



PRECISION

CROP TECH

UAV / DRONE
CROP SPRAYING

Navigation

This talk will cover key points relating to UAV crop spraying:

- What is the technology?
- Attractiveness of using UAVs for crop spraying
- What regulatory controls exist in Canada for UAV crop spraying
- How to overcome the regulatory hurdles

Ground Zero

- PMRA has noted that there are currently no pesticides approved for UAV spraying in Canada.
- Precision Crop Tech has not sprayed pesticides. All flight trials and demonstrations conducted in Canada have sprayed water.
- All Precision Crop Tech pilots have completed aviation ground school or are qualified pilots and have completed specific UAV flight training.
- Key members of the Precision Crop Tech Team are environmental chemists, engineers, remote sensing and GIS specialists, plant nutritionists, agronomists and farmers.



UAV Uses in Crop Production

Monitoring

- Disease detection and mitigation
- Parasite and pest monitoring
- Moisture monitoring
- Soil Erosion Monitoring
- Crop growth monitoring
- Livestock tracking
- Disease outbreak tracking
- Remote aerial monitoring
- Yield estimation
- Weed infestation monitoring
- Environmental impact and wildlife habitat monitoring
- Detect weather-related damage

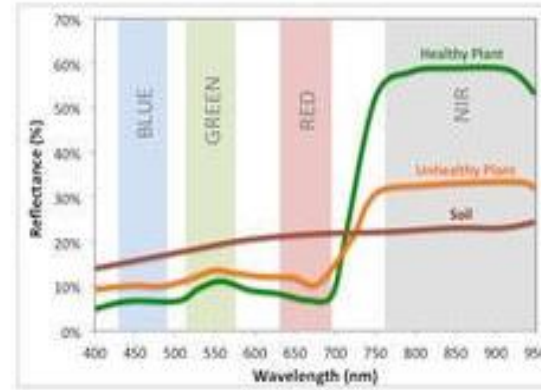
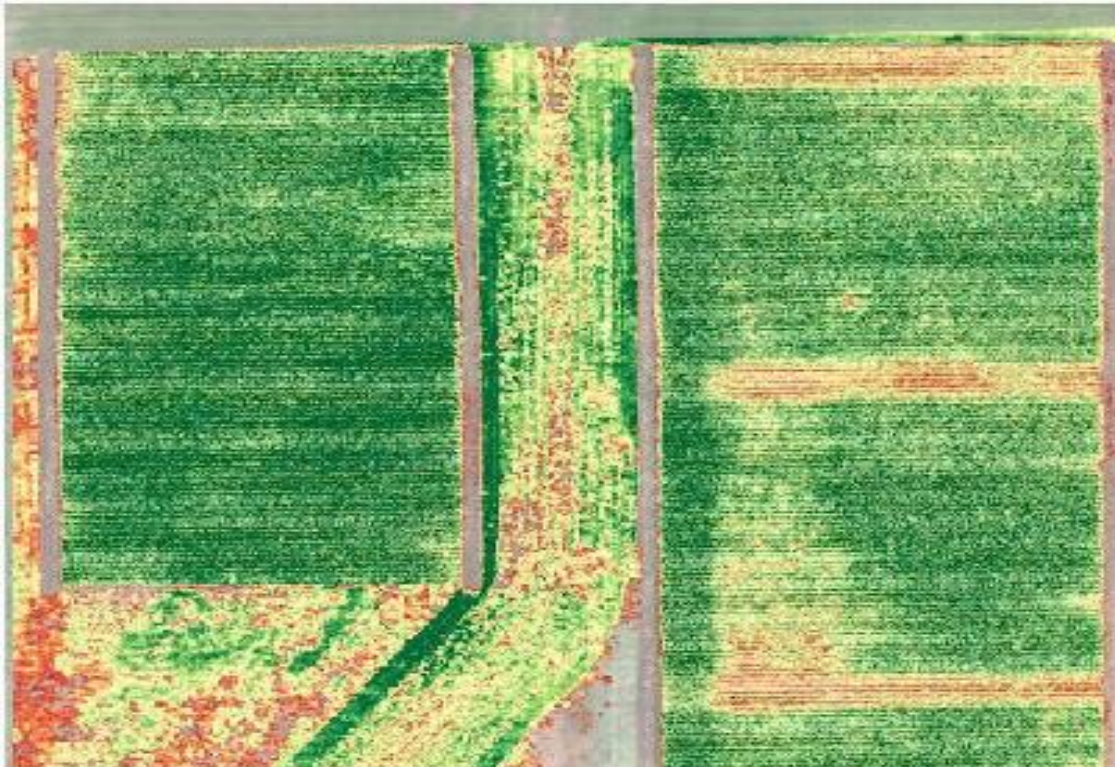
Tracking, sampling and application

- Precision crop spraying
- Reduce herbicide and fertilizer usage
- Crop sampling
- Harvest optimization
- Fertilizer management and application
- Crop inventory tracking
- Asset tracking and management
- Monitor livestock feedlots and pastures
- Estimate yields using biomass calculations
- Locate invasive species and diseased areas
- Survey irrigation and other structural systems

