Experience of the European Commission, Joint Research Centre in R&D for Nuclear Security

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Invited lecture for the
International Symposium on Technology Development for Nuclear Security
Organized by JAEA

Tokyo, October 27th 2016

Contents

- Introduction
- Some JRC R&D Facilities and Infrastructure dedicated to NS
- Examples of JRC Support on 3S to partner DGs
- Some results of JRC R&D in NS (SCINTILLA, ITRAP, C-BORD, …)
- Training/Education programme
- Examples of JRC Outreach Activities in Security and Support to DG DEVCO
- Conclusion

Major Nuclear Security Actors & JRC connections

IAEA.org International Atomic Energy Agency

UN agency, 1957
Safeguards and Verification
Non proliferation,
Additional protocol
Nuclear Security / IEC

EU Member States

EURATOM
Rome treaty 1957
Chapter VII on nuclear safeguards

DG-ENERGY
Nuclear Energy and Safeguards

DG HOME
EU CBRN action plan

JRC
(Joint Research Centre)
Nuclear Security
R&D, T&S support

ESARDA European Safeguards Research & Development Association

INMM INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

EEAS

Other DG's

TRADE
TAXUD

DG DEVCO

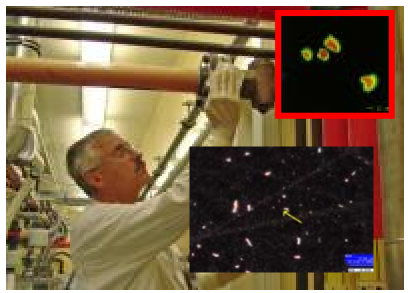
Instrument for Stability & Peace /
Nuclear Safety

Nuclear Security at JRC: Competence Areas

Effective and Efficient Safeguards

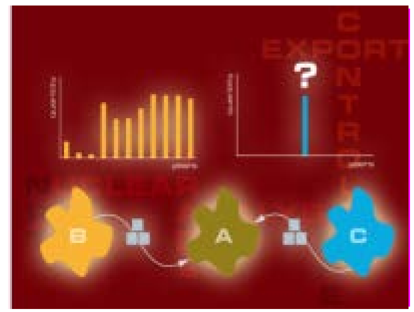
- Nuclear material measurements
- Reference materials
- Containment & Surveillance
- Process monitoring
- On-site laboratories

Verification Absence of Undeclared Activities



- Trace & particle analysis
- In-field tools for investigative inspector
- Reference materials

Nuclear Non Proliferation



- Export control
- Trade analysis
- Non-proliferation studies
- Outreach under INSC

Combating Illicit Trafficking

- Equipment development
- Testing & validation
- Nuclear forensics
- Nuclear preparedness
- National response plan
- CBRN, IcSP, …

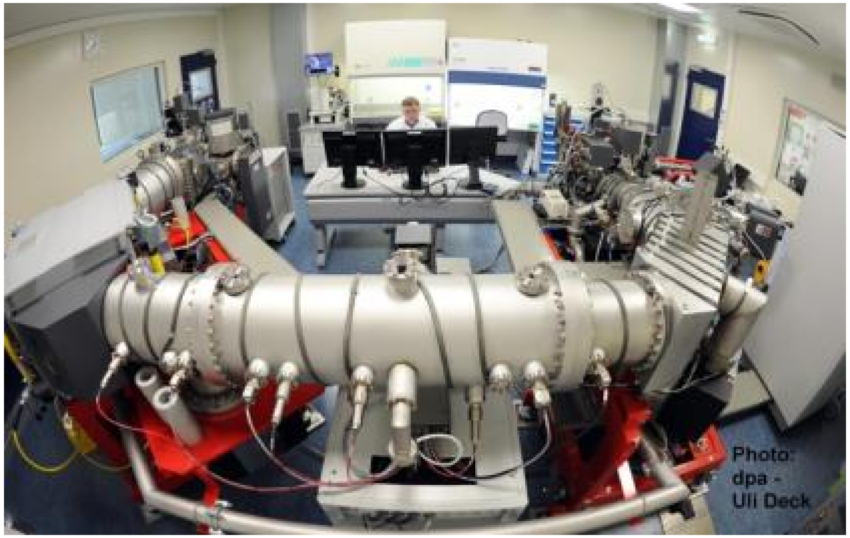
TRAINING & EDUCATION European Nuclear Security Training Centre

The LG-SIMS laboratory at the JRC for particle analysis

European Commission

- ✓ **100 samples/year =>**
  - **~150 screening measurements.**
  - **~1900 isotopic measurements.**
- ✓ The LG-SIMS lab QC system is the only particle laboratory certified under the **ISO17025** in IAEA's international network of laboratories.
- ✓ There are continuous **R&D efforts to improve** the analytical capabilities.
- ✓ There are on-going **collaborations** with other laboratories at IAEA, CEA, JAEA, NORDSIM and UWA.

