Office of Counterterrorism and Counterproliferation
Nuclear Incident Policy and Cooperation

*Workshop on the Implementation of the International Radiation Monitoring Information System*

*29 Nov – 2 Dec 2021*
*Vienna, Austria*

# *Aerial Measuring System (AMS)*


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AERIAL MEASURING SYSTEMS
AMS

# Aerial Radiological Search Operations


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# Outline

**Aerial Measuring System**

**Spectral Advanced Radiological Computer System (SPARCS)**

**Case Study:**
**U.S. Aerial Measuring System Response to the Fukushima Accident**

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# Aerial Measuring System (AMS)

**An Aerial Measuring System (AMS) is a capability for emergency response to search, locate, identify, quantify, and map radiological incidents and accidents.**

**For large-scale incidents or accidents, the AMS can provide rapid assessment of ground contamination and aid in developing protective action recommendations for the public.**

**AMS is a critical capability for rapidly locating radiation sources or dispersed radiation contamination, but equally as important, for confirming the absence of radiation.**

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# AMS Missions

- Emergency Response
  - Lost or Stolen Radiation Source
  - Radiation Dispersal Incident
  - Nuclear Power Plant Accident
- Baseline Surveys
  - Nuclear Facilities
  - Major Public Events
  - City Surveys
- Environmental Monitoring
  - Nuclear Facilities
  - Contaminated Site Restoration

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# AMS Aircraft

## Incidence Response

### Airplane or Helicopter

- Rapid response
- Altitude 1000–2000 ft (~300–600 m)
- Line spacing 2000–4000 ft (~600–1200 m)
- Speed 70–140 kts (~50–95 km/h)
- Flight time 3–6 hours
- Large area survey, low resolution
- Lower sensitivity (1 large detector)

## Consequence Management

### Helicopter

- Deliberate response
- Altitude 150–300 ft (~45–90 m)
- Line spacing 300–500 ft (~90–150 m)
- Speed 70 kts (~50 km/h)
- Flight time 3 hours
- Detailed survey, high resolution
- High sensitivity (multiple large detectors)

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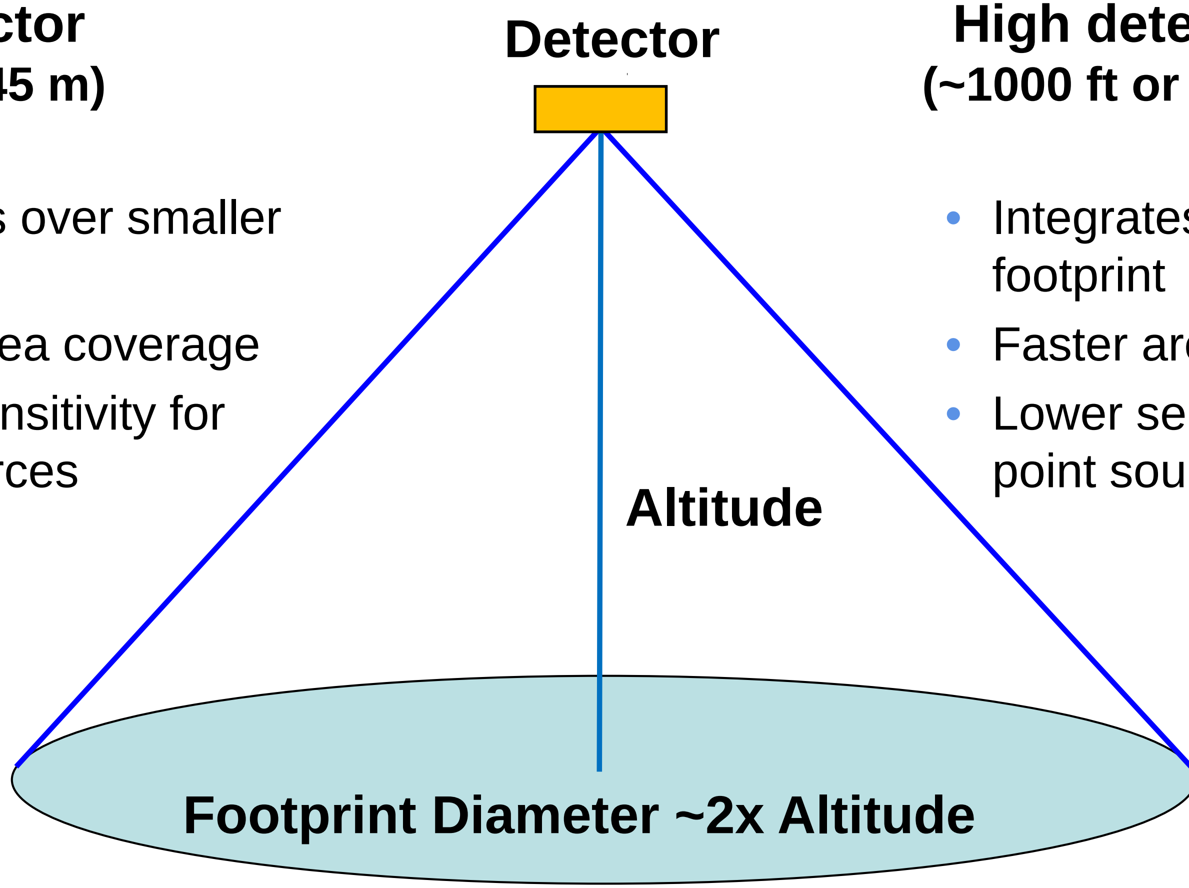
# Aircraft Altitude Considerations

**Low detector**
**(~150 ft or 45 m)**

- Integrates over smaller footprint
- Slower area coverage
- Higher sensitivity for point sources




**High detector**
**(~1000 ft or 300 m)**

- Integrates over larger footprint
- Faster area coverage
- Lower sensitivity for point sources

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# Detection Sensitivity

***To determine if an aerial search is applicable, one must first calculate the Minimum Detectable Activity (MDA)***

$$\text{Detection sensitivity} \sim \frac{C \times S \times B \times A \times E \times e^{-(\mu \times \rho \times D)}}{4\pi \times D^2}$$

where:

| | |
|---|---|
| C | 1 disintegration/second/Bq |
| S | radiation source activity (Bq) |
| B | gamma ray decay branching ratio |
| A | detector geometric cross section ($cm^2$) |
| E | detector total intrinsic efficiency |
| D | aircraft altitude (cm) |
| $\mu$ | air mass attenuation coefficient ($cm^2/g$) |
| $\rho$ | air density ($g/cm^3$) |

***Increase detection sensitivity by increasing detector size and reducing the aircraft speed and altitude***

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# Aerial Radiological Search for a Lost or Stolen Radiation Source


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# Lost Source – Road Search

- Obtain best estimates of lost or stolen source radioisotope and activity
- Determine the optimal altitude and speed to maximize detection probability
- Assume source may be shielded
- Determine GPS coordinates for start point and end point
- Develop the flight plan and brief team
- Monitor detector count rate and inform pilot of any radiation hot spots
- Perform bow ties over hot spots to localize position
- Radio GPS positions of hot spots to ground team for response

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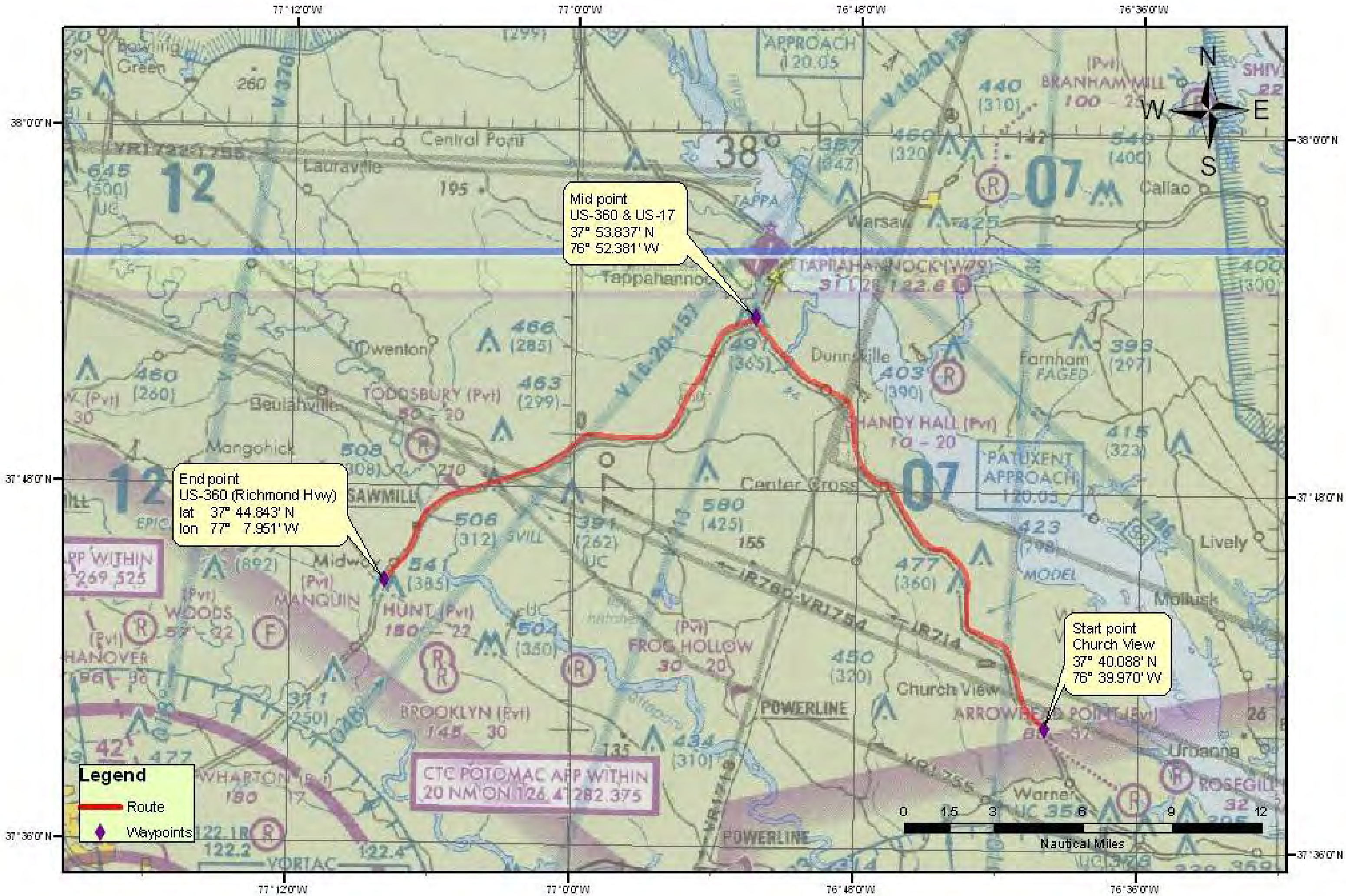
# Lost Source – Road Search