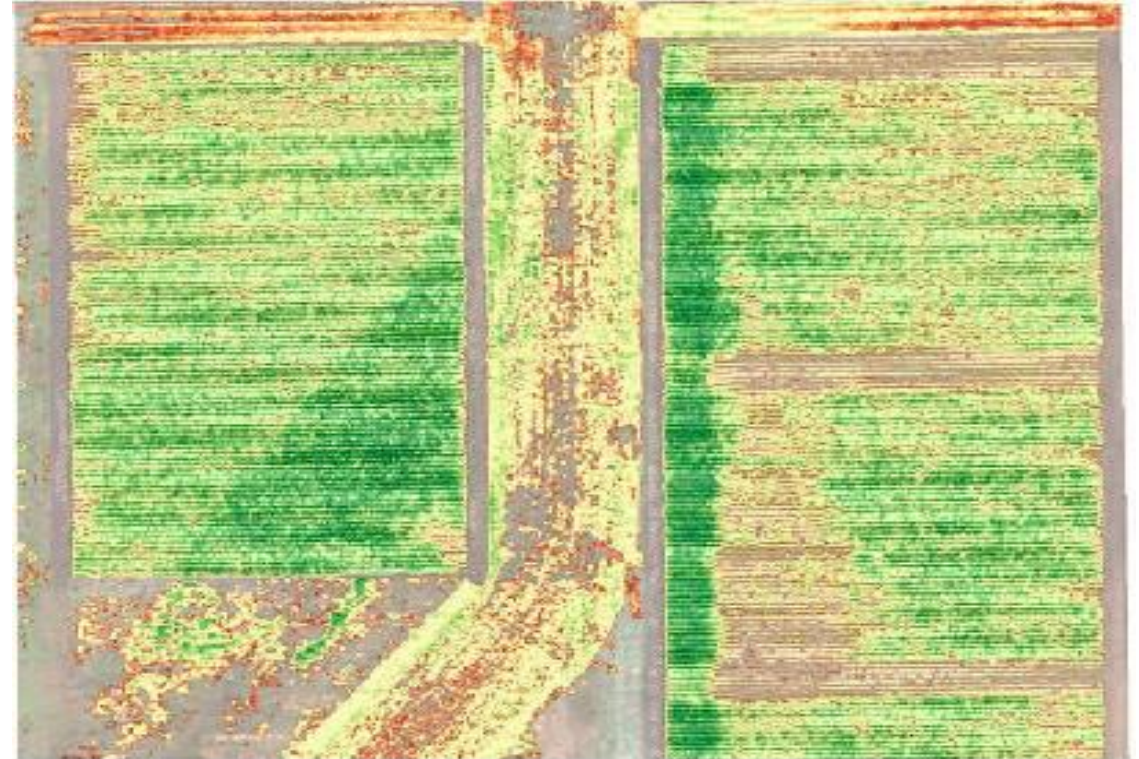
UAV Imaging



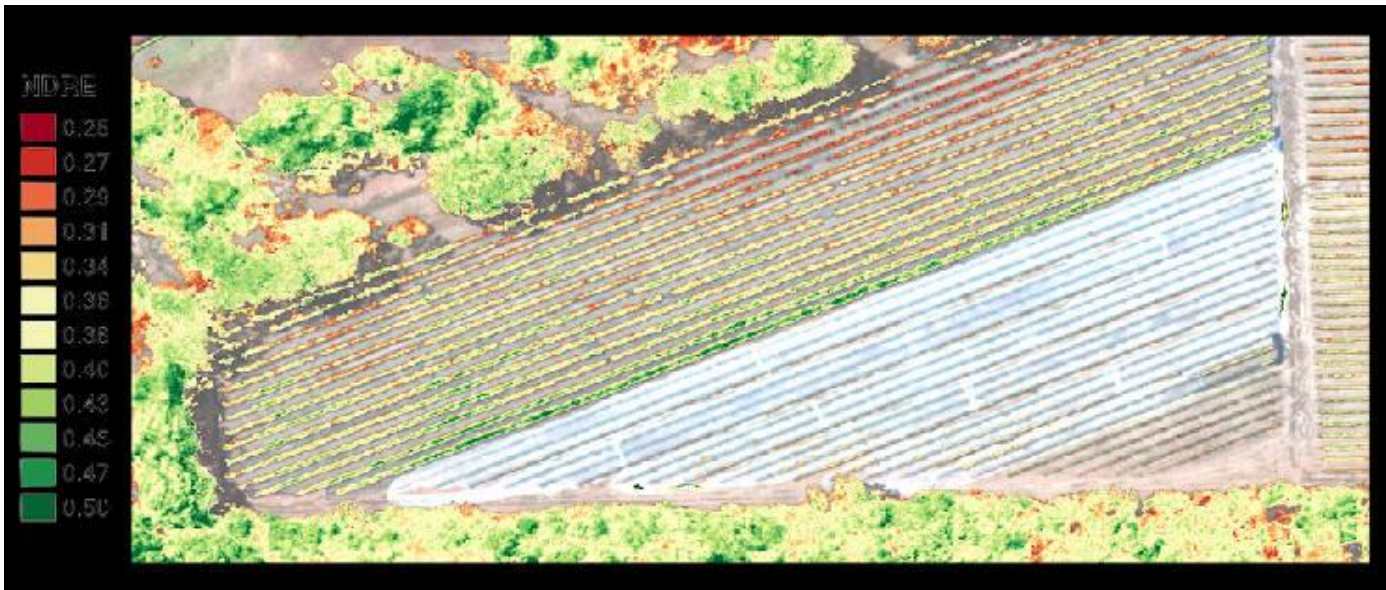
Converted Single Lens Camera
Blue, Green, Red



