



IAEA

International Atomic Energy Agency
Atoms for Peace and Development

Utilization of UAV Based Radiation Monitoring Technology for Radiological Mapping

IAEA Activities

Petr Sladek

IAEA Nuclear Science and Instrumentation Laboratory
Physics Section, Division Physical & Chemical Sciences
Department of Nuclear Sciences & Applications
Vienna, Austria
e-mail: p.sladek@iaea.org

Organizational Structure

Nuclear Science and Instrumentation Laboratory



IAEA, International Atomic Energy Agency

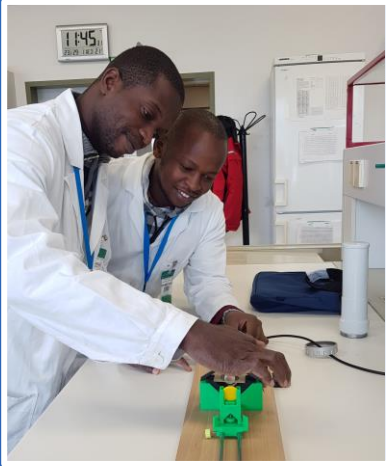


NAPC, Department of Nuclear Sciences and Applications



Physic Section

NSIL Activities



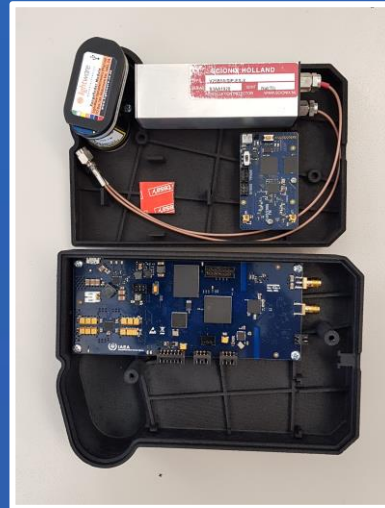
Trainings



Missions



Expertise



Development



Capacity Building

Nuclear Science and Instrumentation Laboratory
Helps Member States (MSs) to develop, operate and maintain various nuclear instrumentation and spectrometry techniques in support of a wide range of applications such as health care, food, agriculture, environment, forensics, cultural heritage, and materials science.

NSIL Projects - UAV Based Radiological Mapping



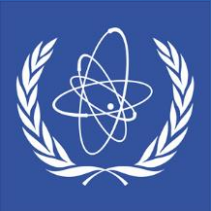
Project with Fukushima Prefecture, Japan 2018



Measurement Mission - San Rafael Argentina 2016



UAV Expert Mission Brazil 2018



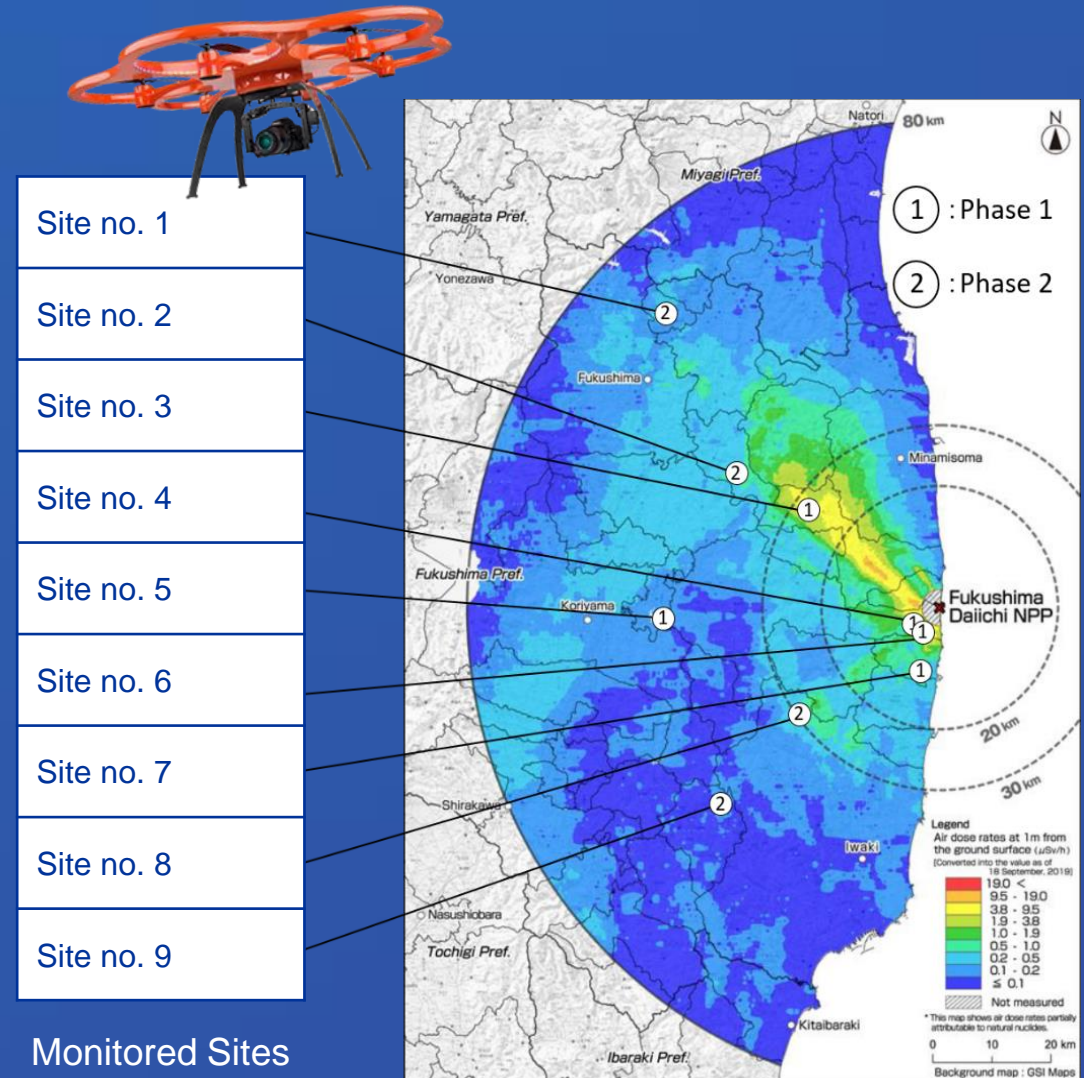
Project with Fukushima Prefecture 2012-2020



Rapid Environmental Mapping with UAV



UAV (Aibotix) based system and its instrumentation components delivered to the Fukushima Prefecture.

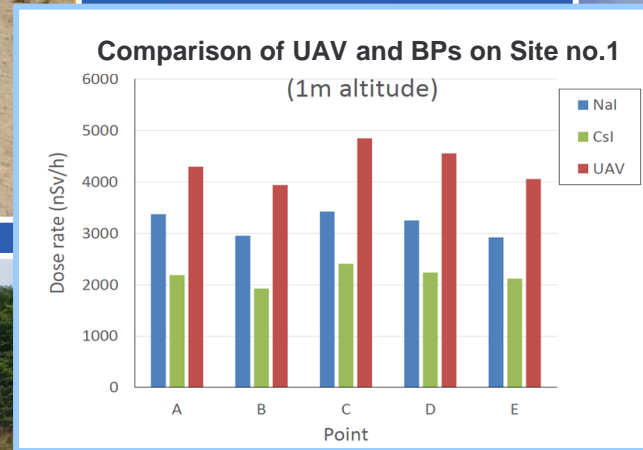


Monitored Sites

Project with FP – Verification of Methodology



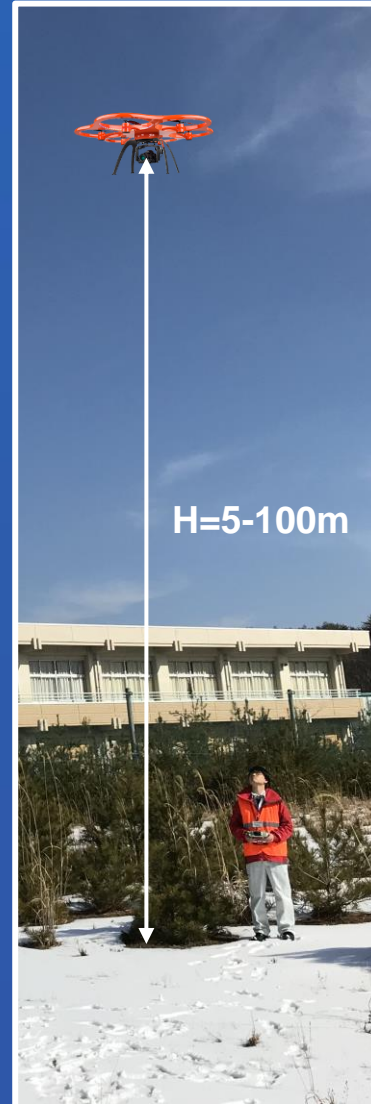
Comparison of
UAV and Ground
Measurement



