EPA ASPECT Program

Chemical, Oil and Radiological Remote-Sensing

ASPECT Case-Studies
Region 5 RRT Meeting
November 3, 2011

CAPT John Cardarelli II
Mark Thomas
Timothy Curry
Paul Kudarauskas

Outline

- Aircraft Platform
- ASPECT Program (how to activate ASPECT)
- Detection Technologies (Chem, Rad, Oil)
- Operational Parameters / Costs
- Case Studies
  - El Dorado Response (Chemical Detection)
  - BP Oil Spill (Oil Detection)
  - Welsbach Superfund Survey (Radiological Detection)

ASPECT Platform

Airborne Spectral Photometric Environmental Collection Technology

Aero Commander 680 FL/G Platform

Crew: Two Pilots, One Operator

Speeds:

Data Collection at ≈110 kts
Cruise at 180 to 200 kts

Range/Aloft Time:

Up to 1,100 NM
Aloft Time 4 to 6 hours

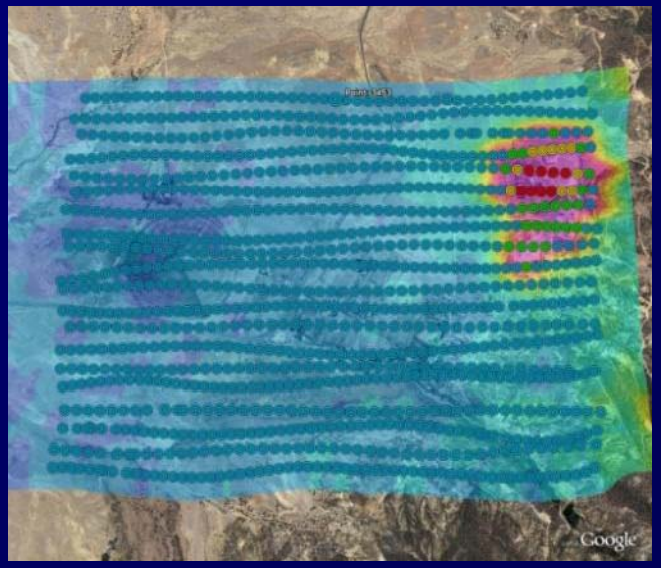
Survey Altitude:

Data Collection at 300 to 3,000 ft AGL

Ground Needs – Standard FBO

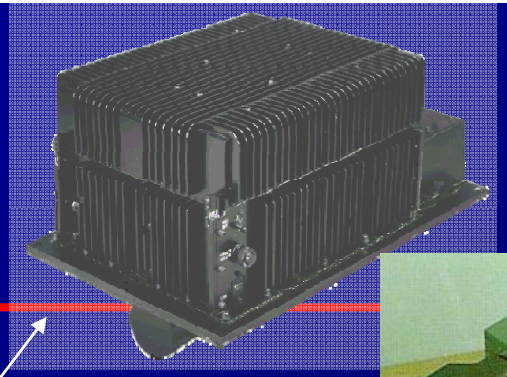
ASPECT Program

- Nation's only **24/7** Airborne **Chemical**, **Radiological**, and **Situational Awareness** Remote Sensing Aircraft
- Provides information to the first responder that is **timely, useful,** and **compatible** with numerous software applications
- **Multi-role responses** (homeland security, emergency response, environmental characterization, and climate monitoring)
- Provides **infrared & photographic images** with **geospatial chemical** and **radiological** information
- **≈ 120 Deployments since 2001**
- **Five Primary Sensors/Systems**



Methods of Activation

CURRENT SYSTEMS



- ASPECT Uses Five Primary Sensors/Systems:
  - ✓ An Infrared Line Scanner to image the plume
  - ✓ A High Speed Infrared Spectrometer to identify and quantify the composition of the plume
  - ✓ Two Gamma-Ray Spectrometer Packs for Radiological Detection
  - ✓ High Resolution Digital Aerial Cameras with ability to rectify for inclusion into GIS
  - ✓ Broadband Satellite Data System (SatCom)

Program ASPECT

Equipment View

Sensor Station View

Operator Station

CHEMICAL DETECTION
Case Study 1

El Dorado Chemical Company

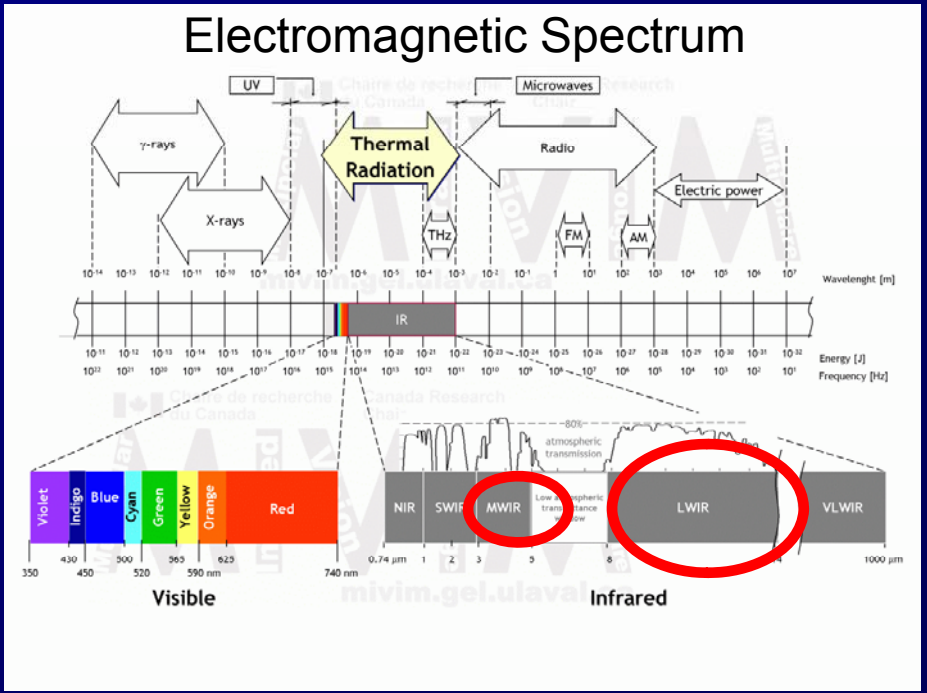
Ammonia Nitrate Fire

Bryan, Texas

July 30, 2009

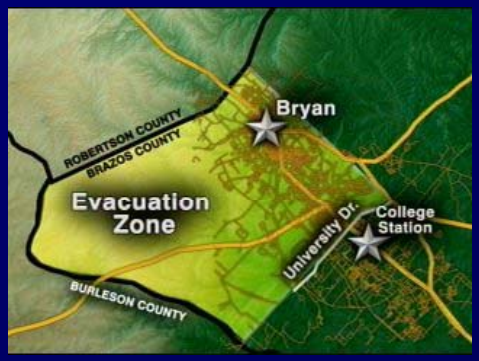
ASPECT chemical detection is based on infrared spectral analysis via an open-path infrared spectrometer.

It does NOT take air samples.

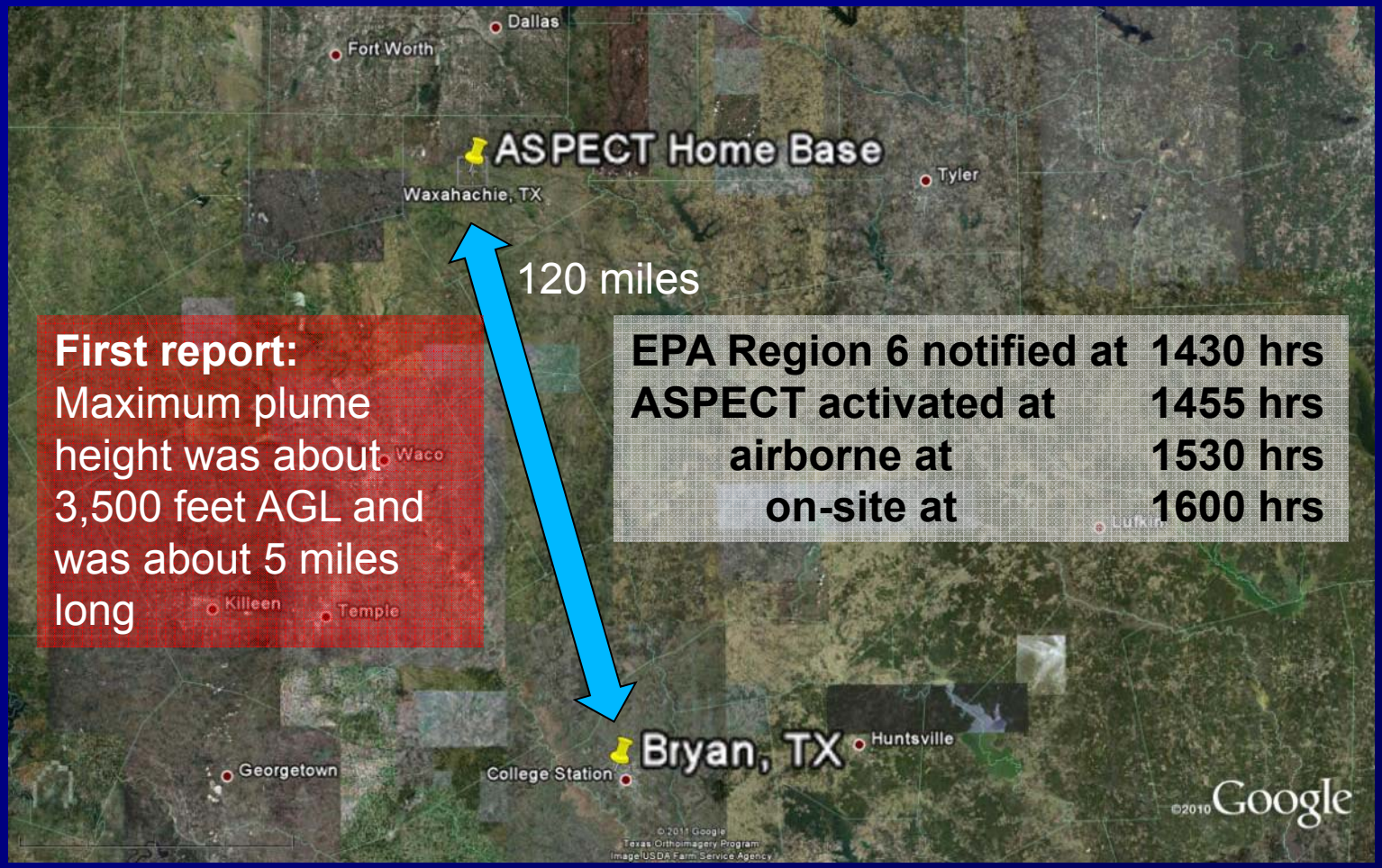


El Dorado Chemical Fire

- July 30, 2009
- Around noon, sparks from welding started the fire
- Ammonia nitrate
- News reports smoke plume extended 60 miles
- 34 people injured (including 20 firefighters)
- Evacuation of Bryan City (N=72,000)



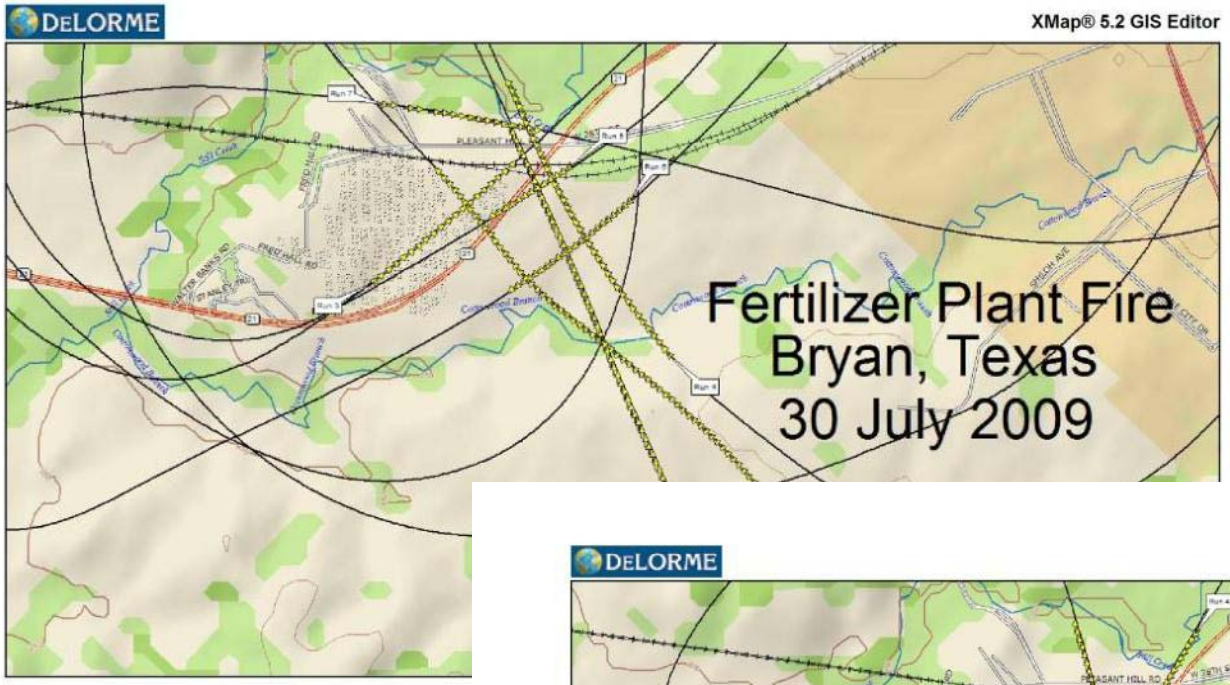
ASPECT Deployed



Georectified Aerial Photos

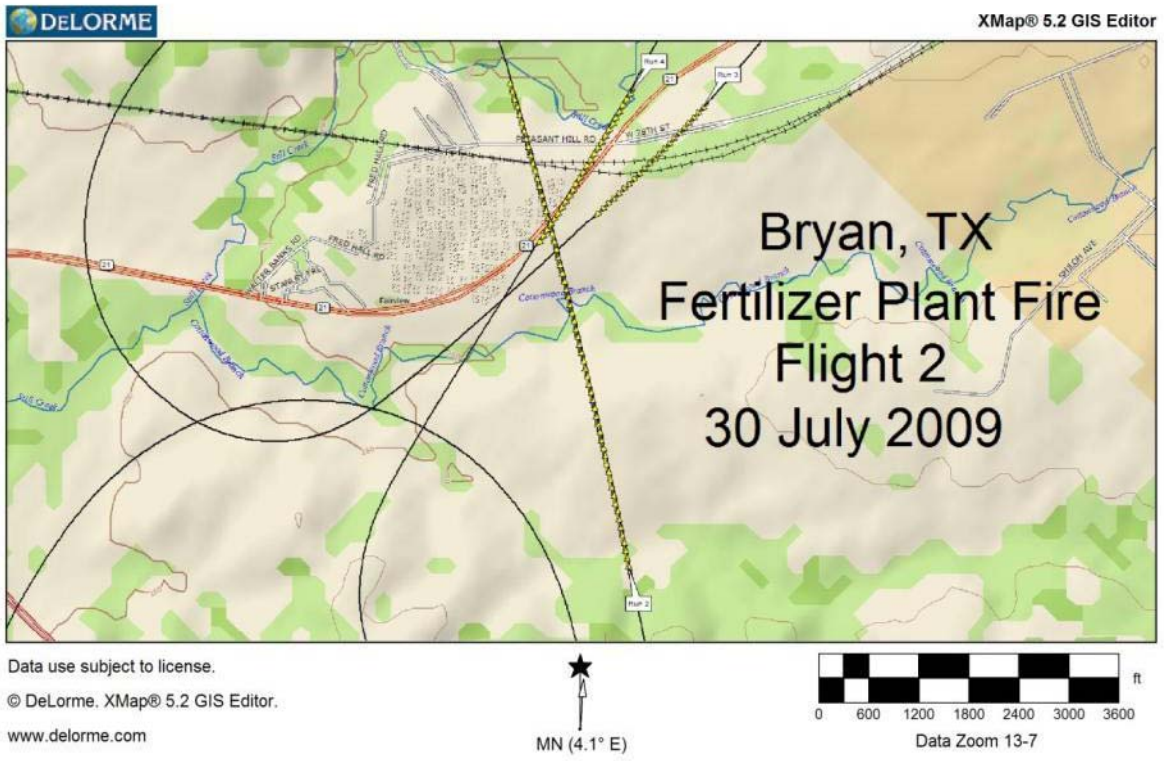
Flight 1
1600 hrs

Flight 2
1800 hrs



FLIGHT 1
7 passes
Infrared images
IR spectrometry
Aerial Photography

Ammonia (2-5 ppm)
Ozone

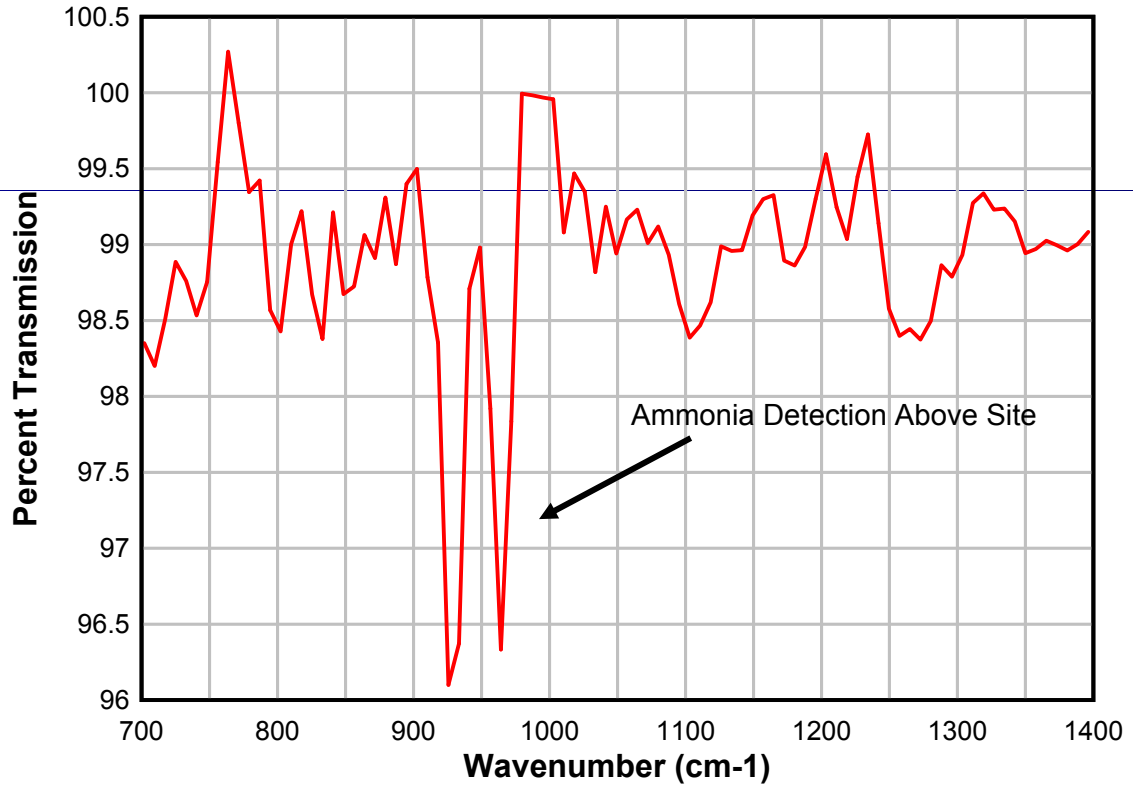


FLIGHT 2
2 passes
Infrared images
IR spectrometry
Aerial Photography

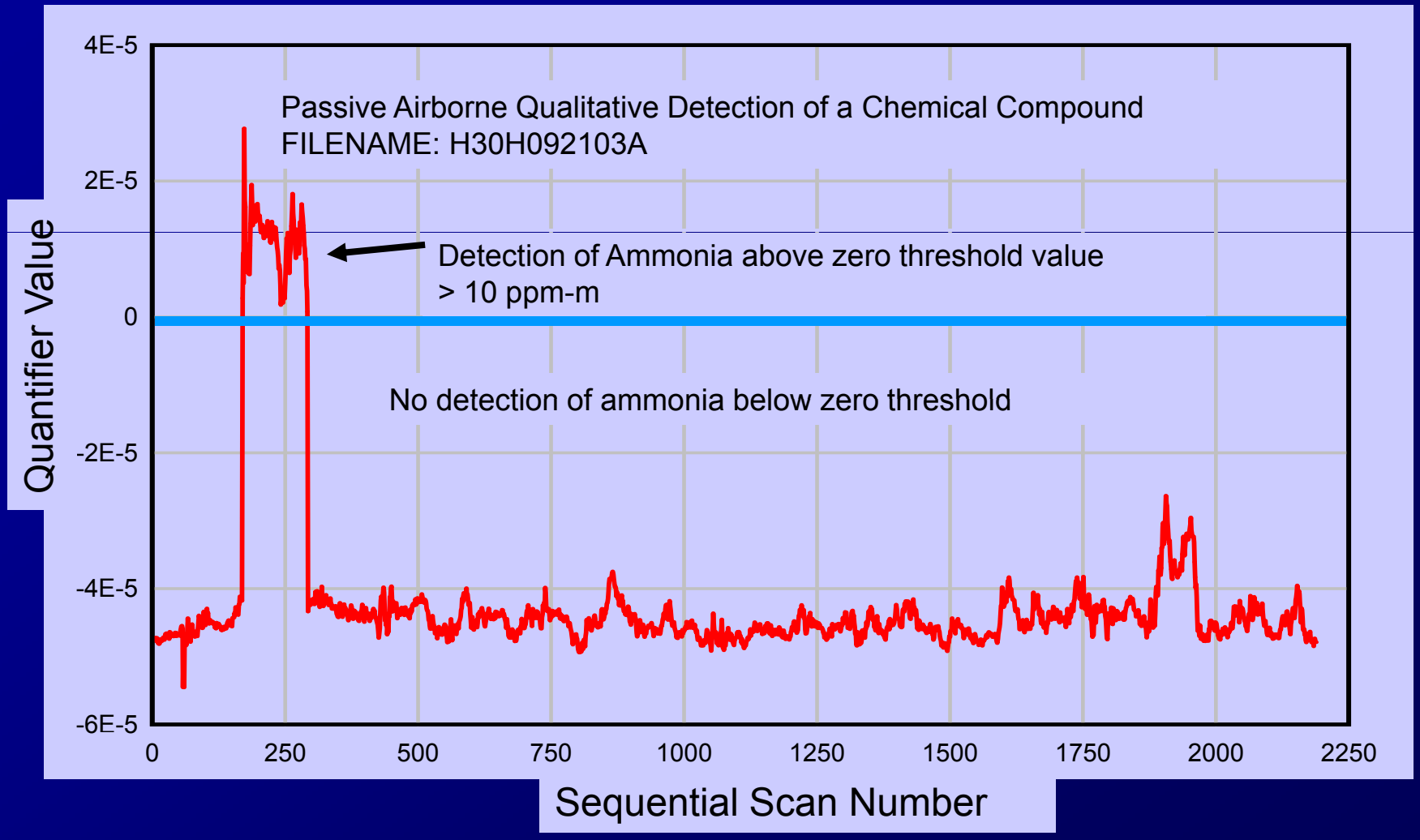
Ammonia (0.5 ppm)

Ammonia Spectra

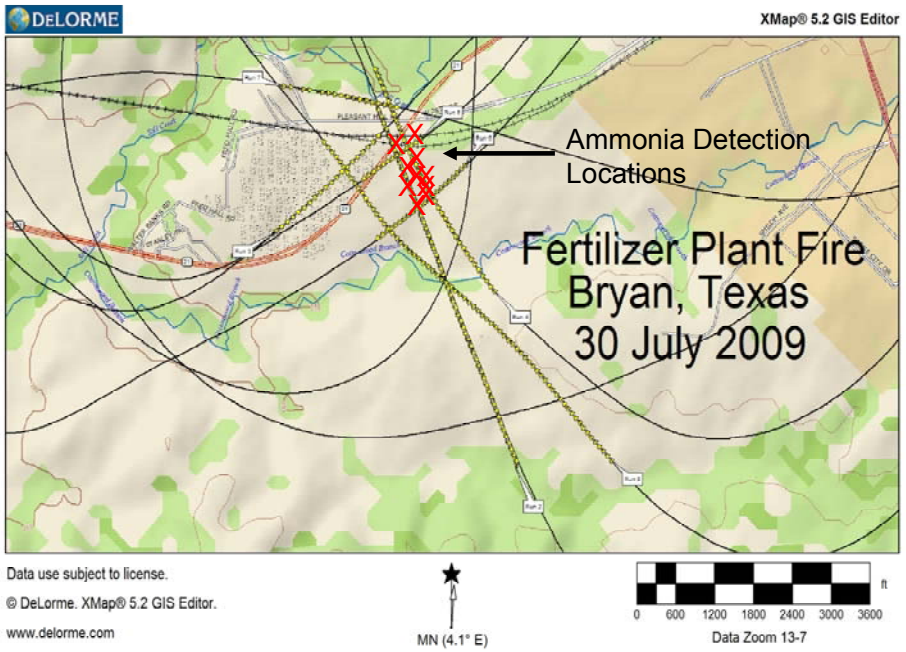
(70 spectra collected per second)



Example Chemical Plume Cross-Cut



Automated Compound Detection
Ammonia Detection



72 Automated Chemical Detection Algorithms

Detection limits range from ppb to ppm depending on chemical

Acetic Acid	Cumene	Isoprene	Propylene
Acetone	Diborane	Isopropanol	Propylene Oxide
Acrolein	1,1-Dichloroethene	Isopropyl Acetate	Silicon Tetrafluoride
Acrylonitrile	Dichloromethane	MAPP	Sulfur Dioxide
Acrylic Acid	Dichlorodifluoromethane	Methyl Acetate	Sulfur Hexafluoride
Allyl Alcohol	Difluoroethane	Methyl Ethyl Ketone	Sulfur Mustard
Ammonia	Difluoromethane	Methanol	Nitrogen Mustard
Arsine	Ethanol	Methylbromide	Phosgene
Bis-Chloroethyl Ether	Ethyl Acetate	Methylene Chloride	Phosphine
Boron Tribromide	Ethyl Formate	Methyl Methacrylate	Tetrachloroethylene
Boron Triflouride	Ethylene	MTEB	1,1,1-Trichloroethane
1,3-Butadiene	Formic Acid	Naphthalene	Trichloroethylene
1-Butene	Freon 134a	n-Butyl Acetate	Trichloromethane
2-Butene	GA (Tabun)	n-Butyl Alcohol	Triethylamine
Carbon Tetrachloride	GB (Sarin)	Nitric Acid	Triethylphosphate
Carbonyl Chloride	Germane	Nitrogen Trifluoride	Trimethylamine
Carbon Tetraflouride	Hexafluoroacetone	Phosphorus Oxychloride	Trimethyl Phosphite
Chlorodifluoromethane	Isobutylene	Propyl Acetate	Vinyl Acetate

Manual assessment of 500+ other chemical compounds

OIL DETECTION
Case Study 2

Deepwater Horizon Oil Spill

ASPECT Gulf Oil Mission

- EPA Activation
  - ✓ Region 6: 28 April – 3 August 2010
  - ✓ Region 4: 6 June – 11 July 2010

- Mission Assignment
  - Chemical detection
  - Aerial Photography
  - IR imagery (Oil Detection and Spotting)
  - Condense data into standardized aerial oil spotting reports

Why ASPECT can detect oil

Radiance = ϵT^4

- ϵ = emissivity *(how efficient an object irradiates infrared energy)*
- T = temperature
  - Oil and water have similar temperatures in open water (ϵ driven properties)
  - Oil on marshland has different temperatures (T driven properties)

Oil $\epsilon \approx 0.75$ to 0.82 depending on thickness of surface oil

Water $\epsilon \approx 0.93$

ASPECT Gulf Oil Users

- EPA Region 4
- EPA Region 6
- EPA Headquarters
- US Coast Guard Houma
- US Coast Guard Mobile
- NOAA
- State of Louisiana
- State of Mississippi
- BP
- Public (via Google Earth)

