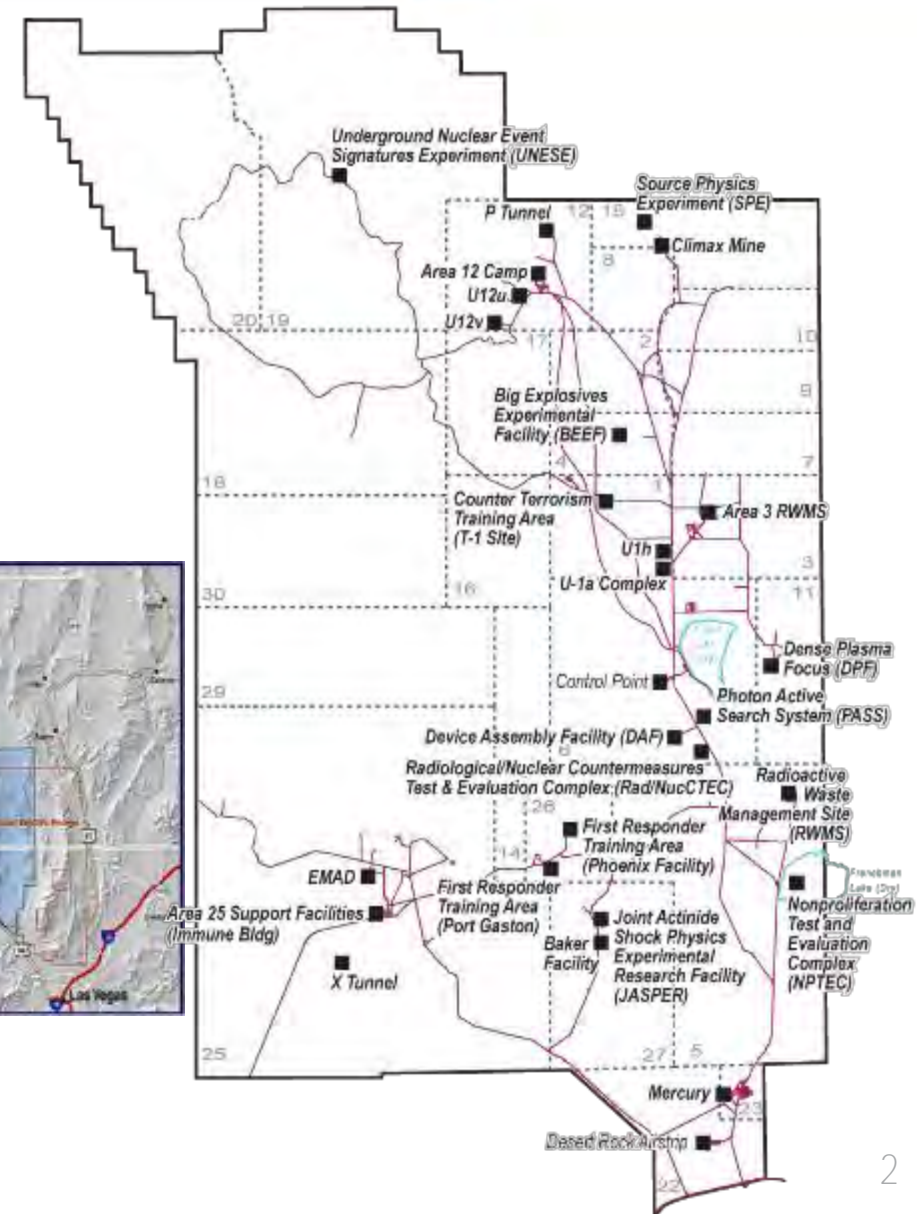


Autonomous Ground-based Robotic System for Preparatory Consequence Management Radiation Mapping and Forensic Studies

This work was done by Mission Support and Test Services, LLC, under Contract No. DE-NA0003624 with the U.S. Department of Energy National Nuclear Security Administration Office of Emergency Operations, Office of Defense Programs, and supported by the Site-Directed Research and Development Program. DOE/NV/03624--1991.

Nevada National Security Sites: Unique Natural Resource

- Ideal location
 - ▣ Size
 - ▣ Remoteness
 - ▣ Free from encroachment
 - ▣ Safe and secure
- Large: 1,355 square miles of federally owned land – Size of Rhode Island
- Surrounded by Nevada Test and Training Range
- Safe: Outstanding safety record; VPP Superior Star
- Diverse: Supports a wide range of national security missions



Nevada National Security Sites - Missions

- ❑ The Nevada National Security Site helps ensure the security of the United States and its allies by supporting the stewardship of the nuclear deterrent, providing emergency response capability and training, and contributing to key nonproliferation and arms control initiatives.
- ❑ We execute unique national-level experiments, support national security customers through strategic partnership programs, manage the legacy of the Cold War nuclear deterrent, and provide long-term environmental stewardship for site missions.

Stockpile Stewardship



Global Security



**Environmental
Management**



US DOE/NNSA Consequence Management

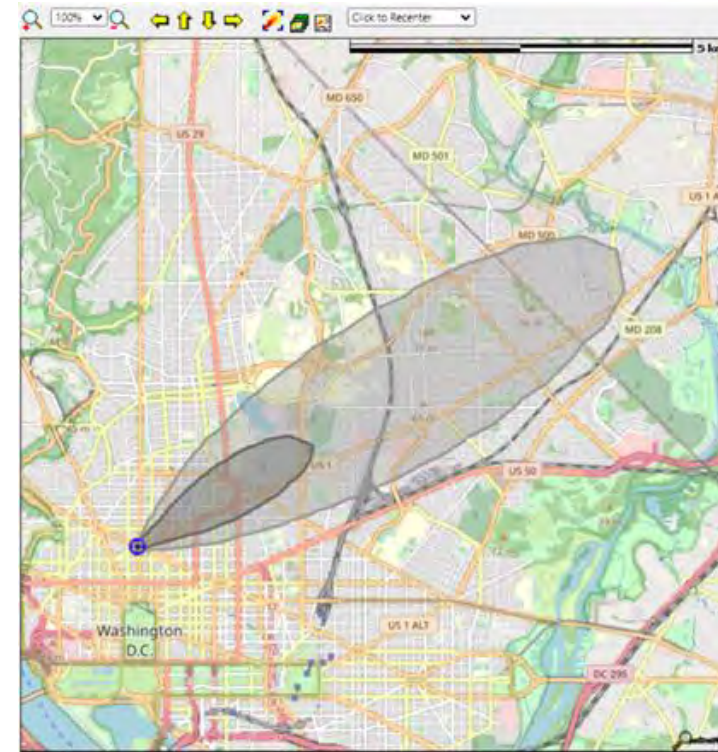
- ❑ The Consequence Management Home Team (CMHT) will be activated immediately during normal business hours (Pacific Time Zone) and will be activated within two hours otherwise.

- ❑ The Consequence Management Response Team (CMRT) is “prepared for deployment” within six hours after activation. Along with the assets, FRMAC provides an operational framework for coordinating of all federal off-site radiological monitoring and assessment activities during a response to a radiological emergency to support the coordinating agency and state(s), local, and/or tribal governments.