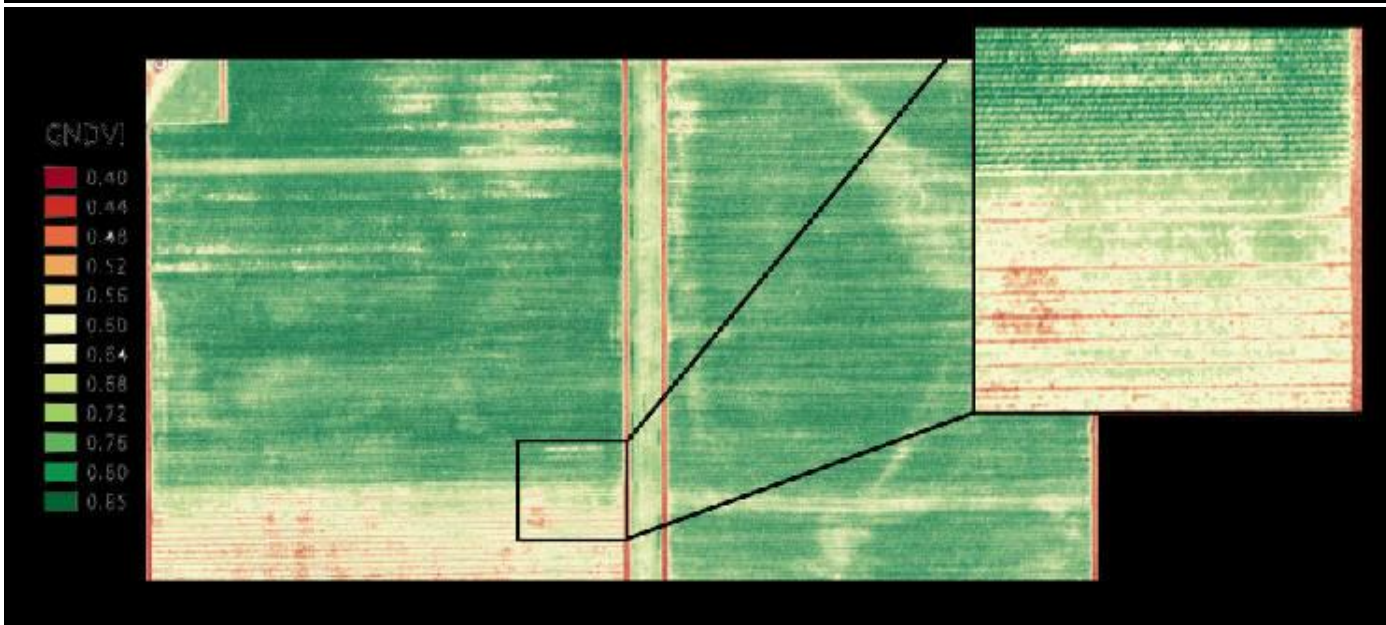
Multispectral Camera
Blue, Green, Red, Red Edge, Near-Infrared