Mission Statistics

April 28 to August 3, 2010

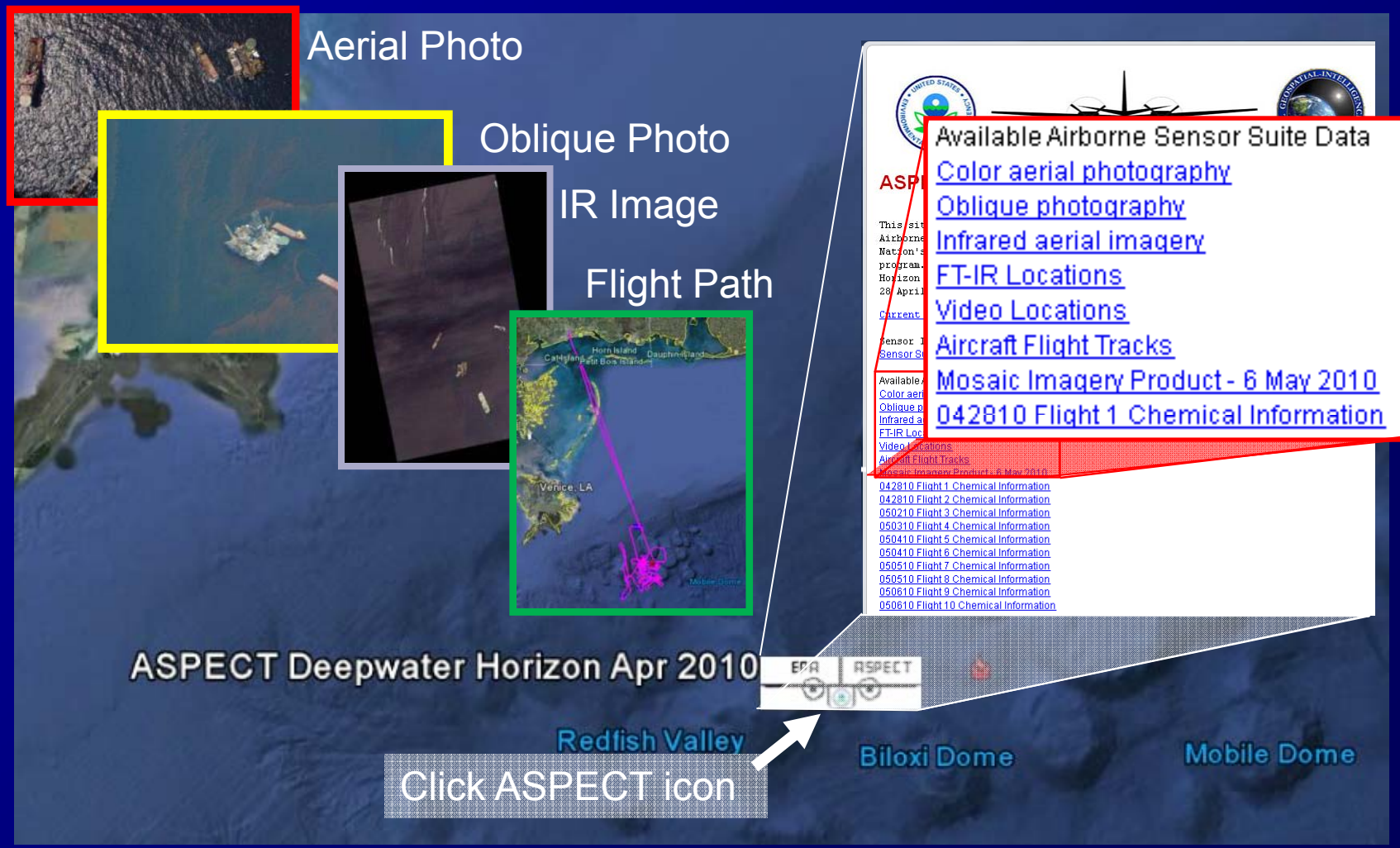
- 86 survey flights
  - ✓3087 data collection runs
  - ✓294 flight hours
- 2,544,000 interferograms assessed
- Over 4.5TB processed data
- 14,972 digital photos
- 6,593 oblique photos
- 2,100 infrared images
- 372,000 unique users of the data
- 1.2 Million times ASPECT web data were accessed

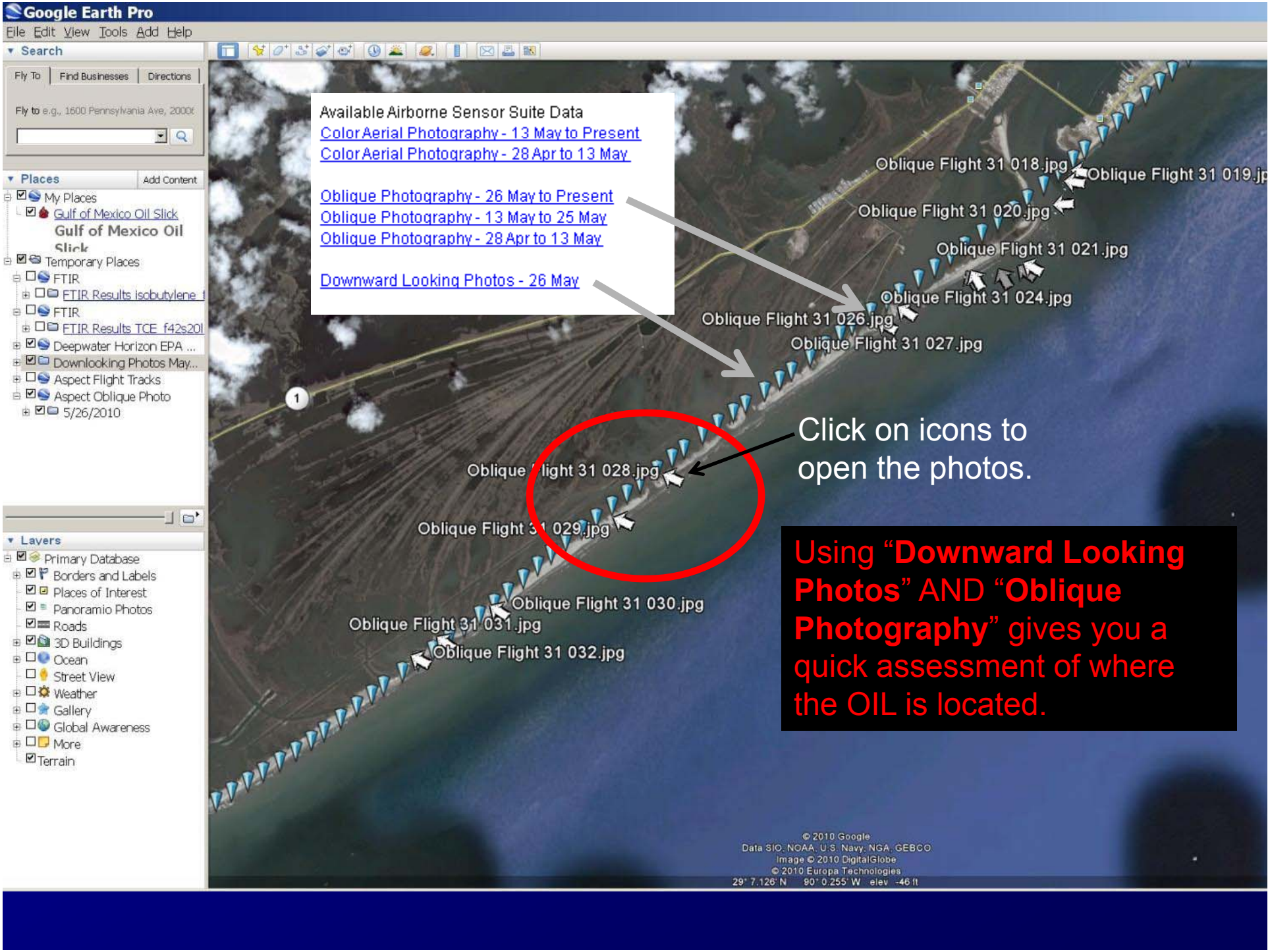
Google Earth® Application

You need to download free Google Earth® software found at:

http://earth.google.com/

EPA ASPECT Data

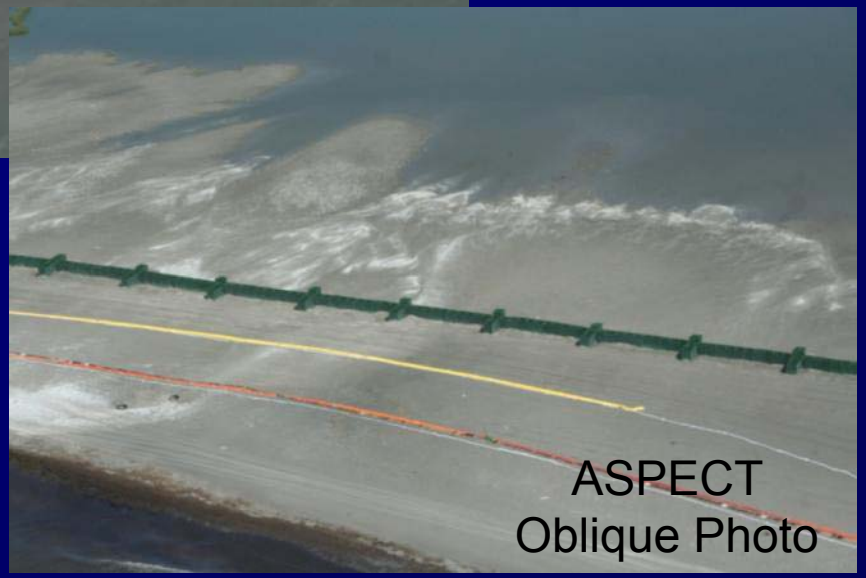



Google Earth Pro
File Edit View Tools Add Help
Search
Fly To
Find Businesses
Directions
Places
Add Content
My Places
Gulf of Mexico Oil Slick
Temporary Places
FTIR
FTIR Results isobutylene
FTIR
FTIR Results TCE f42s20l
Deepwater Horizon EPA ...
Downlooking Photos May...
Aspect Flight Tracks
Aspect Oblique Photo
5/26/2010
Layers
Primary Database
Borders and Labels
Places of Interest
Panoramio Photos
Roads
3D Buildings
Ocean
Street View
Weather
Gallery
Global Awareness
More
Terrain
Available Airborne Sensor Suite Data
Color Aerial Photography - 13 May to Present
Color Aerial Photography - 28 Apr to 13 May
Oblique Photography - 26 May to Present
Oblique Photography - 13 May to 25 May
Oblique Photography - 28 Apr to 13 May
Downward Looking Photos - 26 May
Oblique Flight 31 018.jpg
Oblique Flight 31 019.jp
Oblique Flight 31 020.jpg
Oblique Flight 31 021.jpg
Oblique Flight 31 024.jpg
Oblique Flight 31 026.jpg
Oblique Flight 31 027.jpg
Oblique Flight 31 028.jpg
Oblique Flight 31 029.jpg
Oblique Flight 31 030.jpg
Oblique Flight 31 031.jpg
Oblique Flight 31 032.jpg
Click on icons to open the photos.
Using "Downward Looking Photos" AND "Oblique Photography" gives you a quick assessment of where the OIL is located.
© 2010 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2010 DigitalGlobe
© 2010 Europa Technologies
29° 7.126' N 90° 0.255' W elev -46 ft

Using ASPECT Google Earth data to narrow search for oil on beaches

May 26, 2010; 9:28 a.m. CST

Data can be accessed within 20 minutes from landing.

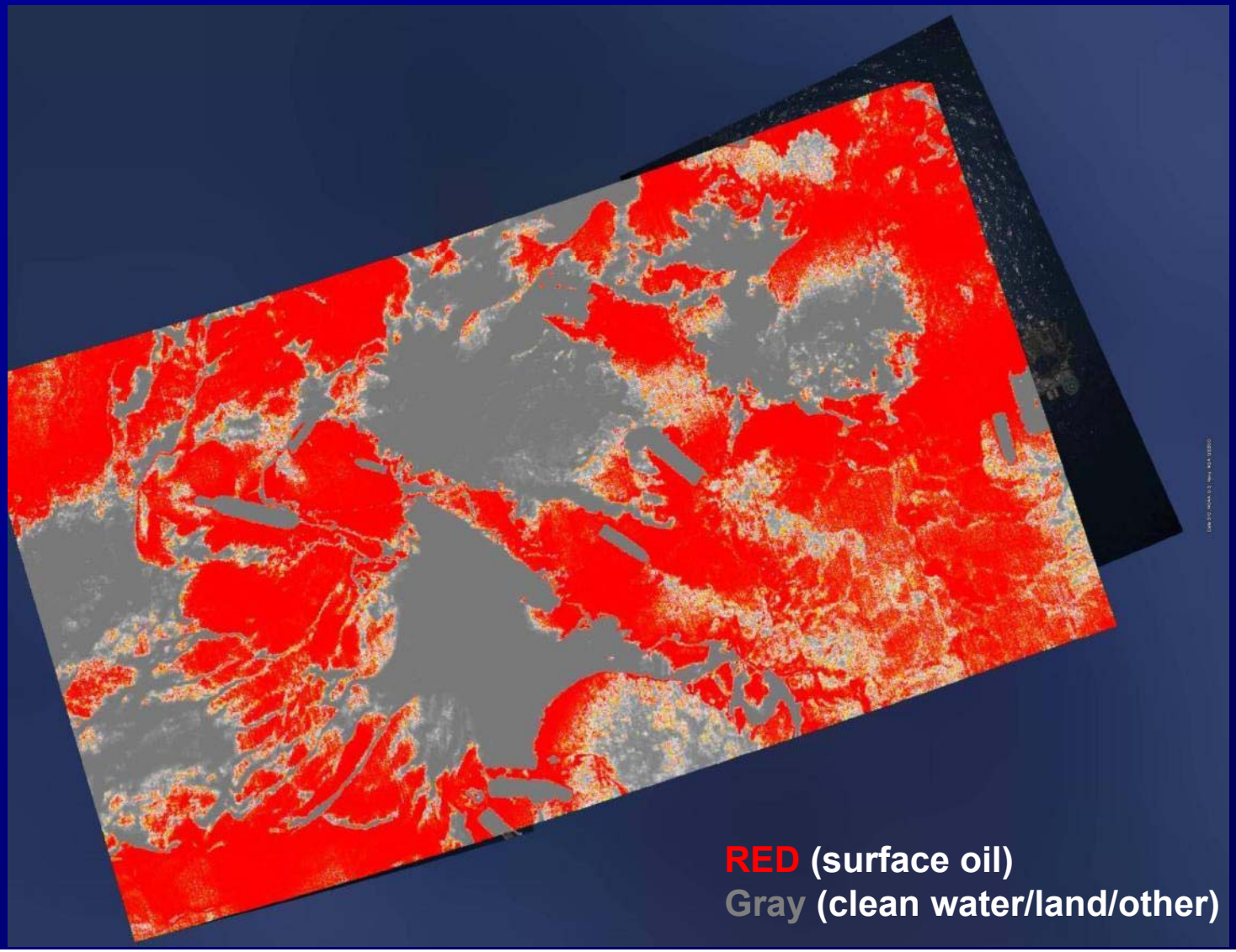


Deep Water Oil Detection

Unsupervised Classification Infrared Image

Deep Water Oil Detection

Supervised Pattern Recognition of IR Image

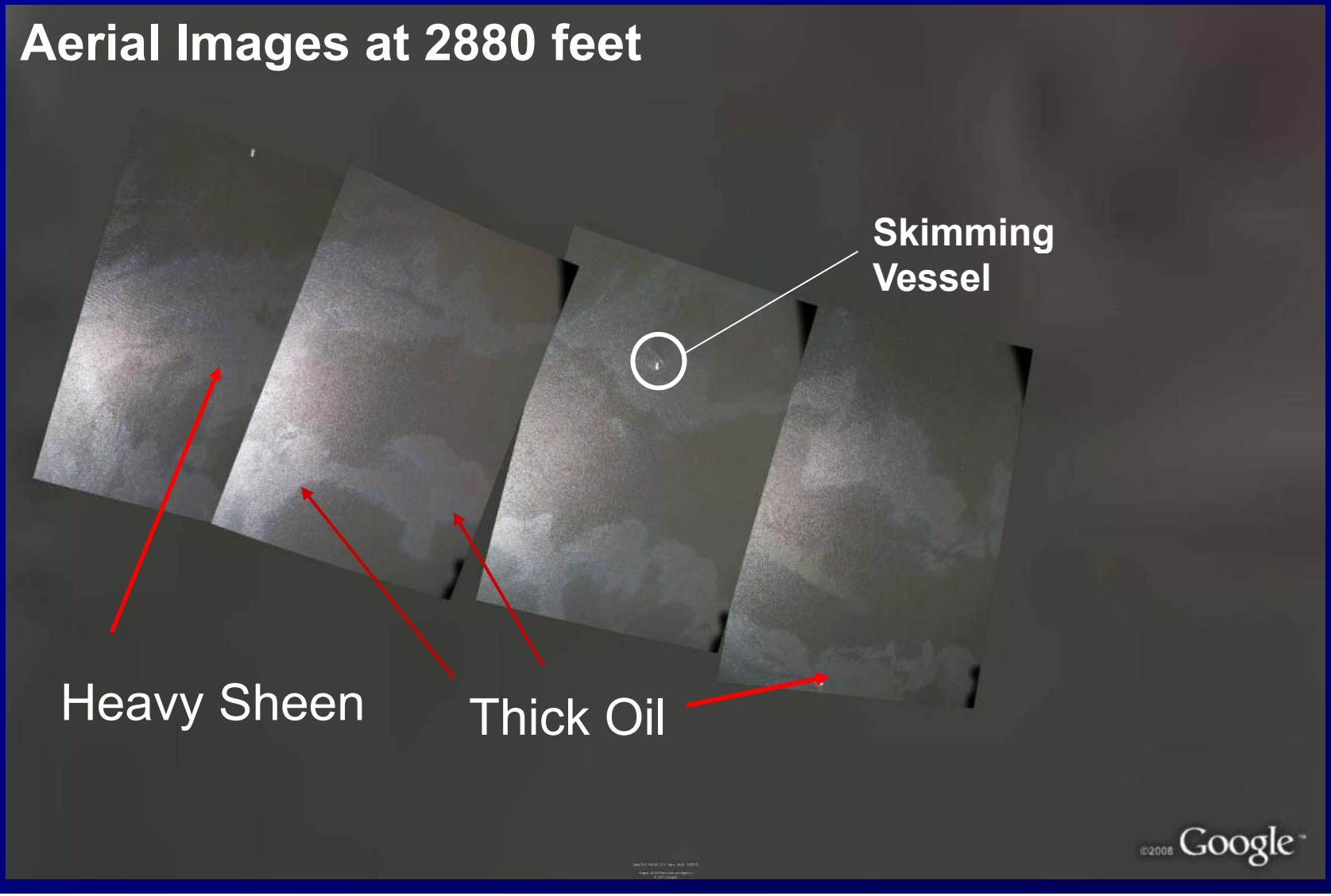


Near Shore Oil Detection

- The ASPECT Team was tasked to explore the possibility to use infrared technology to detect and locate oil in near shore/shallow waters
- The Unsupervised Classifier approach was successful in waters greater than 6 feet
- For waters less than 6 feet a Spectral Pattern Recognition technique was utilized

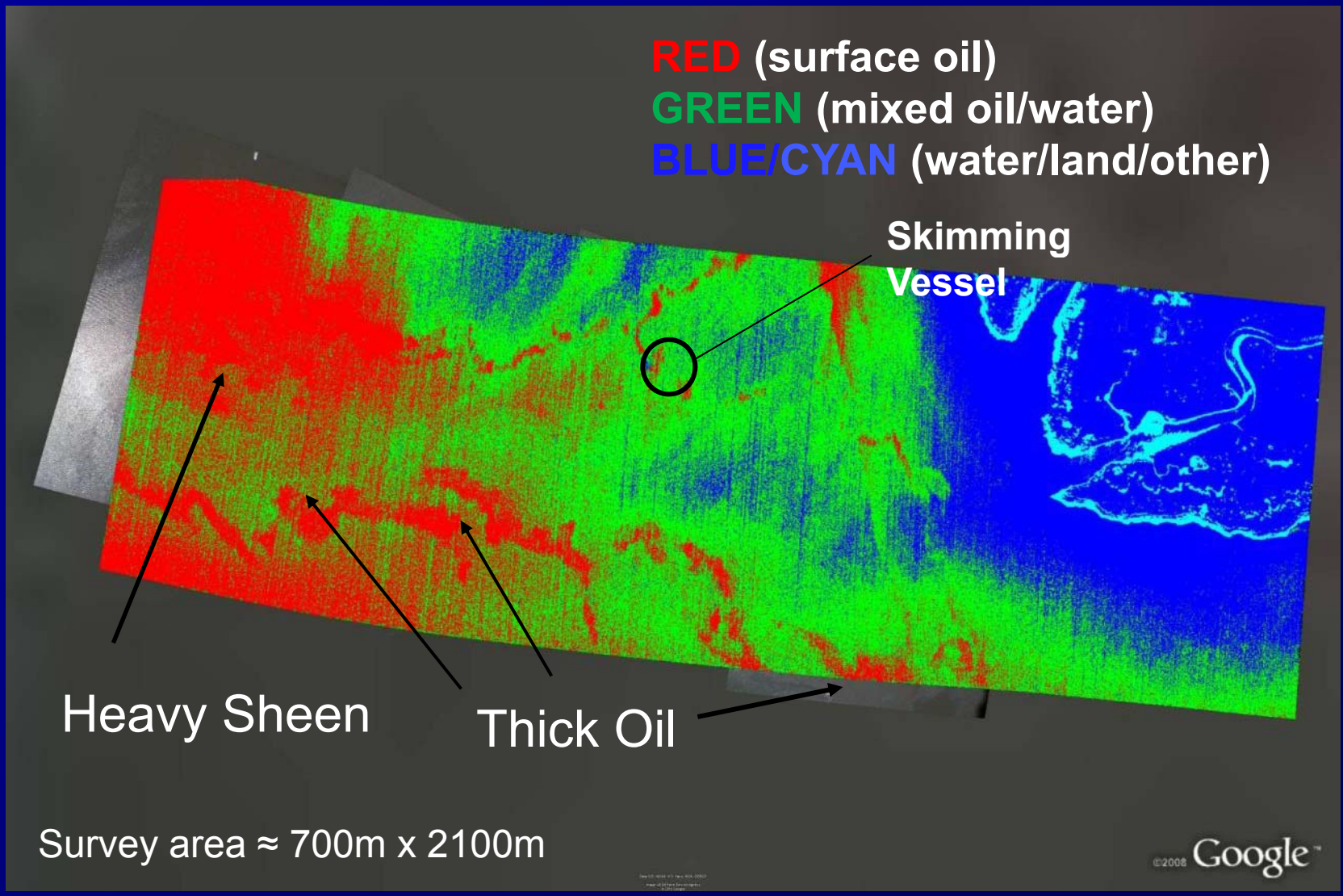
Near Shore Oil Detection

Aerial Imagery – Barataria Bay



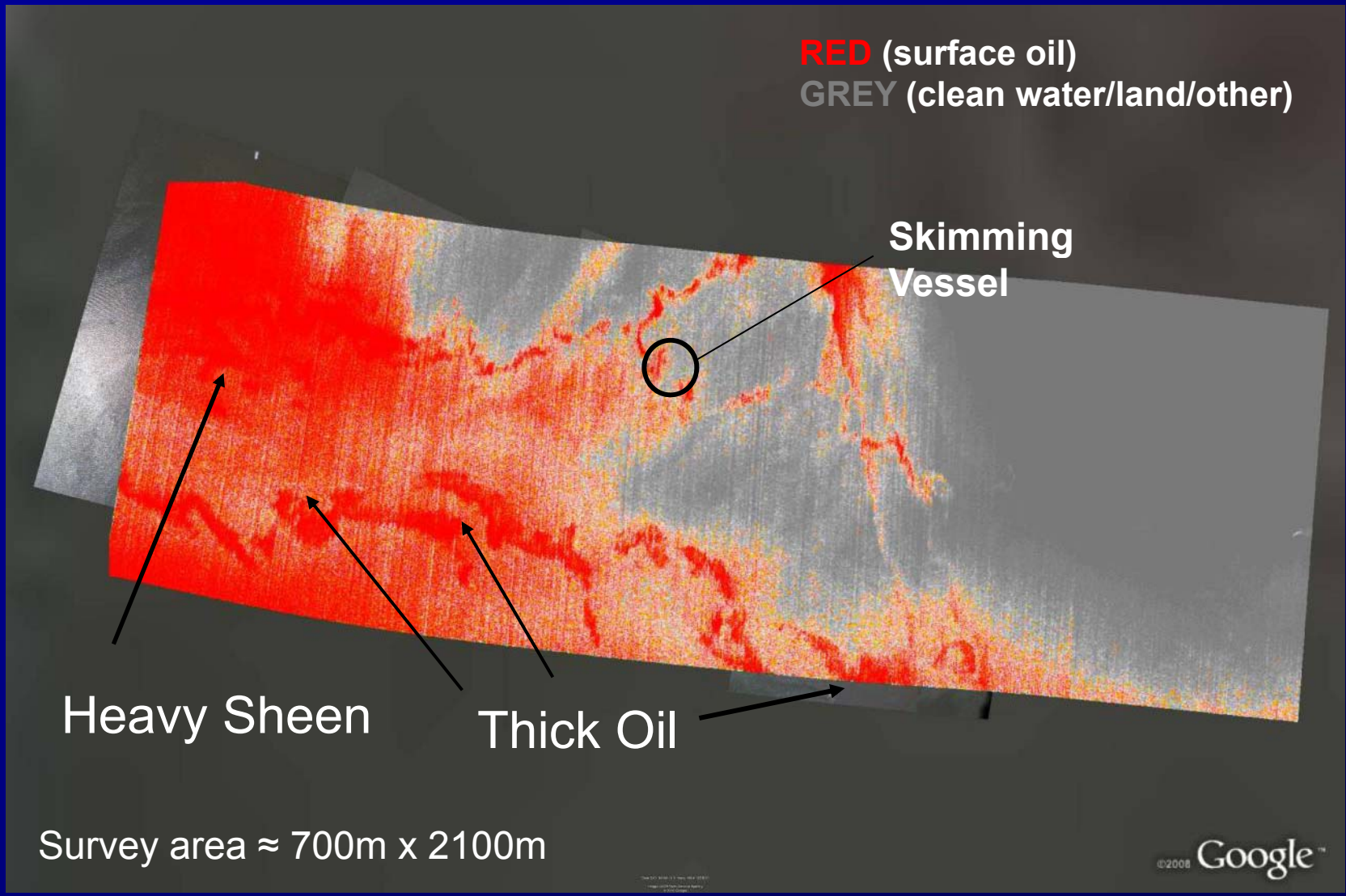
Near Shore Oil Detection

Unsupervised Classification Infrared Image



Near Shore Oil Detection

Supervised Pattern Recognition of IR Image

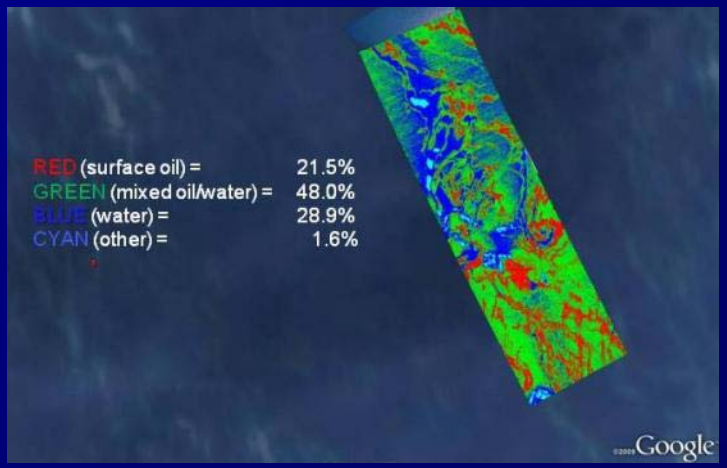


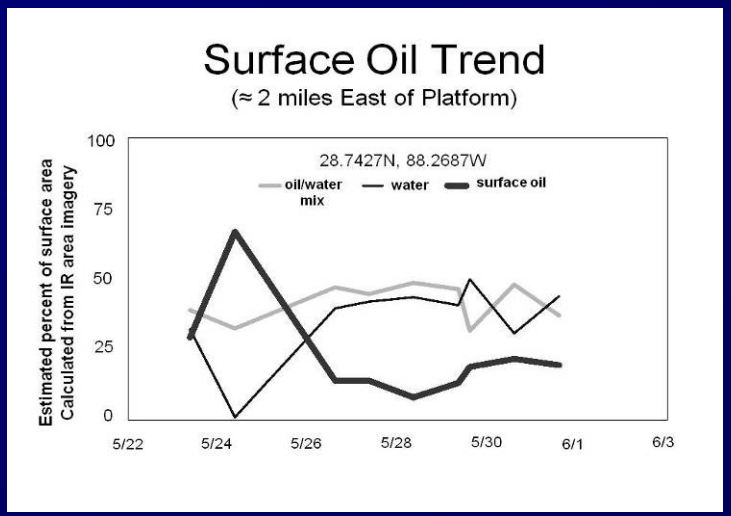
Spectral Analysis of Oil

Oil Coverage and Trend Analysis

- The ASPECT team developed a series of IR Spectral tools permitting the type and coverage of oil to be quantified

- Over a month period, ASPECT collected data approximately 2 miles east of the recovery site. A trend analysis indicated that between 24 May and 26 May the surface characteristic of the oil changed potentially due to dispersant operations





Acceleration of Data Products

- Mississippi instructed ASPECT to "*speed up the delivery of data to the skimming/booming teams*".
- ASPECT initiated an acceleration program to:
  1. Incorporate on-board data processing
  2. Immediate reports of oil detection using an improved SatCom link to the ASPECT reach back team
  3. Concurrent reports of oil observations to the respective UC with a run-time aerial observation report
     - After the flight crew indicated the mission was completed, the run-time oil report was marked draft and forwarded to the UC
     - Once the aircraft returned to base, data was processed, confirmed and a final report with hyper-link data was forwarded to the UC
- The turn on data was reduced from 4 hours to about 5 minutes.

