Environmental (& *"other"*) Applications *(of Nuclear Techniques)*

Lectures III & IV

Changing Environment

Cultural Heritage

…with an eye on "Novel Systems"

Iain Darby

IAEA

International Atomic Energy Agency

uk_npss Bristol 2013

PART I – ENVIRONMENTAL IN-SITU (CONTINUED)

AERIAL MEASURING

US Aerial Measuring System

Mission

AMS provides responsive aerial and ground-based measurements to detect, analyze, and track radioactive material before and during emergencies.

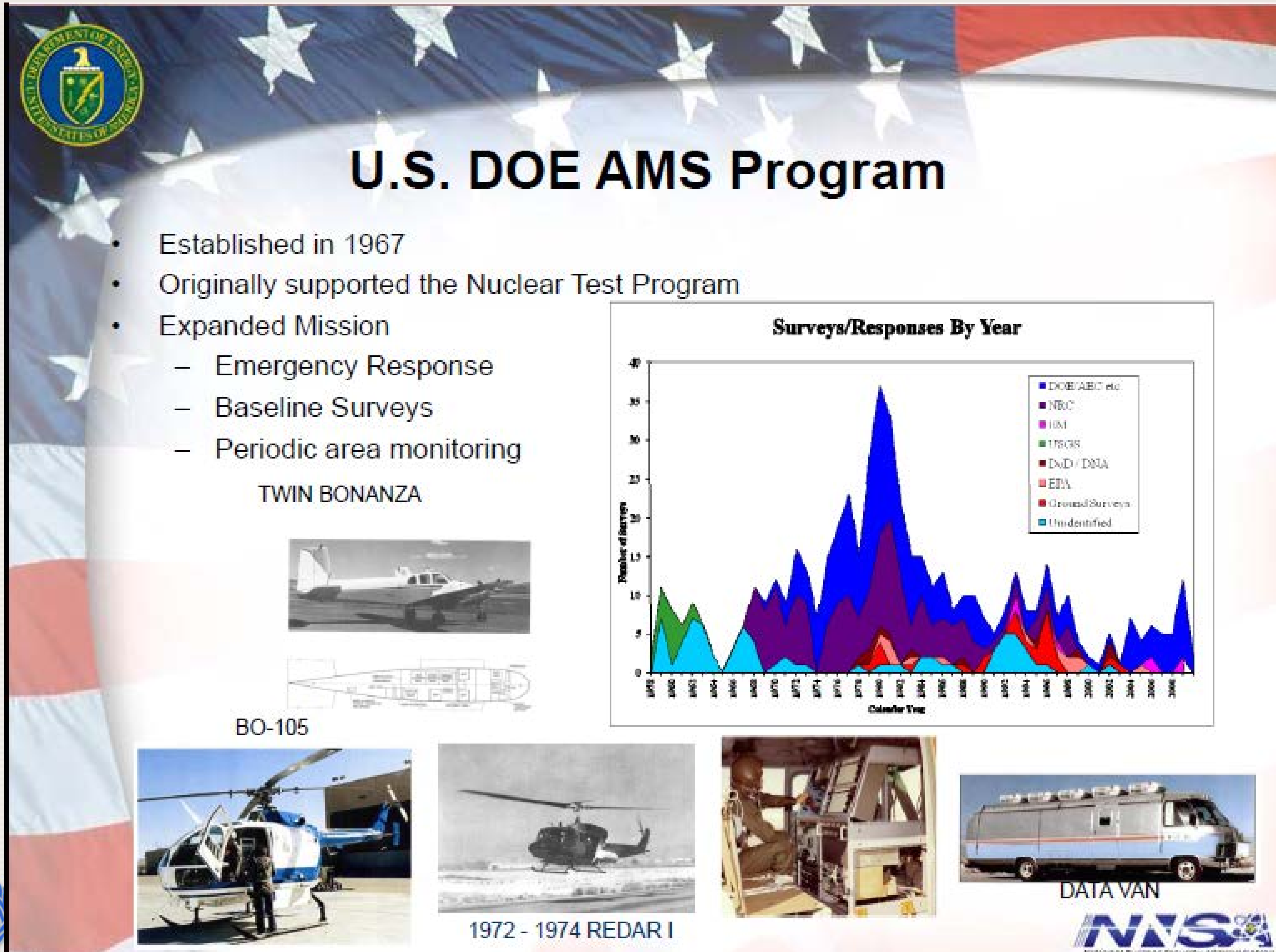
This includes Mission Planning, Acquisition, Post-Analysis, and Reporting.

Colin Okada, Ph.D.
National Security Technologies, LLC

This work was done by National Security Technologies, LLC, under Contract No. DE-AC52-06N25946 with the U.S. Department of Energy.

US Aerial Measuring System

US Aerial Measuring System

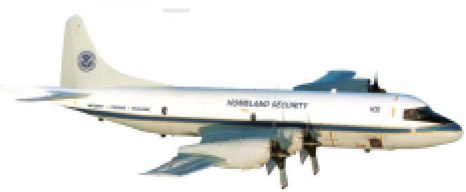


US Aerial Measuring System

AMS Mission Equipment - Aircrafts

Beech King Air B-200 (DOE)
- Twin-engine turbo prop
- IFR (all weather) rated
- 260 knots (300 mph)
- Range 1130 nm (1300 sm)
- Max Endurance 5 hrs (without refueling)

Bell-412 (DOE)
- Twin-Pac turboshaft engine
- IFR (all weather) rated
- 120 knots (140 mph)
- Range 360 nm (410 sm)
- Max Endurance 3 hrs (without refueling)



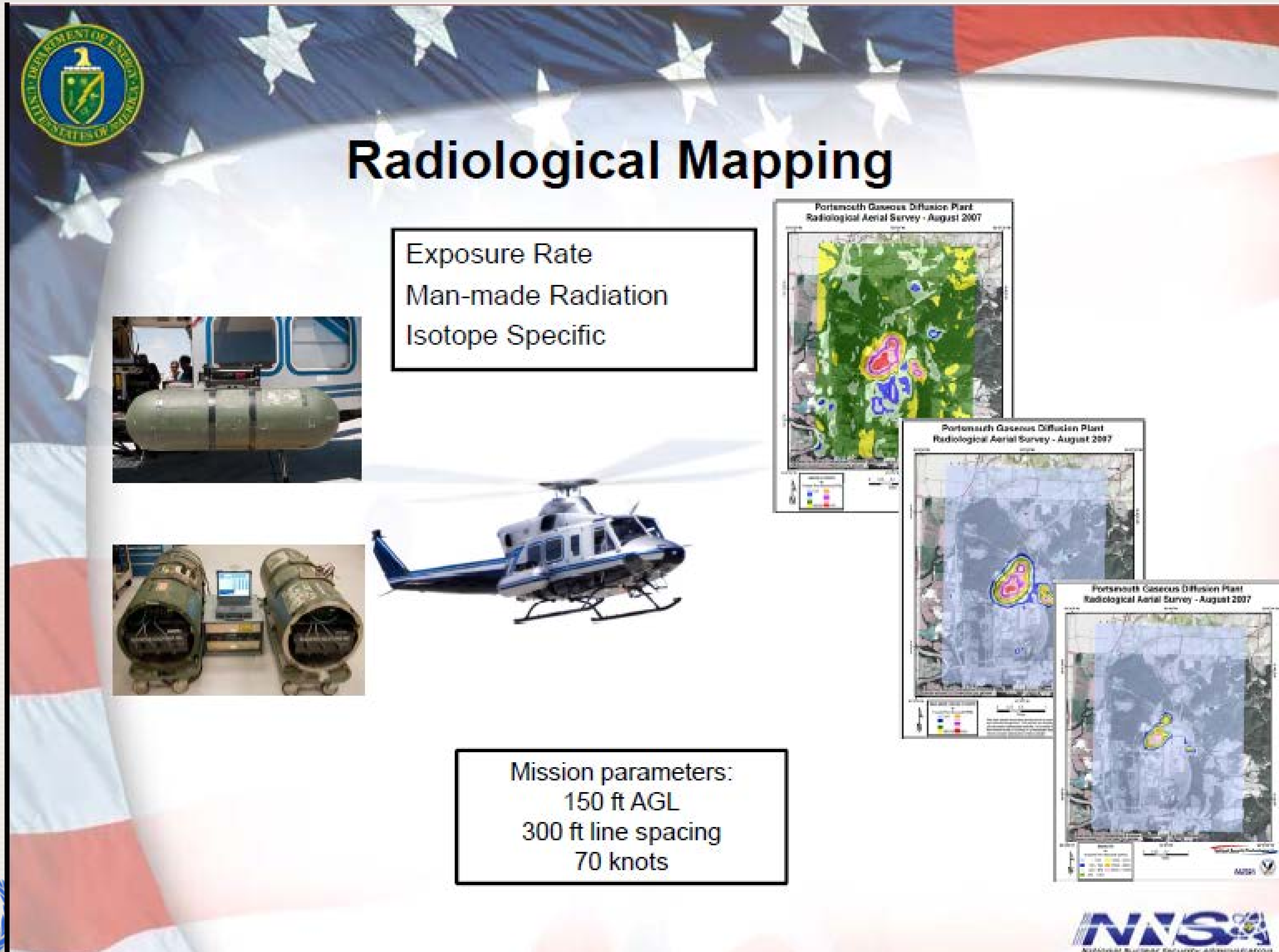
P-3 (DHS)
- Four engine turbo prop
- IFR (all weather) rated
- 400 knots (460 mph)
- Range 4000 nm (4600 sm)
- Max Endurance 12 hrs (without refueling)

Aero Commander 680 (EPA)
- Twin-piston engine
- Non pressurized
- 100 knots (115 mph)
- Range 1100 nm (1260 sm)
- Max Endurance 4-6 hrs (without refueling)

National Nuclear Security Administration

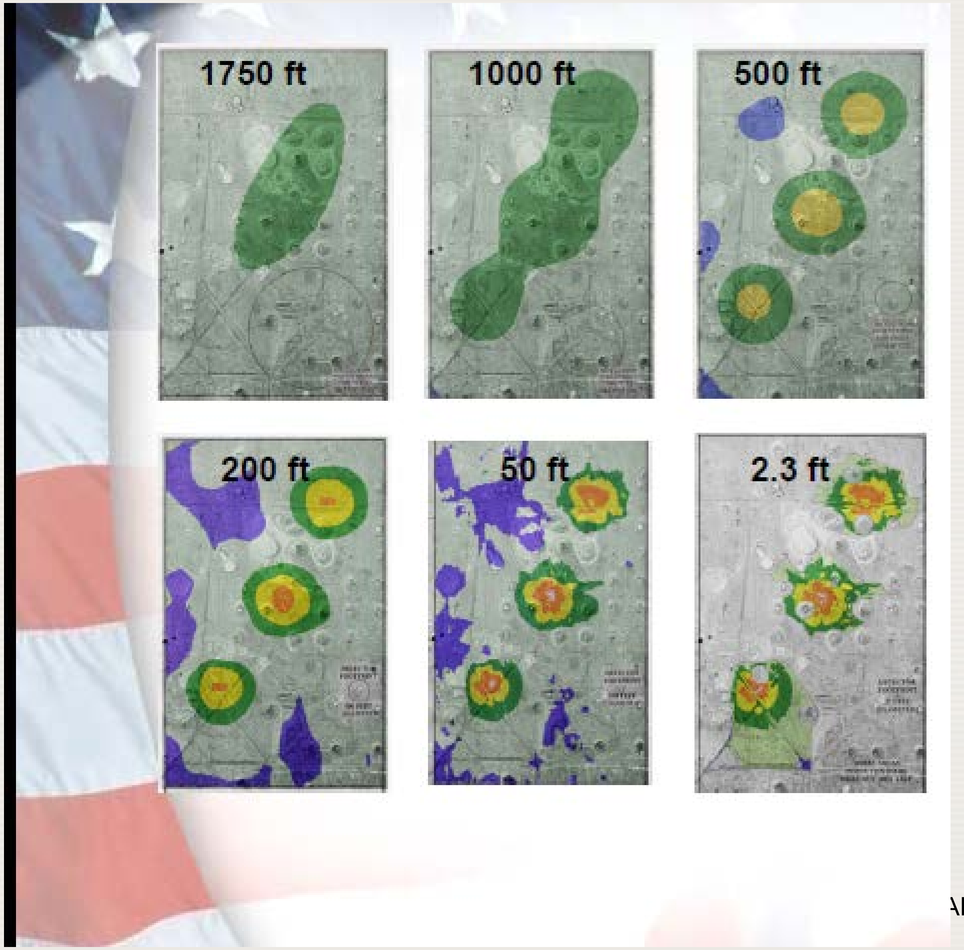
US Aerial Measuring System

US Aerial Measuring System

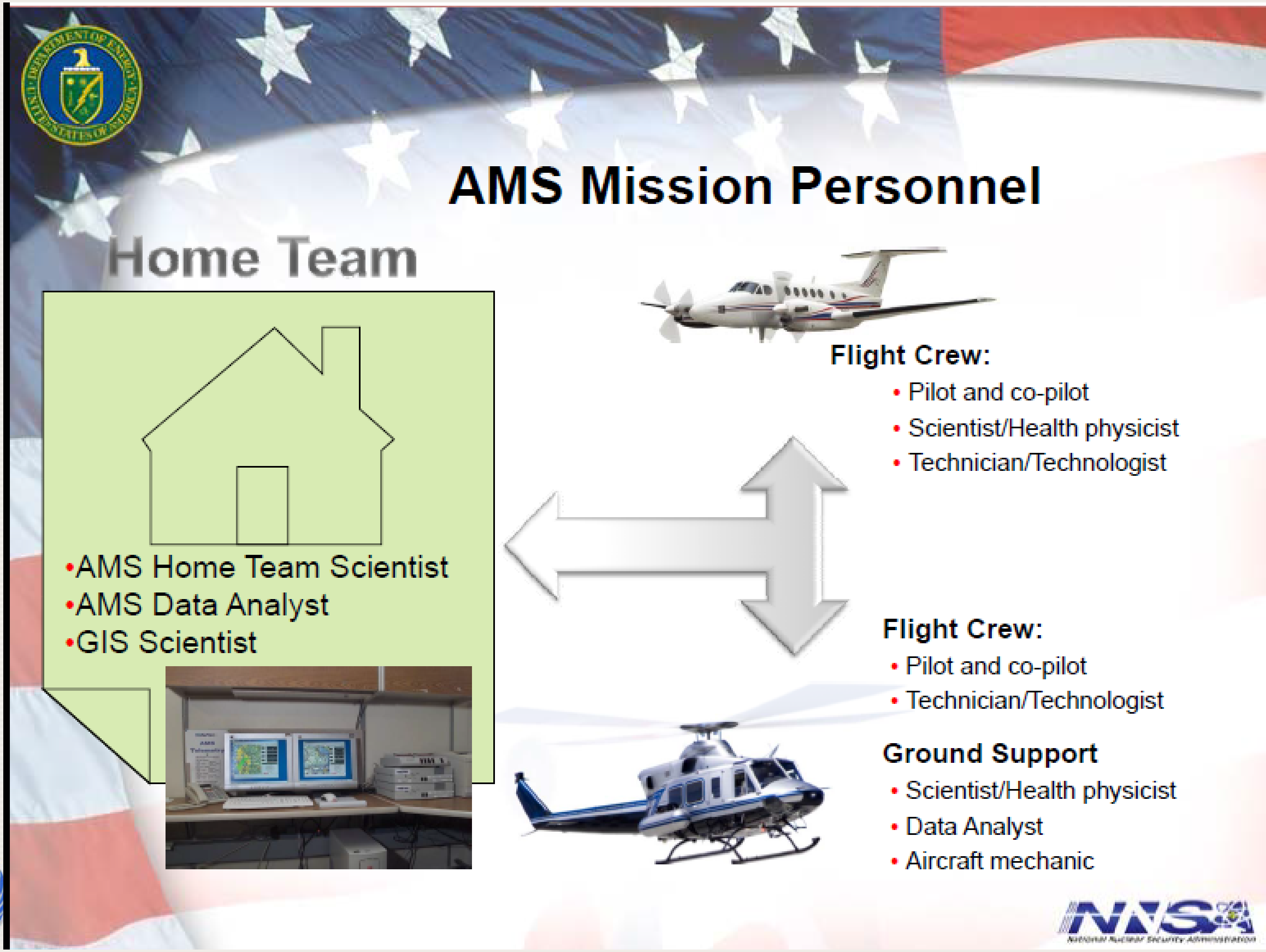


US Aerial Measuring System

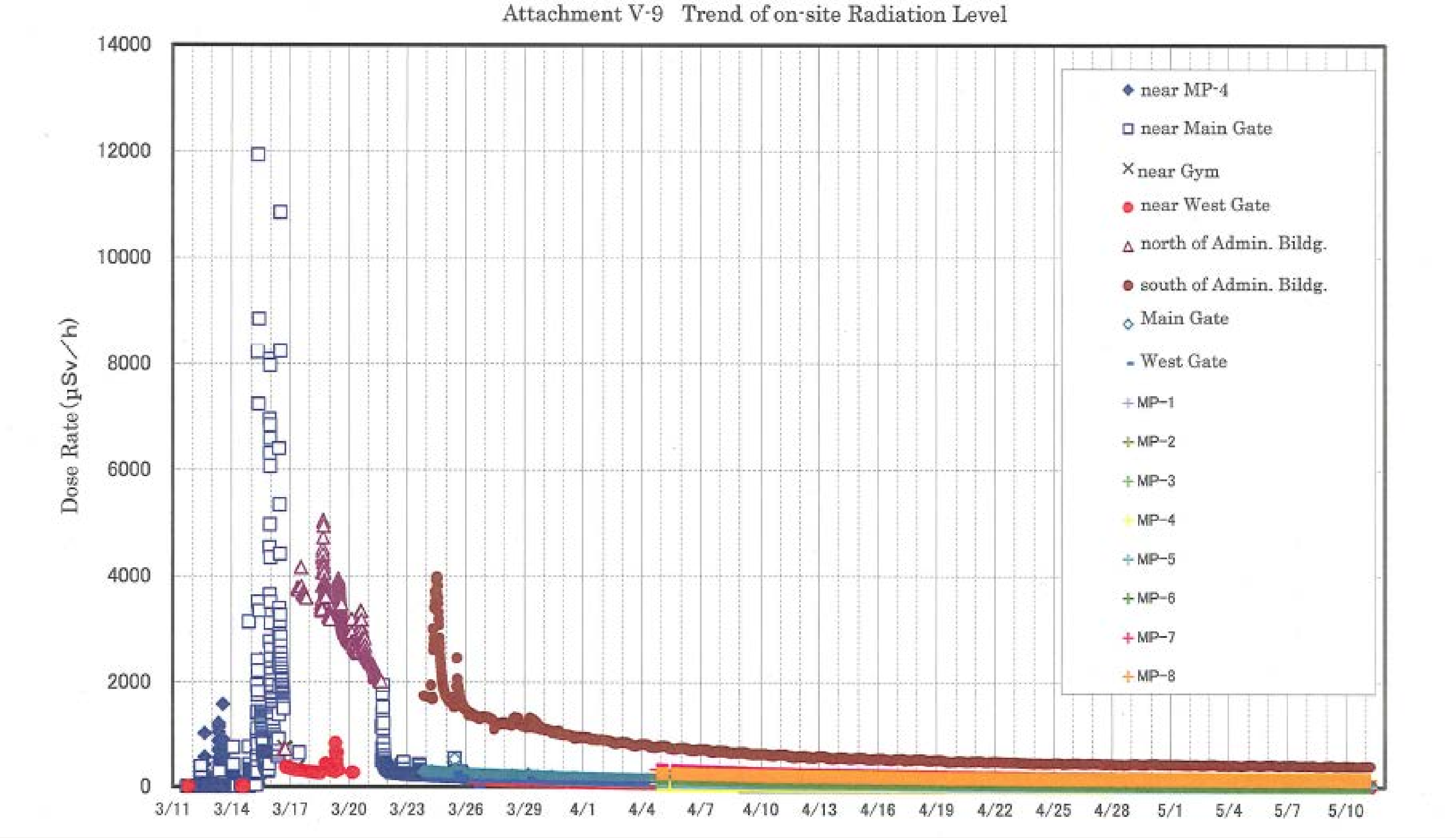
Resolution vs Altitude



US Aerial Measuring System



Trend of on-site Radiation Level



Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety – The Accident at TEPCO's Fukushima Nuclear Power Stations – attachment V9 (June, 2011, Nuclear Emergency Response HQ)

http://www-pub.iaea.org/MTCD/Meetings/cn200_documentation.asp

Fukushima Dai-ichi

Fukushima Dai-ichi

Fukushima Dai-ichi

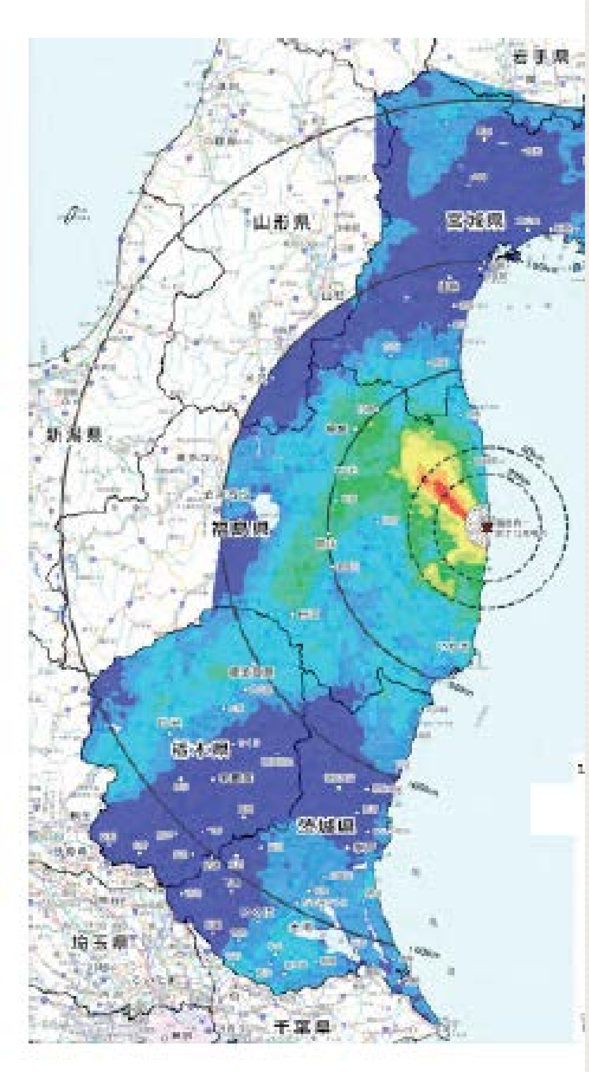
Options at the time of the Accident

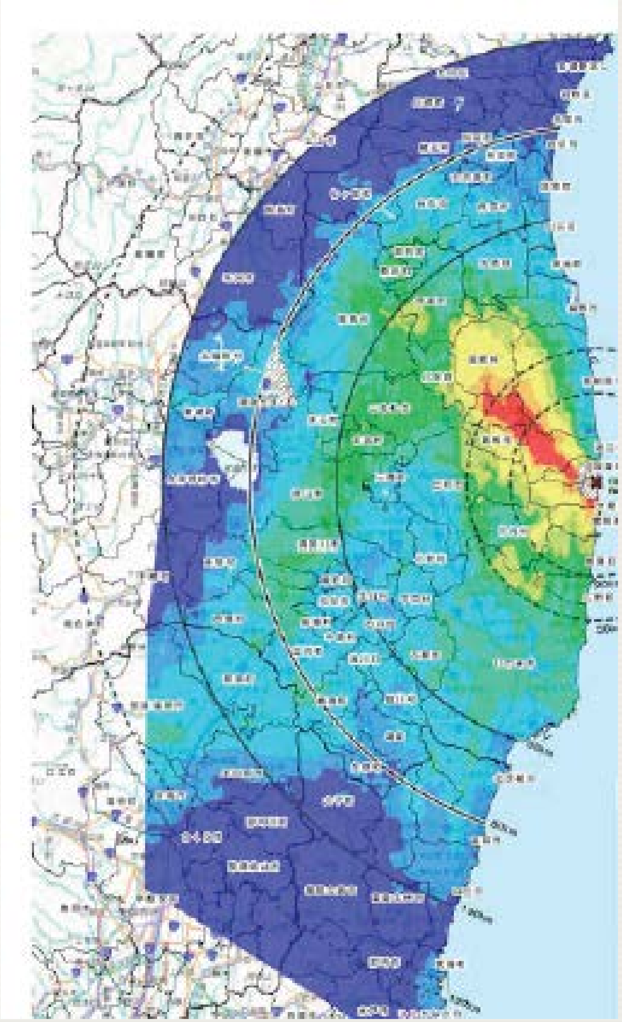
- At the time of the Fukushima accident at the IAEA only the Dept of Safeguards had capabilities for environmental (i.e. radiological) mapping e.g. mobile gamma spectrometry. However, within the Agency the Dept of Safeguards is quite separate from the other departments and only concerned with Safeguards, i.e. non-proliferation.
- Only the US, specifically the NNSA Aerial Measuring System, had a stand-by capacity for aerial monitoring and mapping
- Such a large scale system, based on piloted aircraft, is expensive to maintain and deploy, but the only way to cover large areas of the scale of $100 km^2$ or more.

Monitoring after the Fukushima Accident

- After the Fukushima Accident aerial monitoring was carried out by US DOE and Japanese MEXT. The first report was issued on 6 May 2011, covering measurements taken from 6-29 April 2011
- Aircraft used: Bell 412, Bell UH-1, Beechcraft C-12
- Data from 42 flights, height between 150m and 700m
- The surveys were repeated to see the development over time and the range of the surveys was extended to cover a large part of Japan
- The exclusion zone was ultimately based on these measurements

AMS Surveys (illustrative maps)





ASPECT *(abridged)*

Courtesy of Gene Jablonowksi US EPA

- Airborne Spectral Photometric Environmental Collection Technology (ASPECT)
- Nations only **24/7** Airborne **Chemica**l, **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, training & exercises)
- Provides **infrared & photographic images** with **geospatial chemical** and **radiological** information
- **Six Primary Sensors/Systems:**
  - Infrared Line Scanner
  - High Speed Infrared Spectrometer
  - Digital Aerial Cameras
  - Gamma-ray Spectrometers
  - Neutron Detectors
  - Satellite Transmission

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Discussion and/or presentation of products is for informational purposes only and not an endorsement.

ASPECT Platform

Aero Commander 680 FL/G Platform

Crew: Two Pilots, One/Two Operator

Speeds:

Data Collection at ≈185 km/hr (100 kts)
Cruise at 333 to 370 km/h (180 to 200 kts)

Range/Aloft Time:

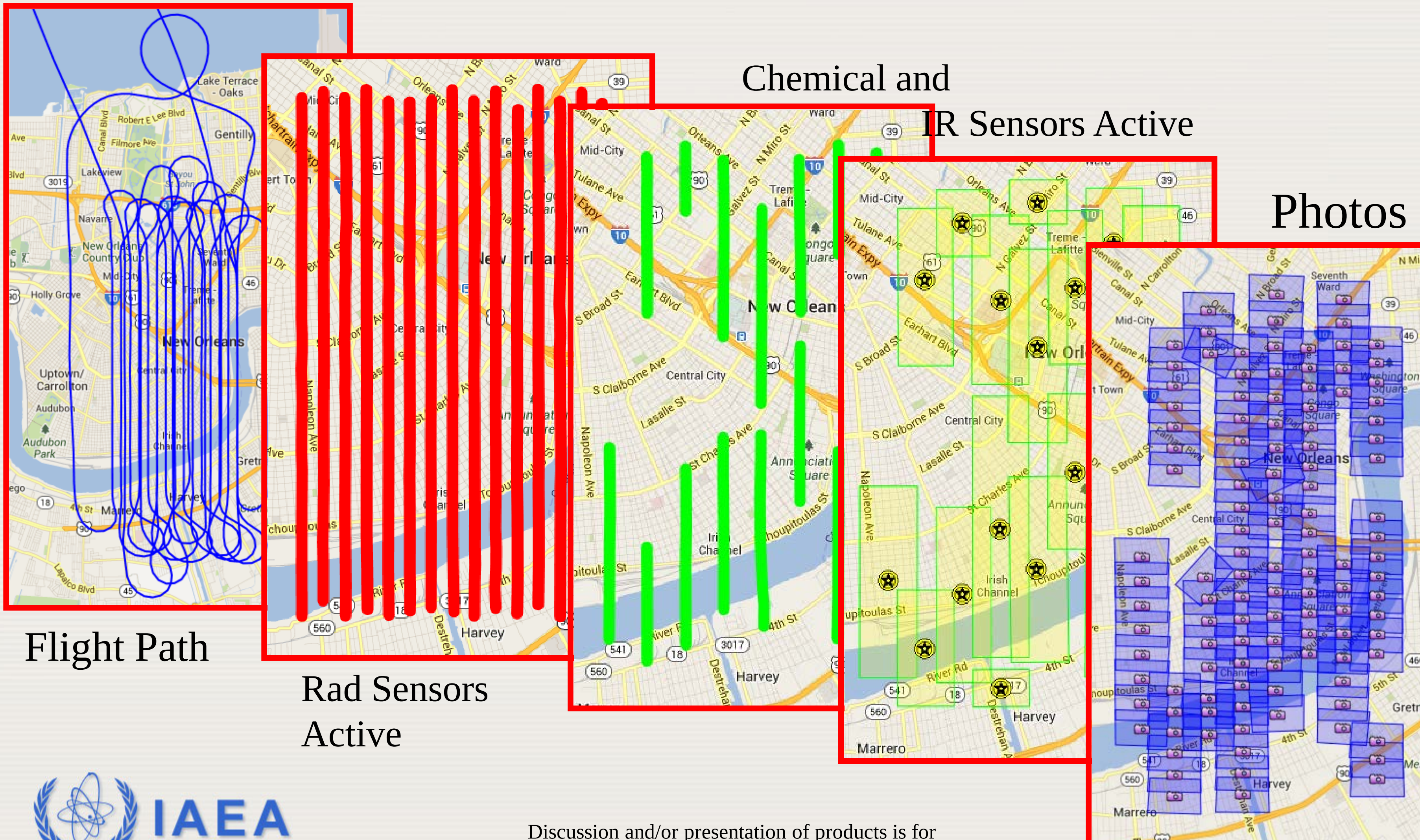
Up to 2000 km (1,100 NM)
Aloft Time 4 to 6 hours

Survey Altitude:

Data Collection at 90 to 900 meters (300 to 3,000 ft) AGL

Ground Needs – Standard FBO

ASPECT
Google Map Products



Flight Path

Rad Sensors Active

Chemical and IR Sensors Active

Photos

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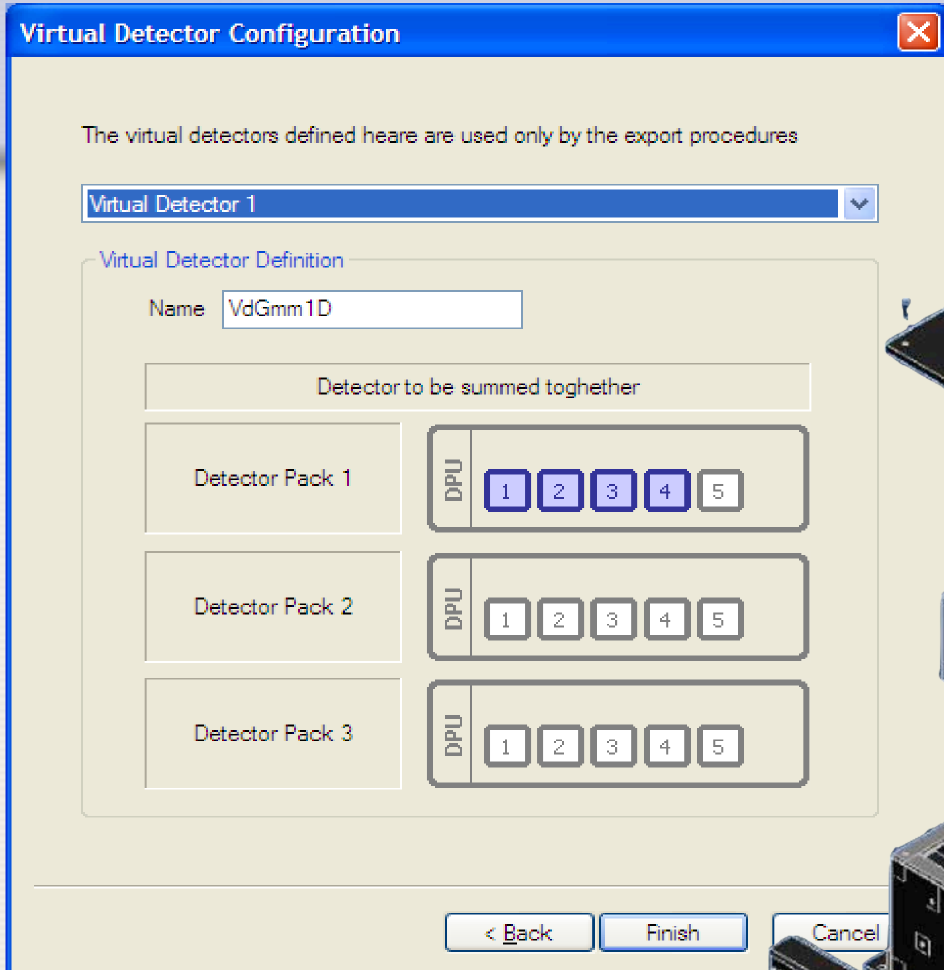
Discussion and/or presentation of products is for informational purposes only and not an endorsement.