UAV Imaging

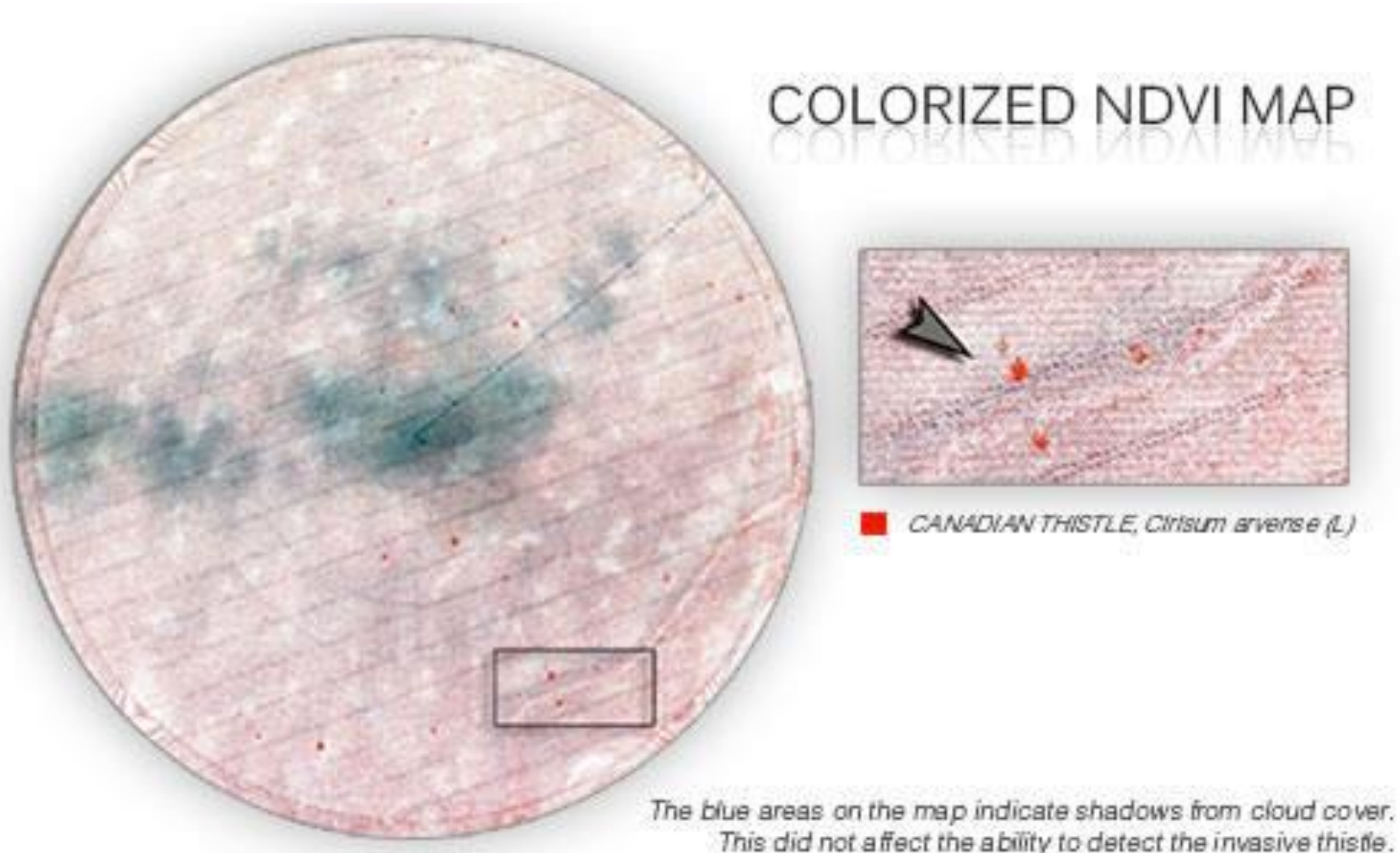


Vineyard (from 400 ft)
NDRE (Red Edge-Based NDVI)



Corn (from 400 ft)
Green-Based NDVI

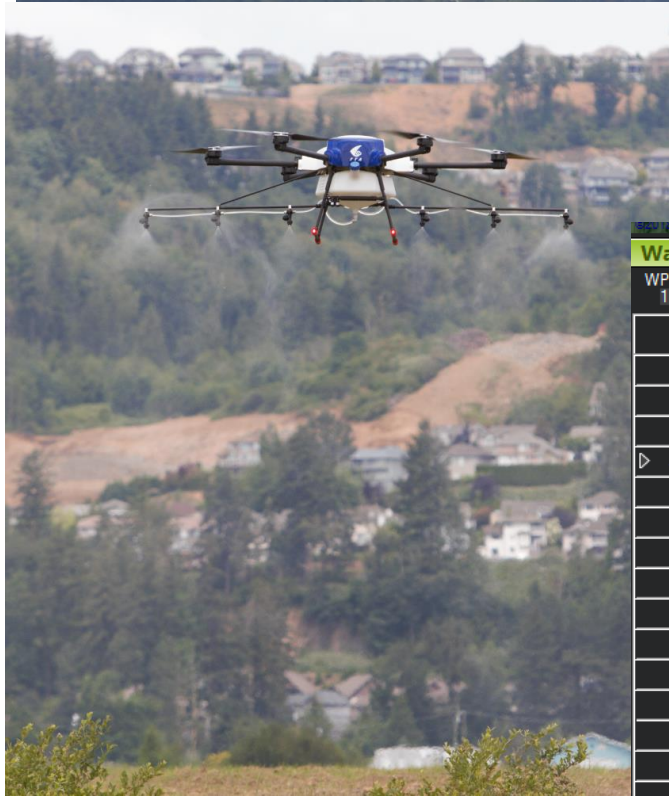
Invasive Species Detection: Canadian Thistle



A NDVI map helped confirm the presence of a Canadian Thistle infestation on this 122 acre corn field. A flat rate herbicide prescription was applied to the entire field. Aerial imagery inspections confirmed that only 0.6 acres required treatment.

An herbicide reduction of over 99% would have been possible with a variable rate prescription, decreasing the overall environmental impact and yield loss.

Crop Spraying



Waypoints

WP Radius: 1 Loiter Radius: 15 Default Alt: 100 Terrain ☐ Verify Height ☐ Add Below Alt Warn: 0 ☐ Spline

	Command	Dela				Lat	Long	Alt	Delete	Up	Down	Grad %	Angle	Dist	AZ
1	DO_CHANGE_SPEED	7	7	0	0	0	0	0	X			0	0	0	0
2	TAKEOFF	2	0	0	0	49.018691	-122.235375	5	X			0	0	0	0
3	WAYPOINT	1	0	0	0	49.018746	-122.235596	4	X			55.0	28.8	7.9	301
4	WAYPOINT	1	0	0	0	49.019326	-122.235614	4	X			0.2	0.1	64.5	359
5	WAYPOINT	1	0	0	0	49.019377	-122.235661	4	X			-0.7	-0.4	6.6	329
6	WAYPOINT	1	0	0	0	49.018745	-122.235633	4	X			-0.2	-0.1	70.3	178
7	WAYPOINT	1	0	0	0	49.018745	-122.235676	4	X			-3.3	-1.9	3.1	270
8	WAYPOINT	1	0	0	0	49.01942	-122.235703	4	X			0.3	0.1	75.1	358
9	WAYPOINT	1	0	0	0	49.019463	-122.235747	4	X			-1.0	-0.5	5.8	326
10	WAYPOINT	1	0	0	0	49.018745	-122.235717	4	X			-0.3	-0.2	79.9	178
11	WAYPOINT	1	0	0	0	49.018744	-122.235759	4	X			-3.2	-1.9	3.1	268
12	WAYPOINT	1	0	0	0	49.019505	-122.235788	4	X			0.3	0.2	84.6	359
13	WAYPOINT	1	0	0	0	49.019551	-122.235834	4	X			-0.9	-0.5	6.1	327
14	WAYPOINT	1	0	0	0	49.018746	-122.235797	4	X			-0.4	-0.2	89.6	178
15	WAYPOINT	1	0	0	0	49.018745	-122.235828	4	X			2.8	1.6	2.0	268