Developed Methodology for Measurement
Verification of Dose Rate Compatibility (UAV vs Ground
Instruments) on Site

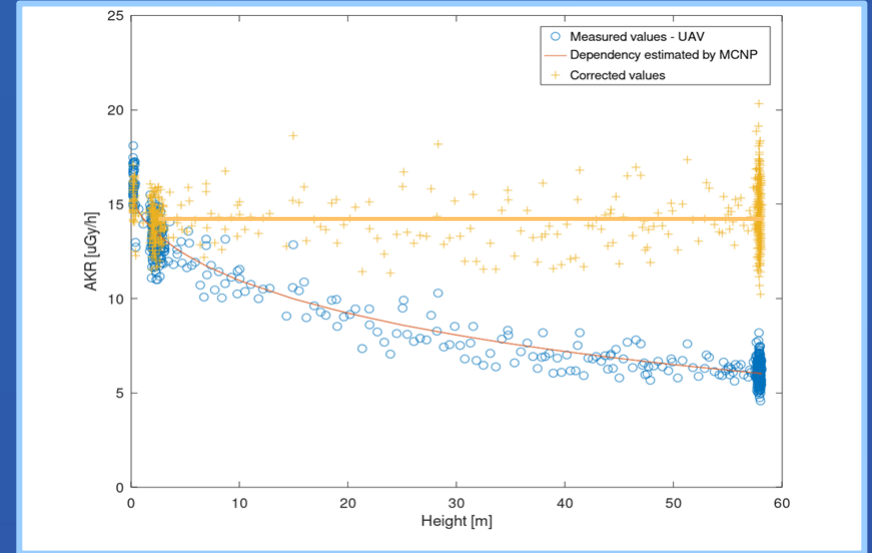
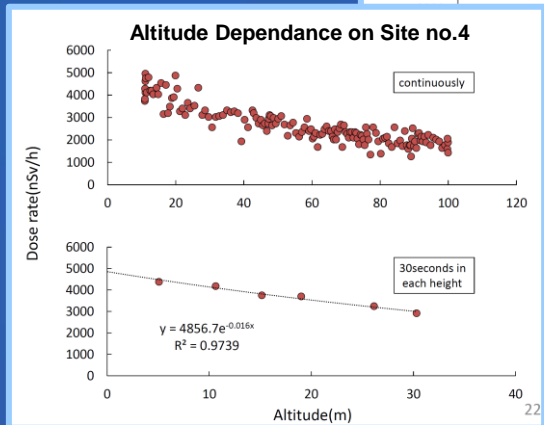
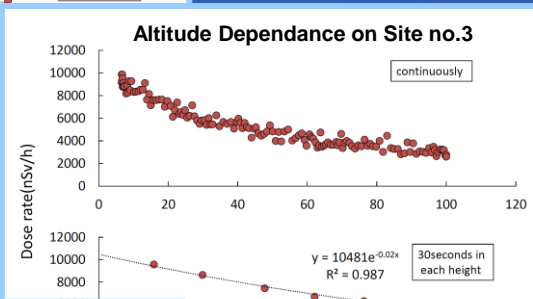
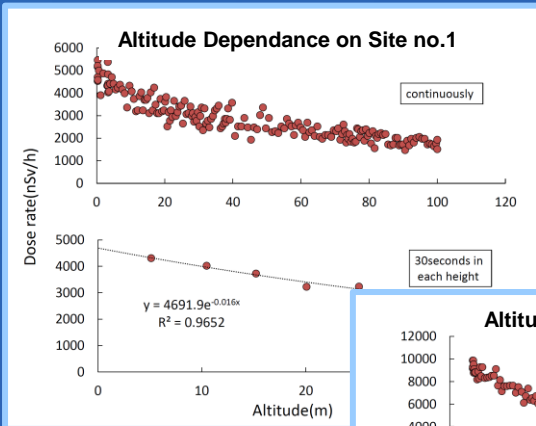
Project with FP – Altitude Correction