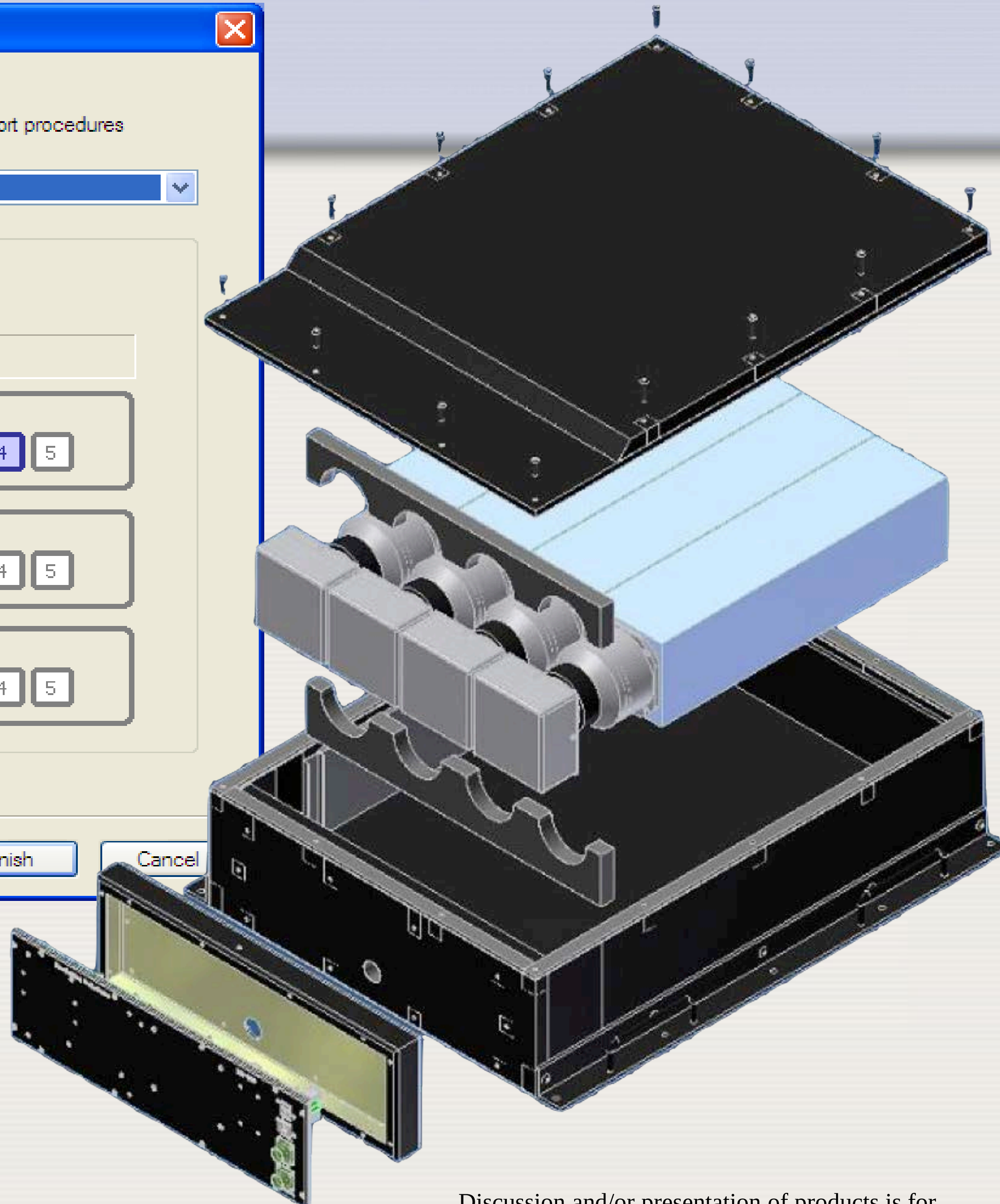
ASPECT GEM

Gamma Environmental Mapper

- ASPECT GEM project initiated in 2008
- Provides improved airborne gamma-screening/mapping for response to…
  - Radiological Dispersal Devices
  - Improvised Nuclear Devices
  - Rad-contaminated sites
- Detection MCA hardware based on…
  - Multiple 5 x 10 x 40 cm (2” x 4” x 16” / 2L) NaI detectors; space for four detectors in an RSX-4 unit
  - Multiple LaBr3 detectors optional
  - Airborne applications
- Single-Detector RSX-1 units also used
  - 10 x 10 x 40 cm (4”x4”x16” / 4L) NaI detector
  - Ground applications

Discussion and/or presentation of products is for informational purposes only and not an endorsement.





"Virtual" detectors can be defined by summing multiple detectors

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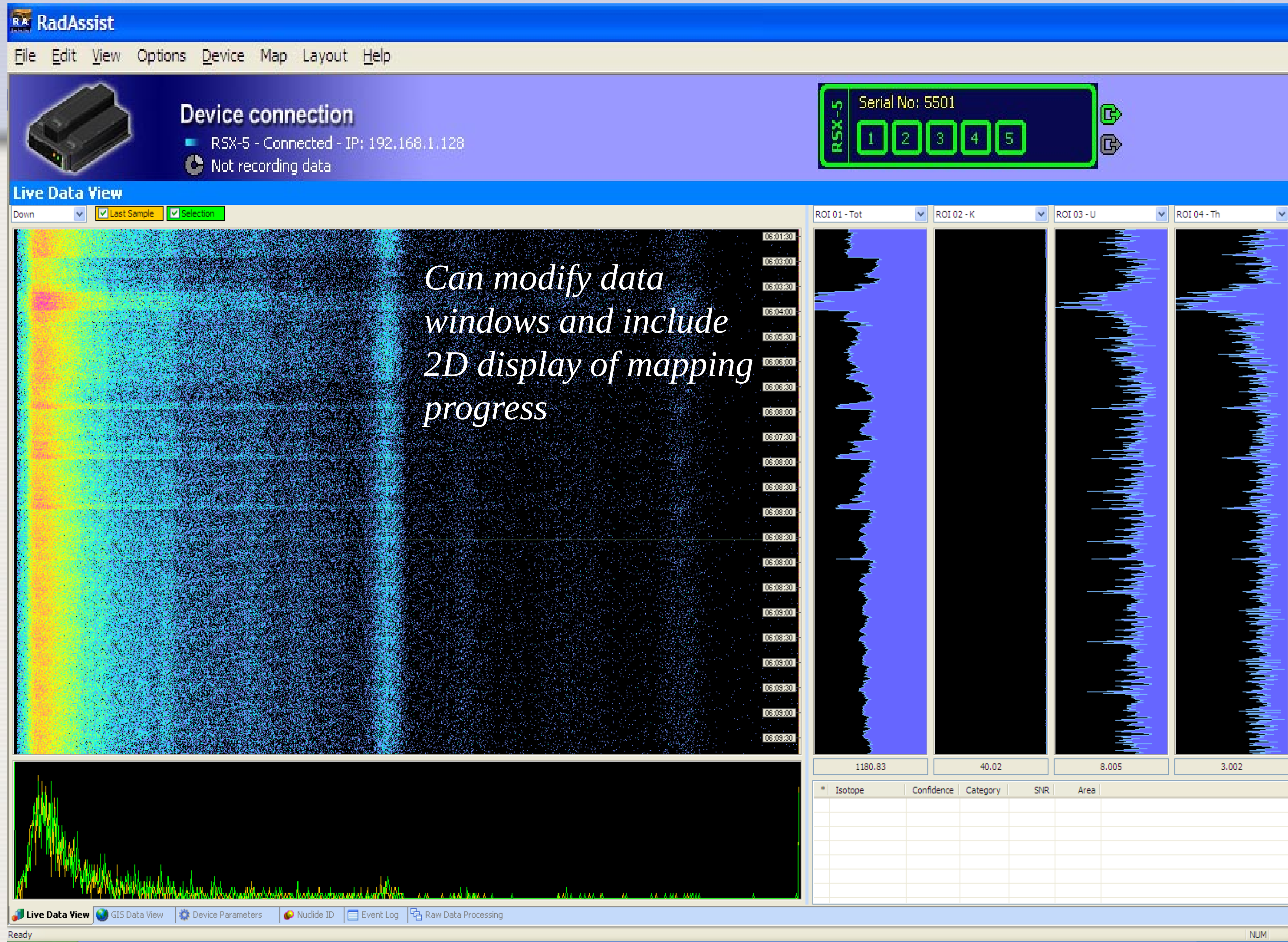
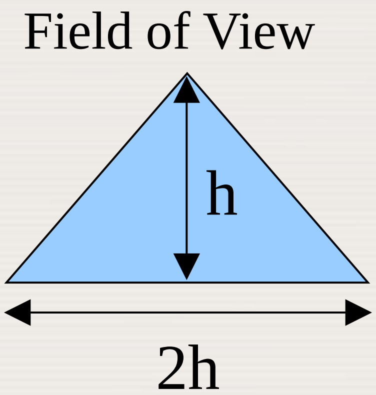
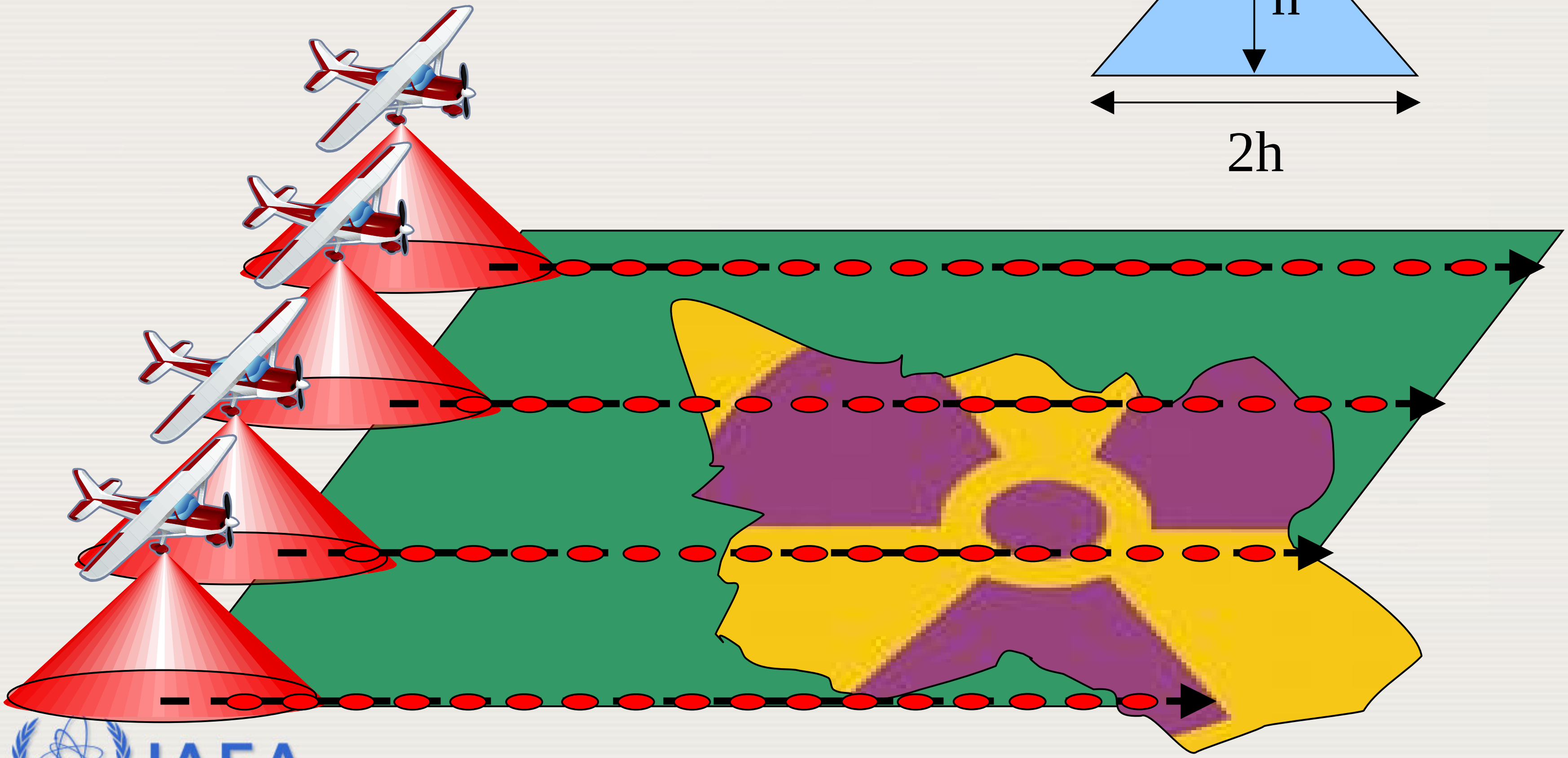


Can modify data windows and include 2D display of mapping progress

ASPECT GEM

Typical Aerial Survey





Discussion and/or presentation of products is for informational purposes only and not an endorsement.

RADIATION MONITORING USING AN UNMANNED HELICOPTER IN THE EVACUATION ZONE SET UP BY THE FUKUSHIMA DAIICHI NPP ACCIDENT AND RELATED TOPICS

TATSUO TORII

FUKUSHIMA ENVIRONMENTAL SAFETY CENTER,

JAPAN ATOMIC ENERGY AGENCY (JAEA)

Fukushima Environmental Safety center, JAEA

Remote radiation sensing Group

Concept：Research and development about the technology which measures and visualizes radiation distantly

Approach from the sky (widely and quickly!)

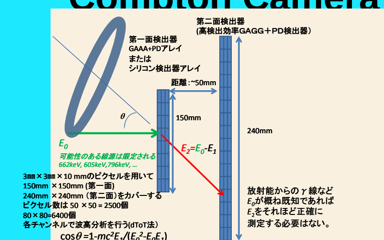
Aerial radiation monitoring

Autonomous Unmanned Helicopter and Airplane

AUH system

Collaboration of JAEA and JAXA

Compton Camera

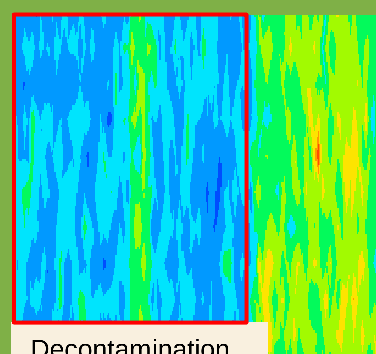


Compton Camera+AUH

JST competitive research funding Furukawa, Univ. Tokyo and Tohoku Univ. (Cooperation of Prof. Vetter,UCB)

Approach from the ground
（Effective of Decontamination）

・Plastic Scintillation Fiber (PSF)



Decontamination

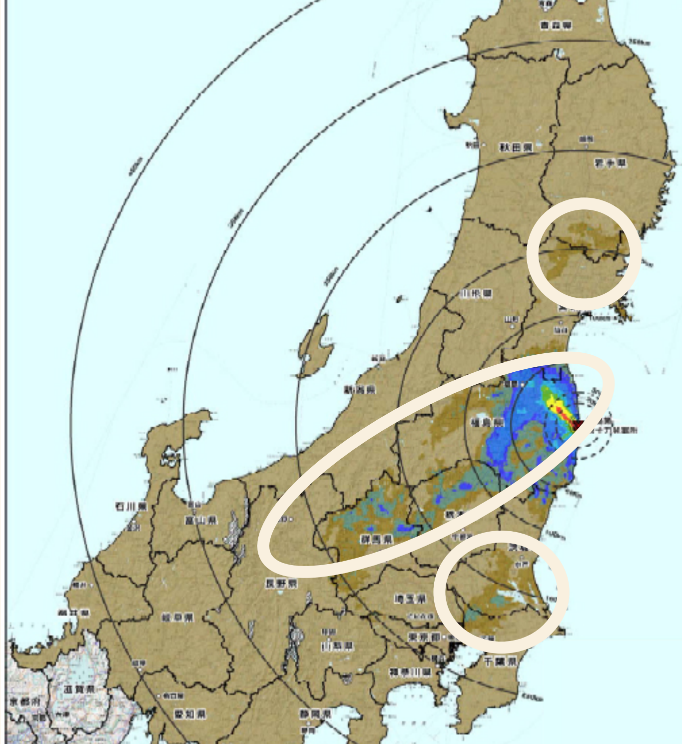
JST competitive research funding .JREC Co. Ltd. and JAEA

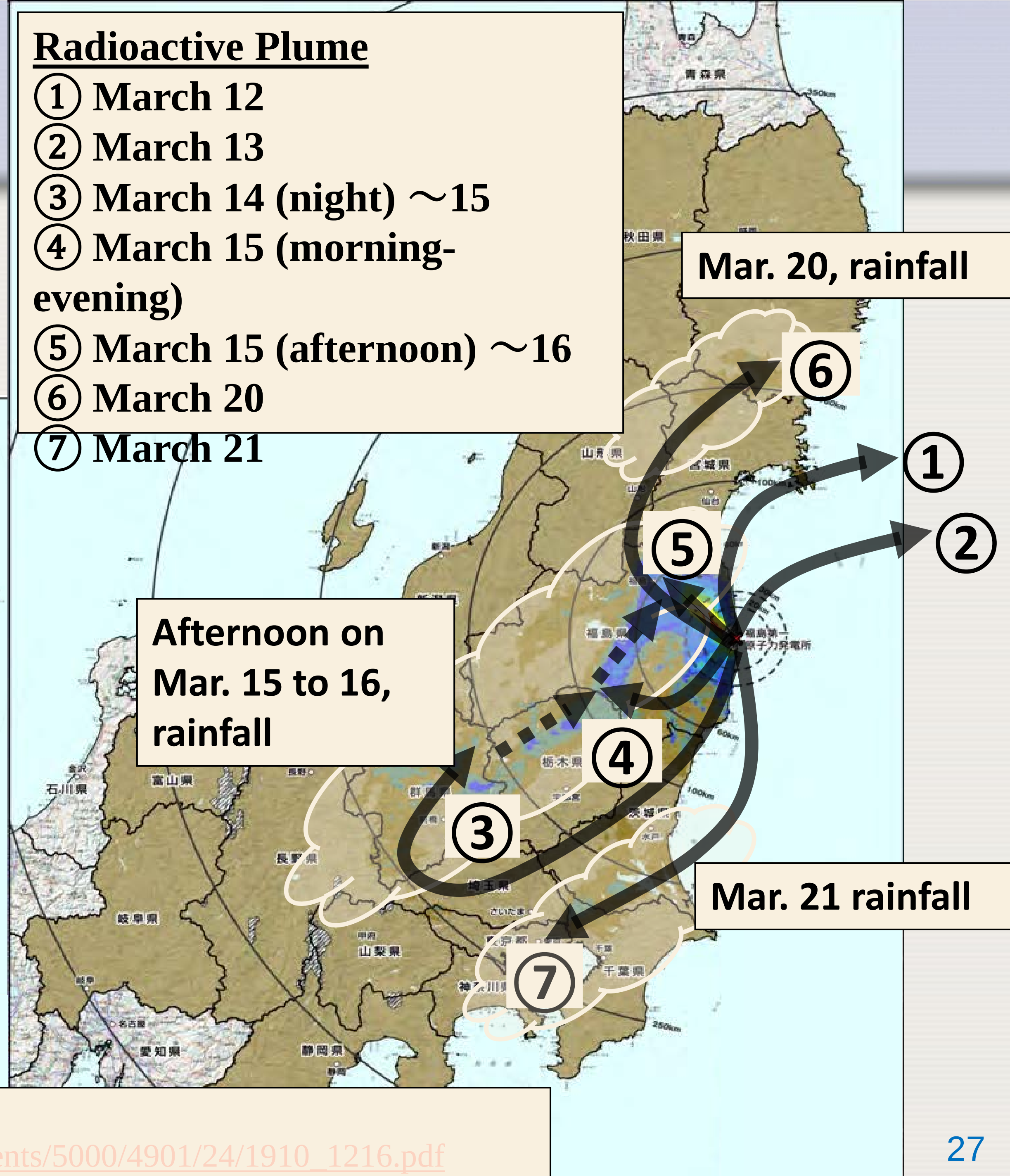
Other Works

・Radioactivity measurement of waterbed

The contamination formation process in the surface of the earth presumed from a diffusion calculation

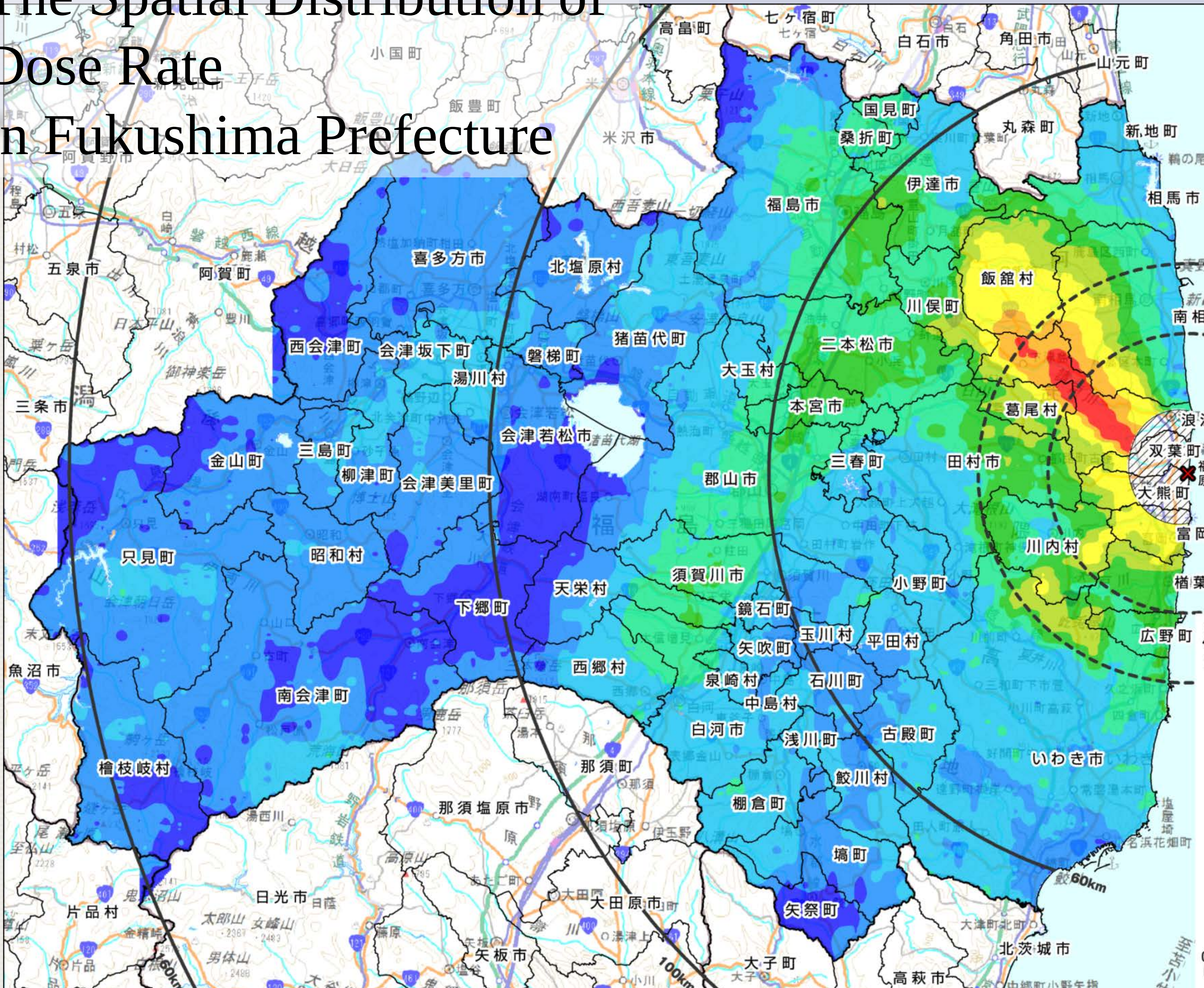
The AMS data





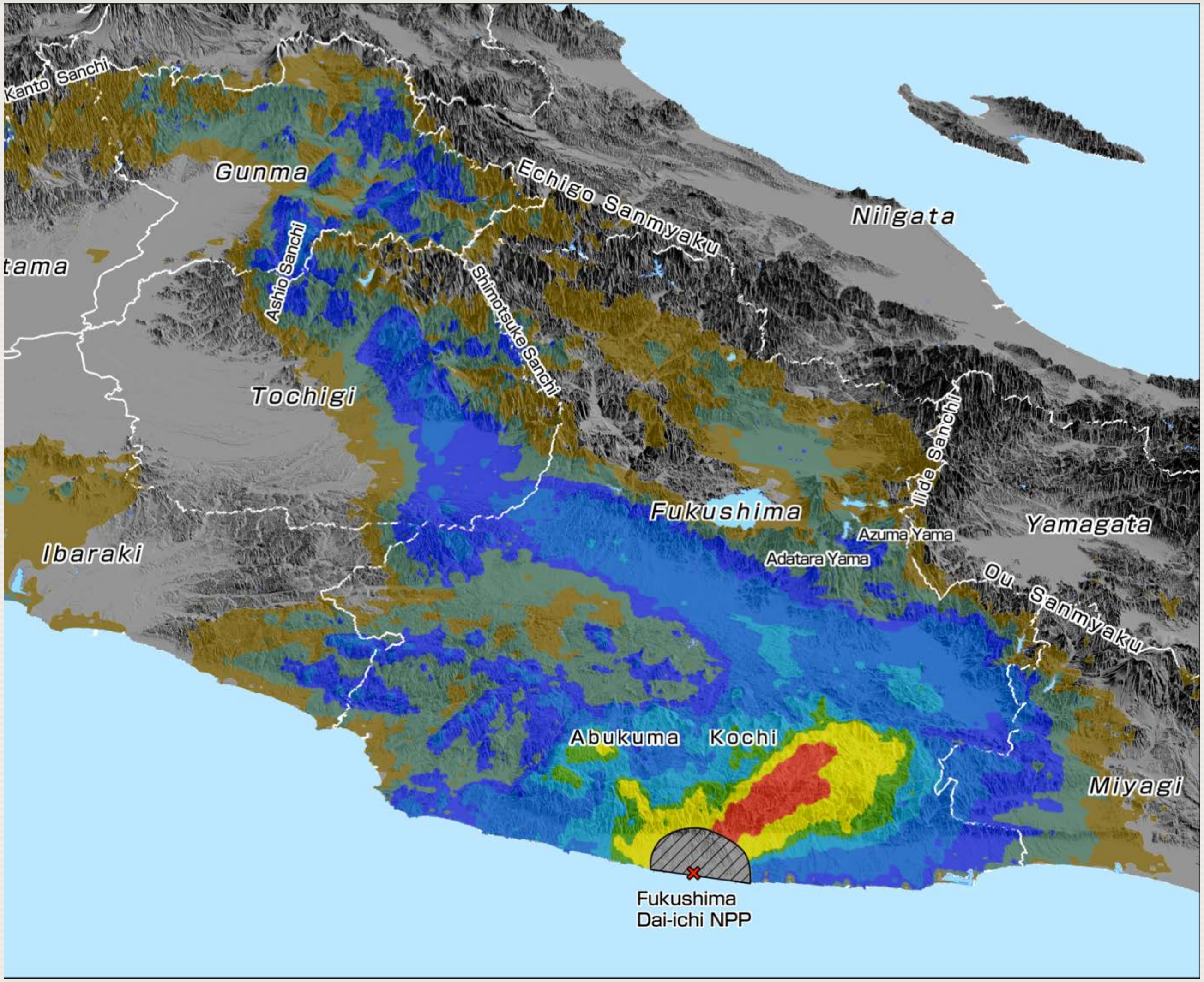
Ref. : http://radioactivity.mext.go.jp/ja/contents/5000/4901/24/1910_1216.pdf

The Spatial Distribution of Dose Rate in Fukushima Prefecture



Fukushima Daiichi NPP

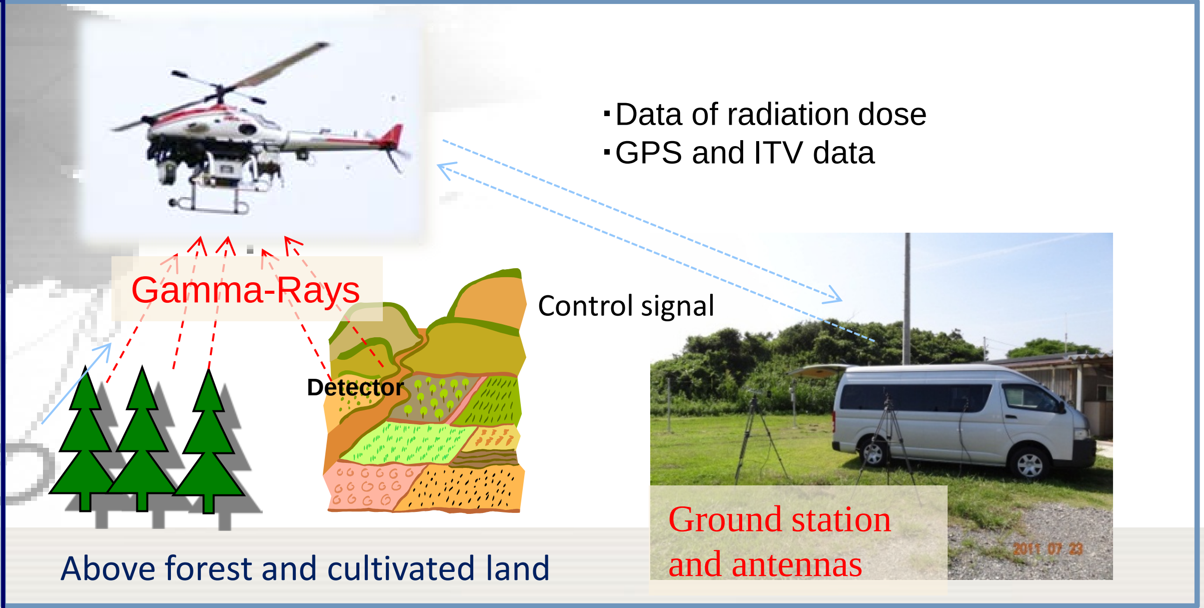
3D map of radiocesium distribution



DEVELOPMENT OF AUTONOMOUS UNMANNED HELICOPTER (AUH) RADIATION SURVEY SYSTEM

《Feature》

1. Measurement at the places (high dose rate areas, forests, rice fields, etc.) which people cannot come into easily.
2. A ground base can be installed in a safe place (< several kilometers)
3. The image of a measurement place can also be grasped in real time.
4. Position information (GPS, video cam)
5. Programming flight (autonomous flight).
6. Observation at a low altitude (<300m) (outside of the Japanese law)
7. Hovering * People must not be below an unmanned helicopter.



<u>For monitoring around the Fukushima Daiichi Nuclear Power Plant</u>

- Mapping of dose-rate distribution
- Reduction of the operator' exposure
- Small man-power

<u>For decontamination evaluation</u>

- It can measure repeatedly the same place by programing flight.

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The AUH System

Autonomous unmanned helicopter (AUH) : RMAX G1 (Yamaha Motor Co., Ltd.)

