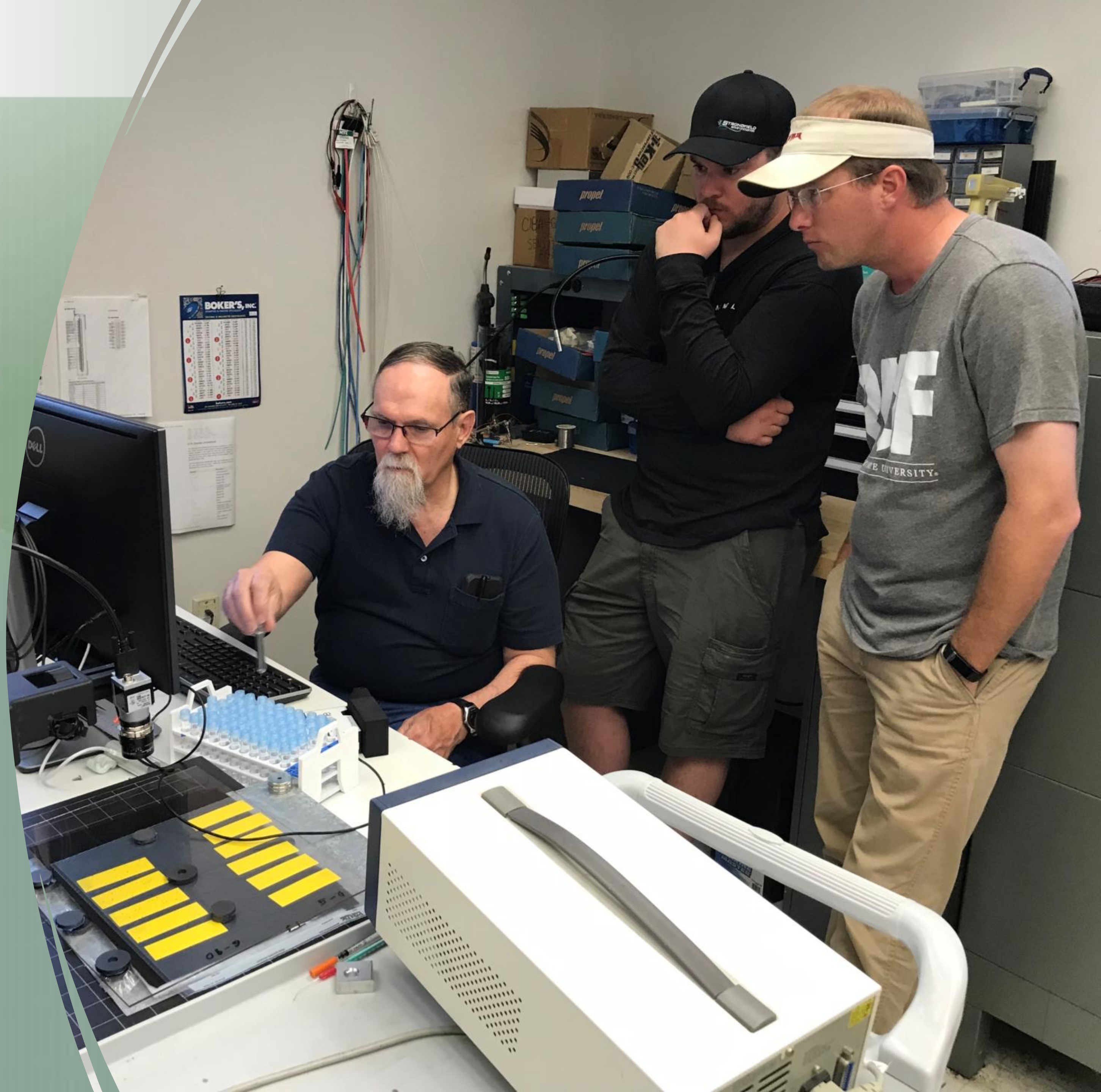
Fluorometric Analysis of Samples



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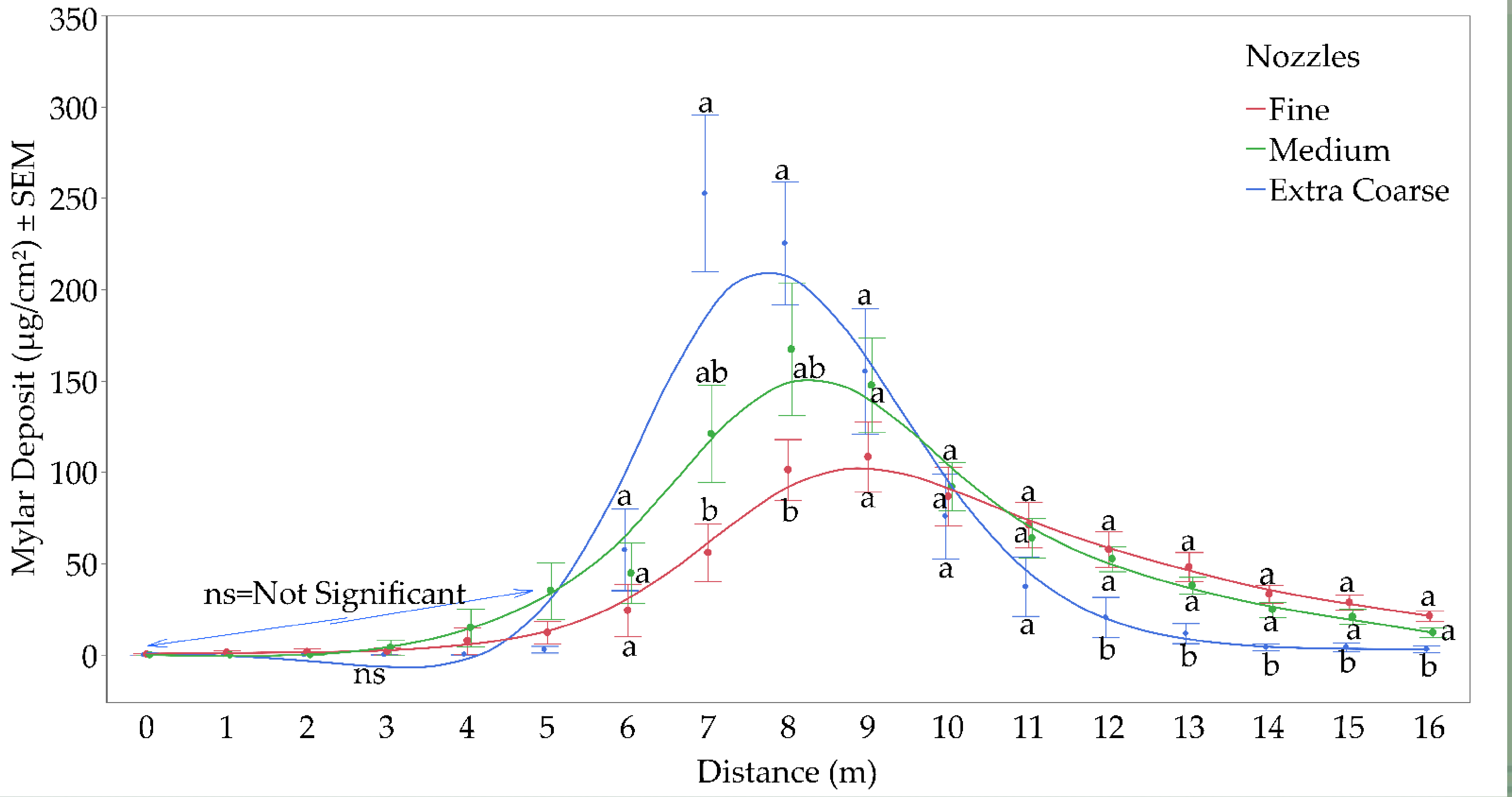

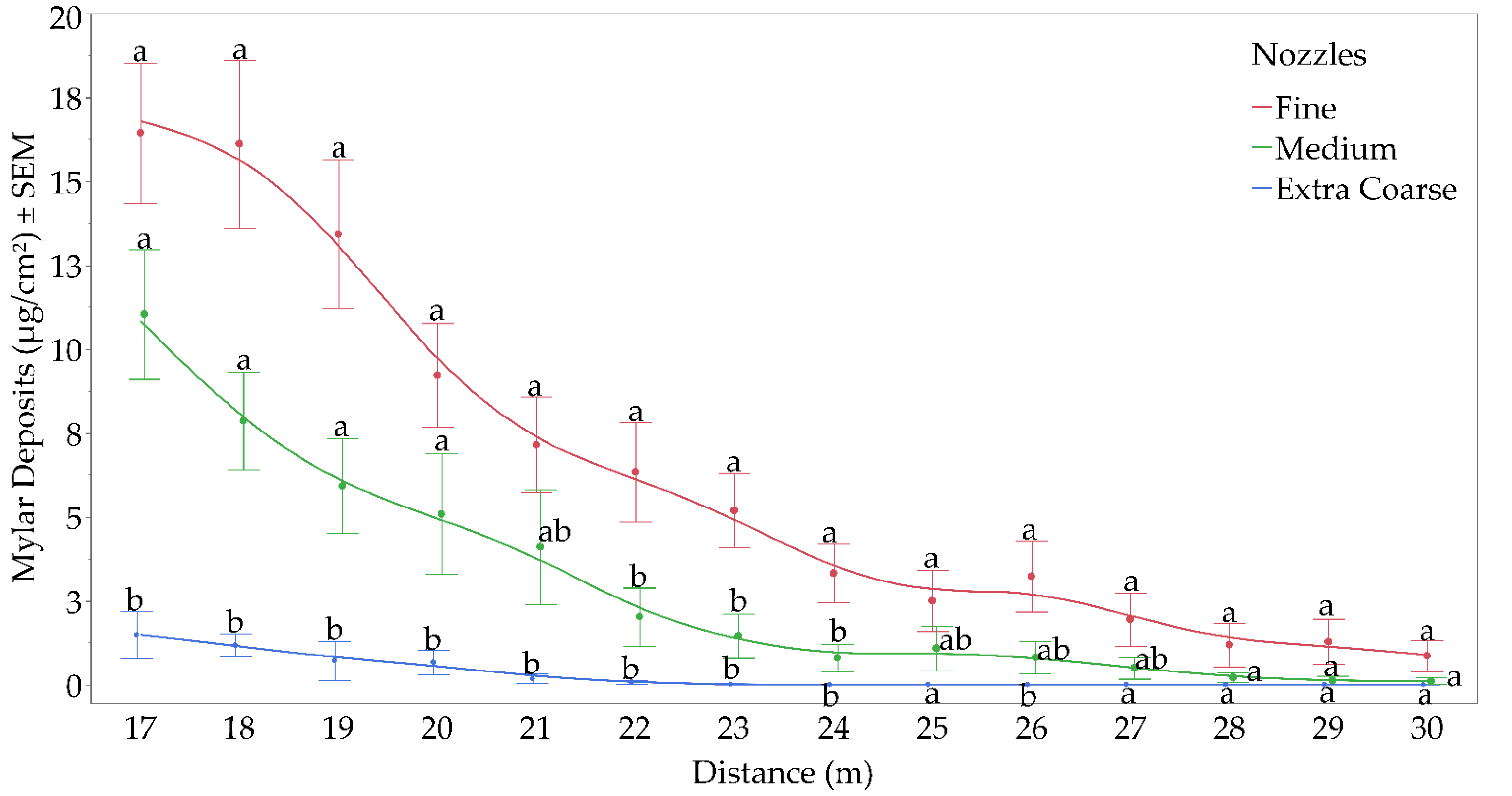
Mylar Deposits (µg/cm²) ± SEM
Distance (m)
Nozzles
Fine
Medium
Extra Coarse
20
18
15
13
10
8
5
3
0
17
18
19
20
21
22
23
24
25
26
27
28
29
30

Conclusions

- Selection of the right nozzles for the job is critical to mitigating drift.
- Finer nozzles may be necessary for adequate coverage but increase drift potential.
- Coarse nozzles can help mitigate drift and protect sensitive downwind areas.
- More data are needed to better understand the effects of spray deposit variability in-field on efficacy.