MCNP Modeling

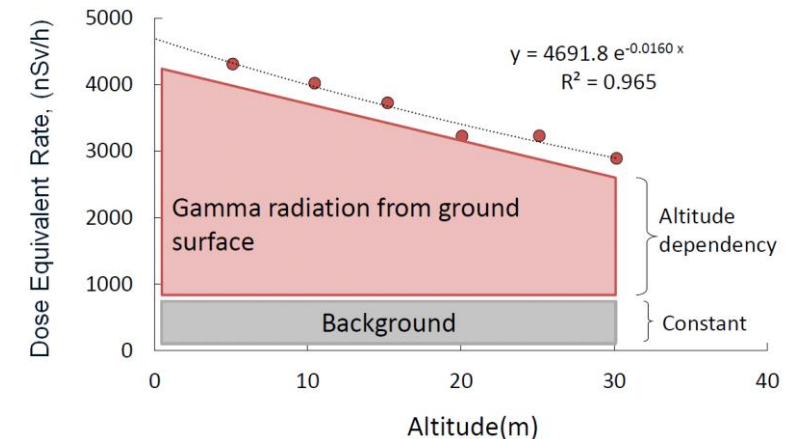


Experimental Data for Altitude Correction

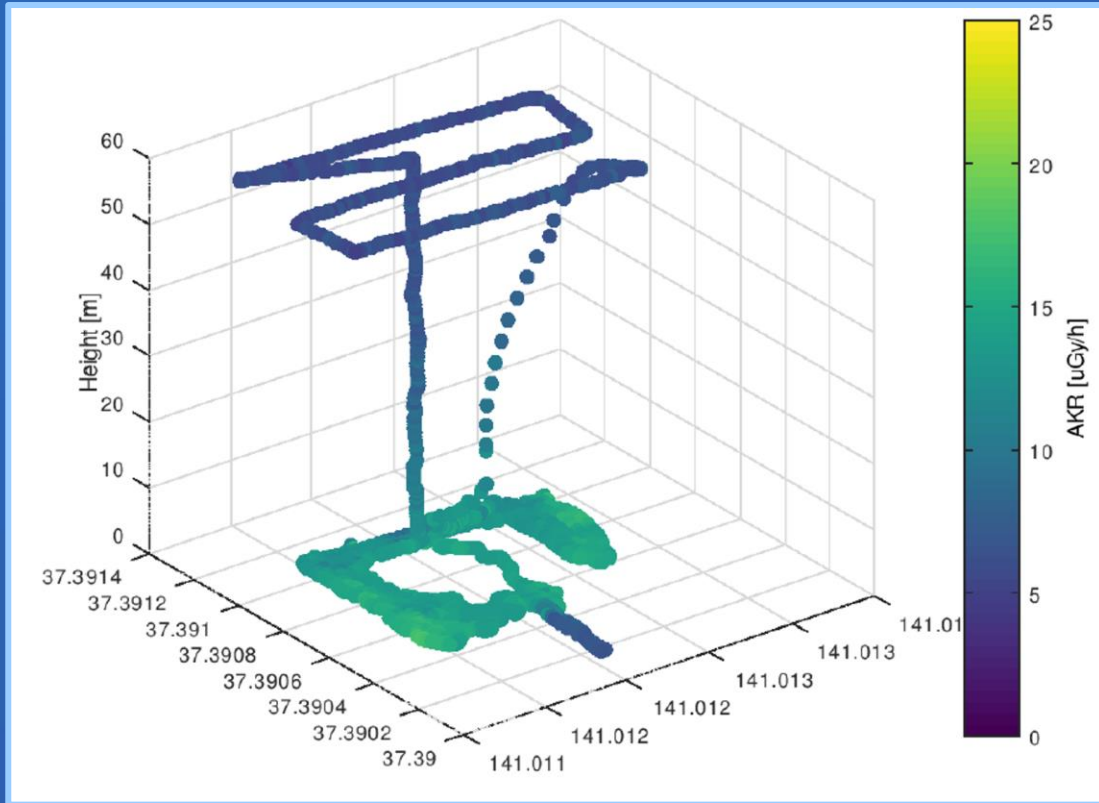
Different Level of Contamination



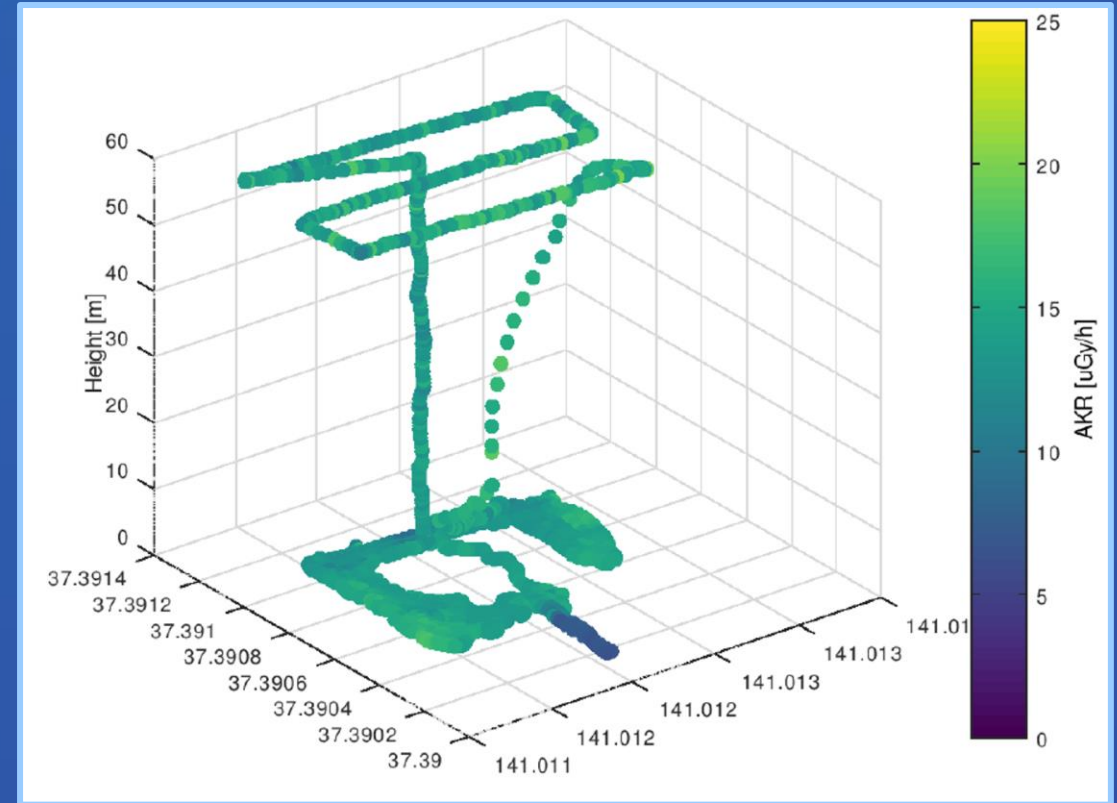
Final Model for Altitude Correction



Project with FP – Altitude Correction



Data from Ground and UAV Measurement
(Raw-Non Corrected)

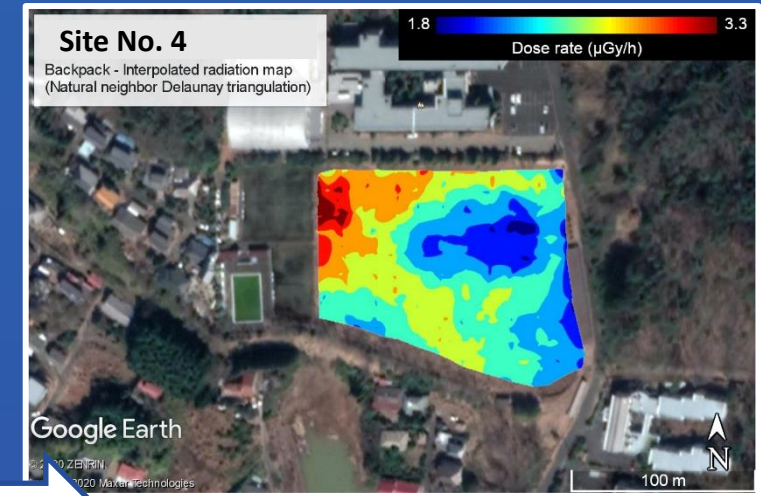
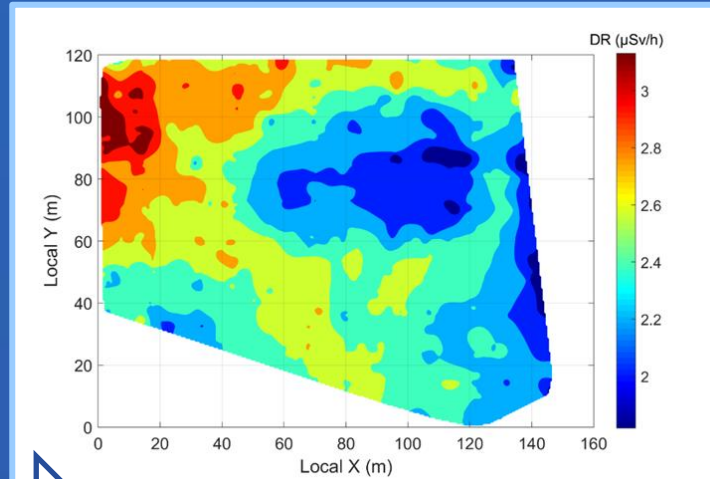
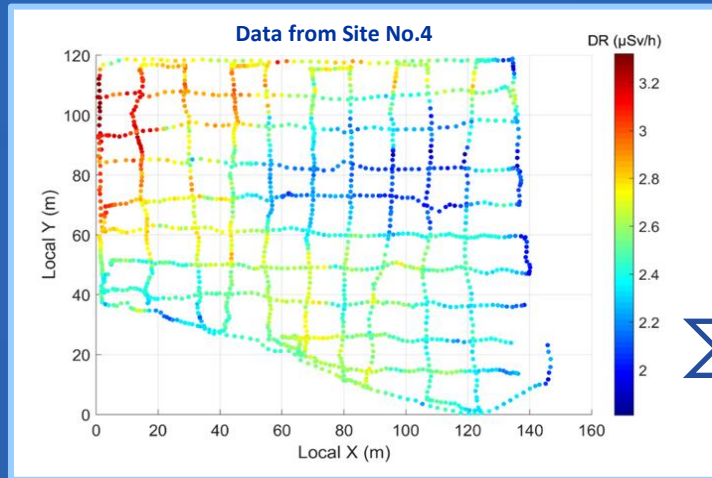


Data from Ground and UAV Measurement
(Corrected by MCNP to 1m Above Ground)

Project FP – Data Interpolation

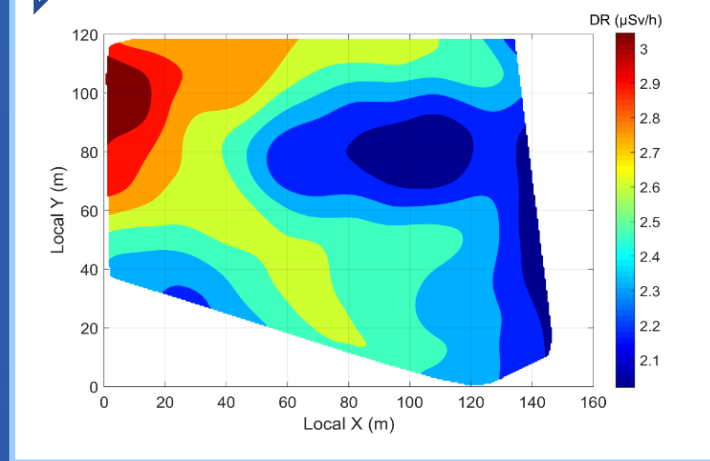
Natural Neighbour Delaunay Triangulation

Final Dose Rate Color Scale Map



Raw data from survey.