1. Body
- Full length : less than 4 m (including rotors)
- Weight : less than 100 kg

2. Flight performance
- The maximum speed : not less than (air speed) 70 km/h

  * Measurement speed: ~ 30 km/h
- Flying duration: 60 minutes or more
- The highest altitude : not less than 250 m (Japanese regulation)
- Hovering accuracy : 3 m or less
- Range of flight : not less than 3 km
- When a control signal does not arrive at the ground station, it returns automatically.

3. Program flight
- A flight schedule is drawn up on a computer display.
- A ground image can be checked using ITV mounted on the helicopter.
- ITV is controllable by the ground station. .

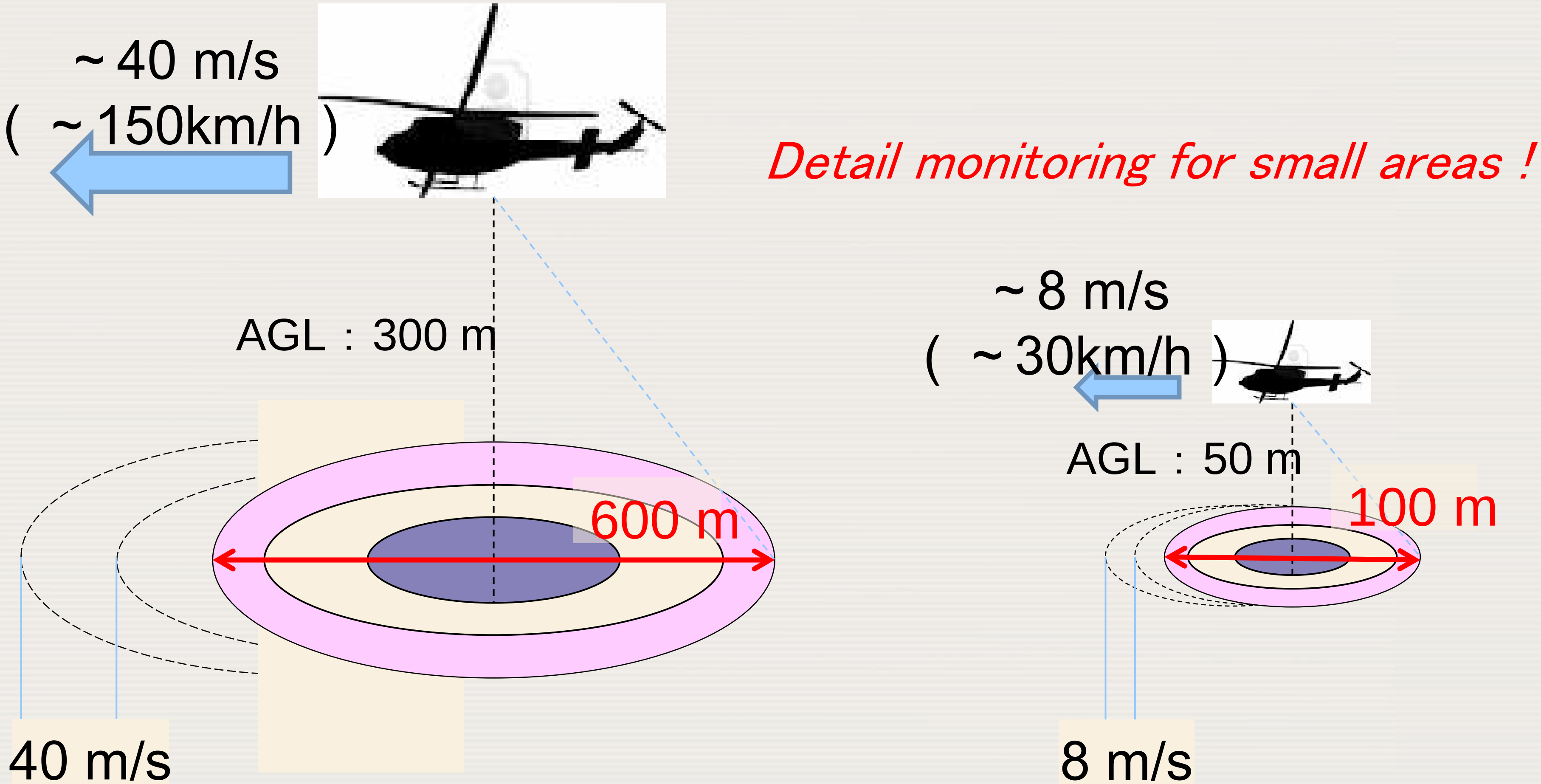
4. Pay-Load
- Loading weight : not less than 10 kg (at sea level)

Objection：Establishment of the monitoring procedures and application around the Fukushima Daiichi NPP

In the RANET Fukushima Center

Torii-san

Measurable Area by the AMS and the AUH



Aerial Monitoring

Monitoring by the AUH

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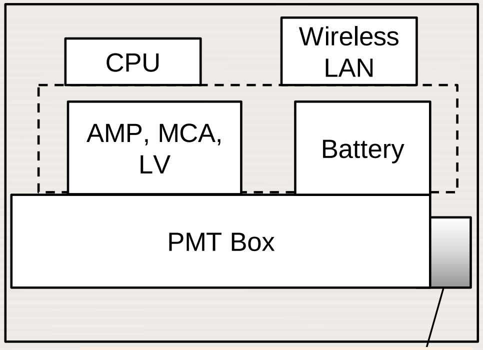
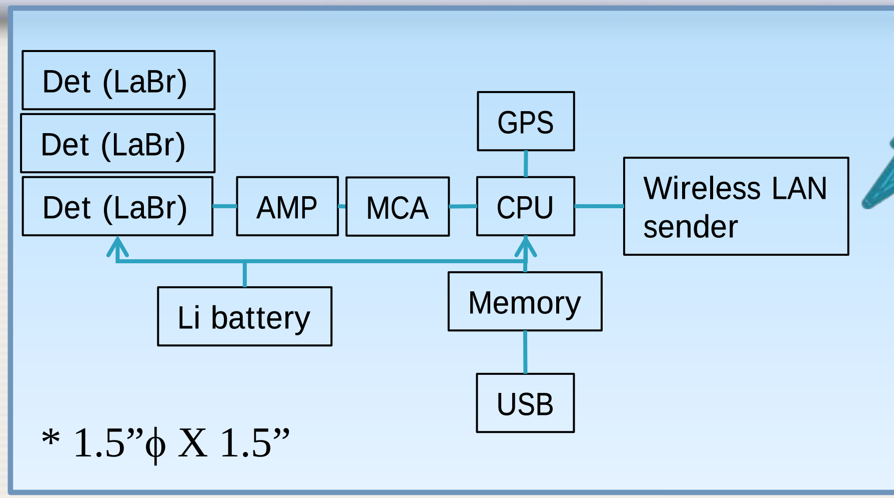
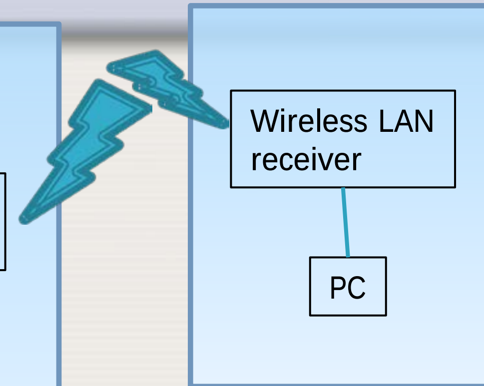
Detector for the AUH

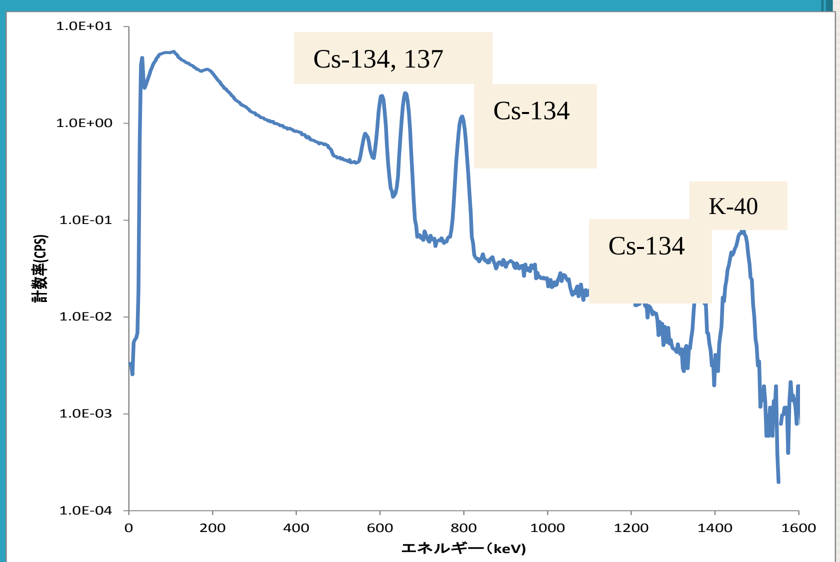
Detector Unit



1.5” LaBr3(Ce)x3



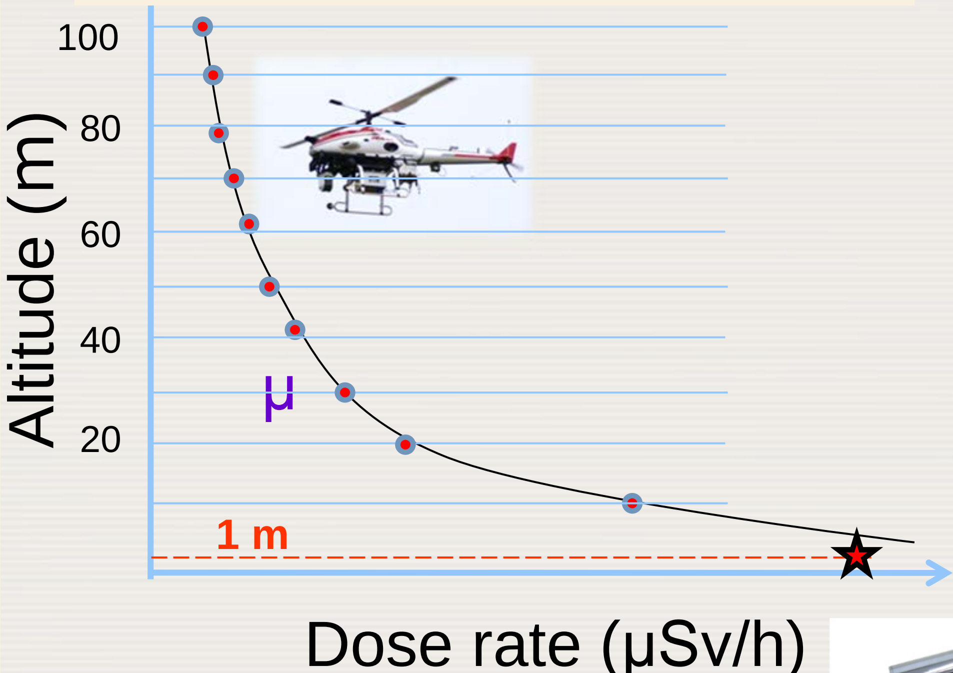




- **Store the position data and gamma spactrum**
- **Down link of the position and the count data**

Data Analysis

Dose rate conversion factor (CD) and effectual attenuation factor (μ) (at the test-site)



Ground measurement
(Dose rate of 1 m above the ground)

The air dose-rate conversion factor (CD=B/A) is calculated from the measured value of 1 m above the ground by the NaI survey-meter (A) and the counting rate at 50 m AGL (B).

↓

Relationship of a counting rate and flight altitude by changing the fight level of AUH (ex. Altitude on the ground: 10-100 m, each 10 m)

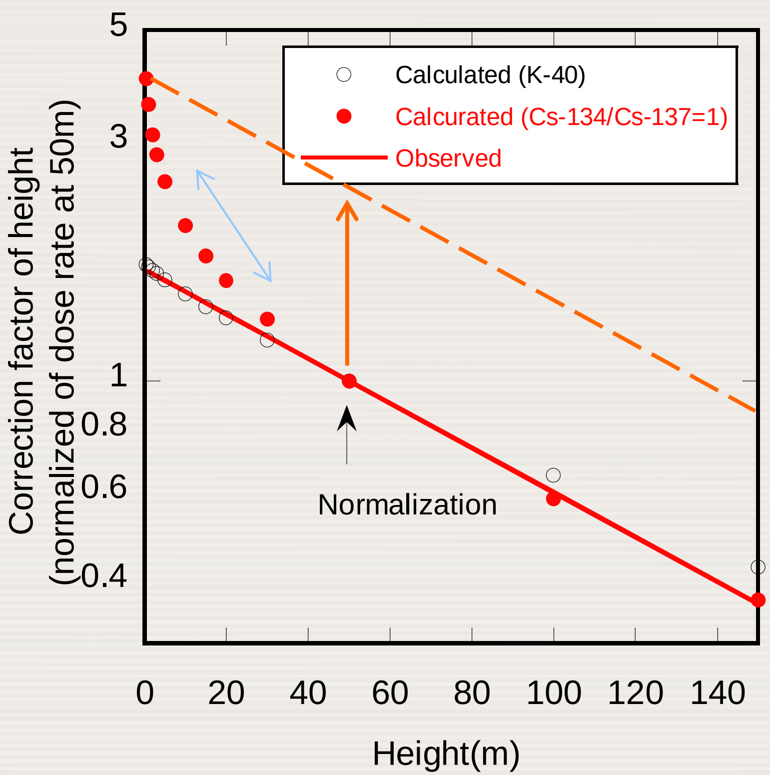
↓

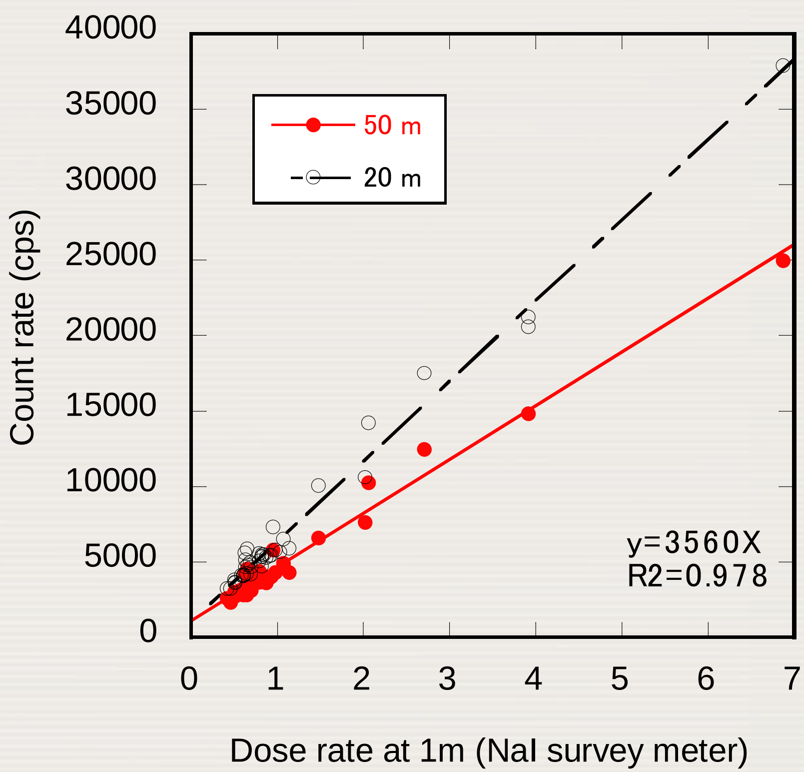
Effective attenuation coefficient **(μ)**

↓

Conversion into the dose rate of 1 m above the ground

Dose conversion factor and the attenuation coefficient





- Since it changes exponentially at a high altitude (> 20m), we can obtain the dose rate easily.
- Since the radiation which comes flying from various angles enters into the detector, a counting rate varies rapidly in a low altitude.

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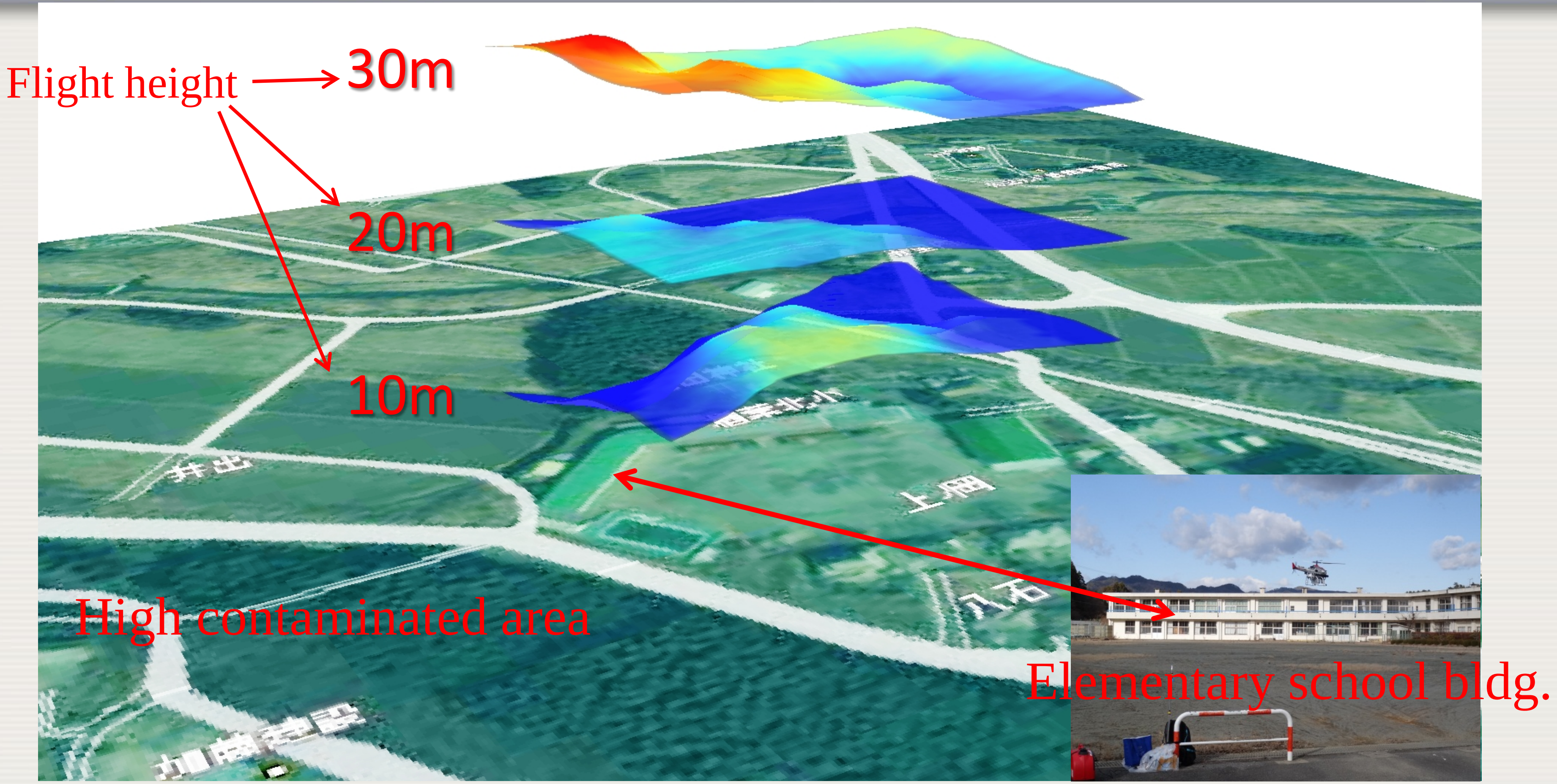
Air dose-rate depends strongly on the AGL in low altitude (< 20m).

Altitude dependency of dose-rate evaluation at 1m height above the ground.



Evaluation of air dose-rate at the altitude of 1m varies with fight elevation.

- Shielding by a building
- Radiation from directions of slant (forests) and/or skyshine

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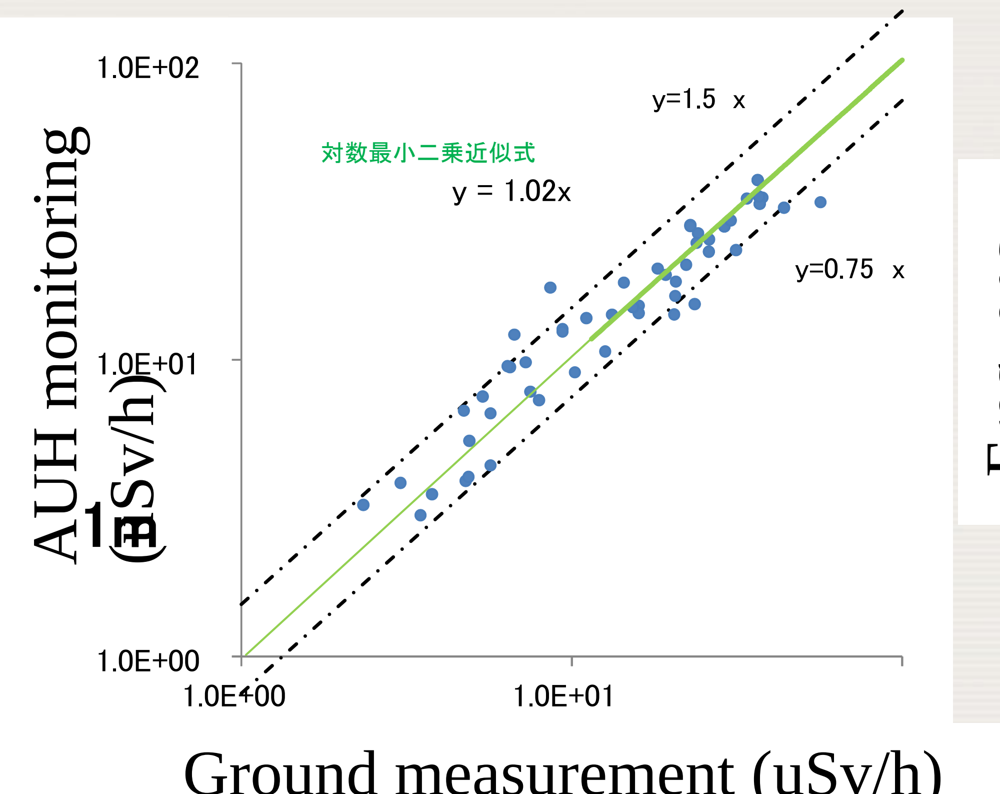
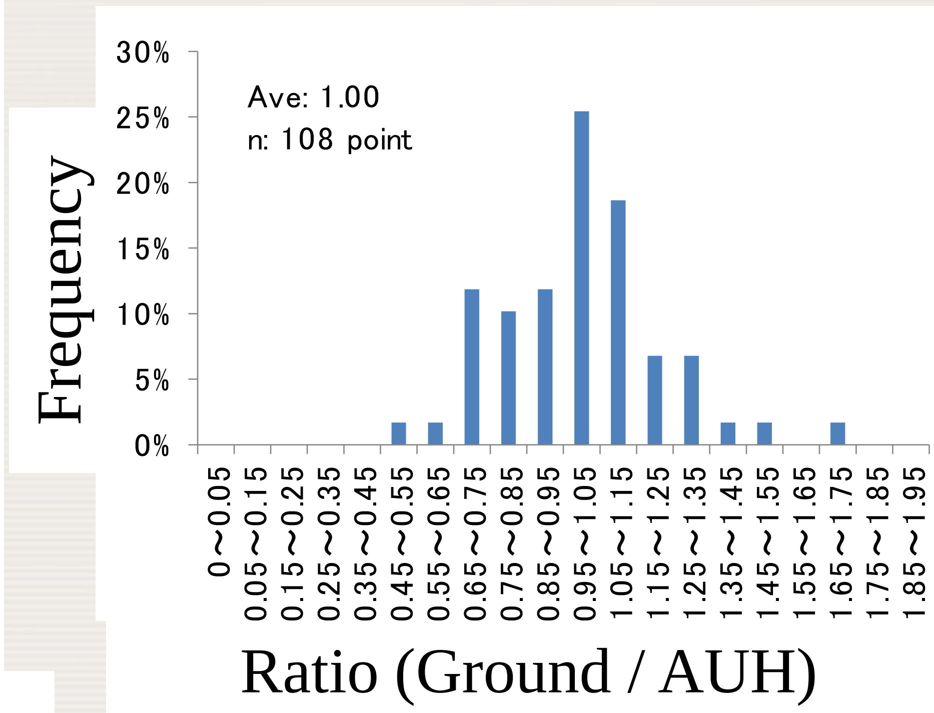
Comparison with the Ground Measurements

- These results agreed well within the range of 0.75 – 1.5





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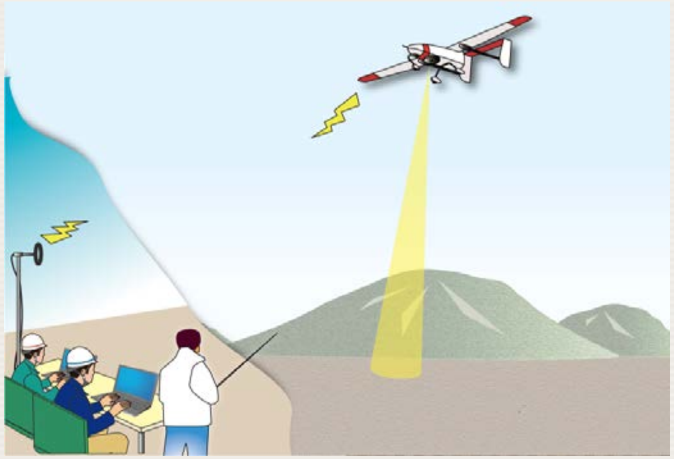
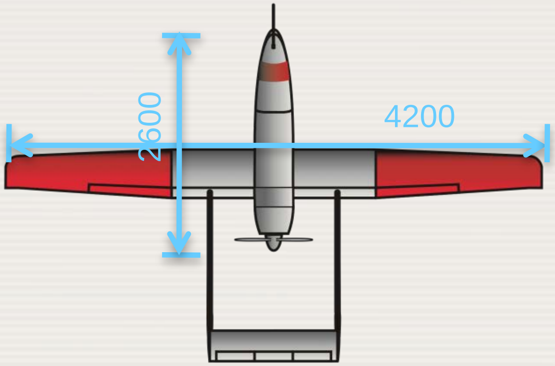
UARMS:
Unmanned Airplane for Radiation Monitoring System

- Collaboration with JAXA (Japan Aerospace Exploration Agency)
- Autonomous UAV
- Two detectors (NaI, Plastic Scintillator)
- Flight duration: 8 hrs
- Flight range: > 100 km





Mar. 27, 2013, Shikabe Airport, Hokkaido

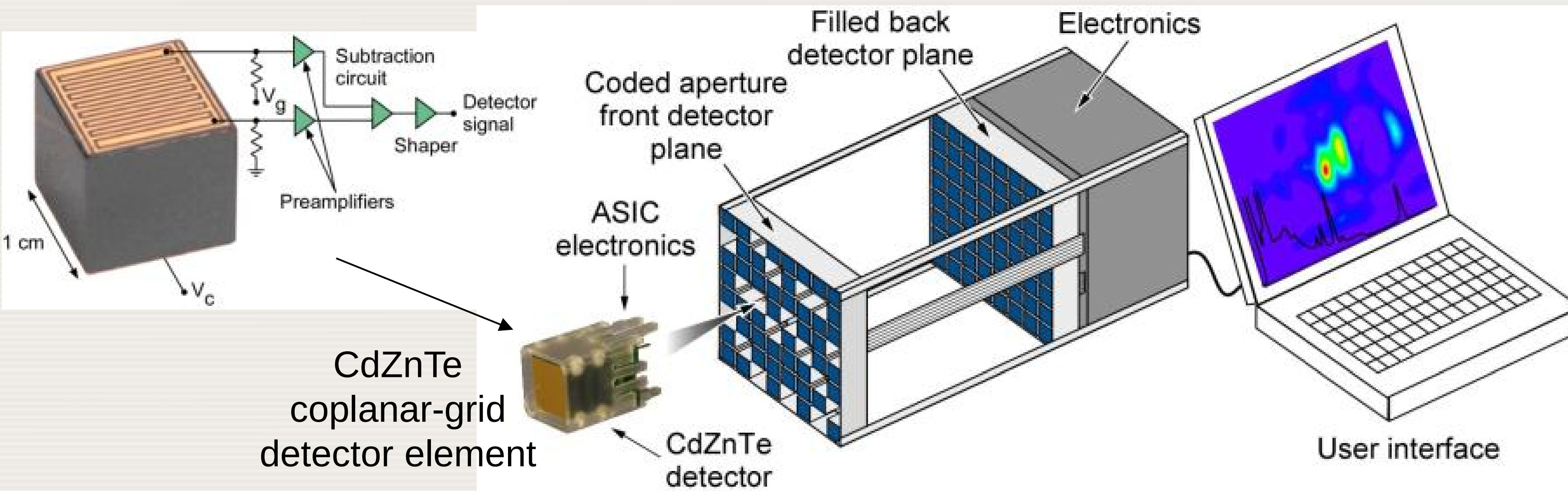
Implementation of the High Efficiency Multimode Imager (HEMI) for Conducting Gamma-Ray Surveys in Fukushima, Japan

- Kai Vetter[1,2], Benjamin Sturm[1], Daniel Chivers[1], John Kua[1], Michelle Galloway[1,2], Mark Amman[1], Paul Luke[1], Hiroyuki Takahashi[3], Yoshiaki Shikaze[4], Tatsuo Torii[4]
- [1]Lawrence Berkeley National Laboratory
- [2]University of California, Berkley
- [3]University of Tokyo
- [4]Japan Atomic Energy Agency

The High-Efficiency Multi-Mode Imager, HEMI

Modular, Coplanar Grid (CPG) CdZnTe (CZT) based detector array:

- 32+64 CPG CZT detectors arranged in two layers.
- Front layer as active coded aperture mask or as Compton scatter detector.
- Simple, room-temperature, and scalable detection and imaging system.



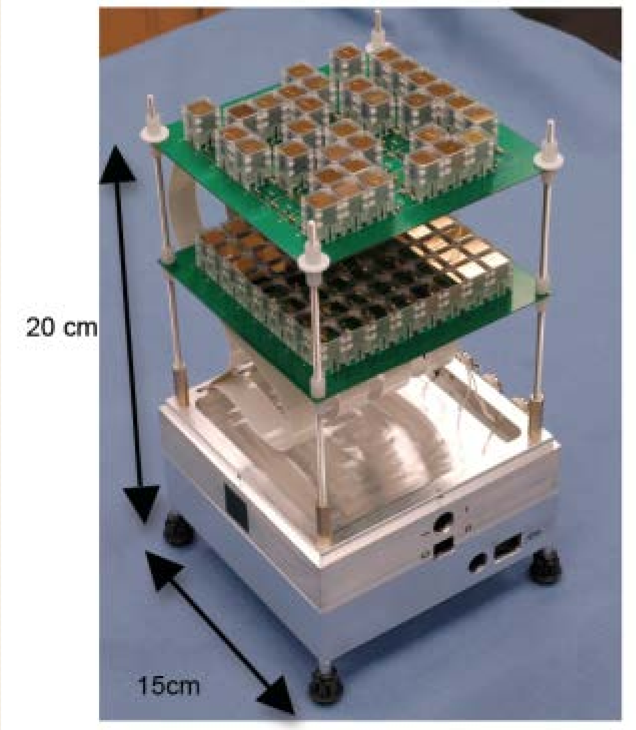
Detect, identify, and locate nuclear materials over broad range of energies (<100 keV - ~ 3 MeV) with reasonably good energy resolution of ~2.5% at 662 keV.