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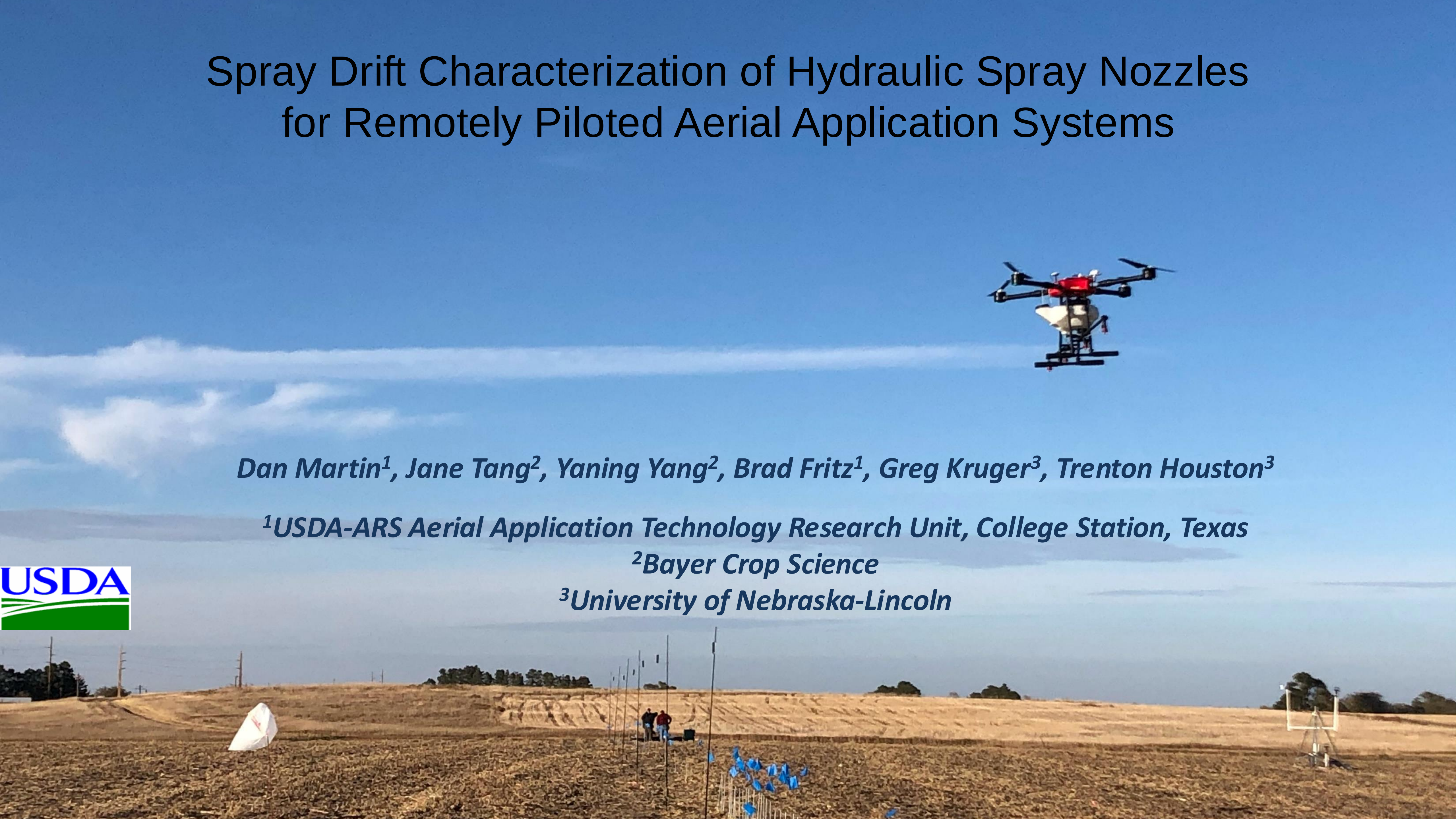

Spray Drift Characterization of Hydraulic Spray Nozzles for Remotely Piloted Aerial Application Systems

Dan Martin[1], Jane Tang[2], Yaning Yang[2], Brad Fritz[1], Greg Kruger[3], Trenton Houston[3]

[1]USDA-ARS Aerial Application Technology Research Unit, College Station, Texas
[2]Bayer Crop Science
[3]University of Nebraska-Lincoln

Objectives

The objectives of this study were to:

1) Characterize the differences in drift potential between a 22L RPAAS and a ground sprayer.

2) Quantify the downwind spray drift resulting from a Medium and an Extra Coarse nozzle.

- 4 Treatments (Randomized)
- 2 Spray Platforms (Tractor and RPAAS)

Experimental Design

- 4 Treatments (Randomized)
- 2 Spray Platforms (Tractor and RPAAS)

Experimental Design

Experimental Design

- 4 Treatments (Randomized)
- 2 Spray Platforms (Tractor and RPAAS)
- 2 Spray Nozzles (Medium and Extra Coarse)
- TT110-01 (Medium)
- TTI110-01 (Extra Coarse)
- Boom Height – 24”
- Ground Speed 3.0 m/s (M)
- 4.4 m/s (XC)
- Pressure – 40 psi
- Swath – 4.6 m (M)
- 3.1 m (XC)
- 2.0 GPA

- 4 Treatments (Randomized)
- 2 Spray Platforms (Tractor and RPAAS)
- 2 Spray Nozzles (Medium and Coarse)
- TT110-01 (Medium)
- TTI110-01 (Extra Coarse)

Experimental Design

Experimental Design

- 4 Treatments (Randomized)
- 2 Spray Platforms (Tractor and RPAAS)
- 2 Spray Nozzles (Medium and Coarse)
- TT110-01 (Medium)
- TTI110-01 (Coarse)
- 12 Replications
- Application Height – 3m
- Groundspeed – 3 m/s
- System Pressure – 40 psi
- Swath – 4.6 m (M)
- 3.1 m (XC)
- 2.0 GPA

Study Layout

Deposition Samplers

Drift Samplers

Weather Stations

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Drift Sampler Deployment


IMPORTANT

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Remote Pilots

Aerial Application

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Deposition Sample Collection

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Drift Sampler Collection

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Results

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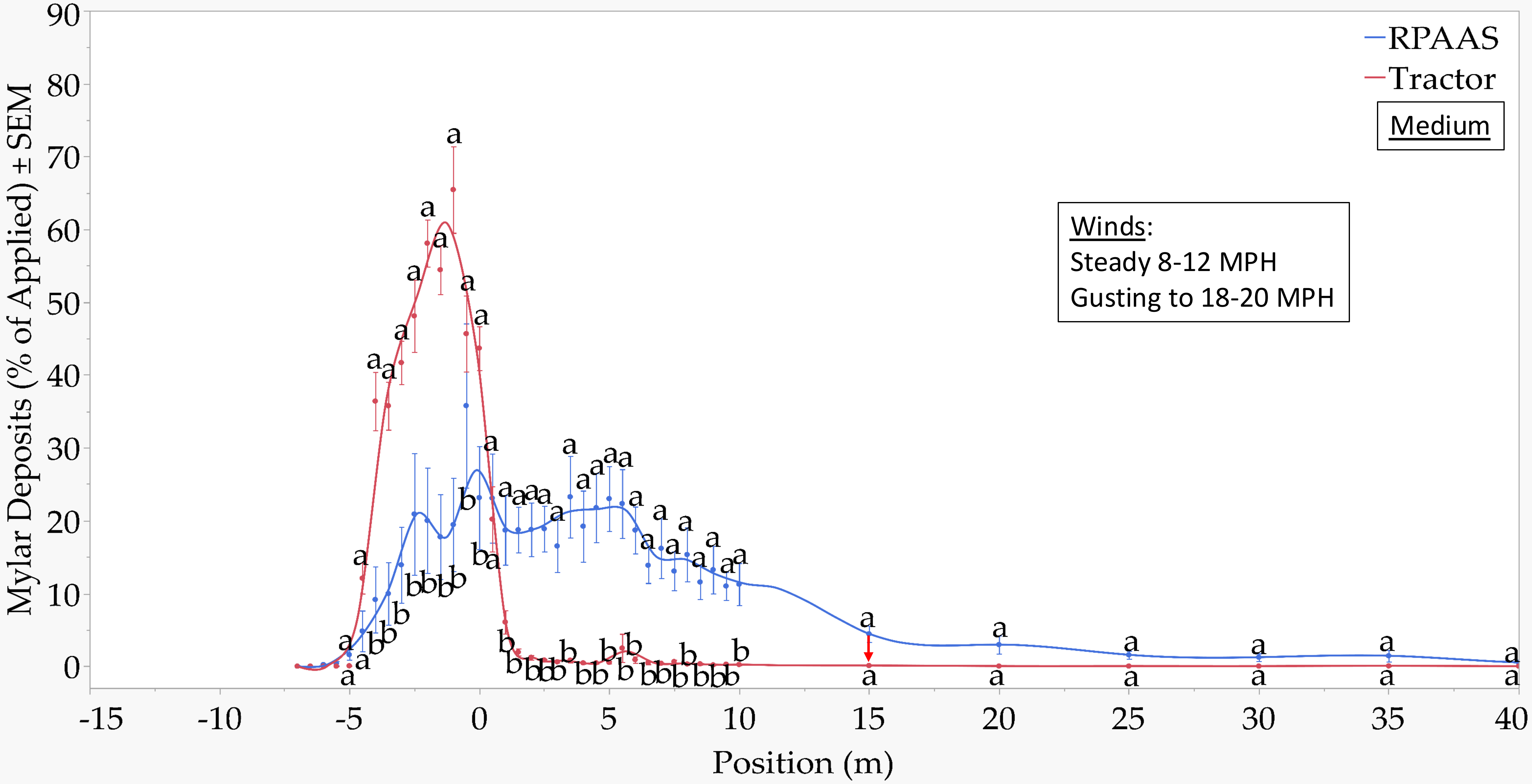
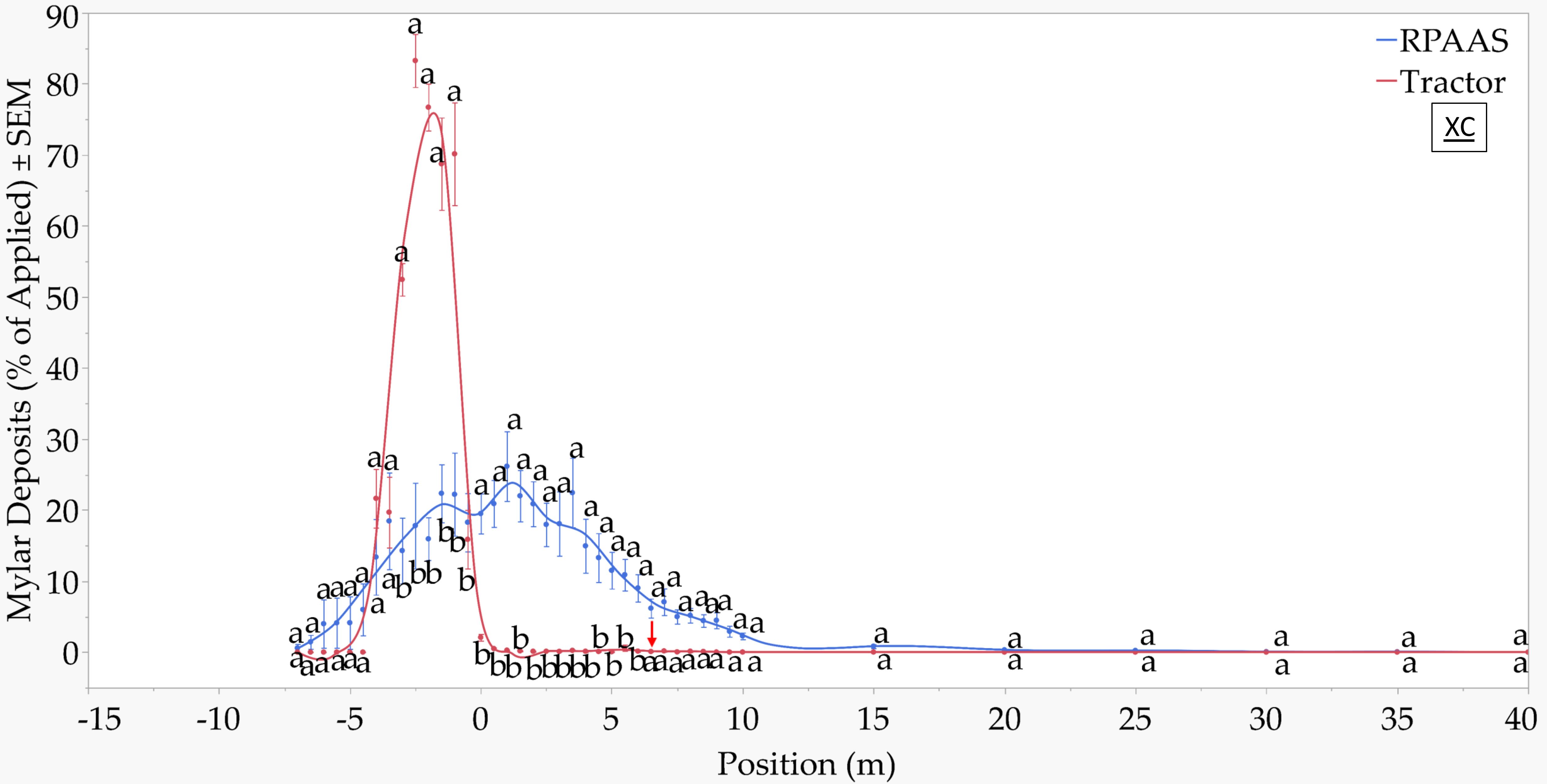
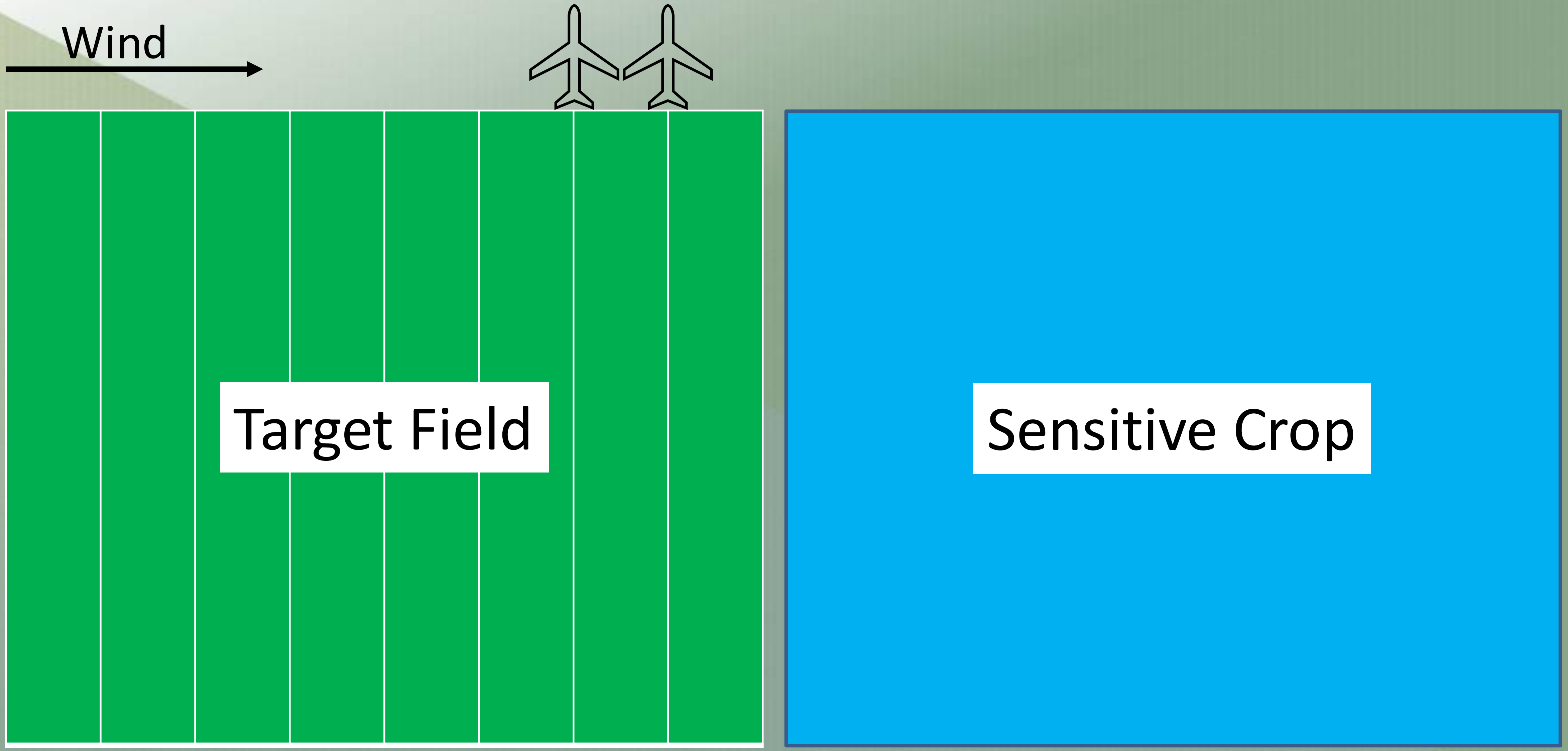