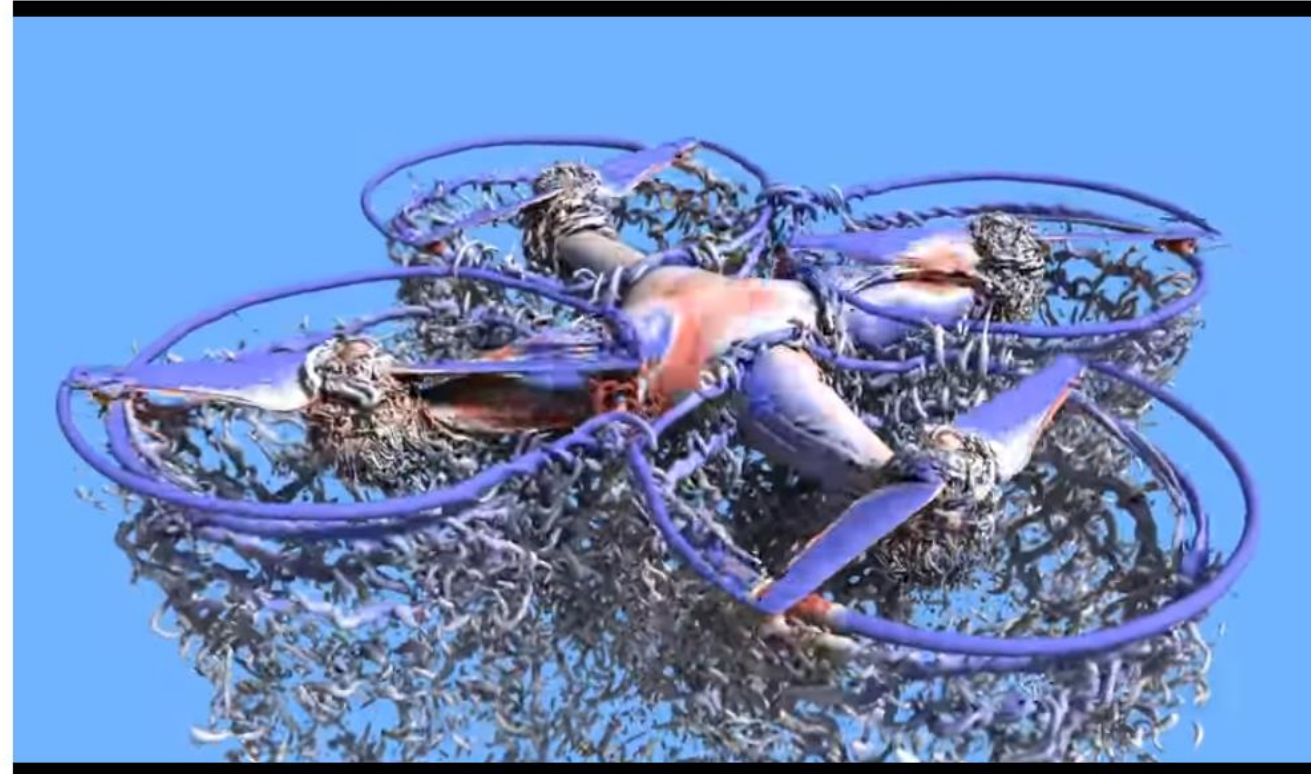
Operational Risks

- Aerial crop spraying
 - Starts before and ends after the field edge so there is overspray
 - Vortices and high speed entrain spray upwards and spray is more prone to evaporation
- Hand spraying
 - Operators dangerously exposed
 - Inconsistent application
 - High cost
- Vented orchard spraying
 - Operators exposed
 - Accelerate spray in fast outward blown moving air stream therefore evaporative loss is high
 - Spray upwards to reach the tips of plants so overspray and spray loss



Main Operational Benefits of UAVs

- Quality spray deposition:
 - Three dimensional wetting pattern due to turbulent vortices from up to eight rotors
 - Downward directed spray
 - Centimetre accuracy in spraying
 - Height control
 - Spray volume control
 - Speed control
 - Less drift than manned aerial application
- Safe and reliable operation
 - Preprogrammed autonomous flight
 - Failsafe systems
- Uses commercially available spray nozzles like Tee Jet
- Early access to water logged fields
- No soil compaction
- No crop damage
- Reduced applicator exposure to chemicals
- Targeted delivery reducing time and chemical costs.



Simulation of the DJI Phantom 3 during flight. Airflow interactions are shown as undulating lines. Pressure changes are shown using color. Areas of high pressure are red, low are blue.
Credits: NASA Ames Research Center/NASA Advanced Supercomputing Division/Tim Sandstrom