Main customers: **DG-ENERGY, IAEA, ABACC, KINAC** and the **JRC forensic group.**



The LG-SIMS laboratory was inaugurated in June 2012, established from a joint effort by the JRC and DG-ENERGY.

Joint Research Centre

European Commission

In Field Measurements for DG ENER

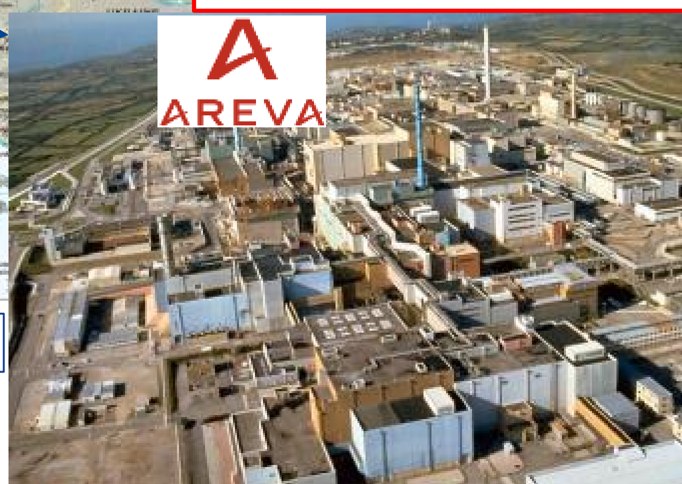
JRC-Karlsruhe

COMPUCEA In Field

Sellafield Ltd

16 Years On-Site Laboratories at commercial reprocessing plants

AREVA



Joint Research Centre

OSL Sellafield, UK

- Glove box environment + hot cell environment (THORP)
- Material received:
  - Product material (plutonium and uranyl nitrates, Pu and U oxides)
  - MOX (pellets and powders)
  - Spent fuel (THORP), diluted dissolved spent fuel, oxalates
- Techniques:
  - K-edge densitometry (Pu and U concentration)
  - X-ray fluorescence (U/Pu ratio, also absolute low Pu or low U)
  - Gamma spectrometry (Pu isotopics, Am/Pu ratio)
  - Mass Spectrometry (Pu and U isotopics)
  - Isotope Dilution Mass Spectrometry (large spikes)

Laboratory 100A

Laboratory 102

LSS La Hague, France

Laboratory 1219 IDA + MS

Laboratory 1339 PuO_2 chain + Compucea

- Hot cell environment (and glove boxes for low activity work)
- Material received:
  - Concentrated input solutions, rinsing solutions
  - Retreated plutonium nitrate product
  - Uranyl nitrate product, oxalates
  - Plutonium product (PuO_2)
  - RTR Research and Test Reactor spent fuel
- Techniques:
  - Equivalent to the OSL Sellafield, but with:
  - Three Hot Cell Hybrid K-edge/XRF densitometers fitted with automated sample changers