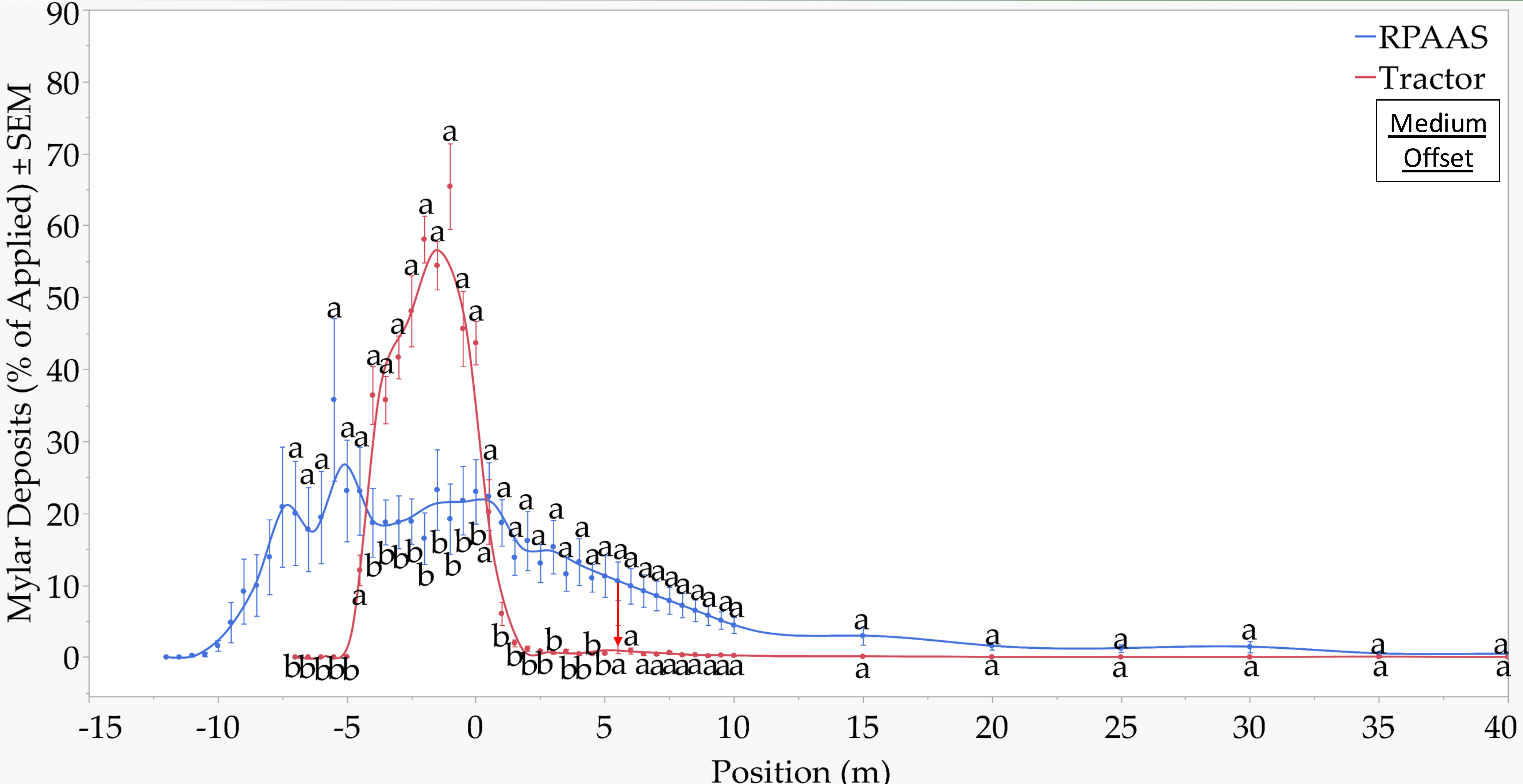
Results



Swath Offset

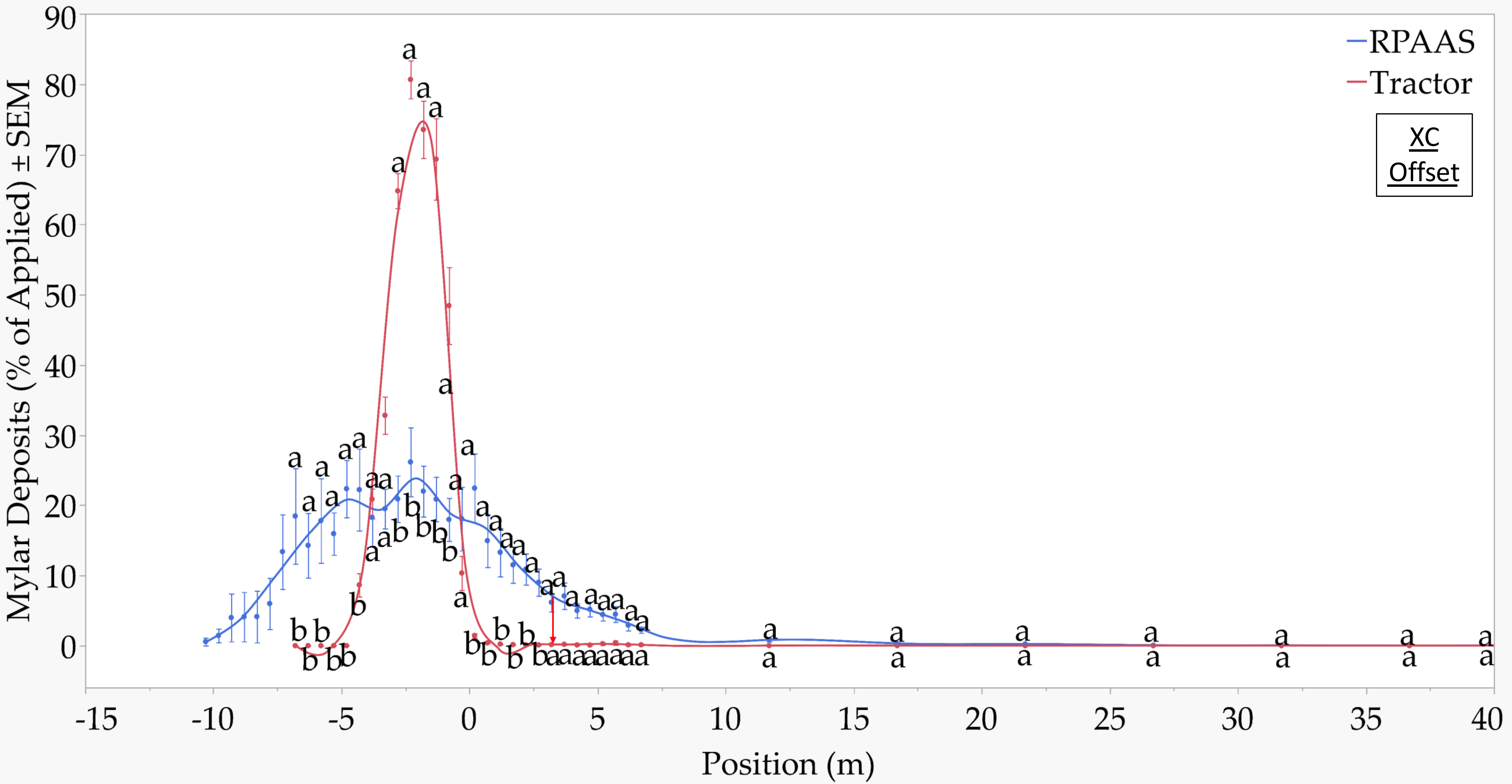


Results



RPAAS
Tractor
Medium Offset
Mylar Deposits (% of Applied) ± SEM
Position (m)

Results


Mylar Deposits (% of Applied) ± SEM
Position (m)
RPAAS
Tractor
XC Offset

Conclusions

- Spray released from a drone with a boom height of 10 ft. was displaced further downwind than spray released from a tractor with a 2 ft. boom height.
- Selection of a spray nozzle with a coarser droplet spectrum reduced downwind movement of spray particles.
- Spray applications in a crosswind increased the effective swath of the RPAAS but also reduced the application rate.
- Offsetting the downwind edge spray pass of the RPAAS by one full swath can significantly reduce spray movement from the target site.
- Swath offset should be considered when quantifying spray drift.

Effect of Nozzle Configuration on Spray Drift from a Remotely Piloted Aerial Application System

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Quantify spray drift from an RPAAS with different nozzle configurations

Objective

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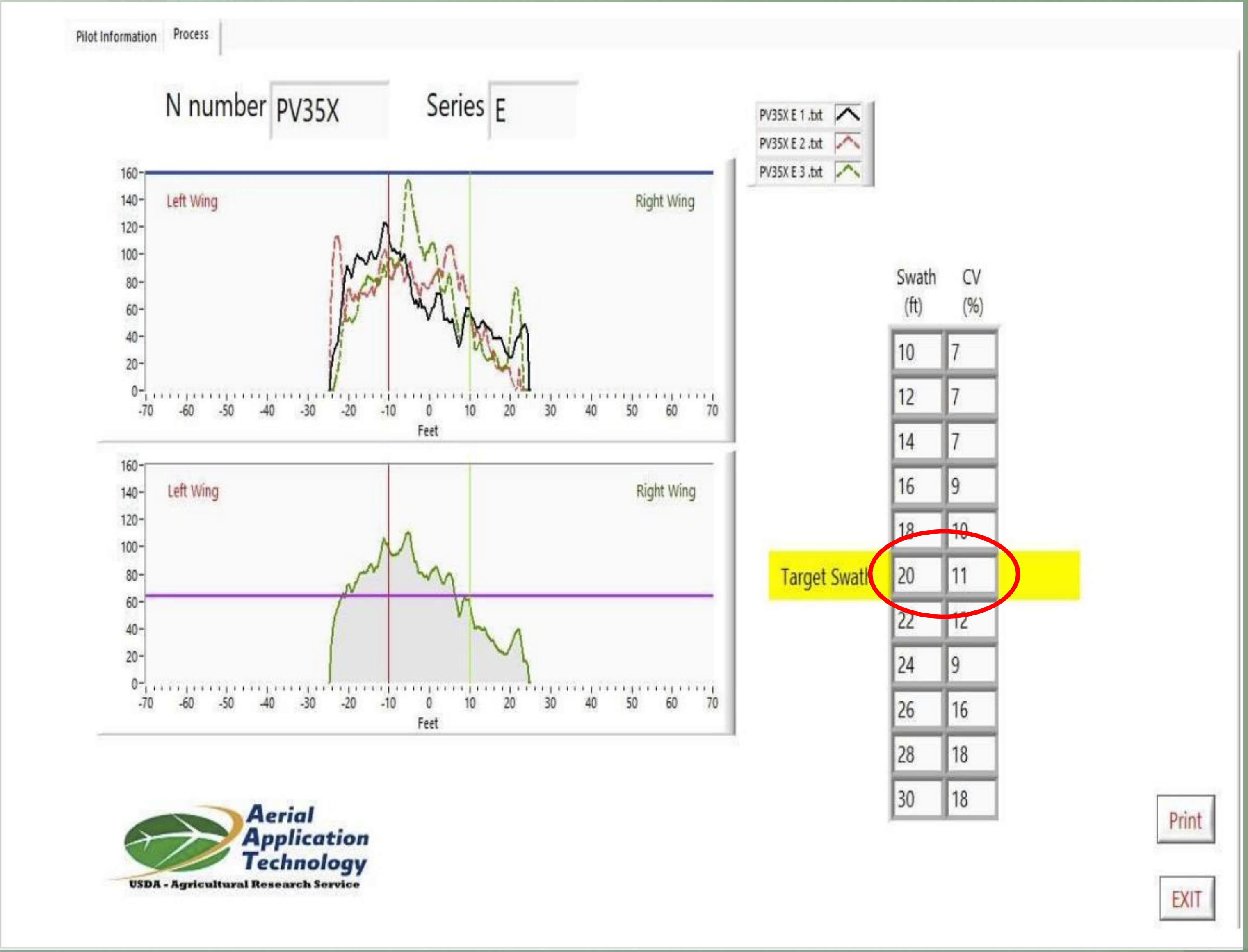
USDA/Syngenta Spray Drift Study

