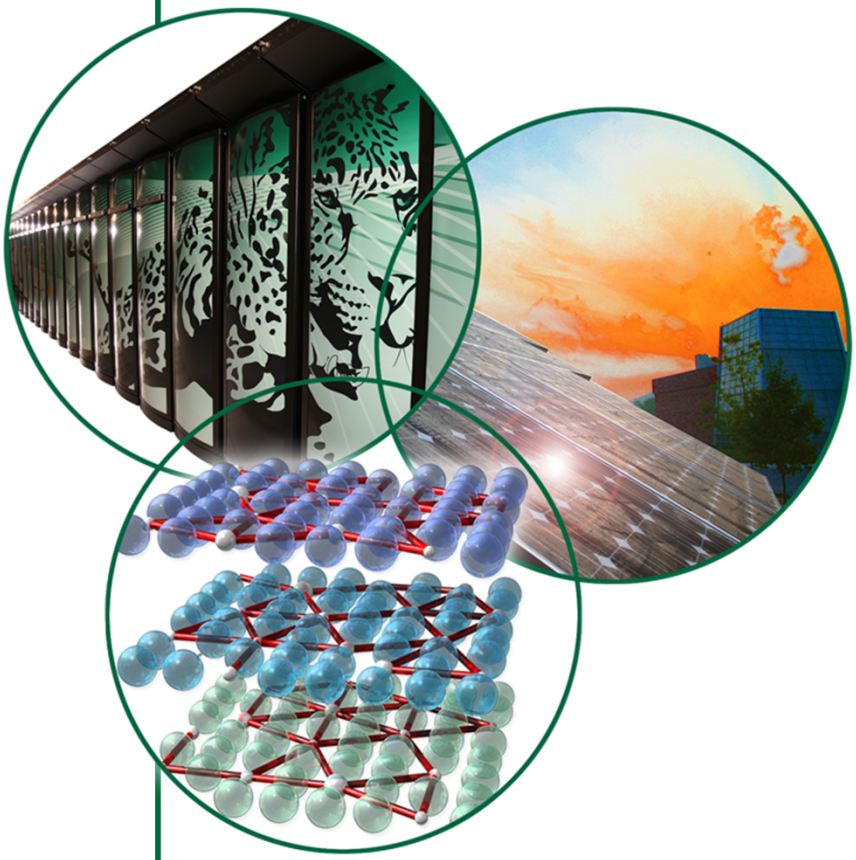
Field Trial of a Highly Portable Coded Aperture Gamma Ray and 3D Imaging System

Ana C. Raffo-Caiado
International Safeguards Group
Global Nuclear Security Technology Division



34th ESARDA Working Group Meeting
Luxembourg
22-24 May 2012

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Introduction

- First field trial of a 3D + gamma-ray imaging system
- Instrumentation tested is able to Image, Detect and Identify the type and location of nuclear material
- Trial took place at the Paducah Gaseous Enrichment Diffusion Plant, during 5 days in August 2011
  - Only operating enrichment facility in the United States
  - Produces low enriched nuclear fuel for power plants
  - Facility has been in operation since 1952
  - Four large process buildings comprise over 70 acres of factory space
  - Collected data at several locations. All data collection, processing, and analysis were performed on site using automated software developed for use on the sensor

What Were We Testing For

- Verification of declared technical design information of nuclear facilities is an important aspect of every safeguards approach
- In addition to visual observation, it is relevant to know if undeclared nuclear material is present or has been present in equipment piping and ducts
- The system under investigation allows
  - Identification of changes in piping configurations
  - Location of radioactive material in places where it is not supposed to be, for example in a declared cooling pipe that holds radioactive material