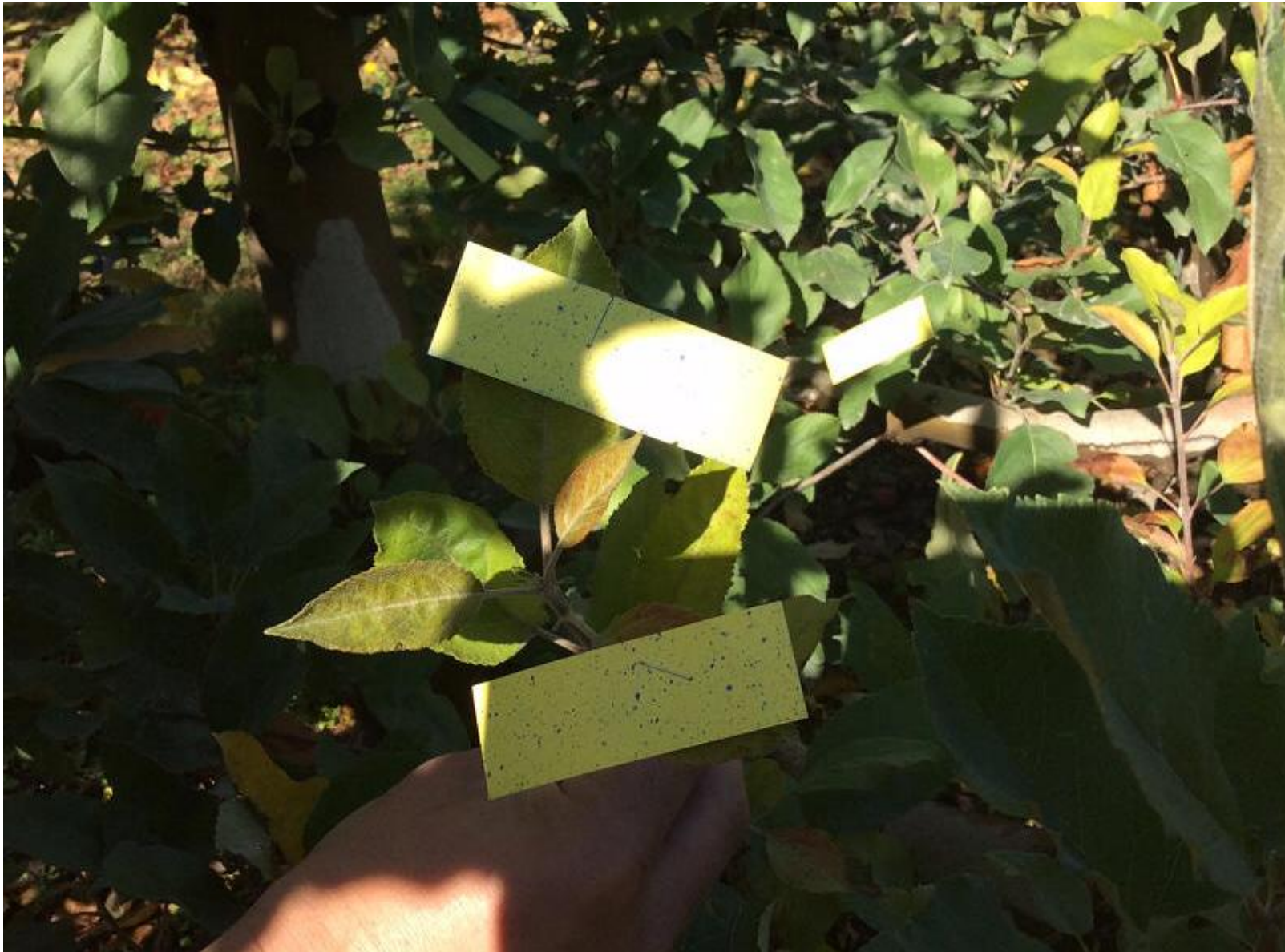
The UAV Litmus Test

Precision Spraying

- Even droplet distribution
- High coverage
- > 90% recovery
- ~ 30% reduction in chemical use



Spray Coverage on the Bottom of Leaves



Uniform Spray Distribution



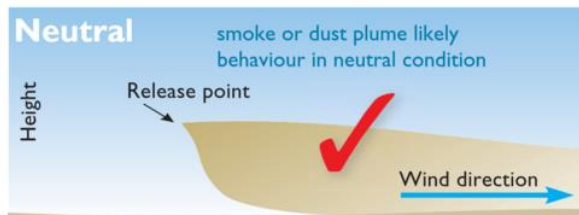
Meteorology



Stable conditions, most likely overnight. Smoke or dust may initially rise but will spread out at the inversion level and may slowly descend at some distance from the release point.



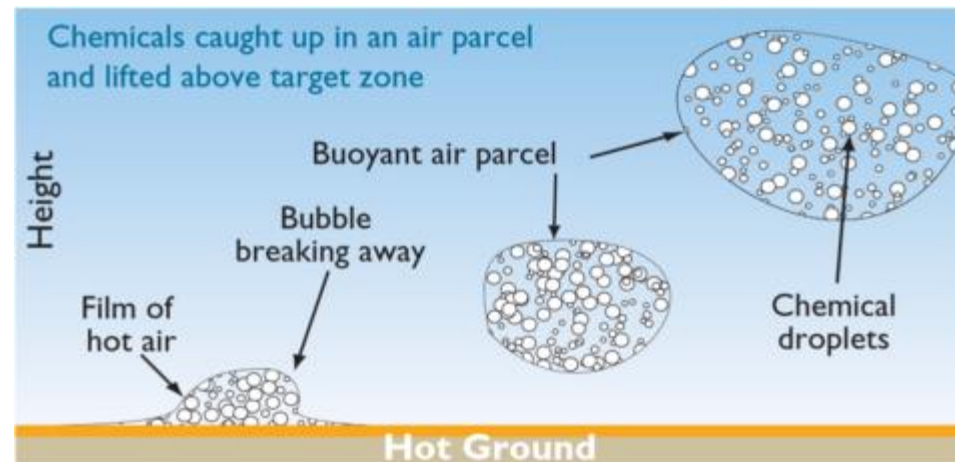
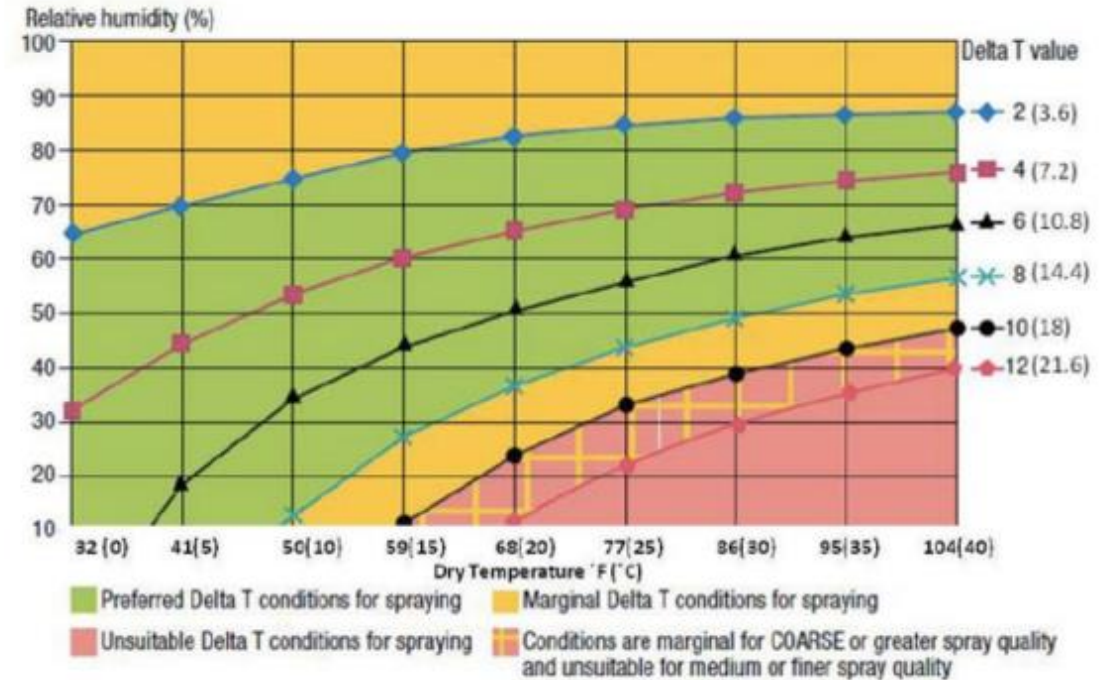
Unstable conditions, most likely mid-morning to late afternoon. Smoke or dust will rise vertically.