- 3 Treatments – Short Boom, Long Boom, Under Rotor
- 15 Replications of each treatment
- Mylar - -7.5 to 15 m (0.5 m spacing)
- Mylar – 16 to 20 m (1.0 m spacing)
- Mylar – 22 to 40 m (2.0 m spacing)
- Brushes – 10, 20, 30, 40 m (@1.5 m height)
- 3600 Mylar Samples   240 Brush Samples

Spray Pattern Testing

Short Boom


Pilot Information
Process
N number PV35X
Series E
PV35X E 1 .txt
PV35X E 2 .txt
PV35X E 3 .txt
Left Wing
Right Wing
Feet
Swath (ft)
CV (%)
10 7
12 7
14 7
16 9
18 10
Target Swath 20 11
22 12
24 9
26 16
28 18
30 18
Print
EXIT
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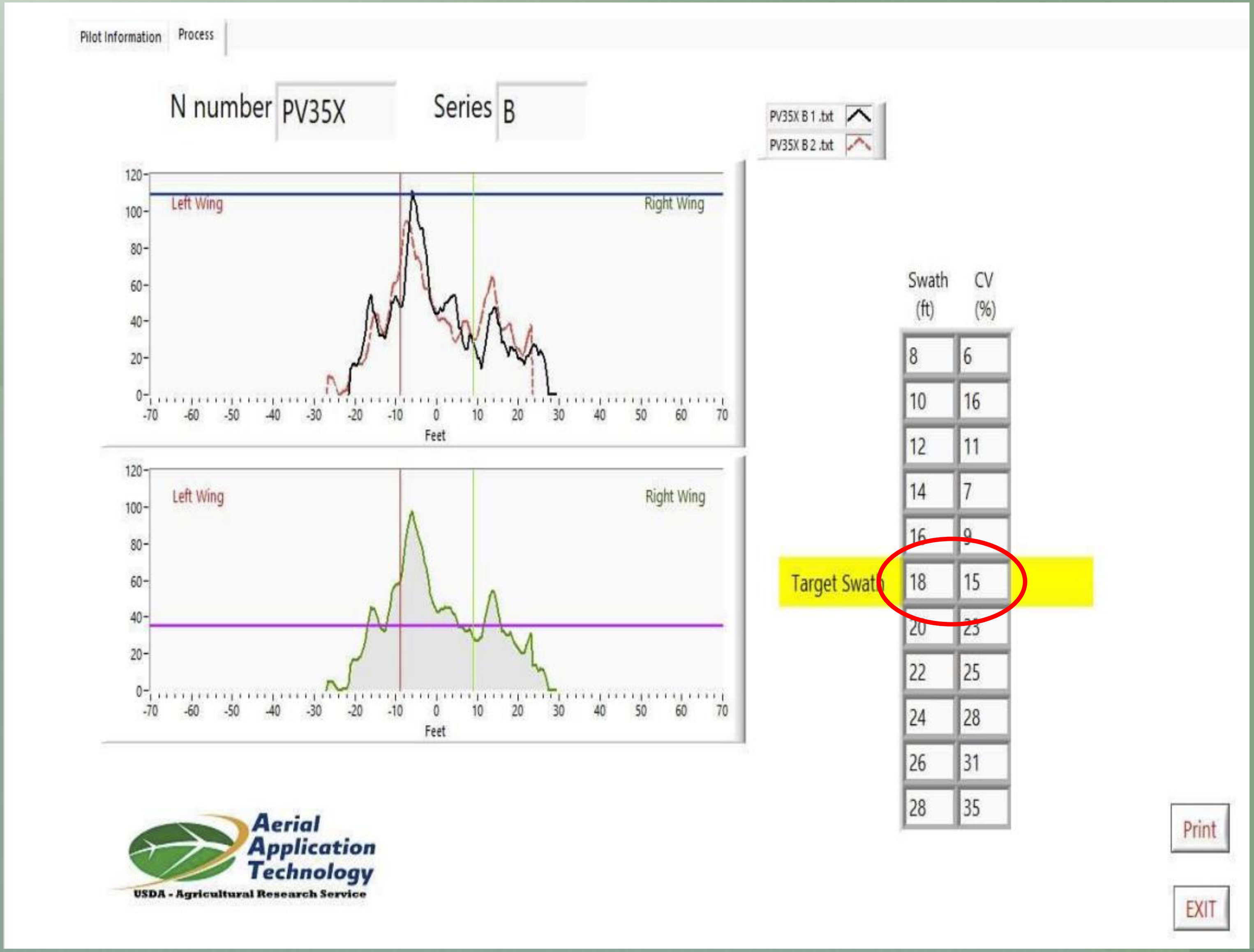
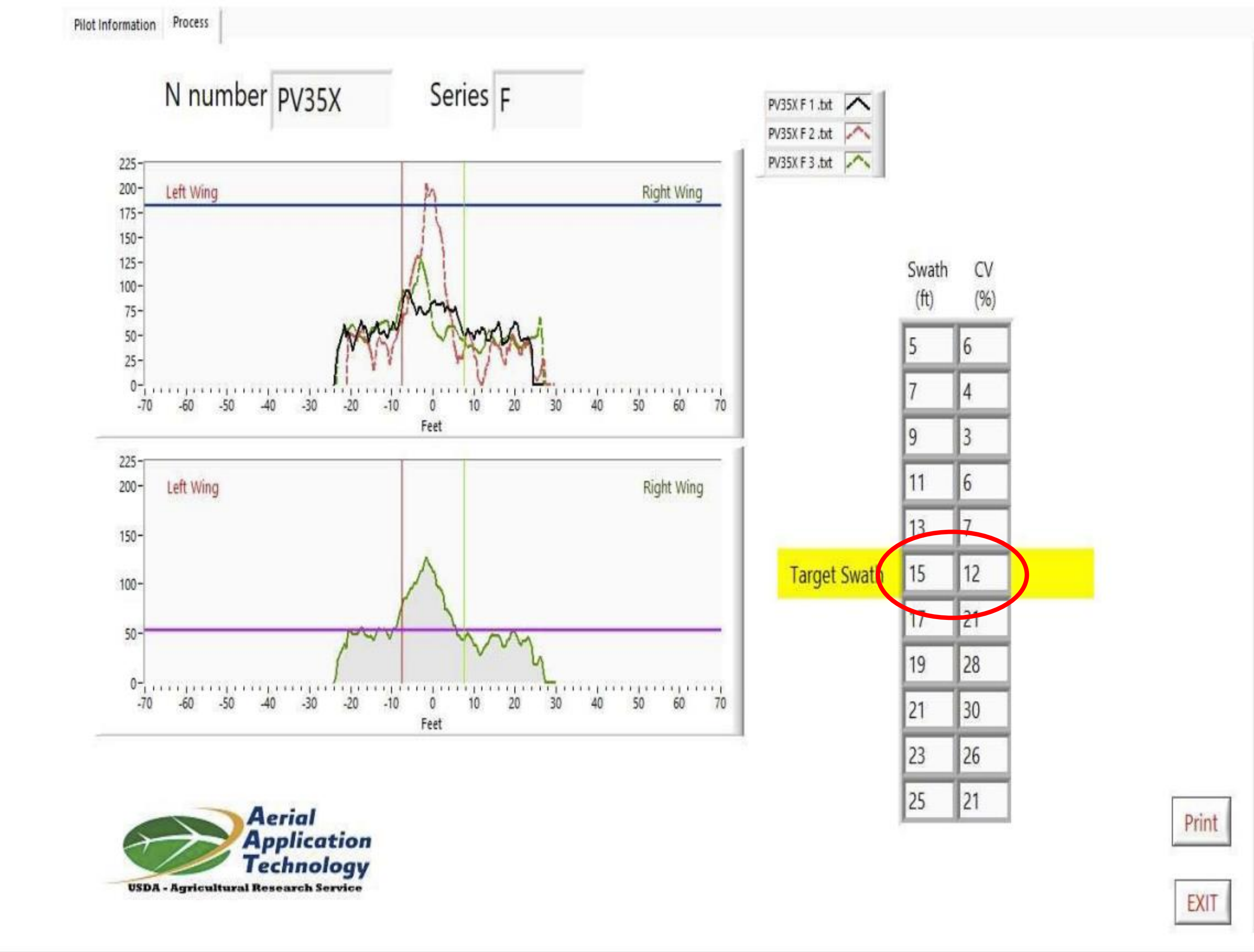
Long Boom



Under Rotor



Pilot Information
Process
N number
PV35X
Series
F
PV35X F 1 .txt
PV35X F 2 .txt
PV35X F 3 .txt
Left Wing
Right Wing
Feet
Left Wing
Right Wing
Feet
Swath (ft)
CV (%)
5 6
7 4
9 3
11 6
13 7
15 12
17 21
19 28
21 30
23 26
25 21
Target Swat
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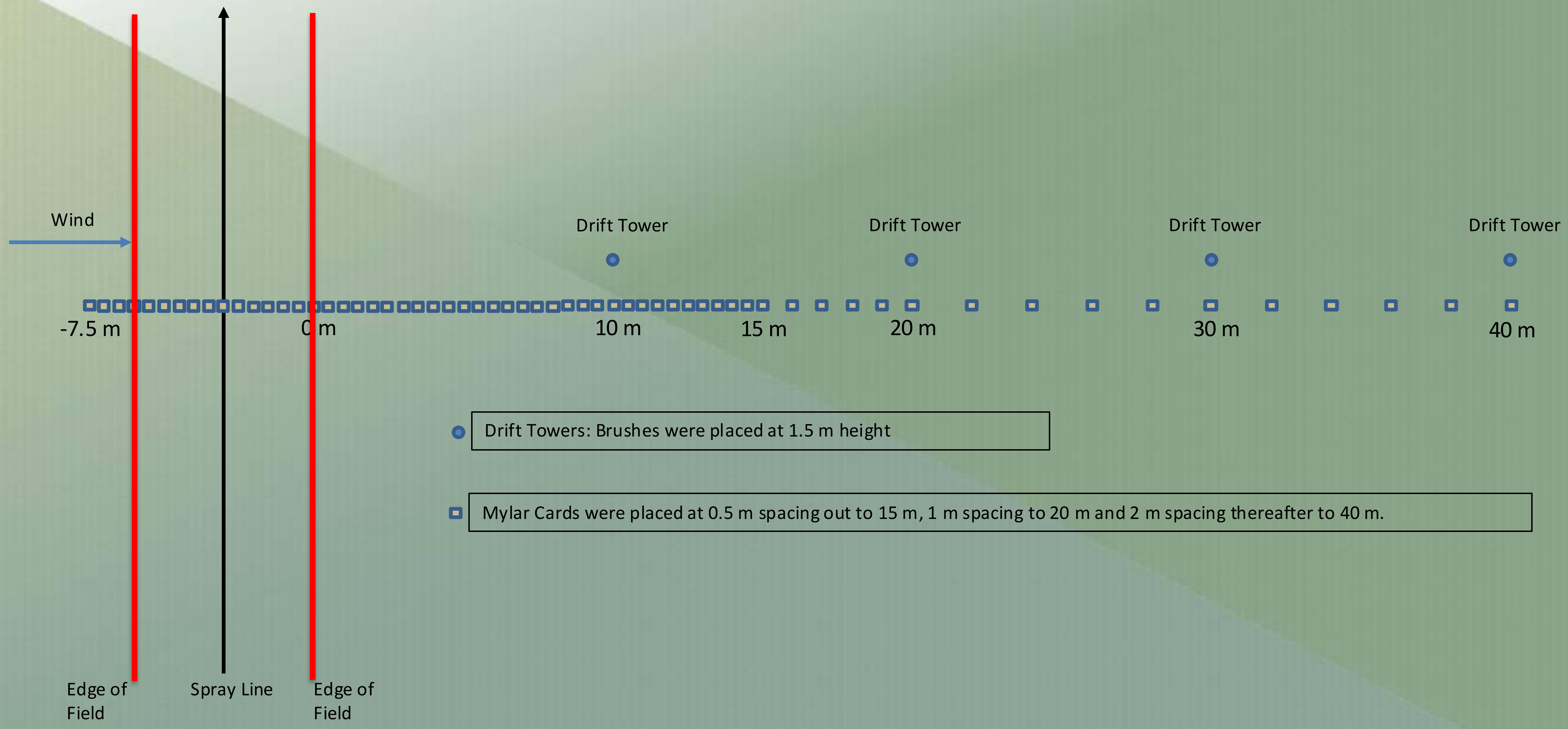
Print
EXIT