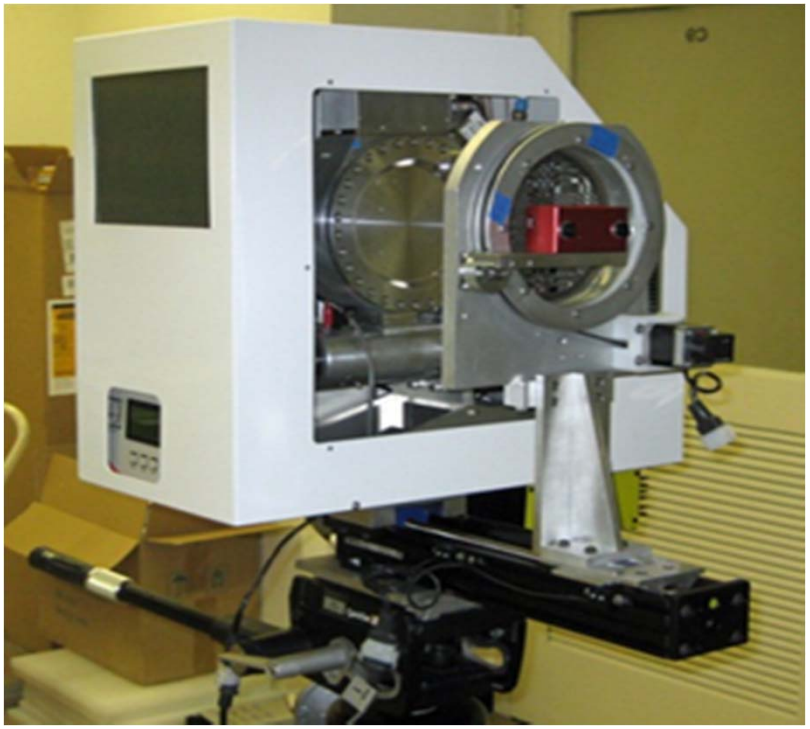
3D Laser Scanner

3D Laser Scanning System
IMAGER 5006

- Developed by JRC-Ispra
- Manufactured by Zoller + Froehlich GmbH (Z+F)
- High-quality, 3D data of the environment surrounding the gamma-ray imager
- Automatically surveys objects within a 360º field of view to determine their location, size, orientation, and form
- Scanner produces high-resolution images by utilizing a sampling rate of up to 500,000 pixels per second
- Collects a set of 3D coordinates and intensities with submillimeter accuracy
- Typical high-resolution scan completes in less than 7 minutes.

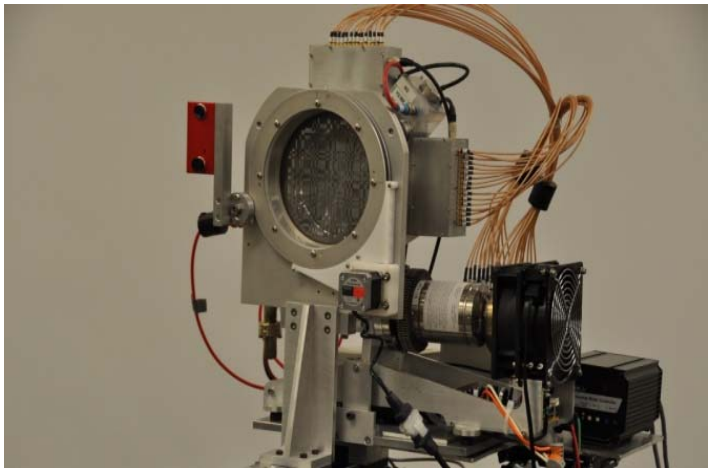
Coded Aperture Imager

- Commercially available mechanically cooled HPGe detector (PHDs Co.) double-sided strip readout using a USB-based, 32-channel system provided by the manufacturer
- Achieves a position resolution of the order of 1 mm in all three dimensions
- Electronics-limited energy resolution of order 1.4 keV full width half maximum
- Weight: ~25 kg
- Operated using an enclosed touch screen computer and housed on a mobile tripod
- Software has been updated to handle motors that perform the mask/antimask rotation automatically
- Focal distance is now handled under computer control as well