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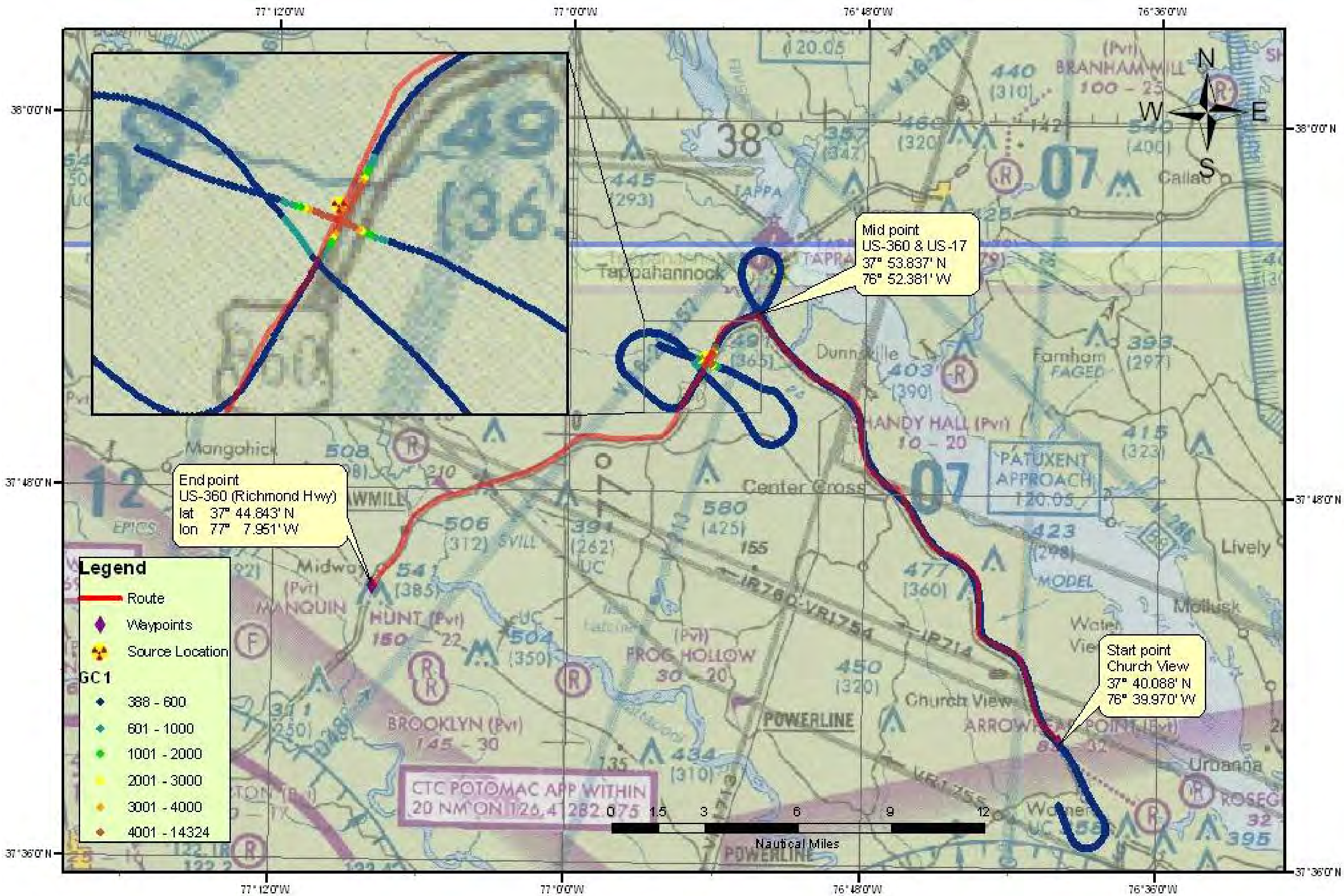
# Lost Source – Road Search



# Lost Source – Grid Search

- Obtain best estimates of lost or stolen source radioisotope and activity
- Determine the optimal altitude, speed, and parallel line spacing to maximize detection probability
- Assume source may be shielded
- Determine GPS coordinates for search grid area
- Develop the flight plan and brief team
- Monitor detector count rate and inform pilot of any radiation hot spots
- Perform bow ties over hot spots to localize position
- Radio GPS positions of hot spots to ground team for response

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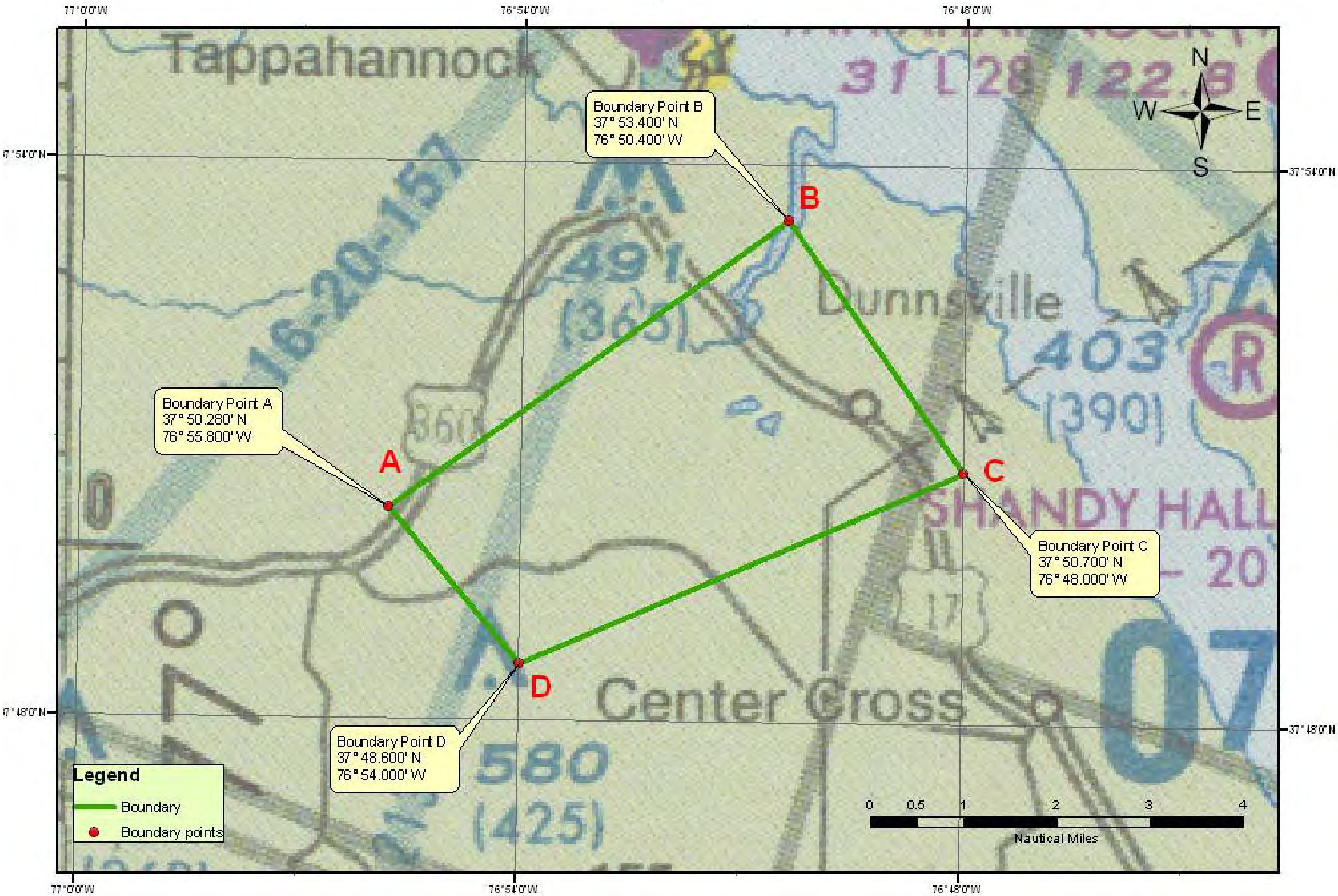
# Lost Source – Grid Search