Method Optimization for
Data Interpolation and
Radiological Map
Creation

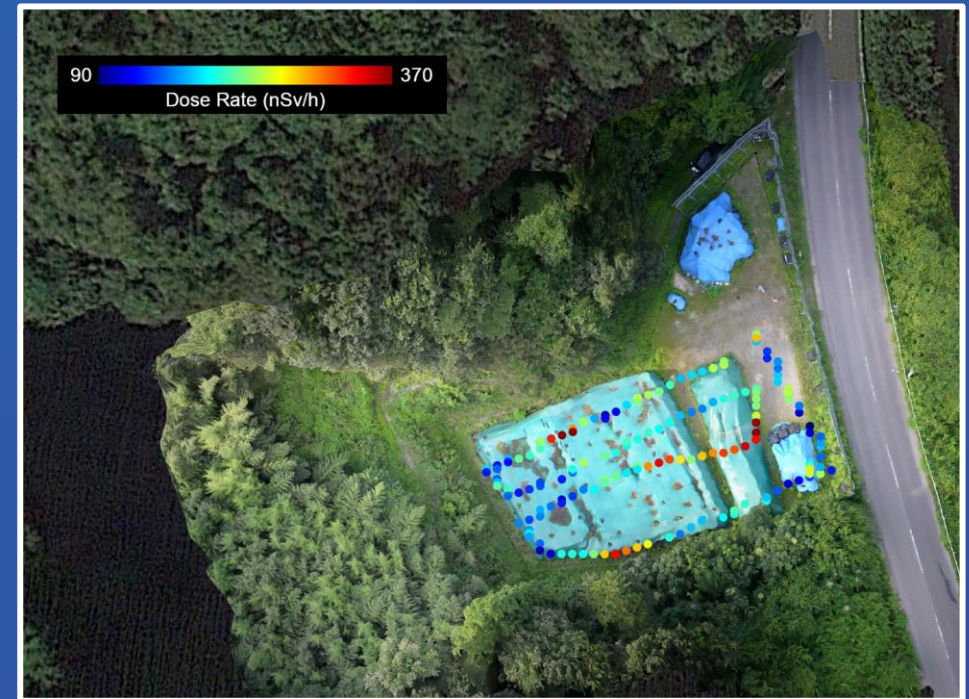
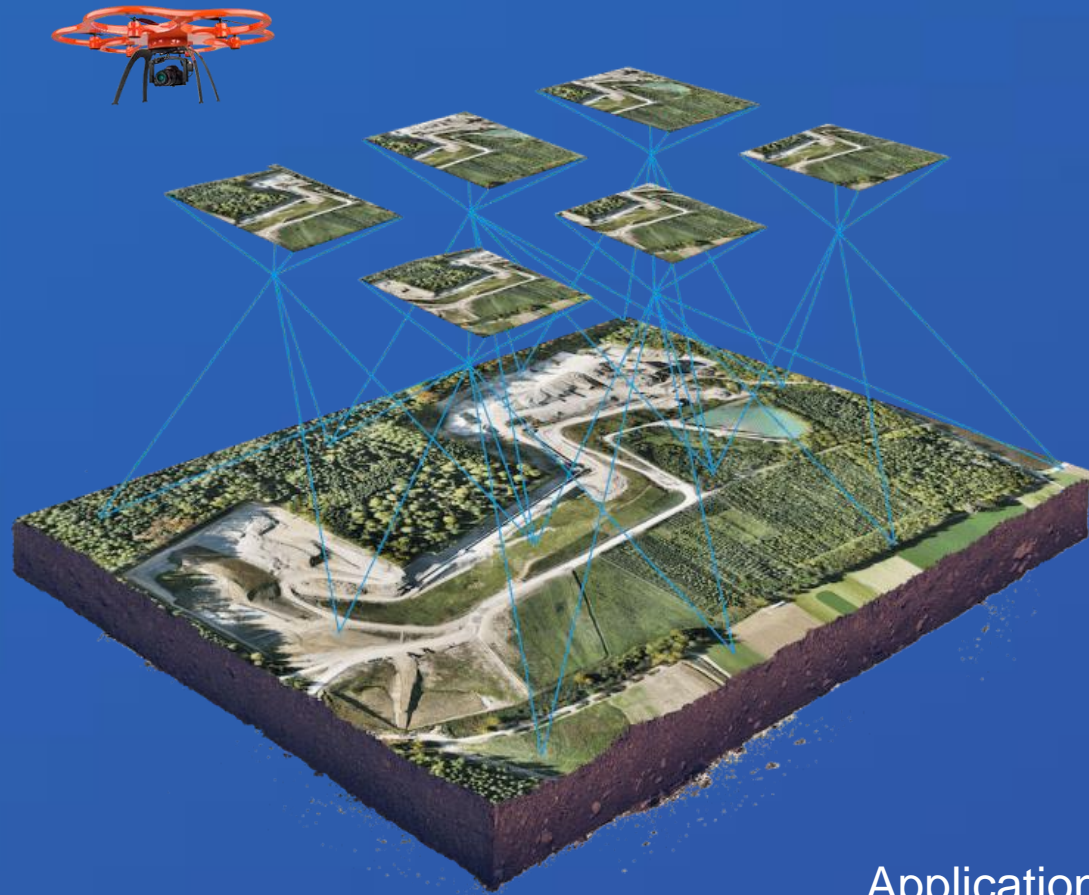


Thin-plate Spline Interpolation



Final Isodoses Map

Project with FP - Implementation of Photogrammetry for UAV Radiological Mapping

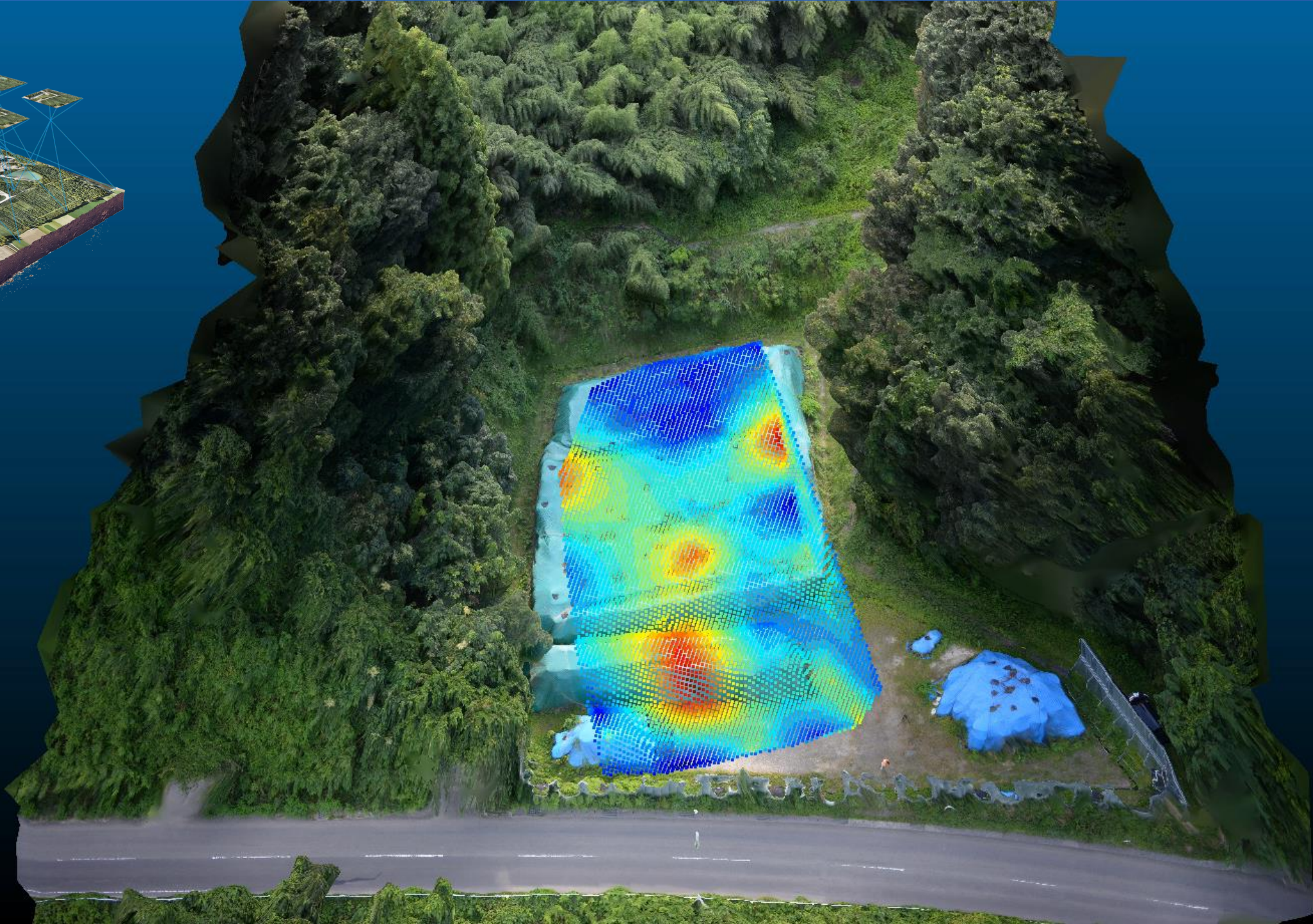
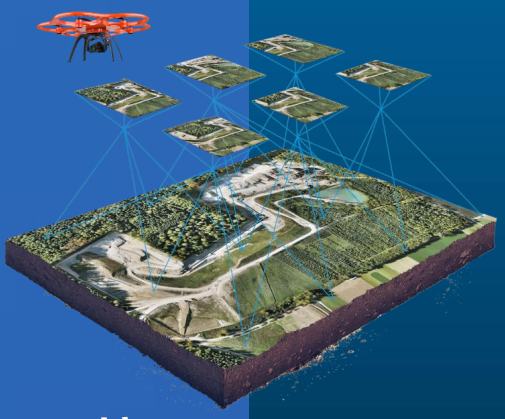