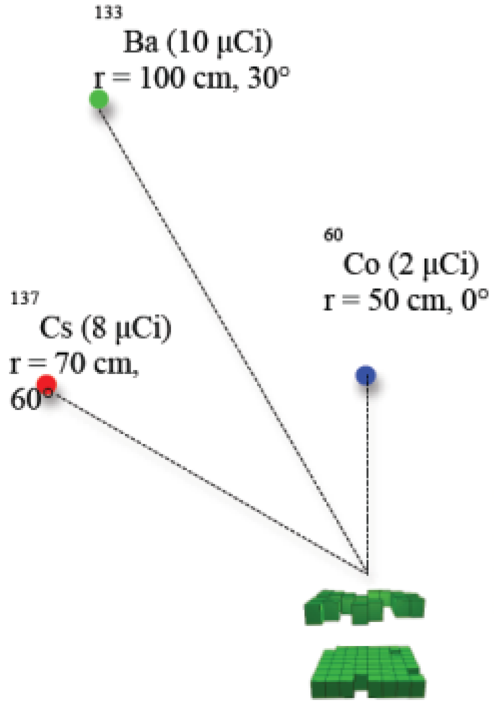
HEMI development and construction funded by Department of Homeland Security, Domestic Nuclear Detection Office

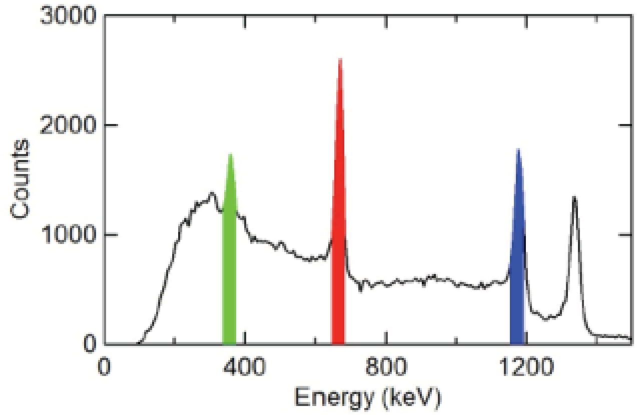
Homeland Security

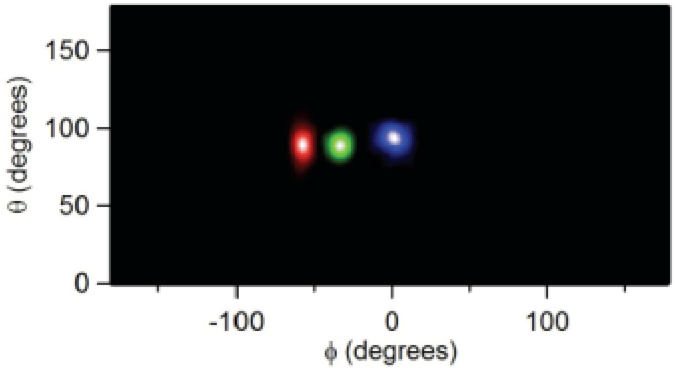
HEMI Prototype

Multi-mode, spectroscopic gamma-ray imaging







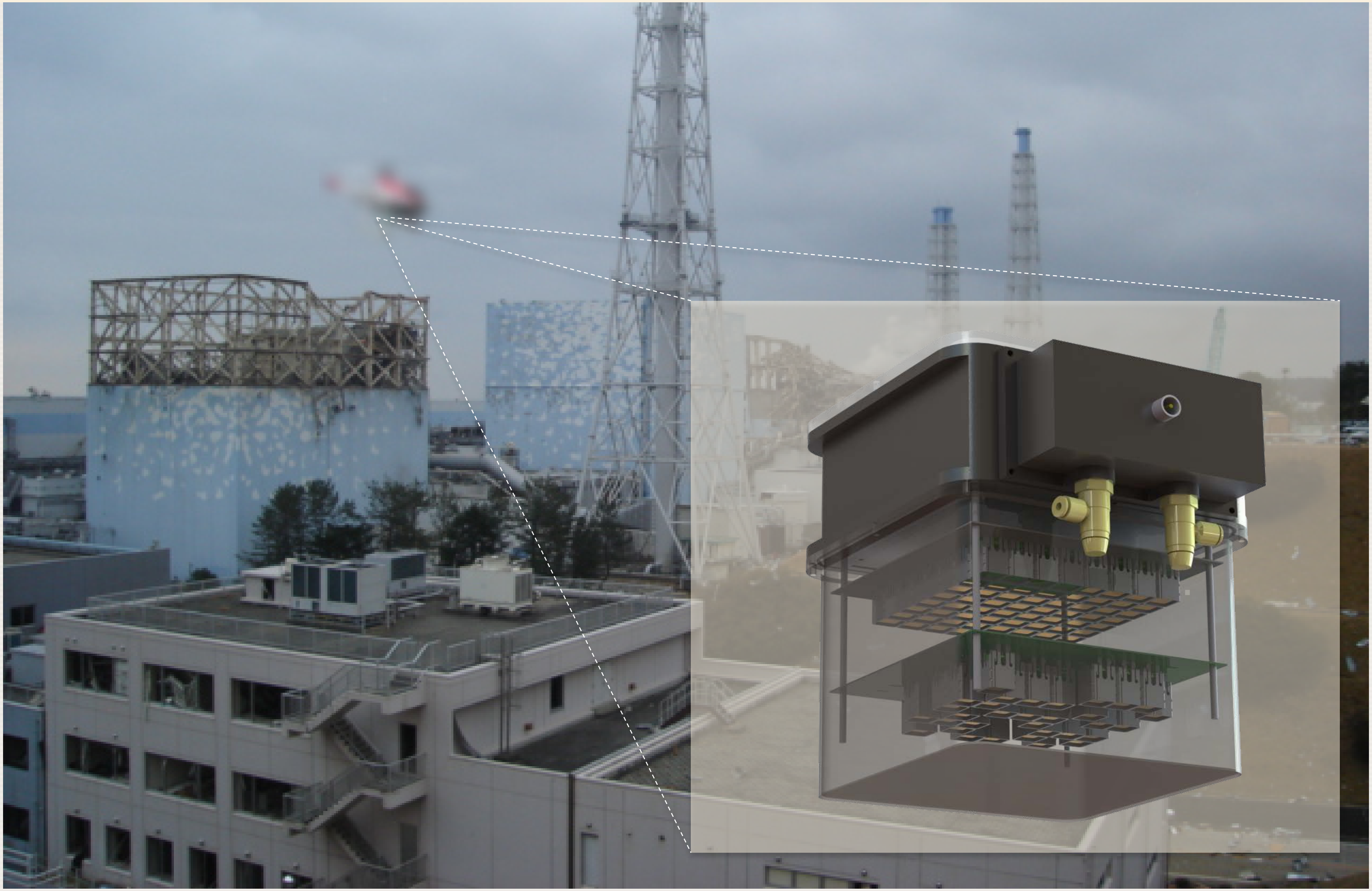


- Compact (15x15x20 cm^3), low power (<10W for instrument itself), modular, and easily scalable Gamma-Ray Imager w/ excellent detector-to-instrument weight ratio (~ 1 lbs detectors vs. ~ 3 lbs of instrument itself).
- Applications: Detection, localization, & monitoring, e.g. Fukushima mapping on small, autonomous helicopters.

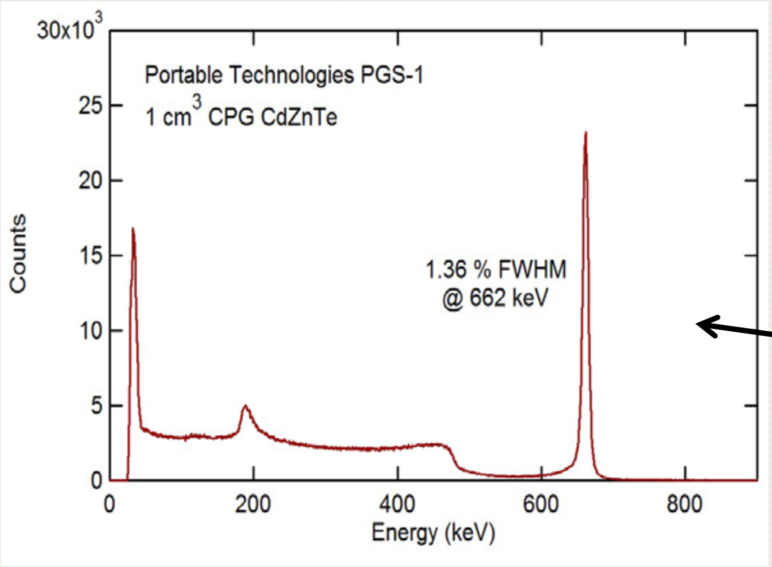
HEMI development and construction funded by Department of Homeland Security, Domestic Nuclear Detection Office

Homeland Security

HEMI will be integrated this summer on board the currently used Yamaha RMAX helicopter in the Fukushima Prefecture



Anticipate next generation HEMI array to have even better performance characteristics



- **Consisting of 2x2 array of HEMI units for aerial surveys – larger sensitivity, larger Field-of-View**
- **Improved coplanar-grid CZT detector energy resolution** of ~**1.5% at 662 keV**
  - **We have demonstrated < 1.4% resolution at 662 keV for a single detector**

NSIL current: Fukushima action plan

Production of a low-cost UAV-based mobile gamma spectrometry system

- Selection of UAV system
- Development and construction of detectors and readout
- Integration of UAV, detectors, geo-information system and software

Deliverables

- UAV with two detector packages (dose rate meter and spectrometer)
- Software, Documentation, Training

UAV's

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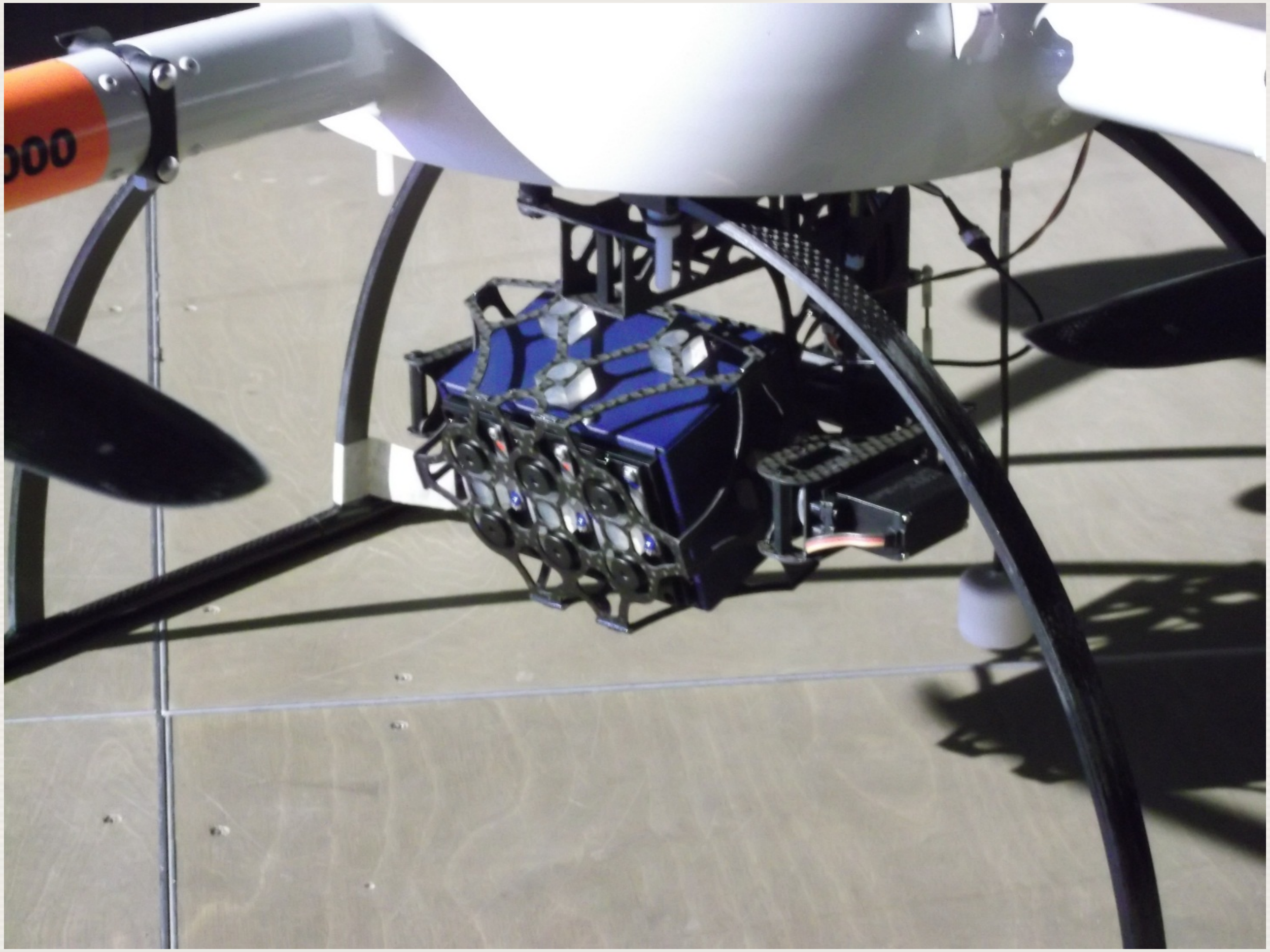
UAV's



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UAV’s

UAV’s


microdrones.com
UAWeek 2012
1st microdrones International
Research Workshop
Flight-Demo md4-1000 / Waypoint (GIS-Raster)
DELL

Draganfly

IAEA

Aibotix X6 Vienna May 2013

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NSAP: NA 9/2: Objectives & Tasks

- Development of Detectors & Readout
  - ❑ Parameterise Detection Limits
    - ➢ Consultancy meeting
    - ➢ RANET Requirements (App E: Measuring Instrumentation)
      - o e.g. Airborne Survey System, Detector, MDA, speed
  - ❑ Acquisition and testing of detectors
    - ➢ Initiated (Dec 2012)

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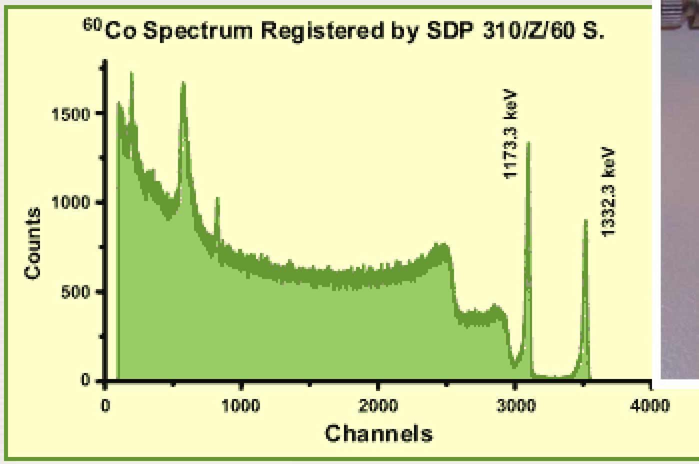
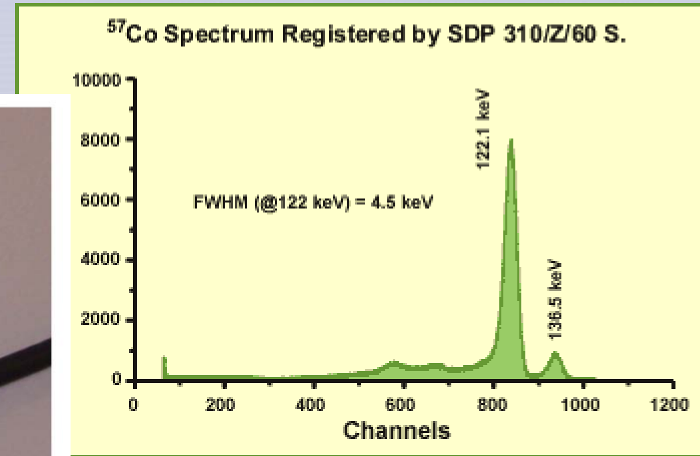
CZT Probe

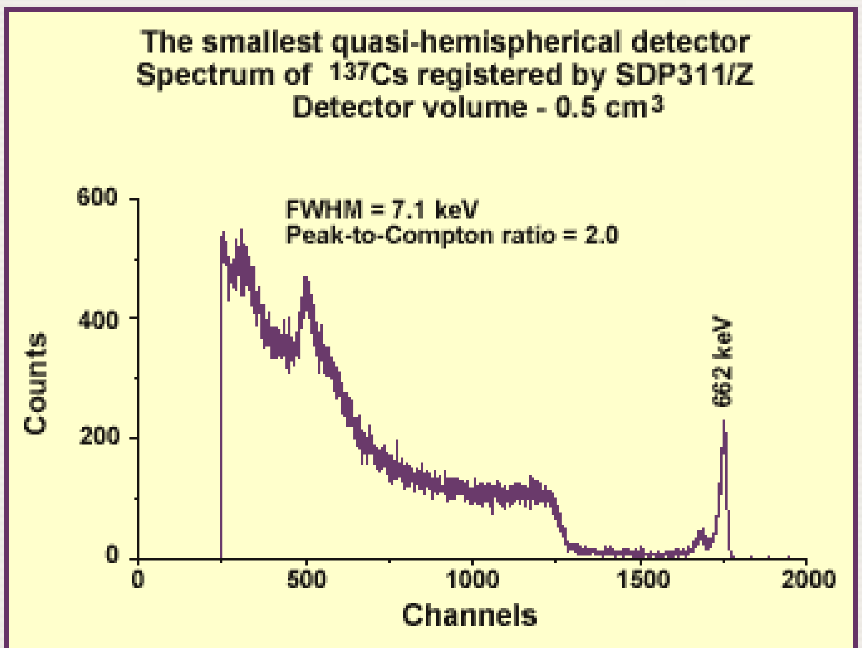


60Co Spectrum Registered by SDP 310/Z/60 S.
1500
1000
500
0
Counts
1173.3 keV
1332.3 keV
0
1000
2000
3000
4000
Channels

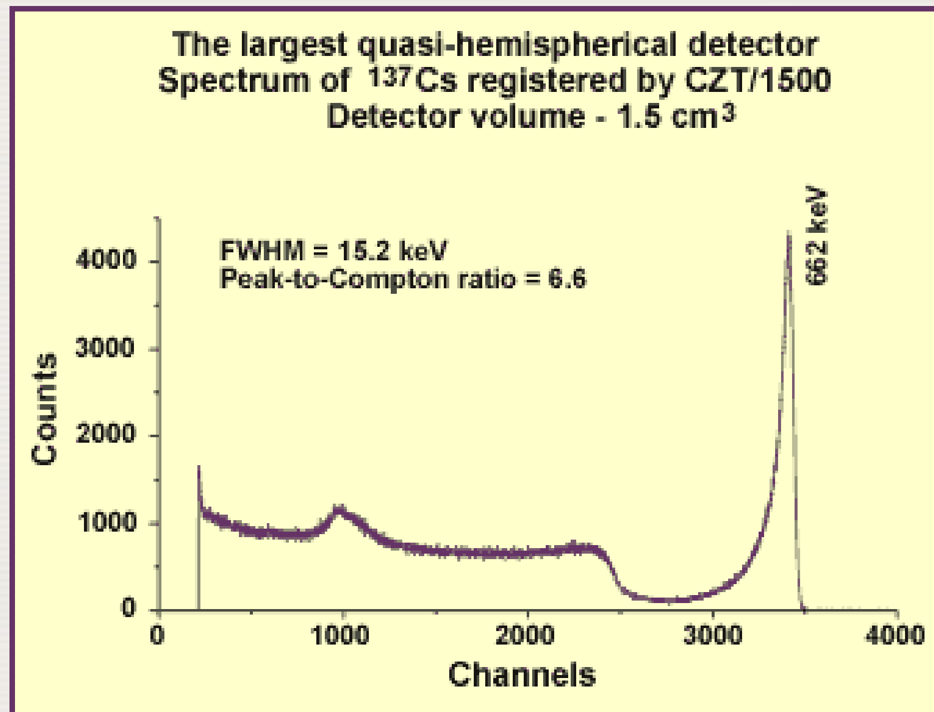
CZT/500S
No. 494



57Co Spectrum Registered by SDP 310/Z/60 S.
10000
8000
6000
4000
2000
0
FWHM (@122 keV) = 4.5 keV
122.1 keV
136.5 keV
0
200
400
600
800
1000
1200
Channels

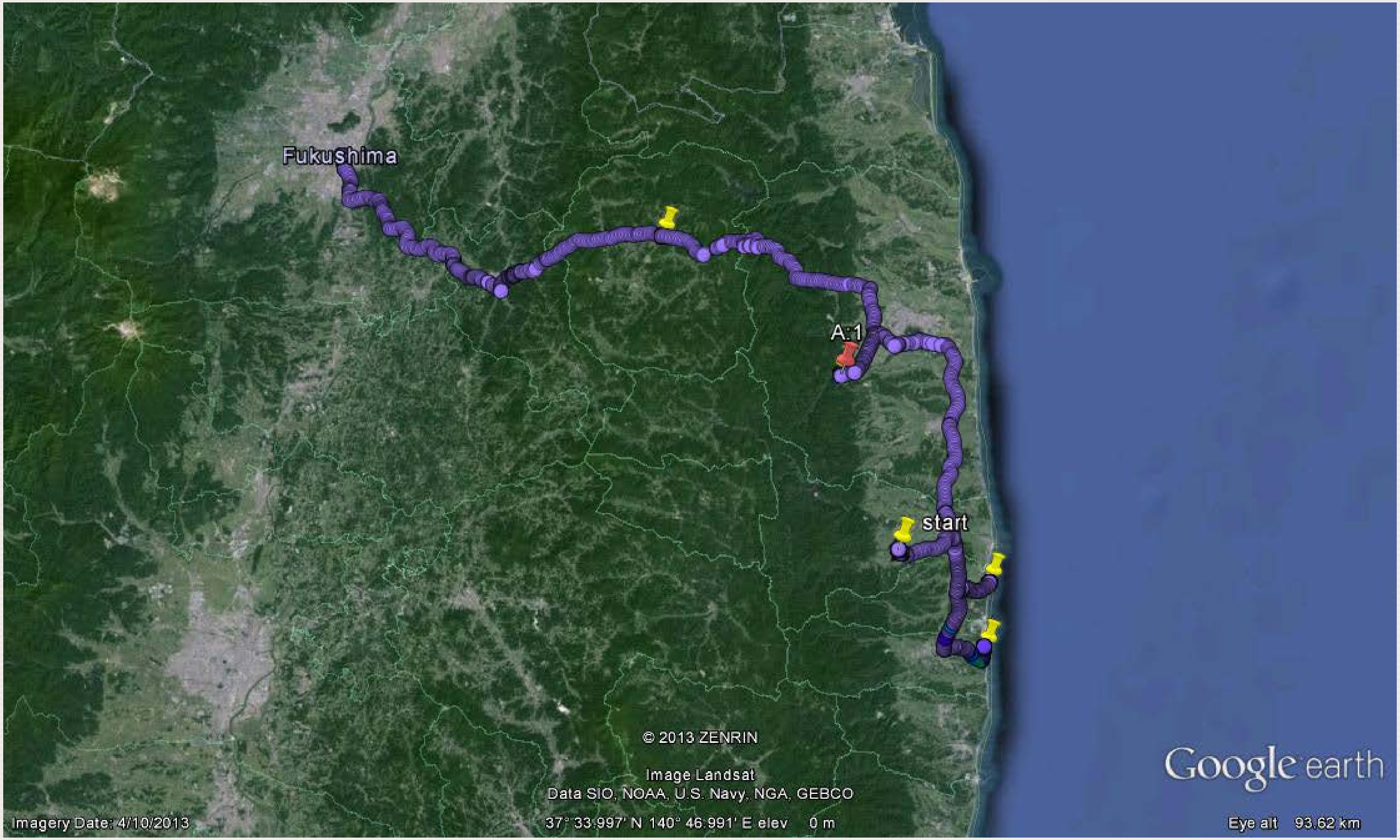


The smallest quasi-hemispherical detector
Spectrum of 137Cs registered by SDP311/Z
Detector volume - 0.5 cm3
FWHM = 7.1 keV
Peak-to-Compton ratio = 2.0
600
400
200
0
Counts
662 keV
0
500
1000
1500
2000
Channels



The largest quasi-hemispherical detector
Spectrum of 137Cs registered by CZT/1500
Detector volume - 1.5 cm3
FWHM = 15.2 keV
Peak-to-Compton ratio = 6.6
4000
3000
2000
1000
0
Counts
662 keV
0
1000
2000
3000
4000
Channels

Fukushima Area



3 Okuma Fish Farming

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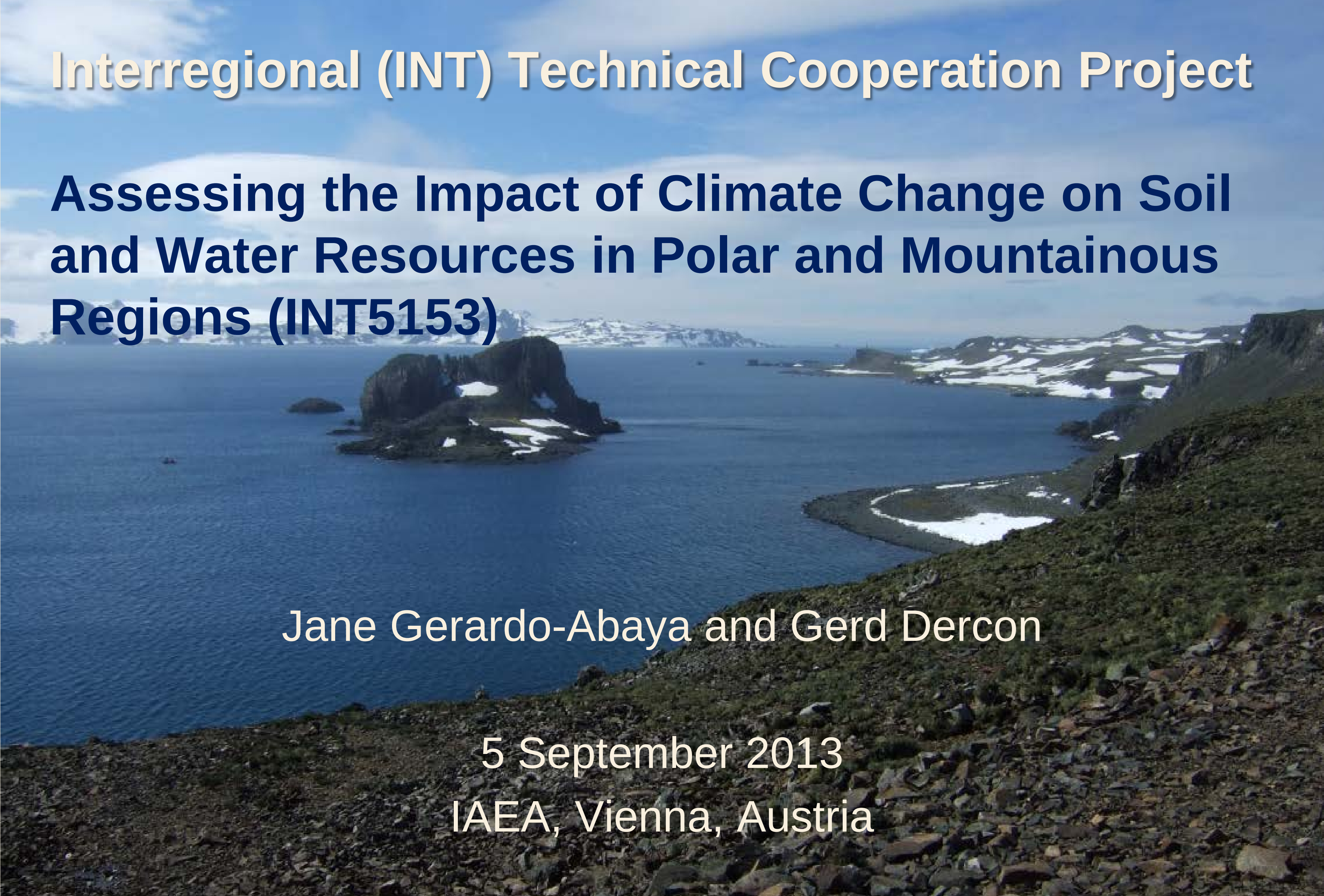
PART II – CLIMATE CHANGE PROJECTS

OCEAN ACIDIFICATION

INT5153 *ASSESSING THE IMPACT OF CLIMATE CHANGE ON SOIL AND WATER RESOURCES IN POLAR AND MOUNTAINOUS REGIONS*

Interregional (INT) Technical Cooperation Project

Assessing the Impact of Climate Change on Soil and Water Resources in Polar and Mountainous Regions (INT5153)



Jane Gerardo-Abaya and Gerd Dercon

5 September 2013

IAEA, Vienna, Austria

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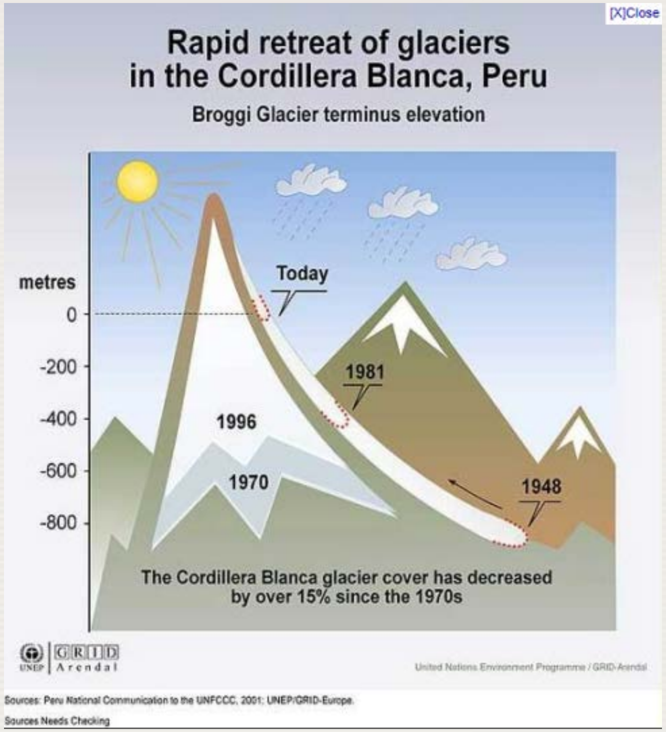
Objective of the INT project

To improve understanding of the impact of climate change on fragile polar and mountainous ecosystems at local and global scale for their better management and conservation

Impact of climate change in polar and mountainous regions

- Nowhere are the effects of climate change more pronounced than in the polar and mountainous regions.
- Impacts of climate change in these regions affect hundreds of millions of people.
- Increasing temperatures are accelerating the melt of seasonal snow cover, glaciers and permafrost, changing and threatening soil and water resources at local and global scale.



Impact of climate change on farming communities in mountainous regions

- In Peru, farming communities are facing the challenge of water shortages for raising crops as well as livestock.
- Farmers are forced to enter in more fragile environments at higher altitudes.

Source: World Bank

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Impact of climate change on soil and water quality

- Glacier retreating and rising soil temperatures are expected to enhance soil degradation (redistribution) and hence affecting carbon and nutrient fluxes.

- Change in permafrost is also linked to increased greenhouse gas emissions
  - CO_2, CH_4


E.A SCHUUR

32 | NATURE | VOL 480 | 1 DECEMBER 2011

Abrupt thaw, as seen here in Alaska's Noatak National Preserve, causes the land to collapse, accelerating permafrost degradation and carbon release.

High risk of permafrost thaw

Northern soils will release huge amounts of carbon in a warmer world, say **Edward A. G. Schuur, Benjamin Abbott** and the Permafrost Carbon Network.

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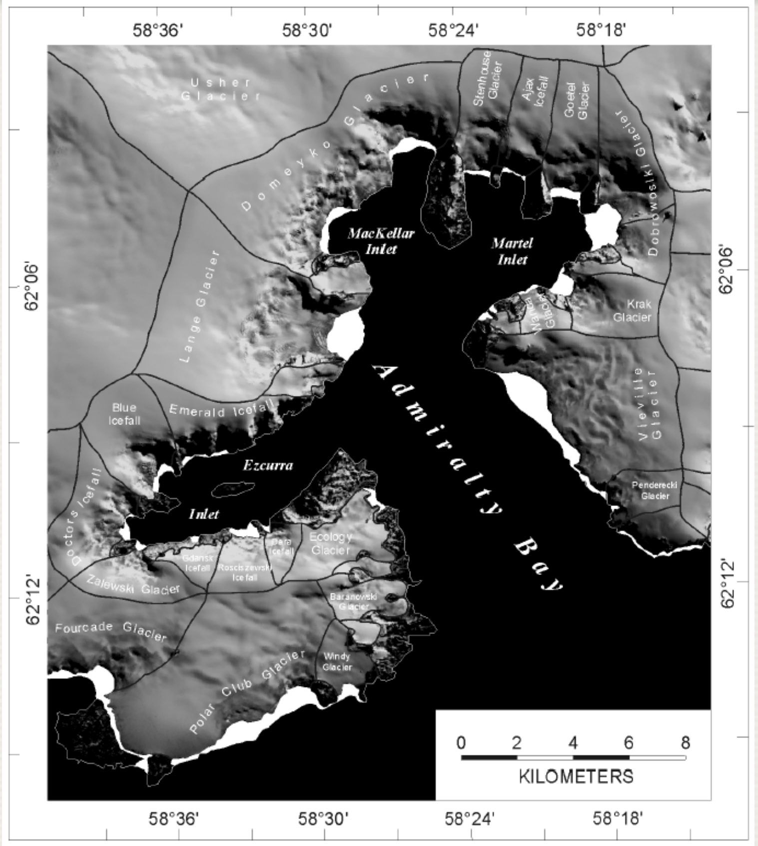
Impact of climate change on polar regions

- Significant changes in the physical and living environment of the polar regions.
- 87% of glaciers along the west coast of the Antarctic Peninsula (AP) have retreated in the last 50 years, and in the last 12 years most have accelerated.
- The AP is contributing to sea-level rise, at about the same rate as Alaska Glaciers (rise of 3 mm/year).