Interaction with Local Officials

- ASPECT personnel were encouraged to work closely with the local officials managing the oil response.
- ASPECT representatives attended daily ops meetings in Biloxi. These meetings caused a change in how ASPECT collected and reported data:
  1. Stronger collaboration with ASPECT and USCG.
  2. Local perspective and needs determined mission assignments. MDEQ and Mississippi National Guard leaders communicated where and how ASPECT data could be most useful.
  3. Increased coordination and communication with all stakeholders regarding operational data.
  4. Improved efficiency of resources from Planning Section.
  5. ASPECT collaborated with NGI scientist to enhance the products and test sensors.

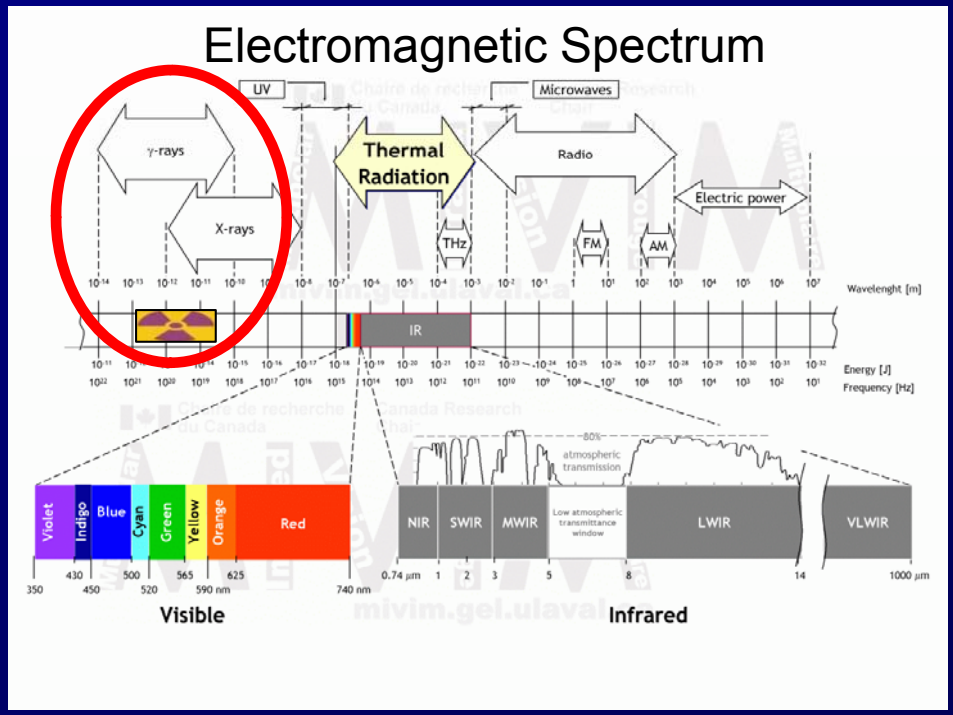
Backup Aircraft

- Primary aircraft (N742W) had to undergo a mandatory yearly airframe inspection during the BP response.
- A critical need for ASPECT products was filled with a backup aircraft (N742WX).
- ASPECT team worked with the local authorities to outfit a second aircraft with a basic set of IR sensors.
- On 23 July, both aircrafts were able to sweep a large region of water south of the Mississippi Barrier Islands. This survey was developed based on technical guidance from the MDEQ and MSNG.

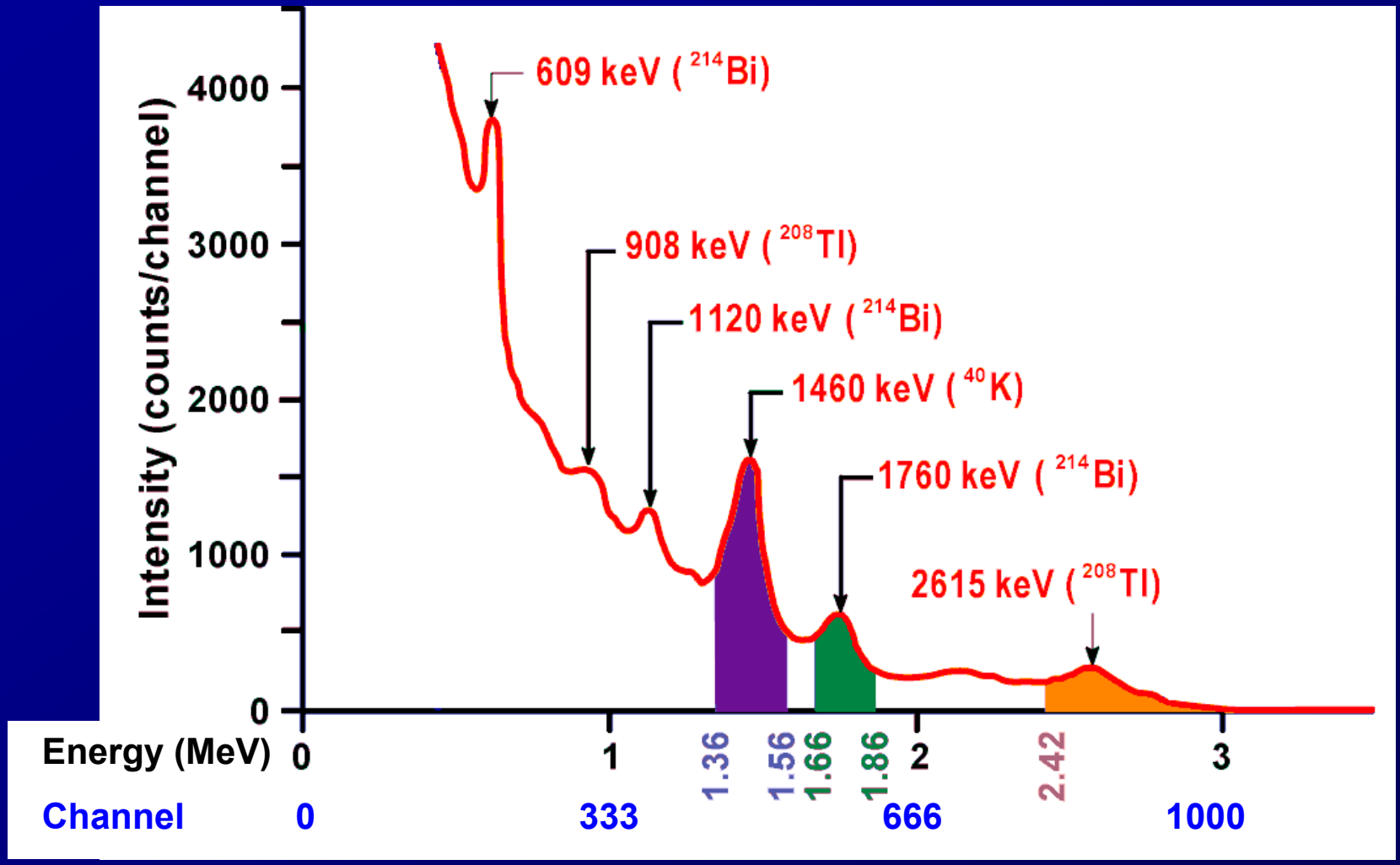
RADIATION DETECTION
Case Study 3

Welsbach Superfund Site
Aerial and Ground-based Surveys
2009-2011

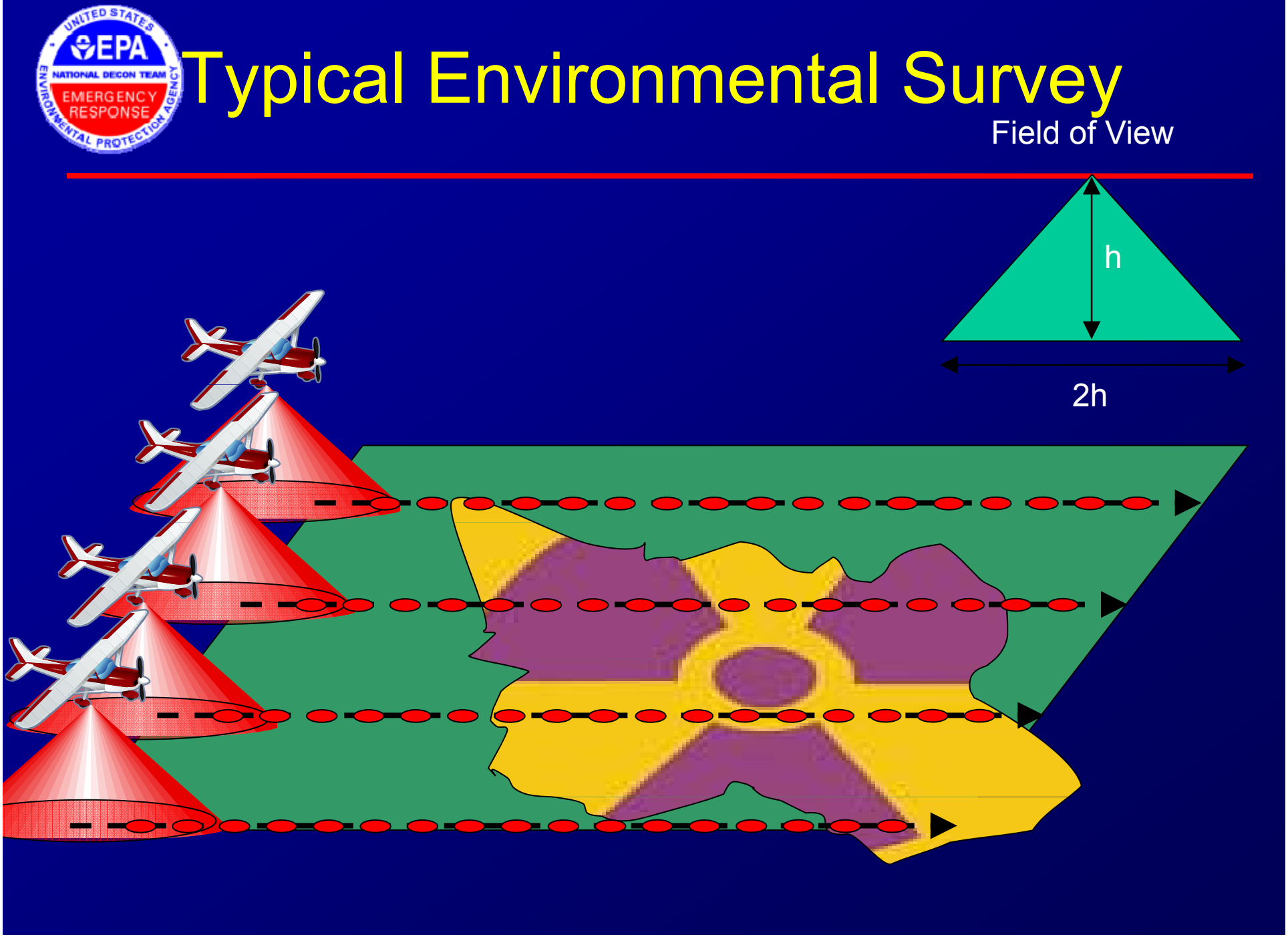
ASPECT radiation detection is based on gamma radiation spectral analysis via an NaI and LaBr detectors.



Typical Gamma-Ray Spectrum



Typical Environmental Survey

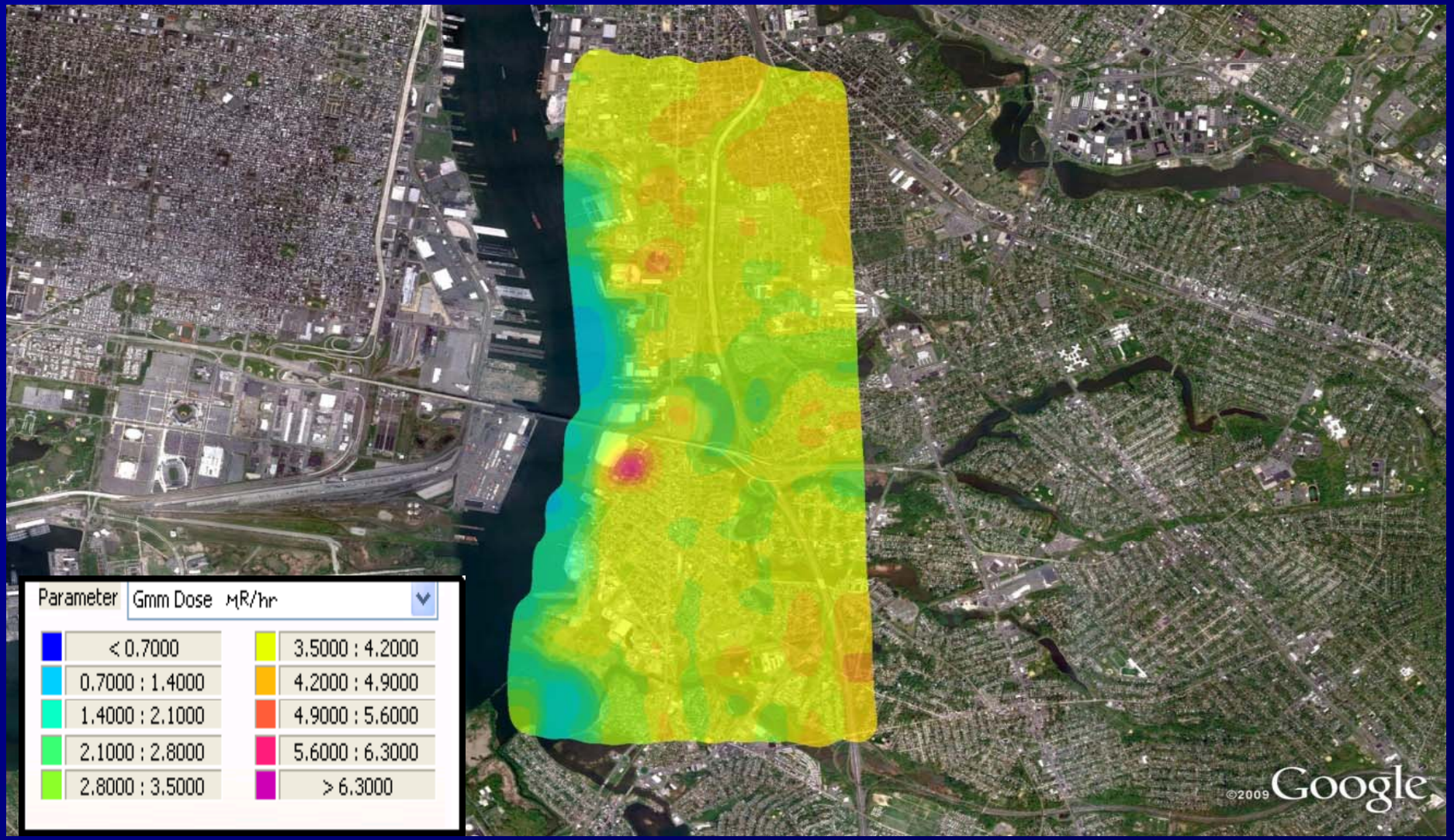


Welsbach Site

- Camden and Gloucester Cities, NJ
- About 5.5 square miles
- Gas lantern mantel manufacturing 1890s to 1941
- Thorium contamination
- 1,100 residential properties
- 1996 – EPA Superfund Site
- 2000 - Clean-up started

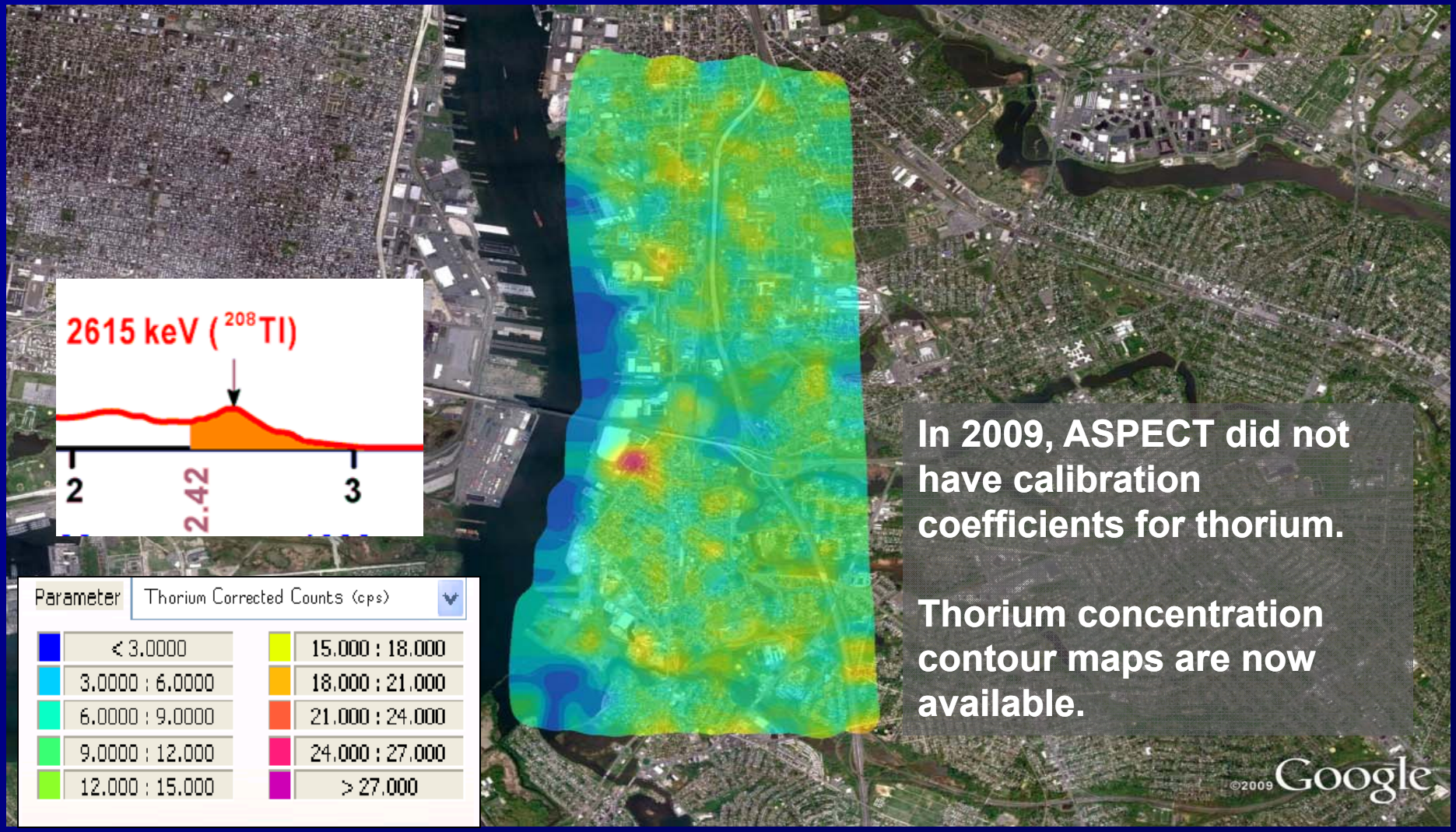
Exposure Rate Contour Map

April 18 & June 6 Combined Surveys, 2009



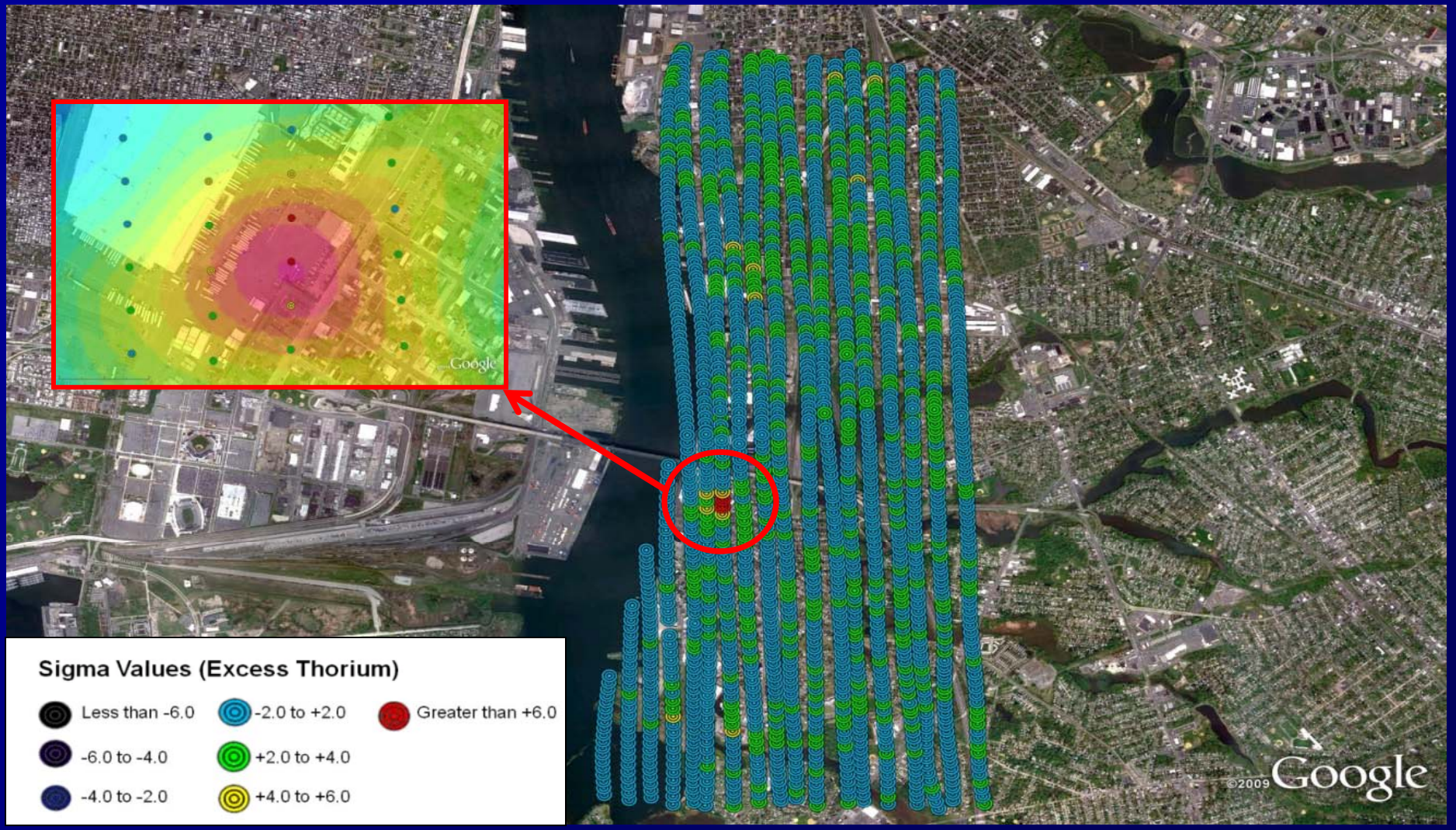
Thorium ROI Count Rate Contour Map

April 18 & June 6 Combined Surveys, 2009



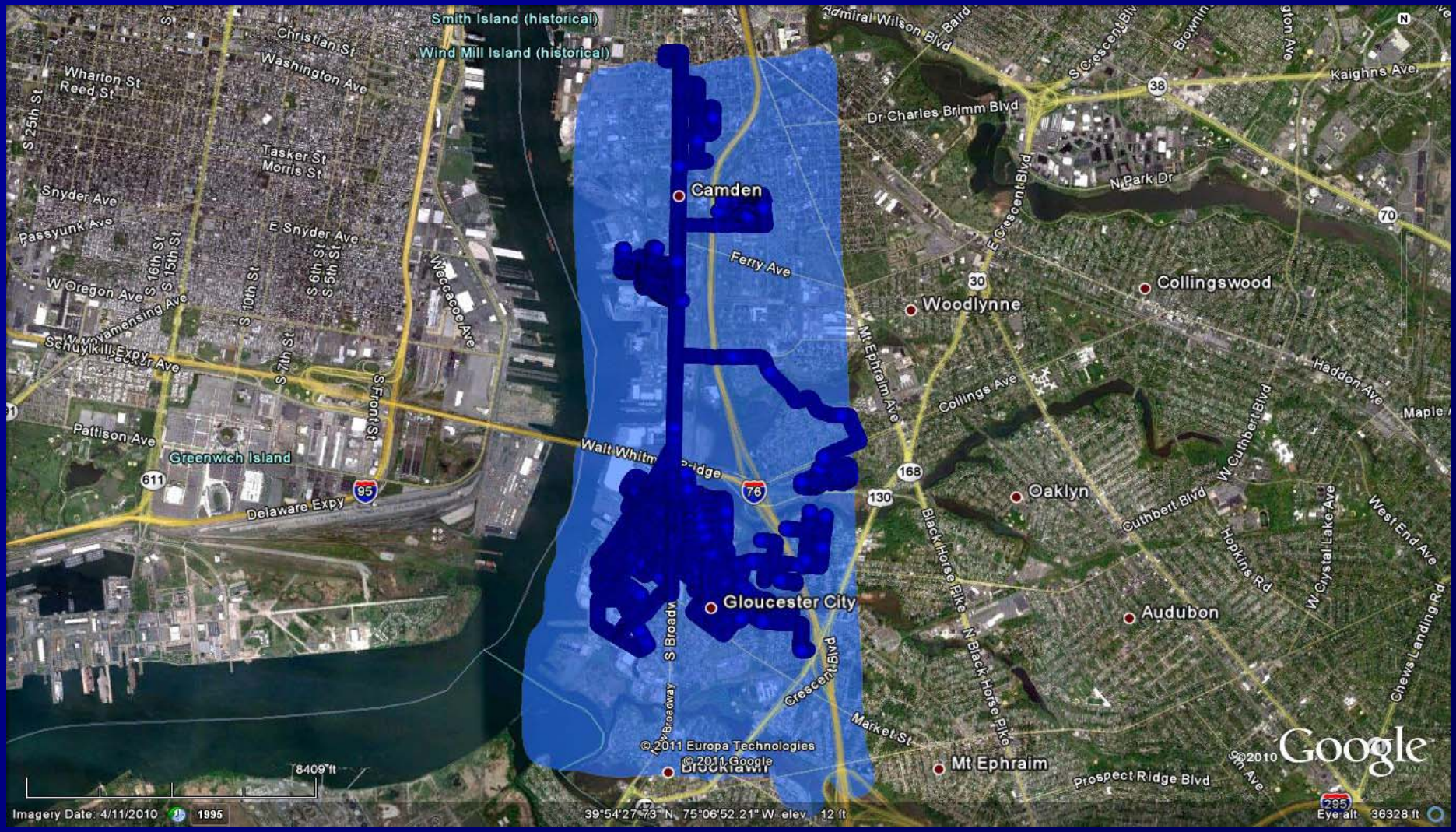
ASPECT Sigma Plot (std dev)