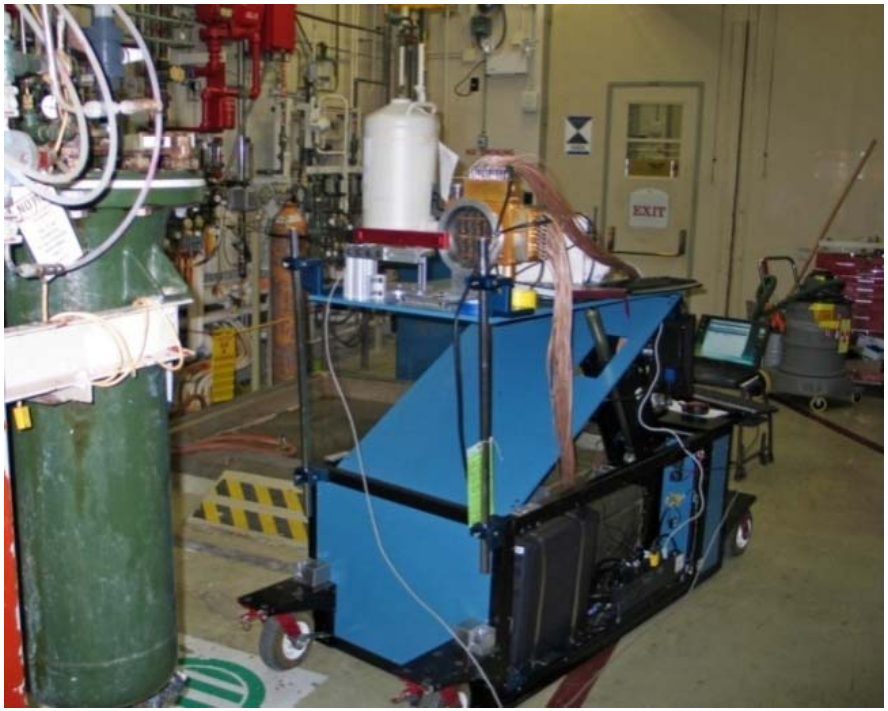


Coded Aperture Imager

- A 1.5 mm thick tungsten modified uniformly redundant array coded-aperture mask is used to encode the images onto the position-sensitive detector
- The mask is designed so that each source in the field of view projects a unique shadow pattern onto the detector
- The patterns from different source locations are mutually orthogonal so that an artifact-free image can be recreated from the measured shadow pattern even if multiple or extended radiation sources are in the field of view.
- A commercial stereo camera is connected to the mask holder.



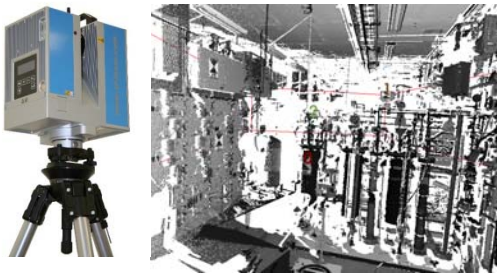
Coded Aperture Imager



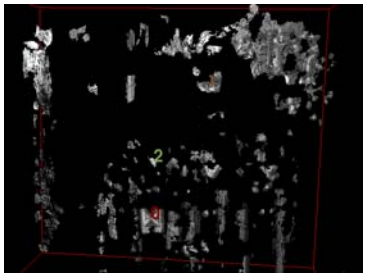
First-generation gamma imager, which required liquid nitrogen cooling and could not be hand-carried

New gamma ray imaging and stereo device

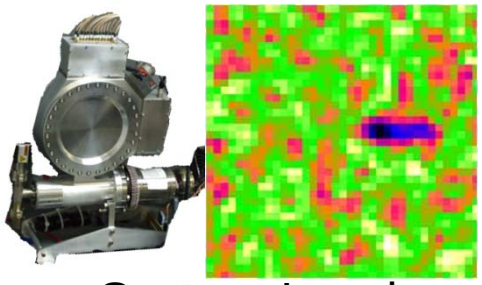
Preliminary Results
Gamma Projection onto 3D Space