Study Layout



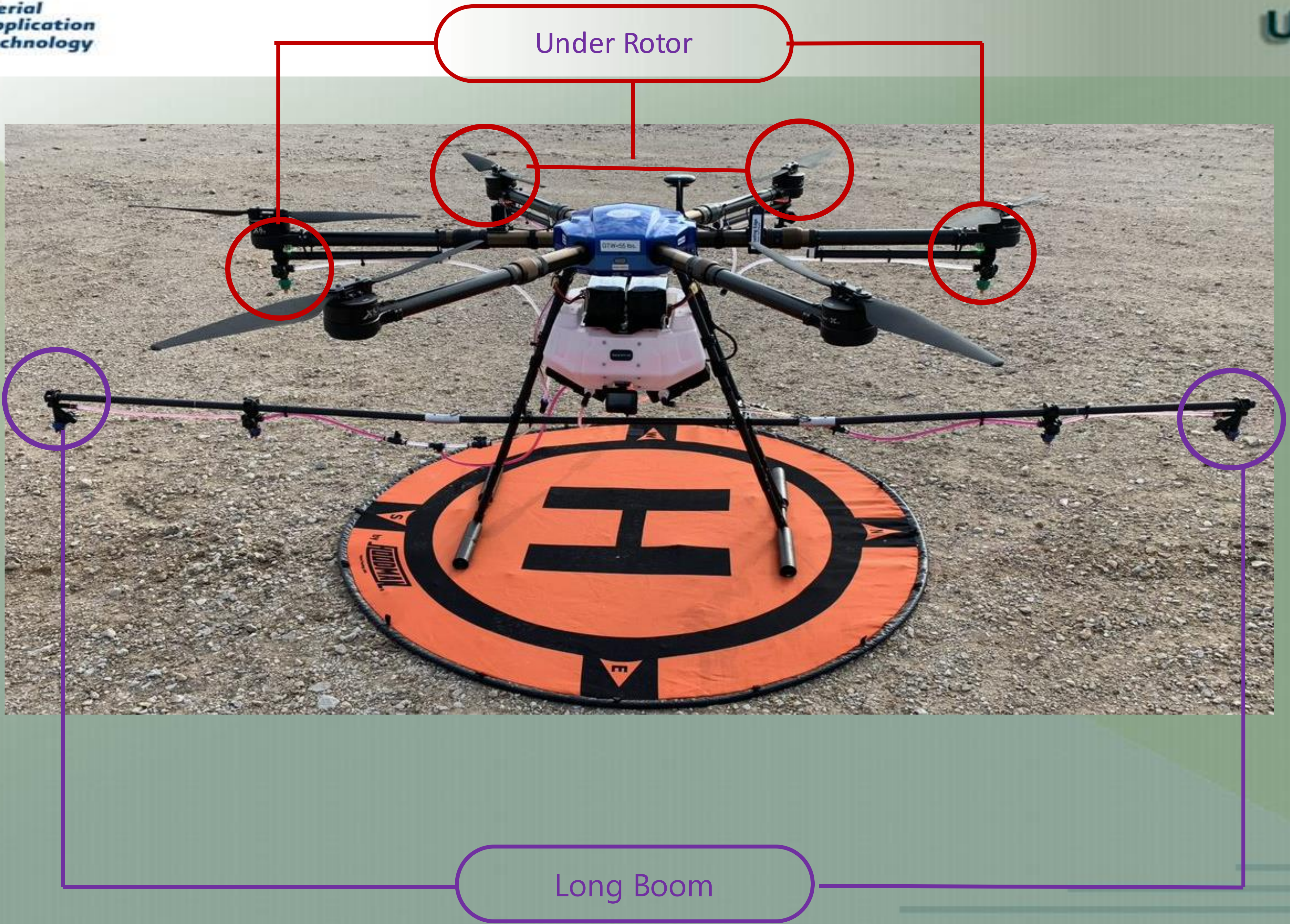
Drift Towers: Brushes were placed at 1.5 m height

Mylar Cards were placed at 0.5 m spacing out to 15 m, 1 m spacing to 20 m and 2 m spacing thereafter to 40 m.