Glaciers retreating (white) in Admiralty Bay in 1956 -1995, Western Antarctica [Braun, 2001].

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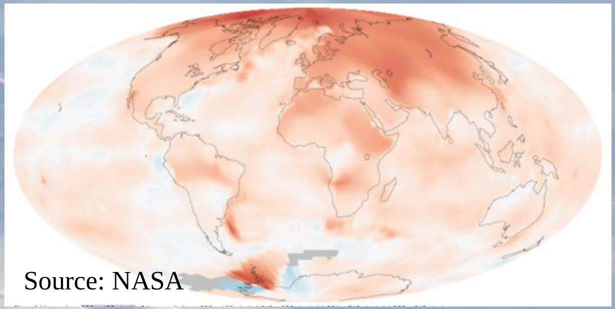
Source: British Antarctic Survey

Link between polar and mountain ecosystems

- In Western Antarctica, climate change is progressing at a rate several times the global average.



Source: NASA

- Research carried out in the soils at the foot of retreating glaciers may provide vital clues as to what the future holds for high mountain ecosystems.

Antarctica shows need for action on climate change, Ban Ki-moon says


Ban Ki-Moon visits Antarctica

11 November 2007 – Ban Ki-moon, during his historic visit to Antarctica, the first by a United Nations Secretary-General, has said warming temperatures on the continent show the growing dangers of climate change and the need for action to address it.

"It is here where our work, together, comes into focus," Mr. Ban said in a statement issued on Friday. "We see Antarctica's beauty – and the danger global warming represents, and the urgency that we do something about it."

The Secretary-General, who has made climate change a priority issue and is working to galvanize support for an international conference to be held in Bali in December on global commitments to stop it, said he is personally determined to push forward.

He said the landscapes on Antarctica are "rare and wonderful" but also deeply disturbing as the ice continues melting at a fast pace.

"All this may be gone, and not in the distant future, unless we act, together, now," he warned.

"Antarctica is on the verge of a catastrophe – for the world."

Need for science based policy making from a multi-disciplinary approach

- UNEP reports reflect need for data and quality assurance of results.
- IPCC needs scientific inputs for policy making.


IAEA in the Antarctic
Assessing impact of climate change on soil quality and soil degradation in Western Antarctica through the use of isotopes
29 Nov – 15 Dec 2011

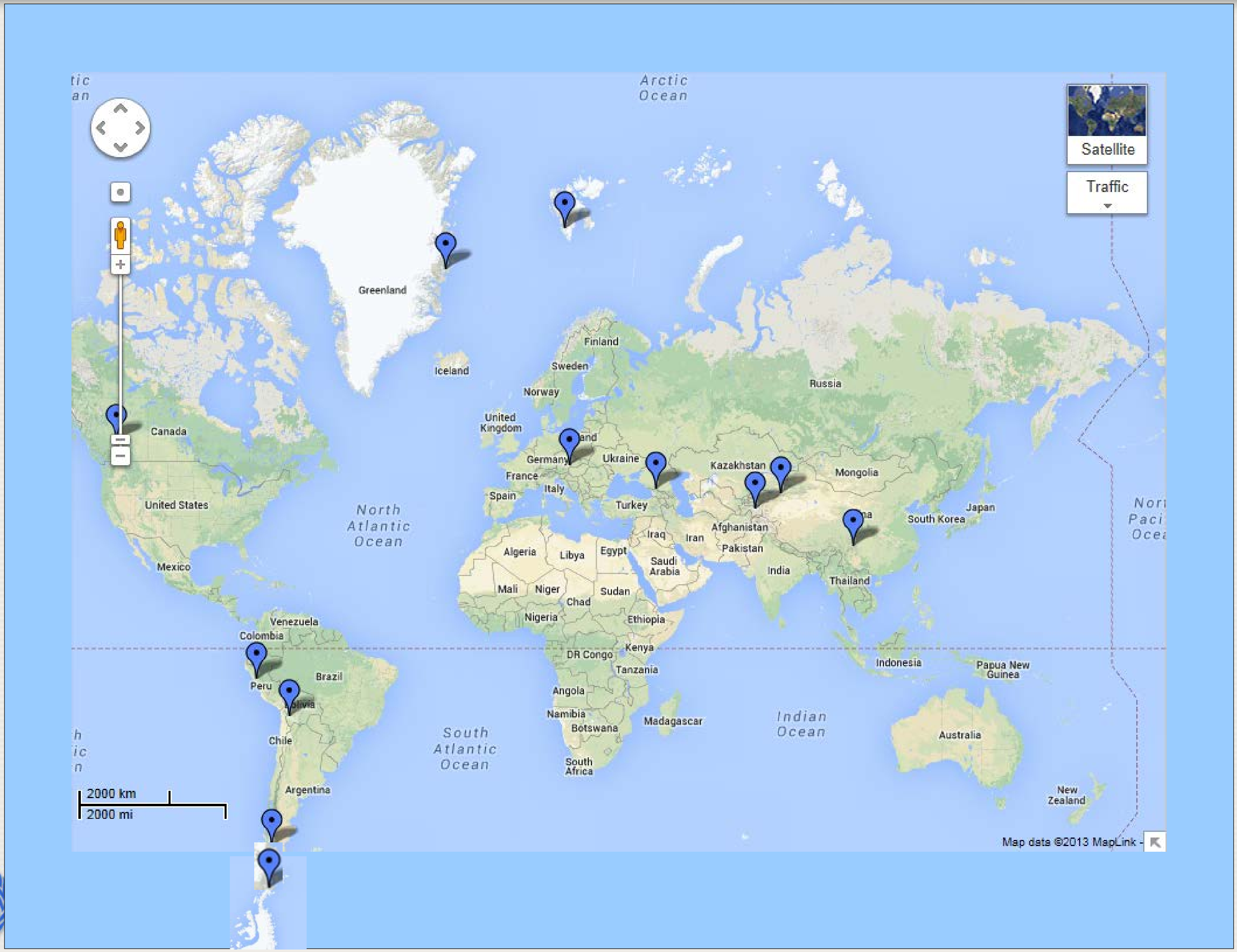
Sampling in Antarctica

- ✓ During thirteen days the team collected samples of soil, sediment, lichen, moss, grass and bird excrement.
- ✓ With every effort made to minimize the impact on the fragile ecosystem, around 150 samples, each weighing between 50g and 400g, were taken, sieved, separated, dried and packed.

Conclusions

- The values of the areal activity density of ^{137}Cs, $^{210}Pb_{ex}$ and ^{7}Be in soils and sediments proved the potential for using FRN's to study land degradation.
- Mass activity values of FRN suggest relatively important soil movement.
- The knowledge gained with this research provided baseline information to establish future sampling strategies.

Sites for Consideration



Nuclear and isotope-based techniques

Four main nuclear and isotope-based techniques will be used in an integrated way:

- Fallout radionuclides (Sediment redistribution and dating),
- Compound-Specific Stable Isotope Analysis (Carbon dynamics),
- C-14 dating and
- O-18 and Deuterium analysis of ice cores (to complement C-14 for the analysis of glacier variability and past ambient temperature)

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Long-term Iconic Indicator

- A simultaneous and long-term interregional approach focusing on a scientific assessment of the impact of climate change on polar and mountainous regions including recommendations for policies aiming the adaptation of communities to climate change is essential.

- A well-recognized, long-term iconic indicator, such as the Keeling curve for CO_2 concentrations, is missing for these ecosystems.

- Benchmark sites can become such indicators.

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UAV's: md4-1000 picture from flight

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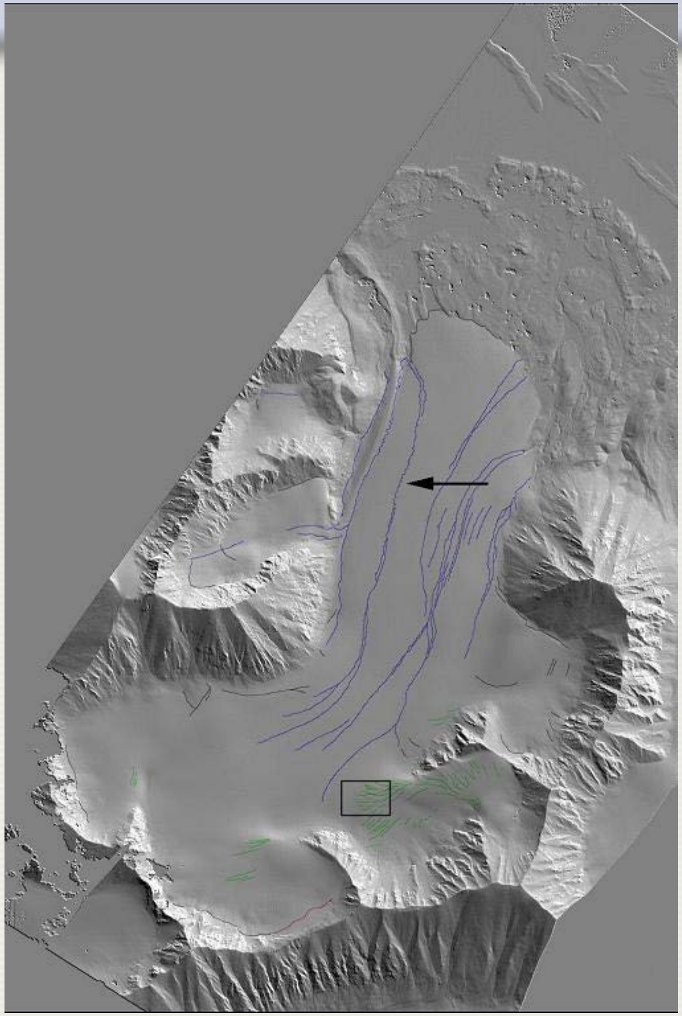
Scott Polar Research Institute



High resolution DEM of Midre Lovenbreen derived from the LiDAR data collected during the summer of 2003. The data are shaded according to slope angle and orientation to highlight the detail in the image. The relatively smooth surface of the glacier itself is easily distinguishable from the rough, unglaciated terrain. Surface meltwater streams on the glacier are highlighted in blue; crevasses in green. The area shown is approximately 5km by 3km, and consists of over 12.5 million individual data points.
{Gareth Rees}

Scott Polar Research Institute
University of Cambridge
http://www.spri.cam.ac.uk/research/projects/lidarforglaciology/

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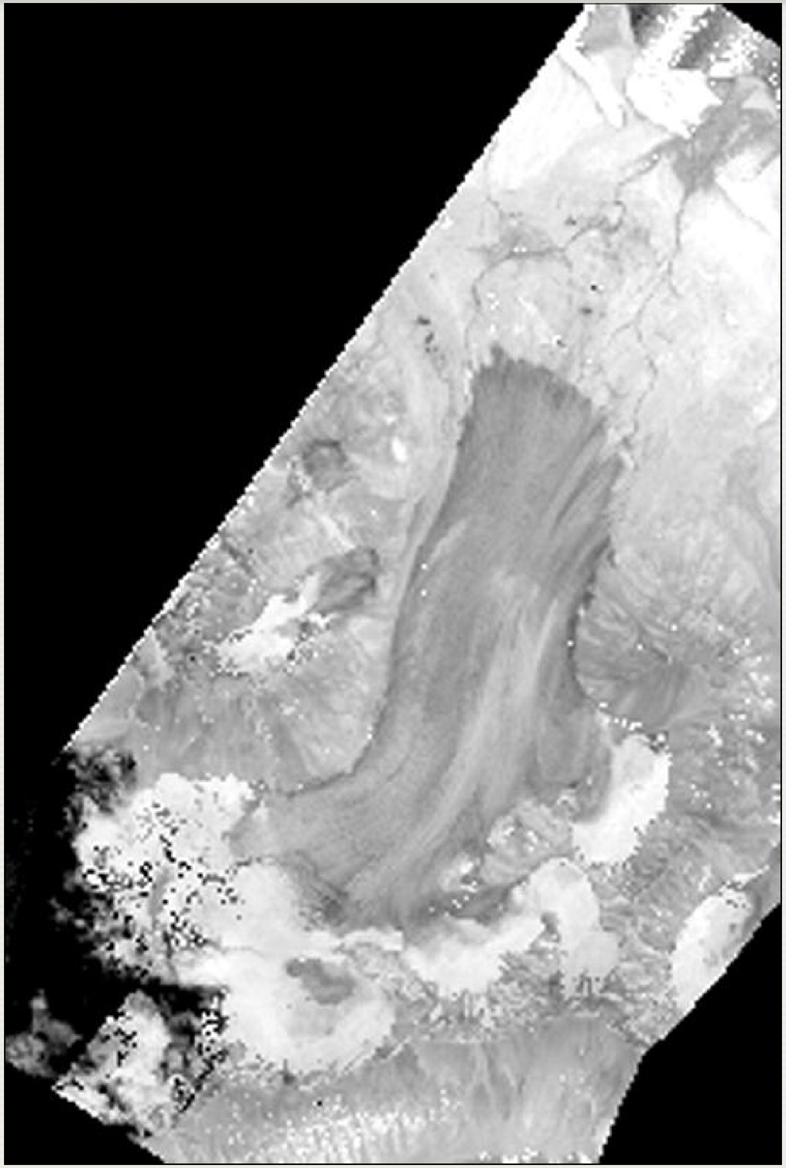
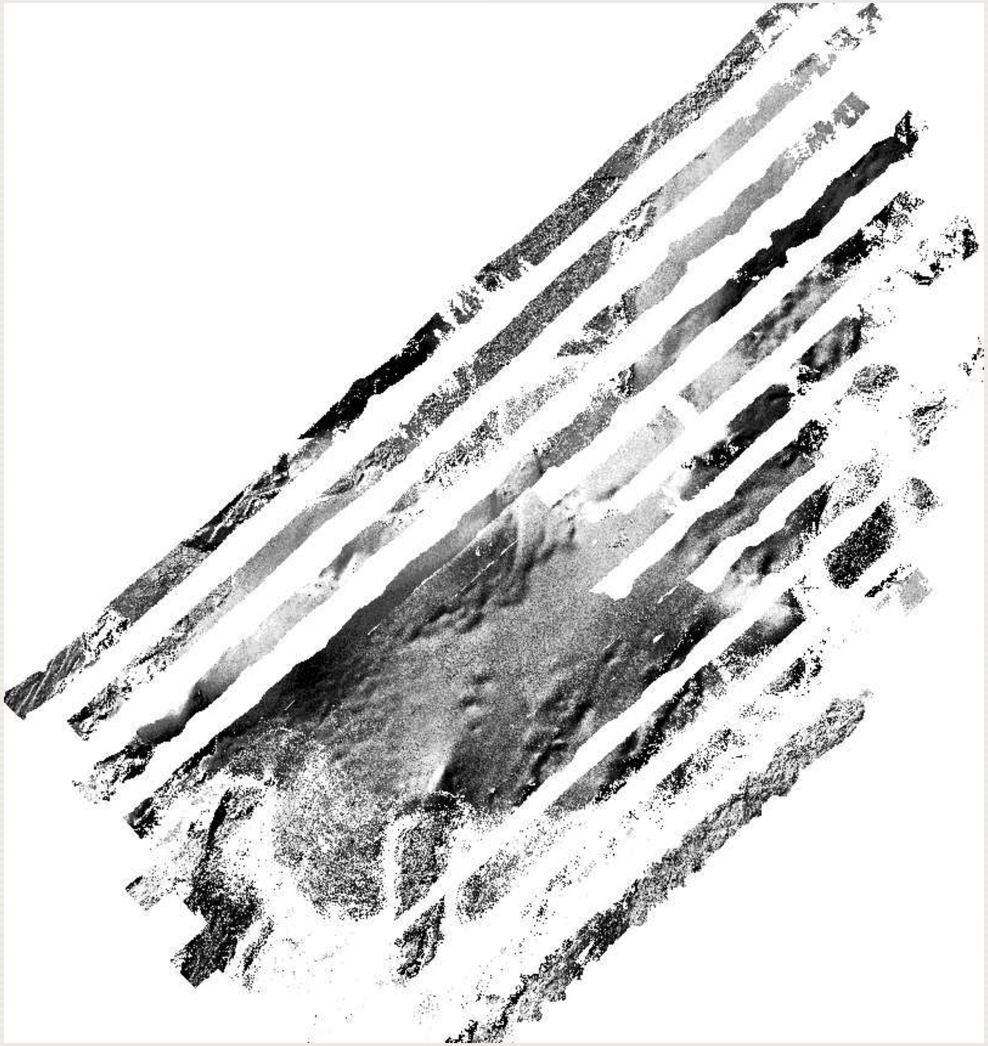
Scott Polar Research Institute

- *Figure 2. Elevation corrected intensity image. The remaining snow-covered areas appear as white/very light grey; bare glacier ice areas as dark/mid grey, and the surrounding topography as mid/light grey.*
- [They] are also investigating the use of these high-resolution data to help determine the surface roughness of glaciers, which is an important control on the fluxes of heat into or out of the surface from the atmosphere, and hence a control on glacier melt rates, and which also affect the reflectance of the glacier surface in satellite radar imagery.



Scott Polar Research Institute

2007 LiDAR preliminary image
Langjokull iceland
http://www.spri.cam.ac.uk/research/projects/langjokullmassbalance/



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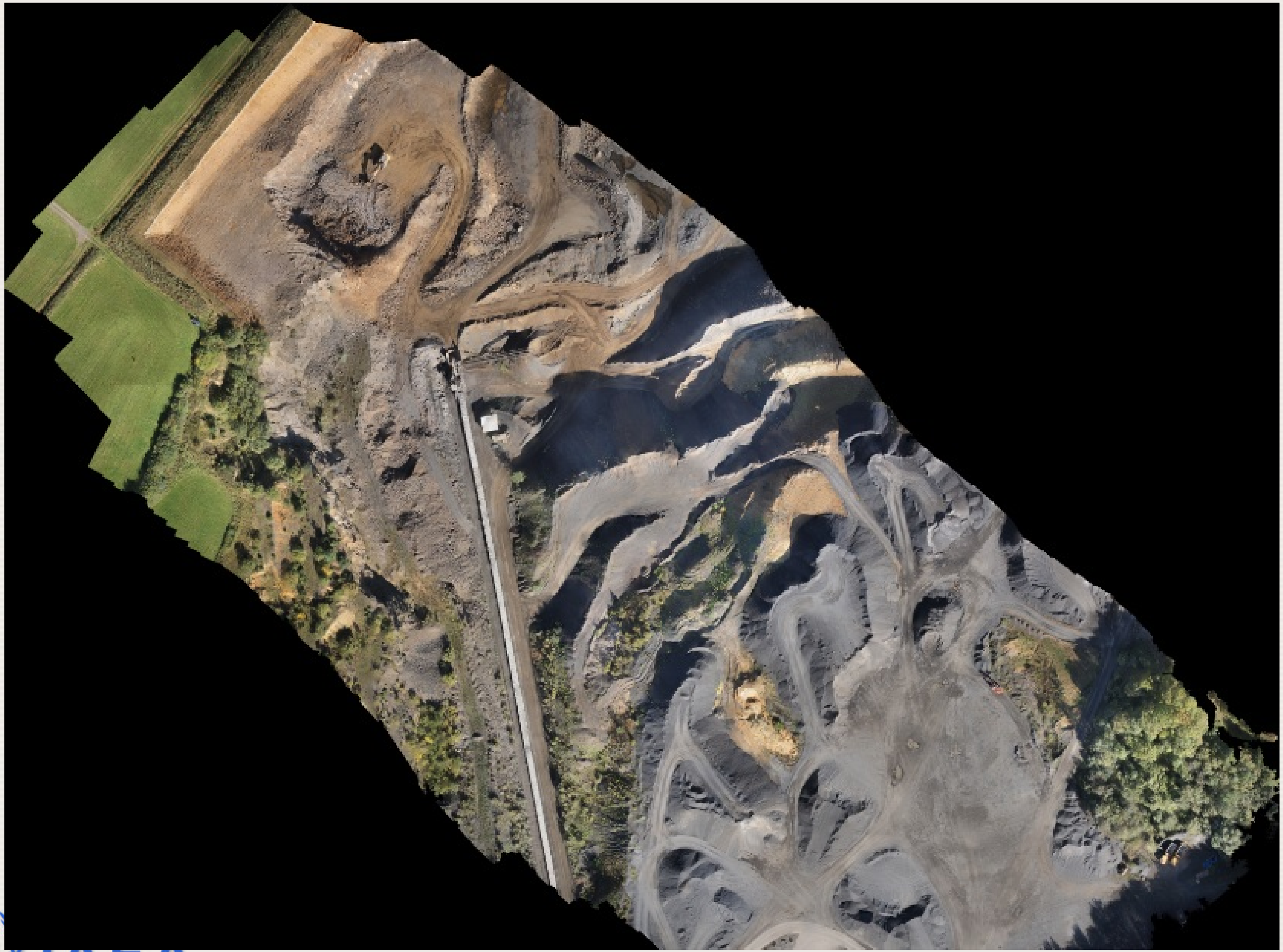
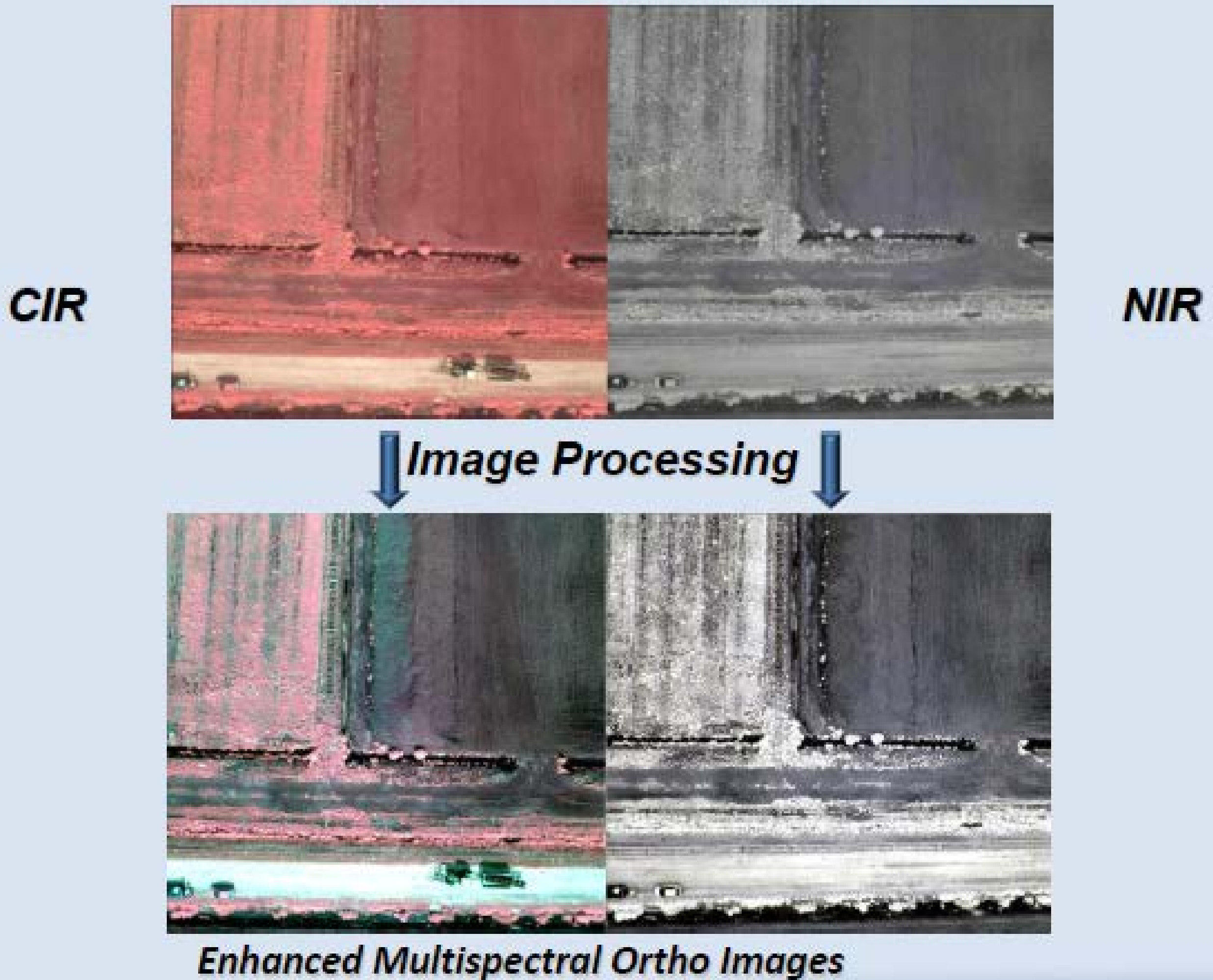
Aibotix X6 Vienna



Microdrones:
Geert Verhoeven, Uni Wien

IA

Microdrones:
Torsten Prinz, Christian Koth (IFGI, WWU)



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http://purl.net/ifgi/copter

ifgicopter

Microdrones: Assesing biodiversity in forests
Stephan Getzin, Kerstin Wiegand (Uni Goettingen)

Press


GLOBUS

Das fliegende Auge

Über allen Wipfeln: Thüringer Wissenschaftler fotografieren Hainich per Drohne

Traum von Harvard an der Gera geplatzt

Weltraumtourist schwebt zur ISS

Braunbären vor Abschuss

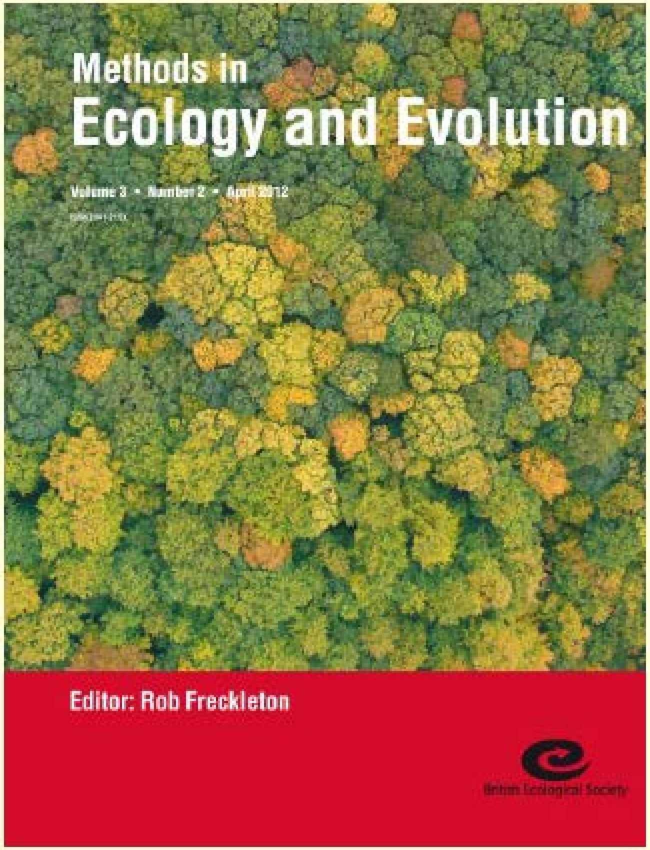


bild der wissenschaft — Issue 8, 2012

NATIONAL GEOGRAPHIC DEUTSCHLAND — Issue 4, 2010

Microdrones: Assesing biodiversity in forests
Stephan Getzin, Kerstin Wiegand (Uni Goettingen)

Remote Sens. 2012, *4*, 1519-1543; doi:10.3390/rs4061519

OPEN ACCESS

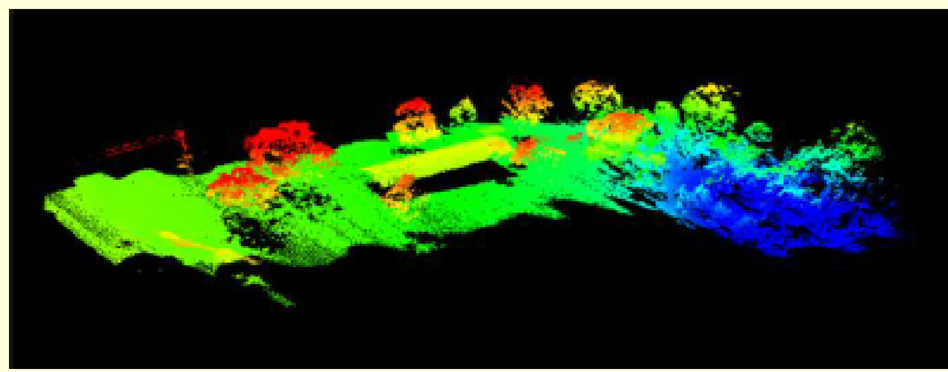
Remote Sensing
ISSN 2072-4292
www.mdpi.com/journal/remotesensing

Article

Development of a UAV-LiDAR System with Application to Forest Inventory

Luke Wallace *, Arko Lucieer, Christopher Watson and Darren Turner

Ibeo LUX laser scanner



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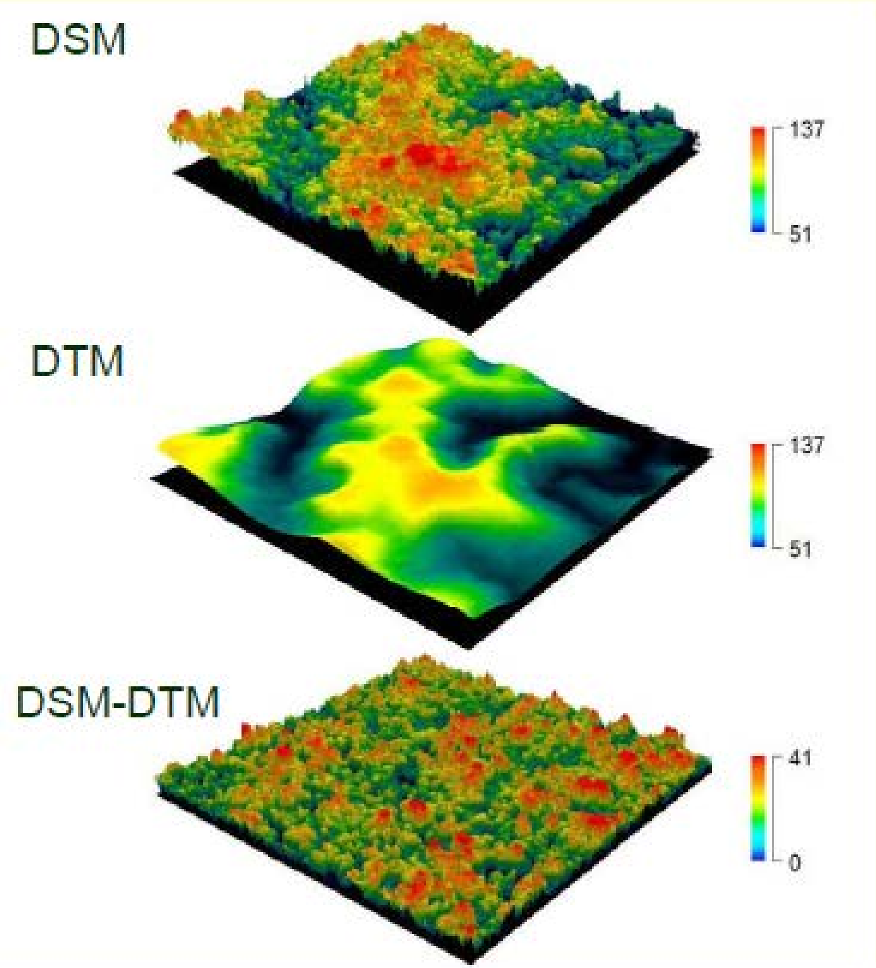
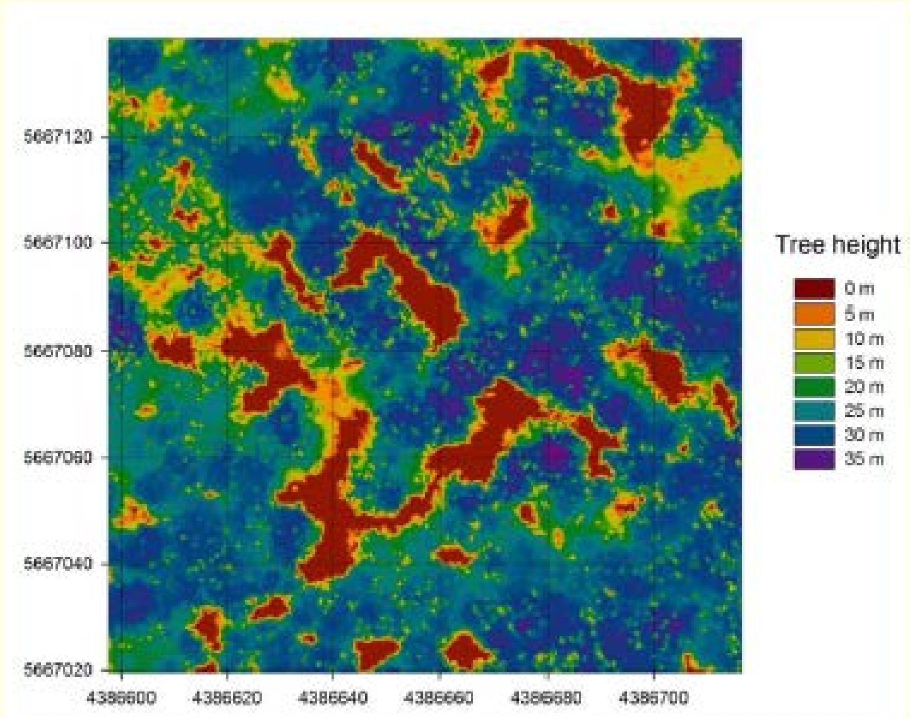
Microdrones: Assesing biodiversity in forests
Stephan Getzin, Kerstin Wiegand (Uni Goettingen)





accurate gap extraction

(Kellner et al. 2009)