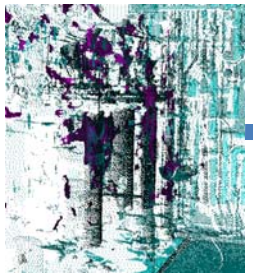
Laser Scanner



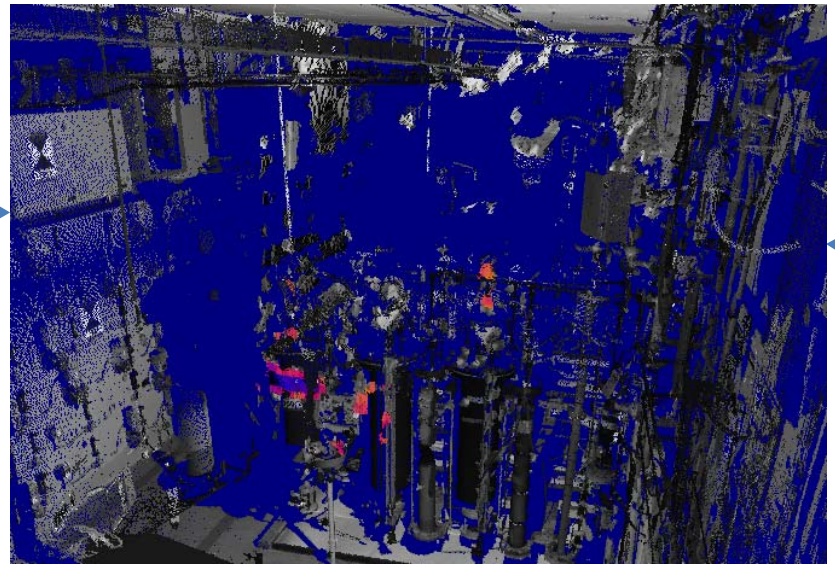
Stereo Vision



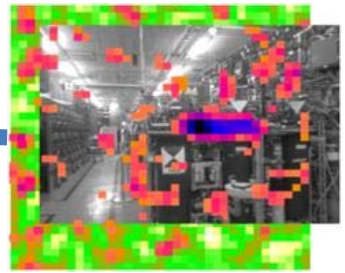
Gamma Imaging



3D alignment based upon corresponded points



Gamma image projection onto laser scan



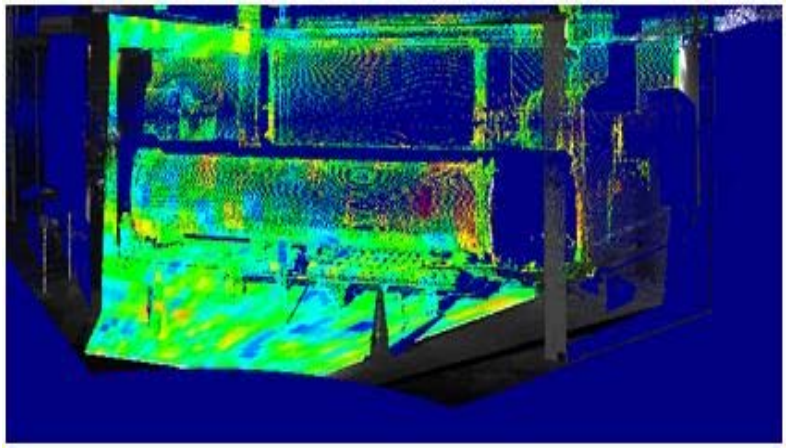
Physically connected with calibrated alignment

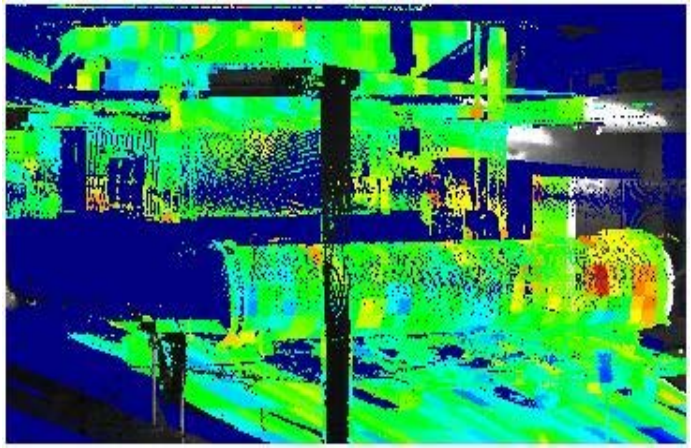
Field Trial—Issues and Solutions

- With the imager:
  - Overheating. Operator provided a portable air-conditioning unit
- With the stereo vision sensor :
  - Unaffected by the heat, vibrations, or other general environmental factors
  - Problems with low light levels in certain imaging locations
- With the 3D laser scanner:
  - Performed remarkably well even near its operating temperature limits. Lithium-ion batteries were removed and stored in an air-conditioned room overnight
  - Workers passing by during scans. To reduce the number of interruptions, a smaller field of view could be used and reduce the scan time