Neutral Conditions, most likely early morning and early evening. Smoke or dust will spread out in an even pattern and fall under gravity, reaching the ground a short distance from the release point.

Optimal spraying conditions

- Neutral stability
- Delta T (2-8 °C (max 10))
- Temperature (5-25°C)
- Wind between 0.5 and 4m/s
- Humidity above 45%
- Morning or evening



Images from Kestrel 5500AG

Washington State Performance and Efficiency Trials



VS



Operating Speed - 3.5 MPH. Coverage rate 1 acre per hour.

- Crop Loss- According to the farm manager, their annual loss is in excess of \$1,000,000 caused by the sprayers knocking the fruit off the plants.
- Best suited to high volume applications – higher drip collection on orchard floor. Soil build up of pesticide.

Operating Speed - 16-22 mph. Coverage rate 10 to 33 acres/hr

Fully Autonomous

Completely automated system

- Crop Loss - None = an increase in yields
- No soil compaction
- Quality spray deposition
- Less chemical needed – 30% reduction
- Limited collection of droplets on Orchard floor.
- Less drift
- Reduced applicator exposure to chemicals
- Safe and reliable operation
- Efficient and cost effective return on investment (ROI)
- Best suited to low volume applications

Cost Comparison

Cost Summary

Typical operational cost per acre:

- UAV Spray \$6 to \$15
- Aerial Spray \$7 to \$14
- Tractor Spray \$4 to \$15.5

Excludes:

- Labour (highest for tractor spraying)
- Initial capital costs (Lowest for UAV highest for aerial)
- Spray material costs
- Trampling cost (None for UAV and aerial spraying)

Average all in cost for vineyards with 12 year amortization on equipment:

- Tractor Spraying 50/hour
- UAV spraying typically \$25 - 35/hour (though data is still scarce)

BOTTOM LINE: Fungicide Application on Canola 50 Bus Canola @ \$11.00/Bus

Crop \$ 550.00	Crop \$ 550.00
By Air \$ 9.00/acre	By Ground \$ 7.50/acre
Trampling 0%	Trampling 3% \$ 16.50/acre
Total \$ 9.00/acre	Total \$ 24.00/acre

Your Bottom Line has Increased \$ 15.00/acre with Aerial Application!

BOTTOM LINE: Insecticide Application on Canola 50 Bus Canola @ \$ 11.00 /Bus

Crop \$ 550.00	Crop \$ 550.00
By Air \$ 9.00/acre	By Ground \$ 7.50/acre
Trampling 0%	Trampling 3% \$ 16.50/acre
Total \$ 9.00/acre	Total \$ 24.00/acre

Your Bottom Line has Increased \$ 15.00/acre with Aerial Application!

BOTTOM LINE: Preharvest Glyphosate Application on Wheat 50 Bus Wheat @ \$ 6.50/

Crop \$ 325.00	Crop \$ 325.00
By Air \$ 8.50/acre	By Ground \$ 7.00/acre
Trampling 0%	Trampling 3% \$ 9.75/acre
Total \$ 8.50/acre	Total \$ 16.75/acre

Your Bottom Line has Increased \$ 8.25/acre with Aerial Application!

Your profit has Increased \$ 19.5/acre with Aerial UAV Sprayer Application!