Application of UAV Photogrammetry for Radiological Mapping

3D Photogrammetry

Results of Monitoring - FP Project

Temporary Waste Storage Site



NSIL Current Development in UAV Based Technology

Testing of Commercially Available Systems



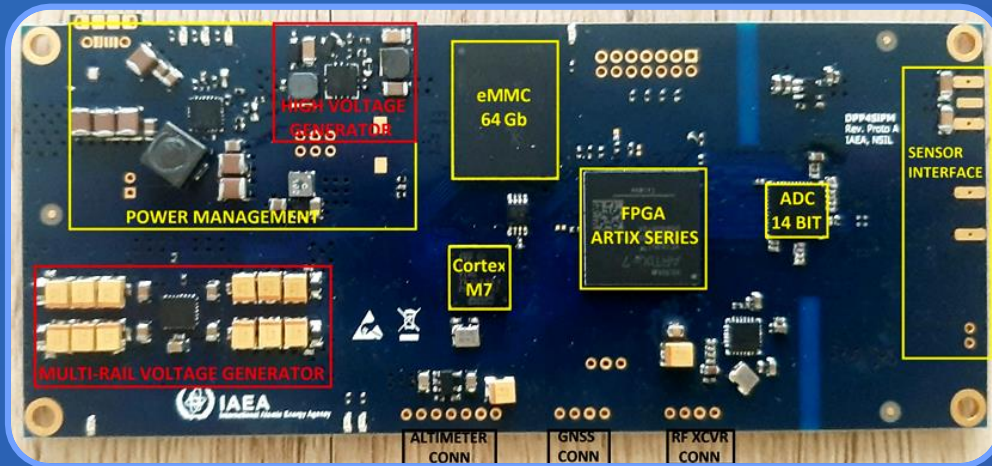
UAV DJI Matrice 210 V2 equipped by
commercial GS module
1x1" SiPM NaI(Tl)

Testing of NSIL Developed Systems

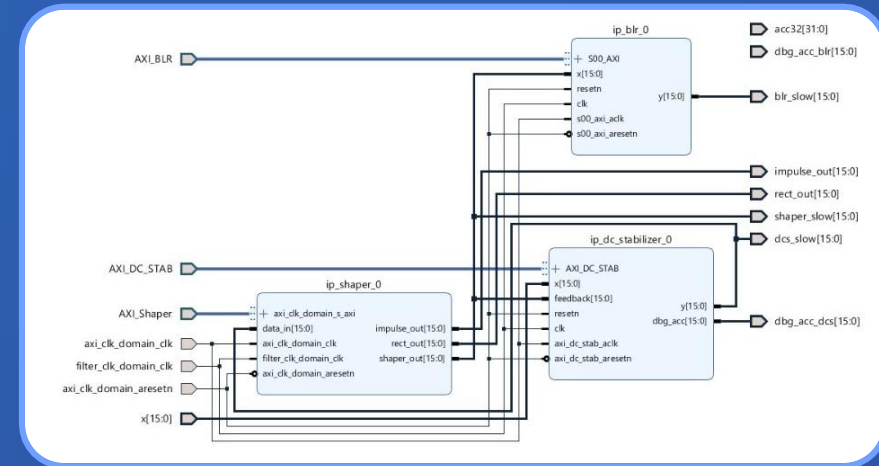


UAV DJI Matrice 210 V2 equipped by
experimental GS module
2x2" NaI(Tl) & 1.5x1.5" SiPM CeBr3

NSIL Current Development in UAV Based Technology



Digital Pulse Processor for UAV (MCA)



New Firmware for DPP



New Type of SiPM Detectors

Non-Hygroscopic Scintillator

Scintillation Detectors Suitable for UAV Application

Hygroscopic Scintillator

Plastic (BC-400)

LYSO

BGO

CdWO₄

LBC

CZT

CsI(Tl)

CLYC⁺

CeBr₃

SrI₂(Eu)

NaI(Tl+Li)

CLLB

LaBr₃(Ce+Sr)

NaI(Tl)

LaBr₃(Ce)

LaCl₃(Ce)

PHR @ 662 keV

N/A

12

10

8.0

7.0

4.5 to 3.5

3.3

2.7

2.2

1.8



Dual detection capability
(for neutron & gamma
identification by PSD method)



Yes for
NaI(Tl+Li)

Yes

Timing capability
(decay of the main
component if <100ns)

2.4ns

36ns

28ns

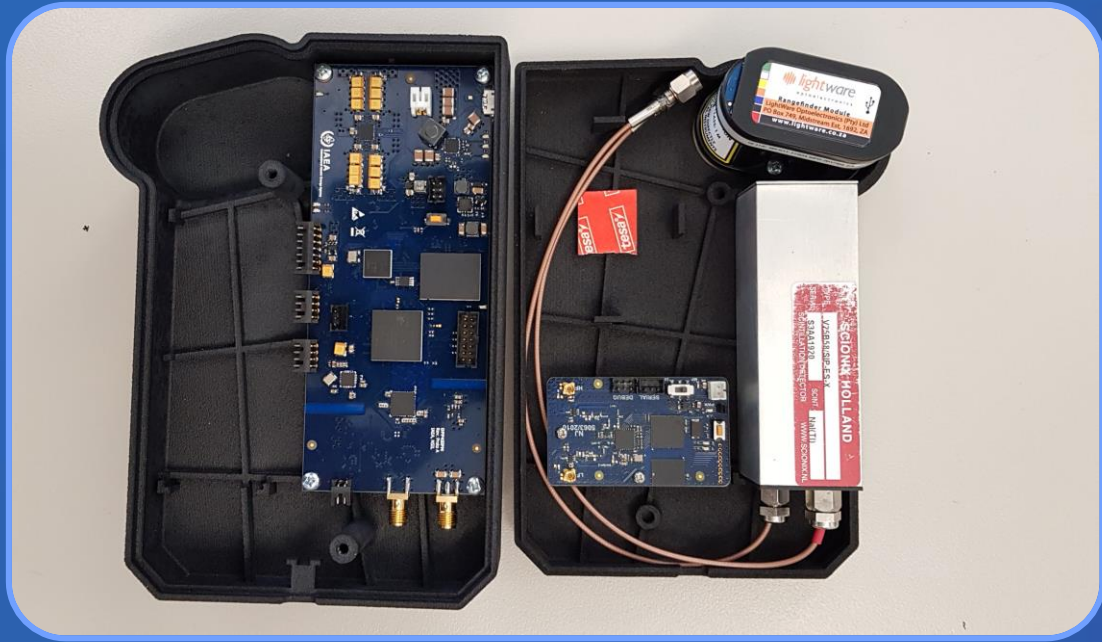
16ns

25ns

CZT – Cadmium Zinc Telluride (Semiconductor), LBC - LaBr_{2.85}Cl_{0.15}(Ce), ... Source: Saint-Gobain Crystals

NSIL Current Development in UAV Based Technology

Digital Pulse Processor for UAV (MCA)



+ GNSS Antenna, Laser Altimeter,
RF Communication, ...

Application of DPP Module on UAV

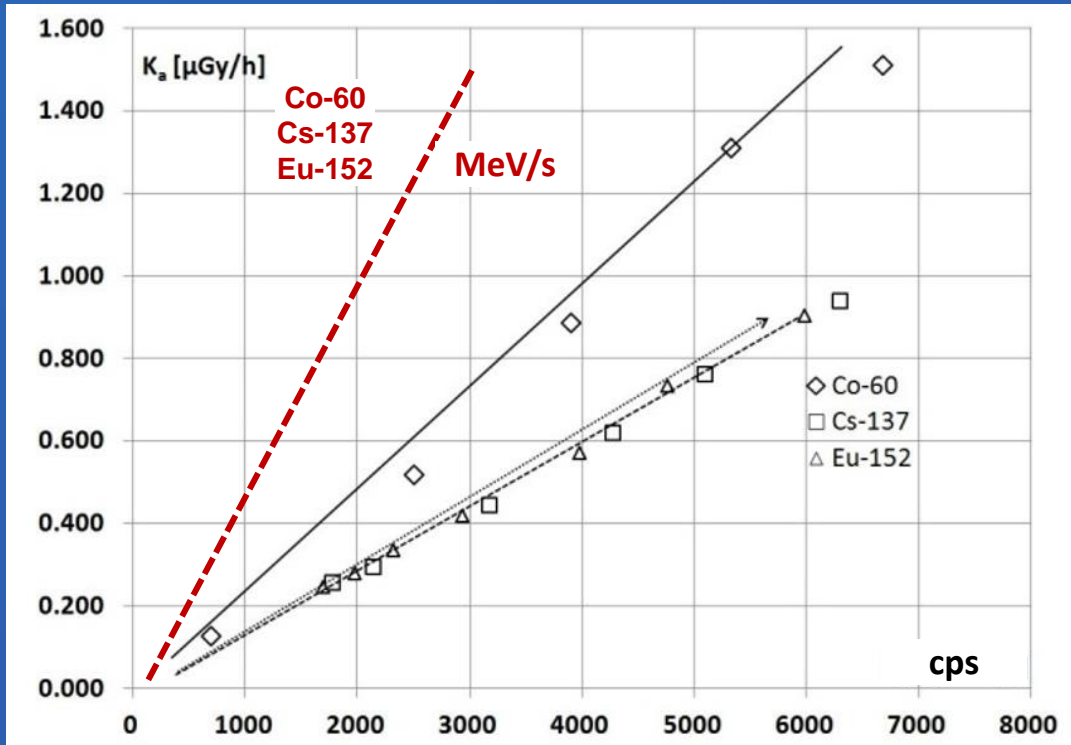


Data Format
SW for Ground Base Station



NSIL Current Development in UAV Based Technology

UAV System Calibration to Dose Rate Measurement

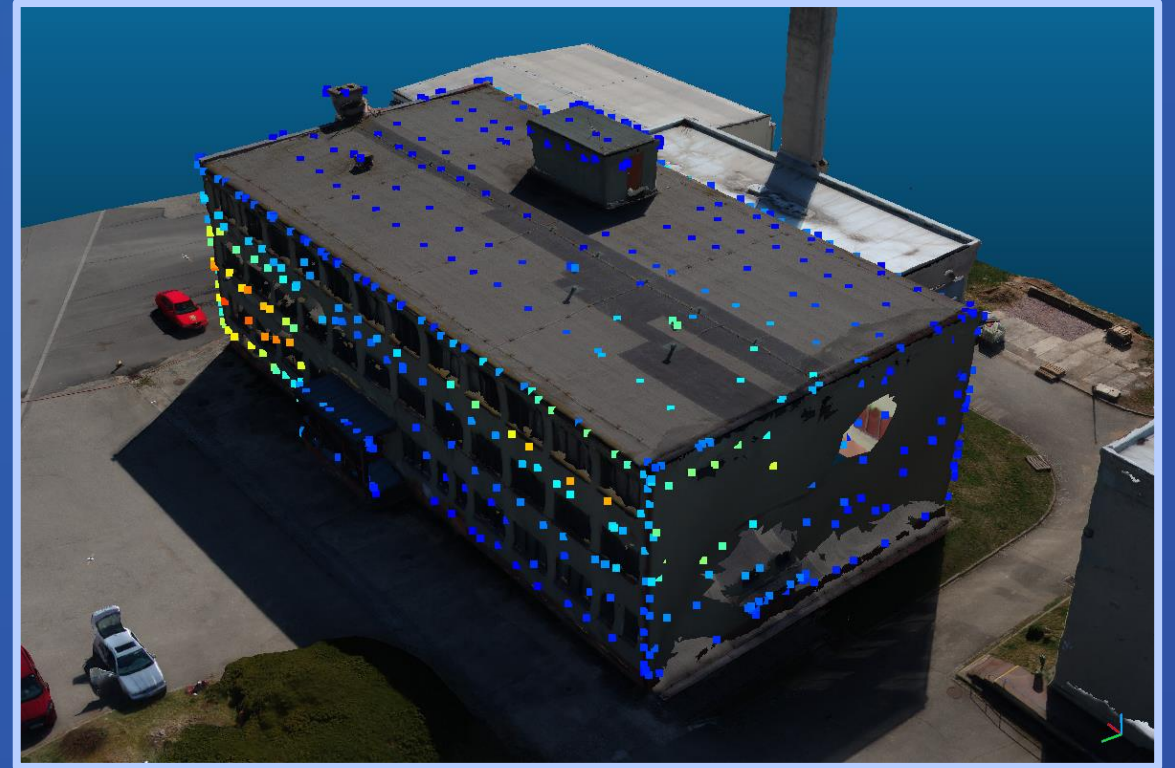
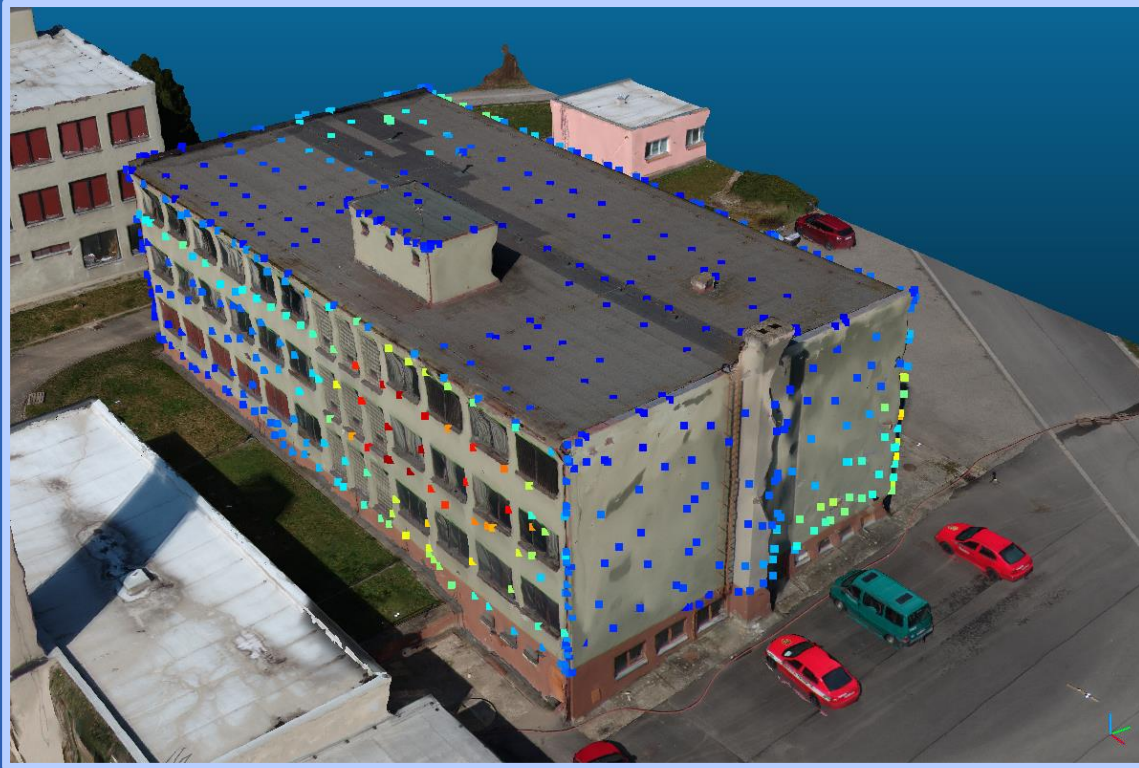


Calibration example of air kerma rate versus total cps for ^{137}Cs , ^{60}Co and ^{152}Eu measured with NaI(Tl) detector.