NARAC Models - Surface distribution of Activity

- ❑ The National Atmospheric Release Advisory Center (NARAC) provides airborne hazards predictions of the consequences of radiological, nuclear, chemical, and biological releases.
- ❑ Under the DOE, NARAC provides real-time computer predictions of the atmospheric transport of material from radioactive releases and of the downwind effects on health and safety.
- ❑ We show results of a model simulation by NARAC for a RDD explosion of 15 KCi teletherapy cobalt-60 source at the center of Washington DC (38.9072° N, 77.0369° W) with 50 lbs. of high explosives

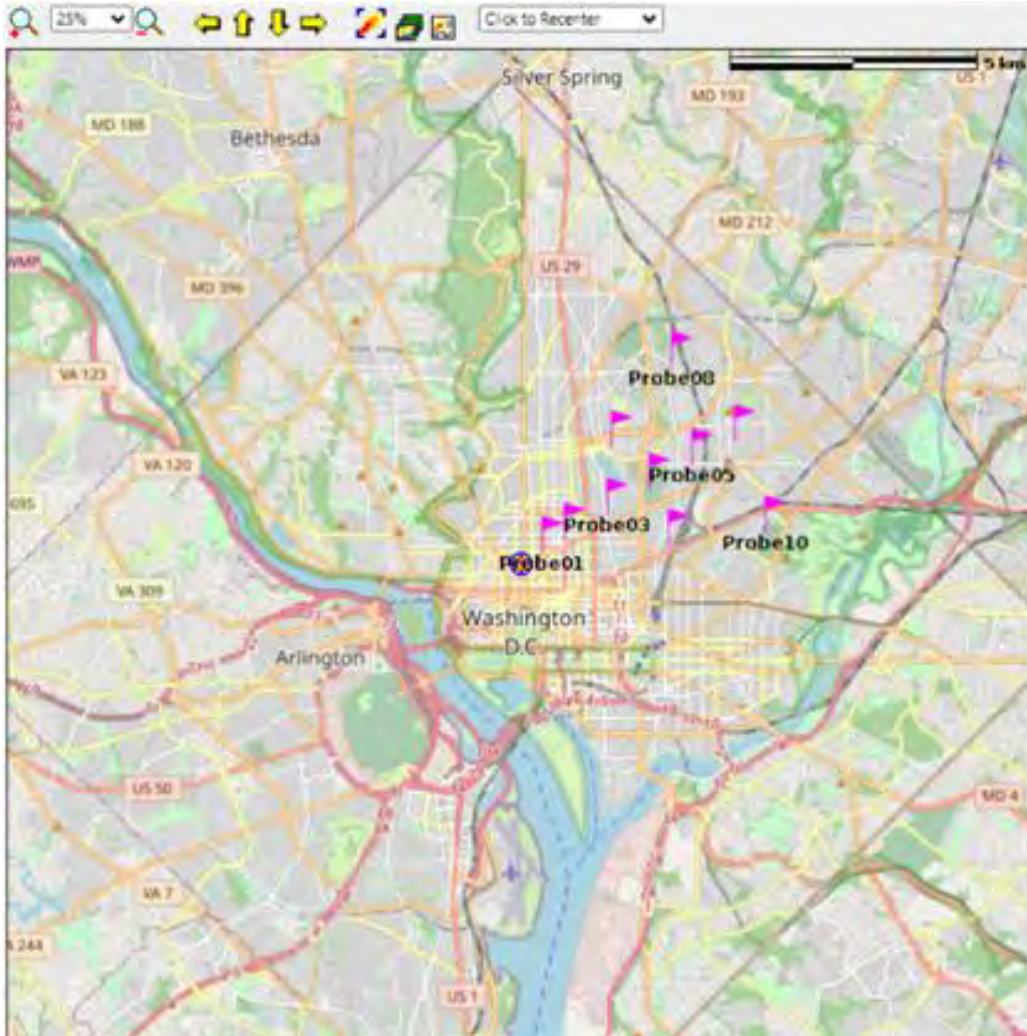


Concentration Levels		
Description	($\mu\text{Ci}/\text{m}^2$) Extent Area	Population
No guidelines specified. Possibly contaminated area. Use to confirm with monitoring surveys.	>1.00E6 0.03km ² 0.001km ²	6
No guidelines specified. Possibly contaminated area. Use to confirm with monitoring surveys.	>10 3.0km ² 1.7km ²	18,200
No guidelines specified. Possibly contaminated area. Use to confirm with monitoring surveys.	>1 8.2km ² 14.2km ²	74,400

Note: Note: Areas and counts in the table are cumulative. Population Source = LandScanUSA2021
Effects or contamination at July 07, 2024 05:44 UTC

Distribution of radioactive material ($\mu\text{Ci}/\text{m}^2$) on the ground after 15 KCi of Co-60 explosion with 50 lbs. of high explosives. Contours show different levels of deposition – the associated text shows number of people affected in the event.

NARAC Models – Ten-Point Monitoring Strategy



Early Phase Dose		
Description	(rem) Extent Area	Population
Exceeds 5 rem total effective dose.	>5 0.1km 35,448m ²	530
Exceeds 1 rem total effective dose.	>1 0.1km 36,377m ²	530

Note: Note: Areas and counts in the table are cumulative. Population Source = LandScanUSA2021

Effects or contamination from July 06, 2024 17:44 UTC to July 10, 2024 17:44 UTC

- ❑ The Ten-Point Monitoring Strategy is a standardized methodology for quickly gathering required radiological monitoring information after a potential release.
- ❑ According to the Federal Radiological Monitoring and Assessment Center (FRMAC) protocol these ten points should be measured for exposure and ground contamination levels before characterization is carried out.

Minority Serving Institutions Partnership Program (MSIPP)

- ❑ The mission of the Minority Serving Institution Partnership Program (MSIPP) is to create and support a sustainable career pathway that prepares a diverse workforce of talented students to make immediate and significant contributions to the Nuclear Security Enterprise (NSE).
- ❑ MSIPP develops strategic partnerships between Minority Serving Institutions (MSIs), Tribal Colleges and Universities (TCUs), and the NSE, investing in student enrichment programs, curriculum development, research efforts, and internship opportunities.

Nuclear Security Science and Technology Consortium (NSSTC)

- ❑ The NSSTC is a consortium based team funded by the National Nuclear Security Administration through MSIPP.
- ❑ The goal is to design and build a sustainable pipeline between the Department of Energy's (DOE) sites/labs and minority-serving institutions, thus creating the next generation world-class STEM workforce.
- ❑ Nuclear science and security experts at University of Nevada, Las Vegas, University of Illinois at Chicago, University of New Mexico, Nevada National Security Site, Los Alamos National Laboratory and Argonne National Laboratory have partnered to address overarching themes within the topical research area of Nuclear Security.
- ❑ The NSSTC provides students with practical experience and training through research projects and experiential learning.

A brief description of the field work proposal that NNSS has been working on is given below:

- ❑ Hosting periodic seminars on modern radiation detection topics to supplement university curricula.
- ❑ Serving on the consortium advisory board to guide MSIs in science experimentation, laboratory expansion and modernization.
- ❑ Bringing synergy to NNSS's Site Directed Research and Development (SDRD) program research emphasis will be given on the following topics: Perovskite detectors; Assay of radiological material via computational studies, and Remote sensing of radiological and nuclear materials.
- ❑ Hosting MSI faculty and post-graduate researchers for visits to the NNSS site, and reciprocally visit collaborating university sites.