Preharvest Fungicide Application on Canola 50 Bus Canola (1.133 ton) @ \$ 12/Bus
 Crop value per acre \$ 600.00
 UAV Air Spray cost \$ 6.00/acre
 Trampling 0%
 Total cost \$ 6.00/acre

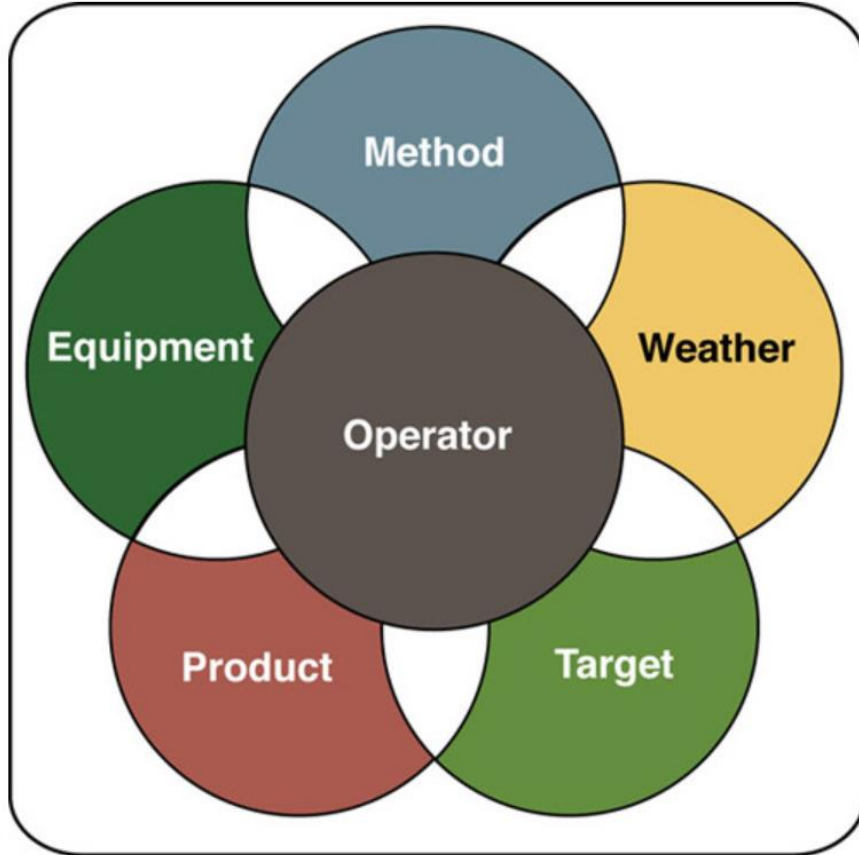
Ground spray cost \$ 7.50/acre
 Trampling 3% \$ 18/acre
 Total cost \$ 25.5/acre

<http://foxcouleeaviation.com/aerial.htm>
<https://www.agprofessional.com/article/big-range-custom-application-costs>
<https://www.slideshare.net/TylerKou1/drone-agriculture-spaying-service>

Service and Cost (No materials included in costs)	Average	Range
Spraying with a self-propelled ground applicator per acre	\$7.30	\$4.00 - \$15.50
Aerial spraying per acre	\$9.60	\$7.00 - \$14.00
Fertilizer applied per acre	\$4.50	\$1.00 - \$8.00
Strip-till per acre	\$17.10	\$15.00 - \$21.00
Trampling per acre	\$6.70	

A typical corn farm will produce an additional 20 to 30 bushels per acre when UAV applications are used. With a bushel selling for around \$4.4 (Price of Jun, 2016), in addition, the mist spray at lower attitude will save your fungicide/herbicide usage by up to 50%. A farmer would receive a net benefit of \$88 to \$150 per acre at an application cost of \$6 more. Obviously, This ratio of UAV application cost and profit gain is 1:20.

UAV Crop Spraying



Equipment	Method	Weather	Target	Product	Operator
Sprayer Design	Spray Technique	Wind	Canopy Morphology	Mode of Action	Aptitude
Air - Assist	Forward Speed	Speed	Time of Season	Timing	Attitude
Orientation	Work Rate	Direction	Density-Area	Formulation	
Volume	Crop-Adapted Spraying	Temperature	Target	Density	
Speed		Relative Humidity	Size	Adjuvants	
Deflectors			Location		
Spray Quality	Carrier Volume				
Pattern	Dose Rate				
Droplet Size					
Nozzle Orientation					

Regulators and Industry Groups – A Summary

- Health Canada
 - PMRA – Currently there are no pesticides/herbicides labelled for use with UAVs.
 - Manufacturers responsibility to test and then apply for label amendments.
- Transport Canada
 - Clear regulations.
 - Drone pilot training requirement.
 - SFOC with recording and reporting requirements.
 - Precision Crop Tech currently working on a risk based site assessment tool for spray applications.
- Ministry of Environment
 - Applicators certificate – Currently covers helicopters and planes – no UAV specific training/testing.
 - Commercial applicators require registration.
- Agriculture and Agri-Food Canada
 - Precision Crop Tech is on a working group to plan trials to test efficacy and trial key pesticides.
 - Flight Demonstrations planned in Ottawa in 2019.
 - Flight Demonstrations completed in Abbotsford and Kelowna in 2018.
- Industry Group- Canadian Aerial Applicators Association
 - Interested but not convinced of technology or safety.
 - Threat to aerial application. UAVs ideal for small farms with precision needs and cannot cost effectively spray large farms.
- Supplier Conformance
 - HSE based in the USA are the only manufacturer that have so far started working towards the requirements that have been set by the FAA and Transport Canada for type certification, maintenance schedules, flight tracking, dual redundancy navigation and control systems.



Field Services

- Soil Testing
- Plant Tissue Testing
- Field Monitoring Systems
- UAV Crop Imaging
- Data Processing and Interpretation
- UAV Crop Spraying



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UAV / Drone

- Full Crop Service
- Sales
- Leasing
- Training
- Maintenance



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