Drift Tower
Mylar Cards

Drift Towers

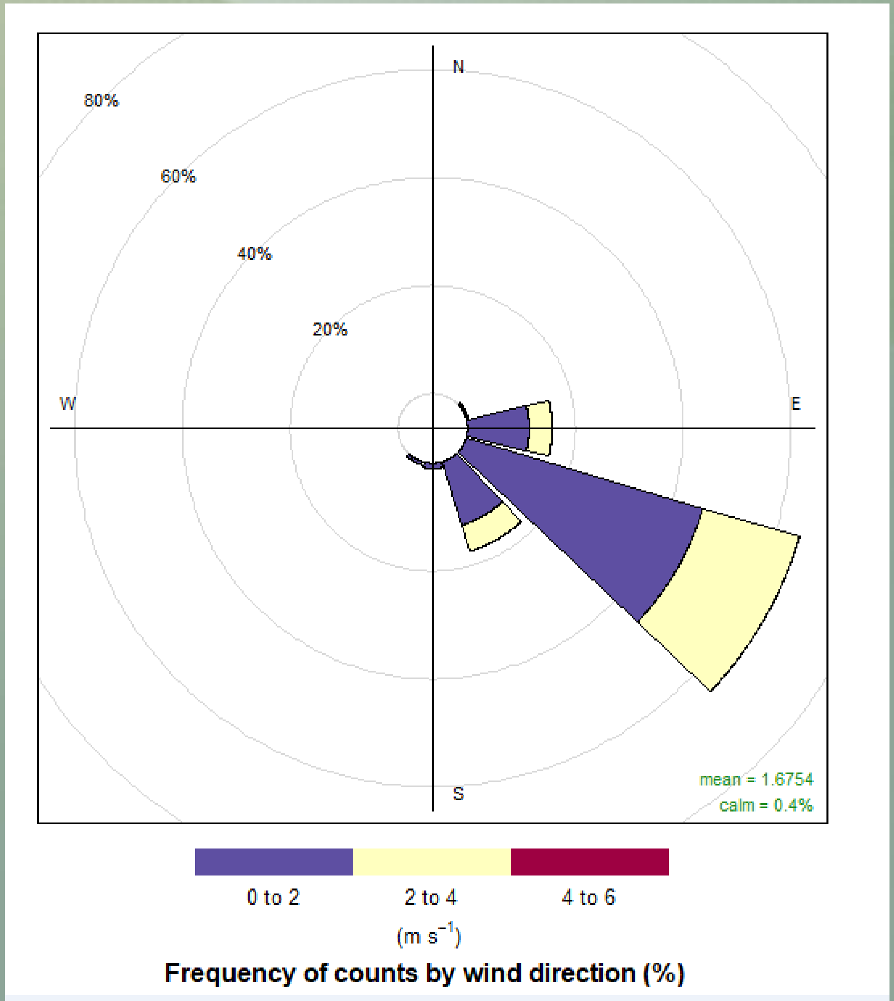

GTW<55 lbs.
H
W
S
N
E


Under Rotor
Long Boom

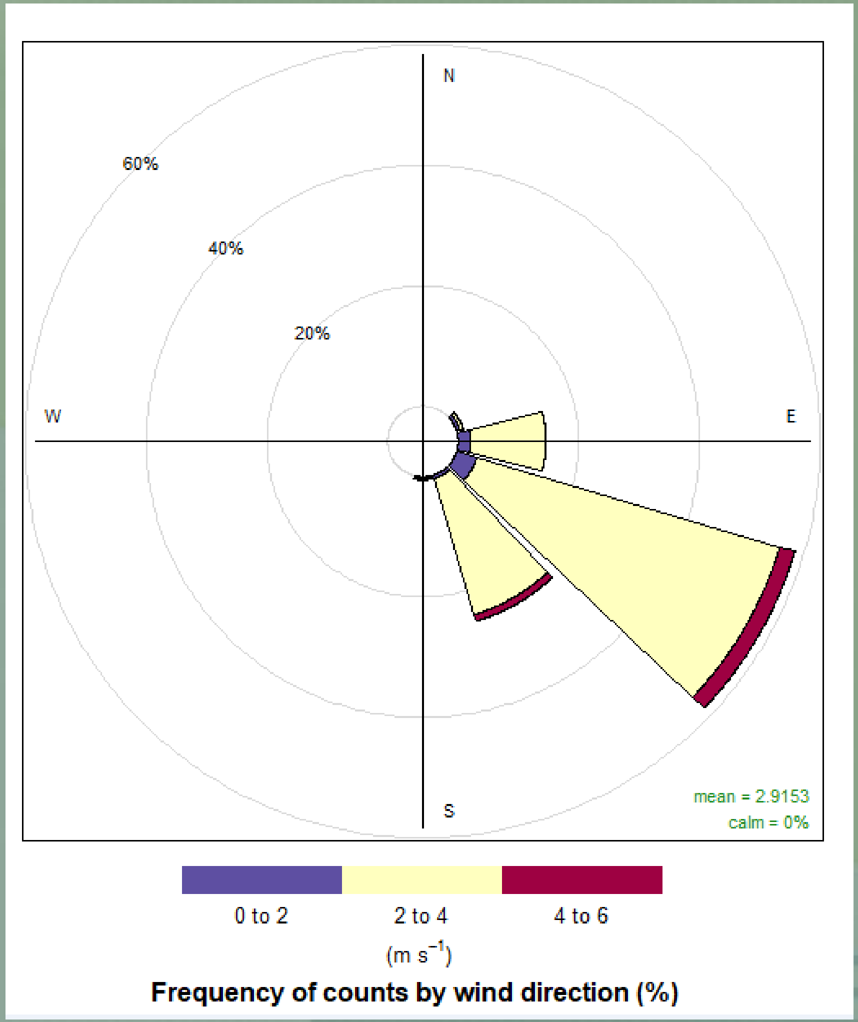

20mm
TeeJet
P.T.C-Φ8mm
G65J

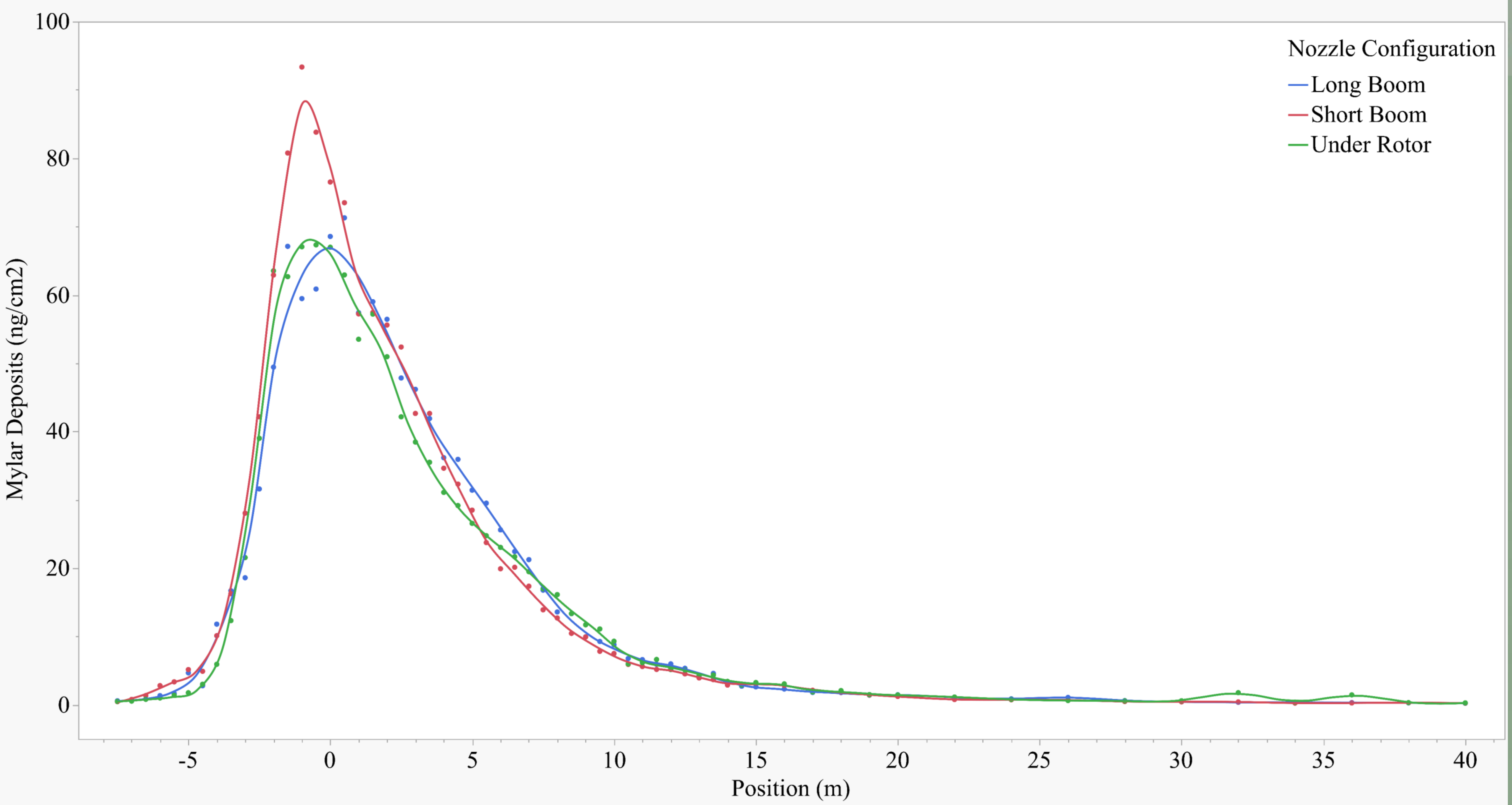
Meteorological Conditions

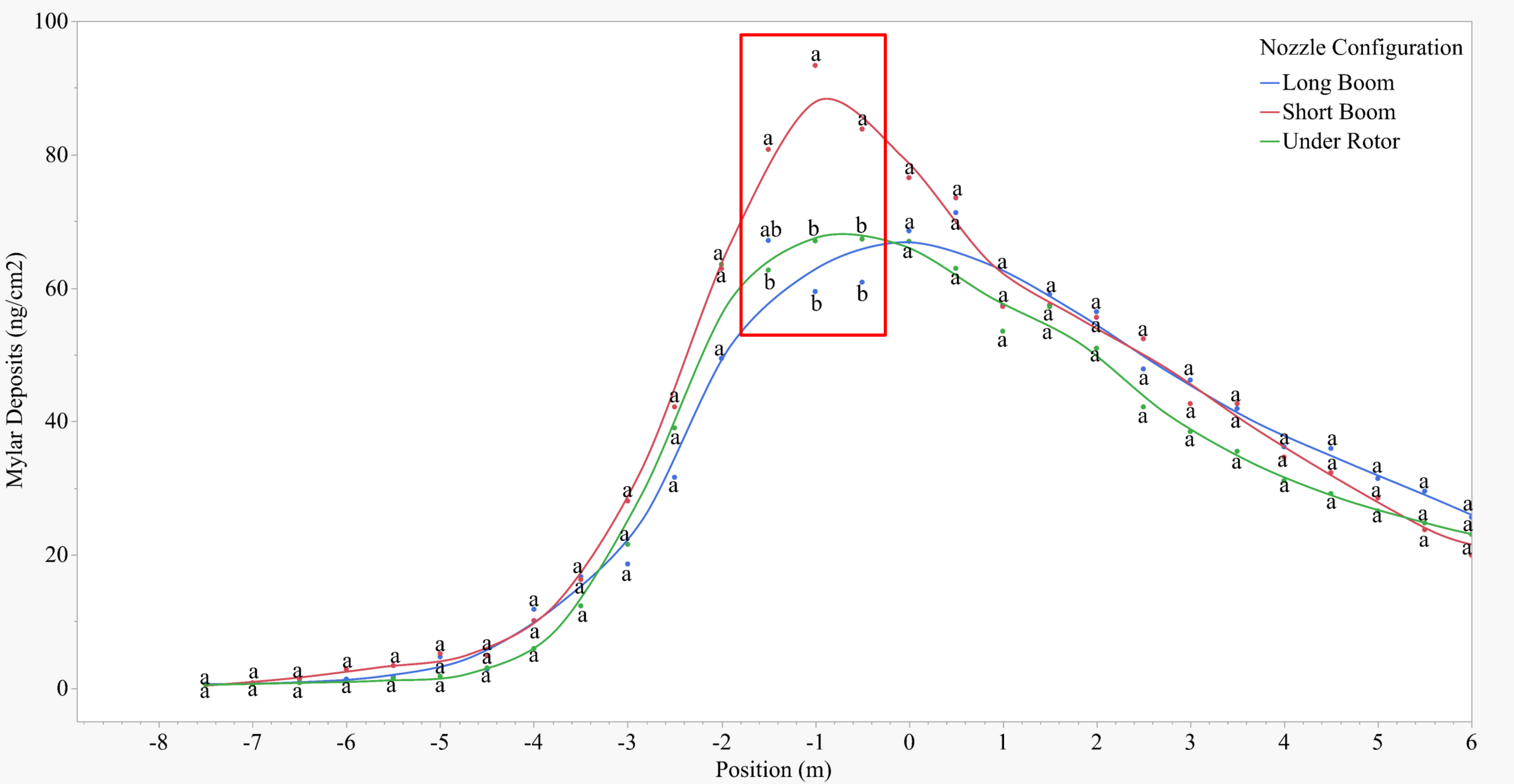
Day 1



Day 2




Nozzle Configuration
Long Boom
Short Boom
Under Rotor
Mylar Deposits (ng/cm2)
Position (m)
100
80
60
40
20
0
-5
0
5
10
15
20
25
30
35
40



Nozzle Configuration
Long Boom
Short Boom
Under Rotor
Mylar Deposits (ng/cm2)
Position (m)

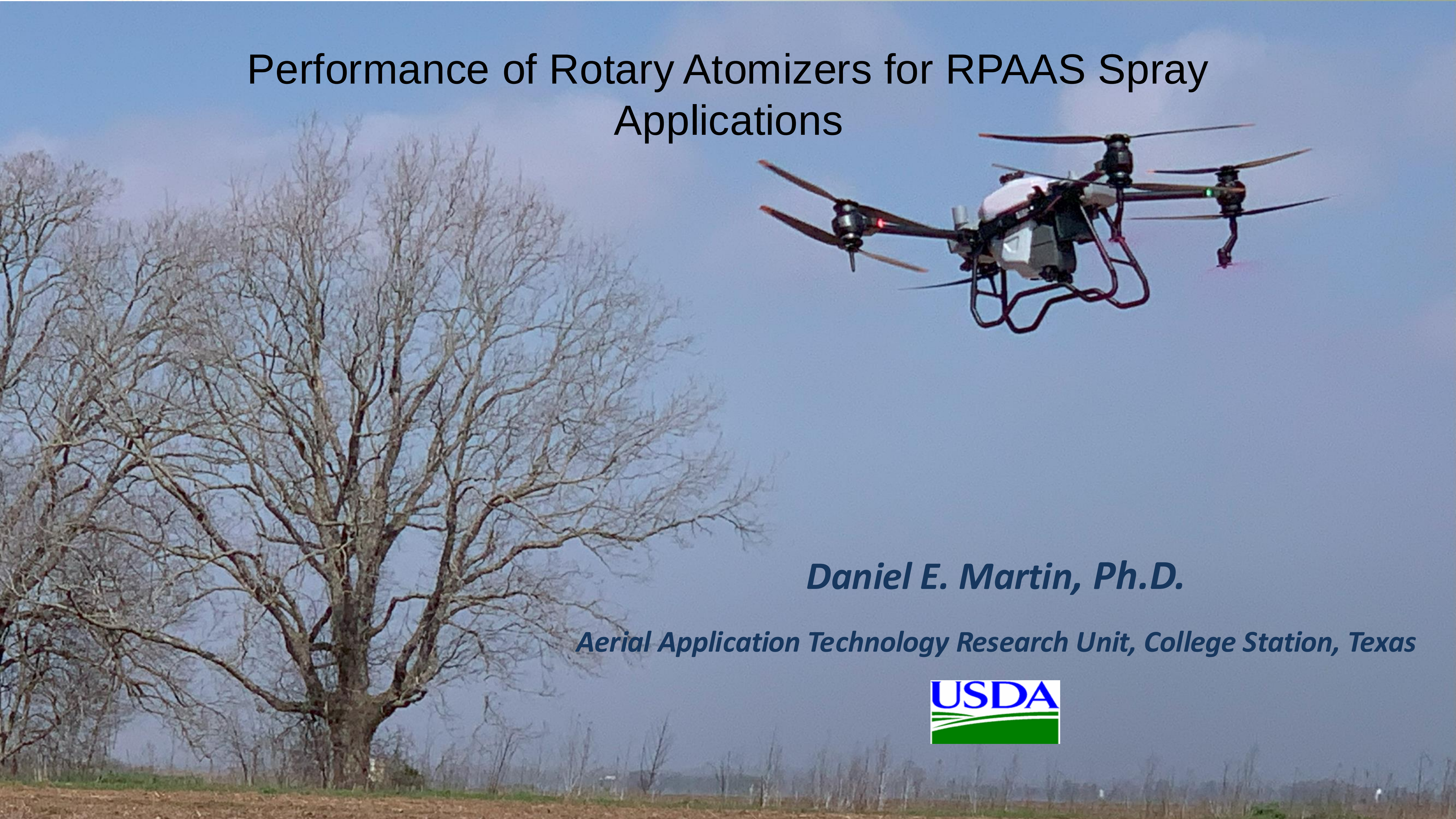
Conclusions

Slight variations in spray pattern and effective swath were documented between the various RPAAS nozzle configurations.

Typical nozzle configurations did not seem to influence spray drift from a commercial 16L RPAAS.

It is important to pattern test your aircraft whenever changing nozzles, speeds, application rates, etc.

Performance of Rotary Atomizers for RPAAS Spray Applications



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Objectives

1) Determine if rotary atomizers deliver the desired droplet size classification.

2) Determine if rotary atomizers “flood” due to increased flowrate.

3) Test a modified rotary atomizer design to see how it affects droplet size.


DJI T-40

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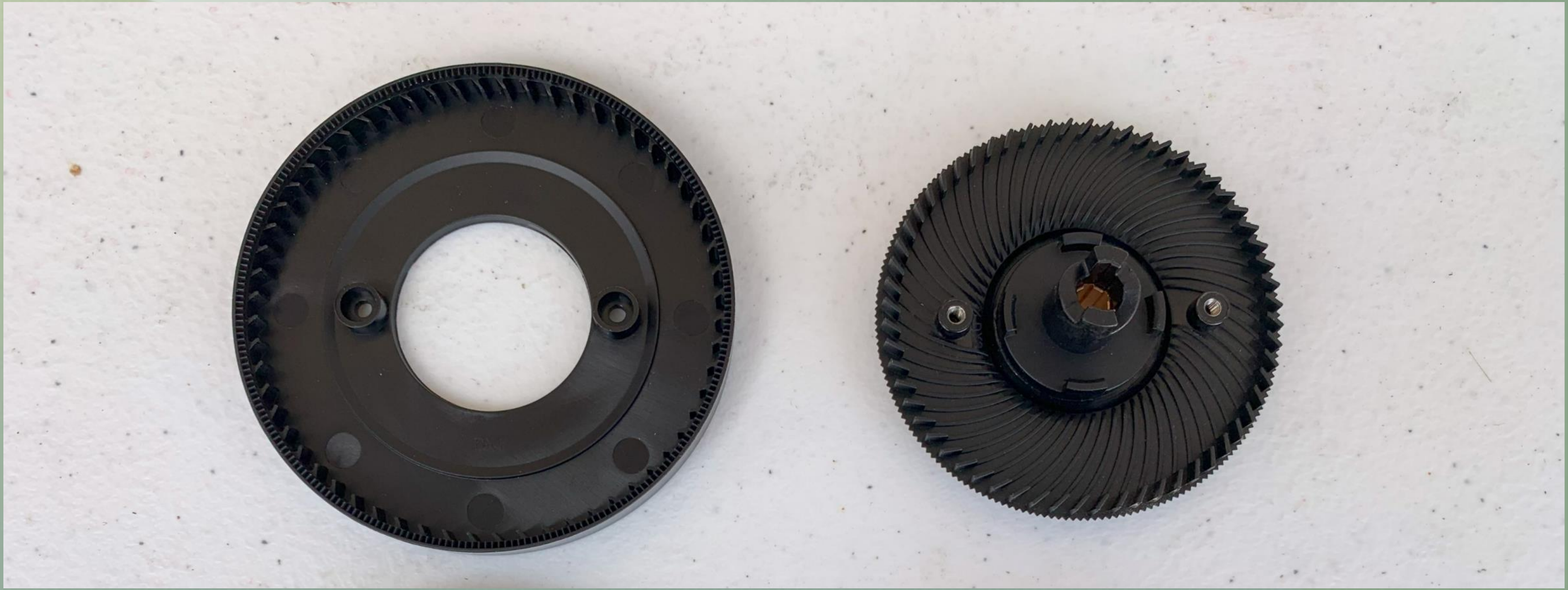
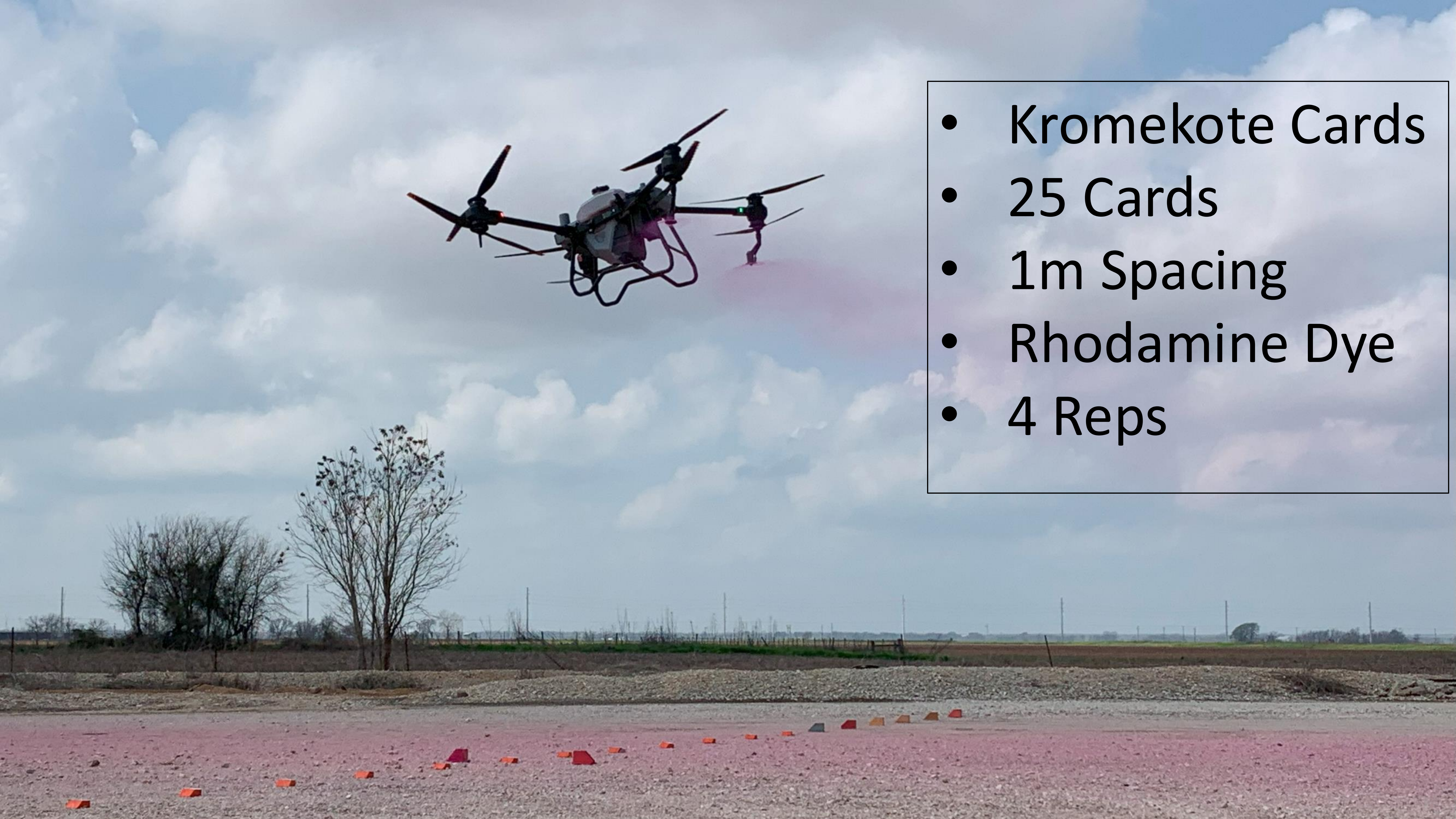
Double Diffusion Nozzle