PART III – Novel Applications

COSMIC MUON SOIL PROBE COSMOS Cosmic-ray Soil Moisture Observing System

Nature's neutron probe: soil moisture at the intermediate spatial scale with cosmic-ray neutrons

- **DARIN DESILETS**
- **Hydroinnova LLC**
- **Albuquerque, New Mexico**
- **USA**
- ***http://hydroinnova.com***

- **Acknowledgements**
- Gary Womack, Pete Shifflet, Steve Hamman

- **COSMOS Team at the University of Arizona:**
- Marek Zreda, Jim Shuttleworth, Xubin Zeng,
- Chris Zweck, Trenton Franz, Rafael Roselum

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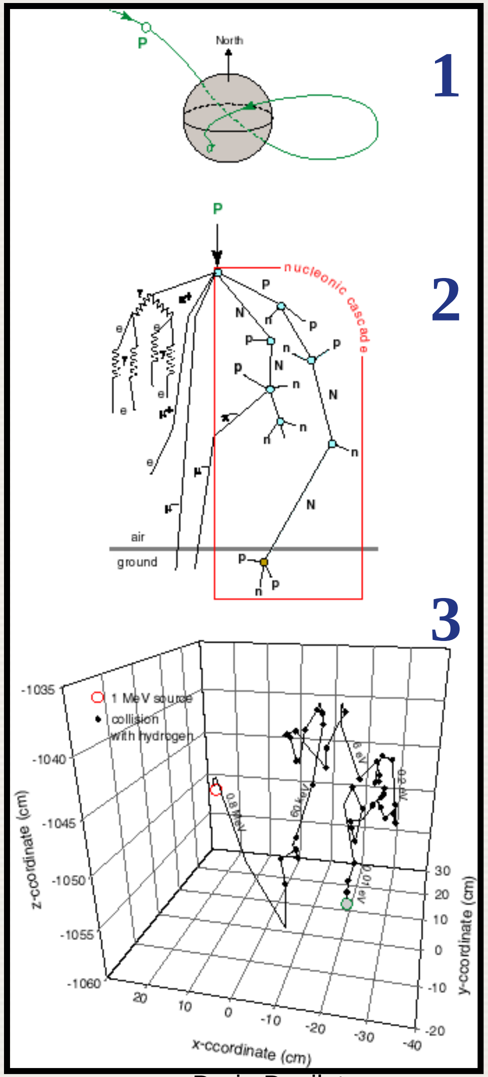
Cosmic-rays and earth

Primary galactic cosmic-ray protons bombard earth →

Successful particles enter the atmosphere and collide with O and N within first 200 mb of atmosphere →

Fast neutrons scatter and become moderated (slowed) through collisions with nuclei→



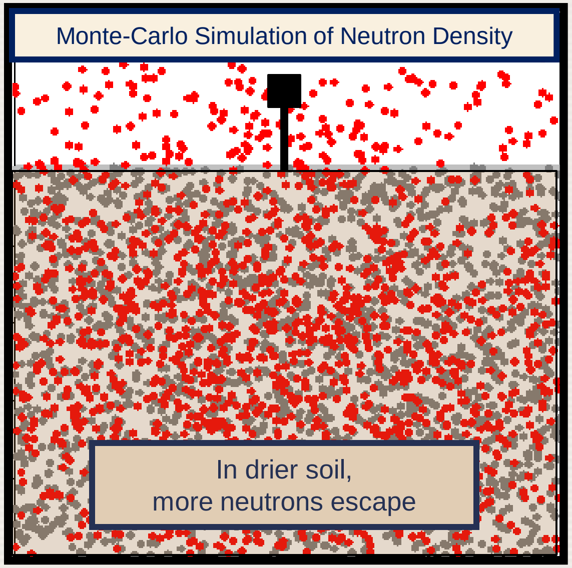
geomagnetic shielding effect

elevation/ pressure effect

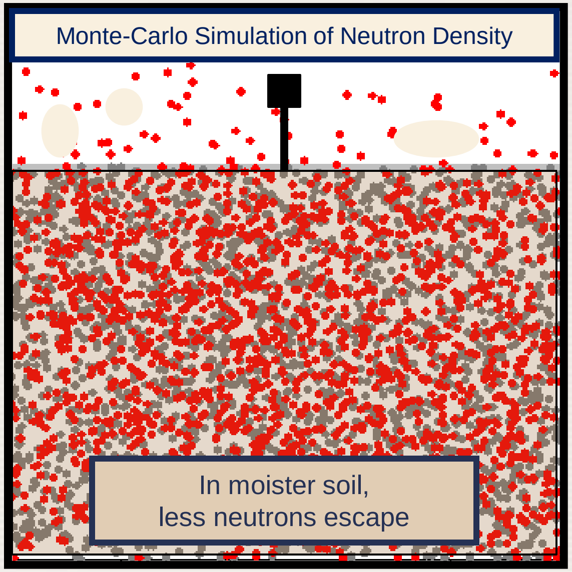
soil moisture effect

Darin Desilets

Neutron intensity at land/air interface



Dry

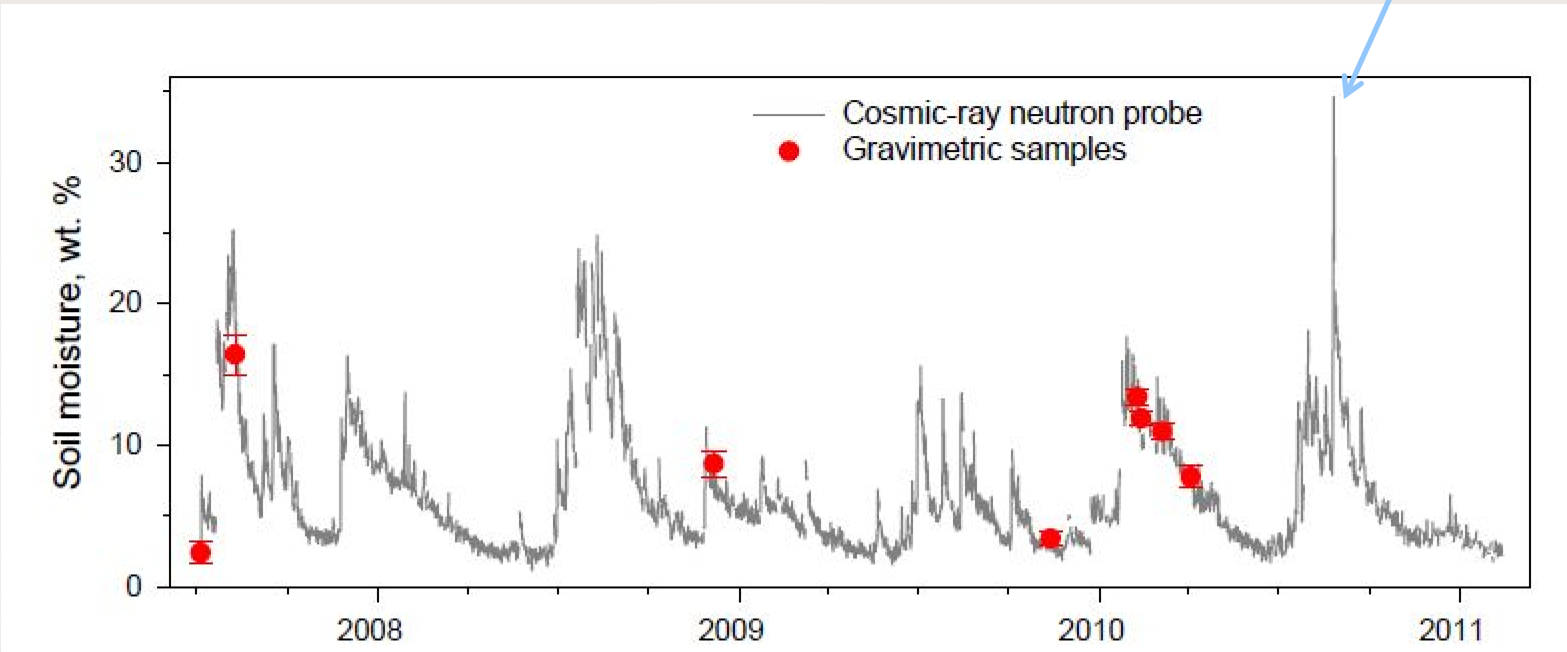


Wet

Results from San Pedro River

Cosmic-ray probe on average is correct to within 0.01 kg kg^{-1}

flood



PART IV – Cultural Heritage

ARCHAEOMETRY

What is science to the arts

- On 7 May 1959, C.P. Snow delivered an influential Rede Lecture called *The Two Cultures*
- *A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity at the illiteracy of scientists.*
- *Once or twice I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics. The response was cold: it was also negative. Yet I was asking something which is about the scientific equivalent of: 'Have you read a work of Shakespeare's?'*

What is science to the arts

I now believe that if I had asked an even simpler question – such as:

What do you mean by mass, or acceleration?

which is the scientific equivalent of saying,

‘Can you read?'

not more than one in ten of the highly educated would have felt that I was speaking the same language. So the great edifice of modern physics goes up, and the majority of the cleverest people in the western world have about as much insight into it as their Neolithic ancestors would have had.

Your skills at the interface of the Arts

Cultural heritage (‘national heritage’ or just ‘heritage’) is the legacy of physical artefacts and intangible attributes of a group or society that are inherited from past generations, maintained in the present and restored for the benefit of future generations.

Physical or ‘tangible cultural heritage’ includes buildings and historical places, monuments, artefacts, etc., that are considered worthy of preservation for the future.

These include preservation and conservation of objects significant to the archaeology, architecture, science or technology of a specific culture.

Scientific studies of art and archaeology present a necessary complement for cultural heritage conservation, preservation and investigation.

Your skills at the interface of the Arts

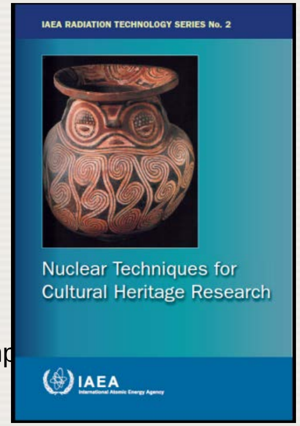
As cultural heritage objects are frequently unique and non-replaceable, non-destructive techniques are mandatory and, hence, nuclear techniques have a high potential to be applied to study these valuable objects.

Nuclear techniques, such as neutron activation analysis (NAA), X ray fluorescence (XRF) analysis or ion beam analysis (IBA), have a potential for non-destructive and reliable investigation of precious materials, such as ceramics, stone, metal or pigments from paintings.

Such information can help to repair damaged objects adequately, distinguish fraudulent artefacts from real artefacts and assist archaeologists in the appropriate categorization of historical artefacts.

Nuclear Techniques for Cultural Heritage Research

- http://www-pub.iaea.org/MTCD/Publications/PDF/p1501_web.pdf



What is Archaeometry?

Archaeo- logy

αρχαίος,
«old» or «ancient»

λόγος,

«explanation»,

« argumentation»

discipline that studies the societies through the observation and interpretation of its material remains (intentional or not intentional)

Archaeo- metry

μέτρον,
«measure»

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Therefore…

Set of actions that are carried out by analysts to characterize some properties of archaeological

(or cultural heritage) objects

Archaeometry:

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Overview of Nuclear Techniques in Art, Archaeology and Conservation Science related analytical studies

Andreas - Germanos Karydas

A.Karydas@iaea.org

IAEA
International Atomic Energy Agency

Outline

- Scientific methods in Cultural Heritage: Aims of investigations, Probes and techniques
- X-rays: X-Ray Fluorescence analysis, Portable spectrometers, Synchrotron Radiation
- Charged particle beams: Ion Beam Analysis
- Neutron beams - Applications
- Imaging with UV-Vis-IR radiation

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Scientific methods in Art and Archaeology

Objectives of the scientific examination

- Identification of chemical / biological constituents
- Structural characterization
- Provenance and dating. Authentication
- Manufacture Technology (metallurgy, pottery, coloring)
- Dietary habits (Human, Animal remains)
- Environmental degradation. Conservation

Scientific methods in CH: Challenges-Requirements

- **Diversity** of materials nature: - Organic, inorganic, biological materials
- **Elemental** /**Molecular** analysis /**Structural** information
- Analysis at different scales from **sub-μm** particles to **cm**- size size samples
- **Quant**itative/**semi-Q** analysis/ **Quali**tative information
- Material **interactions** for environmental impact
- Optimum analytical **range-sensitivity**
- **In-situ analysis**
- **Non-destructive or even non -invasive analysis!**

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Radiation Probes in Art and Archaeology

- **X-rays**

  - X-ray Tubes – unpolarized/polychromatic

  - Synchrotron radiation polarized/tunable monoenergetic

  Depth: sub-micron to mm, spot size cm to micrometer

- **UV, Vis-IR radiation (conventional, SR- sources)**
- **Laser Induced Techniques** (LIF, Raman, LIBS)
- **Neutrons** : Thermalized/ Fast neutrons (cm- scale)
- **Charged particle beams**

  Depth: sub-micron to mm, spot size mm to micron level

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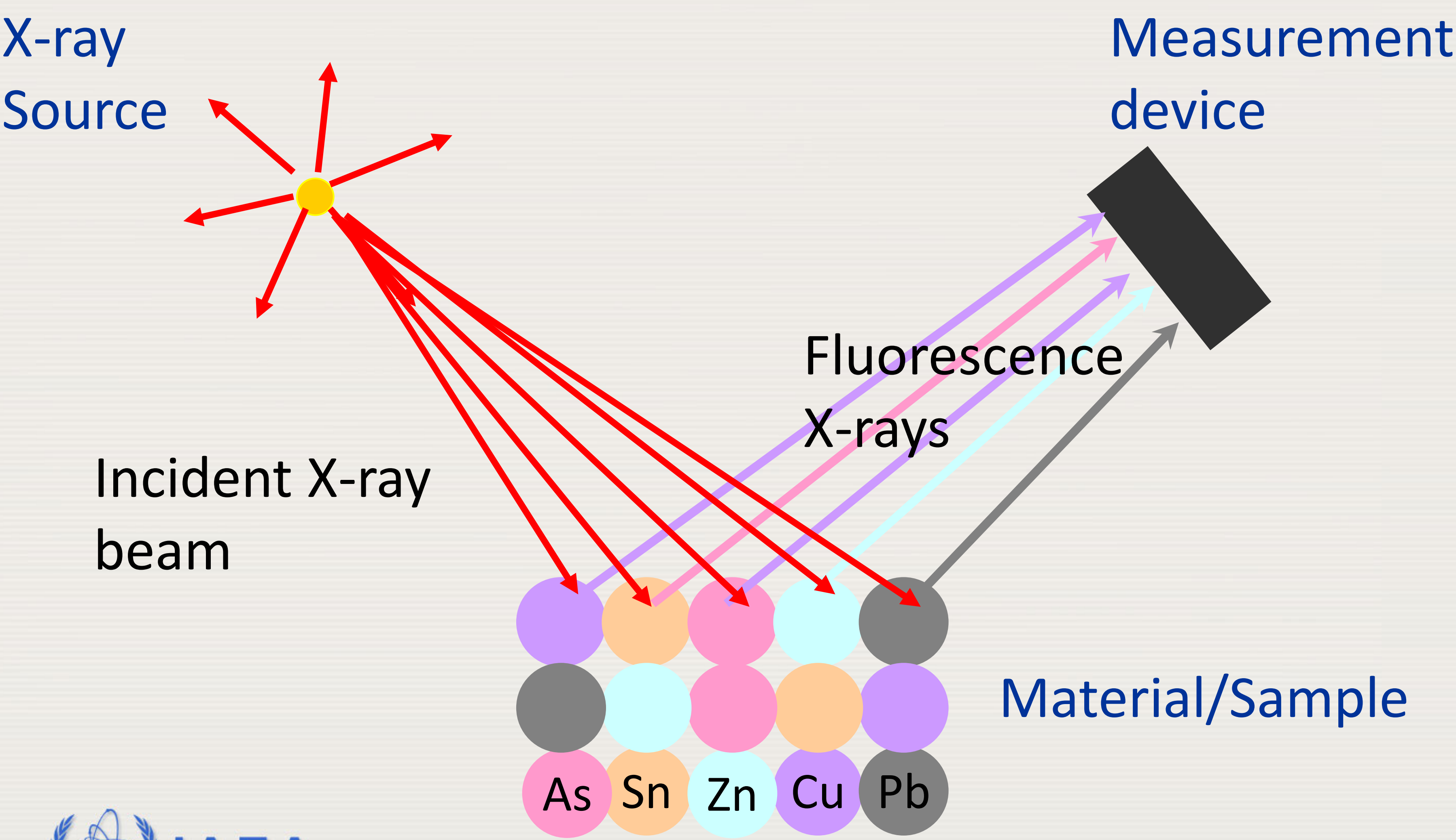
XRF analysis: Illustration of the principle of operation



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X-Ray Fluorescence Analysis - XRF

- Typically, from Z=11 or Z=12 upward.
- Sensitivity within the few ppm range (conventional x-ray sources, best excited elements) or few tens of ppb for synchrotron exciting radiation
- Spatial resolution from mm range down to few micrometers
- Portability, Handheld autonomous operation
- Quantitative information for materials presenting good preservation state
- Poor depth resolution: Confocal micro-XRF, micro-PIXE analysis

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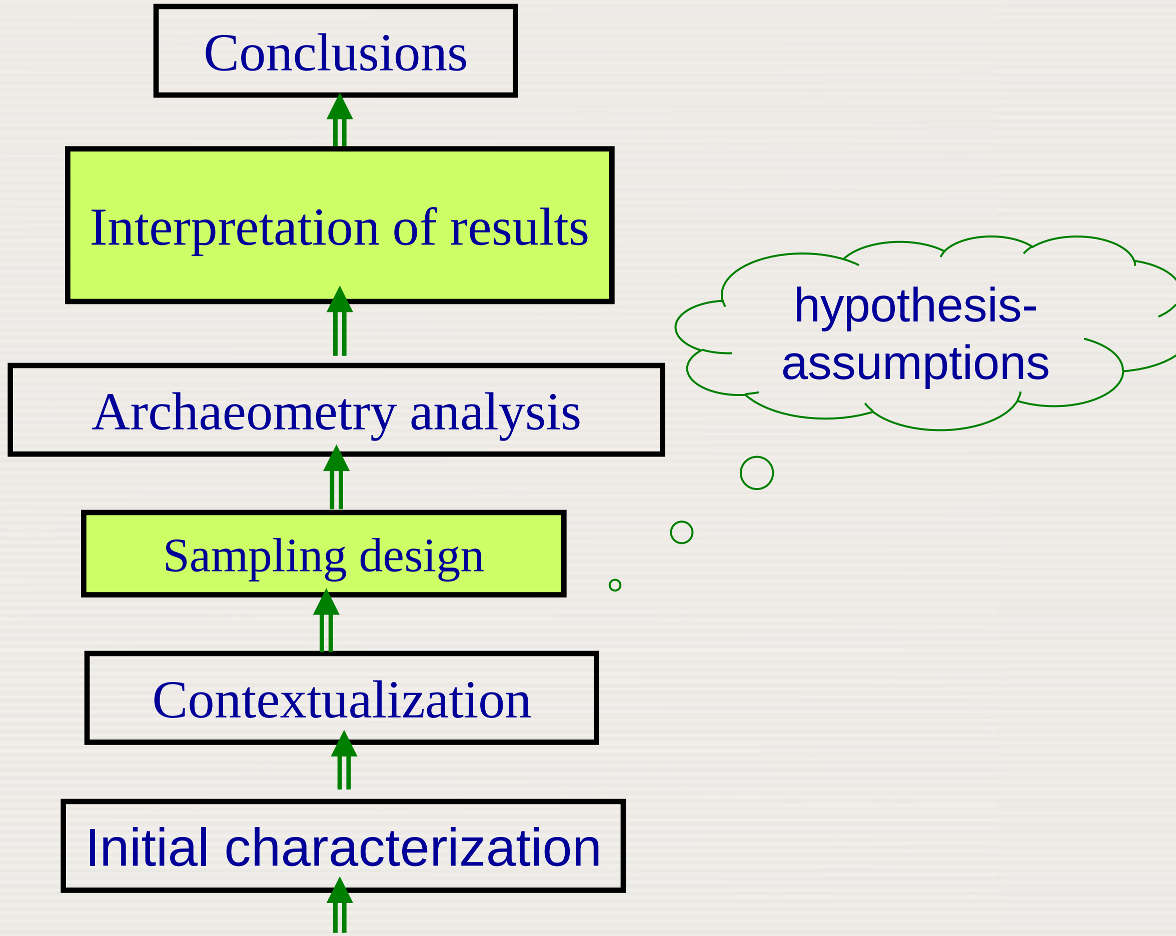
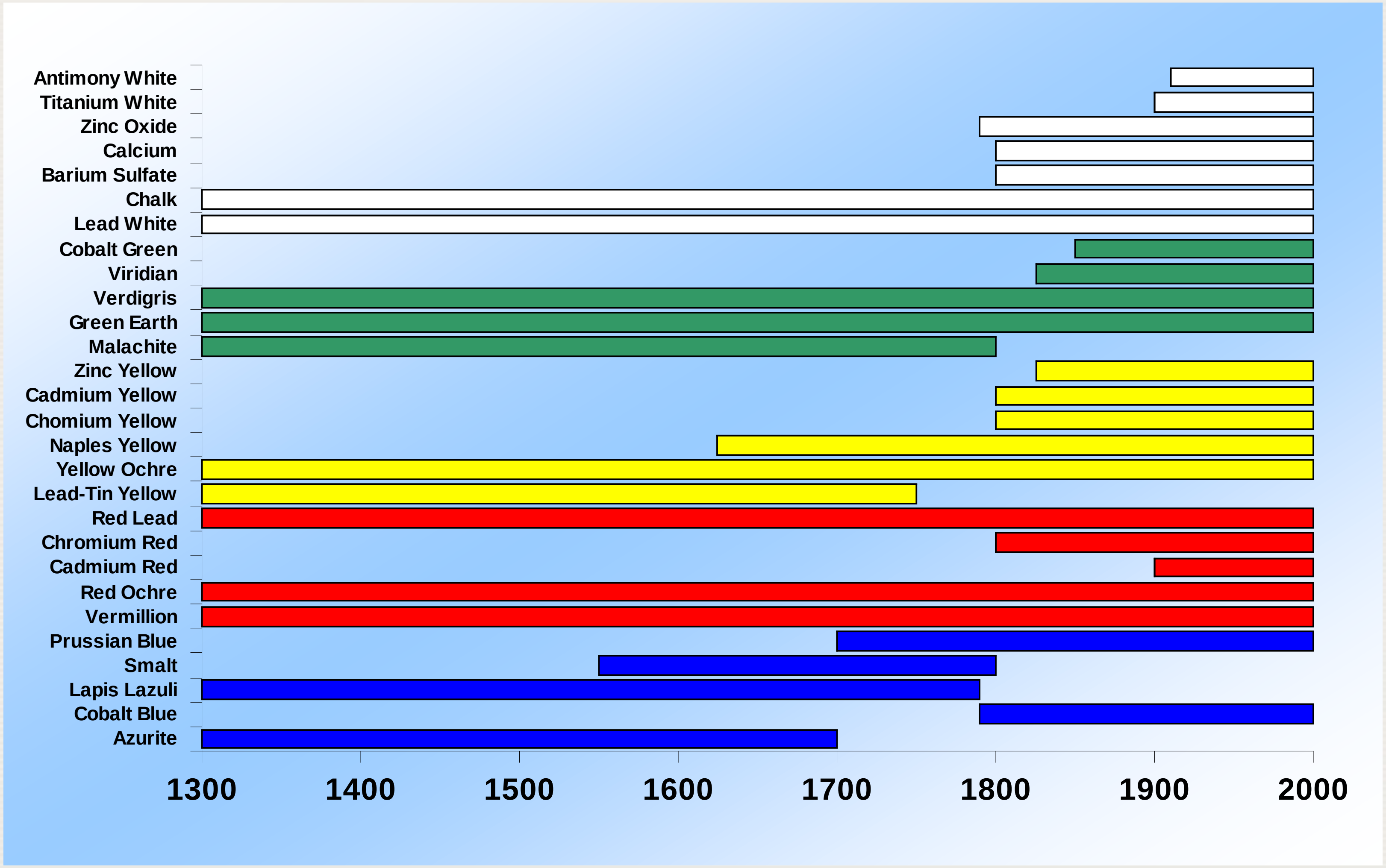
The analysis only works as part of an inter-disciplinary effort…



Chronology of some pigments:



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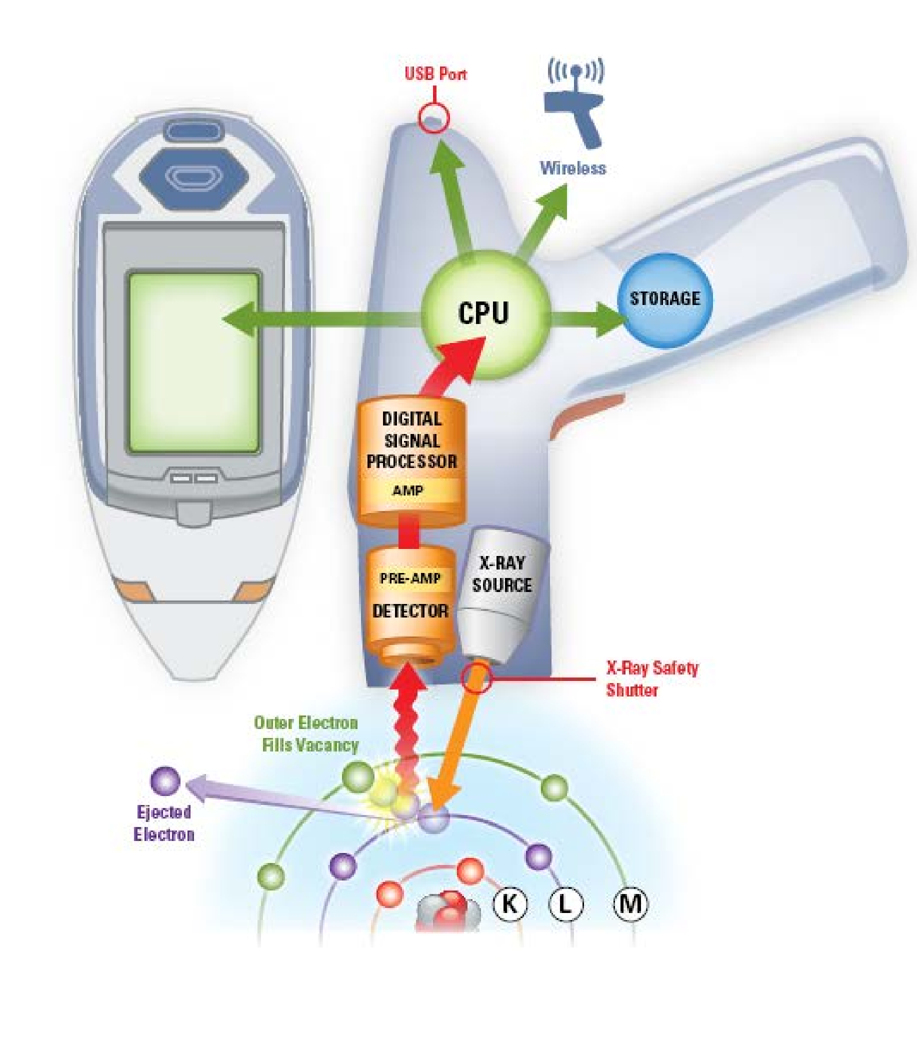
Differentiation by age:

Green	Malachite	$CuCO_3.Cu(OH)_2$	BC	1800
Green	Verdigris	$Cu(CH_3COO)_2.nCu(OH)_2$	BC	1900
Green	Green earth	Fe-Mg-Al-K-hydrosilicate	BC	2000
Green	Cobalt Green	CoOxnZnO	1780	1919
Green	Schweinfurt Green		1800	1930
Green	Chromium Oxide	Cr_2O_3	1810	2000
Green	Emerald Green (Paris green)	$Cu(CH_3COO)_2.3Cu(AsO_2)_2$	1814	2000
Green	Cobalt Green	CoO.5ZnO	1825	2000
Green	Chromium Oxide	Cr_2O_3	1825	2000
Green	Veridian	$Cr_2O(OH)_2$	1859	2000
Green	Guignent Green	$Cr_2O_3.nH_2O+H_3BO_3$	1870	2000