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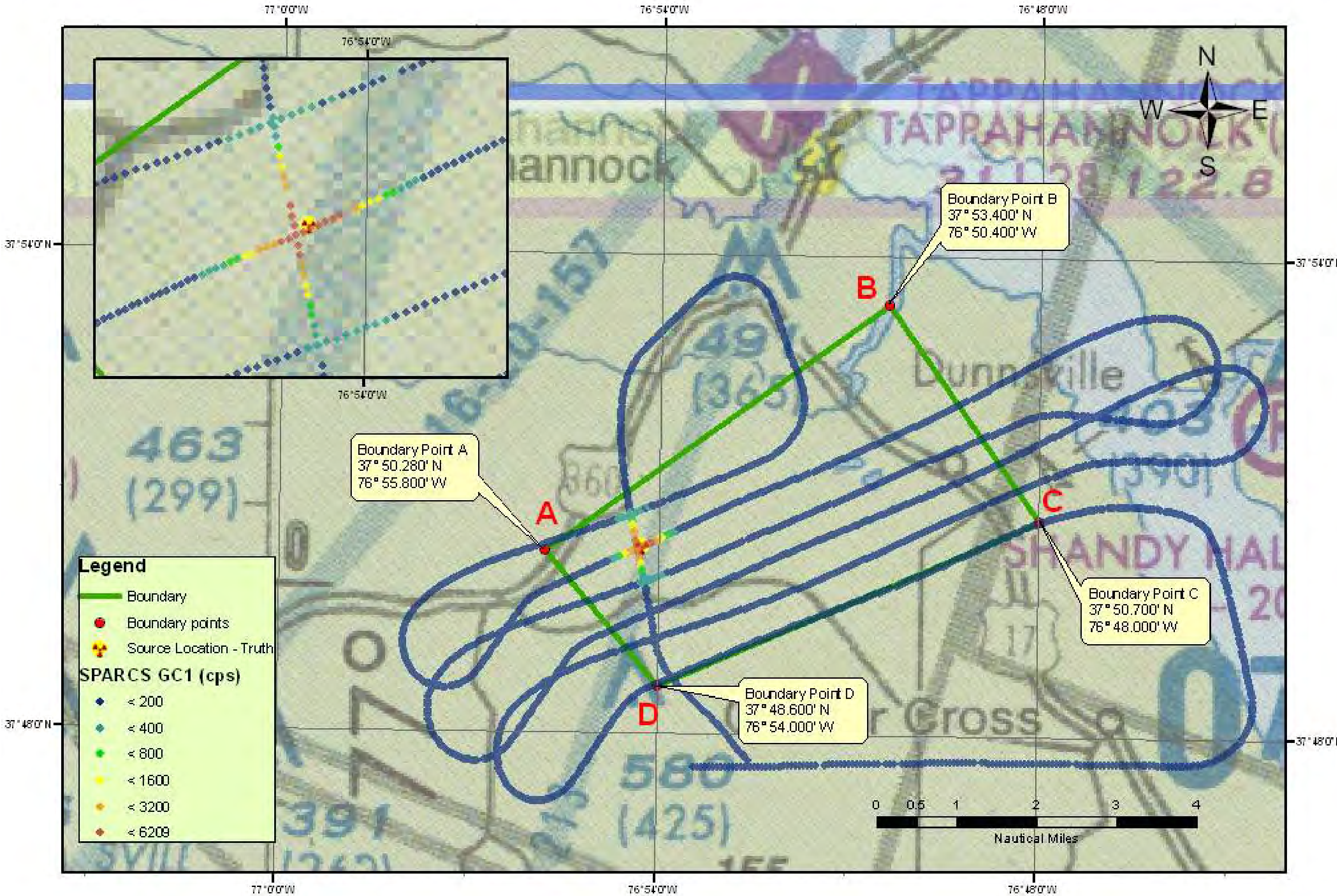
# Lost Source – Grid Search



# Aerial Radiological Mapping of a Dispersed Radioactive Material

## Radiation Dispersal Device Incident
## Nuclear Power Plant Accident

# Ground Deposition Survey

- **Based on the source term estimate and plume modeling projection, determine the ground deposition area**
- **Determine altitude, speed, and line spacing distance to survey the ground deposition in one flight**

**"*bound the problem*"**

- **Determine upwind GPS entry point**
- **Fly parallel or zigzag lines over the deposition area**
- **Verify that the radioactive material release has stopped**
- **Develop the flight plan and brief team**
- **Monitor detector count rate and inform pilot when entering and exiting deposition regions for turns**

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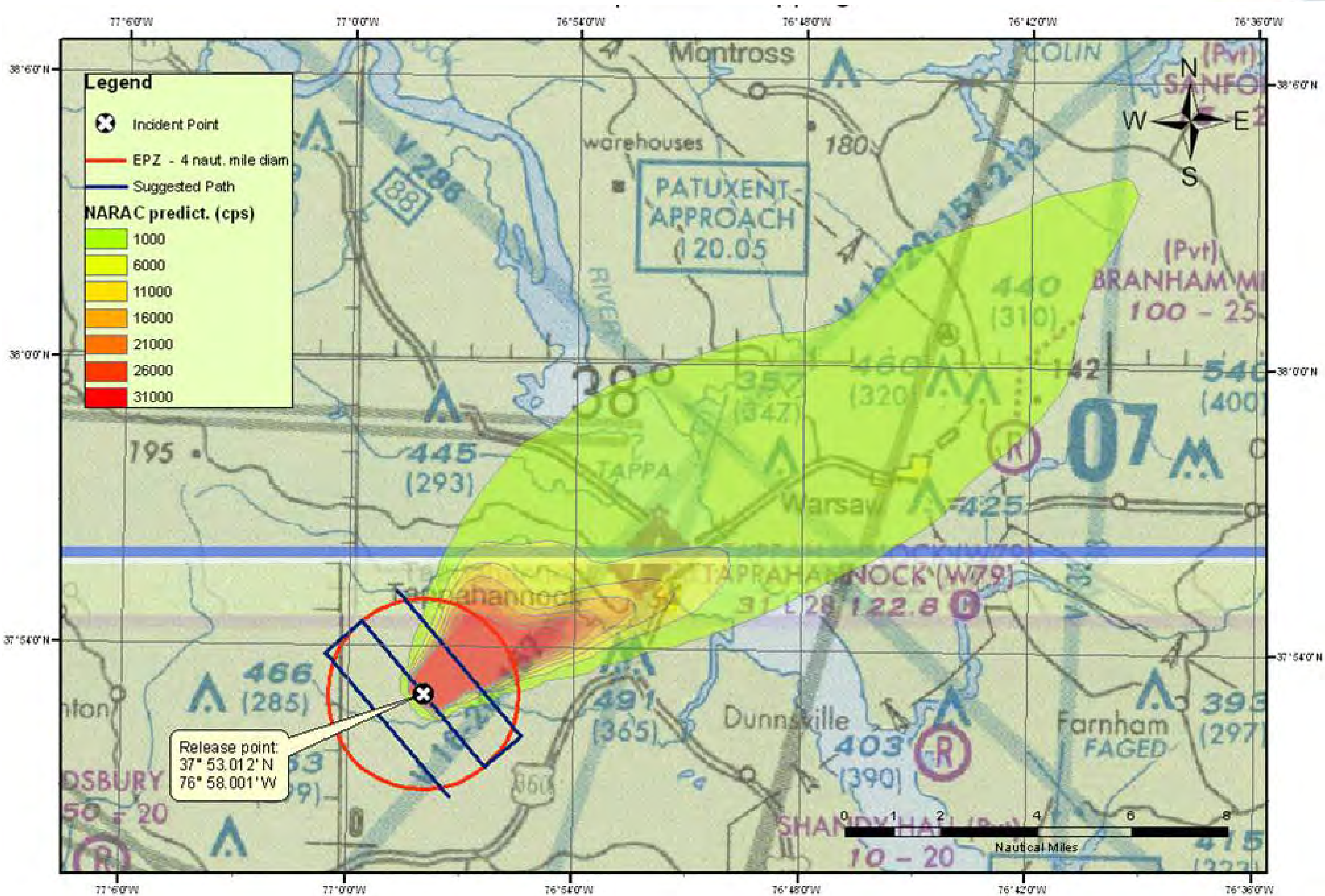
# Ground Deposition Survey