April 18 & June 6 Combined Surveys, 2009



Ground Survey Map

May 2011



Site-specific calibration

Kawasaki and Suburban

Kawasaki = off-road
Suburban = public roadways,
tested detector orientation

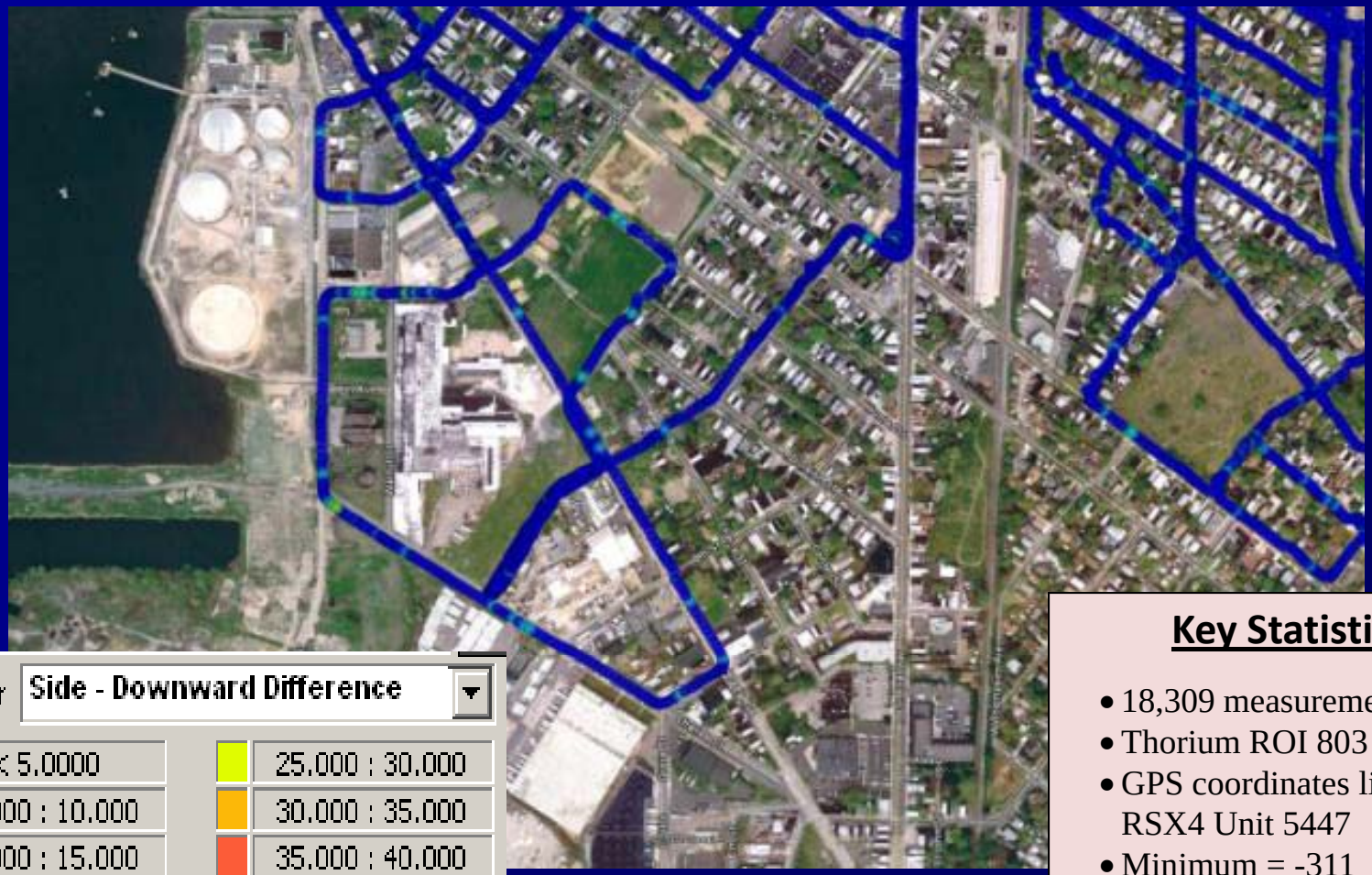
PIC = exposure rate
NaI = count rate

3 locations (High, Medium, Low)

Public Roadway Measurements

Detector Orientation

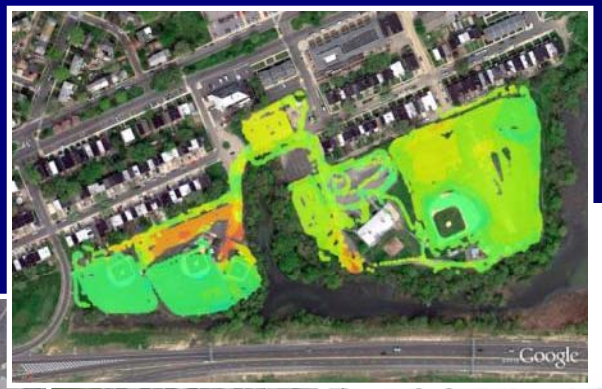
No Significant Findings

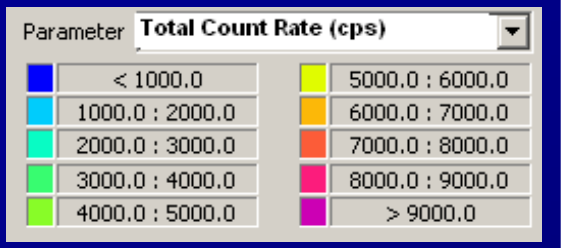


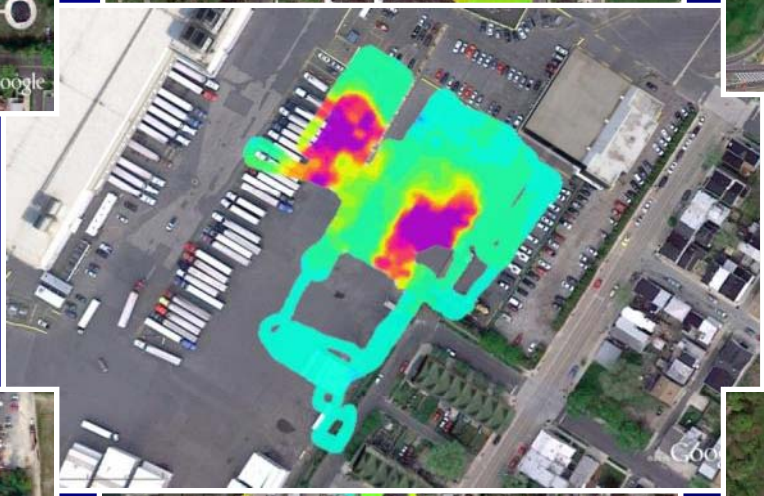
Key Statistics

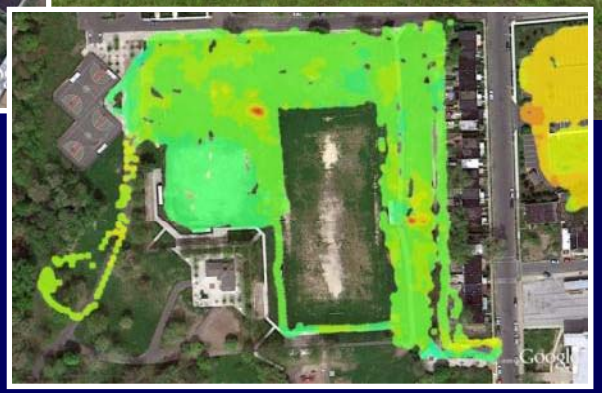
- 18,309 measurements
- Thorium ROI 803 to 937
- GPS coordinates linked to RSX4 Unit 5447
- Minimum = -311
- Maximum = 154
- Median = -2

7 Off-road Surveys









Hot Spot Remediated

ASPECT Team

Mark Thomas, NDT
Timothy Curry, NDT
John Cardarelli, NDT
Paul Kudarauskas. NDT
Robert Kroutil, Dynamac Inc.
Jeff Stapleton, Dynamac Inc.
Dave Miller, Dynamac Inc.

Ray Brindle, Arrae Inc.
Paul Fletcher, Arrae Inc.
Beorn Leger, Arrae Inc.
Richard Rousseau, Arrae Inc.
Mike Scarborough, Arrae Inc.
Paul Lewis, NGA

Deployments and Responses

ASPECT Statistics

50 Emergency Responses

14 SEAR Deployments

12 NSSE Deployments

7 FEMA Activations

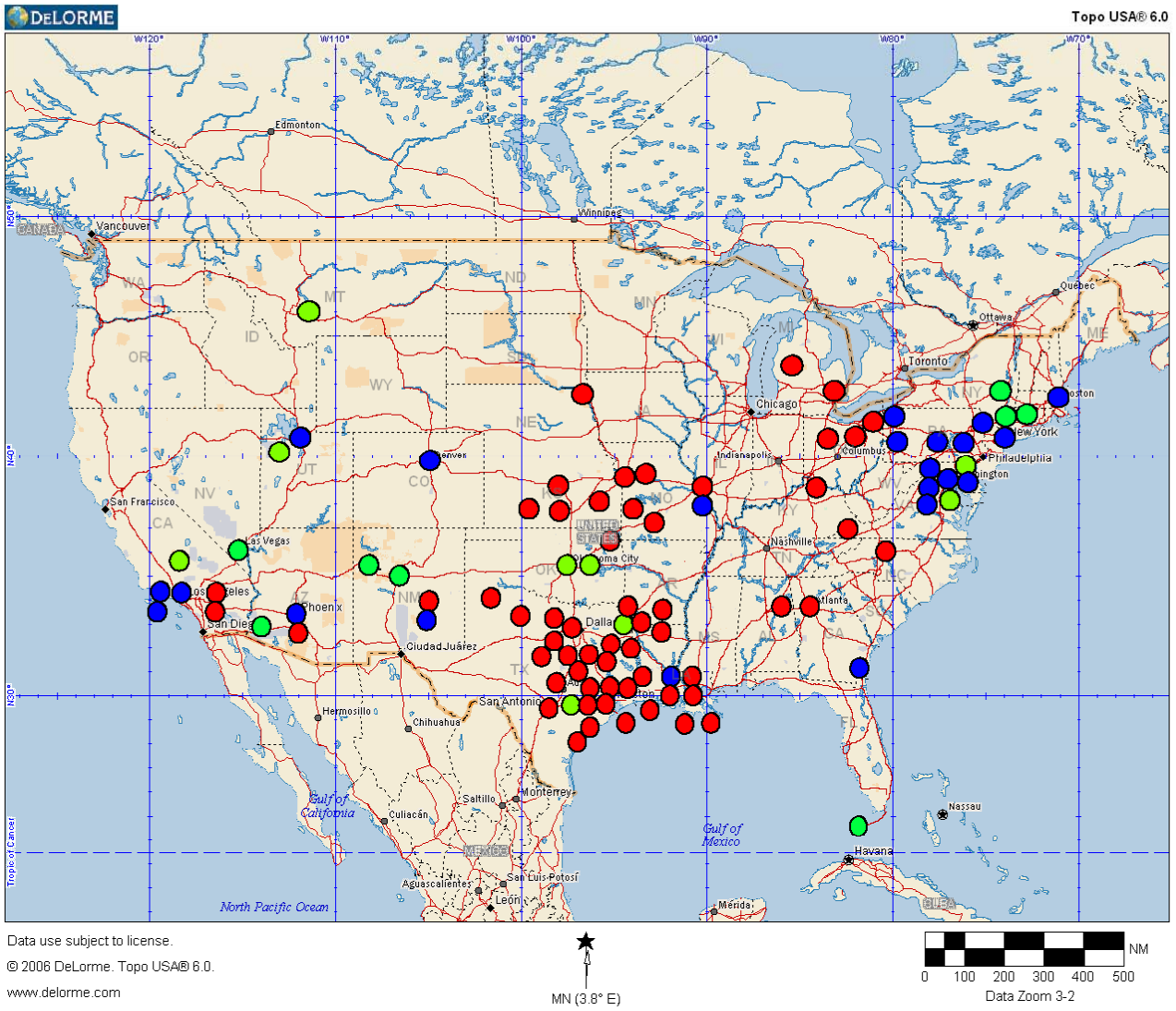
20 Special Projects

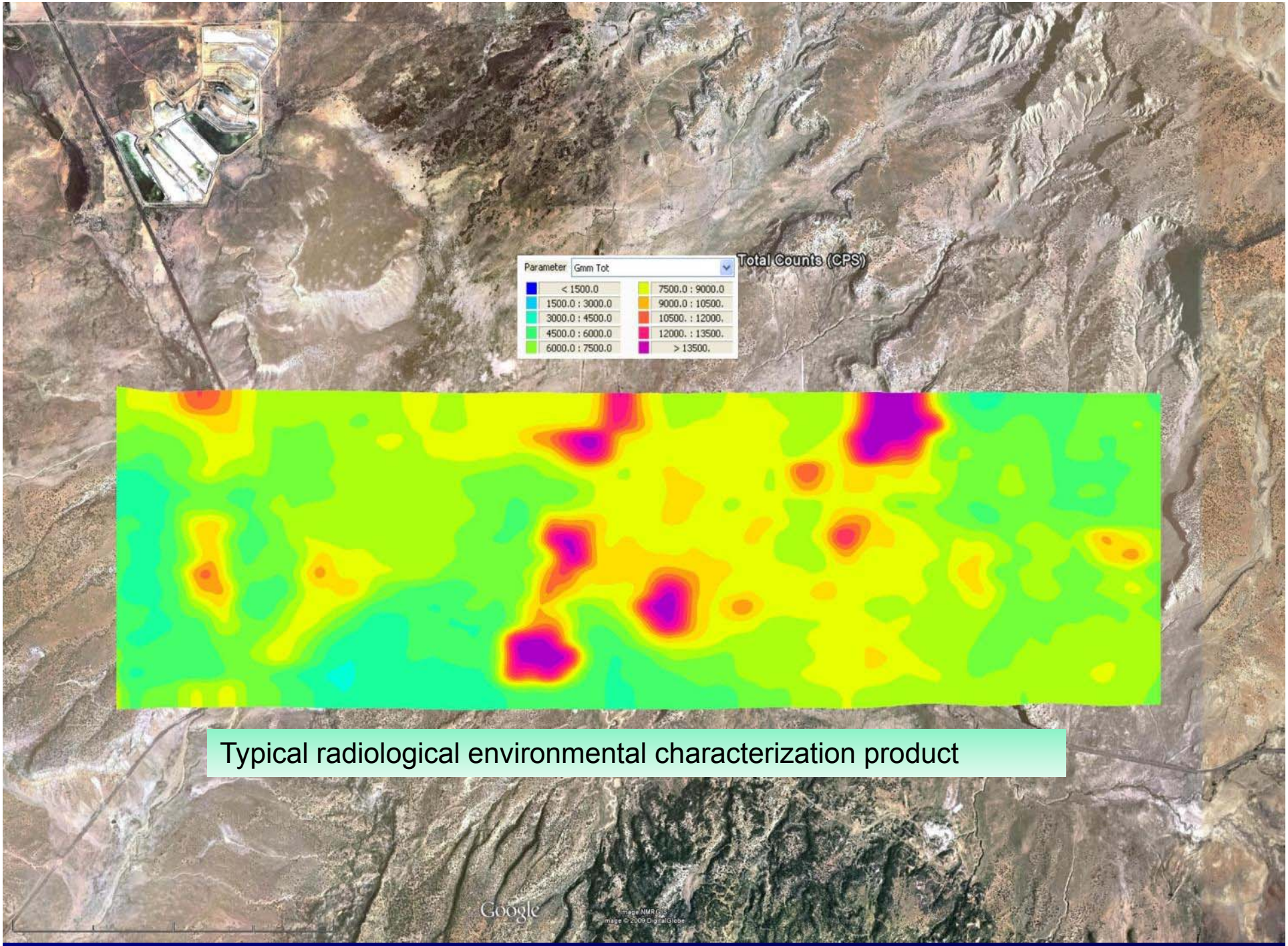
LEGEND

Responses

Deployments

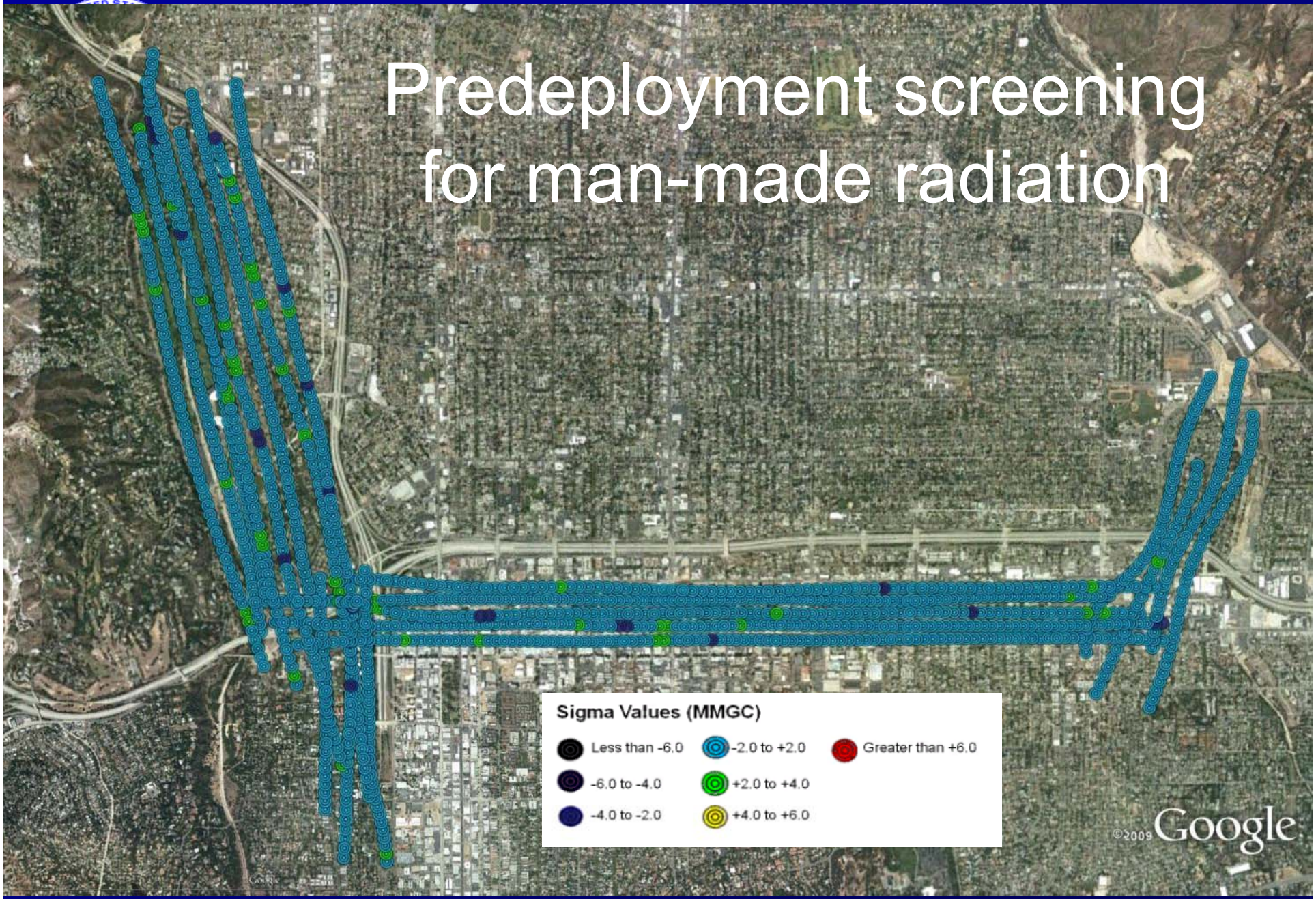
Special Projects





Typical radiological environmental characterization product

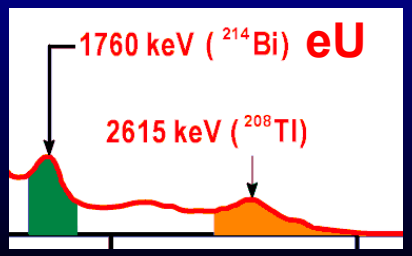
Predeployment screening for man-made radiation

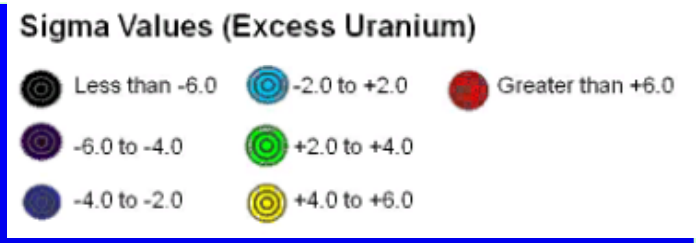


Normal Distribution & Sigma Values

Standard deviation (σ, sigma) represents the spread of the data about the mean. In this survey, the mean value (net "excess eU") was zero.

1 σ = 68.27% of the data
2 σ = 95.45% of the data
3 σ = 99.73% of the data
4 σ = 99.99366% of the data
5 σ = 99.99994% of the data
6 σ = 99.999999% of the data

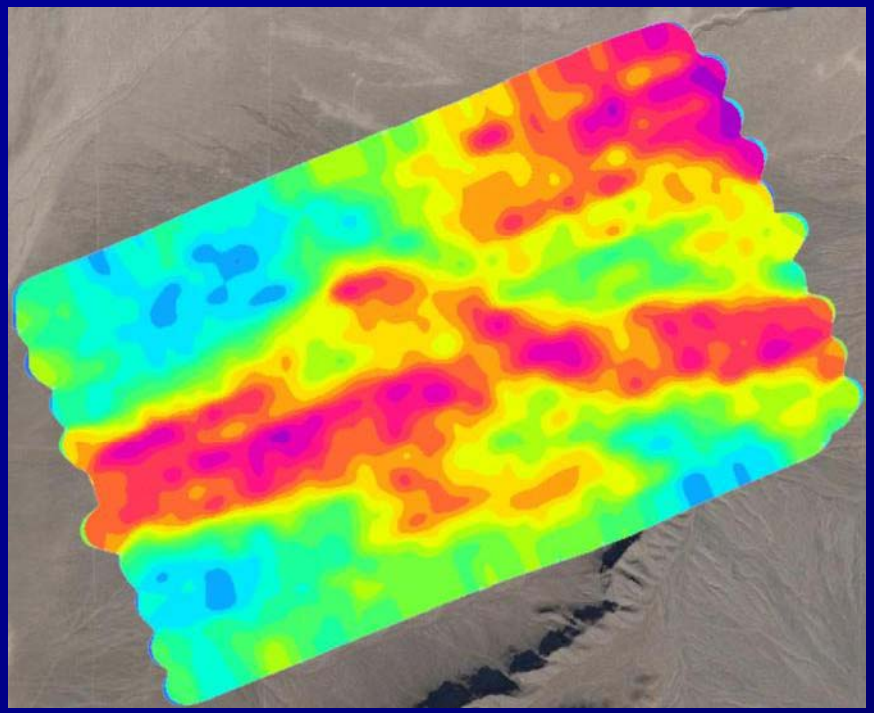




Greater likelihood of excess eU

Advanced Processing Algorithms
(distributed contamination)

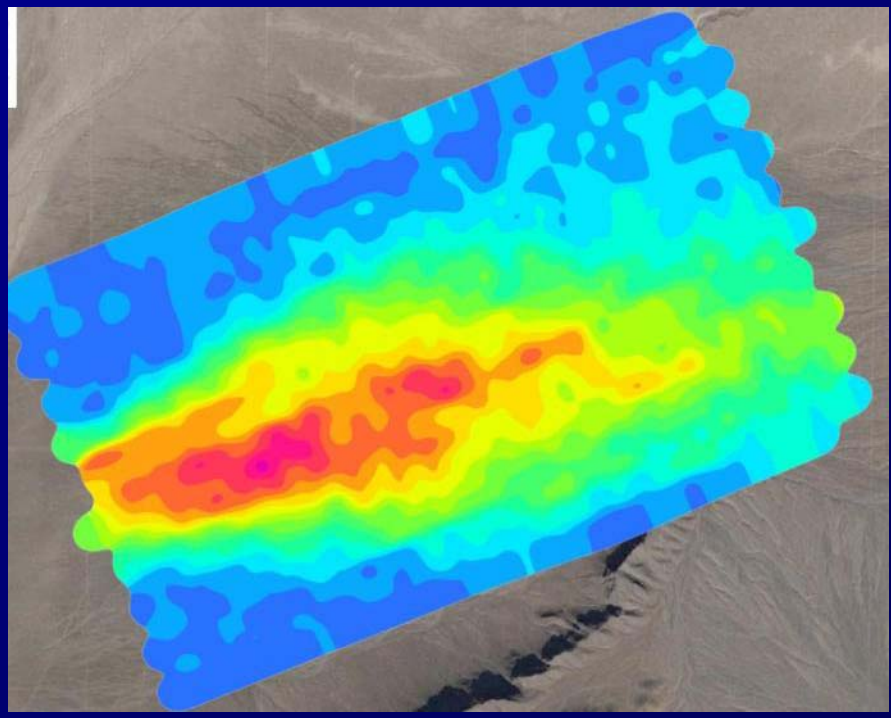
Cs-137 ROI



Total counts in ROI for specific isotopes

Product produced within SECONDS

NASVD : Cs-137 contour

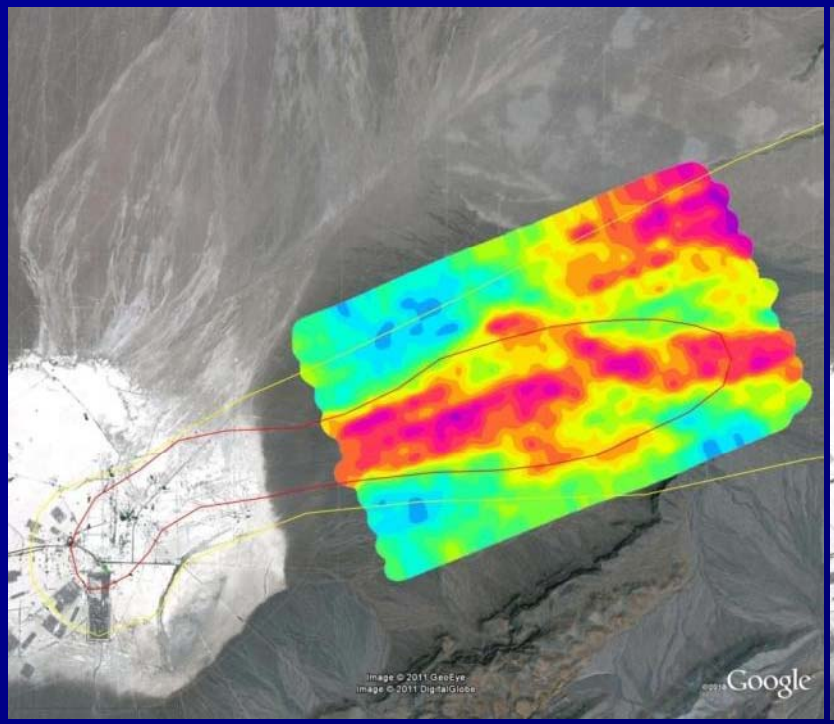


Noise Adjusted Singular Value Decomposition

Product produced within HOURS

Advanced Processing Algorithms
(distributed contamination)