New Developments in XRF: Hand-held analyzer



Ankara, Anatolian Civilization Museum, 2007

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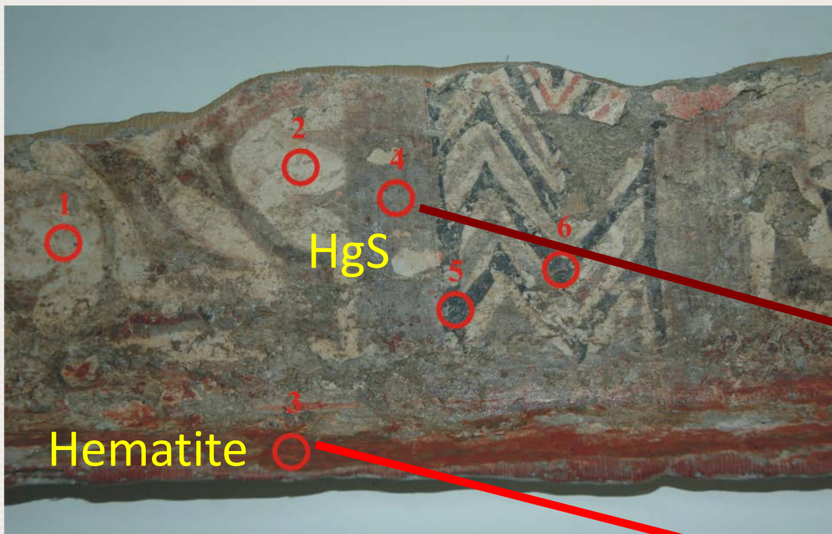
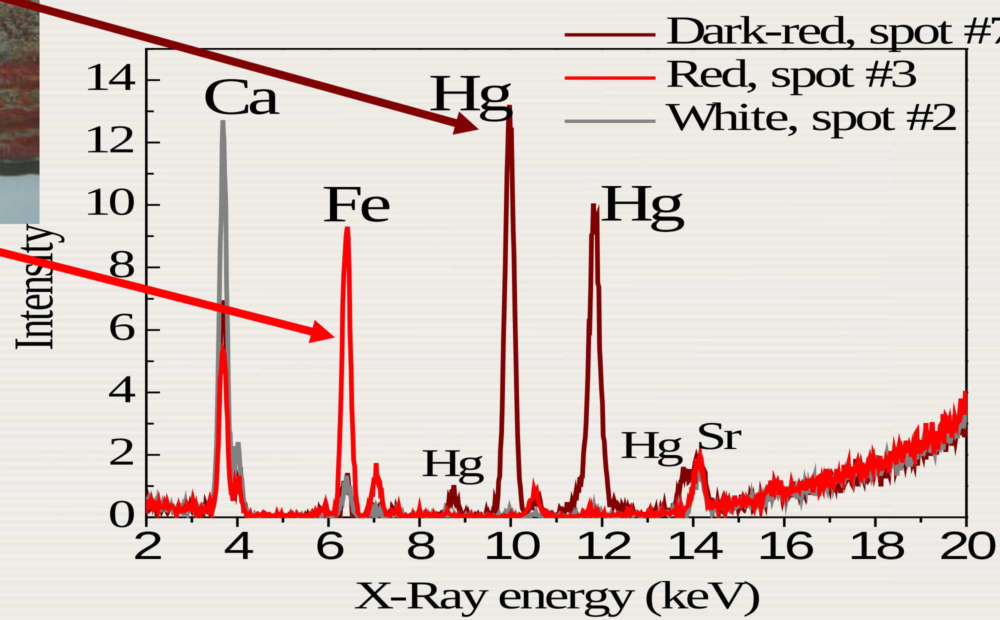
ÇATALHÖYÜK 7000-8000 B.C. Wall-Painting pigments

- ✓Dark Red
- ✓Red
- ✓White
- ✓Black





Hand-held XRF analysis, A. Zararsiz et *al*. 2008

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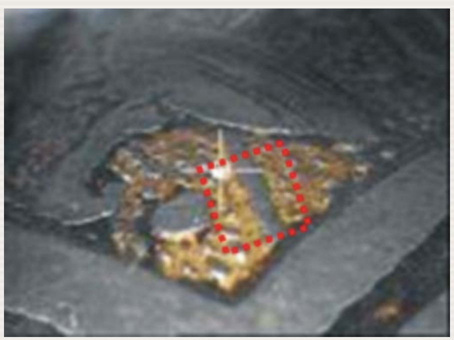
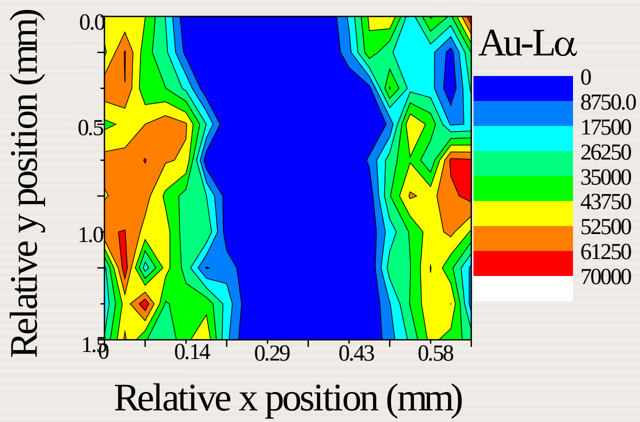
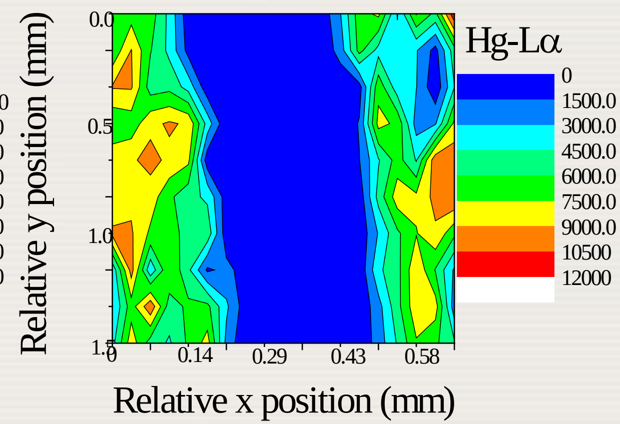
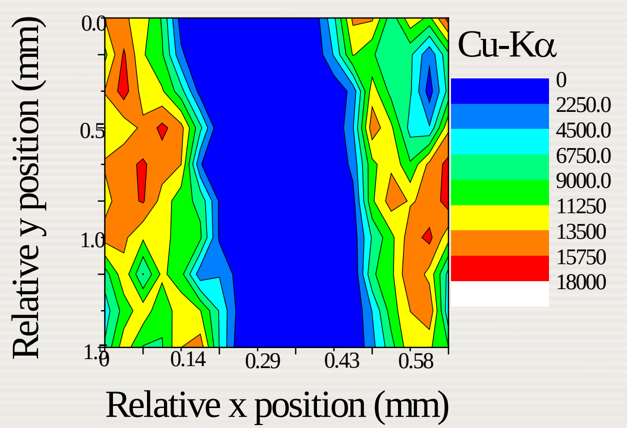
Analytical possibilities: Fire Gilding technique

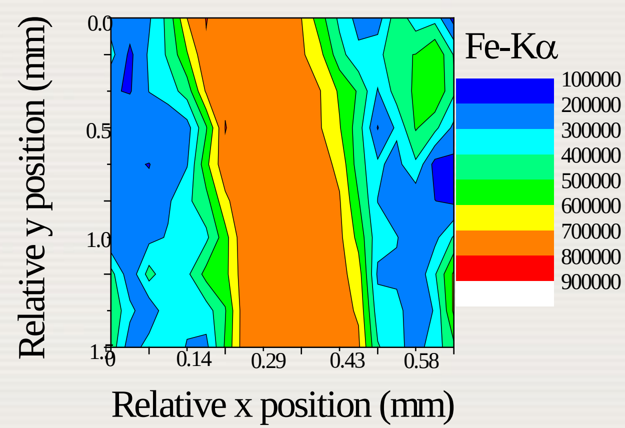
Palace Armoury, Malta











Area scanned: $1.9 \times 1.0 mm^2$
Step size used: 0.1mm
Time per step: 20 s.

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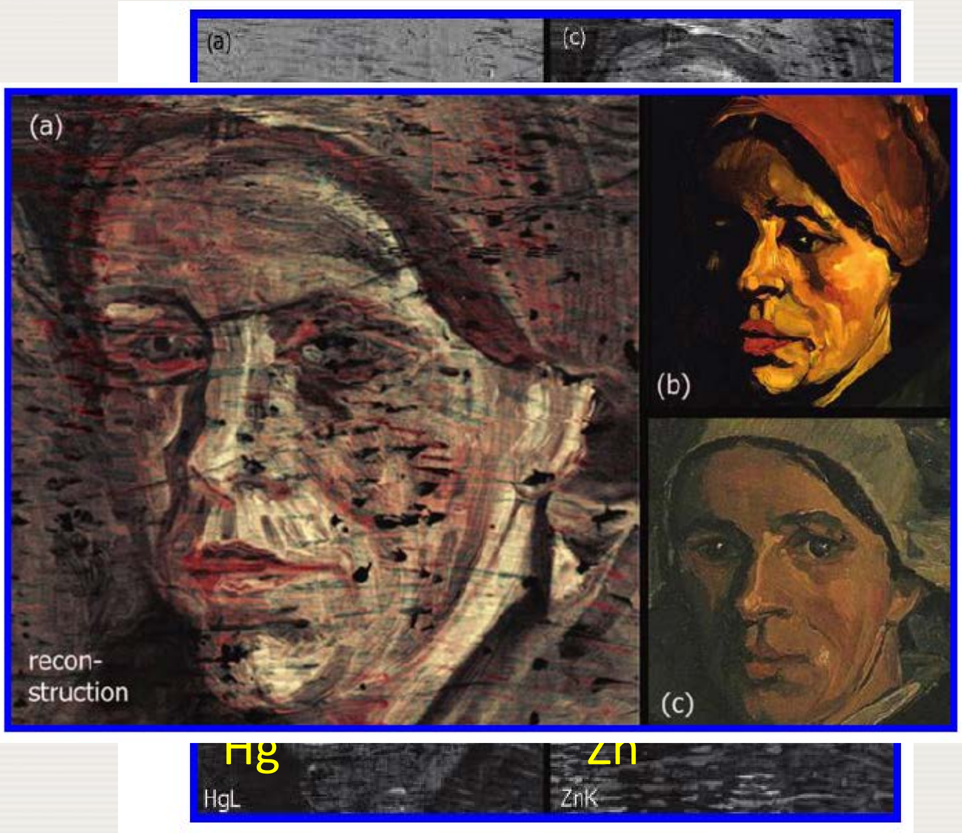
Examples : Elemental mapping by Micro-XRF

DORIS at DESY:

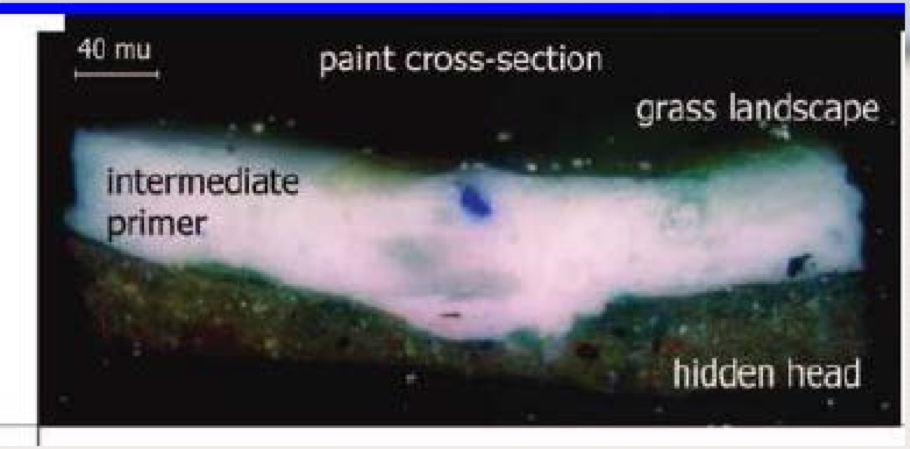
38.5 keV, 0.5x0.5 mm², 2s, 17.5x17.5 cm²



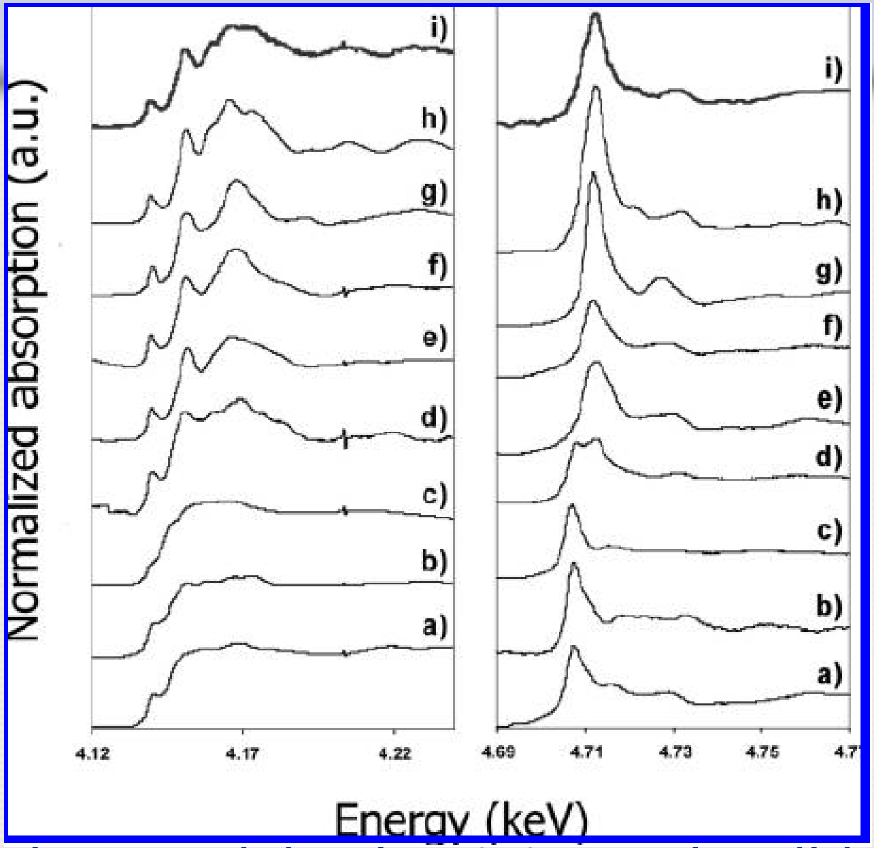
Dik et *al*., Anal. Chem., **2008**, 80 (16)

Vincent van Gogh, *Patch of Grass*, Paris, Apr-June 1887, oil on canvas, 30 cm × 40 cm, Kro¨ ller-Mu¨ ller Museum, Otterlo, The Netherlands

XANES: Identification of chemical compound



XANES (X-ray Absorption Near Edge Spectra) at the Sb-LIII edge and at the Sb-LI edge).



Reference antimony compounds: Sb_2O_3 as (a) valentinite and as (b) senarmontite; (c) Sb_2S_2O, kermesite; (d) Sb_2O_4; (e) Sb_3O_6OH, stibiconite; (f) $KSbO_3 \cdot 3H_2O$; (g) $NaSbO_3OH \cdot 3H_2O$; (h) Naples yellow; and (i) Sb pigment in the cross section of the Van Gogh painting

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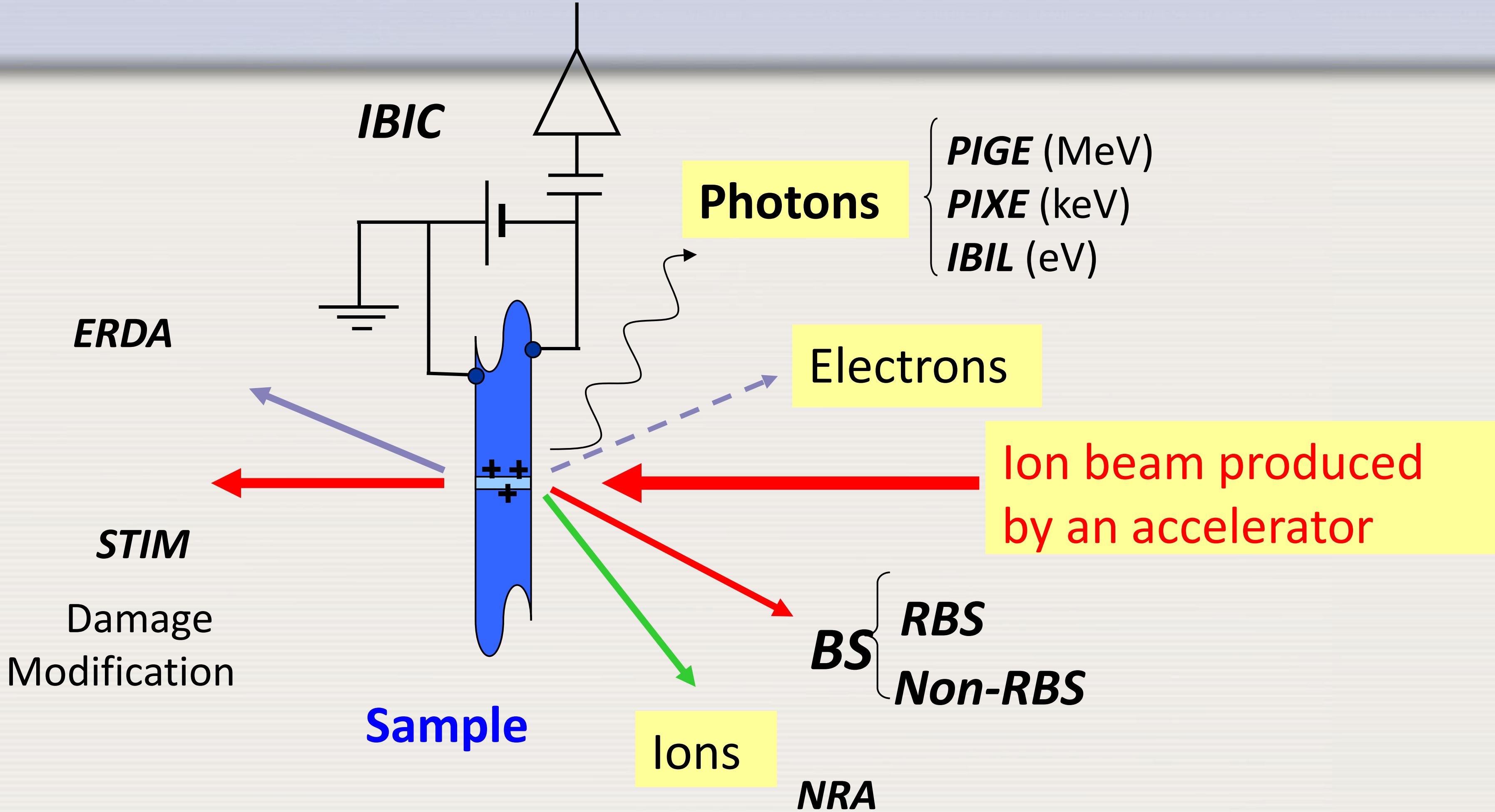
Ion Beam Analysis



MeV ion beam based techniques constitute a powerful tool for the quantitative determination of the composition and structure of matter

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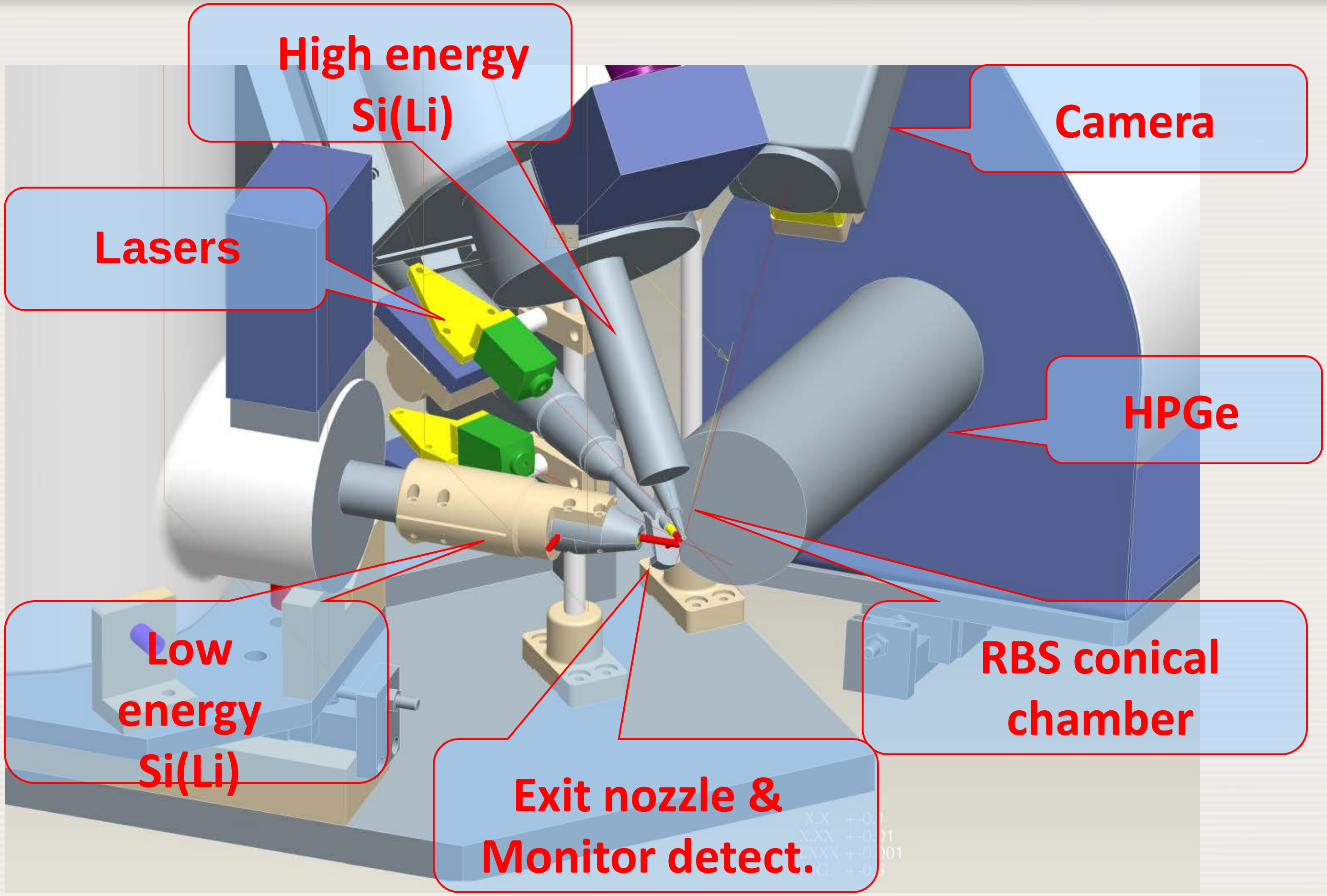
External Ion-Beam Analysis set-up



Sokaras et *al*, NIM B, 2011 NCSR “Demokritos”, Athens

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External Ion-Beam Analysis Set-up

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Synergy of Ion Beam Analysis Techniques

- Multi-elemental and near-surface depth resolved analysis of samples/artifacts.
- Analytical range: Lithium (Z=3) to Uranium (Z=92)
- Analytical sensitivity: From µg/g (ppm) to % level

External Ion-Beam

- Non destructive
- No limitations (in general) for the size or shape of the object
- No heating, reduce damage
- No sampling, no charging, no preparation
- Easy sample positioning

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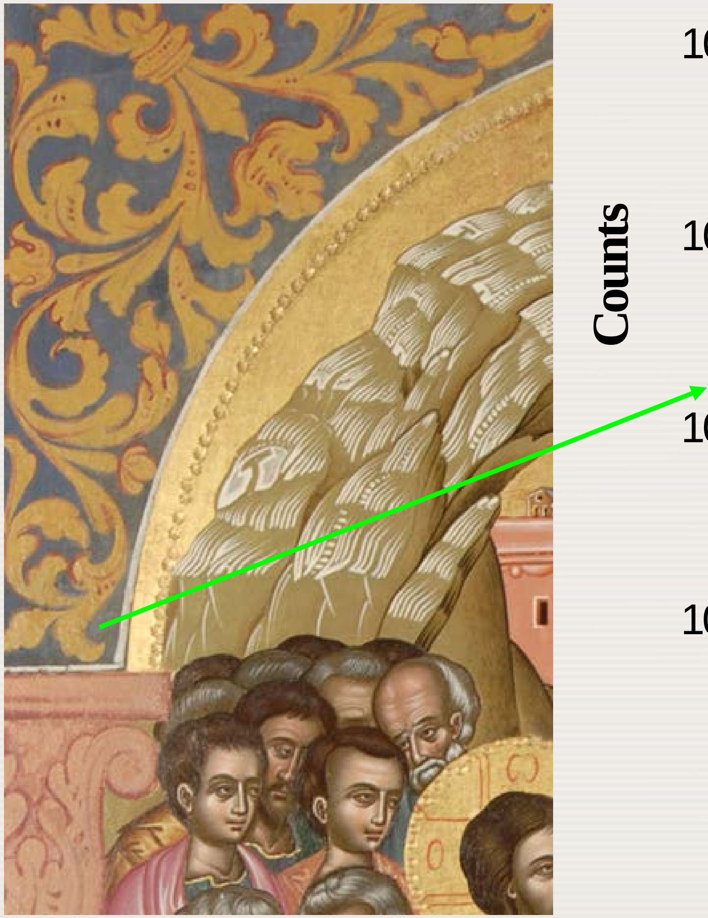
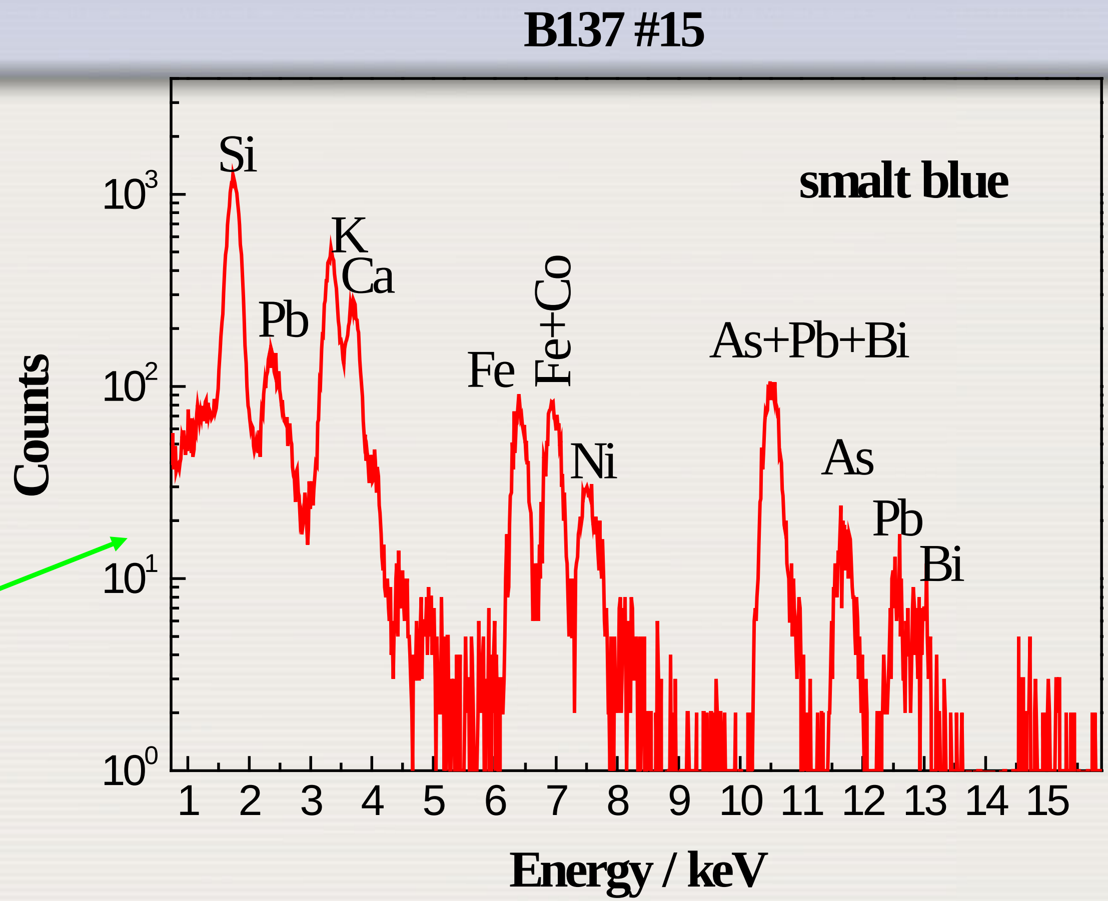
PIXE: Elemental Analysis of smalt





Smalt Blue: Quartz, Smalt minor elements Fe, Co, Ni, As Pb, Bi

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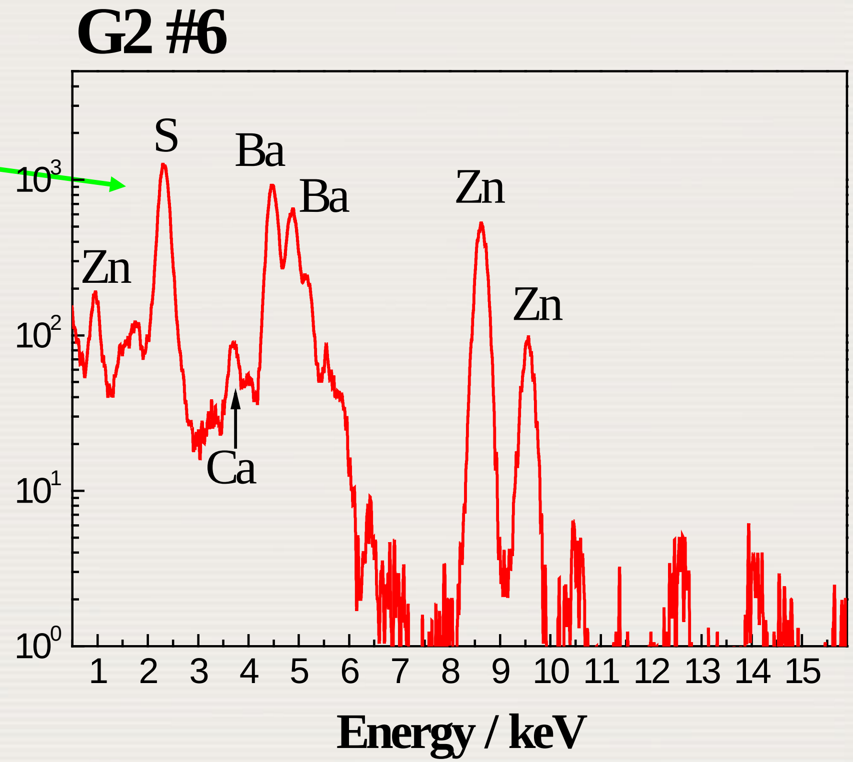
PIXE: Analysis of modern painting pigment



- Lithopone, mixture of ZnS and $BaSO_4$

Greek contemporary painter, Nikos Chatjikyriakos-Gkikas, Benaki museum

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PIGE: Particle Induced gamma-ray emission

Nuclear Reactions may induce isotope specific characteristic γ-rays emission.