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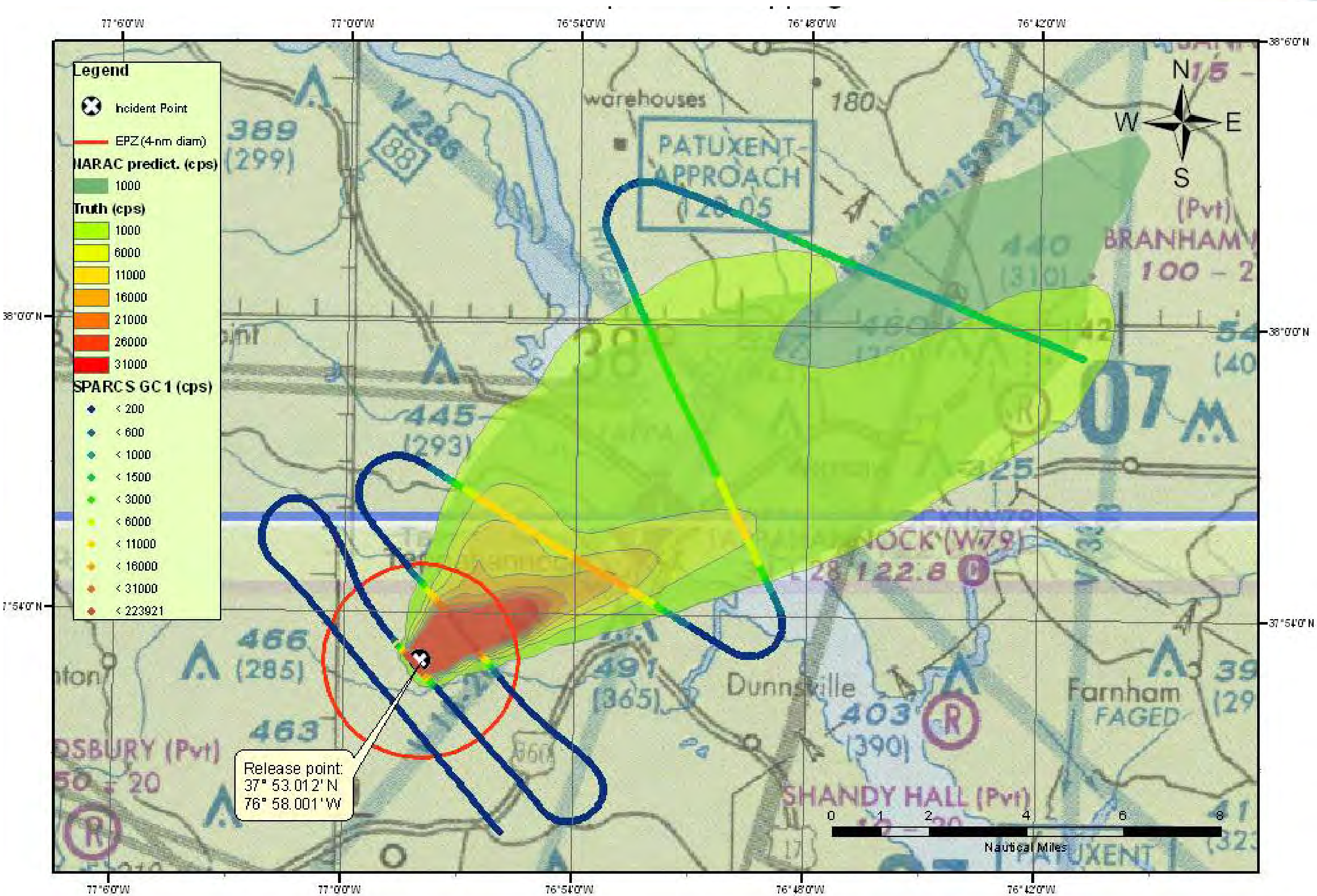
# Ground Deposition Survey



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# Reactor Accident Scenario

In a Nuclear Power Plant (NPP) accident, large quantities of radioactive material can be released into the atmosphere and deposited downwind from the plant. The radioactive contamination is a health risk to anyone in the path of the plume. The goal of the AMS is to rapidly conduct measurements to determine the contaminated area in order to minimize the public exposure.

Emergency managers will use the AMS data to develop protective action guidance for the general public to include shelter in place and evacuation.

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# Radioactive Plume Modeling

A plume model prediction is prepared to aid the emergency managers in developing protective action guidance and for planning the aerial and ground monitoring response for consequence management.

An aerial mission will be conducted to rapidly map the ground contamination deposited downwind of the nuclear reactor site ***in an initial single flight***. The goal is to determine the extent (width) of the ground contamination and the center line (trajectory). The IXP plume model predictions will be used for estimating the survey area and optimizing the flight parameters.


**Map Size:** 41.5 km by 41.5 km **Id:** IXP.rcE8838.rcC1

| (MBq/m2) Extent Area | Population |
|---|---|
| >0.10<br>9.7 km<br>5.8 km2 | 200 |
| >0.01<br>27.1 km<br>67.3 km2 | 4,620 |
| >0.0010<br>67.4 km<br>1,201 km2 | 11,900 |

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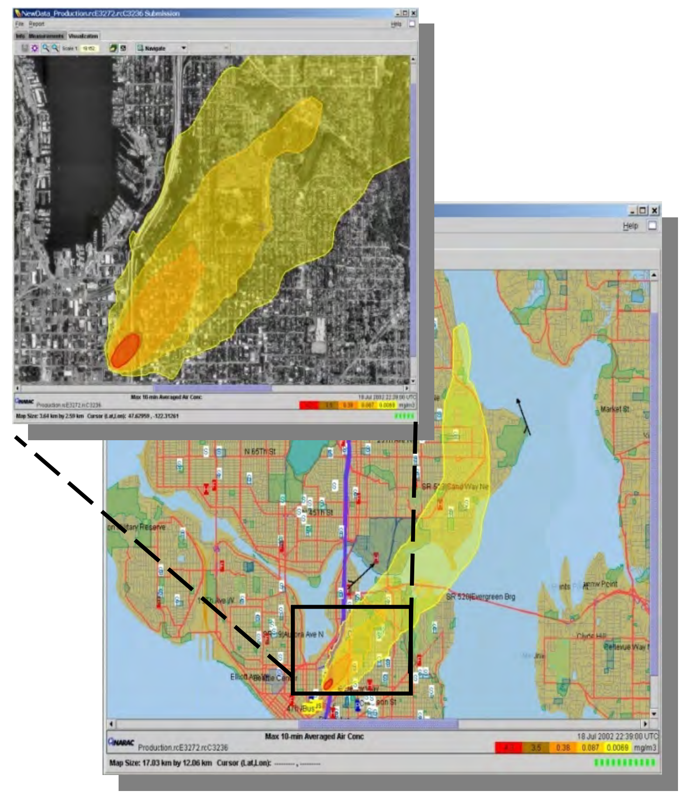
# International Exchange Program (IXP)
# DOE Reach Back Capability

***Real-time computer predictions for atmospheric transport of radioactivity from a nuclear accident or incident***

- **Contact**
  - Call DOE 24/7 at +1-202-586-8100
  - Request IXP assistance
  - Or request access via the IAEA
  - Or submit request via IXP web site at https://ixp.llnl.gov, results in 10 minutes
- **Map Products**
  - Exposure rates
  - Plume deposition
  - Ground contamination
  - Protective action recommendations



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# Aerial Planning – Initial Flight

**Modeling predicted survey area**

6–12 miles (10–20 km) wide
15 miles (24 km) downwind
15 lines, 1 mile (1.6 km) spacing
Line length 8 miles (13 km)
120 miles (190 km) of lines
14 turns at 1 minute/turn
*Time: 90 minutes*

**Aircraft altitude**

1000 feet (300 m) AGL

**Aircraft speed**

100 miles/hour (90 knots)

**Water line**

*Time: 30 minutes*

**Roundtrip transit from airport to survey site**
*Time: 60 minutes*
*(15 minutes in/45 out)*

**Total flight time**

***Time: 180 minutes (3 hours)***

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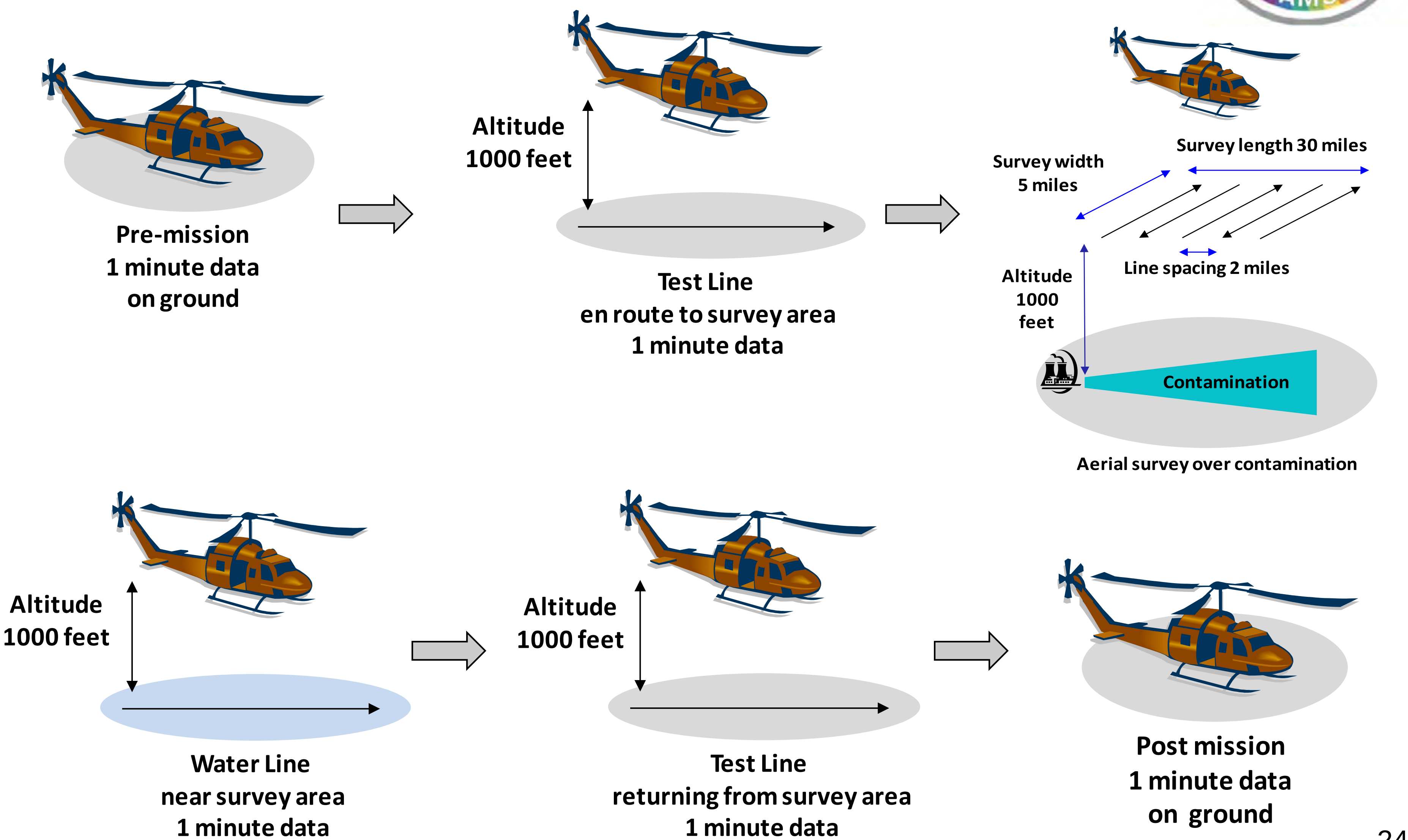
# Aerial Flight Profile for a Nuclear Power Plant Accident



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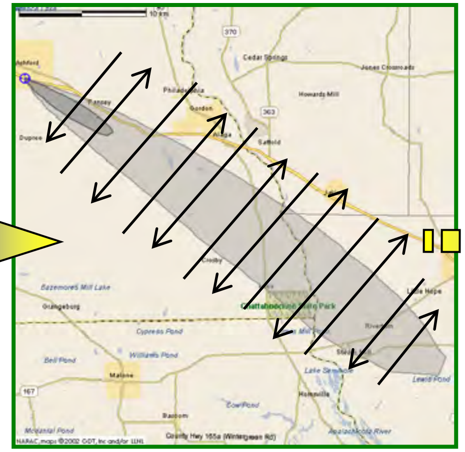
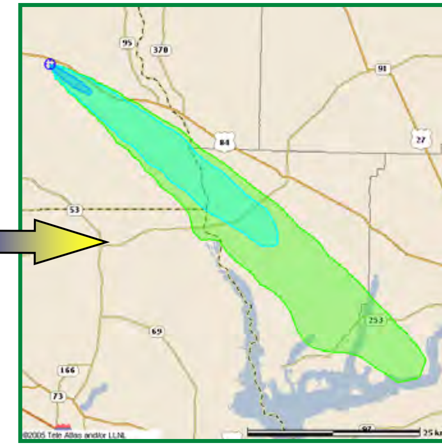
# Ground Deposition Characterization Process

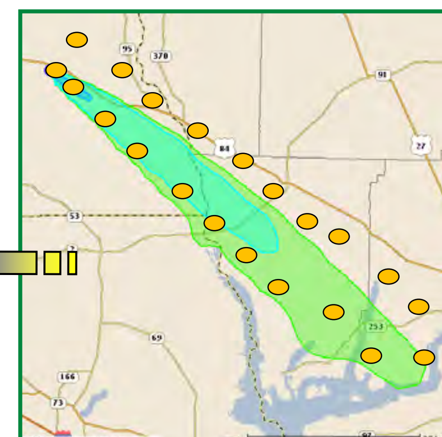
***Smoke plot generated showing wind direction***



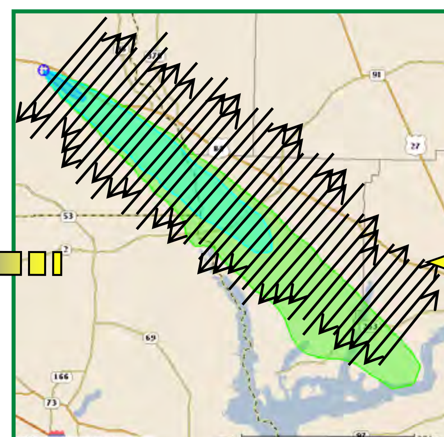
***Airplane data used to bound ground deposition***



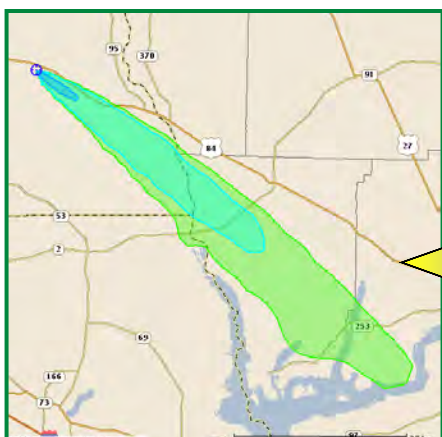
***Plume model normalized to initial aerial data***



***Ground measurements refine local deposition***



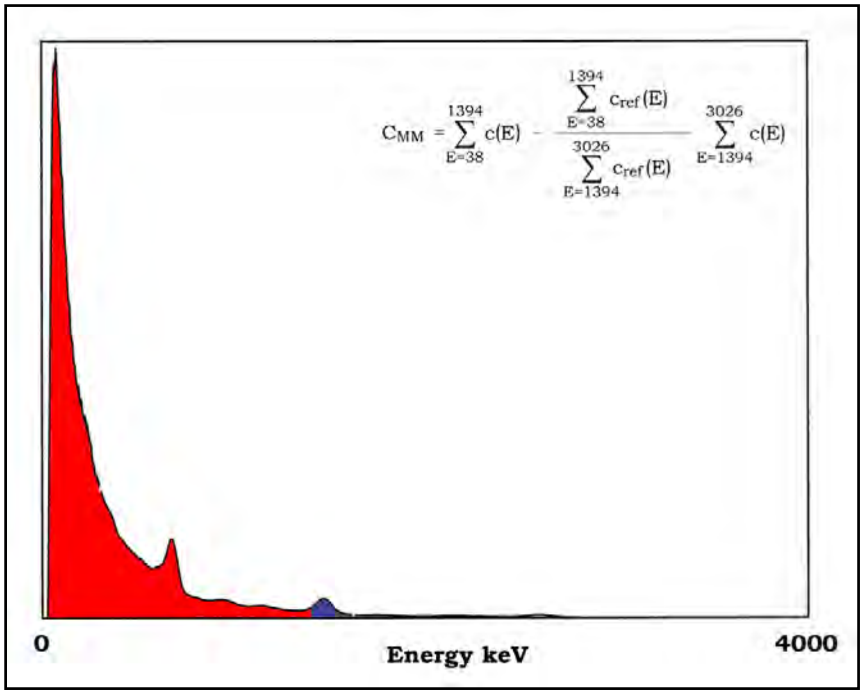
***Helo data provide high-resolution ground deposition***



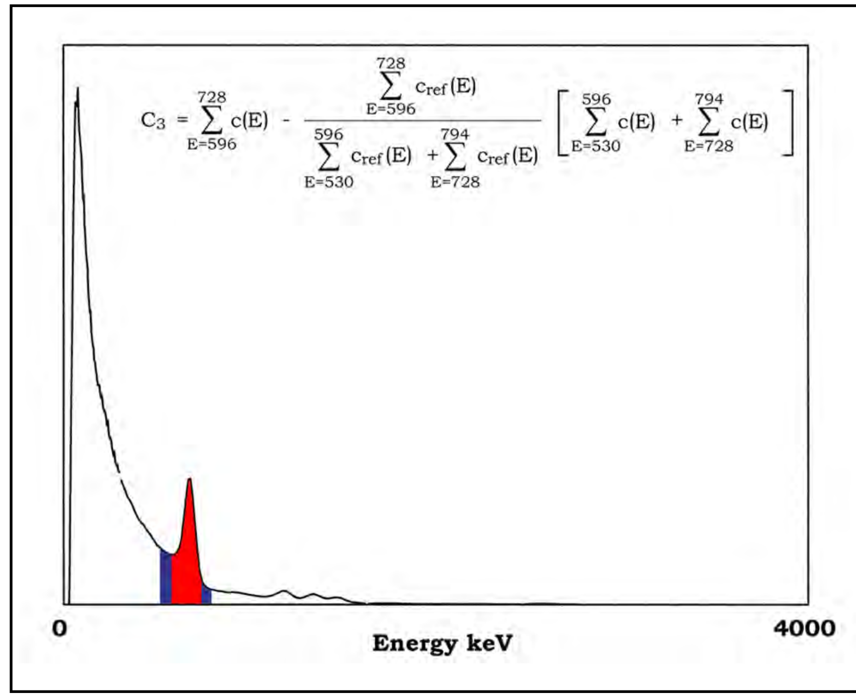
***Long-term characterization of ground deposition***

# Data Analysis

***The gamma ray spectral window stripping process can be used to extract radioisotope information from aerial data***



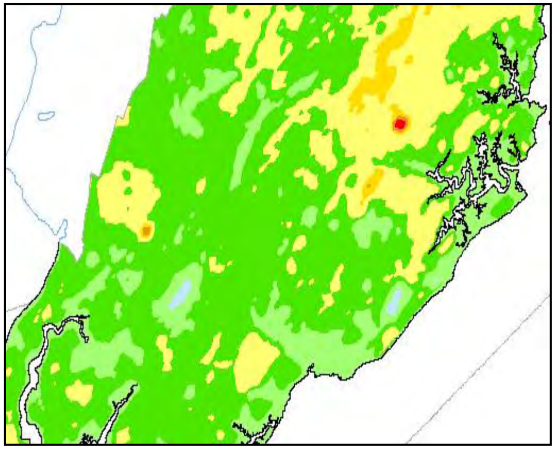

Man-Made Gross Count



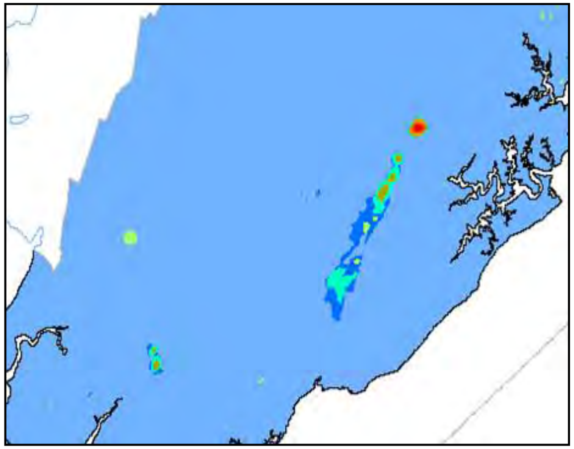

Photopeak Net Count

# AMS Survey Data Products

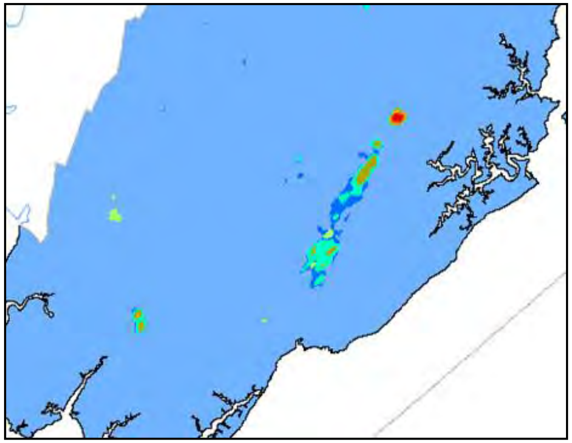
***Detailed high-resolution radiation contour plots can be obtained in the post-processing of aerial radiological data***



**Gamma Gross Count**
**40–3000 keV**

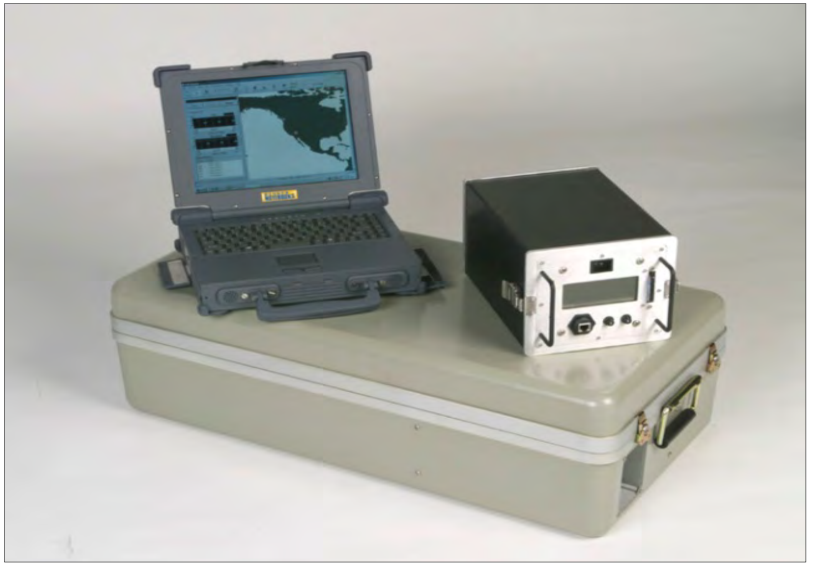


**Man-Made Gross Count**
**Ratio High E to Low E**



**Isotope Net Count**
**Photopeak Only**

# Spectral Advanced Radiological Computer System (SPARCS) for Aerial Radiological Response



# What is SPARCS?

**SPARCS** is a radiological data acquisition and analysis system designed for the nuclear or radiological emergency response mission. It has been used by DOE for over 20 years.

- Modular system that records the gamma radiation levels, spectral data, and GPS coordinates
- Operator display with key data and position tracking on a map
- Portable, relatively light, and durable enough to be mounted on almost any vehicle, boat, or aircraft
- Wide array of applications to include search, portal monitoring, pre-event baseline surveys, aerial measurements, and emergency response
- Easy to install and operate

# Multi-platform Compatible

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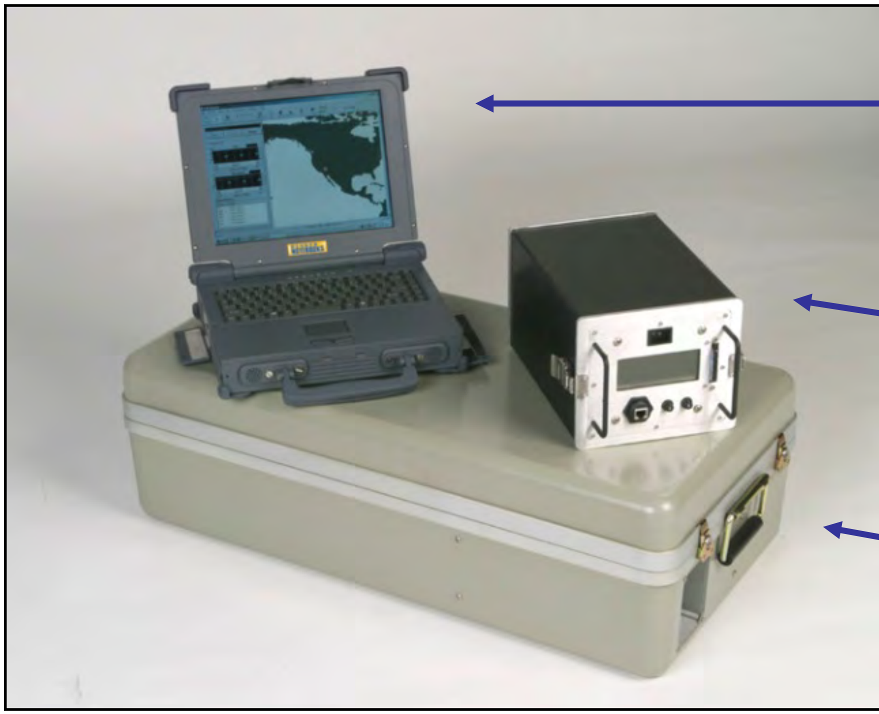
# SPARCS Basic Components



Laptop Display (rugged notebook computer)

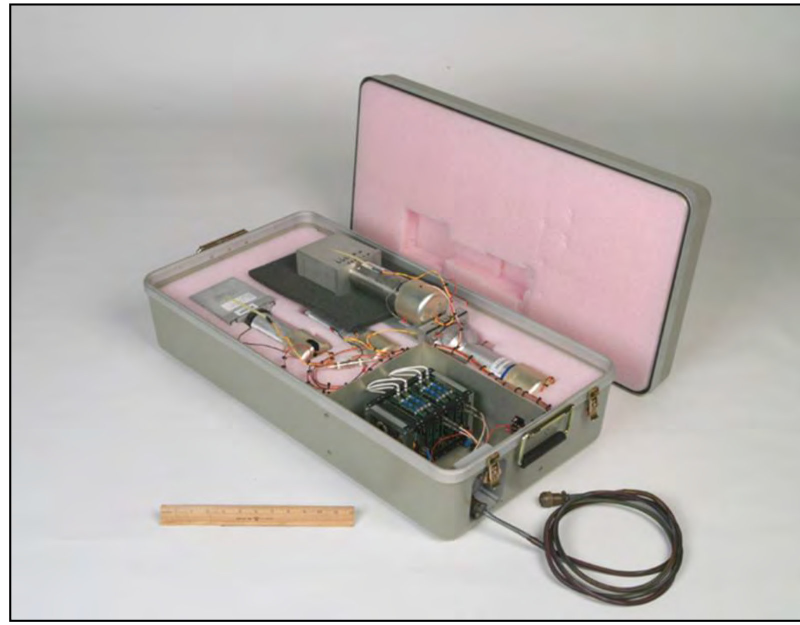
Acquisition and Telemetry Unit (ATU)

Detector Pod

# SPARCS Detector Pod

## Detector Pod:

- Gamma Ray Detectors
  - Sodium iodide
- Support Electronics:
  - HV power supplies
  - Preamplifiers
  - Multichannel analyzers
- Size:
  - 16.5" W × 32.5" D × 10" H (42 × 82 × 25 cm)
- Weight:
  - 68 lb (31 kg)



# Acquisition and Telemetry Unit (ATU)

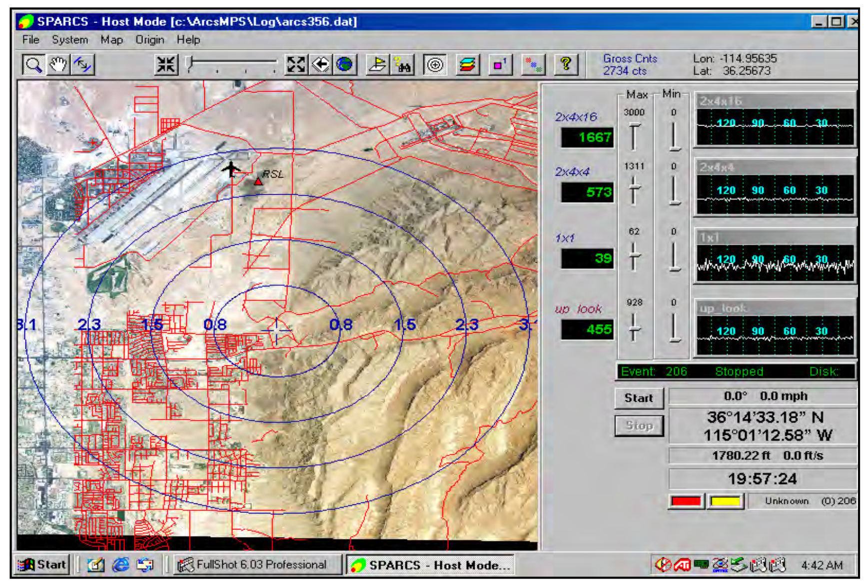
**ATU:**

- Records detector data
- Records GPS coordinates
- Stores data on Compact Flash card
- Provides data for laptop display
- Provides DC power for detector pod
- Size: 7.3" W × 11.5" D × 6.2" H (18 × 30 × 16 cm)
- Weight: 10.5 lb (4.8 kg)

# Laptop Display

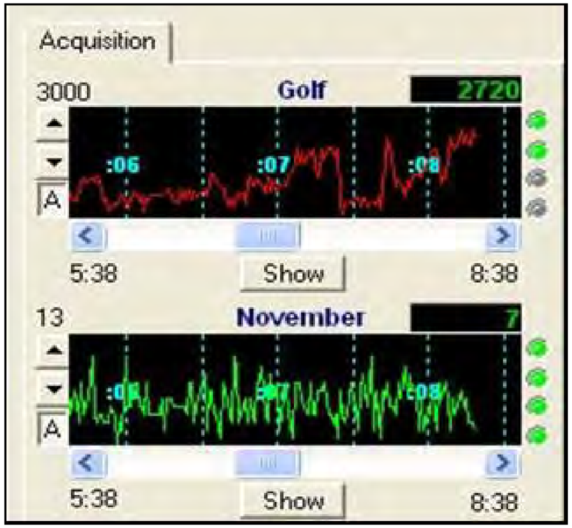
## Laptop Display:

- Rugged laptop computer with touch screen
- Acquisition and calibration software
- Displays gross count data with colored points, or “bread crumbs,” on a moving geo-referenced map

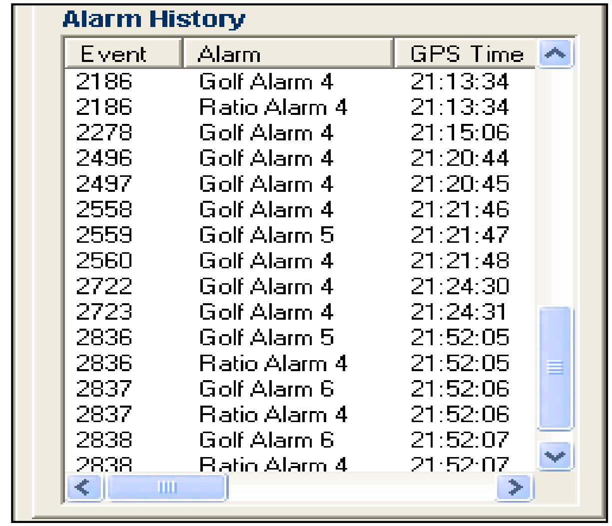


# Operator Display Options

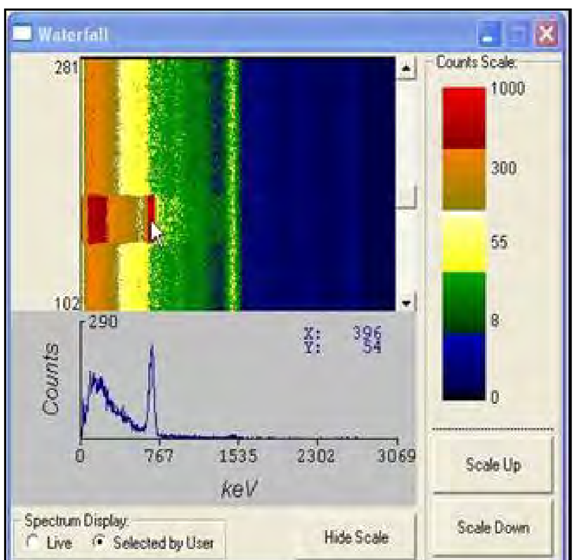
Strip Charts



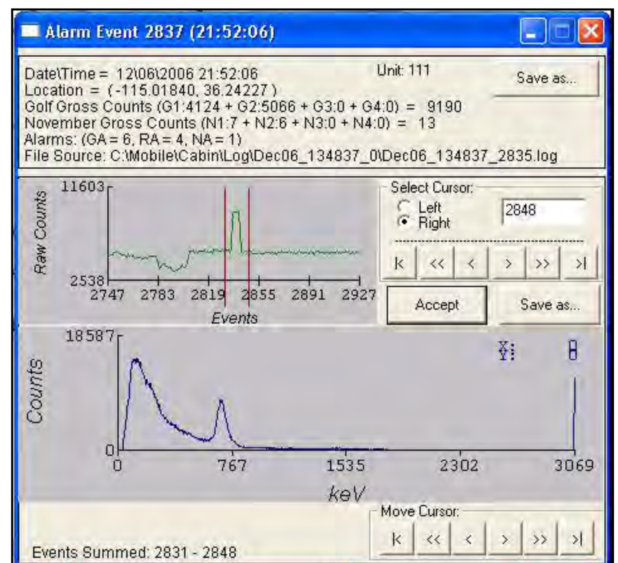

Alarm History




Waterfall Plots




Alarm Events



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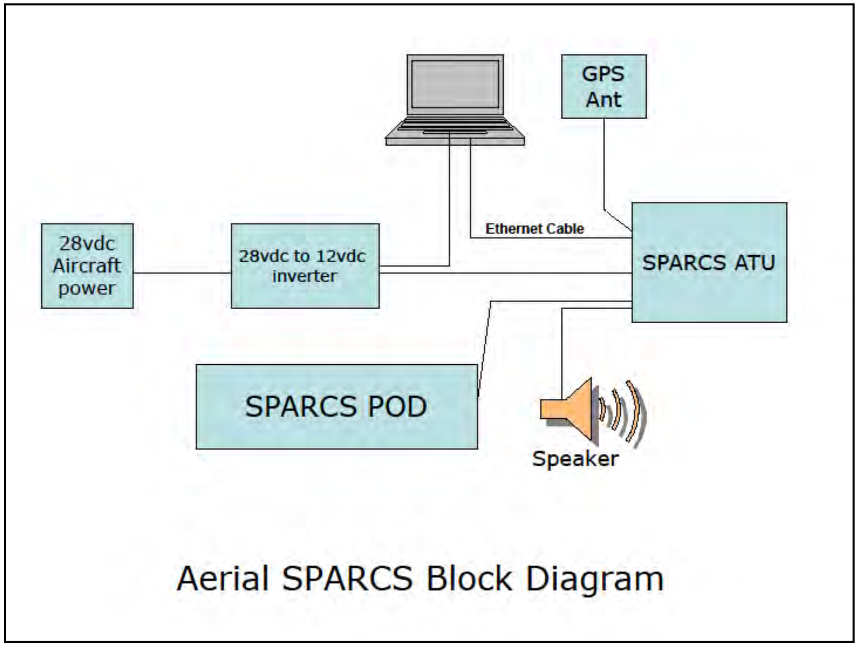
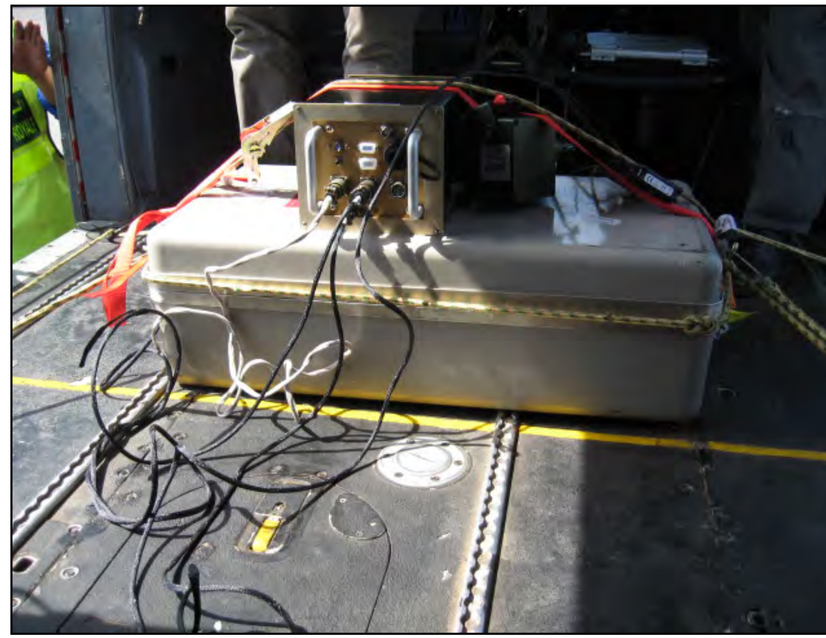
AERIAL MEASURING SYSTEMS AMS

# SPARCS Aircraft Installation




Aerial SPARCS Block Diagram



Rapid installation in any aircraft
Compatible with aircraft power (10–40 volt input)
Aircraft-certified fiberglass detector pod
GPS magnetic mount antenna placed on dashboard
Monitored by technician with radio contact to pilot

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# US DOE Aerial Measuring System Response to Fukushima Accident

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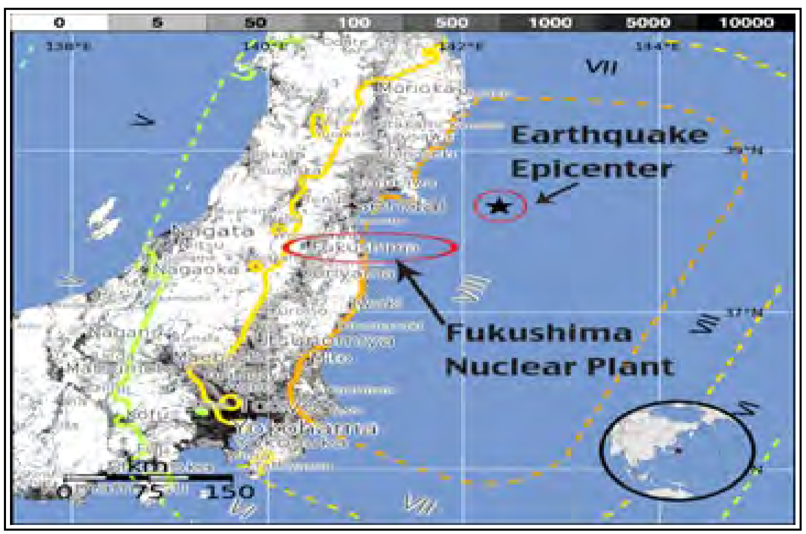
# US DOE Response to Fukushima

AERIAL MEASURING SYSTEMS AMS

*On March 11, 2011, at 1446, an 8.9 magnitude earthquake occurred off the coast of Japan that triggered the Fukushima Dai-ichi reactors to scram. Within minutes, the reactor site was flooded by a 14 m tsunami that caused power loss to the reactor cooling systems. Japan established a 20 km mandatory evacuation zone affecting 110,000 residents. Seawater with boric acid was injected into the reactors to cool the cores. Within days, explosions occurred at all three reactors, resulting in core breach and the release of radioactivity inland.*




# DOE Response Timeline

**March 11** DOE activates the Nuclear Incident Team (NIT) at DOE/HQ and the Consequence Management Home Team (CMHT). The NIT initiates deployment orders for a Consequence Management Response Team (CMRT) and AMS.