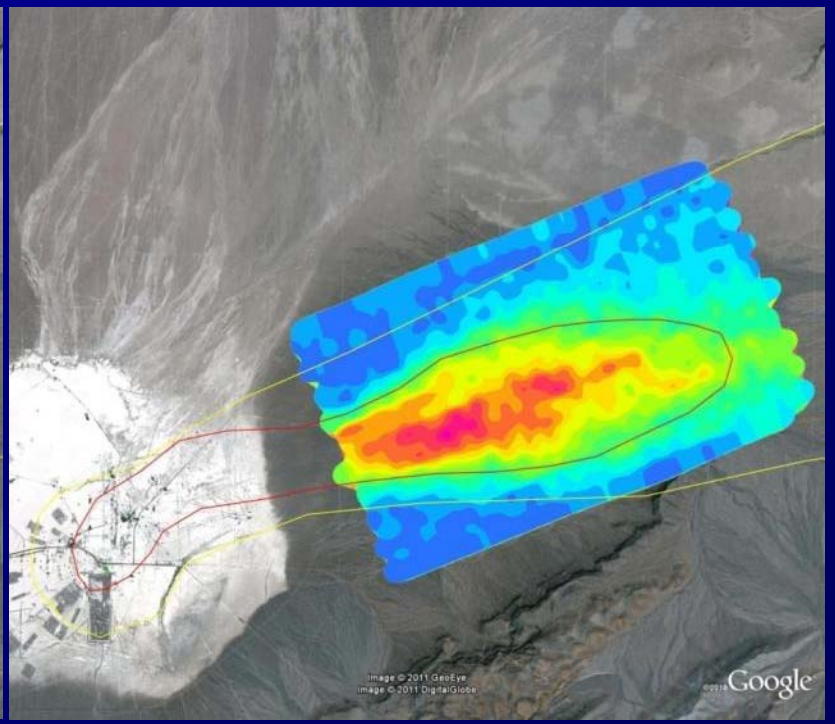
Cs-137 ROI



Total counts in ROI for specific isotopes

Product produced within SECONDS

NASVD : Cs-137 contour



Noise Adjusted Singular Value Decomposition

Product produced within HOURS

Florida Phosphate Mine Survey

January 20, 2011

Total Cost = $25K

- 11K to move aircraft
- 14K to conduct survey, fuel, per diem, and technical support

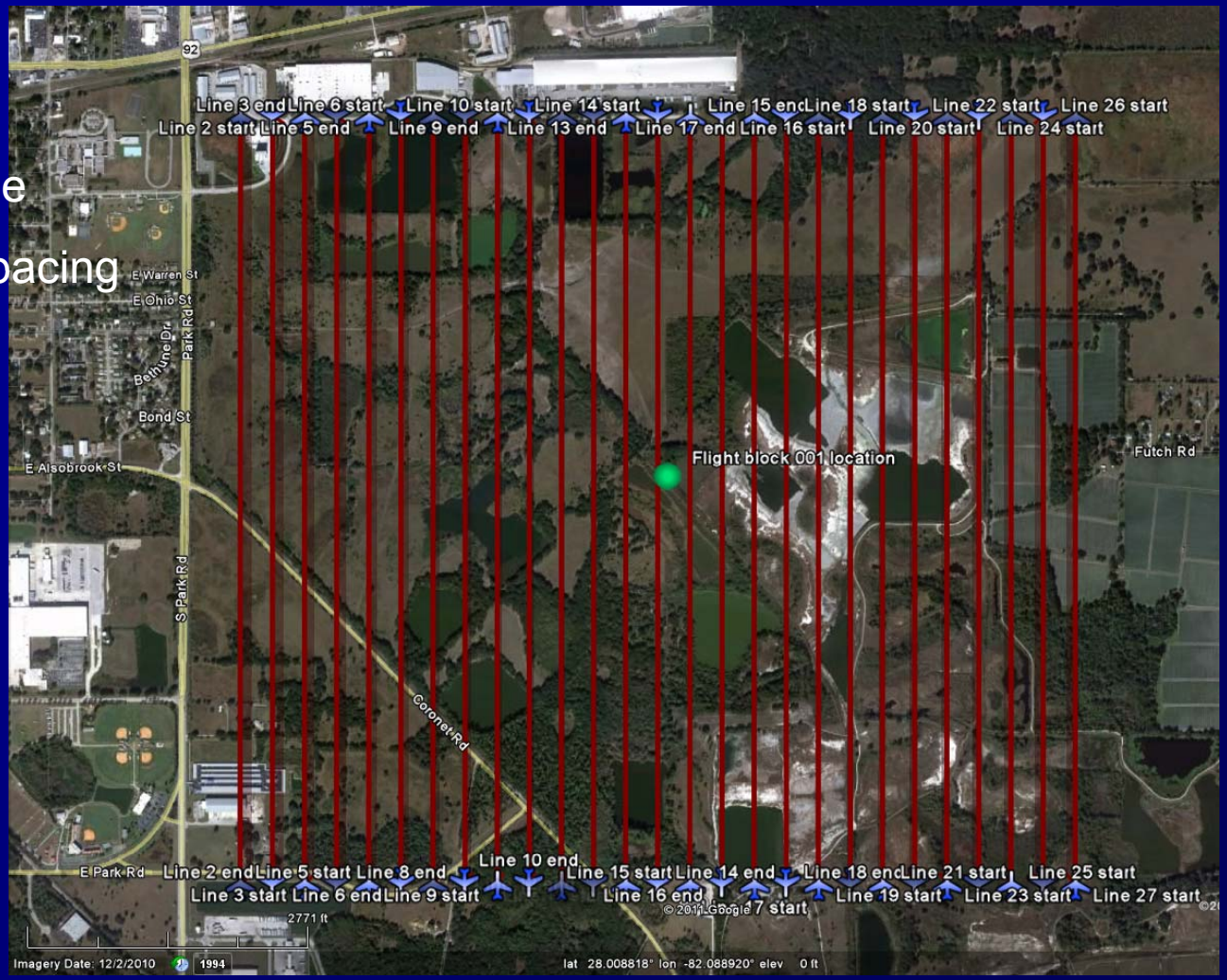
Preliminary products provided with 24 hours.

Flight Planning

1500 Acres

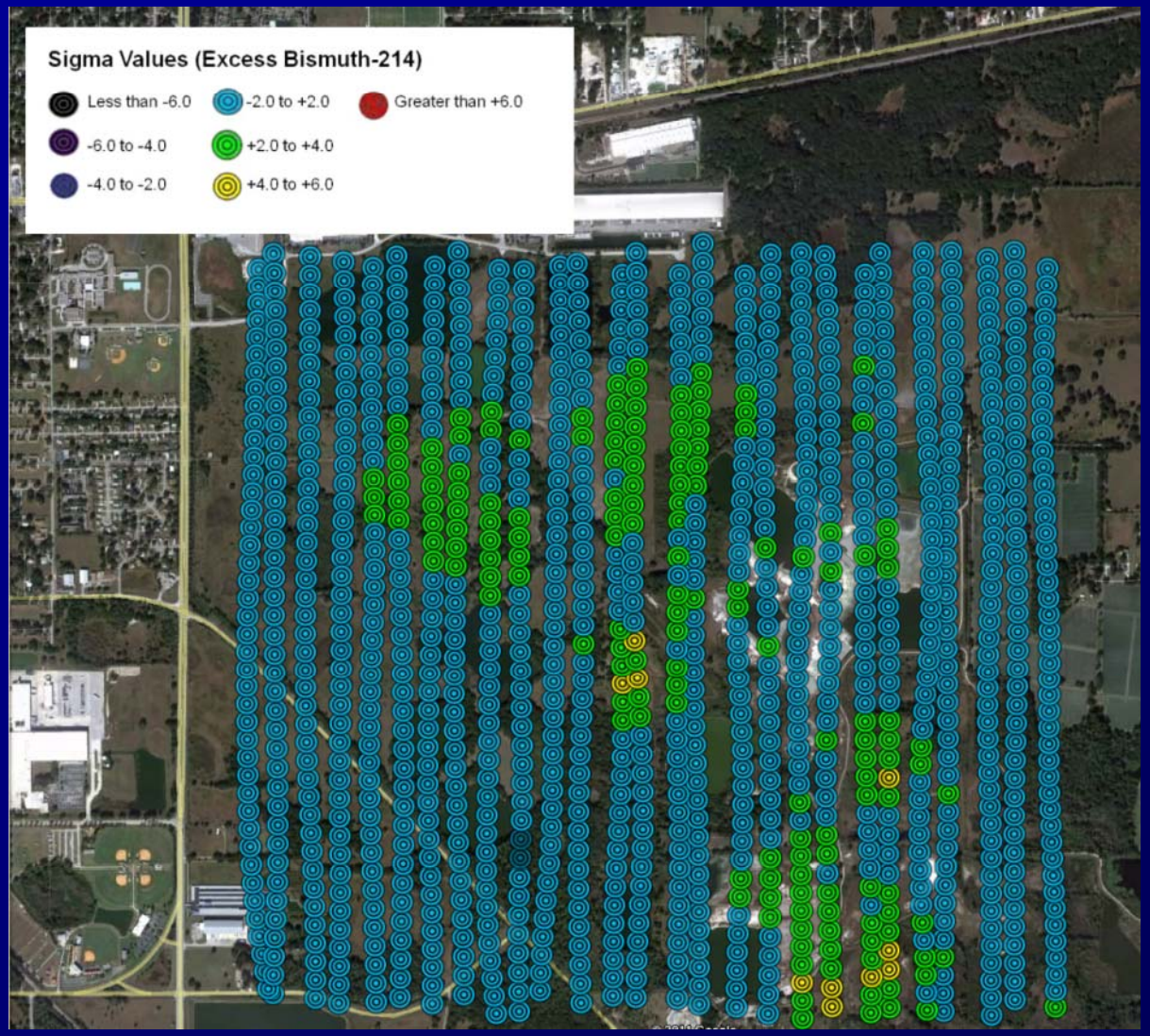
300 ft altitude

300 ft line spacing



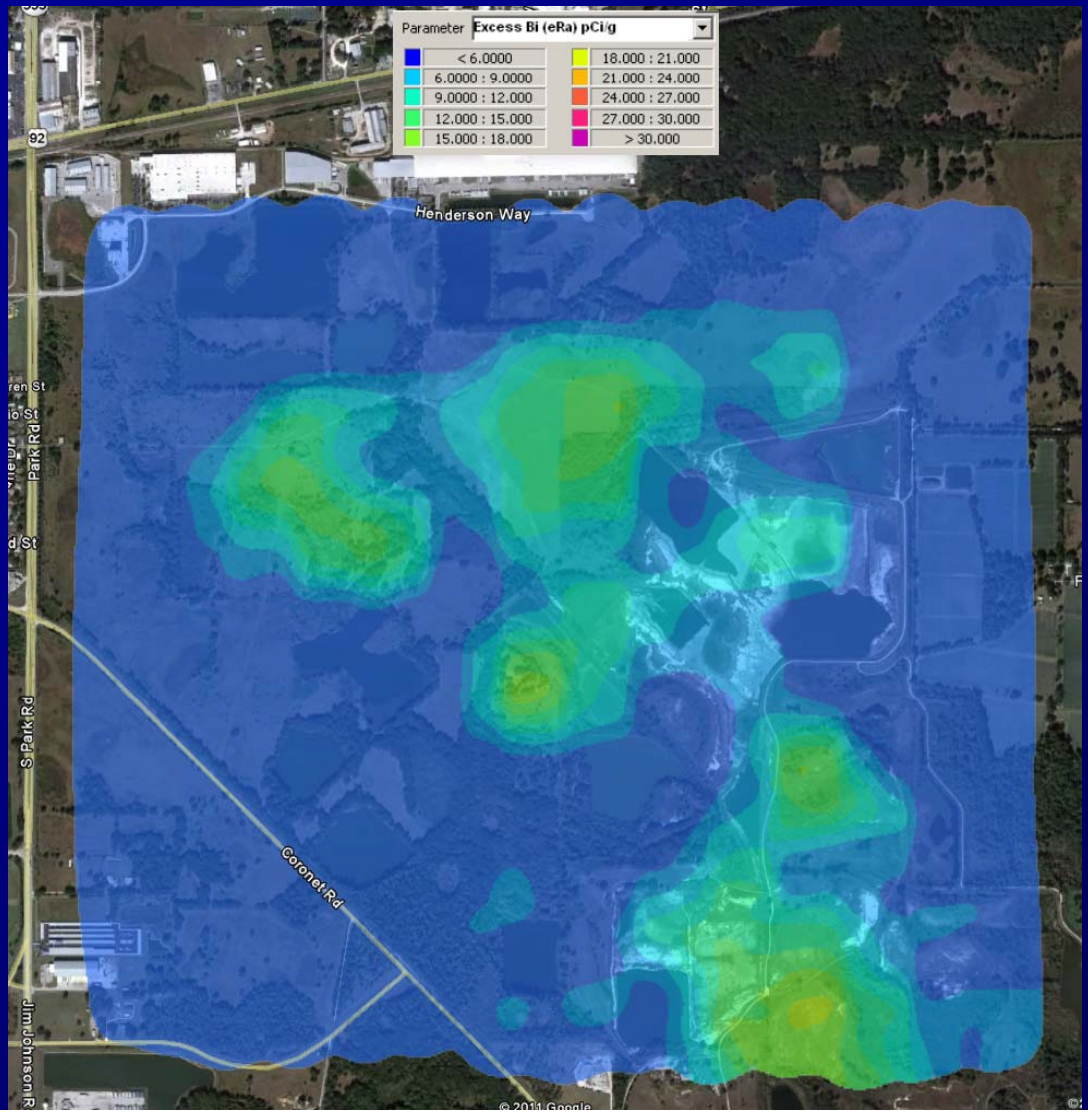
Sigma Plot

300 ft AGL
300 ft Line Spacing

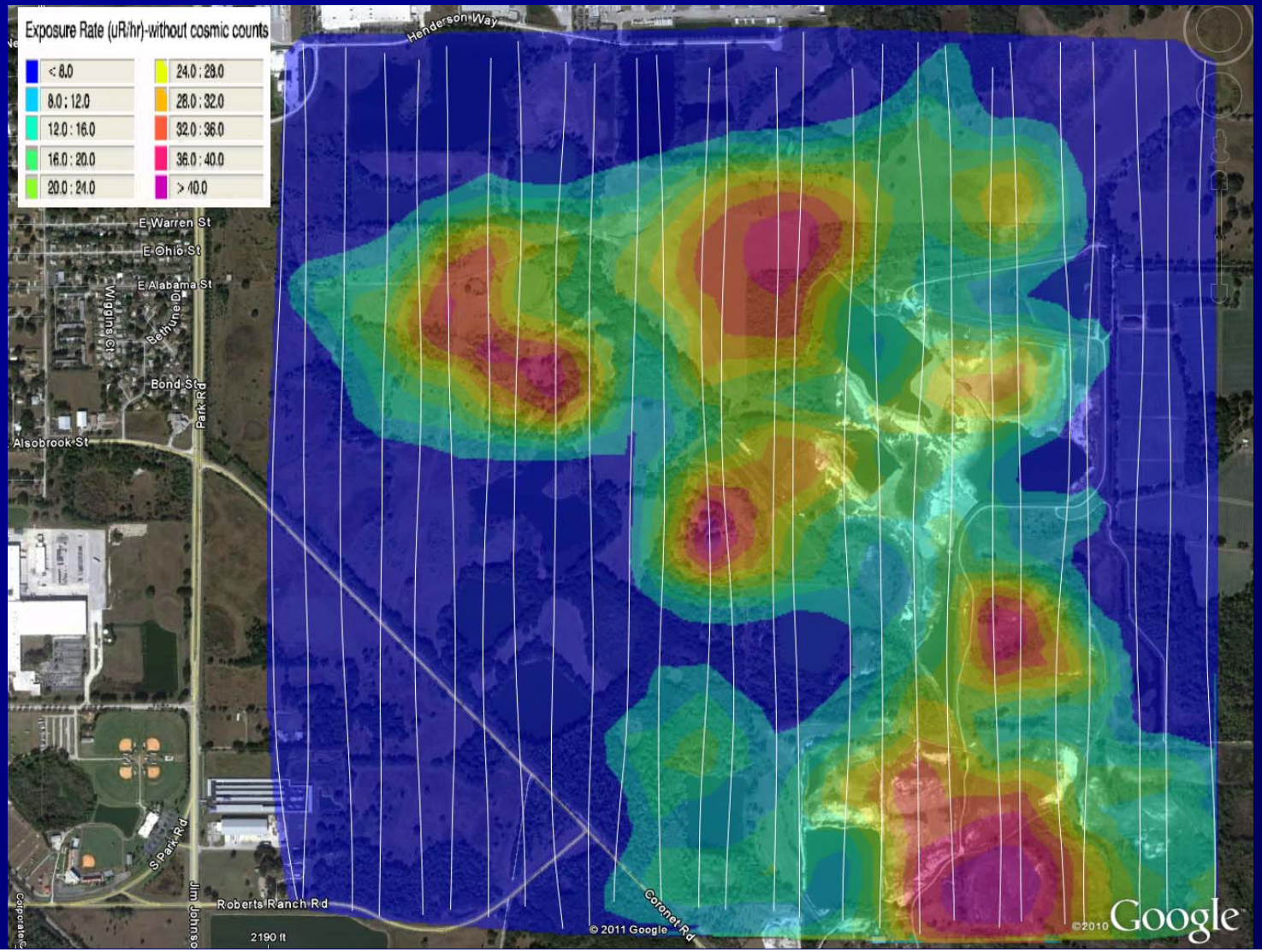


Radium/Uranium Conc. Map

(based on Bi-215, secular equilibrium, pCi/g)

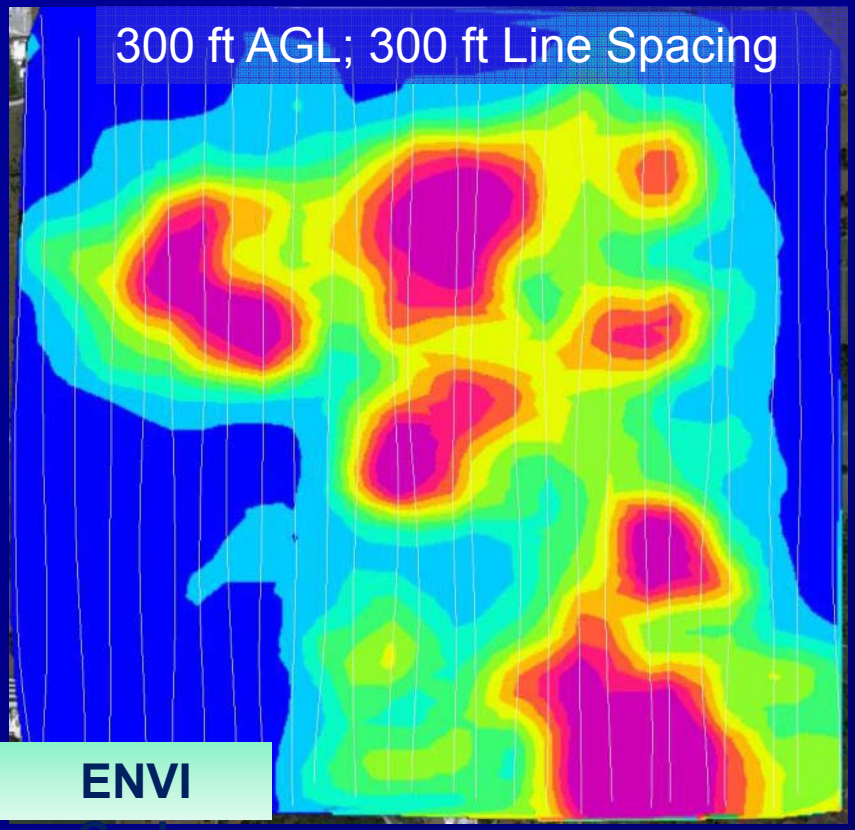


Exposure-Rate Map



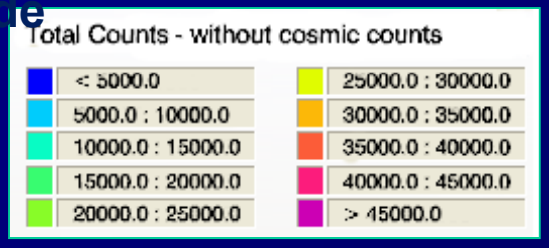
Contouring Algorithms

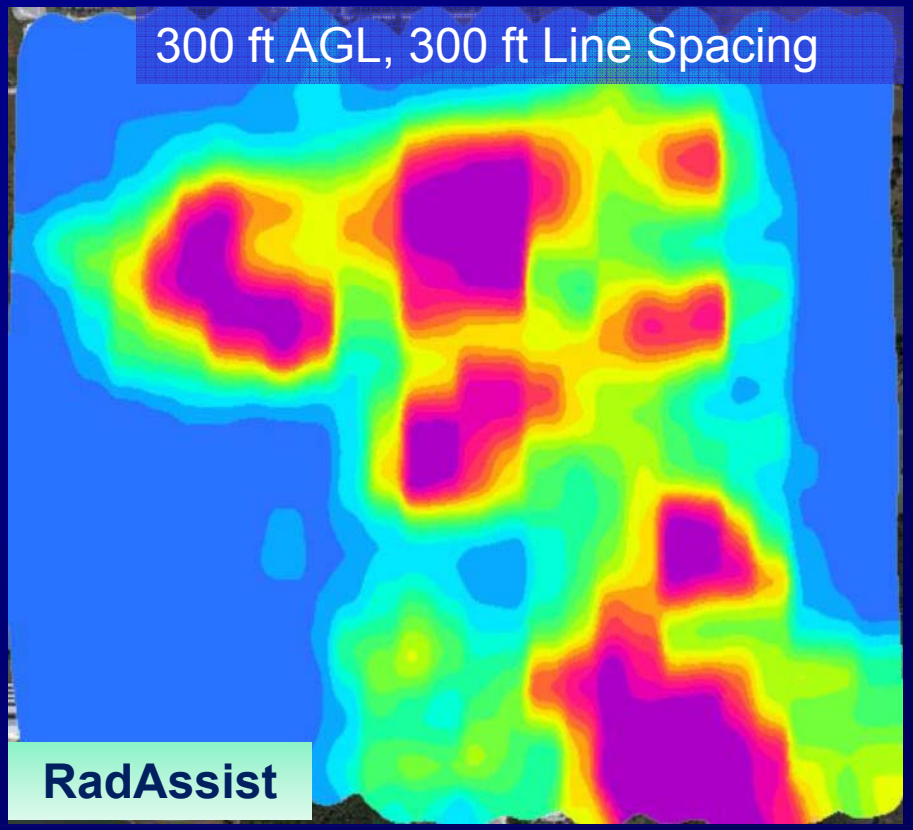
Triangulation vs. **Point Spread Function**