Treatment	Nozzle	Target Rate (GPA)	Speed (m/s)	Target DSC
1	DD	2	7	Medium
2	DD	2	7	Coarse
3a	DD	2	7	Very Coarse
3b	Modified DD	2	7	Very Coarse
4	DD	3	7	Medium
5	DD	4	7	Medium
6	DD	5	7	Medium
7	DD	7	3.7	Very Coarse
8	DD	10	3.7	Very Coarse
9	SD	2	3.7	Very Coarse
10	DD	2	3.7	Very Coarse



- Kromekote Cards
- 25 Cards
- 1m Spacing
- Rhodamine Dye
- 4 Reps


Manual Route (GNSS)
28
92%
29.2L
Task Settings
Spraying Template
Do Not Use Template
Application Rate(L/ha)
18.75
Flow Rate
5.36L/min
Spray Droplet
500 μm
Flight Speed(m/s)
7.0
Route Spacing(m)
6.80
Height Above Crops(m)
3.1
Altitude(m)
0.0
Speed(m/s)
0.0
Distance(m)
0.8
Flow(L/min)
0.0
rea(Ha)
0.0
Start

Manual Route (GNSS)
28
92%
29.1L
Spray Droplet Size
Old Categories
Current Config:Single-Layer
320 μm
500
Very Coarse
Coarse
Medium
Fine
Very Fine
Extremely Fine
Extra Coarse
Coarse
Medium
Fine
Extra Fine
Apply
Altitude(m)
0.0
Speed(m/s)
0.0
Distance(m)
0.8
Flow(L/min)
0.0
Area(Ha)
0.0
Start
L1
L2
L3
R1
R2
R3

Manual Route (GNSS)
35%
27.1L
Spray Droplet Size
Old Categories
Current Config:Single-Layer
400 µm
500
Very Coarse
Coarse
Medium
Fine
Very Fine
Extremely Fine
Extra Coarse
Coarse
Medium
Fine
Extra Fine
Apply
Task Summary
This flight takes 7 s
0.03Ha
0.6L
Task Area
Task completed
Total
0.07 Ha
1.2 L
Altitude(m)
0.0
Speed(m/s)
0.0
Flow(L/min)
0.0
0.0
Disable(R3)


Manual Route (GNSS)
66%
24.3L
Spray Droplet Size
Old Categories
Current Config:Single-Layer
500 µm
500
Very Coarse
Coarse
Medium
Fine
Very Fine
Extremely Fine
Extra Coarse
Coarse
Medium
Fine
Extra Fine
Apply
Altitude(m)
0.0
Speed(m/s)
0.0
Distance(m)
1.1
Flow(L/min)
0.0
eted Area(Ha)
0.0
Start
L1
L2
L3

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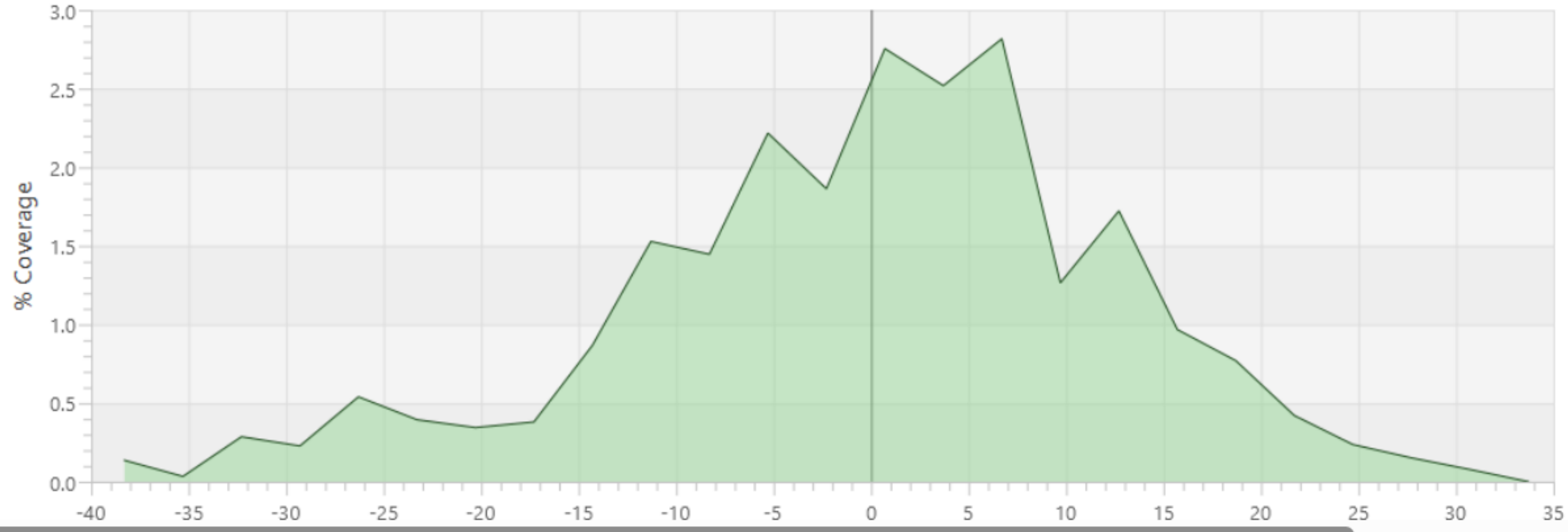
Pilot	

Analyst	
	Dr. Dan Martin USDA-ARS 3103 F and B Road College Station, TX 77845 979-260-9290 Dan.Martin@usda.gov

N713GR - 2

Aircraft		Configuration		Flight Data		Measured Data		USDA Model	
Reg. #:	N713GR	Spray:	Water/Dye			VMD:	218 µm	VMD:	*****
Series #:	2	Target Rate:	4 GPA	Airspeed:	15 mph	Dv01:	127 µm	Dv01:	*****
Make:	DJI	Boom Press:	psi	Spray Height:	10 ft	Dv09:	400 µm	Dv09	*****
Model:	T40	Rotary Atomizer (x2)		Wind Speed:	0 mph	RS:	1.25	RS:	*****
Notes:		Orif. #: , Def. = 90°		Cross-Wind:	0.0 mph	DSC:	F	DSC:	*****
				Ambient Temp:	72 °F	Drops/in²:	82	*Computed based on*	
				Humidity:	92%	Coverage:	0.96%	*reported nozzles*	

-- % Coverage vs. In-Swath Location (ft) --



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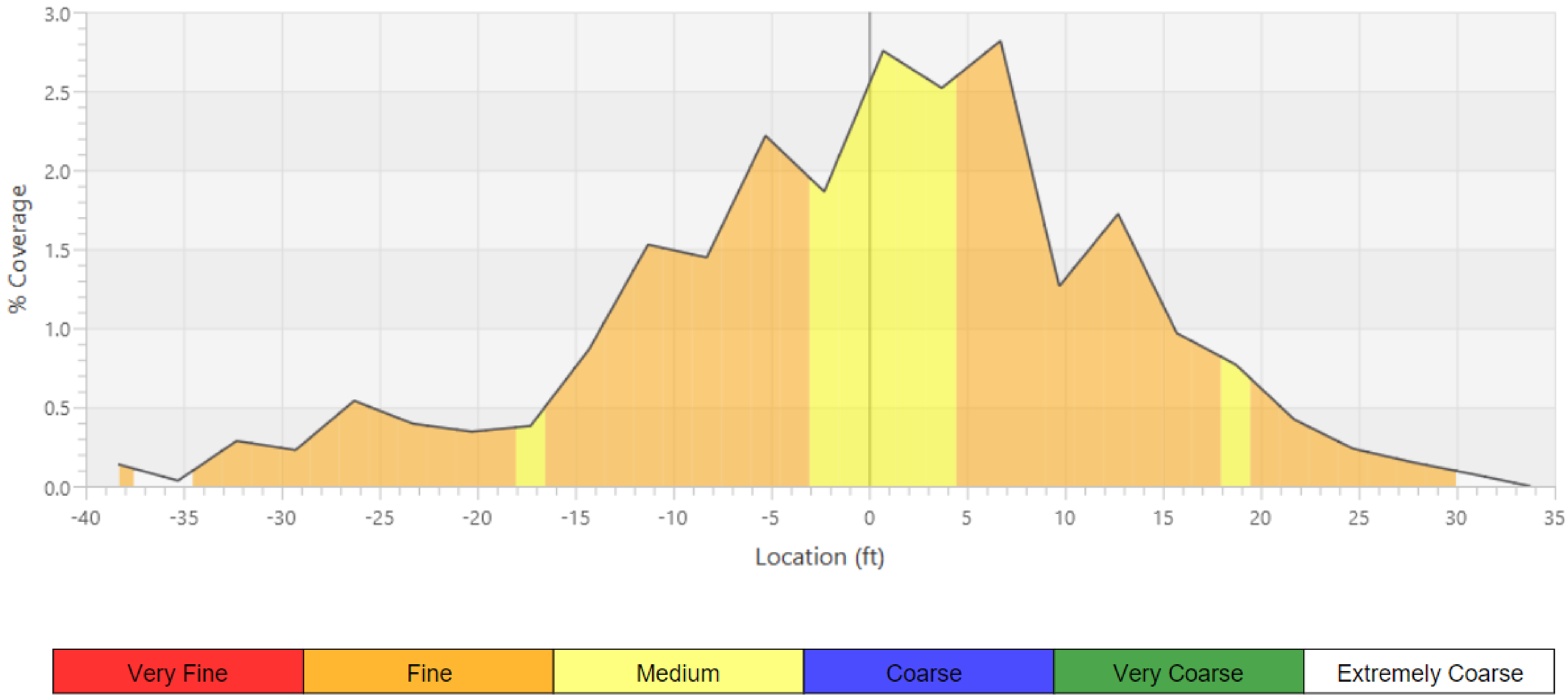

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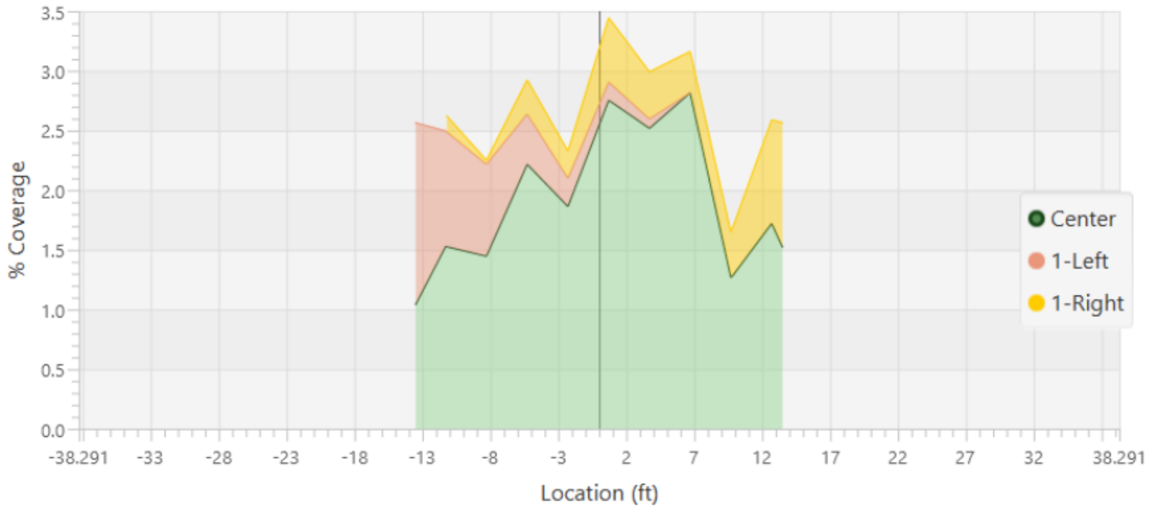
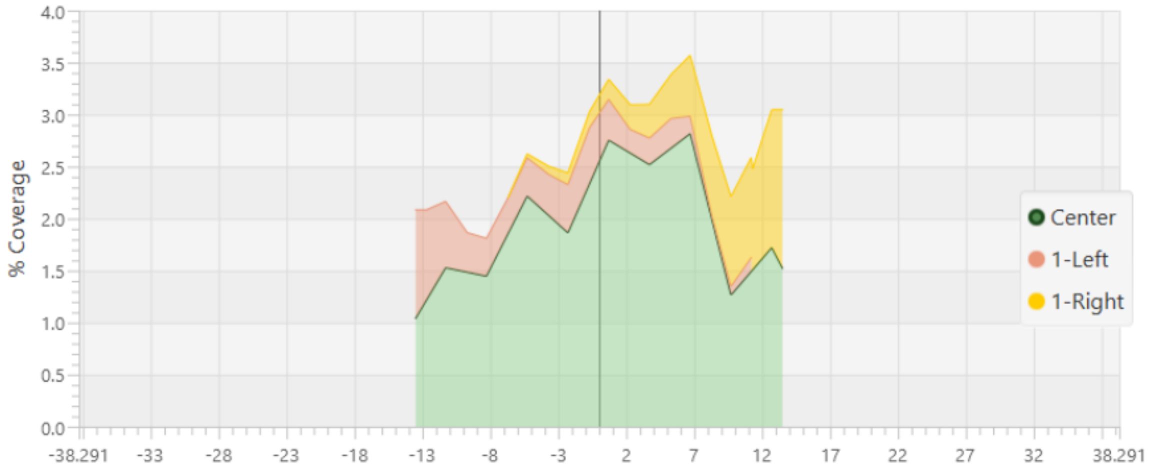
-- Simulated Overlap, In-Field Uniformity --

