Unmanned Autonomous Vehicles (UAV) for Decommissioning

Section Number W12

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Agenda

- Study Introduction and Goals
- Methodology
- Drone Flight
- Data Analysis
- Conclusions

Regulations and Guidance

Regulatory Requirements

- 10 CFR Part 20, Subpart E
- TEDE < 25 mrem/year and ALARA

Guidance Documents

- NUREG-1575: Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)
- NUREG-1507: Minimum Detectable Concentrations with Typical Radiation Survey for Instruments for Various Contaminants and Field Conditions
- NUREG-1757: Consolidated Decommissioning Guidance

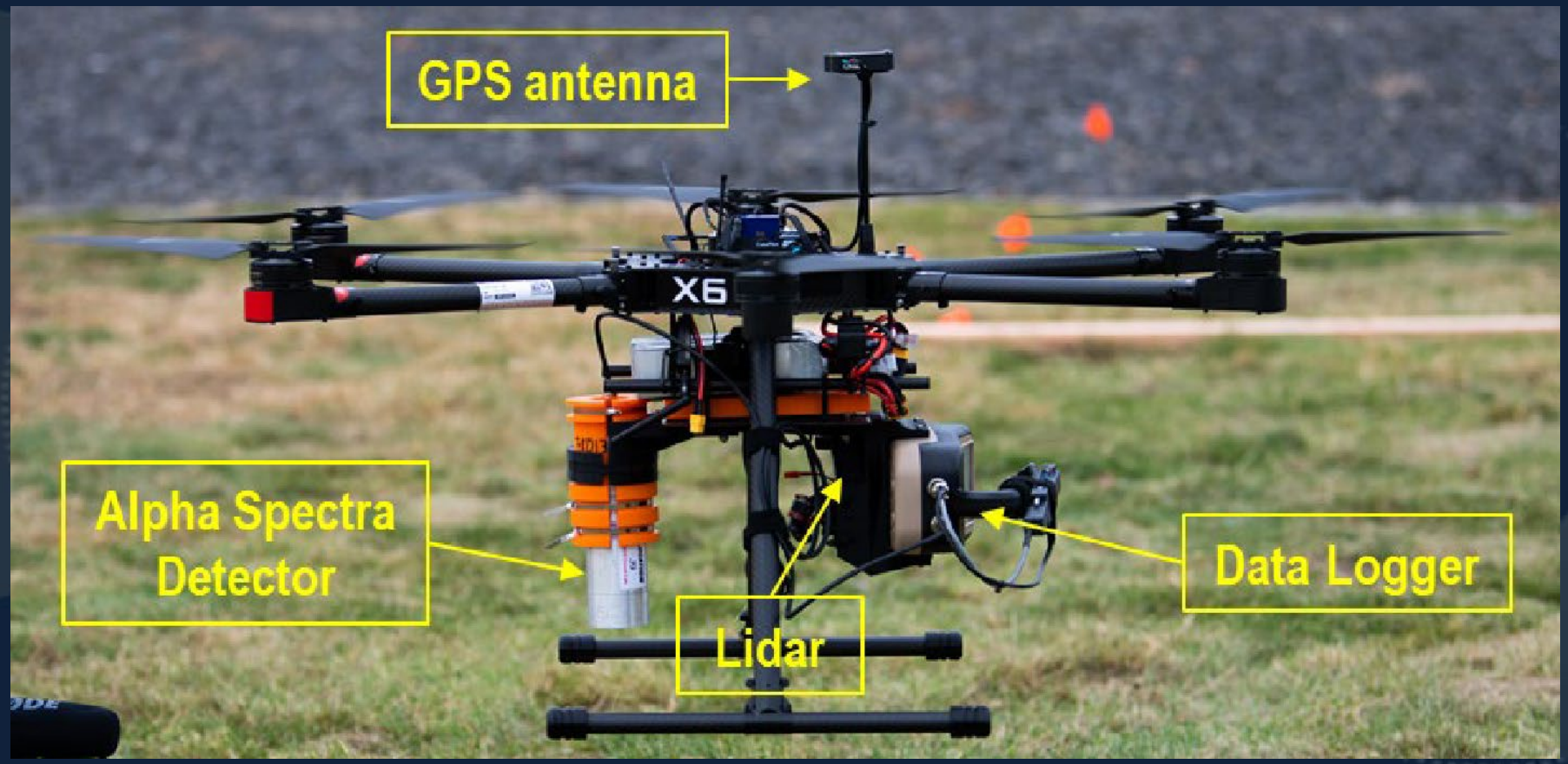
Proof of Concept and Key Questions for Analysis

Did observed UAV paths differ from human planned paths?

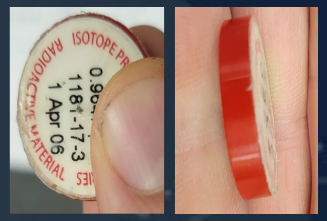
Did survey deviation impact survey results?

Were radiological measurements from human and UAV surveys significantly different?

Aurelia X6 Drone and Payload



Sources and Flight Path Source Position



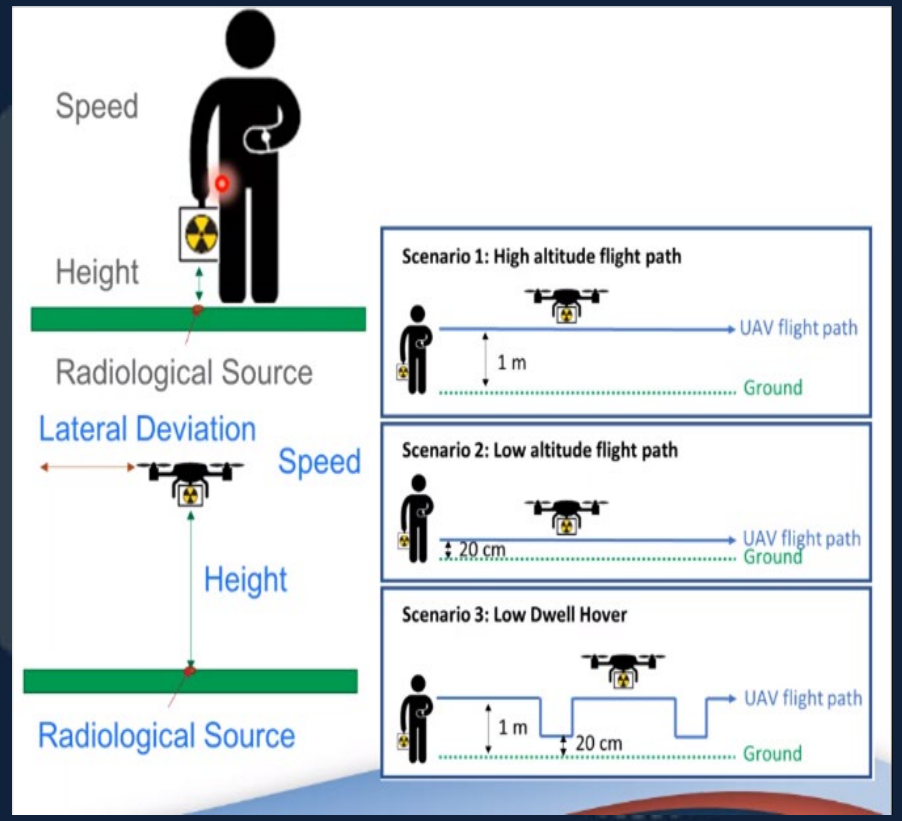
Cs-137 Button/Check Source

Check Source Number	Radionuclide	Activity (µCi) [b]	Distance from Start of Transect (m)
1	Cs-137	13.24	6
2	Am-241	25.19	12
3	Cs-137	3.54	18
4	Cs-137	6.88	24
5	Co-60	5.39	30
6	Co-60	10.28	36
7	Am-241	16.97	42
8	Co-60	3.63	48
9	Am-241	39.34	56