Project Scope

- Proof of concept that remote controlled robot can localize and identify discreet radioactive sources
- Design and construct 2 operational Robots with gamma ray scintillators (sodium iodide) with collimators
- Compare data taken by UNLV UAS and RSL robots on same grid lines with sources distributed in an area

Looking Ahead

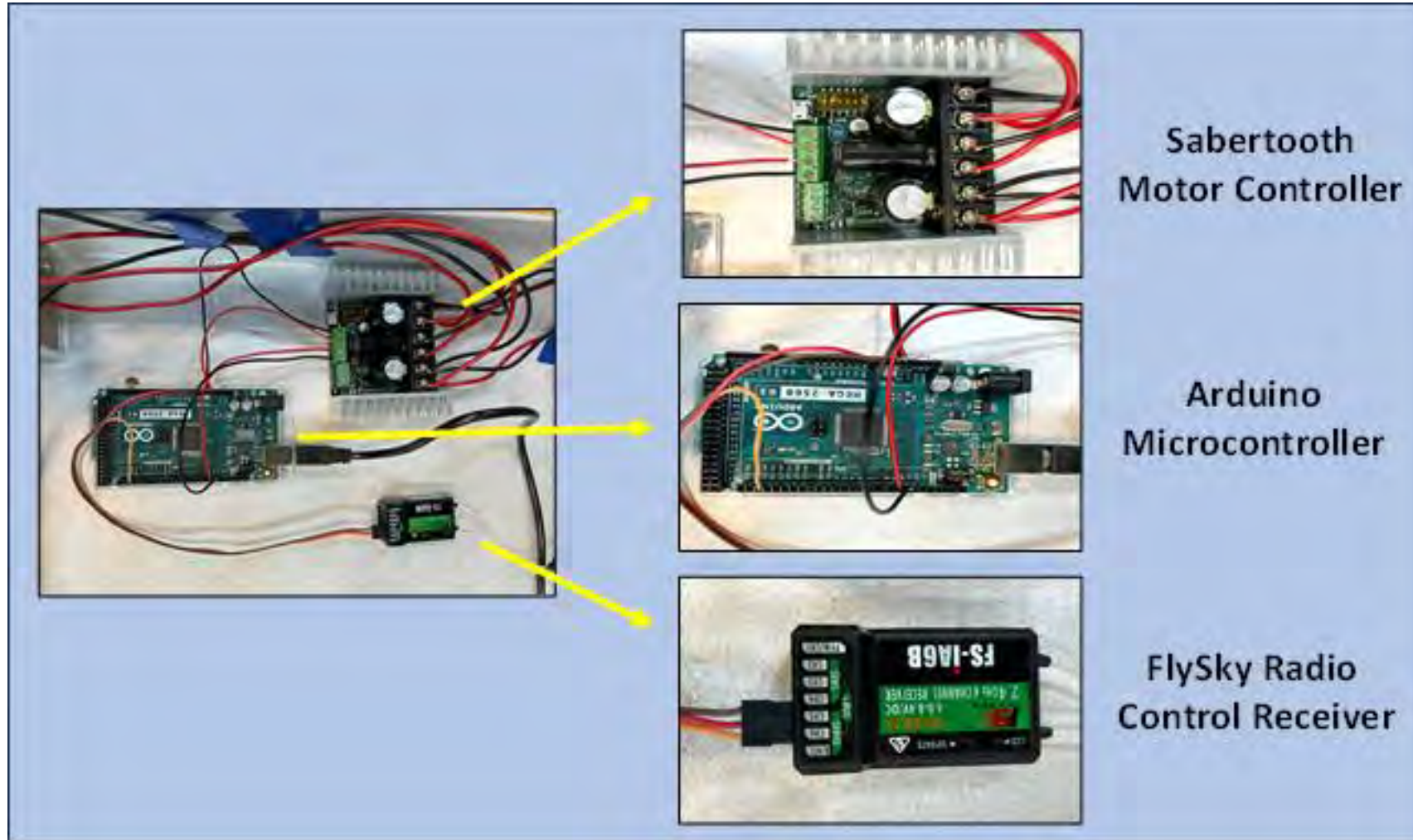
- Work with UNLV Professor Woosoon Yim on algorithm development for localization of sources from networked sensors on robots utilizing ad-hoc mesh network
- Autonomous mobile search without human intervention
- Will provide ground truth measurement for UAS system
- Provide imaging platform

Accomplishments & Benefits

- ❑ Two robots have been constructed complete with sodium iodide scintillators (3"x3" cylinder with tungsten collimator, 2"x4"x4" rectangular slab with lead collimator)
- ❑ Programming for autonomous control is going on so that the Robot can follow a series of way points
- ❑ The devices will be able to localize identify HOTSPOTS where it is unsafe for Radiation workers to perform search operations; it will be able to detect subsurface embedded macro particles that are radioactive
- ❑ New high resolution GPS system has been introduced
- ❑ Two summer interns are partially working on this project
- ❑ Strong collaboration with UNLV (MSIPP-NSSTC project on UAS) – measurements completed yesterday at Stan Fulton Stadium parking lot (UAS + Robot)