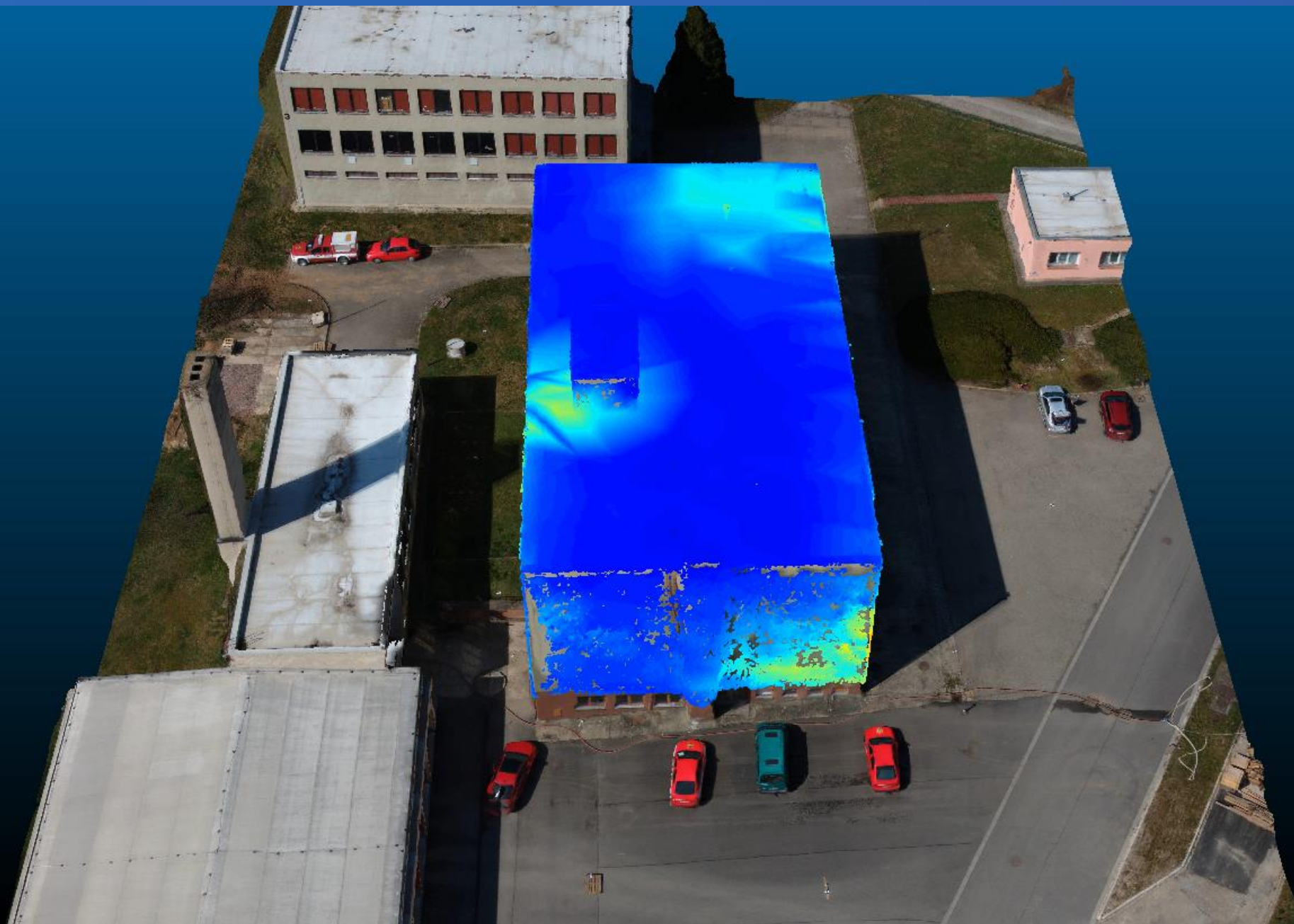
$$E_{ma} = \frac{\sum_{i=j}^n E_a \times N(E_a)}{t}$$

E_{ma} is the relative absorption energy rate in MeV/s, t is the live (real) time, j is the initial channel number and n is the final channel number and $N(E_a)$ is the number of counts with an energy E_a in the interval $E_a, E_a + dE_a$ in a channel over the measuring time t .

Radiological Mapping of Objects/Buildings



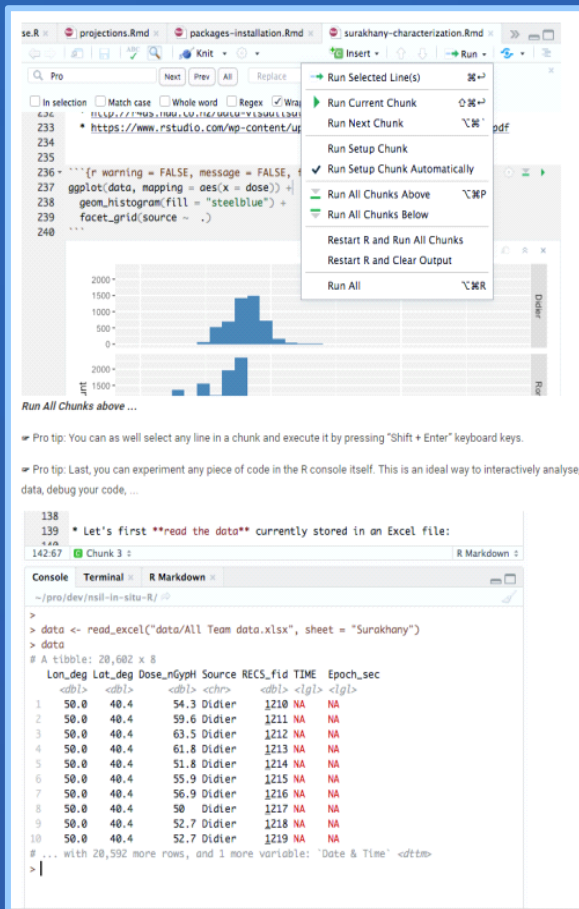
UAV Radiation Monitoring of Building



NSIL Current Development – R-Tool

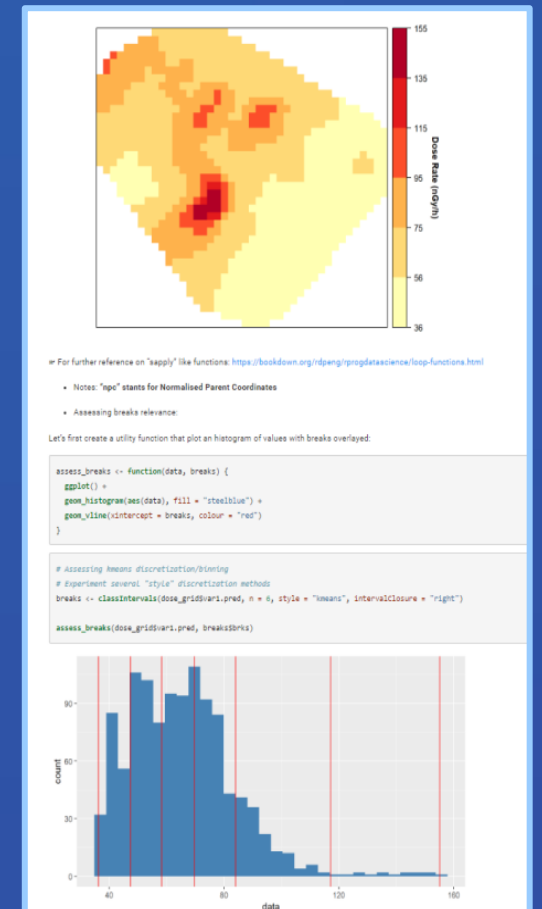
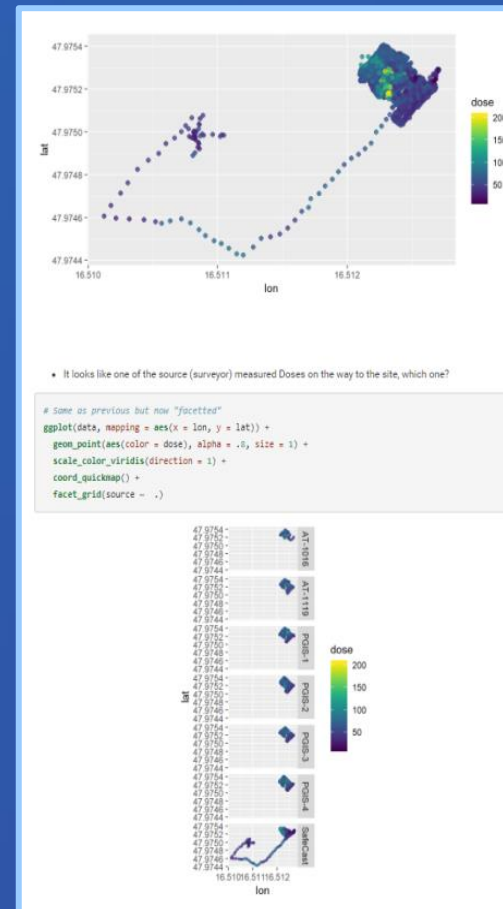
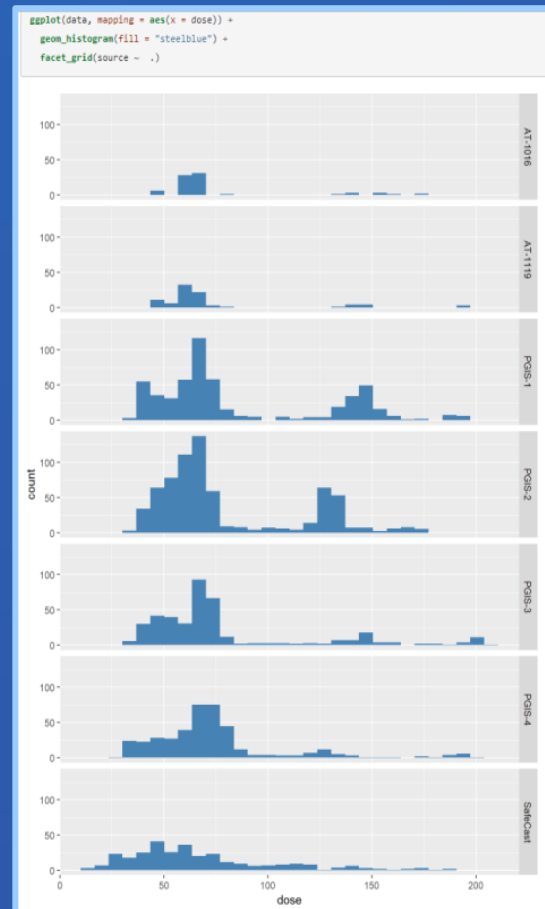
R-based tool developed by NSIL (open source)

Data QC/QA, interpolation, variance analysis, iso-doses & color scale map creation, ...



The screenshot shows the RStudio environment. The script editor contains R code for reading an Excel file and plotting a histogram. The console window shows the output of the code, including a tibble with columns: Lon_deg, Lat_deg, Dose_mgypH, Source, RECS_fid, TIME, Epoch_sec. The data is as follows:

	Lon_deg	Lat_deg	Dose_mgypH	Source	RECS_fid	TIME	Epoch_sec
1	50.0	40.4	54.3	Didier	1210	NA	NA
2	50.0	40.4	59.6	Didier	1211	NA	NA
3	50.0	40.4	63.5	Didier	1212	NA	NA
4	50.0	40.4	61.8	Didier	1213	NA	NA
5	50.0	40.4	51.8	Didier	1214	NA	NA
6	50.0	40.4	55.9	Didier	1215	NA	NA
7	50.0	40.4	56.9	Didier	1216	NA	NA
8	50.0	40.4	50	Didier	1217	NA	NA
9	50.0	40.4	52.7	Didier	1218	NA	NA
10	50.0	40.4	52.7	Didier	1219	NA	NA



Classification of UAV Detection Systems with Regard to IAEA Relevant Areas of Application

Typical Areas of IAEA Interest

- Environmental
- Nuclear Security
- Waste & Remediation
- Radiation Protection
- Water & Agriculture
- Nuclear Sciences & Applications
- Others ...

Small
needed payload <2 kg



Medium
needed payload <10 kg



Large
needed payload >10 kg



Large RAD UAV Systems

- **Advantages:** Large Area Capabilities, High Payload, Long Durability of Operation, High Resistance, Long Distance Data Transmission, High Detection Sensitivity, Application HPGe & Large Scintillation Detectors, Sensitive Gamma Spectroscopy & RN Identification, Real Time Analyse (Stripping/NPA Method), ...
- **Limitations:** Total Weight, High Price, Preparation Time/Transport, Operator and Pilot Navigation, Professional Licence, Special Mounting for Modules & Auxiliary Sensors, Aviation Certification, Issue with Temporary Landing, ...
- **Potential Application:** Environmental Monitoring, Remediation Survey, Search for Uncontrolled Rad Sources, Large Areas with Contamination, Geophysics, HPGe Gamma Spectroscopy, Emergency Action after Nuclear Accidents, Delimitation of Evacuation Zones, ...

Medium RAD UAV Systems

- **Advantages:** Monitoring of Medium Size Areas, Operability & Flexibility of Field Deployment, Effective Ratio Cost /Performance, Good Environmental Resistance, Application of Typical Radiation Detectors, Real Time Data Transmission, Lower Level Altitude Operation, Autonomous Operation and UAV Independence, ...
- **Limitations:** Limited Durability, Preparation Time, Operator for Ground Station, Licenced Pilot, Aircraft Transportation of Batteries, Operation “Line-the-Sight” Distance, Engines Maintenance ...
- **Potential Application:** Dose Rate Mapping, Survey in Radiation Accident, Search for Uncontrolled Rad Sources on Small Areas, Simultaneous Application of Photogrammetry or Lidar, High Dose Rate Areas, Autonomous Operation in Emergency ...

Small RAD UAV Systems

- **Advantages:** Lower System Price, Wider Available on Market, Effective for Monitoring of Small Areas and Low Altitudes, Monitoring of Spots with High Dose Rate Level, Easier Operation in Obstacle Area, Quick Preparation, Easy Transportation, Easier License, ...
- **Limitations:** Lower Detection Sensitivity and Flight Durability, Lower Payload, Limited Real-Time Data Processing and Transmission, Environmental Resistance, ...
- **Potential Application:** Initial System, Demonstration of UAV Based Rad. Mapping Technology, Monitoring of Hot Spots & Areas with High Dose Rate Level, Operation on Small Areas, Monitoring of Objects & Buildings, Security/Emergency Monitoring, ...

Effective Use of UAV Systems for Various Areas of Application

<i>Large UAV Systems</i>	<i>Medium UAV Systems</i>	<i>Light UAV Systems</i>
Nuclear Accidents		
HPGe Gamma Spectroscopy		
Environmental Monitoring		
		Scanning of Objects/Buildings
High Radiation Level		
Uranium/Minerals Mining & Legacy Sites		
		Nuclear Industry Sites
Geophysics		
Hard to Reach Areas (Obstacle Areas)		
Uncontrolled/Lost Sources Search		

Thank you for attention ...



DISCLAIMER

The material reproduced here has been supplied by the authors and has not been edited by the IAEA. The views expressed remain the responsibility of the named authors and do not necessarily reflect those of the government(s) of the designating Member State(s). In particular, neither the IAEA nor any other organization or body can be held responsible for this material.