ENVI

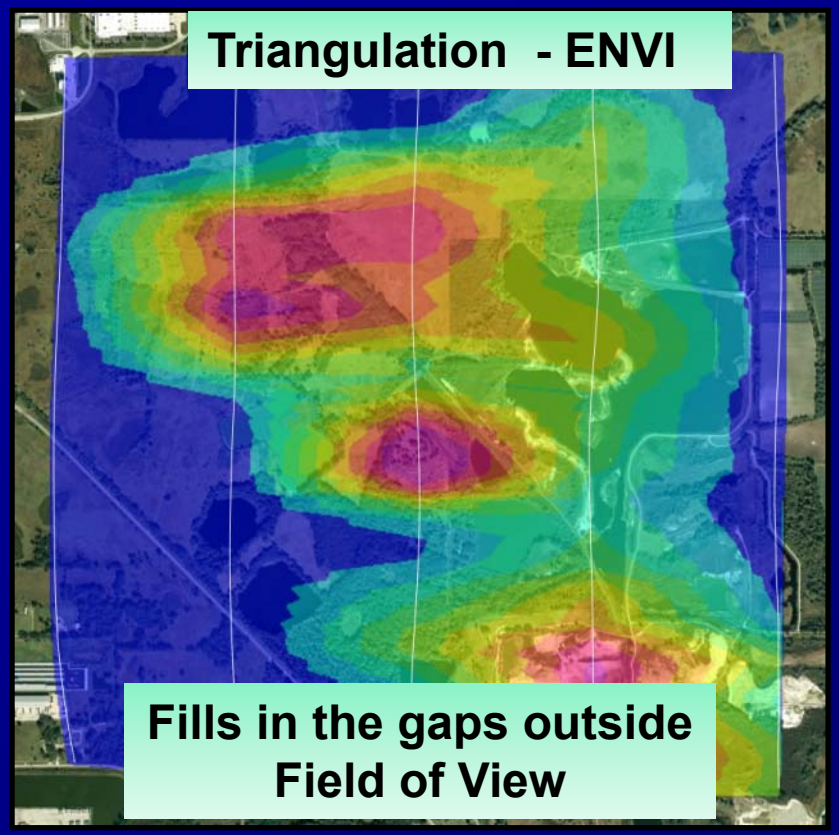
Code



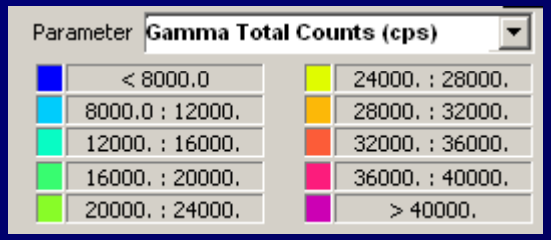


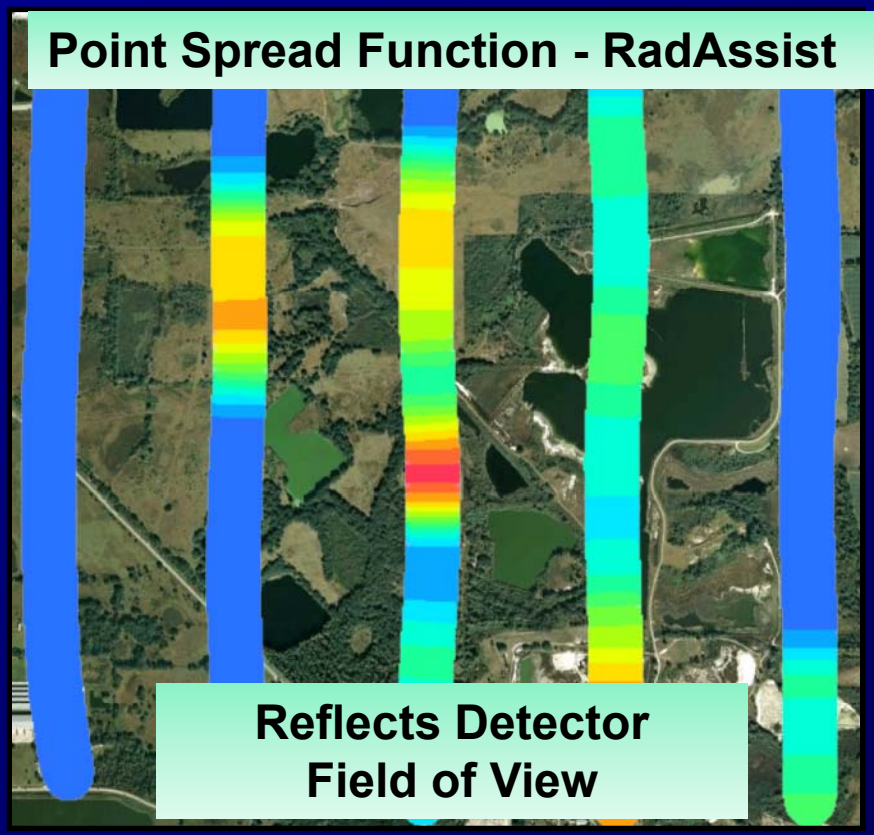
RadAssist

Contouring Algorithms



300 ft AGL
1800 ft Line Spacing

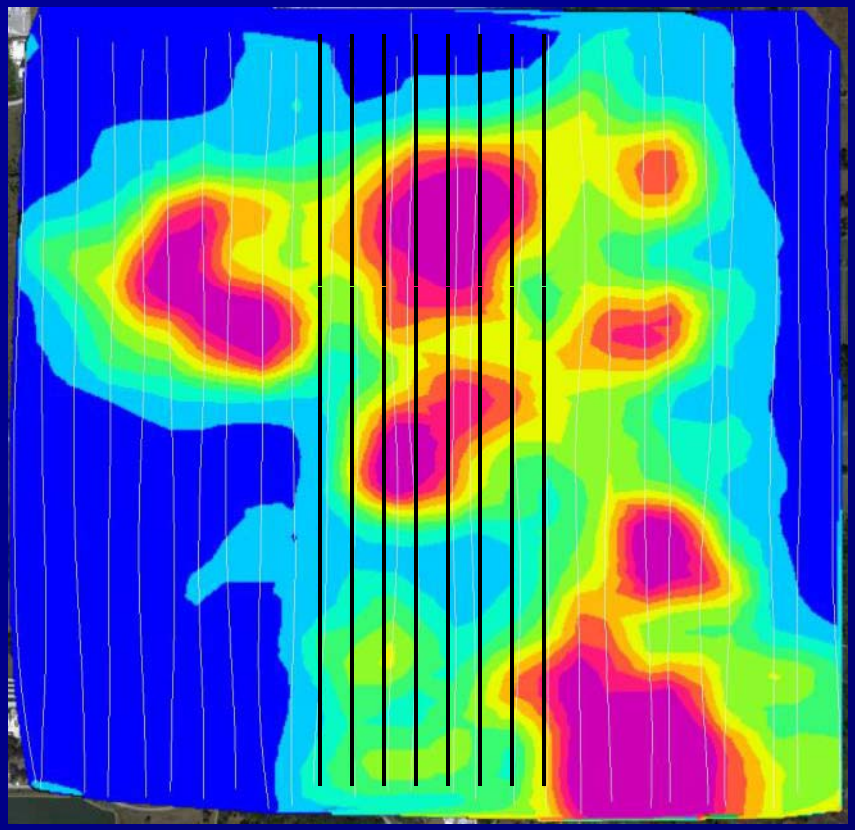




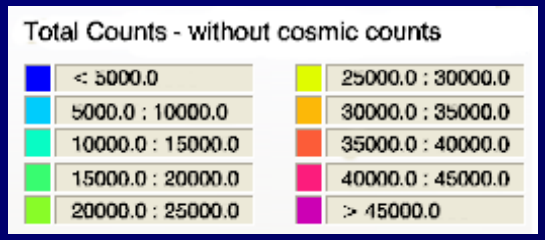
300 ft AGL
1800 ft Line Spacing

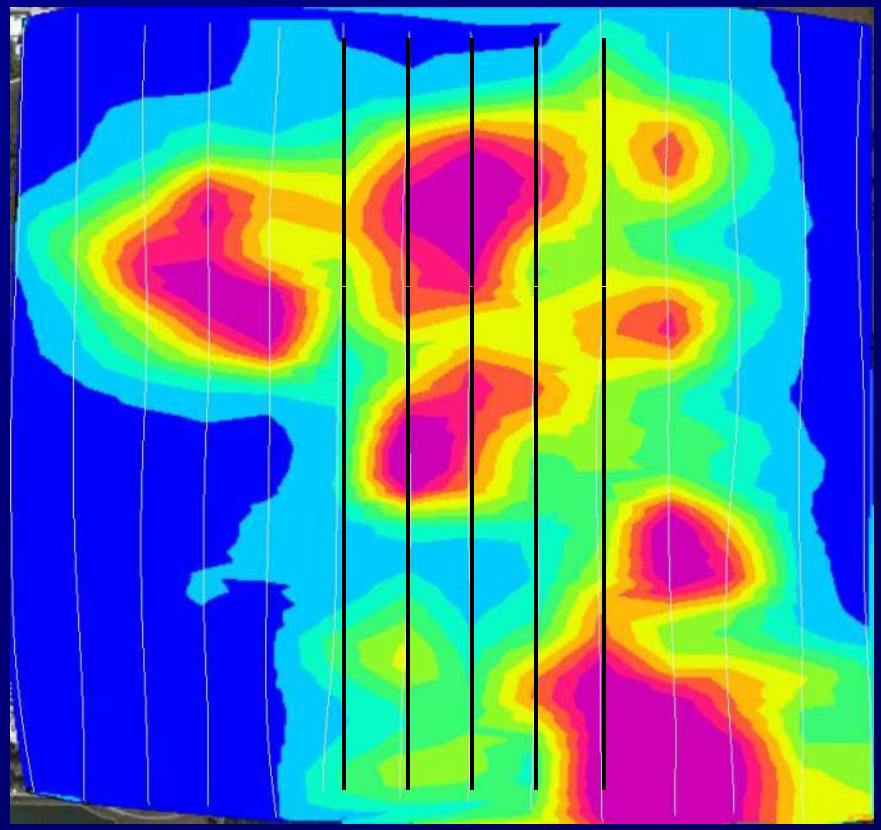
Line Spacing – ENVI Code

No significant changes by flying half the survey lines at twice the distance



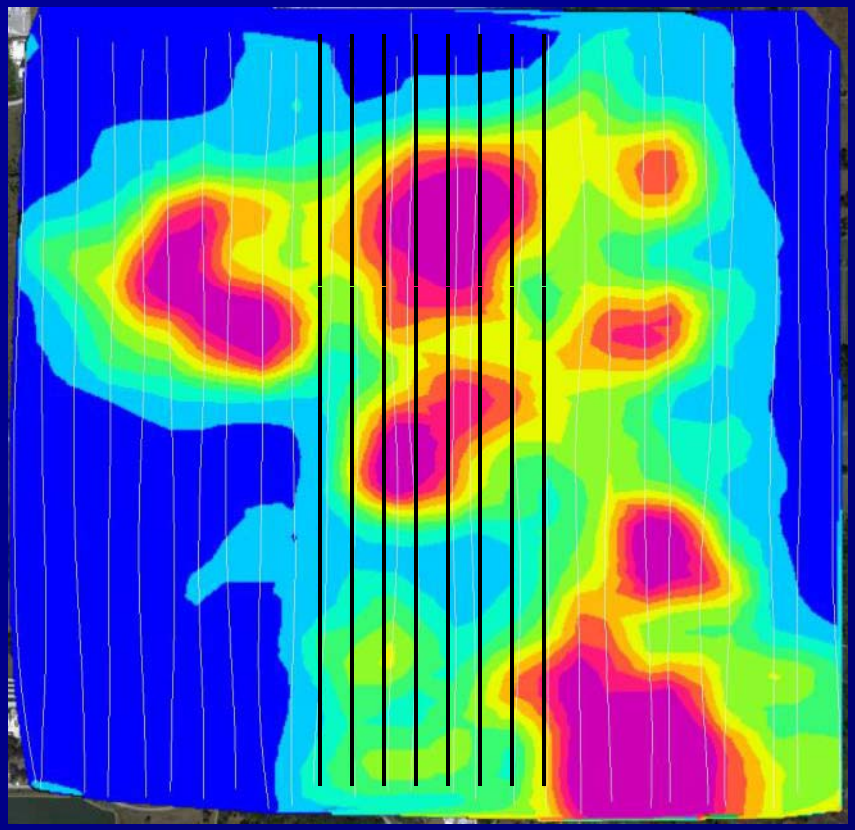
300 ft AGL
300 ft Line Spacing



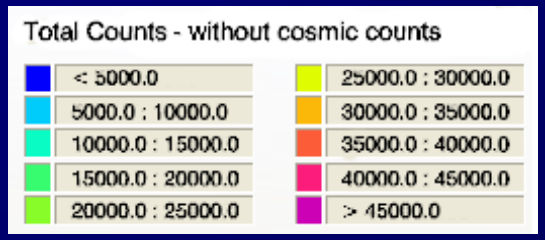


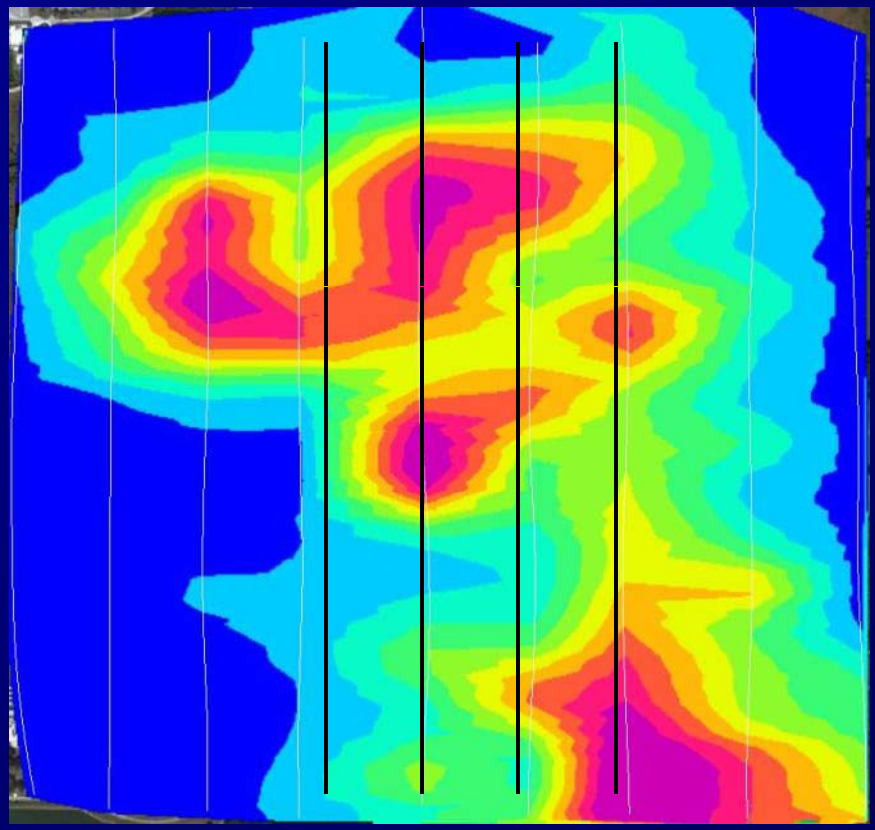
300 ft AGL
600 ft Line Spacing

Line Spacing – ENVI Code



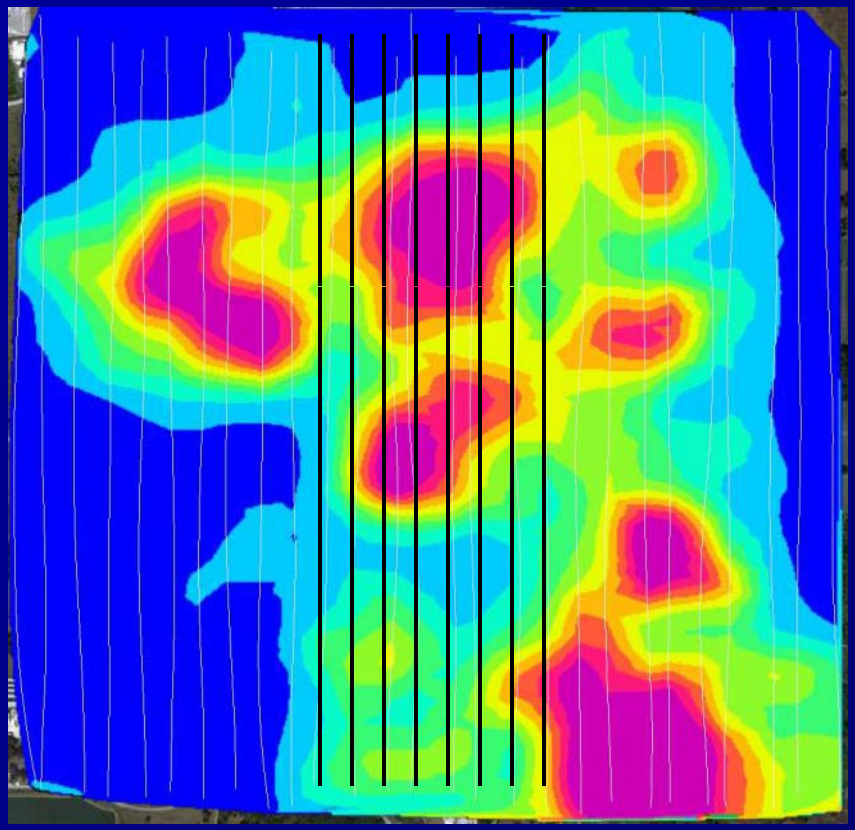
300 ft AGL
300 ft Line Spacing



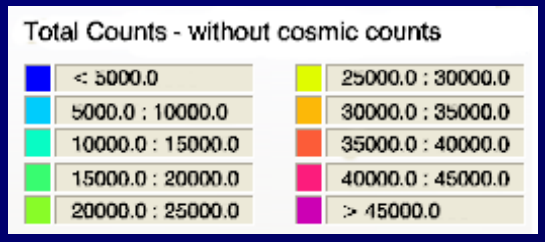


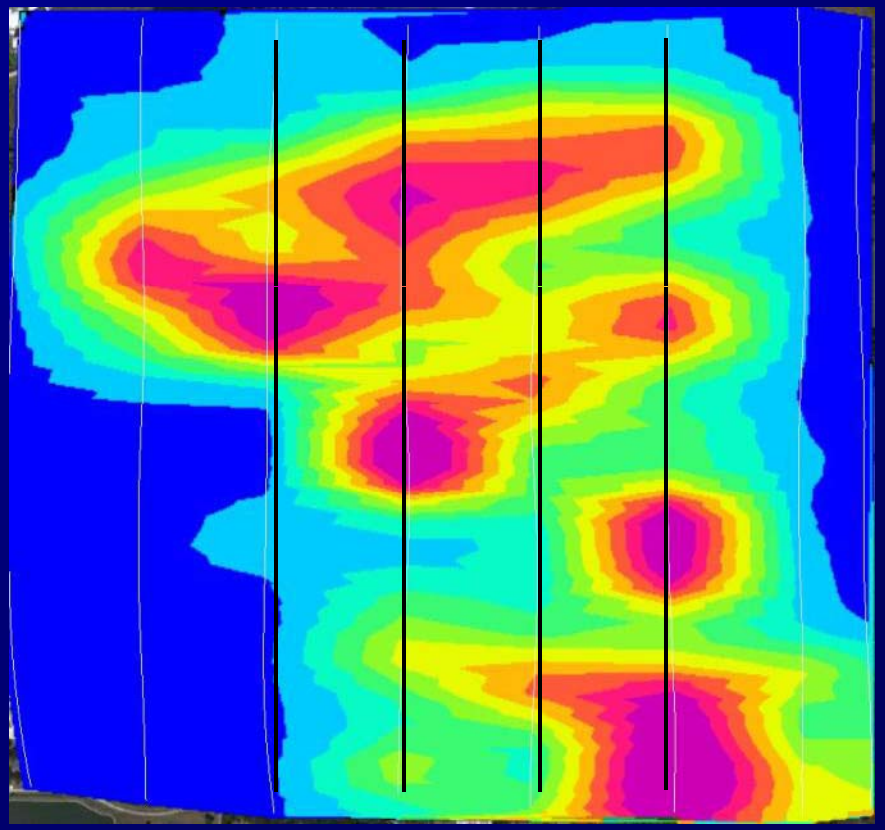
300 ft AGL
900 ft Line Spacing

Line Spacing – ENVI Code



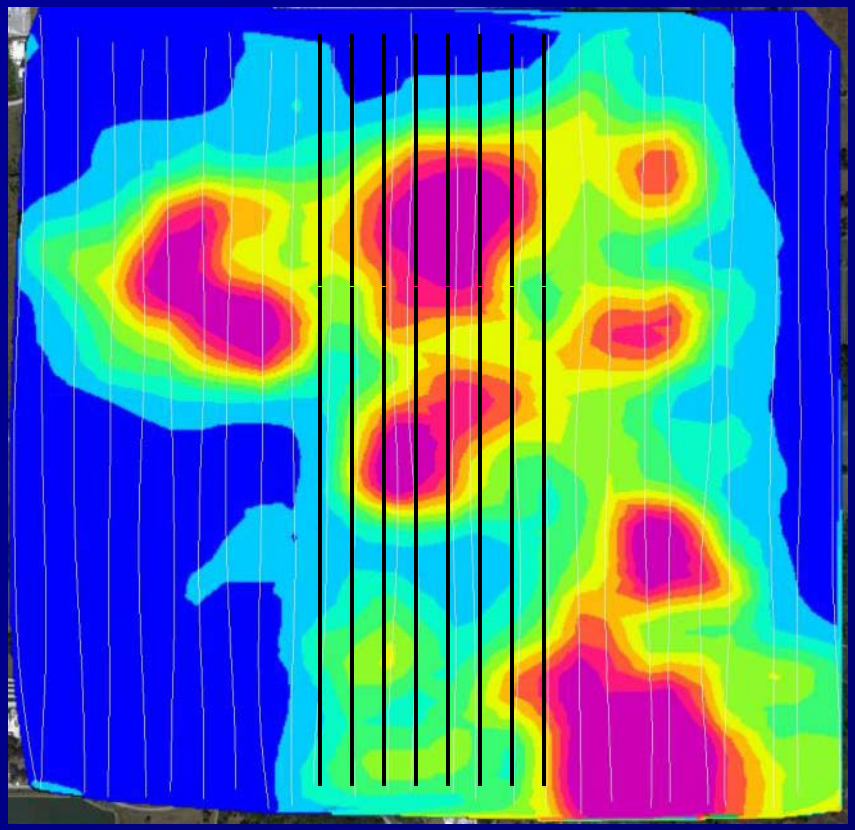
300 ft AGL
300 ft Line Spacing



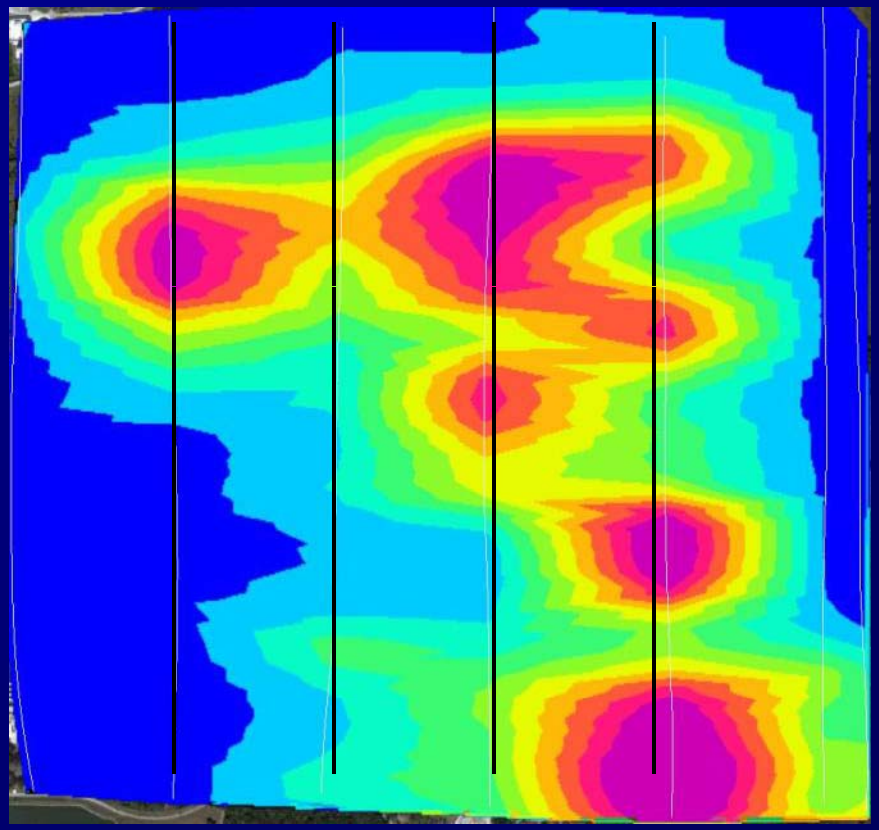


300 ft AGL
1200 ft Line Spacing

Line Spacing – ENVI Code



300 ft AGL
300 ft Line Spacing

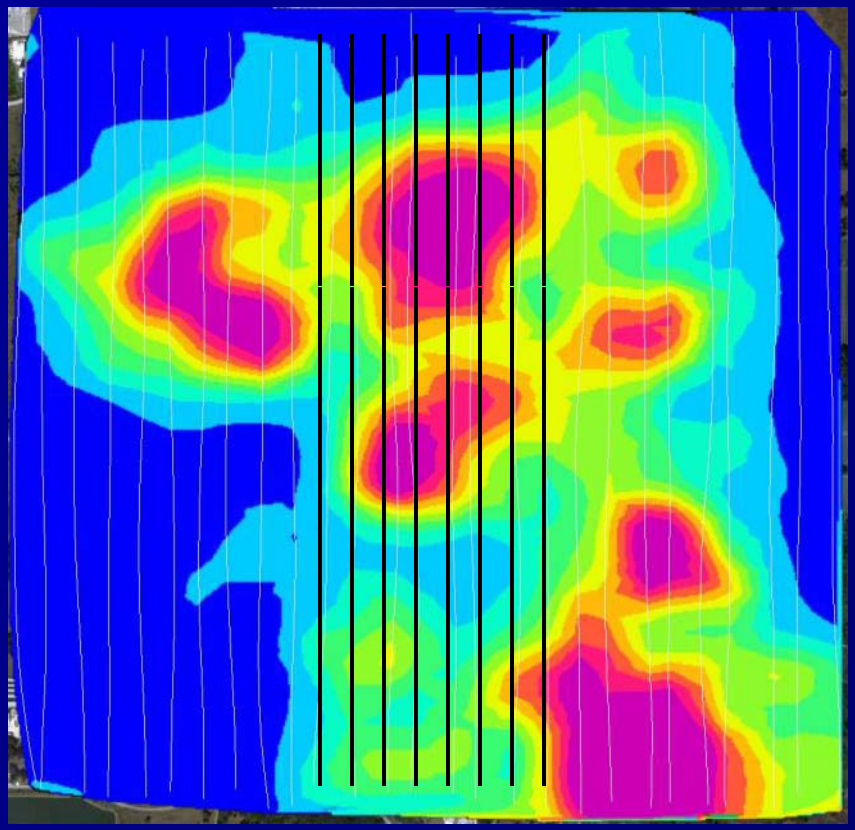


300 ft AGL
1500 ft Line Spacing

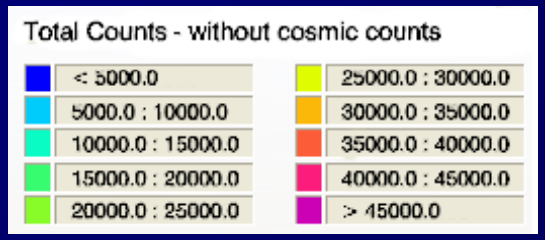
Total Counts - without cosmic counts

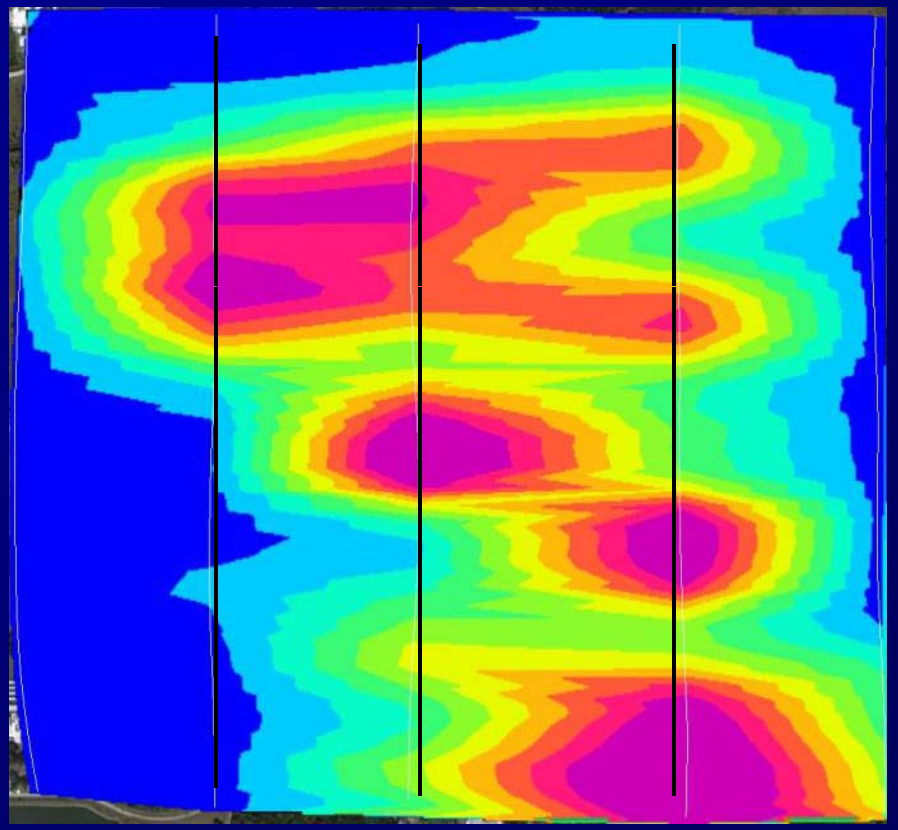
< 5000.0	25000.0 : 30000.0
5000.0 : 10000.0	30000.0 : 35000.0
10000.0 : 15000.0	35000.0 : 40000.0
15000.0 : 20000.0	40000.0 : 45000.0
20000.0 : 25000.0	> 45000.0

Line Spacing – ENVI Code



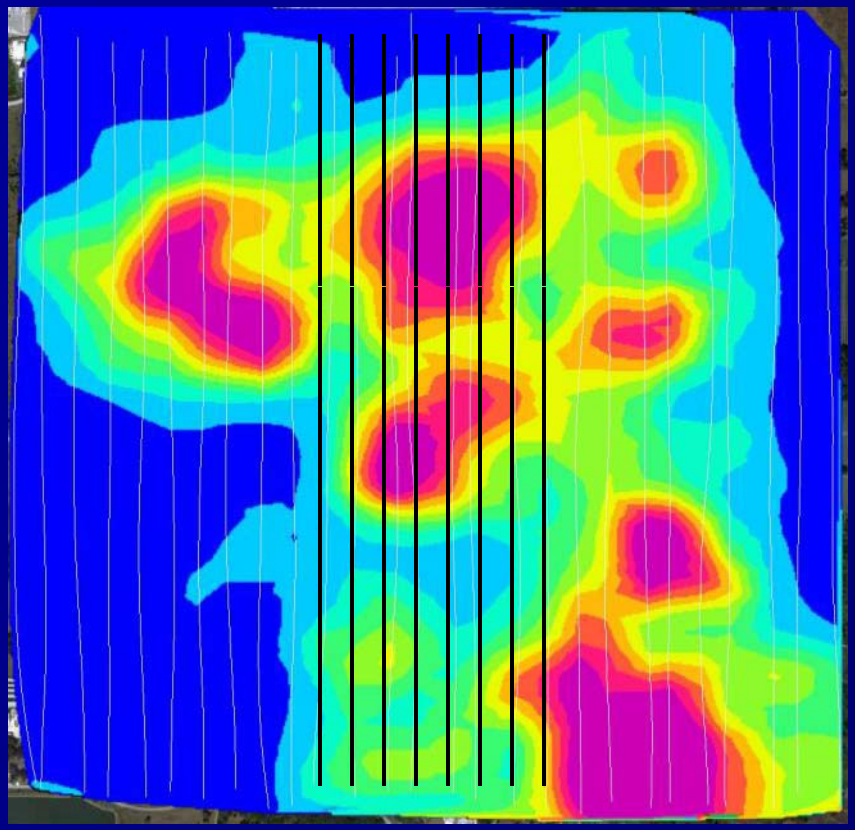
300 ft AGL
300 ft Line Spacing



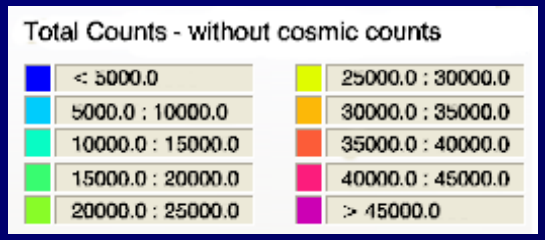


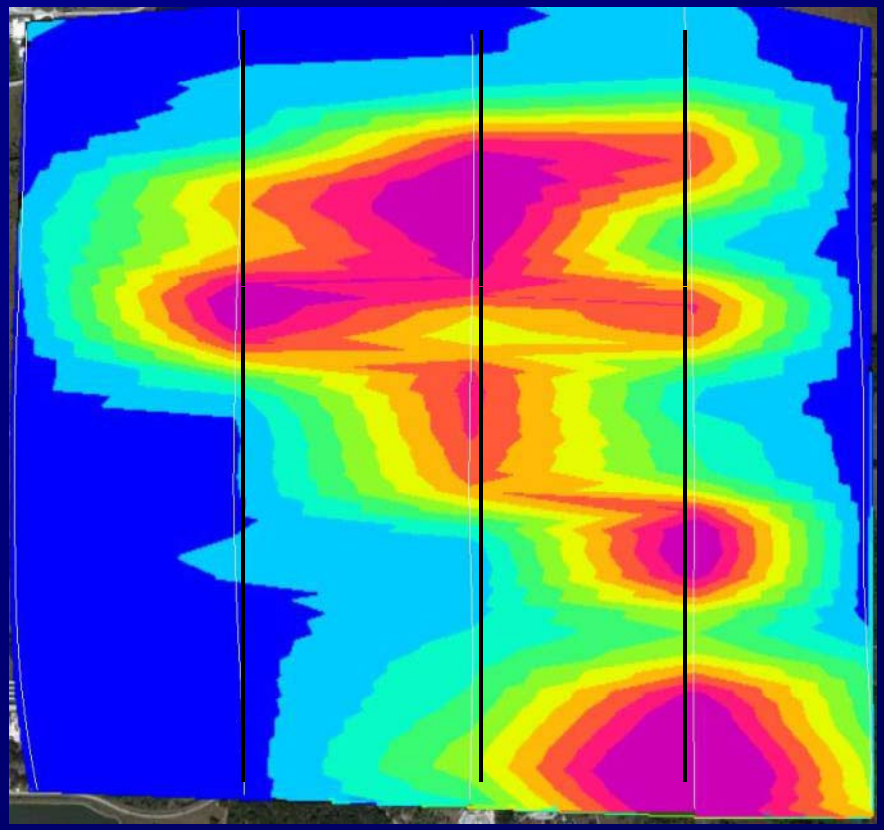
300 ft AGL
1800 ft Line Spacing

Line Spacing – ENVI Code



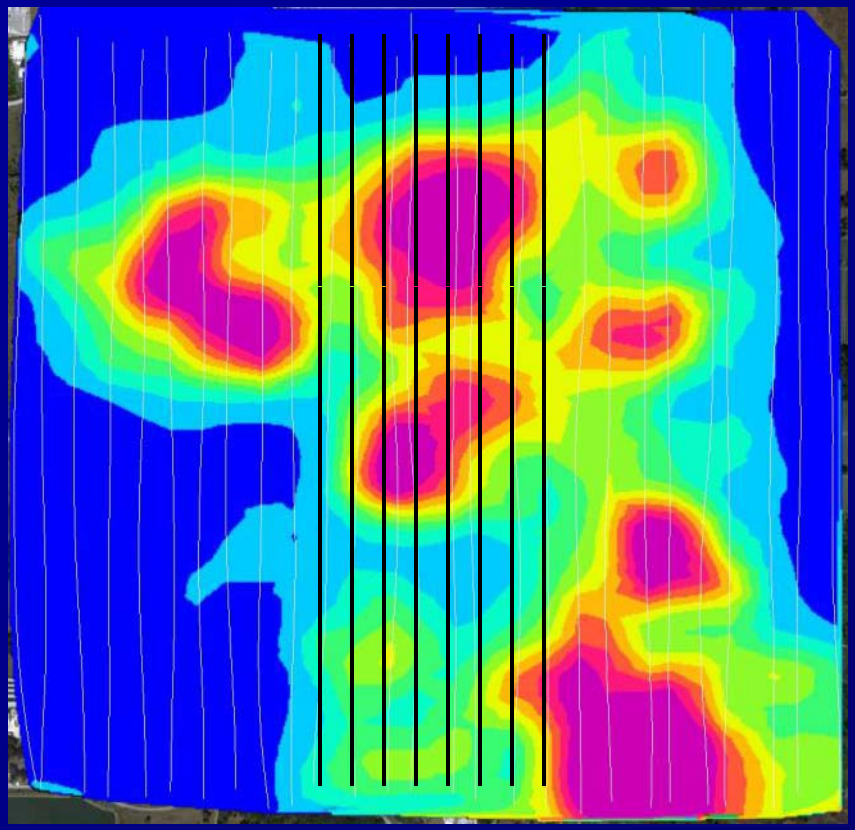
300 ft AGL
300 ft Line Spacing



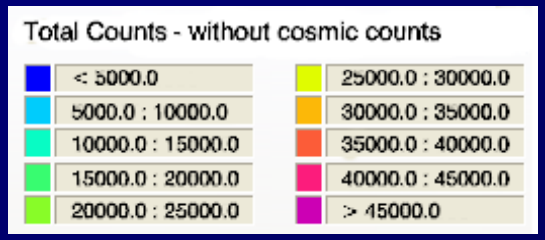


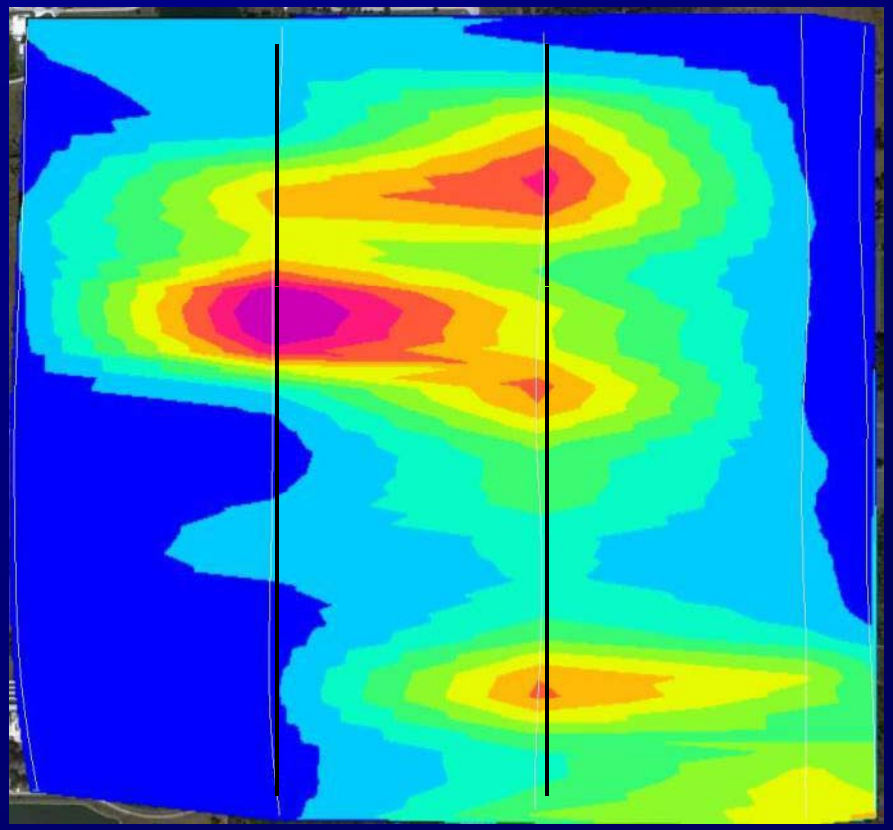
300 ft AGL
2100 ft Line Spacing

Line Spacing – ENVI Code



300 ft AGL
300 ft Line Spacing

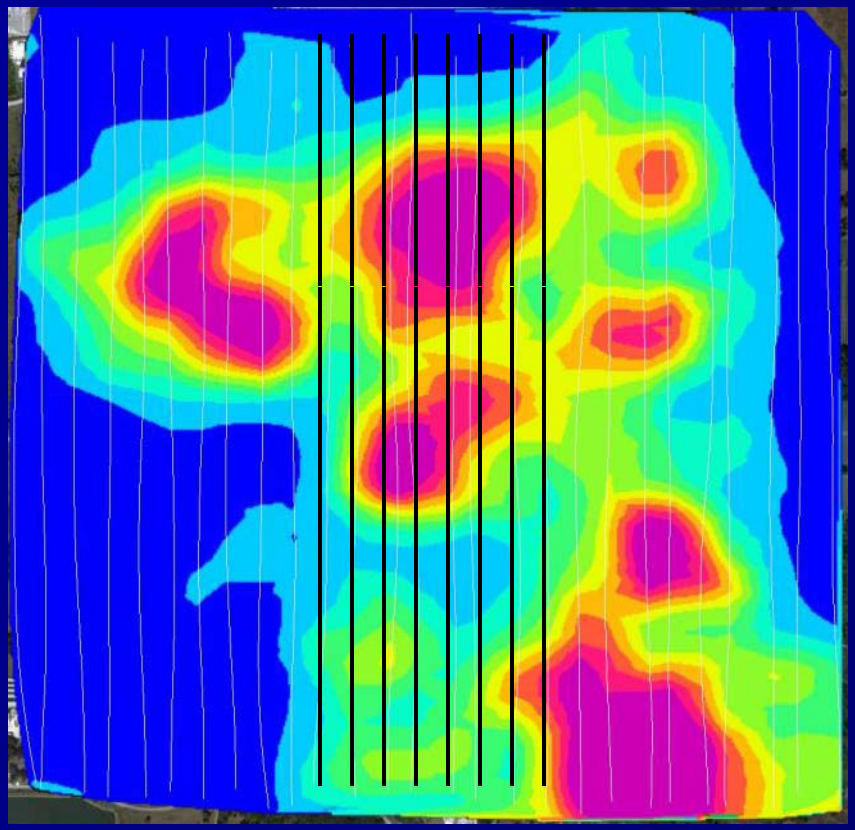




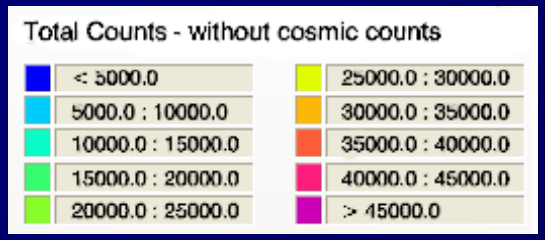
300 ft AGL
2400 ft Line Spacing

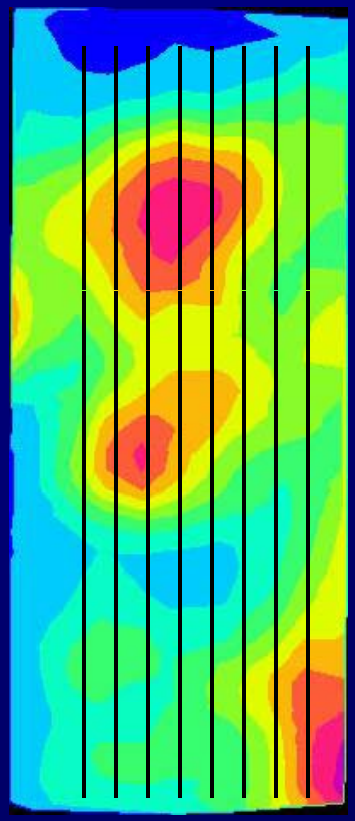
Altitude

No significant changes by flying 200 ft higher (300 AGL vs. 500 AGL)



300 ft AGL
300 ft Line Spacing

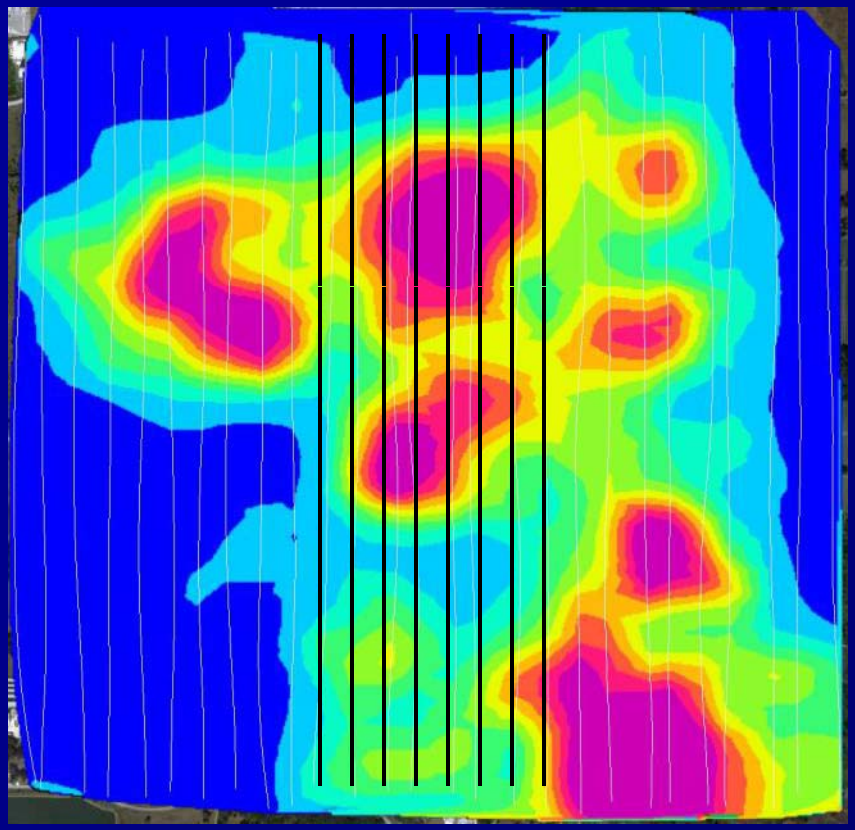




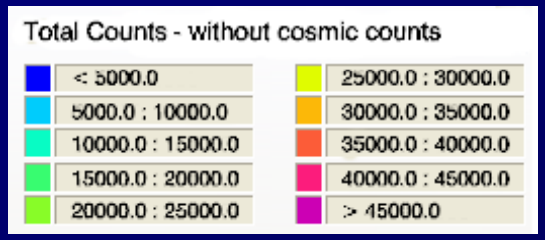
500 ft AGL
300 ft Line Spacing

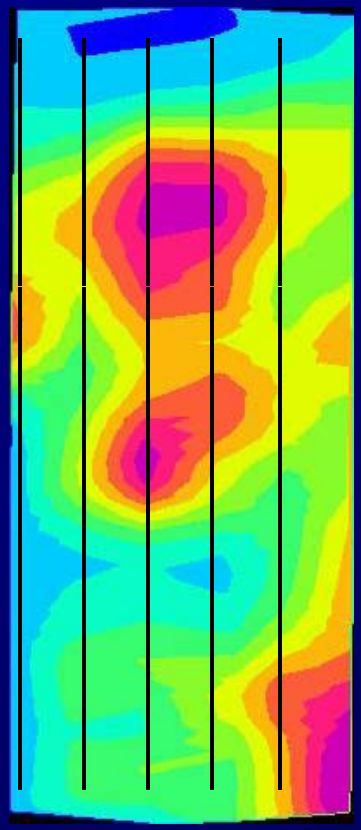
Altitude

No significant changes by flying 200 ft higher (300 AGL vs. 500 AGL)