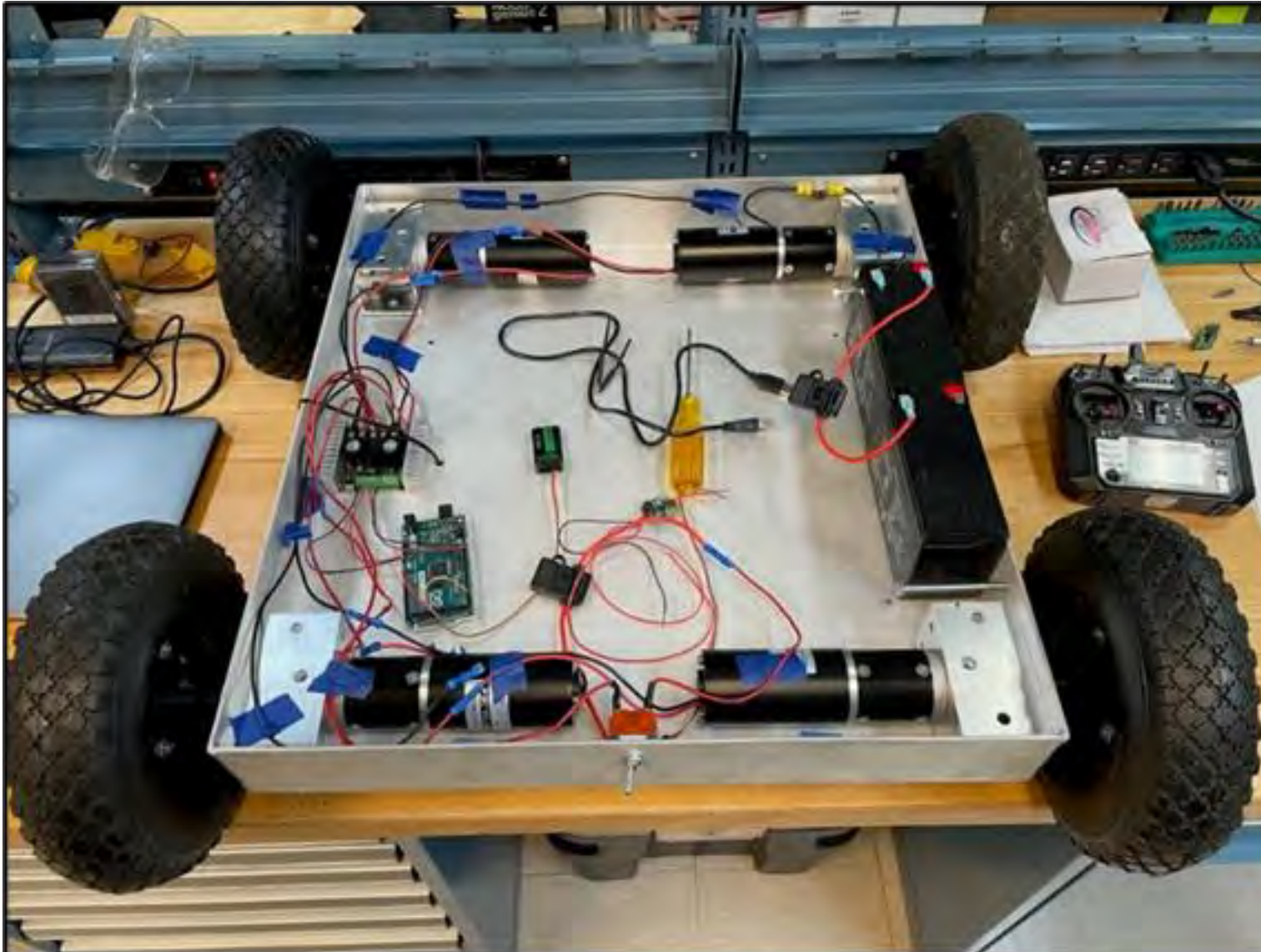


Hardware Features - Controller for the motor movement



- ❑ left, prototype electronics layout, and
- ❑ right, an expanded view of the Sabertooth motor controller,
- ❑ the Arduino microcontroller, and
- ❑ the FlySky radio control receiver

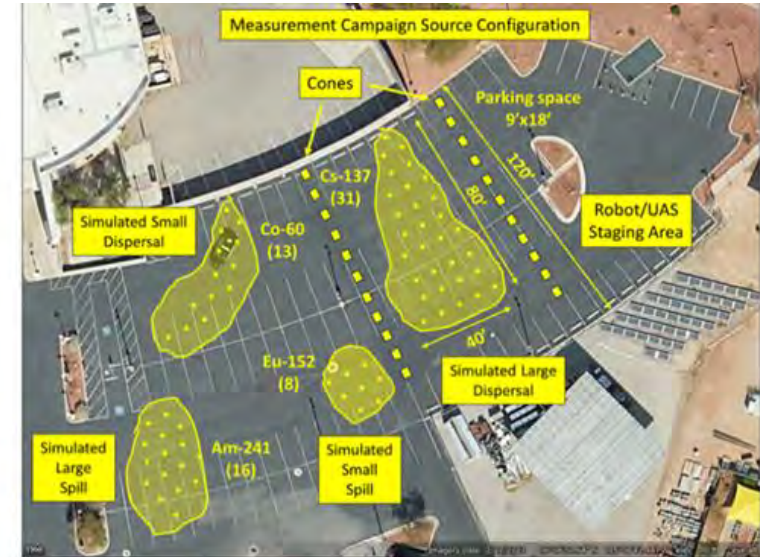
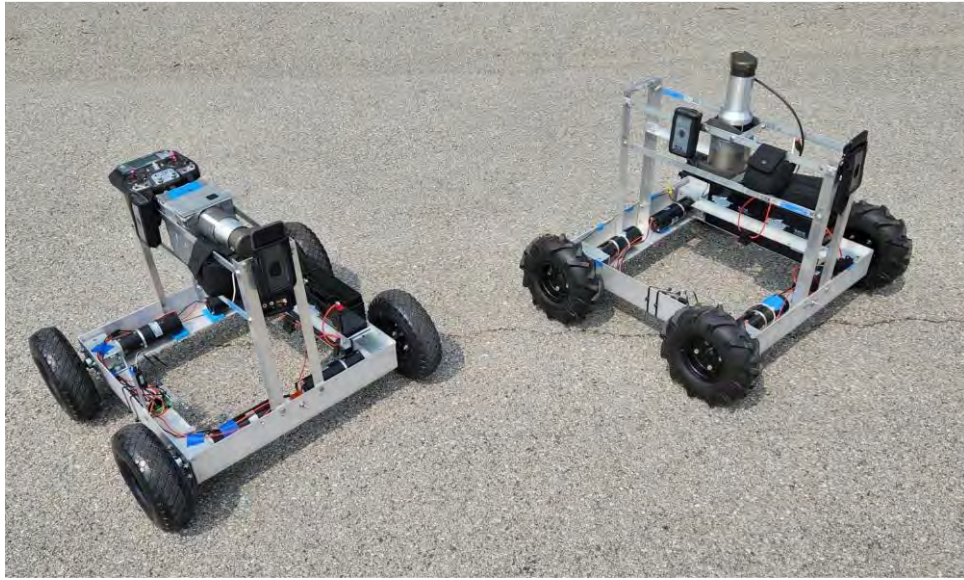
Autonomous Robotic Test System Components on Display



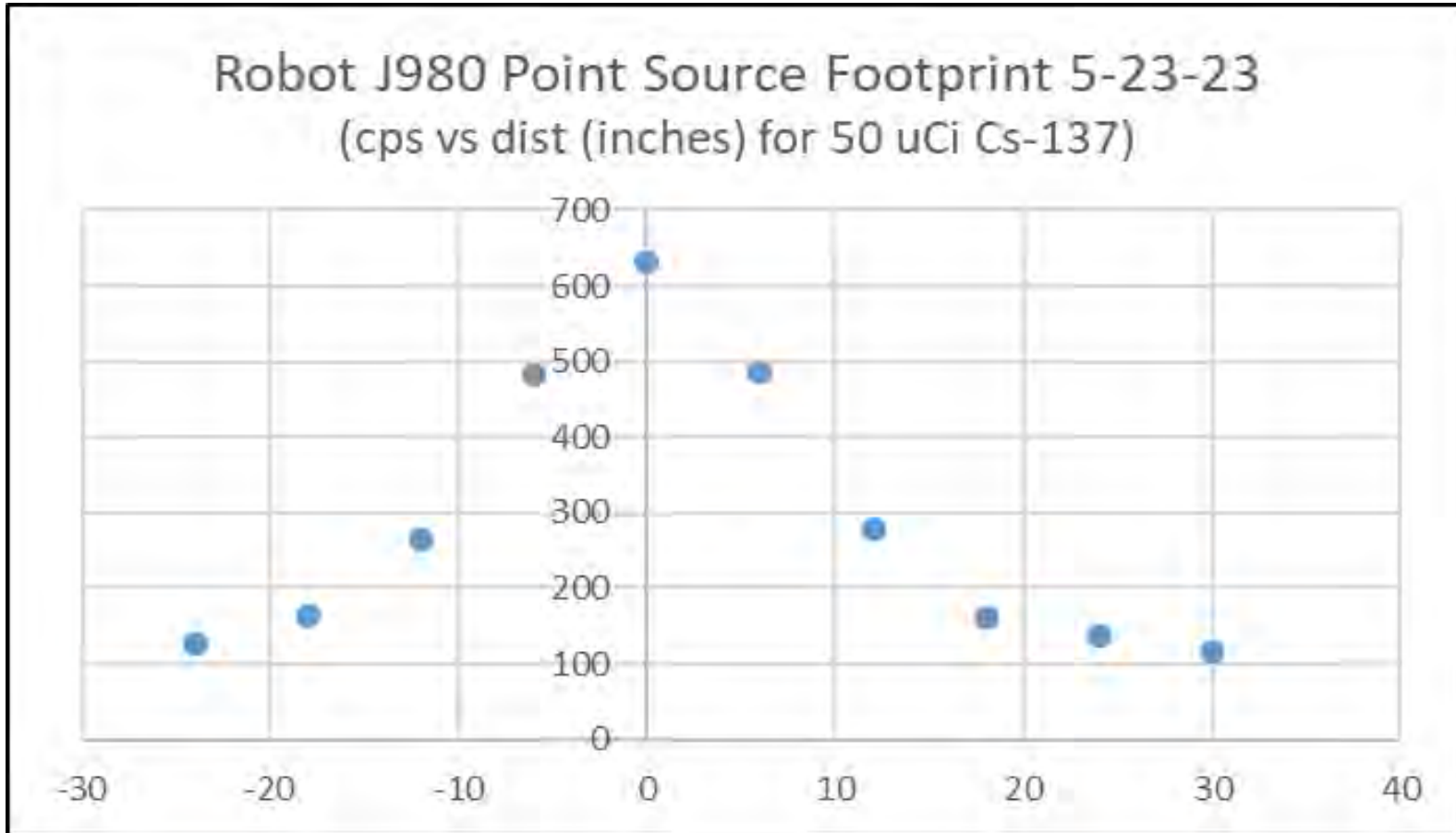
Prototype autonomous robotic test system components on display.

- Batteries, 2 ea. 12 Vdc
- Motor controller, 4 ea.
- Power management Board
- GPS receiver on CHIP (can receive differential GPS)
- FlySky radio control receiver with antenna

UNLV Measurements Platform, Grid Area, Source Placement

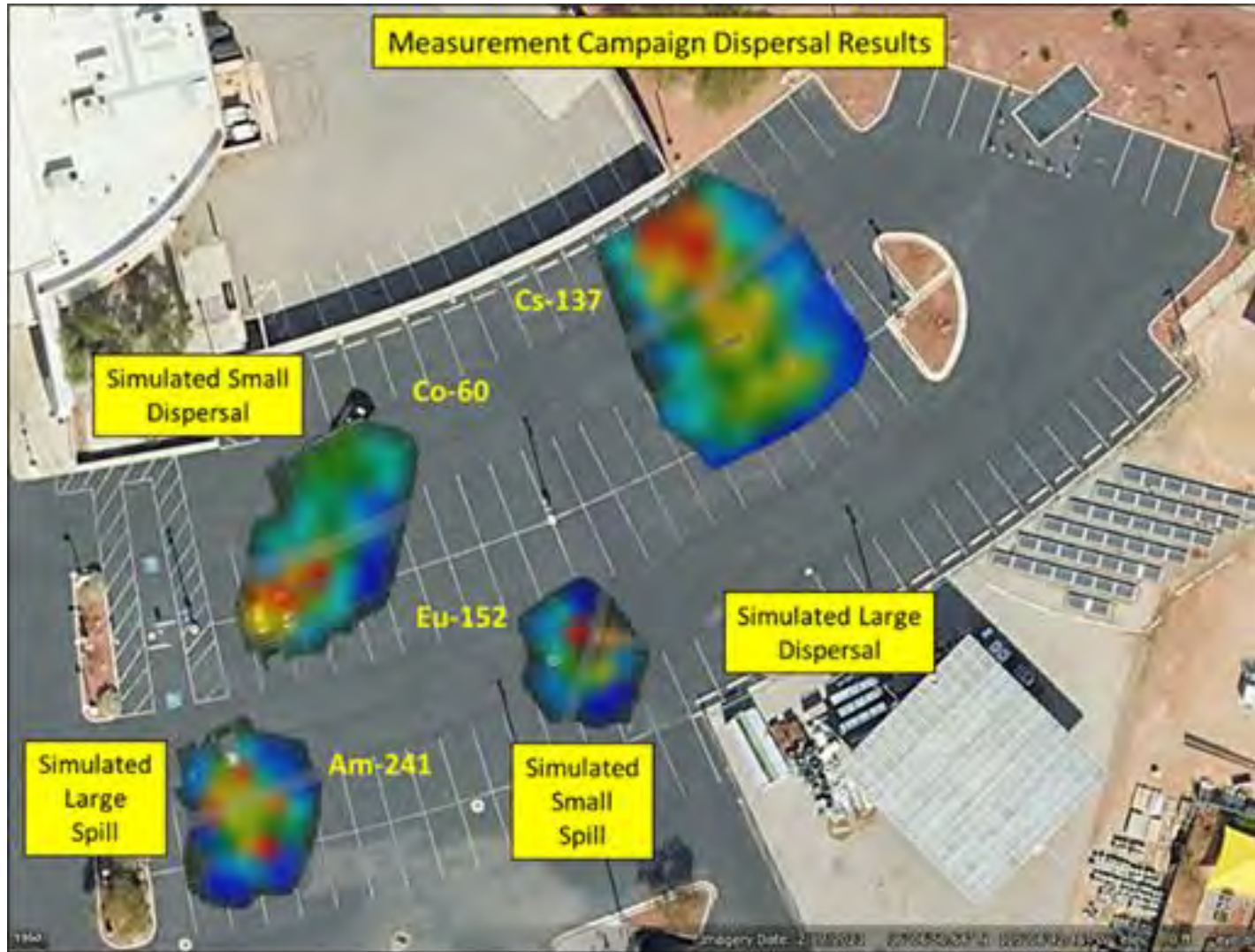


Measure of Collimated Field of View (FOV)



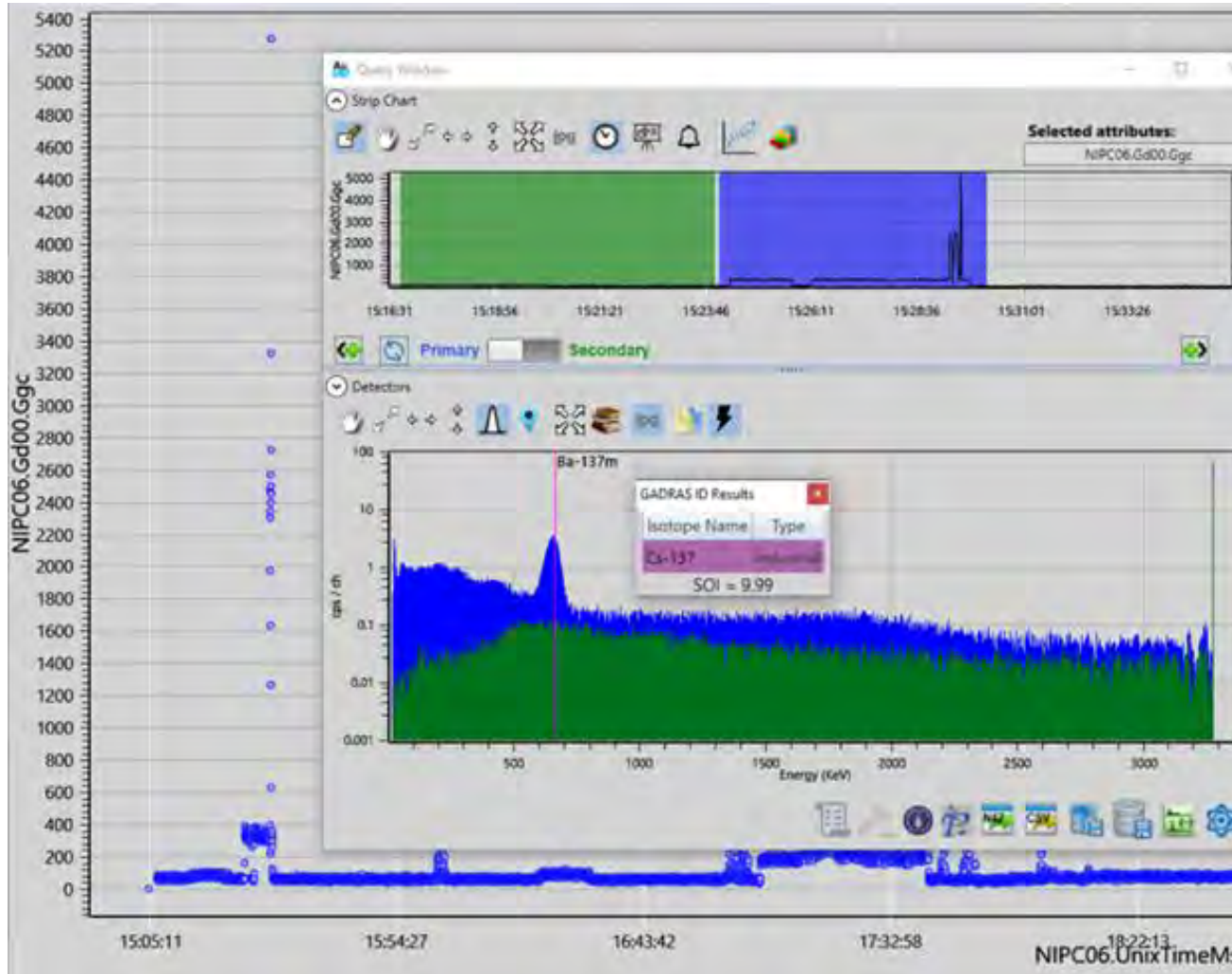
- ❑ Full Width Half Maximum (FWHM) of ~ 20" on the ground is observed.
- ❑ Sources that are on grid lines (at least 3 ft. apart) will always be seen as distinct object without ambiguity.

Source Location, Contour of High-Count Rates Region Ground Deposition Realization



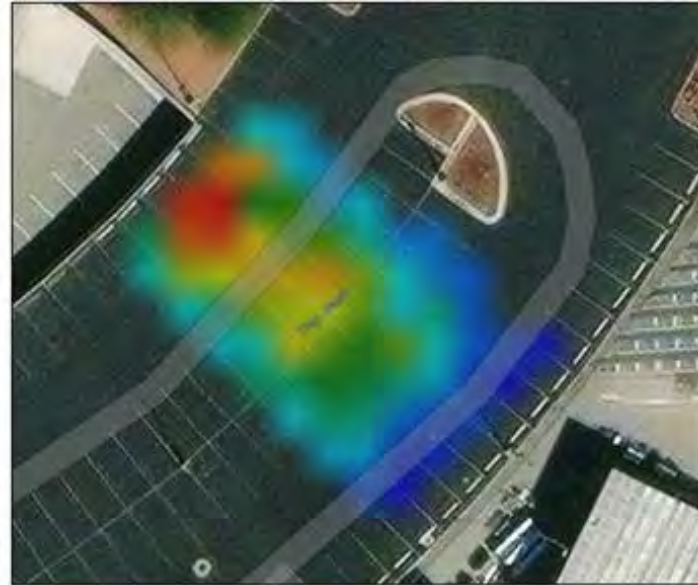
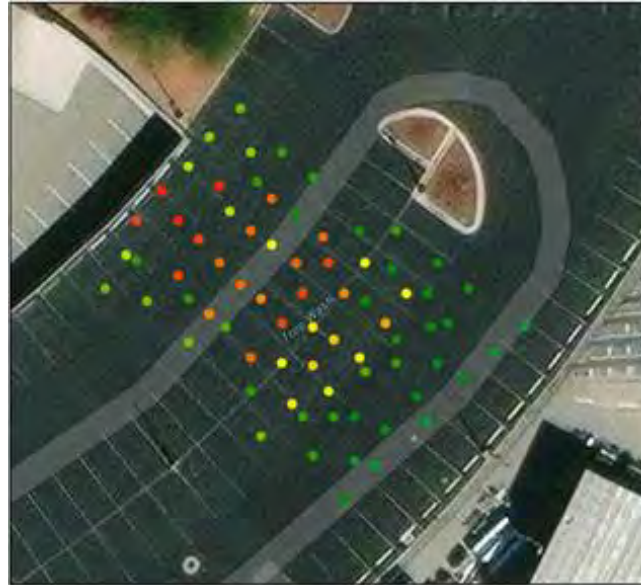
- ❑ The radiation measurement data (gamma count rates at one second interval) was contoured to produce a local radiation map to characterize the entire area containing sources on the ground.
- ❑ The contour resembles the shape and size shown in previous slide 11.
- ❑ The spectral data collected (also every second) supports identification of 4 groups of isotopes in separate clusters (Cs-137 – large deposition, Co-60 – small deposition, Am-241 – large spill, Eu-152 – Small spill)

Spectral Data Analysis Using AVID



- ❑ From the count rate strip charts shown in AVID display one marks the high-count rate area (in blue) and a corresponding background count rates in green (shown on top part of Figure).
- ❑ On the bottom are shown the spectral content of the date with those specific selection of foreground and background.
- ❑ From the built-in analysis tool one can identify the isotope involved with high degree of accuracy, in this case it is Cs-137.