3440 area located at PNNL

PNNL's 3440 Outside Test Track

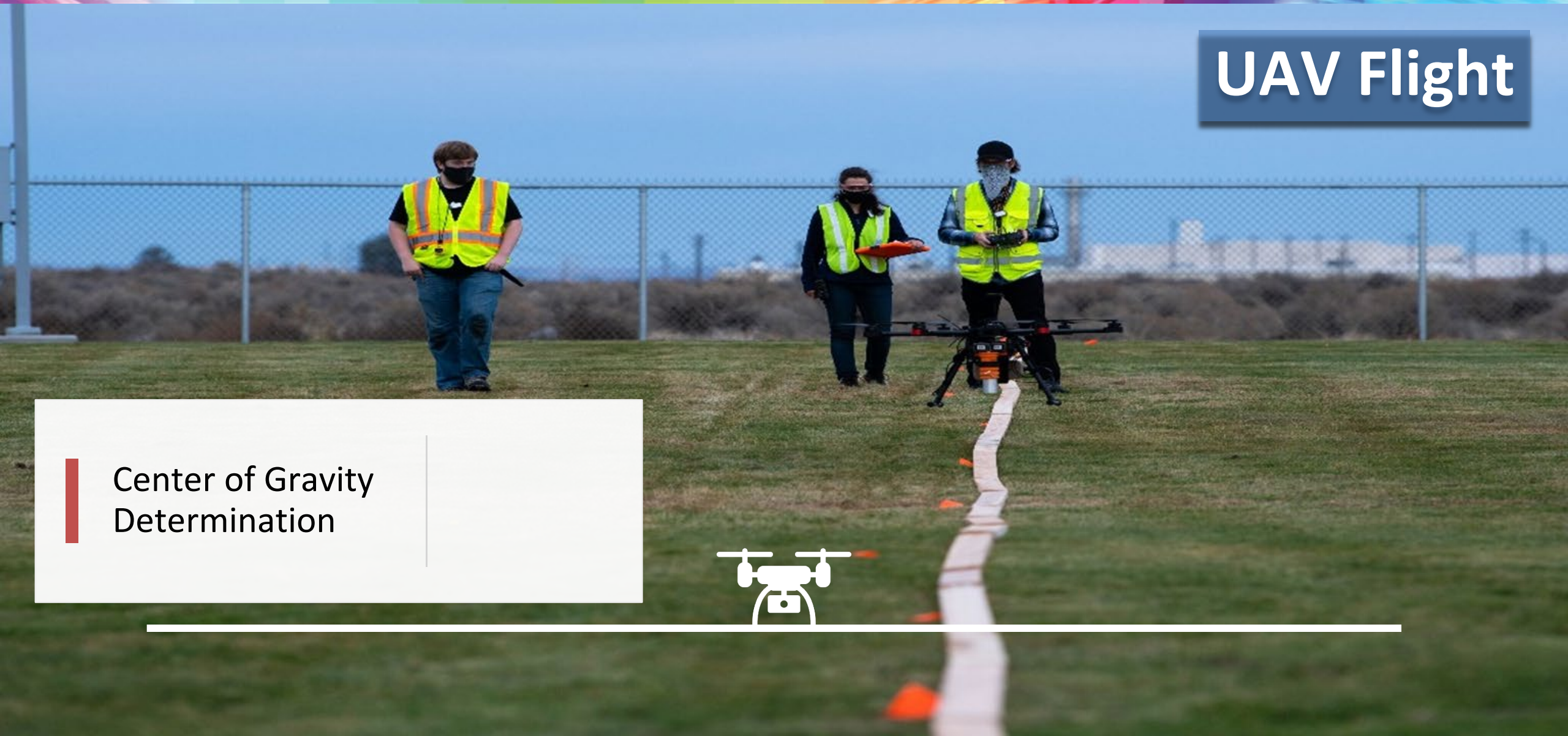
Scanning Technique



Scenario	Survey	Surveyor	Survey Altitude	Detector	Transect	Minimum Altitude (cm)	Maximum Altitude (cm)	Average Altitude (cm)	Median Altitude (cm)	Average Velocity (m/s)
1	9	UAV	Low	Ludlum	Source	2.3	201.3	18.6	15.3	0.20
					Background	-	-	19.3	16.3	0.20
	10	Human	Low	Ludlum	Source	26.4	46.4	32.5	30.4	0.20
					Background	-	-	31.5	30.4	0.20
2	11	UAV	Low	Alpha Spectra	Source	4.2	51.2	27.1	26.2	0.19
					Background	-	-	26.8	25.2	0.19
	6	Human	Low	Alpha Spectra	Source	28.5	51.5	40.2	39.5	0.21
					Background	-	-	35.7	33.5	0.20
3	1	UAV	High	Ludlum	Source	72.1	298.1	91.3	87.1	0.23
					Background	-	-	84.4	81.1	0.26
	2	Human	High	Ludlum	Source	101.5	127.5	108.7	108.5	0.20
					Background	-	-	107.2	107.5	0.18
4	12	UAV	High	Alpha Spectra	Source	84.6	130.6	96.9	96.6	0.19
					Background	-	-	100.5	100.6	0.20
	4	Human	High	Alpha Spectra	Source	97.6	130.6	104.3	105.4	0.20
					Background	-	-	104.1	104.6	0.19

Attribute	Predicted	Actual
Height	5-15 cm	3-100 cm
Speed	0.2-1 m/s	0.2 m/s

UAV Flight

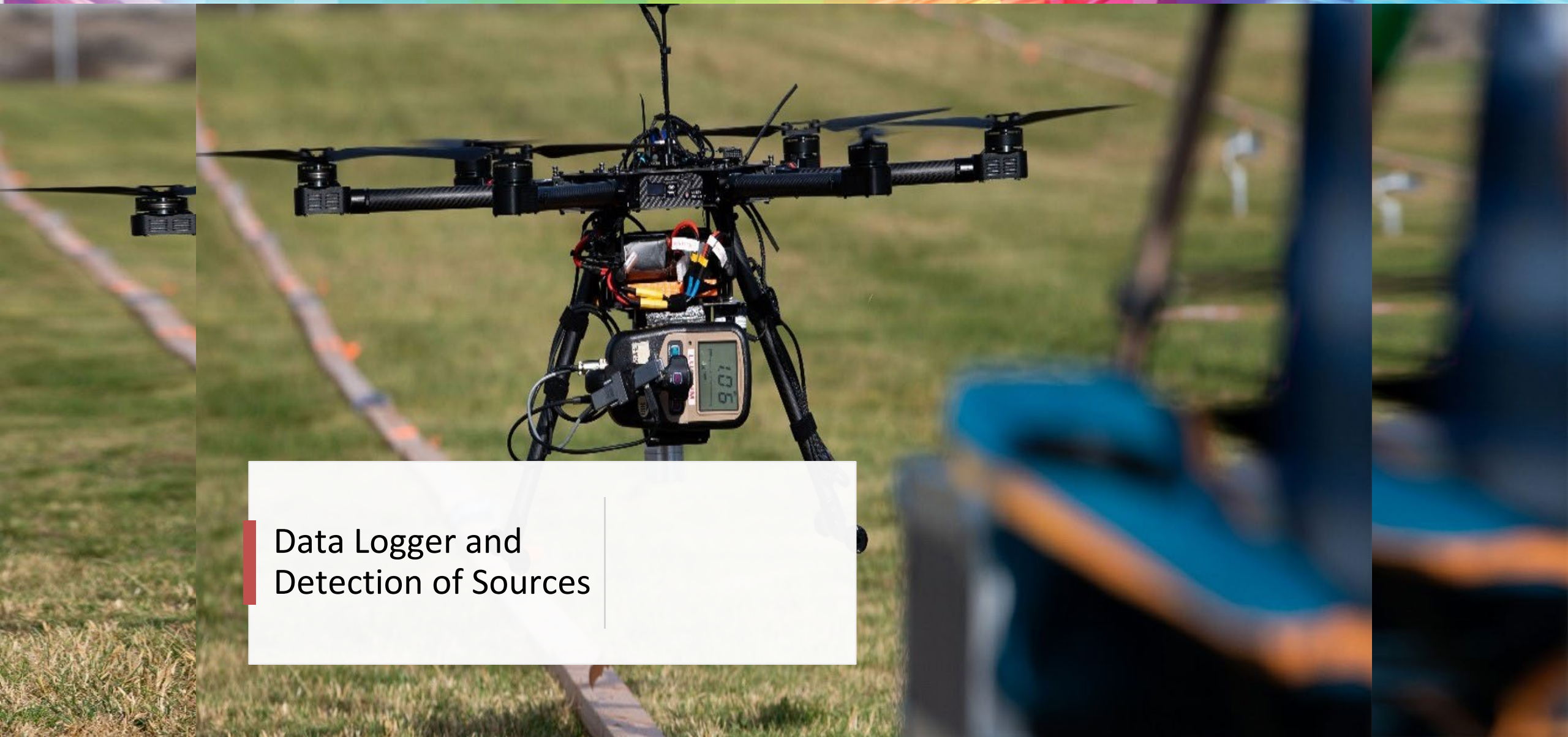


Center of Gravity Determination

NaI(Tl) Detector	Location	Height (cm)	Count rate (kCPM)
Ludlum (2 in x 2 in)	Center	20	7.80
Alpha Spectra (2 in x 0.04 in)	Center	20	1.29
Ludlum (2 in x 2 in)	Center	50	7.87
Alpha Spectra (2 in x 0.04 in)	Center	50	1.29
Ludlum (2 in x 2 in)	North	50	7.82
Alpha Spectra (2 in x 0.04 in)	North	50	1.22
Ludlum (2 in x 2 in)	East	50	6.81
Alpha Spectra (2 in x 0.04 in)	East	50	1.06
Ludlum (2 in x 2 in)	South	50	6.84
Alpha Spectra (2 in x 0.04 in)	South	50	1.02
Ludlum (2 in x 2 in)	West	50	6.73
Alpha Spectra (2 in x 0.04 in)	West	50	1.03

Background Measurements

Human Simulation

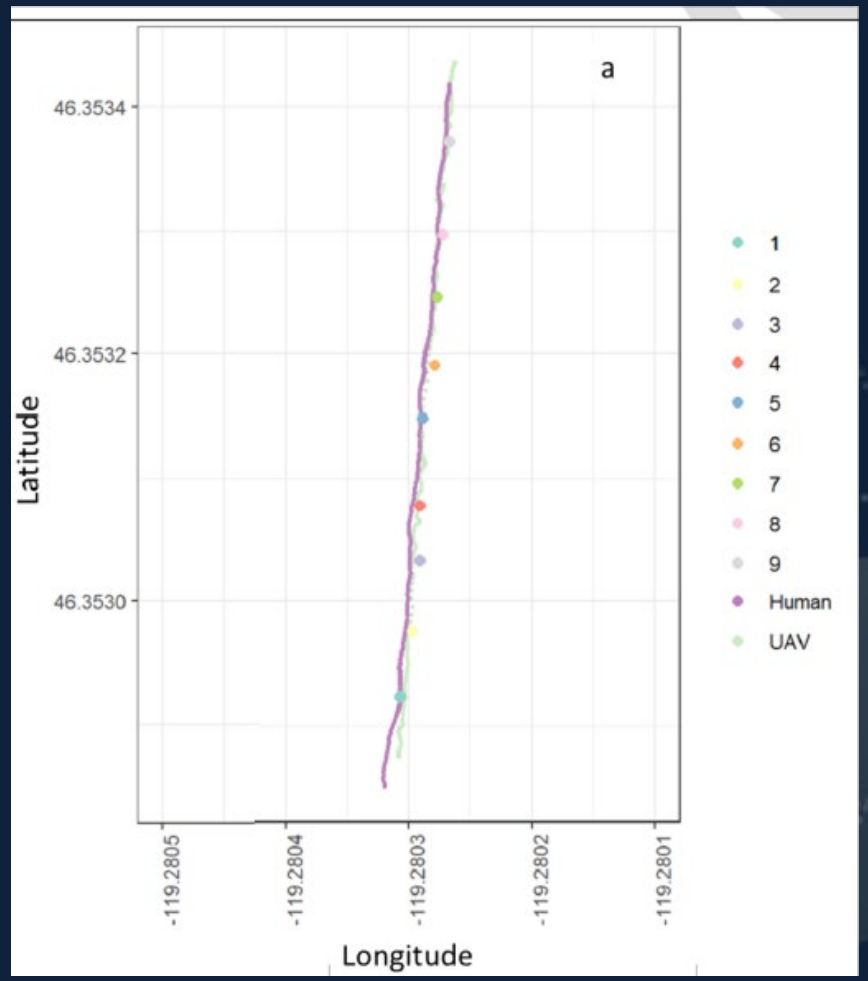


Data Logger and Detection of Sources

Q1 Results: UAV Paths vs. Human Paths?

Statistical equivalence between UAV and human paths

Max slope deviation of 1.9



Q2 Results: Survey Deviation Impacts?

Velocity Variation

±0.3 m/s

Between 1.8-2.6 m/s for human and UAV

Altitude Variation

Greatest for drone in all surveys

Higher altitude surveys had less variation

Q3 Results: Significant Differences in Radiological Measurements?

Scenario	Survey	Vehicle	Instrument	Slope	Absolute difference in slope	p-value	Are the Surveys Statistically Different?
1	9	UAV	Ludlum	11.6442	0.3605	0.5679	No
	10	Human	Ludlum	12.0047			
2	11	UAV	AS	12.6255	0.9123	0.5169	No
	6	Human	AS	11.7132			
3	1	UAV	Ludlum	12.7976	1.6598	0.1179	No
	2	Human	Ludlum	11.1378			
4	12	UAV	AS	13.3101	1.8682	0.0529	No
	4	Human	AS	11.4419			

$\alpha^* = 0.0125$, level of statistical difference for comparison to p-value using equation 7 and a total of 4 tests.

Overall Conclusions

UAV has potential in decommissioning

Ludlum detectors work well in low and high altitudes

Commercially available equipment able to perform surveys

Recommendations for Next Steps

Optimize integration of radiation detection instruments

Consider other radionuclides and detector types

Address environmental condition variation in experimental development

Project Team

Name	Technical Need
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*denotes intern or co-op

Thank you.

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