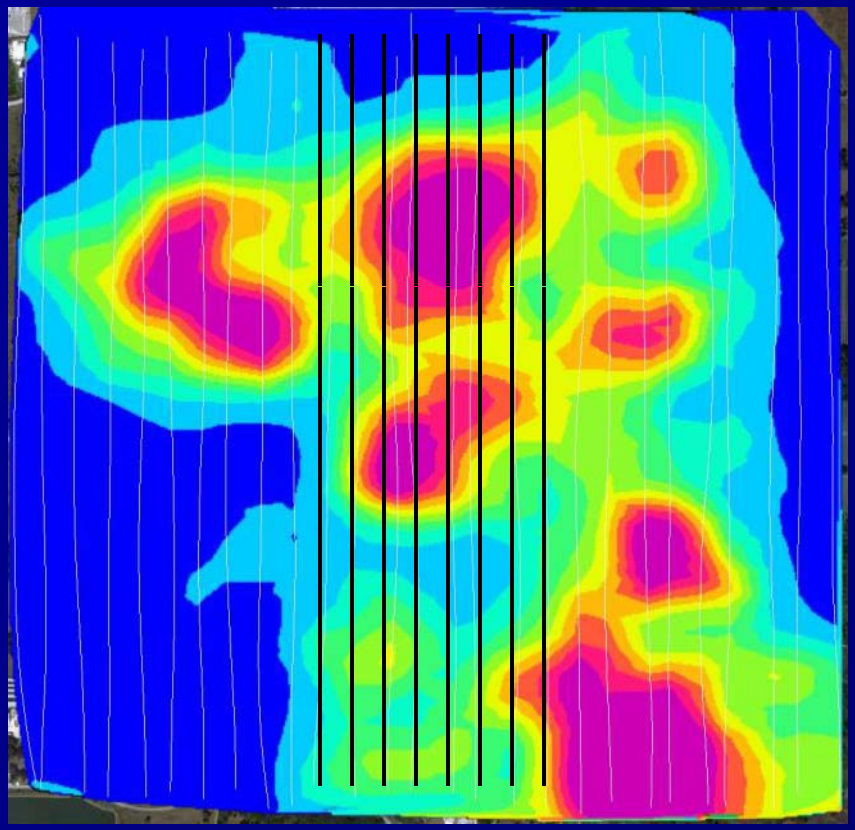
300 ft AGL
300 ft Line Spacing



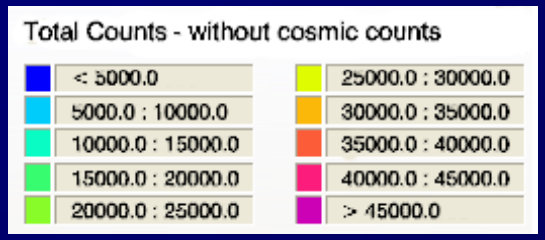


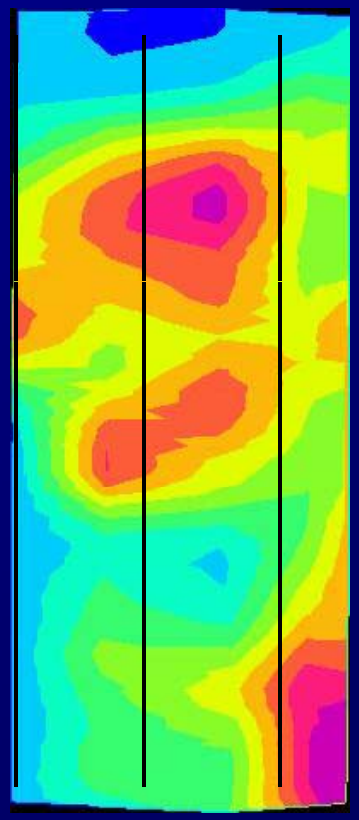
500 ft AGL
600 ft Line Spacing

Altitude
300 AGL vs. 500 AGL



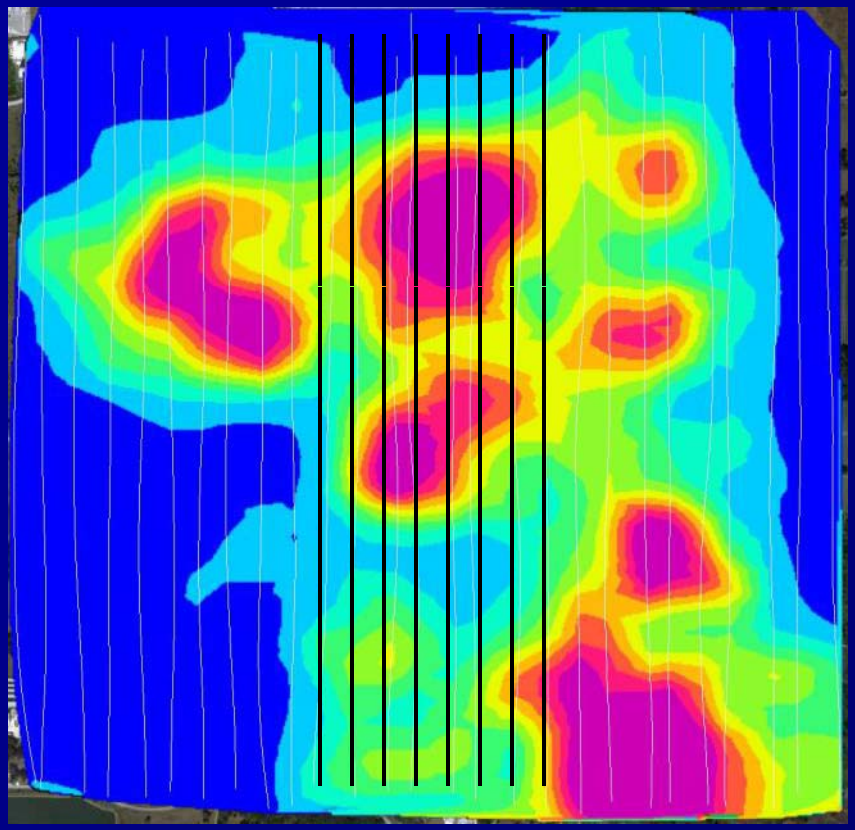
300 ft AGL
300 ft Line Spacing



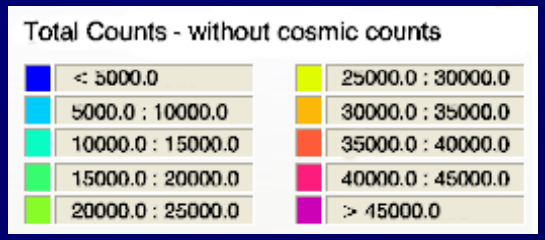


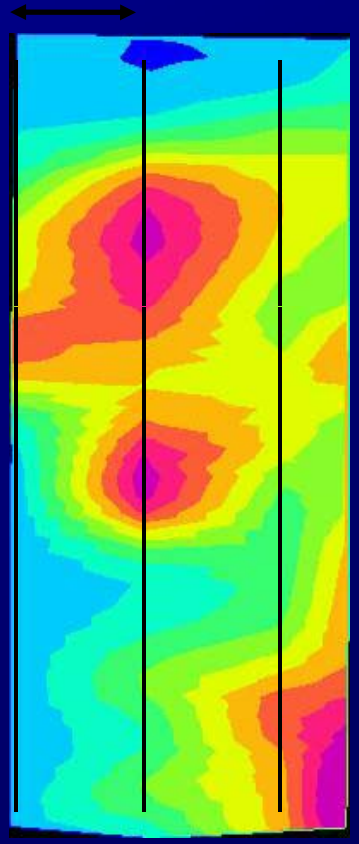
500 ft AGL
900 ft Line Spacing

Altitude
300 AGL vs. 500 AGL



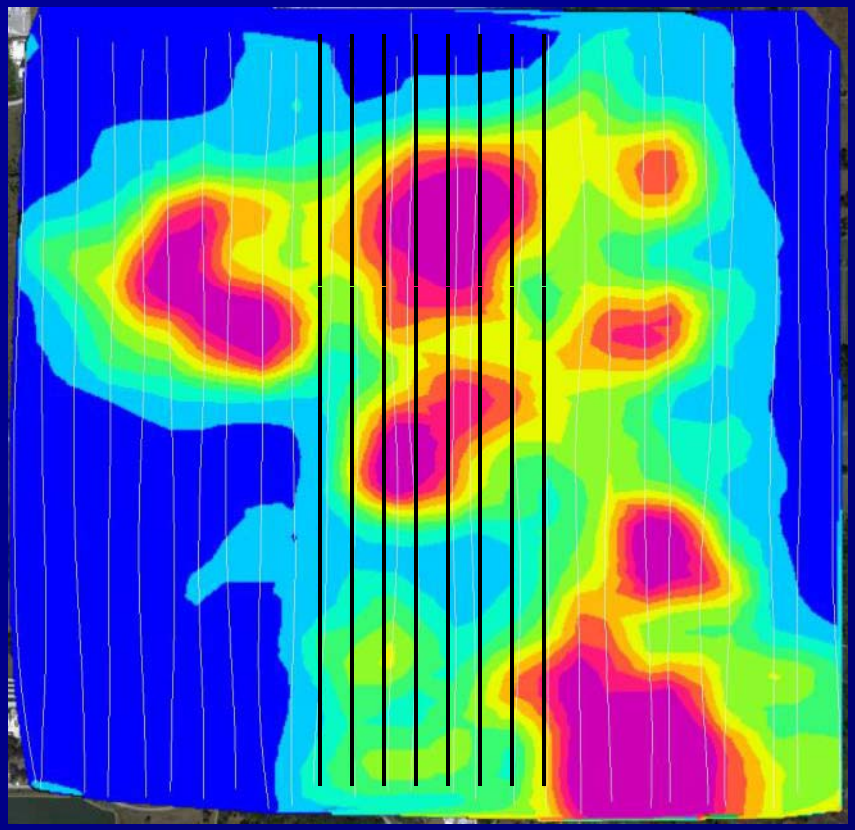
300 ft AGL
300 ft Line Spacing



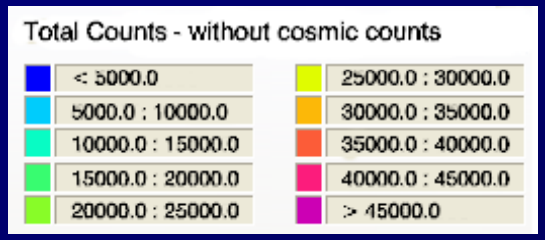


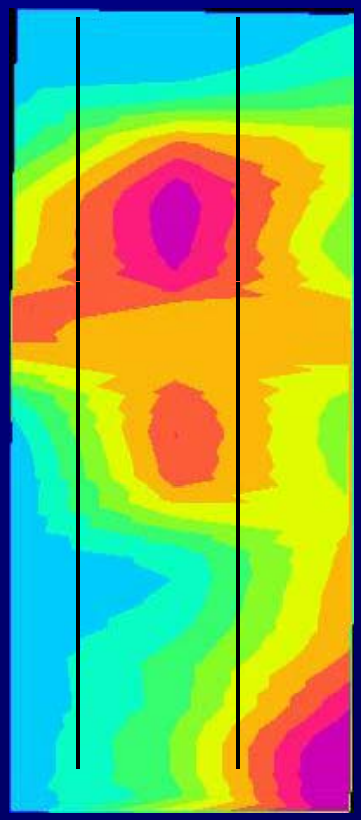
500 ft AGL
1200 ft Line Spacing

Altitude
300 AGL vs. 500 AGL



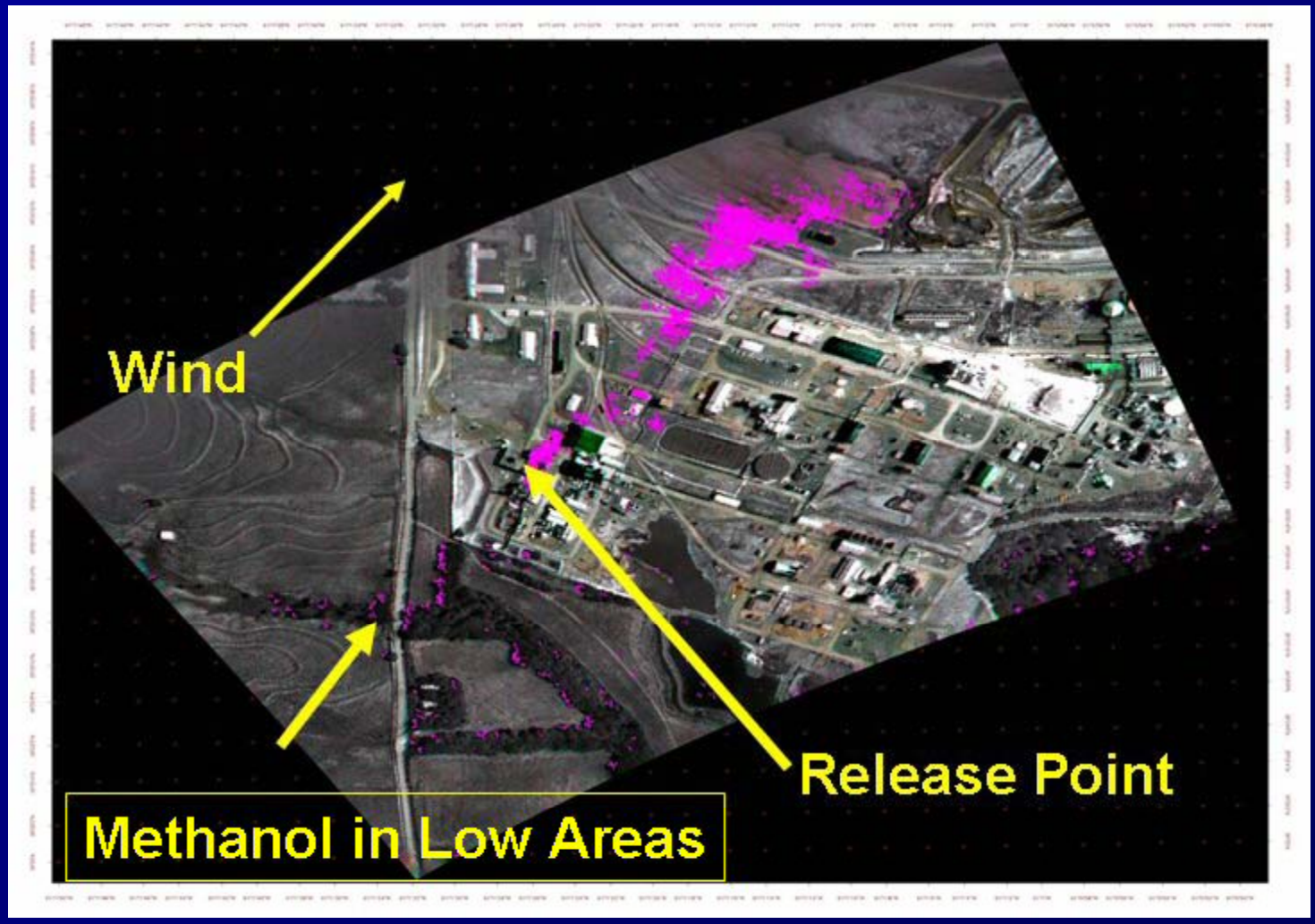
300 ft AGL
300 ft Line Spacing





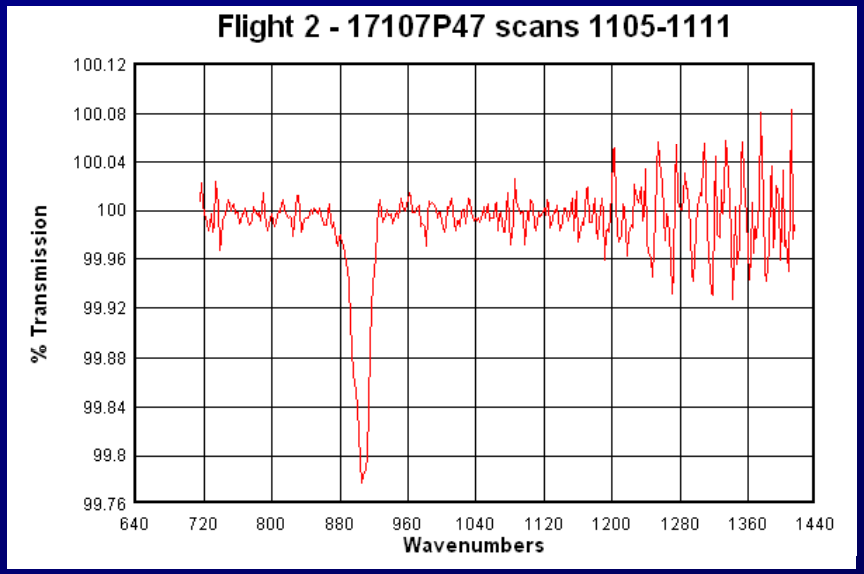
500 ft AGL
1500 ft Line Spacing

Infrared Image of an Industrial Methanol Plume Release



ASPECT Deployment
Train Derailment in Sheperdsville, KY

1,3-Butadiene spectra from ASPECT flight over the fires

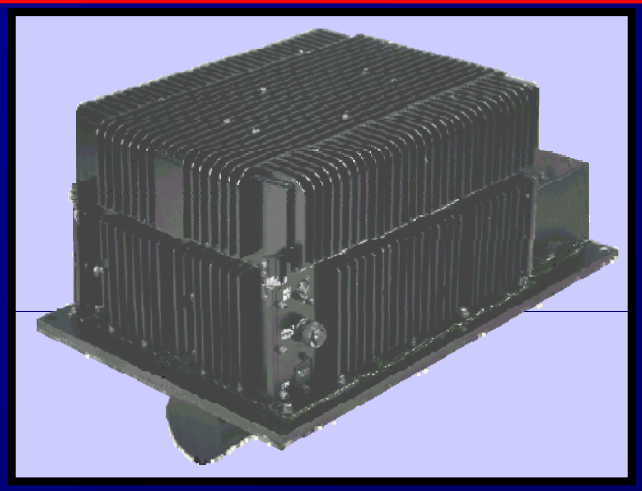


Chemical Report

Run	Compound
1	System Test
2	1,3-butadiene 0 to 0.4 ppm
3	1,3-butadiene 0 to 0.2 ppm
4	1,3-butadiene 0 to 0.4 ppm
5	1,3-butadiene 0 to 0.3 ppm
6	Awaiting data transmittal

Line Scanner RS-800MSIRLS

- Using a scanner speed of about 60 Hz and a field of view of 60^{o} results in a linear infrared image approx ½ mile wide.
- Approx 2.0 square miles can be imaged per minute.
- Chemical discrimination is accomplished using a matrix of 16 cold optical filters having a bandwidth of approx 5 – 20 wave numbers
- Data collection status in approximately 12 minutes from start-up
- One step automated processing



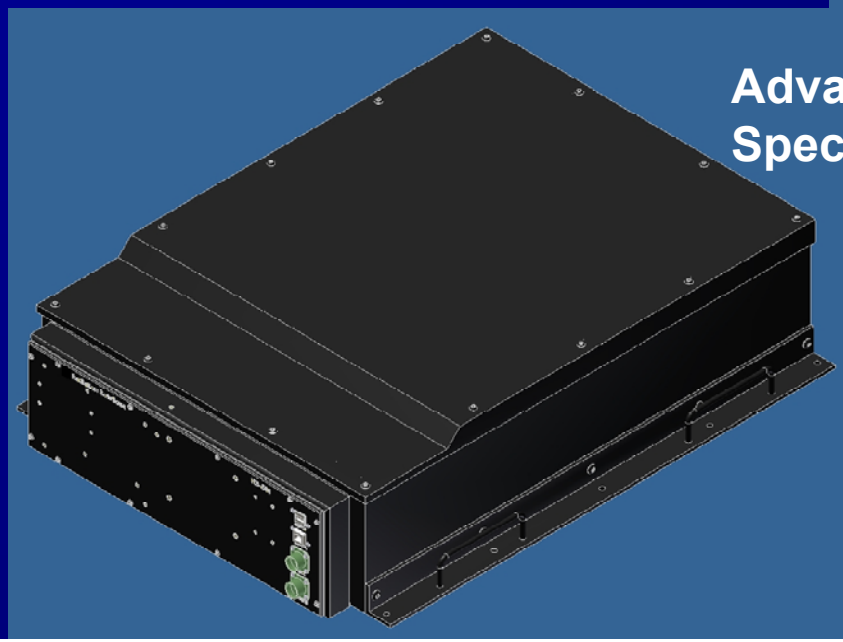
Aircraft Configuration

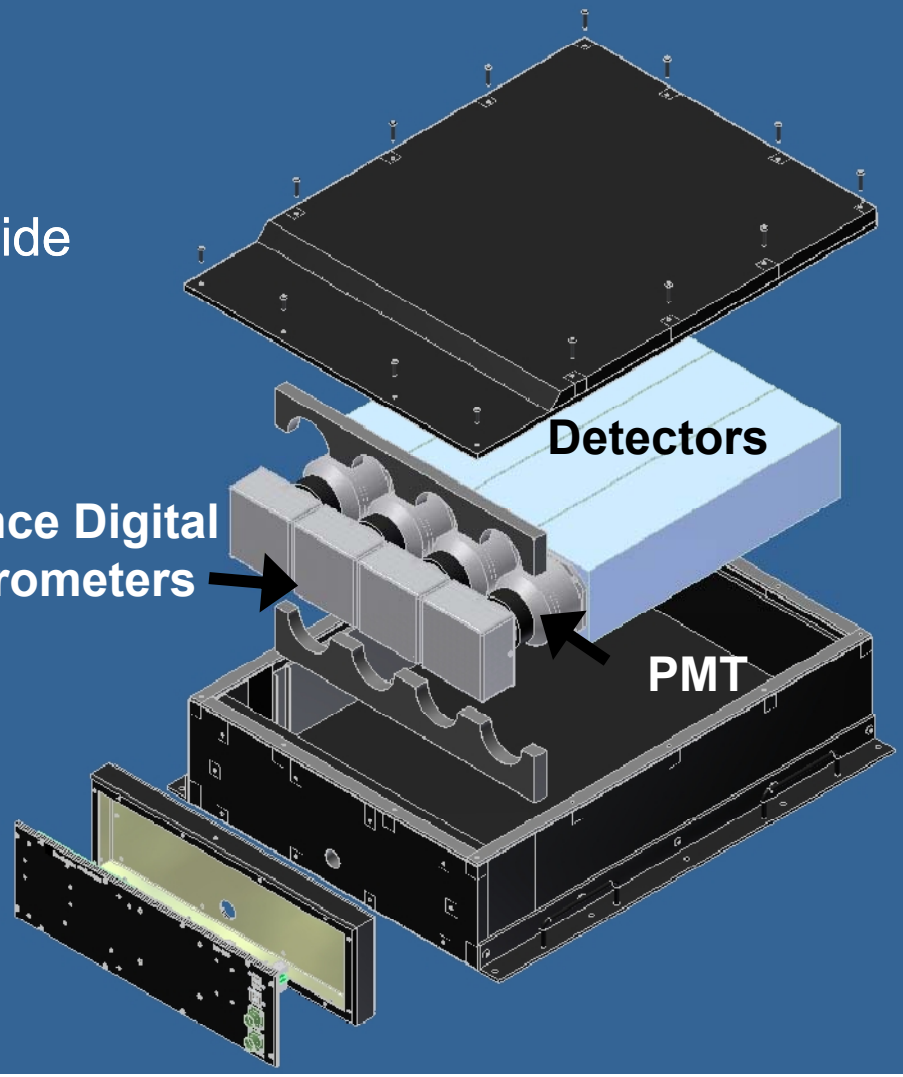
Radiation Detection Technology

Radiation Solutions RS-500

- **8** 2”x4”x16” Sodium Iodide
- Optional
  - up to 12 crystals
  - up to **3** 3”x3” Lanthanum Bromide

2 RS-500 units on aircraft





PHOTOGRAPHY

Aerial Photography

12.5 MPixel High Resolution Digital Camera

Automated Geo-Rectification/GIS Coded Images

Full Ortho-Rectification (Camera Model) Correction

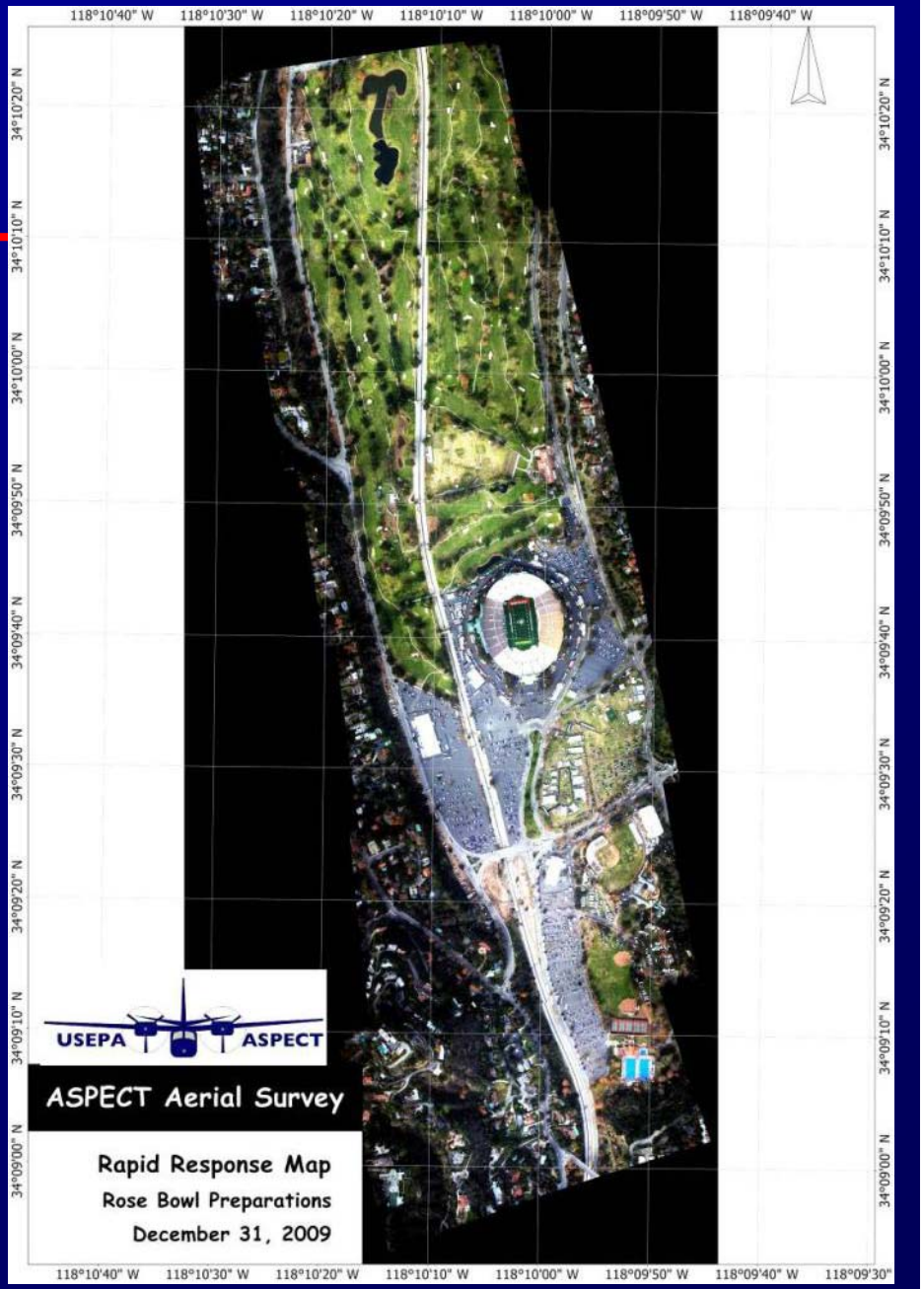
Ability to Process in the Air-Approx 3 Minute Turn-Around

Compressed Transmission of Data Via SatCom

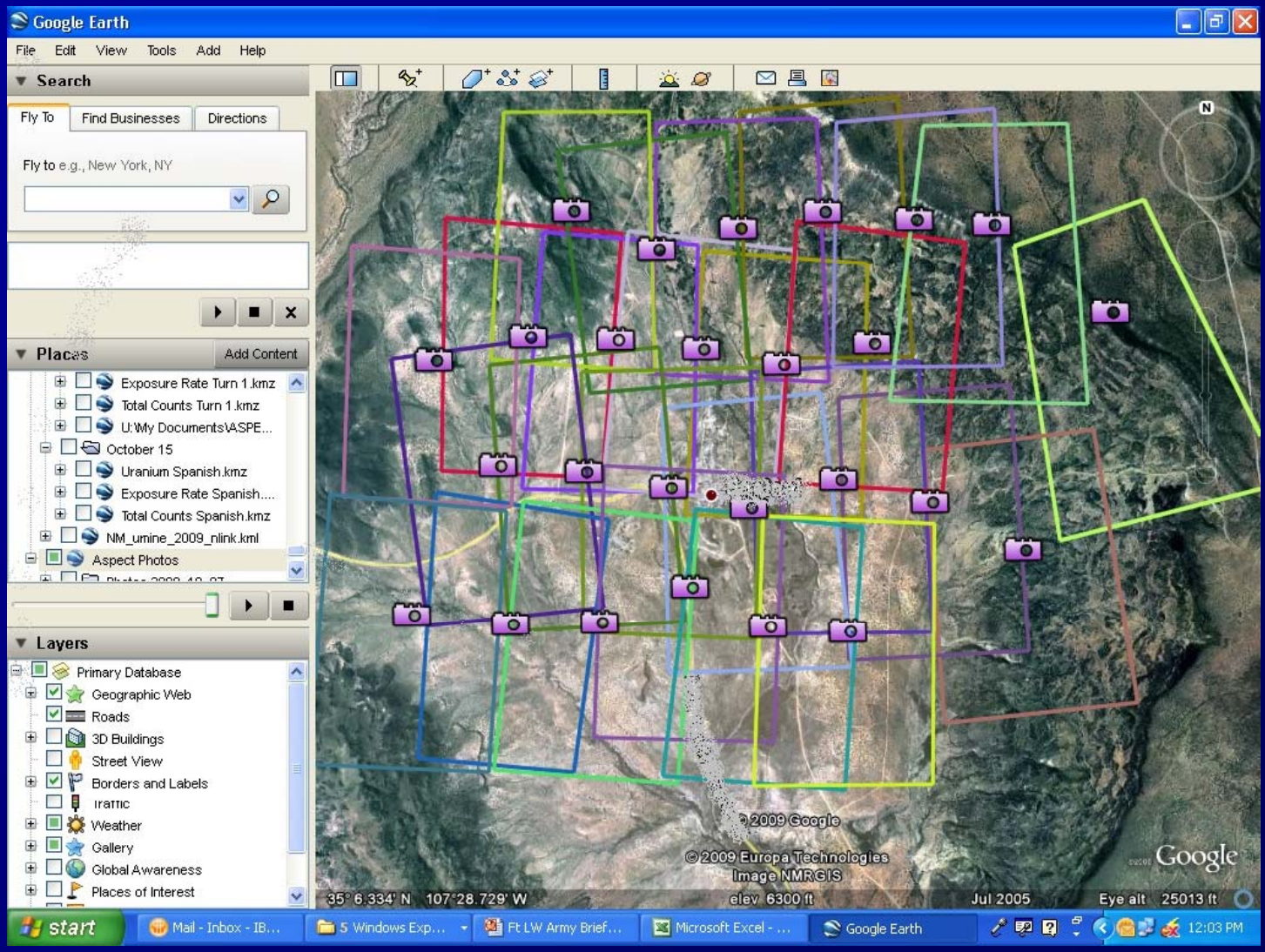
Fast Turn Around on Images – Approx 700 processed images per Hour

Product can be imported into:

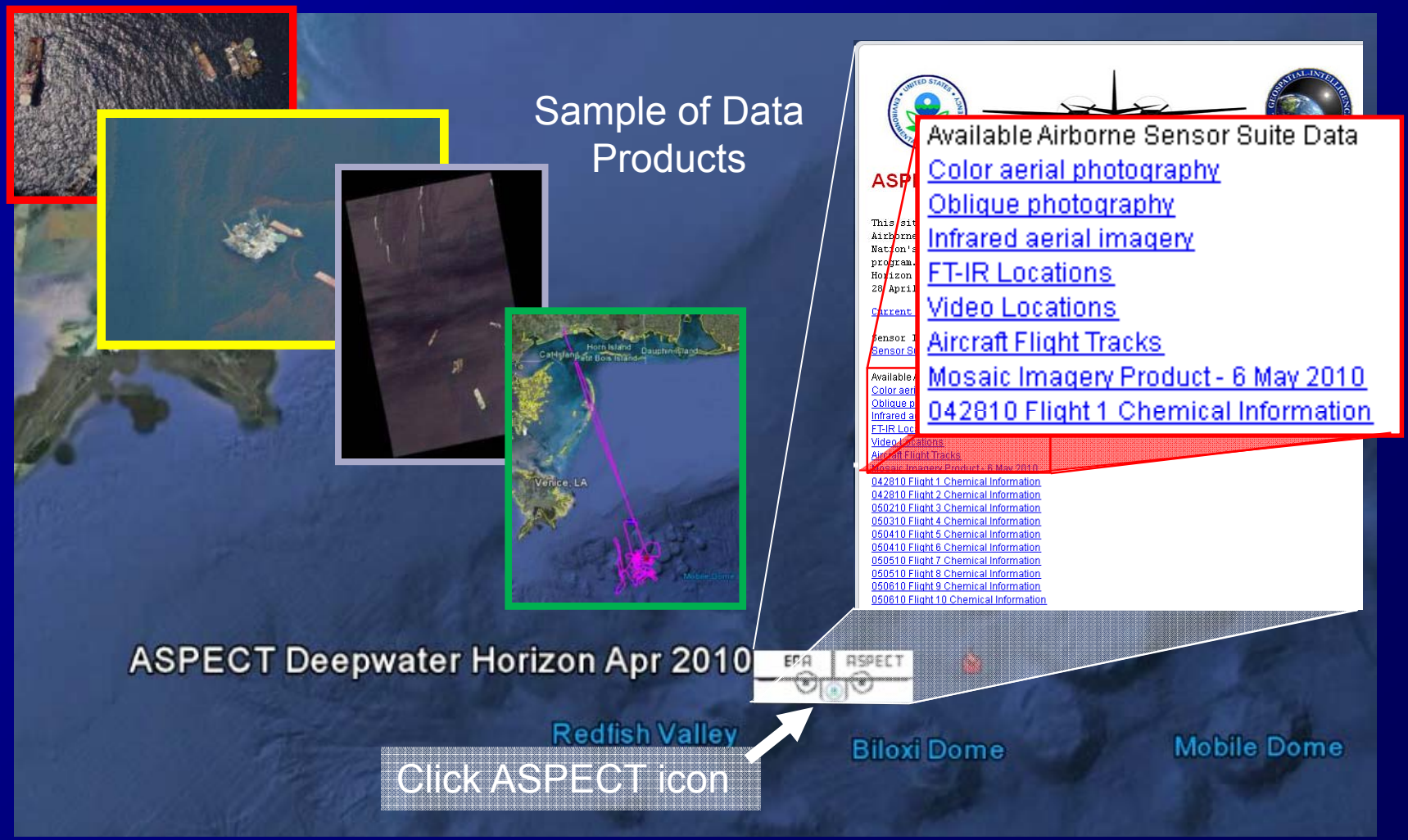
- Google Earth,
- ESRI
- Generic Geospatial software packages.



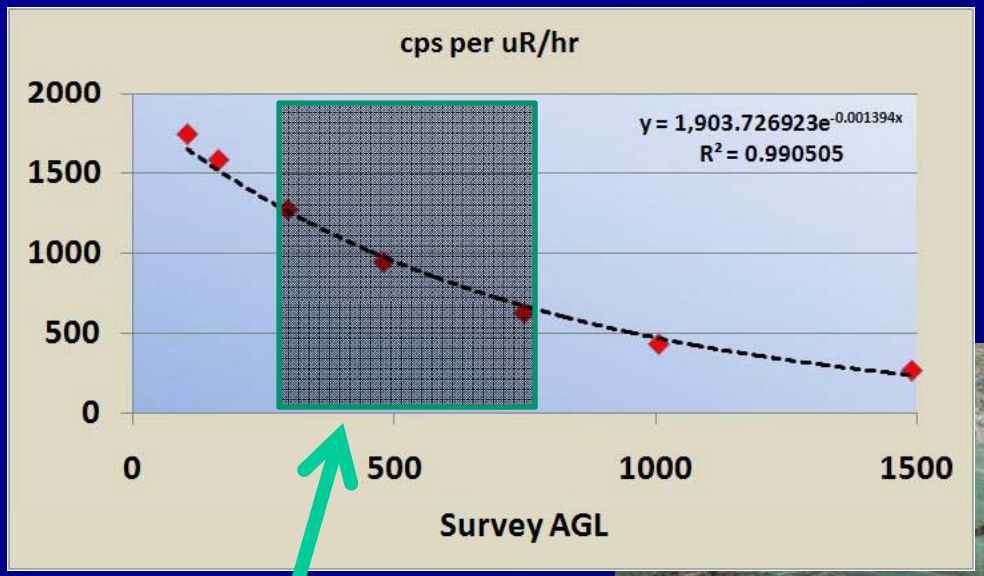
Google Earth Display
Aerial Photo Menu



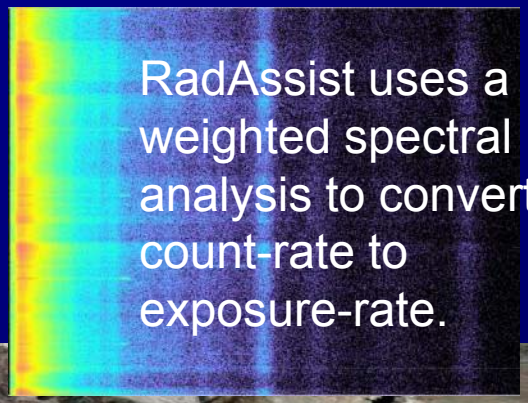
EPA ASPECT Data



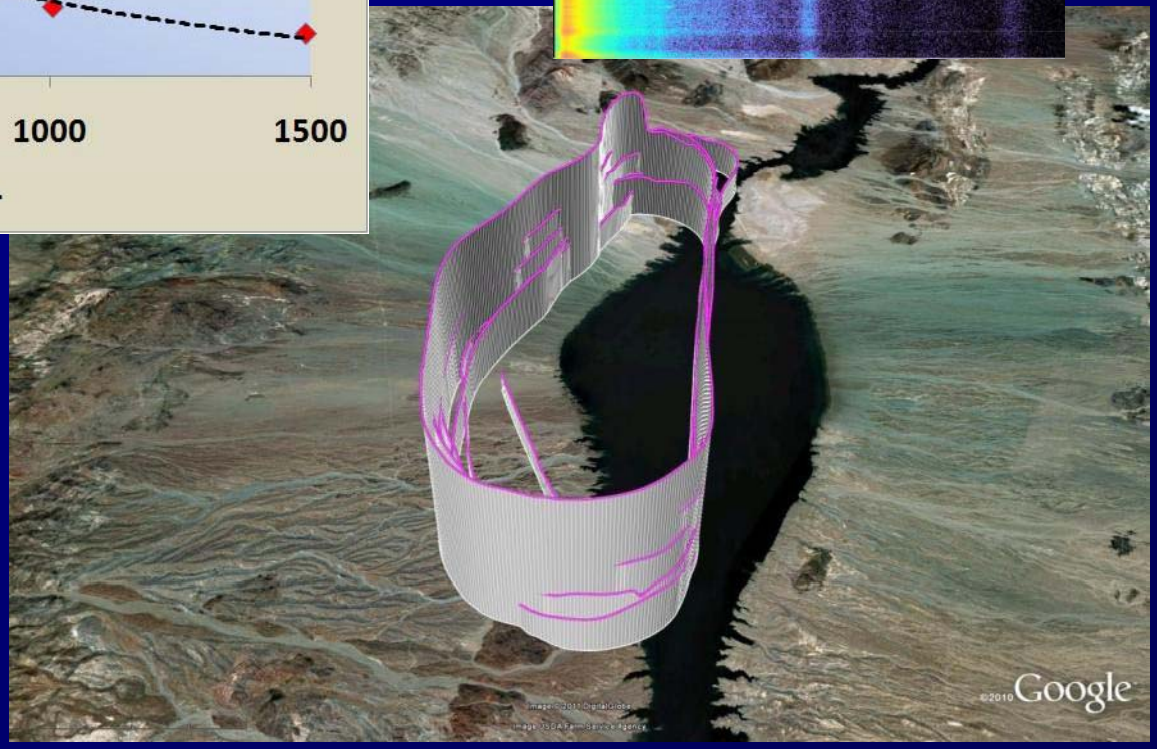
Count-rate to exposure-rate calibration
"DOE" method vs. RadAssist



Typical survey altitudes



RadAssist uses a weighted spectral analysis to convert count-rate to exposure-rate.



Deep Water Oil Detection

- ASPECT Team developed an approach to quantify and locate surface oil in deep waters using remote sensing infrared technology
  - ✓ Multi Spectral Infrared
  - ✓ Unsupervised Classification
  - ✓ Spectral Pattern Recognition (Supervised Pattern Recognition)
- Applicable to other types of oils and industrial accidents in navigable waters
- Trend analysis
  - ✓ Dispersant effectiveness
  - ✓ Oil migration monitoring