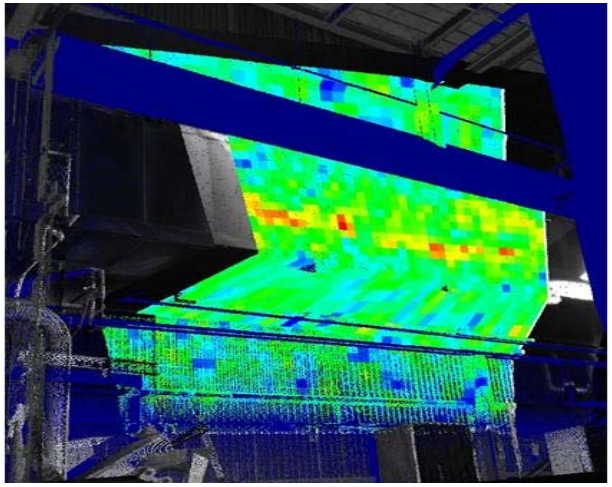
Paducah NDA section manager and Dr. Klaus-Peter Ziock, from ORNL, use the gamma-ray imager to measure a spot deposit identified within the ceiling gallery

Field Trial—Results

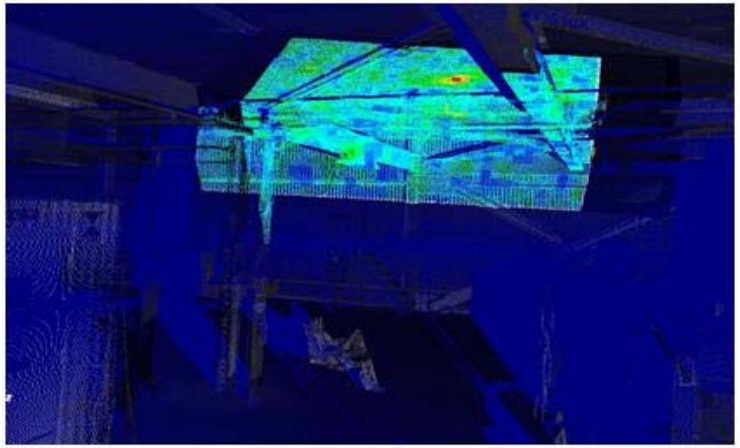




Two 3D views of piping section with right end containing radioactive material



Radioactive pipe flowing through gallery



Location of spot deposit identified within ceiling gallery

Conclusions

- The sensors performed well during the field trial and successfully produced good images
- The gamma-ray imager can be carried by two people, can be assembled on site using simple tools, and can be moved around and operated by a single person
- The laser scanner requires only one person for assembly. The software is user-friendly and was operated on site to combine all of the data in an automated fashion, requiring only a few minutes and clicks of the mouse
- The only challenge faced by the instruments was the thermal environment
  - The mechanical cooler of the gamma-ray imager was unable to handle the hot factory environment
  - This limitation was overcome using a portable air-conditioning unit. In the future, we believe airflow and cooling could be improved
- Instrumentation is field portable and can be successfully operated in the demanding environment of a uranium enrichment plant
- Results show that the associated software can be used to combine the data from the two separate instruments in under 10 minutes

Acknowledgments

Many thanks to:

The entire US Enrichment Corporation staff at the Paducah enrichment facility, who made this field trial possible

Our sponsors and collaborators at other facilities who have participated in various aspects of the development of this project, including

- The U.S. Department of Energy
- The European Atomic Energy Commission
- The Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials