Drones for Decommissioning, an Update…

Pacific Northwest NATIONAL LABORATORY

FALL 2021 RAMP INT'L USERS GROUP MEETING

October 25 – November 4, 2021

Amoret Bunn

with Harish Gadey, Tracy Ikenberry, Deb Fagan, Moses Obiri, Kelly O'Malley & Katie Wagner

Pacific Northwest National Laboratory

RAMP

PNNL-SA-167713

Outline

- Drones = Unmanned Aerial Vehicles (UAVs)
- Using UAVs for Decommissioning
- Goal, Technical Approach and Next Steps…

Drones are…

- Unmanned Aerial Vehicle (UAV)
  - An aircraft ***without*** a human pilot on board
  - Unmanned Aerial System (UAS) is the UAV, ground-based controller and communication system
- Operate under remote control by a human operator (pilot)…

  or with various degrees of autonomy

PNNL's Fixed-wing drone, Arctic Shark

Multirotor UAV

Using UAVs for Decommissioning

Pacific Northwest NATIONAL LABORATORY

Radiological surveys for decommissioning is currently completed by a human collecting scanning data

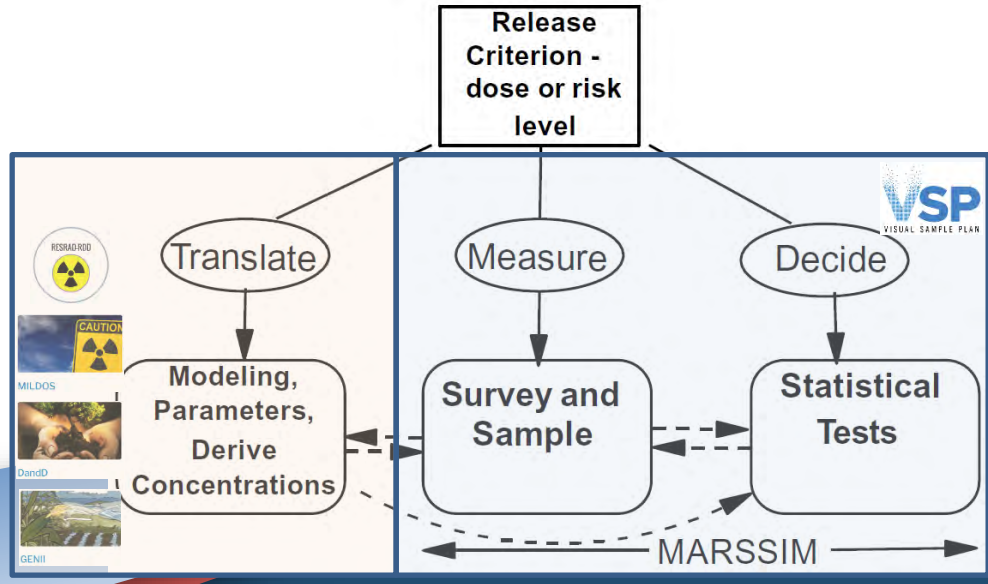
- **Minimum Detection Concentration (MDC)**: DCGL (action level) very low for a final status survey
- **Time**: Human survey took 5 days, with 2 staff

Survey Area:
0.5 Km^2
(5 hectare)

Application of UAVs for NRC's Decommissioning

Pacific Northwest NATIONAL LABORATORY

- Decommissioning is performed in accordance with 10 CFR 50, as part of termination of license (10 CFR 50.82) and release of facility or site for unrestricted use (10 CFR 50.83 and 10 CFR Part 20, Subpart E).
- Guidance for conducting surveys includes:
  - Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) NUREG-1575
  - Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Condition (NUREG-1507)
- Criteria for Decommissioning (10 CFR 20, Subpart E):
  - Site will be considered acceptable for unrestricted use if residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group **does not exceed 0.25 mSv/year** (25 mrem/year)



RAMP

Goal of Project

Goal:

- ✓ Demonstrate use of UAVs (drones) for decommissioning activities, improving knowledge of scanning systems, meeting Action Levels (DCGLs) and for possible inclusion in guidance documents and computer tools (such as VSP)

How: Outdoor Scenario

- ✓ Test and evaluate UAVs ability to meet the Data Quality Objectives (DQOs)

Hypotheses:

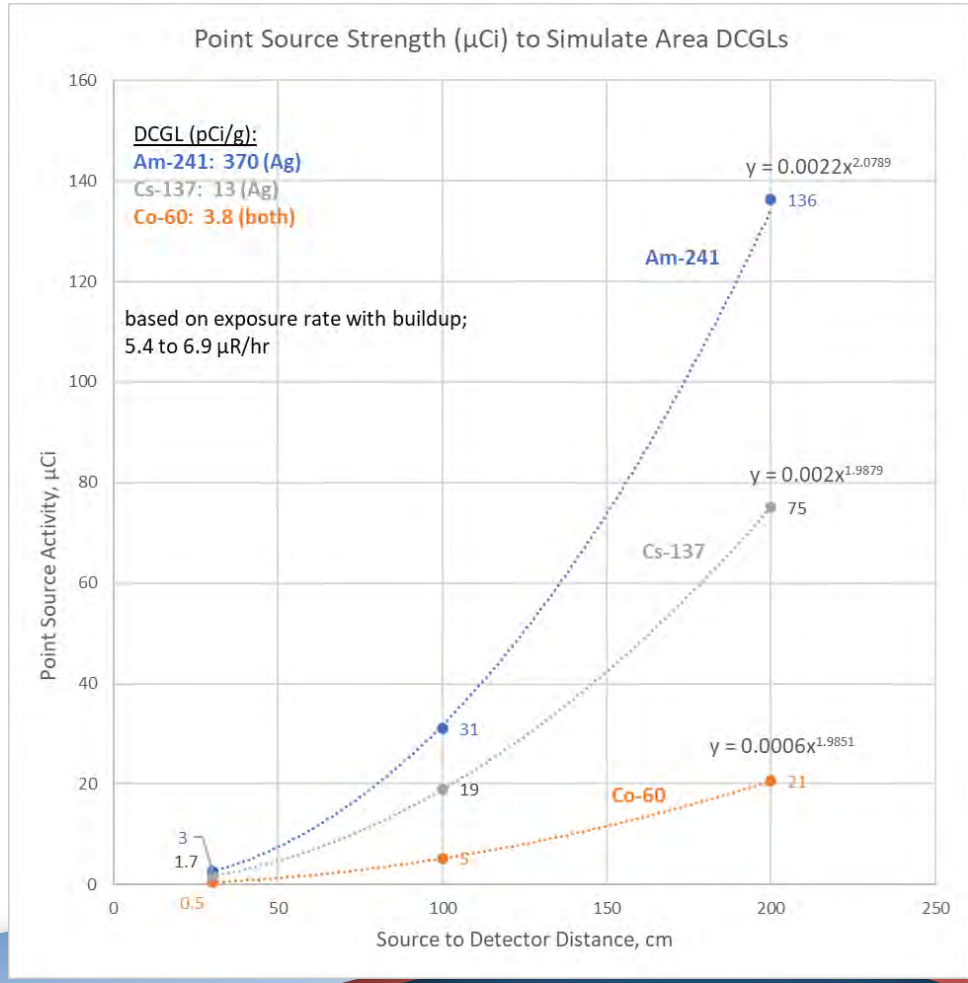
H_0: Measured radionuclide distributions between human and UAV surveys are the same

H_A: Measured radionuclide distributions between human and UAV surveys are different

Technical Approach: Radionuclides for Evaluation

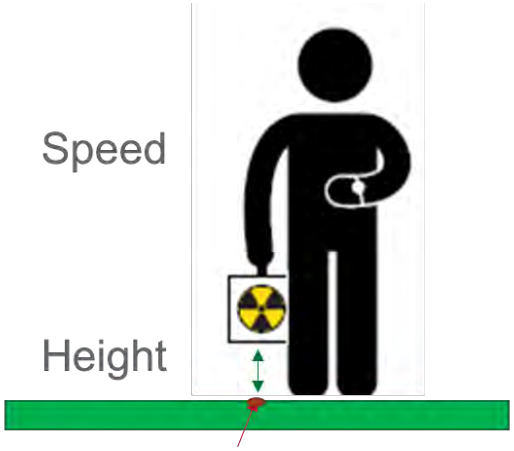
- Initial plan based on review of decommissioning documents:
  - Co-60
  - Cs-137
  - Am-241
  - Sr-90
- Translation of 25 mrem/yr to Derived Concentration Guideline Levels (DCGLs)
  - 10 CFR 20.1402, NUREG-1575 and NUREG-1757

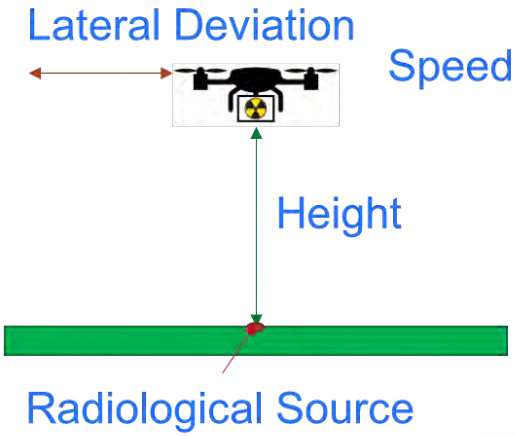
Nuclide	DCGL (pCi/g)	Point Source Activity (µCi)		
		30 cm	100 cm	200 cm
Co-60	3.8	0.5	5	20
Cs-137	13	2	20	75
Am-241	370	3	30	140

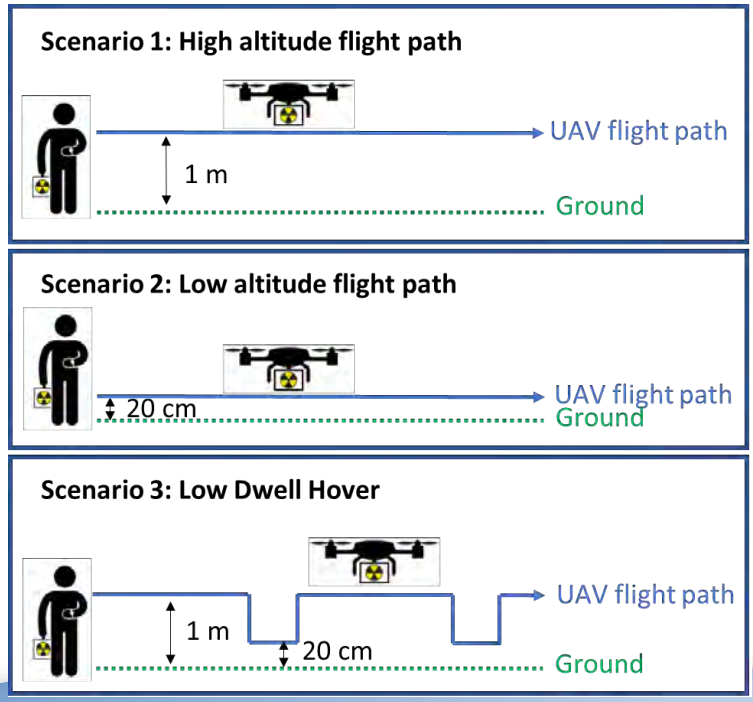


Technical Approach: Data Collection

- Human survey design:
  - NUREG-1507
  - NUREG-1575
- Height
  - 20 cm
  - 1 m
  - Low Dwell Hover
- Speed
  - 0.2 m/s
  - 1 m/s







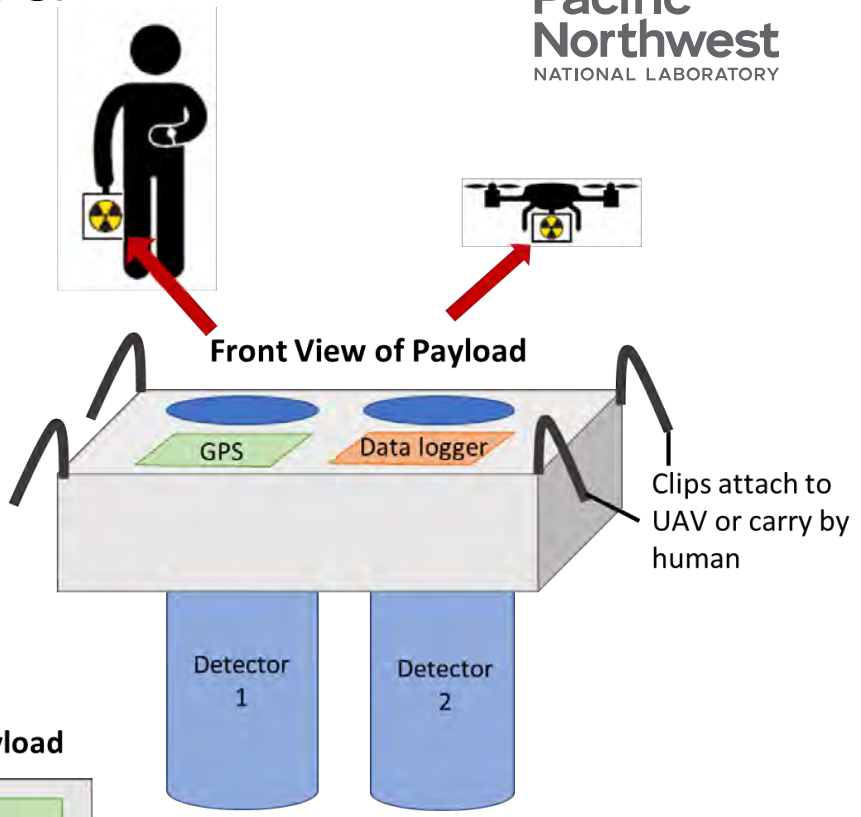
UAV (Drone)

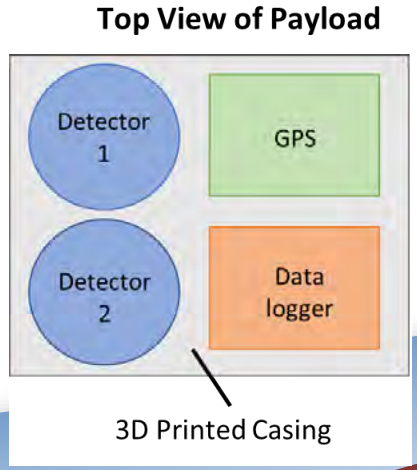
- UAV Options at PNNL expanding:
  - For payload weight, need a hexacopter (i.e., 6 propellers)
  - All options meet criteria for Federal standards and E.O. 13981

Aurelia X6

UAV Payload

- Radiation detectors
- Data Logger
- GPS
- Key decisions:
  - Availability of instruments
  - UAV concerns:
    - Weight
    - Center of gravity (balance)





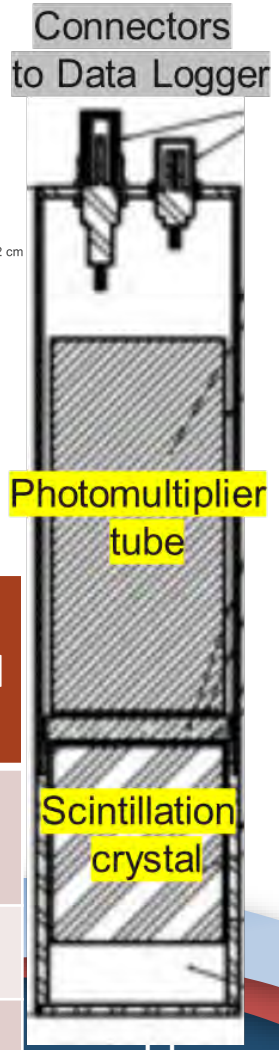
Payload: Radiation Detectors

Pacific Northwest NATIONAL LABORATORY

Selected Detector: NaI Scintillation Detectors

- Rationale for NaI scintillation detector:
  - Abelquist (2014): "Outdoor scans are usually performed using NaI scintillation detectors with various sized NaI crystals."
  - Time to respond – fast (milliseconds or less)
  - Sensitive – for isotopes of interest
  - Rugged
- For Proof-of-Concept to meet NRC Decommissioning criteria: Only need count rate detector
- Calibration of detectors prior to surveys

Ex. Cs-137 Button (or Check) Source



Isotope	Energy*	NaI Detector 1 2" ϕ x 2" thickness crystal 250 keV - 1.5 MeV range	NaI Detector 2 2" ϕ x 0.04" thickness crystal 20 keV - 300 keV range
Co-60	1173 keV, 1333 keV	X	
Cs-137	662 keV	X	
Am-241	59 keV		X

Payload: Radiation Detectors, continued

Pacific Northwest NATIONAL LABORATORY

a priori Minimum Detectable Concentration (MDC)

$$MDC\ (pCi/g) = \frac{d' \times \sqrt{b_i} \times (60/i)}{\sqrt{p} \times CPMR \times ERC}$$

d': index of Sensitivity

b_i: background (cpm)

i: counting interval (sec)

p: surveyor efficiency

CPMR: counts per µR/hr

ERC: µR/hr per pCi/g

Notes:

- Variables related to human factors: d', p, and i
- Experimental conditions will change the MDC, therefore PNNL will calculate a range for the study, covering options for height, speed, isotope-specifics, and other variables.

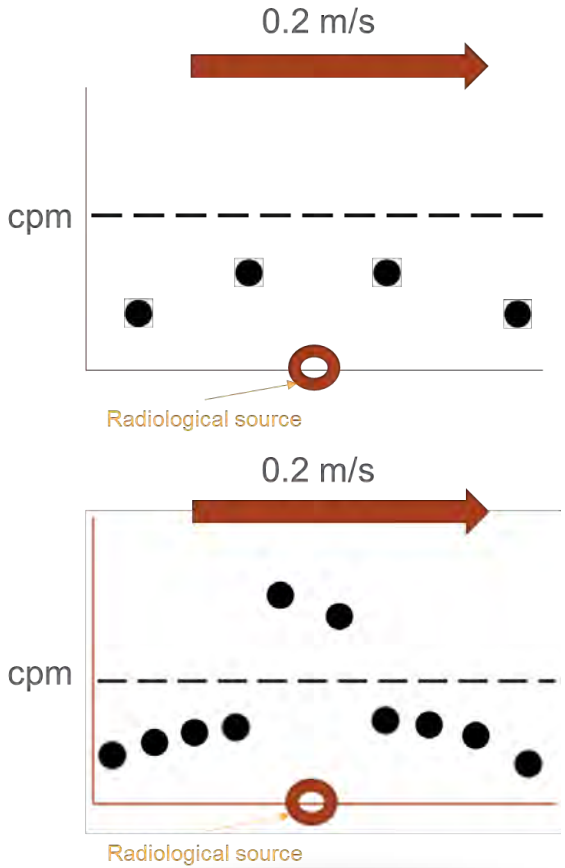
Reference: NUREG-1507, Rev. 1, page 6-13

RAMP

Payload: Data Logger

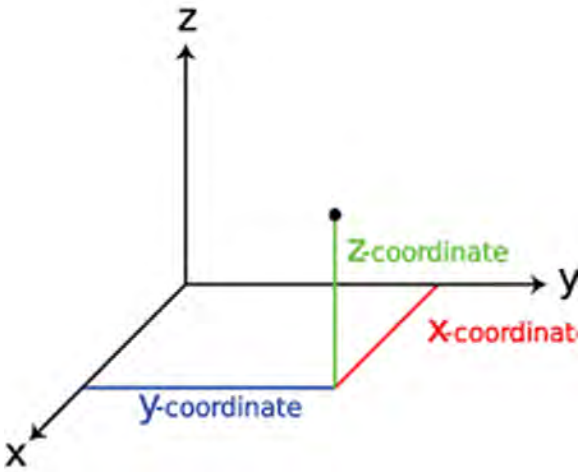
Ludlum 3000 Digital Survey Meter

- Typical manufacturer/model for decommissioning surveys
- Optimal pairing with radiation detectors
- Modified with serial port for increased data storage
  - Typical system <2000 records
  - We need more data for the speed of surveys, ensuring we do not miss the sources
- Modified to reduce weight



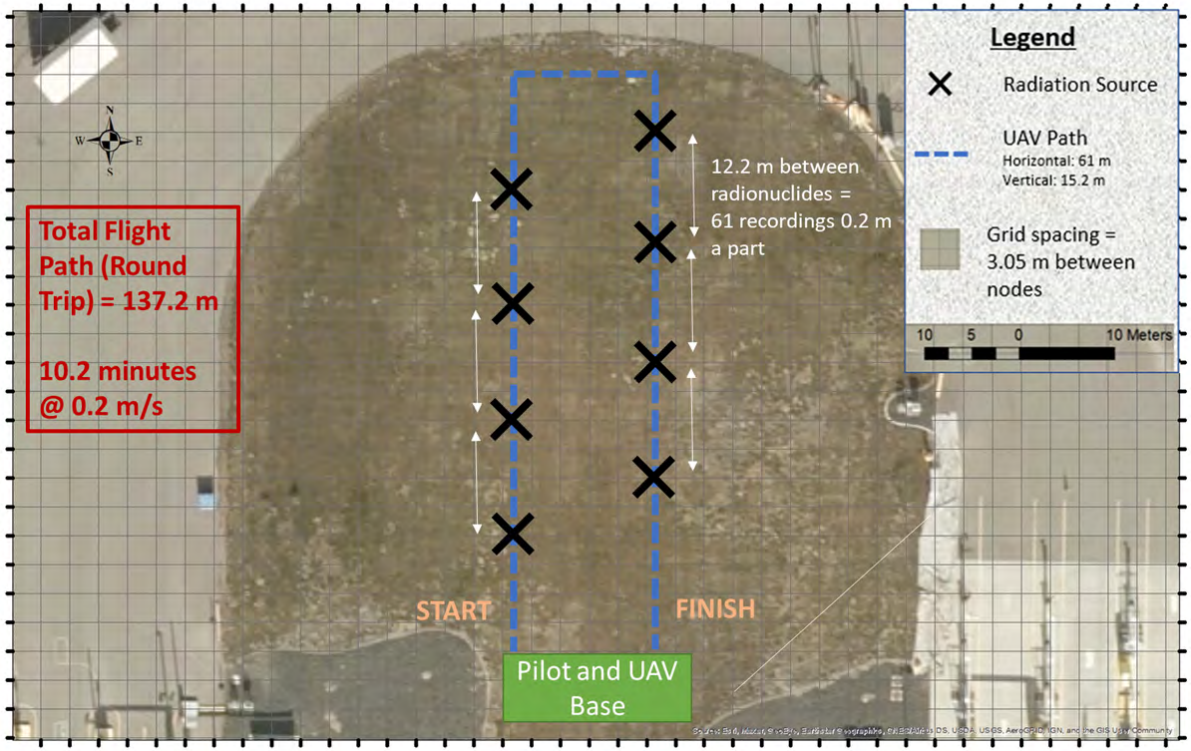
Payload: Geospatial device

- Need to know position of payload in 3 dimensions and time
  - Accuracy and precision important for this study
- Position information will be linked to radiation measurements
  - Data logger records CPM and time
  - GPS records x, y, z positions and time



Collection of data: Human and UAV

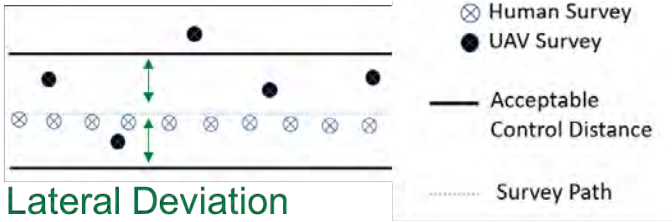
- One data logger, 2 detectors
- Background measurements
  - Conducted before button sources deployed
- Radiation measurements



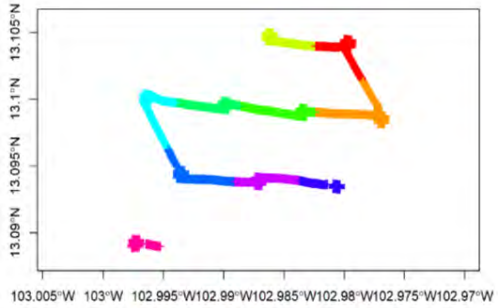
Data Analyses: Statistical Approach

Pacific Northwest NATIONAL LABORATORY

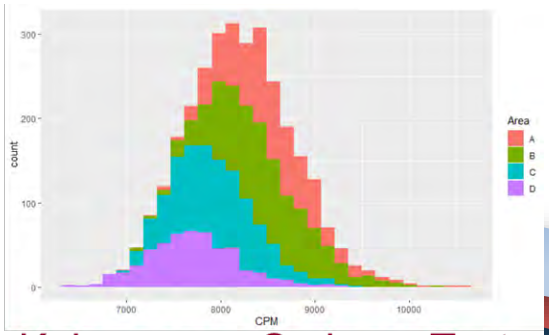
- Lateral Deviation: Navigational accuracy
  - Mean distance & standard deviation between detector location and source on survey path
- Continuous scan data, spatial distribution: Moran-I Test
  - Result will partition continuous data collected across the survey path into zones
  - Zones are analyzed next
- Data distribution: Kolmogorov Smirnov Test
  - Compares mean, standard deviation, and shape of two dependent datasets (e.g., zones) from human and UAV surveys



Lateral Deviation



Moran-I Test



Kolmogorov Smirnov Test

Next up…

- Plans for data collection in November 2021
- Final report
  - Data analysis
  - Define the scientific/technical opportunities for the future of “Drones for Decommissioning”

Questions?