Light elements: Li, B, Na, Mg, Al, Si

Element	$E_p = 1.77$ MeV		$E_p = 4.0$ MeV	
	γ-Ray (keV)	Reaction	γ-Ray (keV)	Reaction
Li	478	$^{7}Li(p, p'\gamma)^{7}Li$	478	$^{7}Li(p, p'\gamma)^{7}Li$
B	429	$^{10}B(p, \alpha\gamma)^{7}Be$	718	$^{10}B(p, p'\gamma)^{10}B$
F	6129	$^{19}F(p, \alpha\gamma)^{16}O$	197	$^{19}F(p, p'\gamma)^{19}F$
Na	440	$^{23}Na(p, p'\gamma)^{23}Na$	440	$^{23}Na(p, p'\gamma)^{23}Na$
Mg	585	$^{25}Mg(p, p'\gamma)^{25}Mg$	585	$^{25}Mg(p, p'\gamma)^{25}Mg$
Al	1779	$^{27}Al(p, \gamma)^{28}Si$	1014	$^{27}Al(p, p'\gamma)^{27}Al$
Si			1779	$^{28}Si(p, p'\gamma)^{28}Si$
P			1266	$^{31}P(p, p'\gamma)^{31}P$

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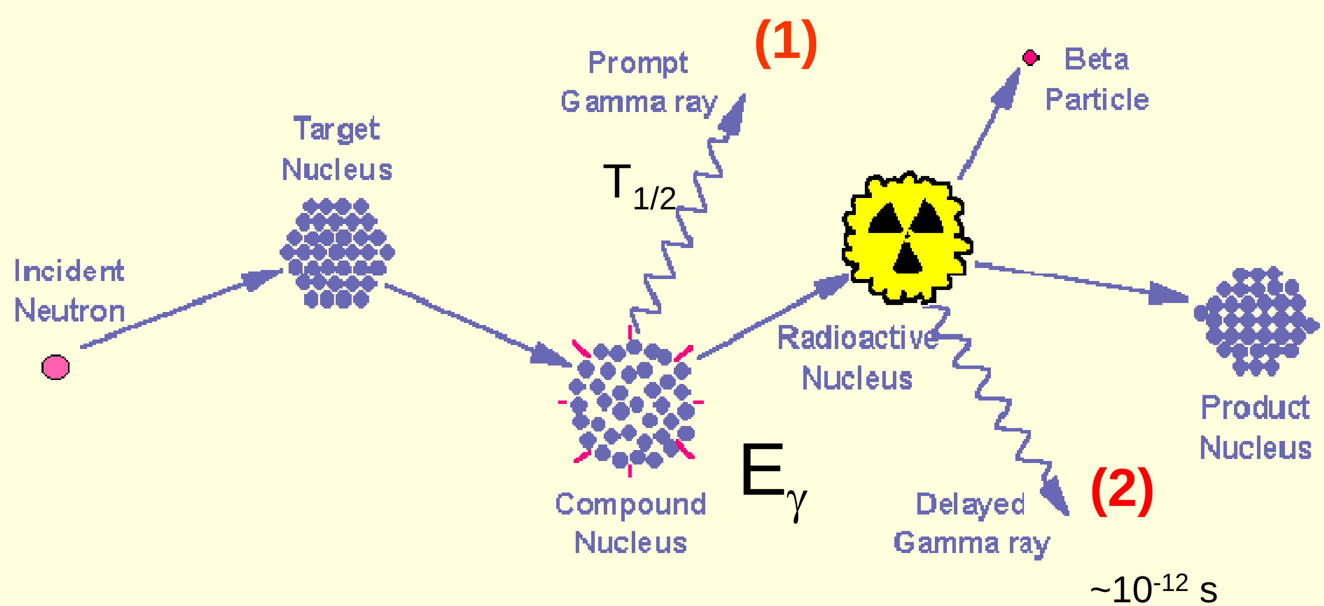
Neutron Activation Analysis -NAA

Neutron capture by a target nucleus followed by emission of gamma rays



(1) Prompt-gamma neutron activation analysis (PGNAA)

(2) Delayed-gamma neutron activation analysis (NAA)

Instrumental (INAA), *minimum sample preparation*

Radiochemical (RNAA), *chemical analysis of the sample*

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Neutrons tomography image

Very high interaction probability of thermal neutrons with H, C and O

Hercules Pomarius,
Willem van Tetrode’s, 1520-1588
Renaissance bronze figurine

Grey color: Bronze
Yellow color: Core material (silicate based, clay)

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R. Van Lang et al. , ABC, 395, 7, 2009, 1949-1959

El-Greco: The Baptism of Christ (1568)

- nd techniques before cleaning
  - CT scan
  - X-ray radiography
  - UV,VIS, IR examination with a multi-spectral imaging
  - Holographic interferometry (1)
  - Stereoscope
  - nd XRF (analysis of 30 spots in 4 hours at 15 and 40 KeV)
- nd techniques after cleaning
  - FT n-IR
  - LIBS
  - Holographic interferometry (2)

Aloupie et al, Benaki, Journal, 2006

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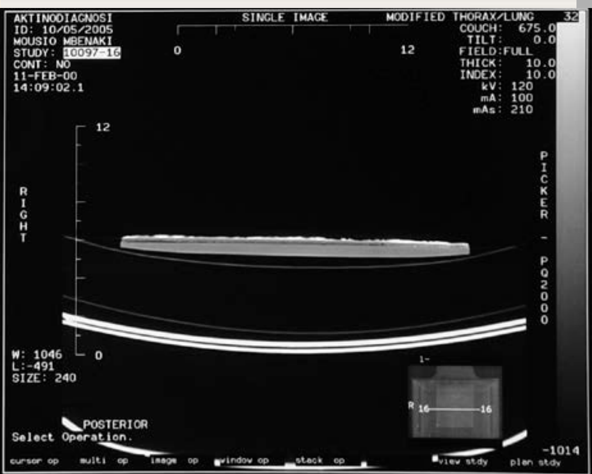
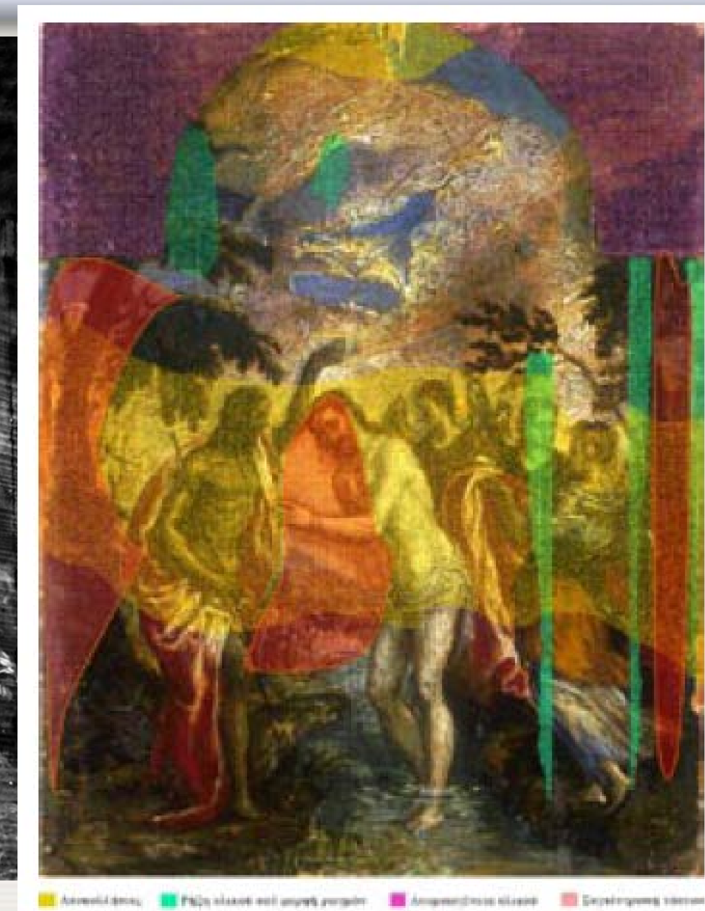
El-Greco: The Baptism of Christ



Computer Aided Tomography (CAT)

Aloupie et al, Benaki, 2006

X-Radiography



Digital holographic speckle interferometry by IESL-FORTH

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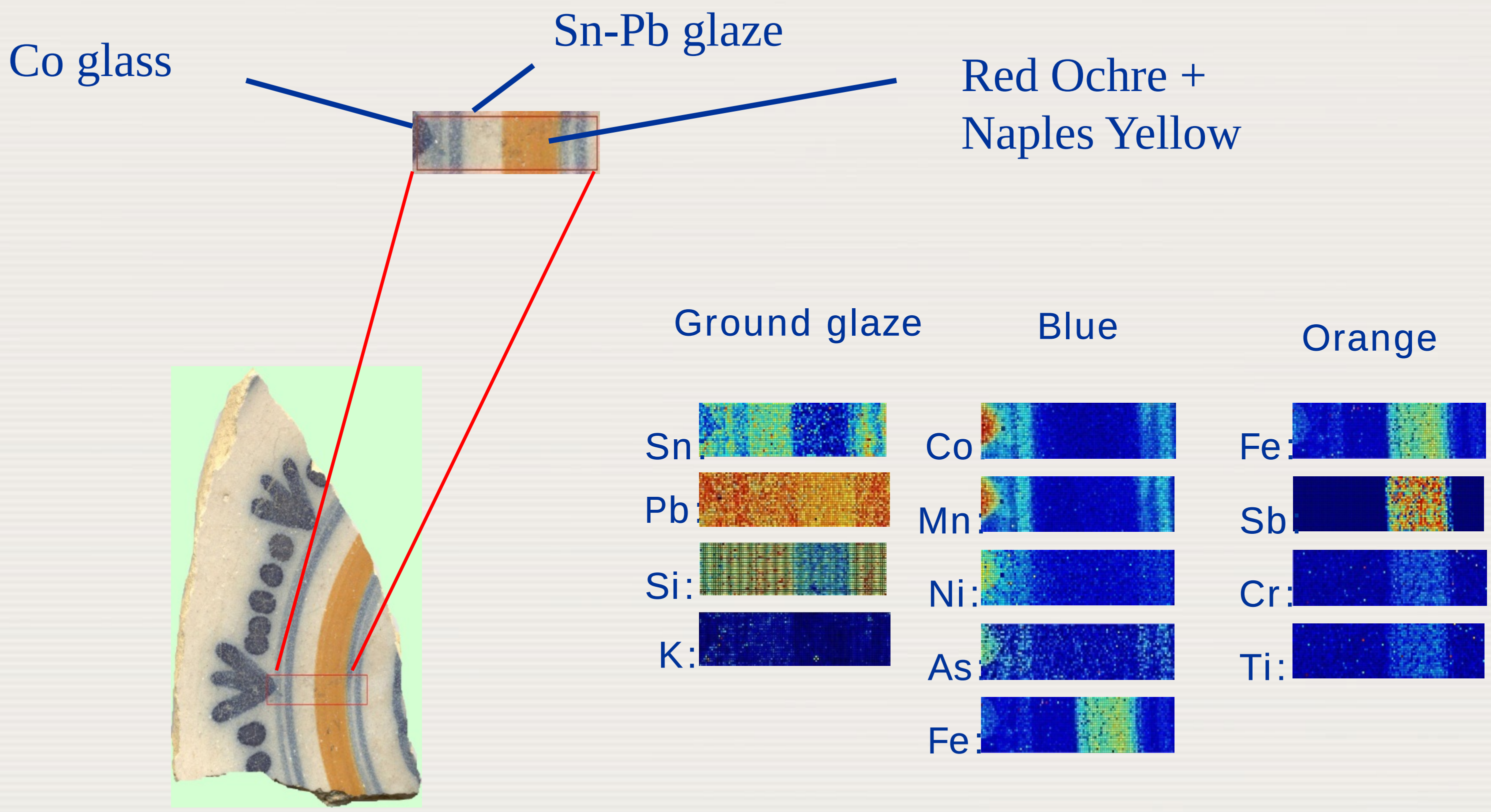
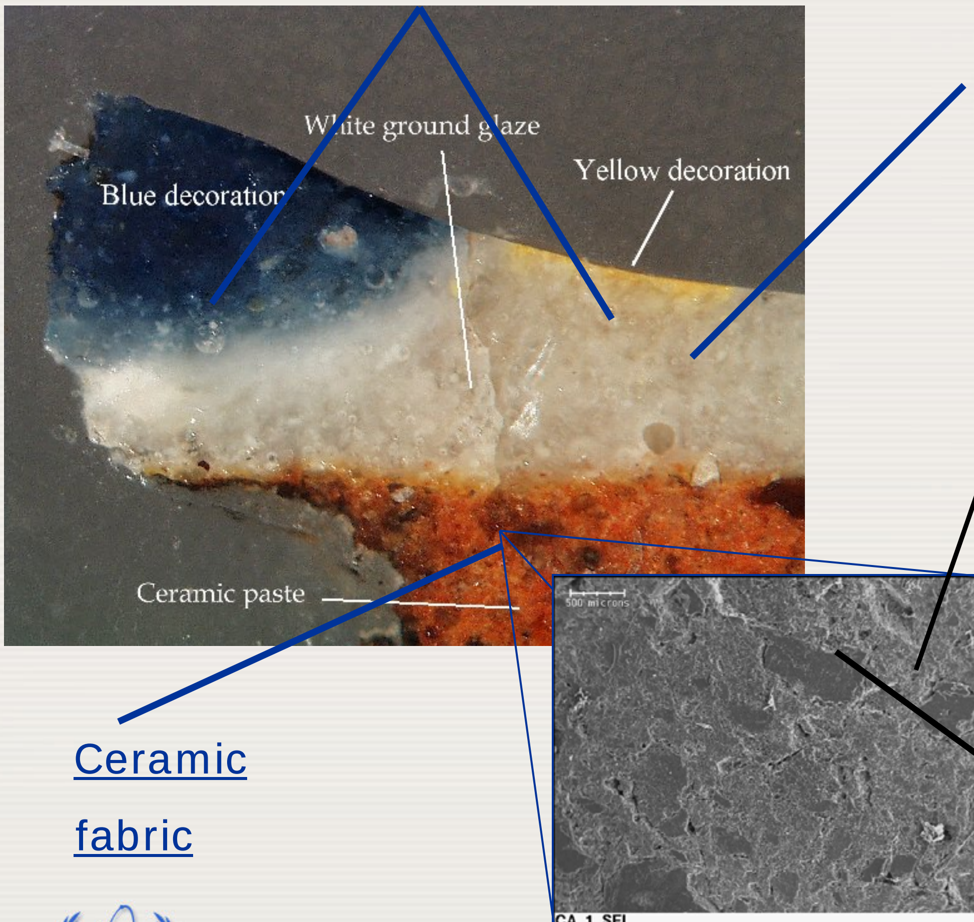
μ-XRF identification of coloring materials in Majolica glazes (XVIII)



What can be informative in ceramic analysis?

Color decorations…which can be quite heterogeneous



Ground glaze:

Proportions of major constituents (Alkali or lead oxides, tin oxide, aluminum from using clays, etc.)

Trace elements in the main constituent

Fired clay fraction:

Elements that have higher variability in the geological diversity, and which concentrate in hydrolyzed sediments

Temper inclusions:

Elements that form the more abundant minerals

Ceramic fabric

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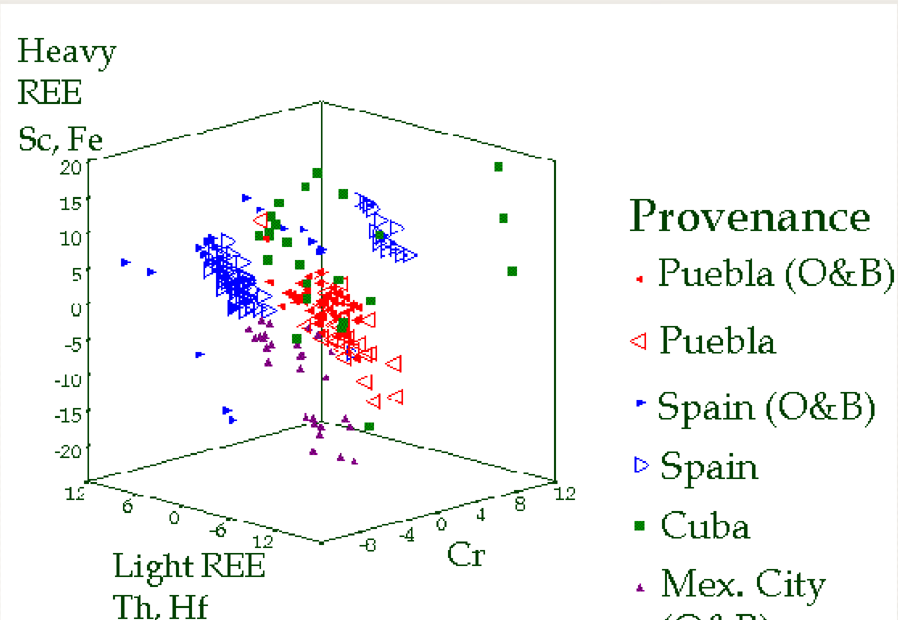
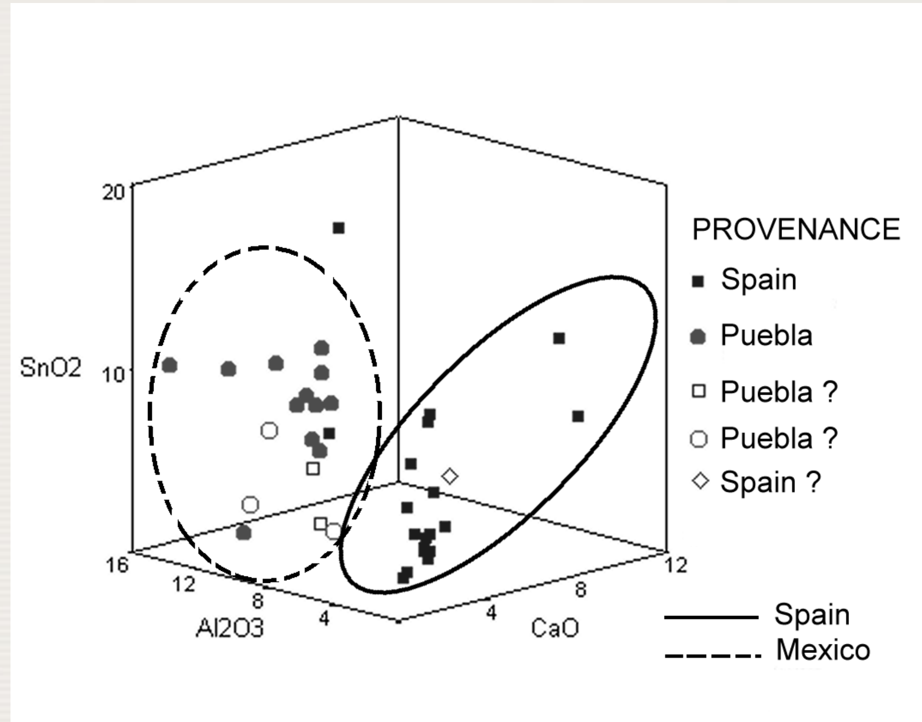
Case 1: Classification of Majolica based on non-destructive glaze analysis

Ceramic fabric

White glaze



NAA



μ-XRF

Ref: *R. Padilla, Schalm O., Van Espen P., Janssens K., Arrazcaeta R. Micro analytical characterization of surface decoration in Majolica pottery. Analytica Chimica Acta 535(2005) 201-211*

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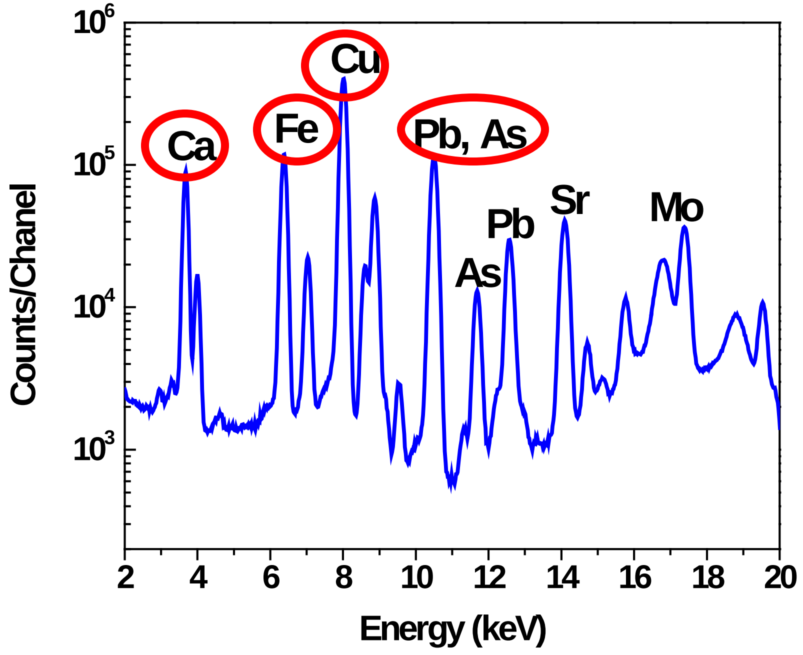
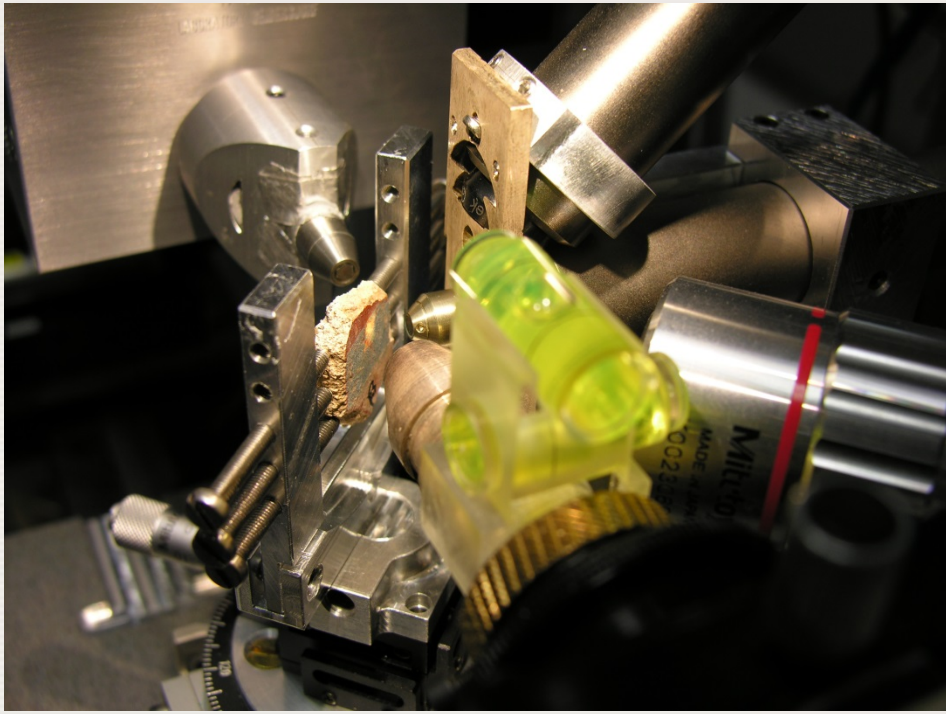
3D analysis of Roman period (2 cent BC) painted plasters @IAEA Laboratories

In support of understanding the elaboration of raw materials and application of painting techniques in antiquity.





Micro-XRF spectrum from the analysis on extended area

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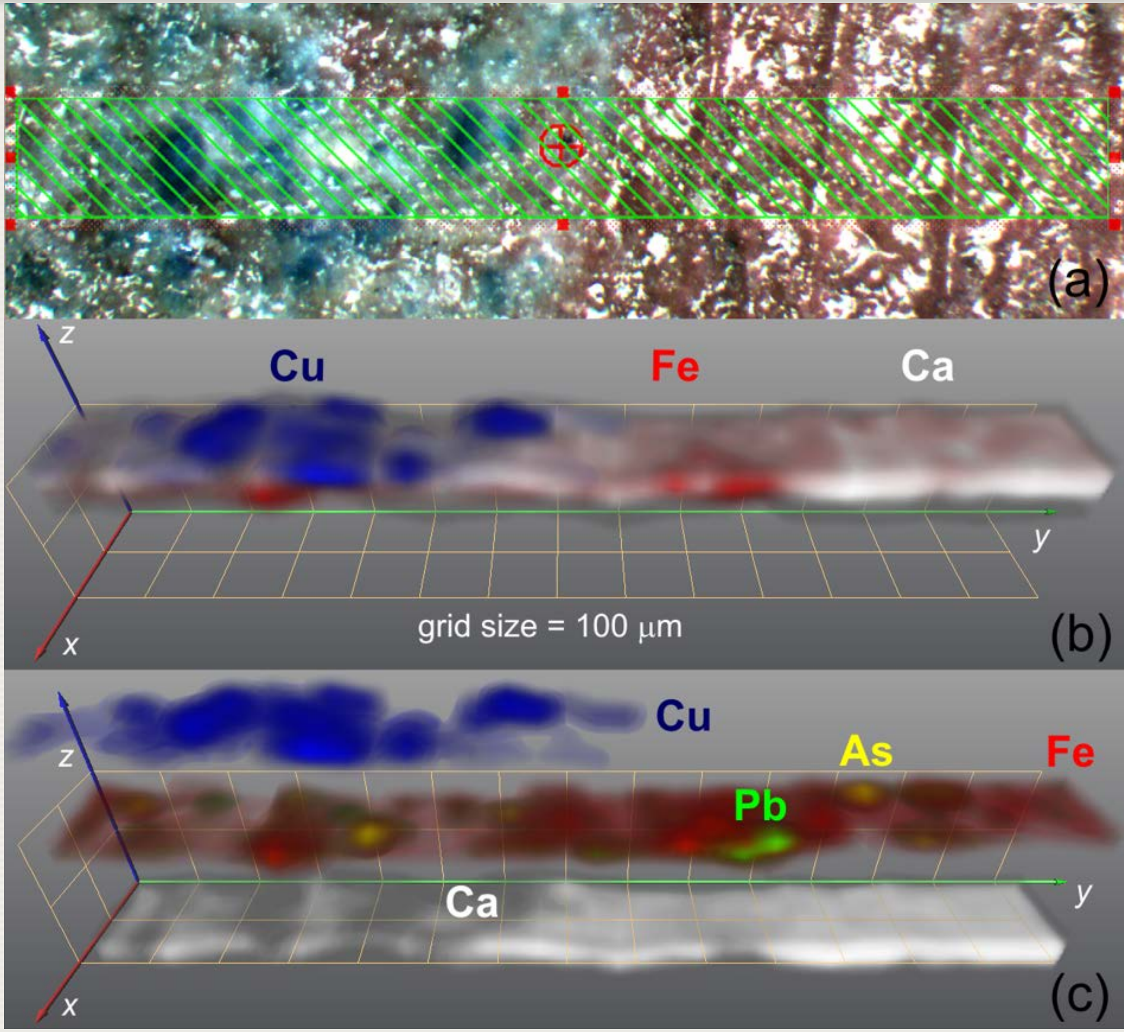
3D analysis of Roman period (2 cent BC) painted plasters @IAEA Laboratories

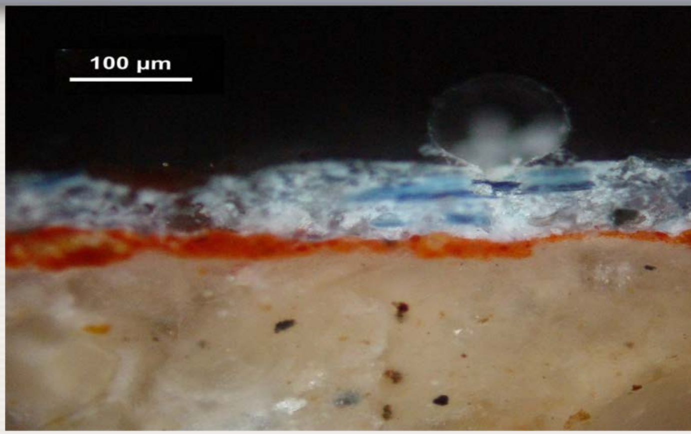
Egyptian Blue (Cu)
Red ochre (Fe)

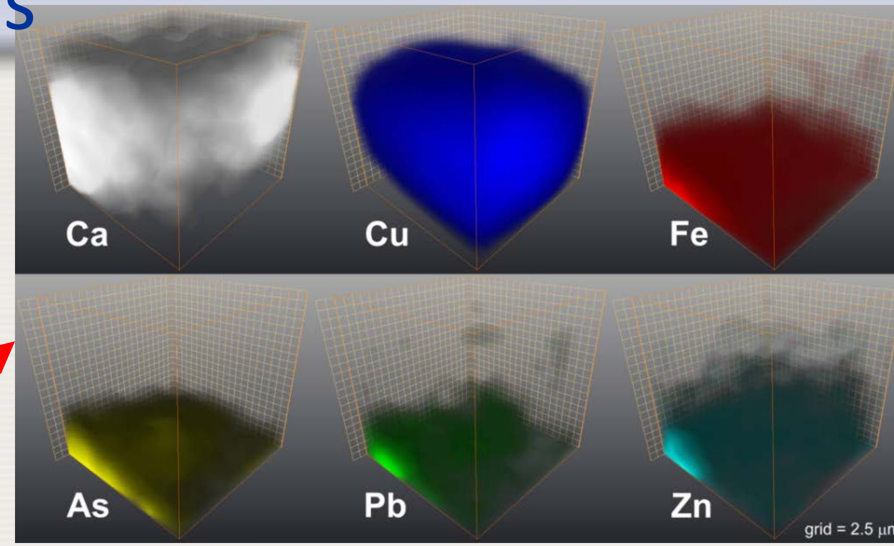
Pb and As are constituents trace-minor elements of the iron based ochre paint layer

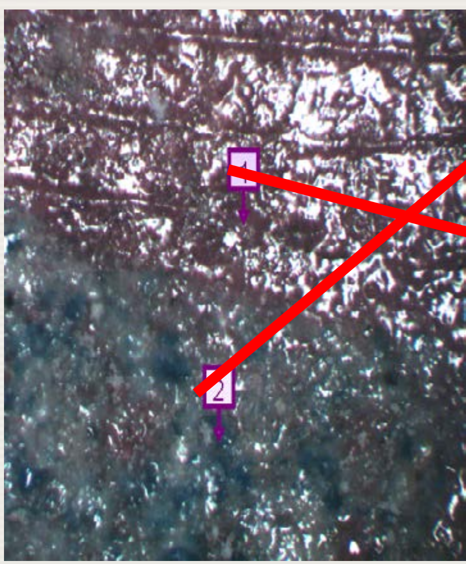
Volume:
20 µm x 1440 µm x 293 µm,
xyz scanning spacing:
40 µm X 40 µm x 3 µm



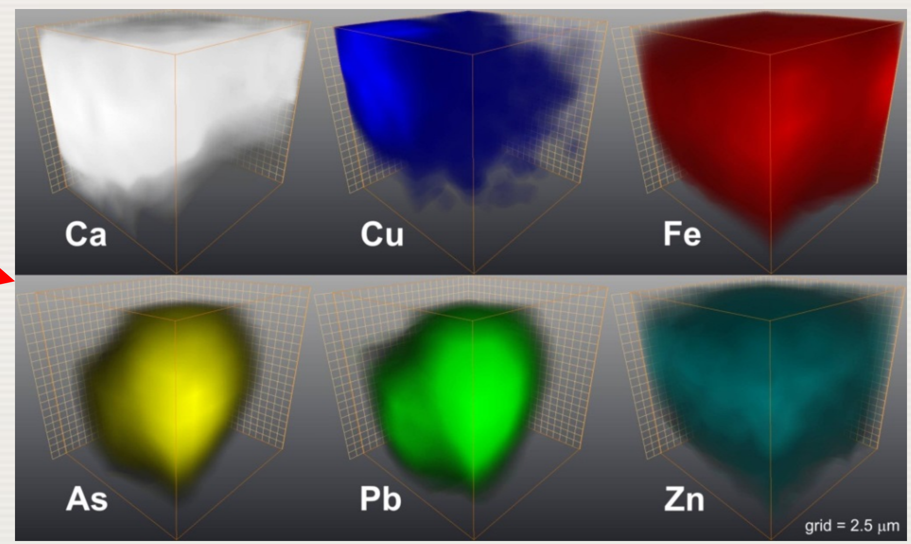
3D analysis of Roman period (2nd cent. BC) painted plasters @IAEA Laboratories







56 µm/55 µm/55µm
5.6 µm/5.5 µm/5µm



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Comment

- The complexity of cultural heritage related materials due to their heterogeneity at different scale of magnitude and diversity of contained materials requires the optimized synergistic application of different analytical techniques based on radiation probes

- The big advantage of radiation probes in CH is that in several cases the analysis and full characterization can be conduced in a fully non-invasive way and some times in-situ

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Mexican Feathered Headdress

The 16th century feather headdress in the Museum of Ethnology Vienna is the most renowned of the few remaining pre-Columbian “Arte Plumaria” artefacts, which were made by feather artisans (*Amantecas*) using traditional techniques in the territory of present day Mexico. The recorded history of the headdress begins in 1596, when it is first mentioned in the estate inventory of the art collection of Archduke Ferdinand II of Tyrol at Ambras Castle [1]. Due to its age, the variety of materials used, its history and former restoration treatments, the artefact today is one of the most sensitive and demanding objects of the museum. Concerning the study of the piece itself the emphasis lies on the identification of manufacturing techniques, the various materials, the old restoration measures and its conservation.

Mexican Feathered Headress

- **Aim of the study:**
- Revealing the presence of inorganic toxic elements that could be associated to the

use of pesticides in past conservation interventions,

- Identifying pigments on the structural elements of the object
- Distinguishing the authentic gold and the gilded brass ornaments, which were

added in the 19th century.

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Mexican Feathered Headress

- **Experimental:**

Handheld XRF (Niton XL3t, GOLDD):

- miniaturized air-cooled X-ray tube (thin Ag anode in transmission geometry)
- Max. operational values: 50 kV, 200 μA, 2.5 W
- SDD detector (30 mm^2, 178 eV)

Measurement conditions:

- Main: 50 kV, filtered
- Light: 8 kV, unfiltered

Saliera

http://www.youtube.com/watch?v=mZuhhdN33l8

IAEA Helps Protect a Once-stolen Masterpiece
Boldly stolen and then buried deep in an Austrian forest, the 16th century golden masterpiece called the Saliera has found its way into the hands of nuclear detectives and 21st century technology. Vienna´s curators, historians, and art lovers could not be happier.

The END