**March 14** CMRT/AMS departs for Japan with 33 personnel and 17,000 lb (7800 kg) of equipment on a US Air Force C-17 airplane.

**March 16** CMRT/AMS arrives Yokota Air Base 0155 JST. Situation upon arrival includes radioactivity in the air at Yokota and the news reporting continued reactor releases. First AMS flight at 0805 JST over Yokota detects no ground deposition and near background dose rates.

**March 17** First AMS flights to conduct surveys over the Fukushima prefecture exclusion zone

**March 22** First AMS data from both helicopter and airplane flights published on DOE website

***The DOE Team remained in Japan until May 28, working with Japan and providing daily multiple aircraft AMS surveys and supporting ground monitoring. The data were used to provide emergency and intermediate phase protective action guidance to protect the public.***

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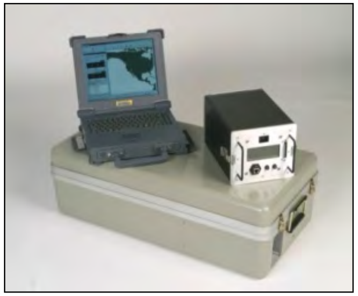
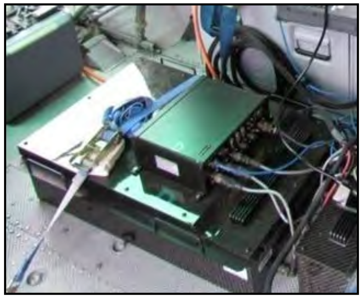
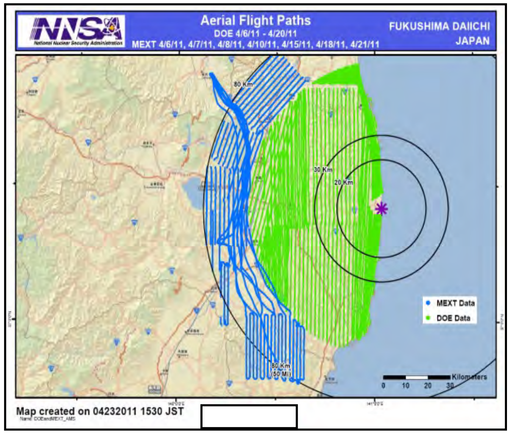
# AMS Operations in Japan



**Multiple Aircraft**

**Detection Systems**





**Integrated Data Products**

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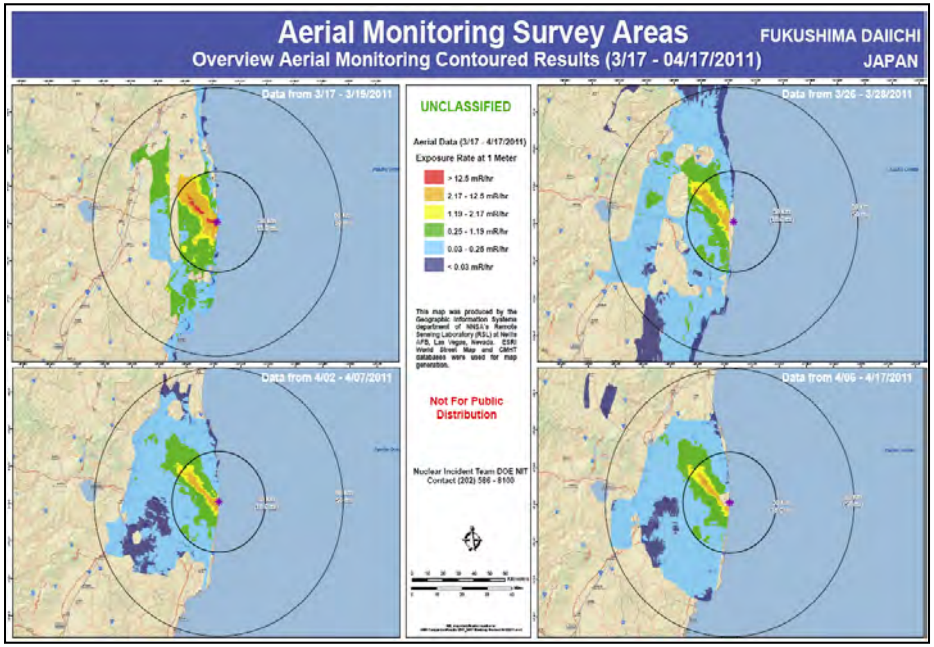
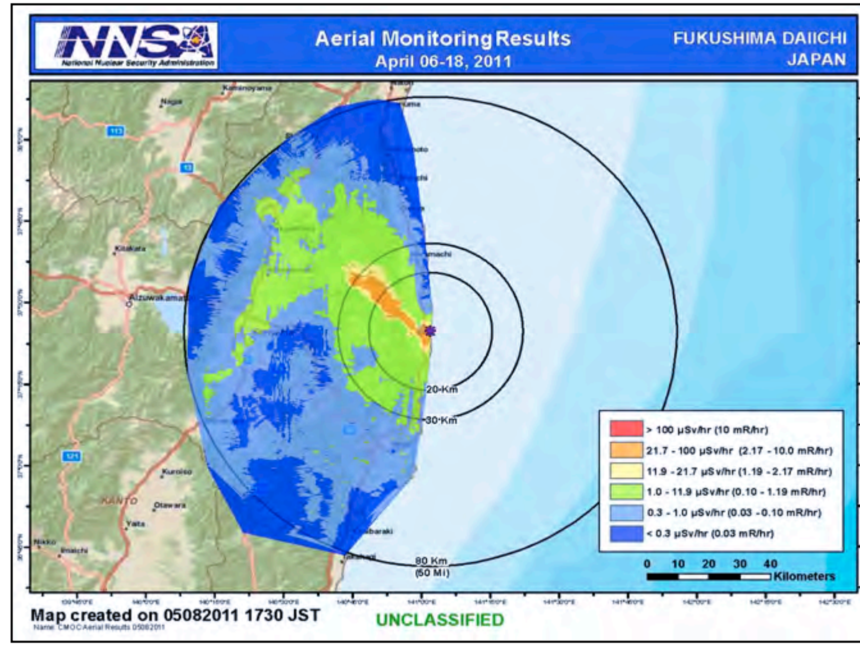
# AMS Monitoring Results




March 17 to April 17




April 6-18

***From March 16 to May 28, DOE conducted over 100 AMS flights and 525 flight hours over an area of 25,000 km$^2$ out to 80 km from Fukushima***

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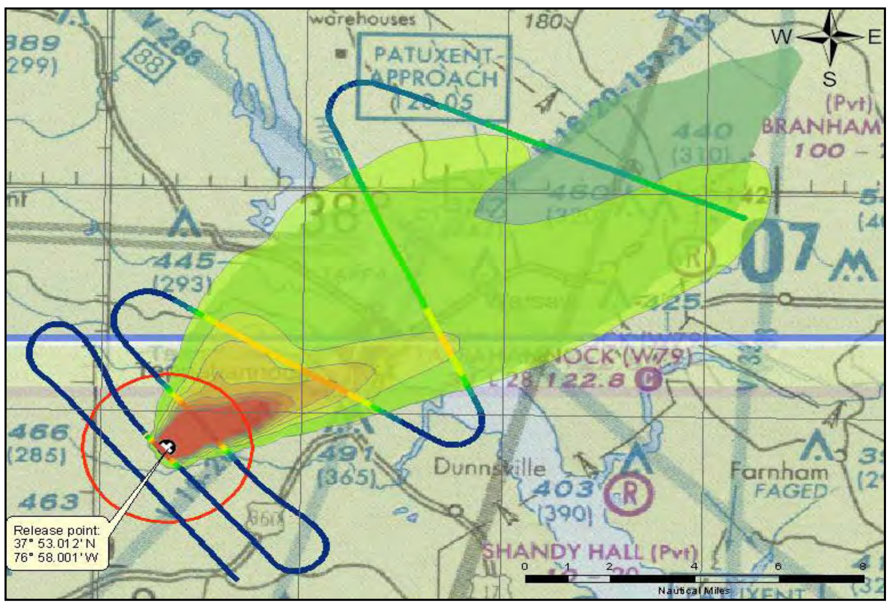
AERIAL MEASURING SYSTEMS AMS

# Aerial Measuring System

## Questions?

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