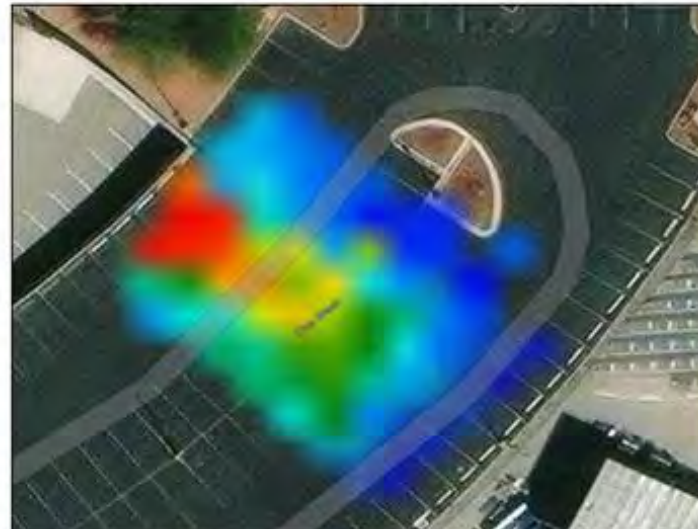
Foot Prints from Collimated vs Uncollimated Map-Data



NIPC6, 3x3, 3/27/24

Cs-137 Uncollimated

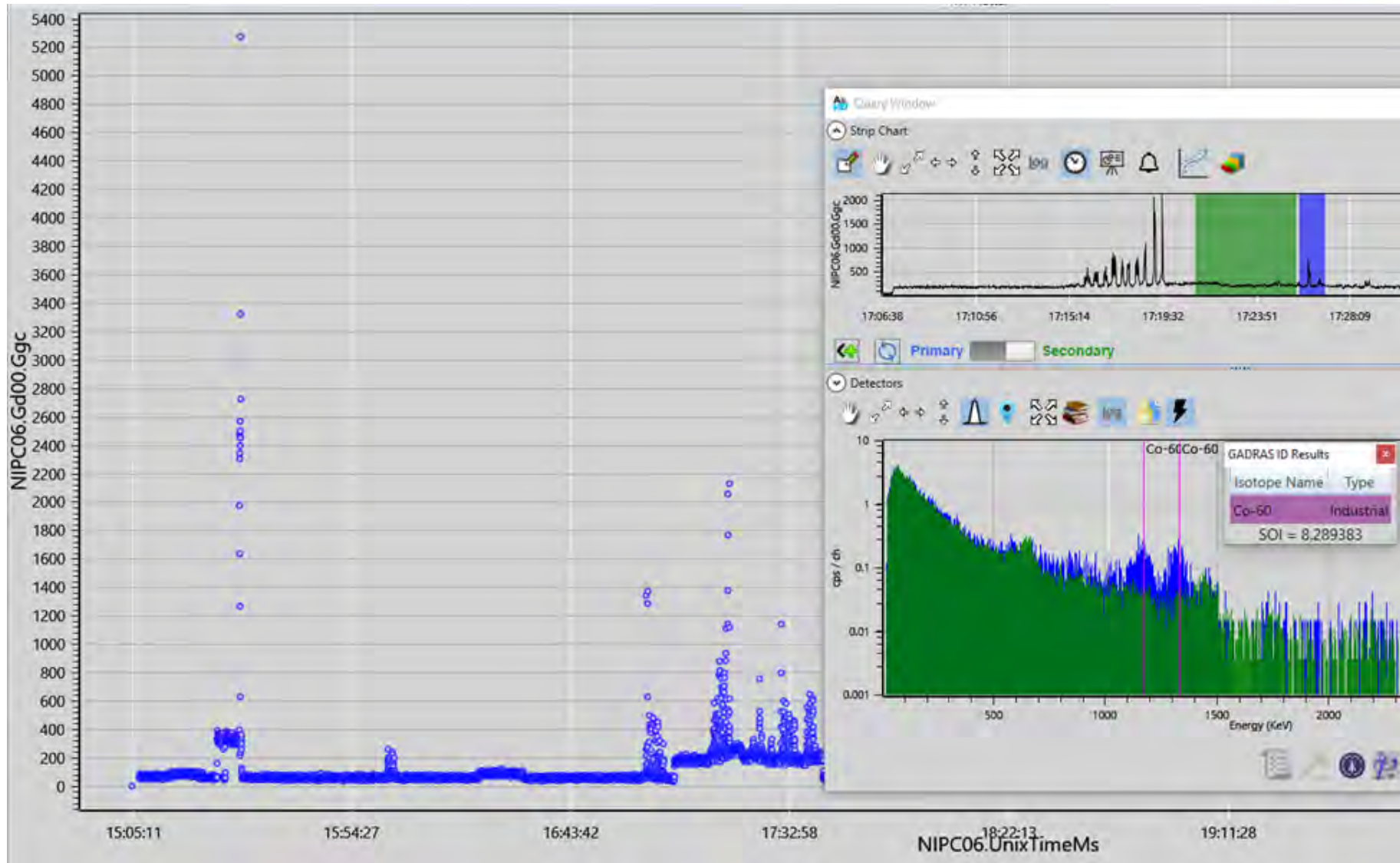
Symbol	Upper Bound
● (Blue)	550.000000
● (Cyan)	950.000000
● (Green)	1350.000000
● (Yellow)	1750.000000
● (Red)	2150.000000



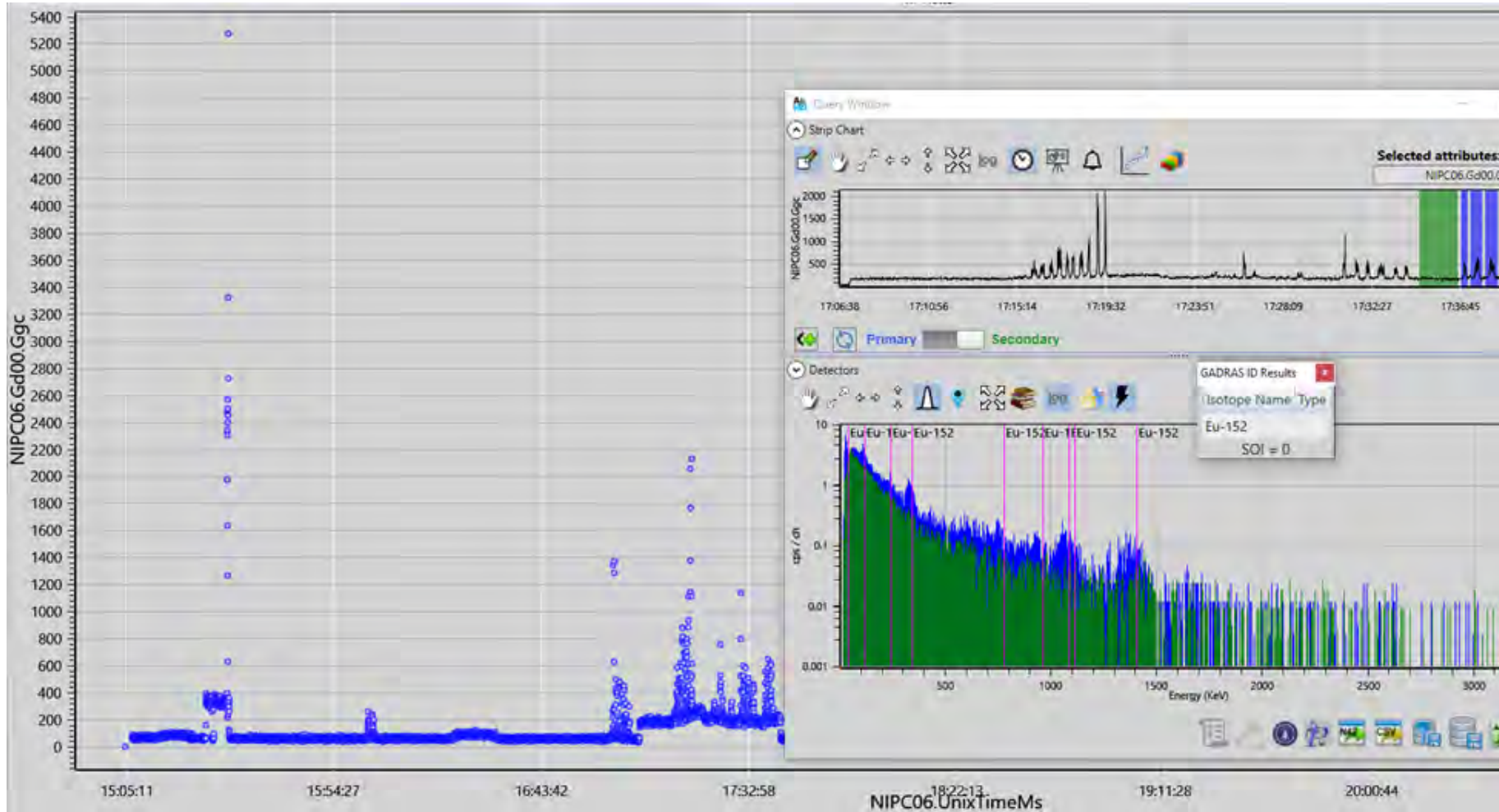
Cs-137 Collimated

Symbol	Upper Bound
● (Blue)	300.000000
● (Cyan)	500.000000
● (Green)	800.000000
● (Yellow)	1100.000000
● (Red)	1400.000000

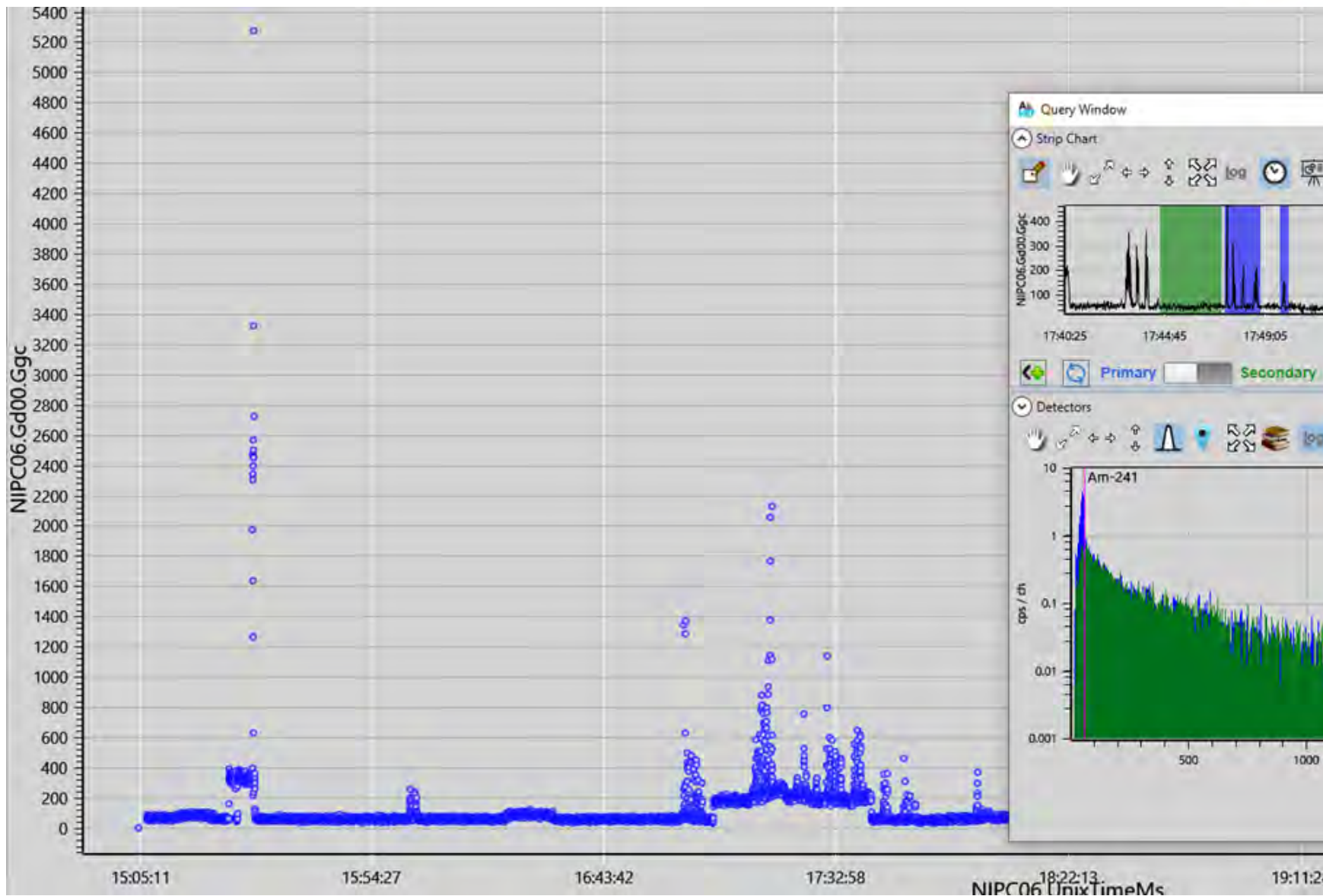
Co-60 Identification



Eu-152 Identification (Complex Spectra)



Am-241 Identification



Nuclear Forensic – How Do Robots Fit in?

- ❑ In the event of a radiological dispersal device explosion, some fragments resulting from the explosion will be contaminated with radioactive material.
- ❑ In a forensics investigation, some of the fragment could be critical in providing key information about the device and who is responsible.
- ❑ Using advanced remote controlled robot technologies to enter the highly contaminated area at ground zero and search through the complex fragmentation field for critical evidence may be key to the forensics investigation.
- ❑ The objective of US DOE/NNSA nuclear forensic program is to detect nuclear materials out of regulatory control or of foreign origin, identify the radioisotopes involved and quantify the materials and figure out the origin of the materials to facilitate attribution.
- ❑ US DOE/NNSA's Office of Counterterrorism and Counterproliferation developed its Nuclear Forensics Material Analysis Program (NF-MAP) capabilities to answer these questions.
- ❑ NF-MAP delivers timely, specific, state-of-the-art forensic results for nuclear materials found outside regulatory control, whether intercepted, discovered, or taken from an undetonated nuclear device,
- ❑ The ground robot systems (with simple attachment to manipulate samples, retrieve materials) could be of immense importance to nuclear forensic investigations.

Conclusion and Future Plans

- ❑ Successfully constructed 3 robots with fully functional collimated radiation sensor based on GAMUT Data Acquisition System.
- ❑ Collected large amount of ground-based data during SNOW EAGLE measurement campaign at Idaho National laboratory (INL)
- ❑ Worked on auto driving through way points and figured out solutions for way points given in terms of GPS coordinates and/or distances and direction with reference to a starting point
- ❑ Will work with UNLV (Prof. Woosoon Yim) in algorithm development for Bayesian Search algorithm
- ❑ Will incorporate gamma imaging devices like H3D CZT based lightweight
- ❑ Have incorporate Wi-Fi still camera (forward looking and down looking)
- ❑ Planning to conduct a survey of old uranium mine in tribal land in New Mexico

UNLV/NNSS Team with Equipment for Measurement Campaign