Racetrack



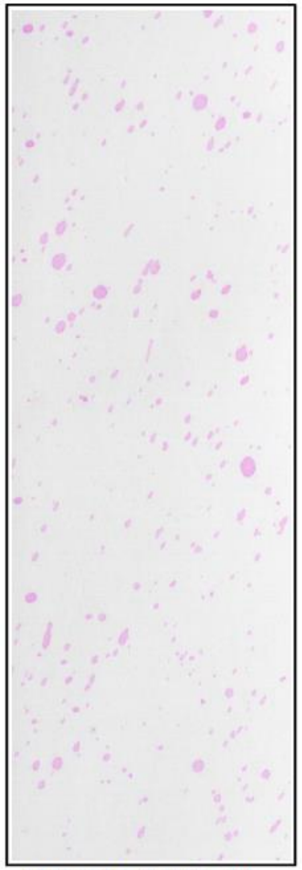
Swath	CV
21 FT	6%
23 FT	7%
25 FT	11%
27 FT	15%
29 FT	18%
31 FT	21%
33 FT	25%

Back and Forth

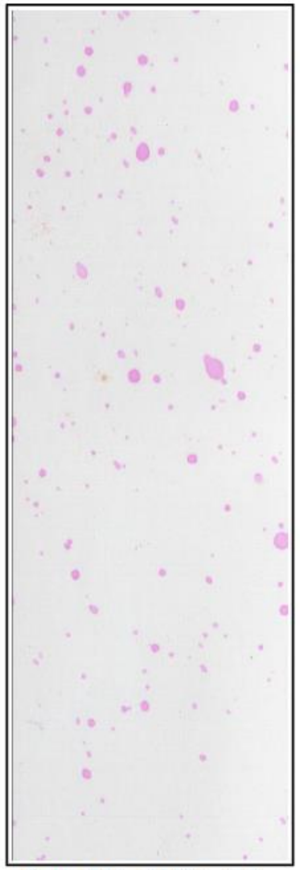


Swath	CV
21 FT	18%
23 FT	17%
25 FT	19%
27 FT	19%
29 FT	19%
31 FT	22%
33 FT	24%

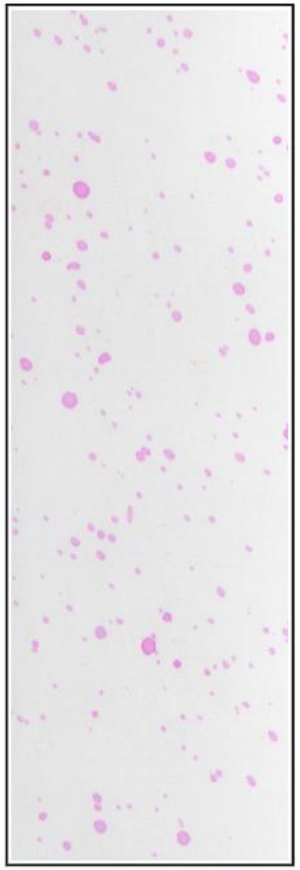
DJI-T40-T1R1_30
Cov. = 1.45%
D/in^2 = 108.91
VMD = 213 µm
Dv01 = 131 µm
Dv09 = 470 µm
RS = 1.59%
DSC = F



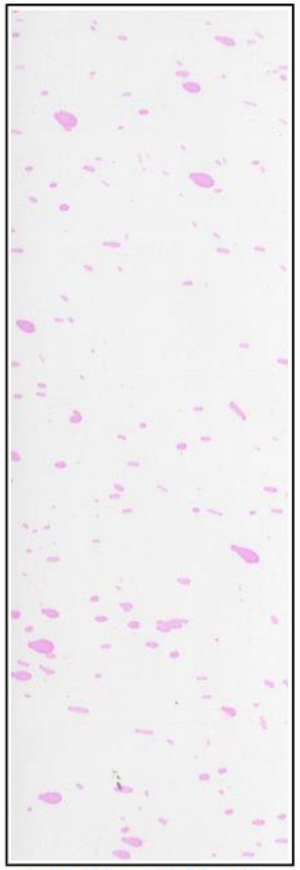
DJI-T40-T1R1_33
Cov. = 2.22%
D/in^2 = 241.23
VMD = 176 µm
Dv01 = 117 µm
Dv09 = 283 µm
RS = 0.94%
DSC = F



DJI-T40-T1R1_36
Cov. = 1.86%
D/in^2 = 91.98
VMD = 275 µm
Dv01 = 160 µm
Dv09 = 424 µm
RS = 0.96%
DSC = M

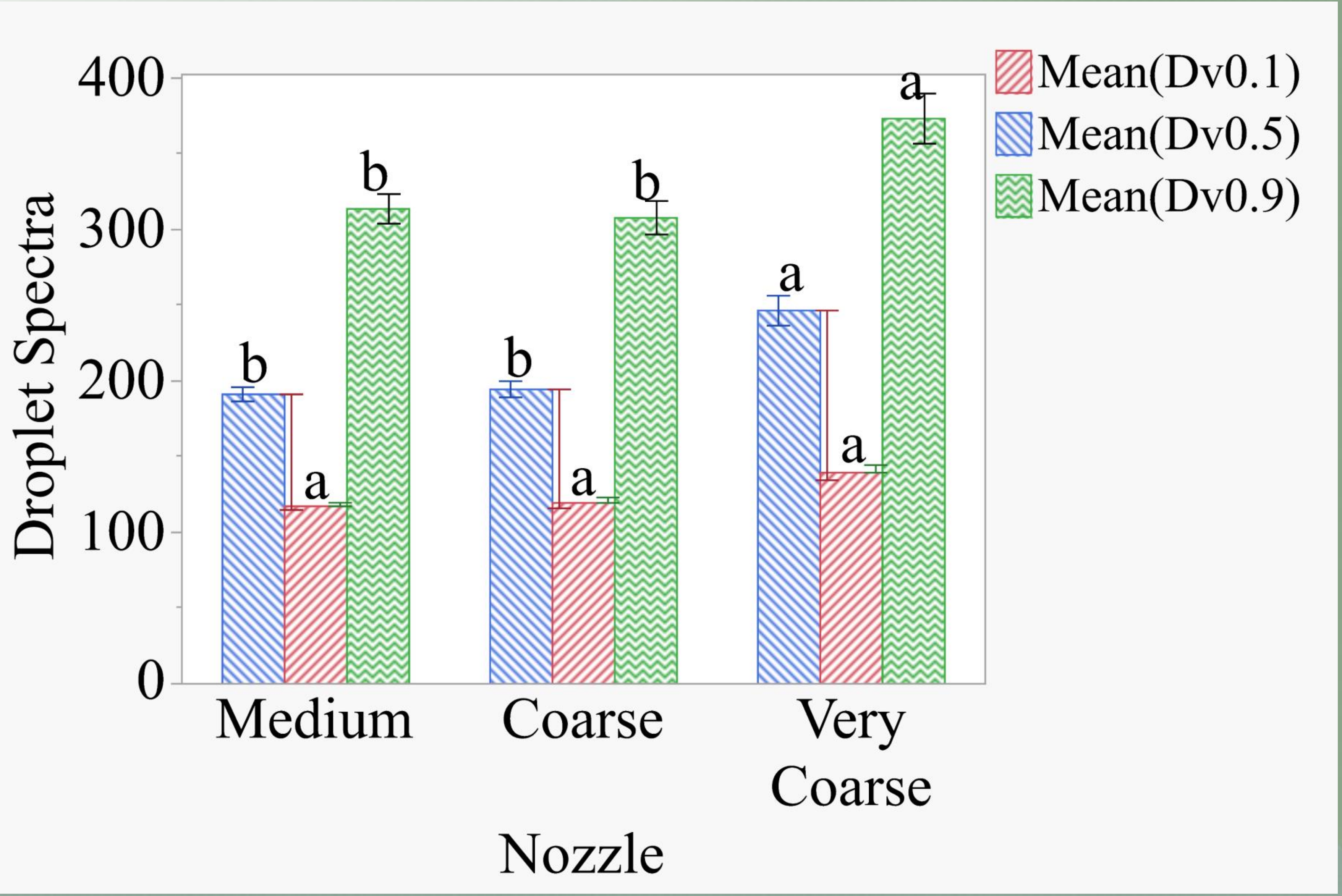


DJI-T40-T1R1_39
Cov. = 2.75%
D/in^2 = 106.77
VMD = 290 µm
Dv01 = 173 µm
Dv09 = 424 µm
RS = 0.87%
DSC = M



DJI-T40-T1R1_42
Cov. = 2.52%
D/in^2 = 143.03
VMD = 254 µm
Dv01 = 144 µm
Dv09 = 403 µm
RS = 1.02%
DSC = M

Treatment	Nozzle	Target Rate (GPA)	Speed (m/s)	Target DSC
1	DD	2	7	Medium
2	DD	2	7	Coarse
3a	DD	2	7	Very Coarse
3b	Modified DD	2	7	Very Coarse
4	DD	3	7	Medium
5	DD	4	7	Medium
6	DD	5	7	Medium
7	DD	7	3.7	Very Coarse
8	DD	10	3.7	Very Coarse
9	SD	2	3.7	Very Coarse
10	DD	2	3.7	Very Coarse


Droplet Spectra
400
300
200
100
0
Mean(Dv0.1)
Mean(Dv0.5)
Mean(Dv0.9)
b
a
b
b
a
b
a
a
a
Medium
Coarse
Very Coarse
Nozzle

Targeted vs. Actual Droplet Size Classification (DSC)

Treatment	Nozzle	Target Rate (GPA)	Speed (m/s)	Target DSC	Actual DSC
1	DD	2	7	Medium	Fine
2	DD	2	7	Coarse	Fine
3a	DD	2	7	Very Coarse	Fine/Medium

Why is this Important?

GROUP	2	HERBICIDE

OUST® XP HERBICIDE

Dispersible Granules

Active Ingredient	By Weight
Sulfometuron-methyl {Methyl 2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino]-carbonyl]amino]sulfonyl]benzoate}	75%
Other Ingredients	25%
TOTAL	100%

EPA Reg. No. 432-1552

EPA Est. No. _________

ACCEPTED
03/08/2018
Under the Federal Insecticide, Fungicide and Rodenticide Act as amended, for the pesticide registered under EPA Reg. No. 432-1552

Nonrefillable Container
Net: _________
OR
Refillable Container
Net: _________

Editorial Note – [Bracketed text] is optional

KEEP OUT OF REACH OF CHILDREN

CAUTION

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle.
(If you do not understand this label, find someone to explain it to you in detail.)

See [Back][Side] Panel for First Aid Instructions and [Leaflet][Booklet] for Complete Precautionary Statements and Directions for Use. (Note to reviewer: Location of additional precautionary statements, directions for use will vary between those listed, depending on container type/size.)

FIRST AID

IF IN EYES: Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first five minutes, then continue rinsing eye. Call a poison control center or doctor for treatment advice.

Have the product container label with you when calling a poison control center or doctor, or going for treatment. You may also contact 1-800-334-7577 for emergency medical treatment information.

MANDATORY SPRAY DRIFT REQUIREMENTS

Aerial Applications:

- Do not release spray at a height greater than 10 ft above the vegetative canopy, unless a greater application height is necessary for pilot safety.
- Applicators are required to use an Extremely Coarse or coarser droplet size (ASABE S572.1) for all applications.
- The boom length must not exceed 65% of the wingspan for airplanes or 75% of the rotor blade diameter for helicopters.
- Applicators must use ½ swath displacement upwind at the downwind edge of the field.
- Nozzles must be oriented so the spray is directed toward the back of the aircraft.
- Do not apply when wind speeds exceed 10 miles per hour at the application site.
- Do not apply during temperature inversions.

Ground Boom Applications:

- Apply with the nozzle height recommended by the manufacturer, but no more than 3 feet above the ground or target vegetation unless making an industrial turf application, in which case applicators may apply with a nozzle height no more than 4 feet above the crop or target vegetation.
- Applicators are required to use an Extremely Coarse or coarser droplet size (ASABE S572.1) for all applications.
- Do not apply when wind speeds exceed 10 miles per hour at the application site.
- Do not apply during temperature inversions.

Boom-less Ground Applications:

- Applicators are required to use an Extremely Coarse or coarser droplet size (ASABE S572.1) for all applications.
- Do not apply when wind speeds exceed 10 miles per hour at the application site.
- Do not apply during temperature inversions.

Conclusions

- Pattern Test your aircraft before use.
- Trust, but verify.
- You, as the applicator, are liable for your applications.
- Understand the limitations of your systems.


The Future
Higher Payloads
Larger Aircraft
Drone Swarms


Pyka Pelican
75 gallon Payload
150’ Runway to Takeoff and Land
NewAtlas.com

Pyka Pelican

38’ Wingspan
20’ Long

Pyka Pelican

90 mph Cruising Speed
70 mile range
135 acres/hr


N354WS
EXPERIMENTAL

Rotor AI

In Summary

- Spray drones are an emerging technology that give us one more tool for our toolbox.
- They are not a magic bullet.
- The regulatory environment around them will be evolving as the technology advances.
- They may be able to help growers be more efficient, cost-effective and environmentally responsible than current application technologies.

2025 RPAAS Workshop - Kansas