European Commission

Joint Research Centre

European Commission

Safeguards contribution to DG ENER

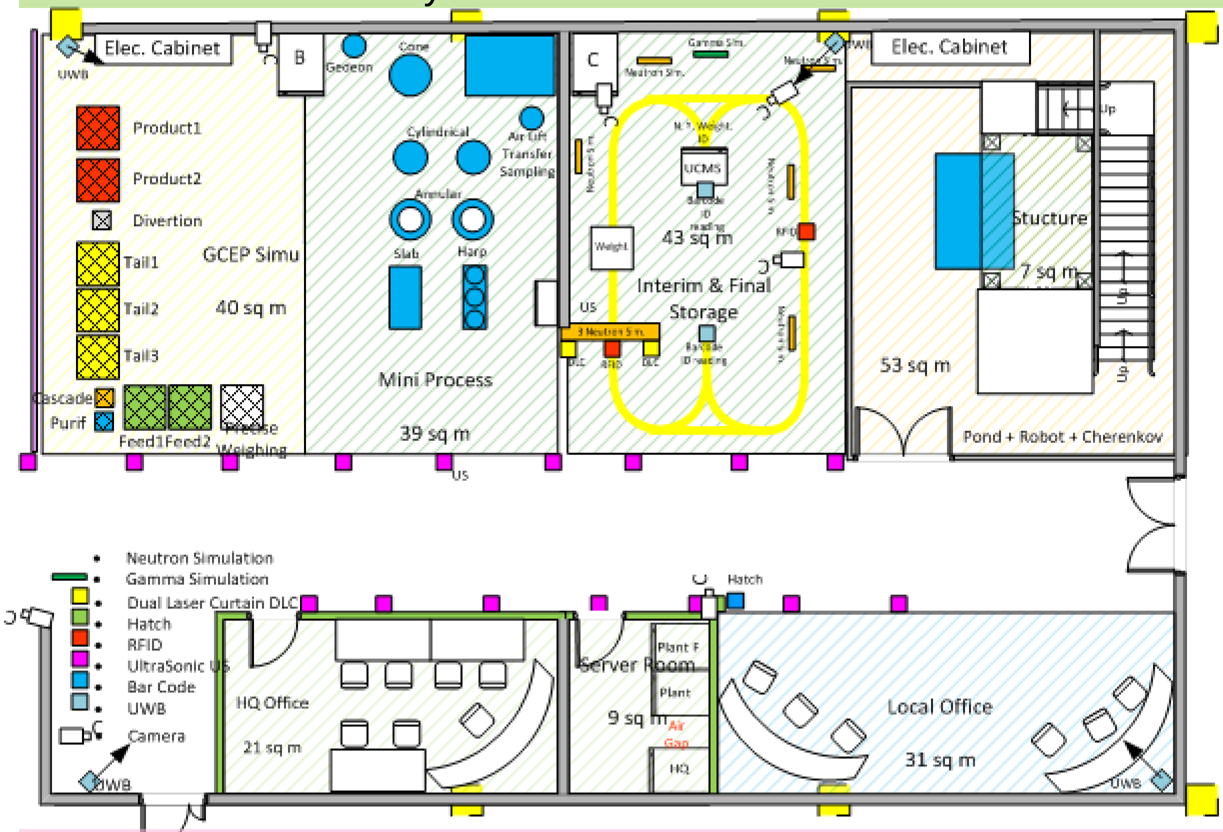
- OSL/LSS Throughput
  - ~ 315 On-Site analyst weeks per year (119 LSS + 151 OSL)
  - ~ 800 samples per year: U and Pu assay, density, Am assay, Pu and U isotopics
  - 2400 measurements/year, > 3000 including QC and QA (amounting to approximately 7500^{+} replicate measurements)
- Other work includes
  - Technical advice to DG ENER
  - Detailed investigations into discrepancies
  - Recommendation via DG ENER to the operator for improvements in nuclear analytical measurements
  - Assistance to the operator after agreement with DG ENER
  - Technical developments
- COMPUCEA In Field
  - Usually Juzbado and Västerås (30-40 samples)
  - 2016 exceptionally only Västerås

AS3ML: The Advanced Safeguards Measurement, Monitoring and Modeling Laboratory

Process Monitoring Techniques

European Commission

To perform testing and benchmarking activities, the PM group has at its disposal the AS3ML with a reduced scale liquid process installation, a GCEP mockup, a place dedicated to the transfer of itemized (nuclear) material to simulate most of the activities of the fuel cycle.



As no nuclear material is being used in the AS3ML, simulators are being developed to mimic the acquisition by gamma and neutron detectors.

The laboratory is also equipped with several networks to study data transfer and storage as well as encryption, authentication and cybersecurity in collaboration with other directorates.

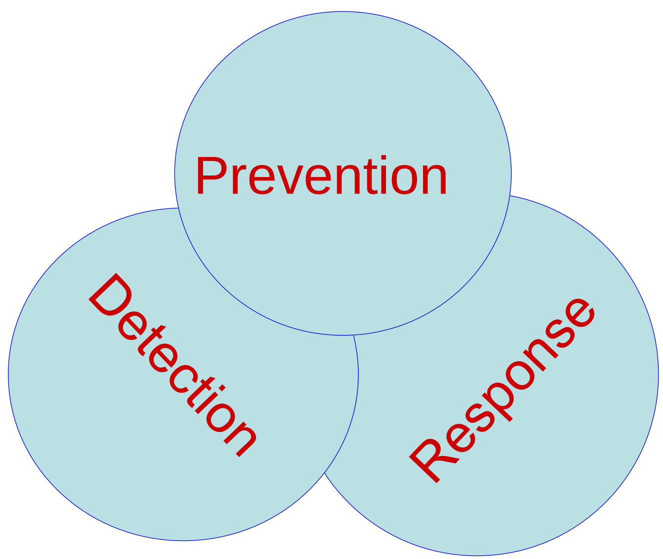
Process Monitoring activities require a good knowledge of signal acquisition, data pre-processing, and analysis as well as a good knowledge of the capabilities offered by the nuclear and non-nuclear instrumentation.

NUCLEAR SECURITY

Addresses nuclear and other radioactive materials out of regulatory control

Threats

- Illicit trafficking
- Proliferation
- Malicious use
- Nuclear Terrorism



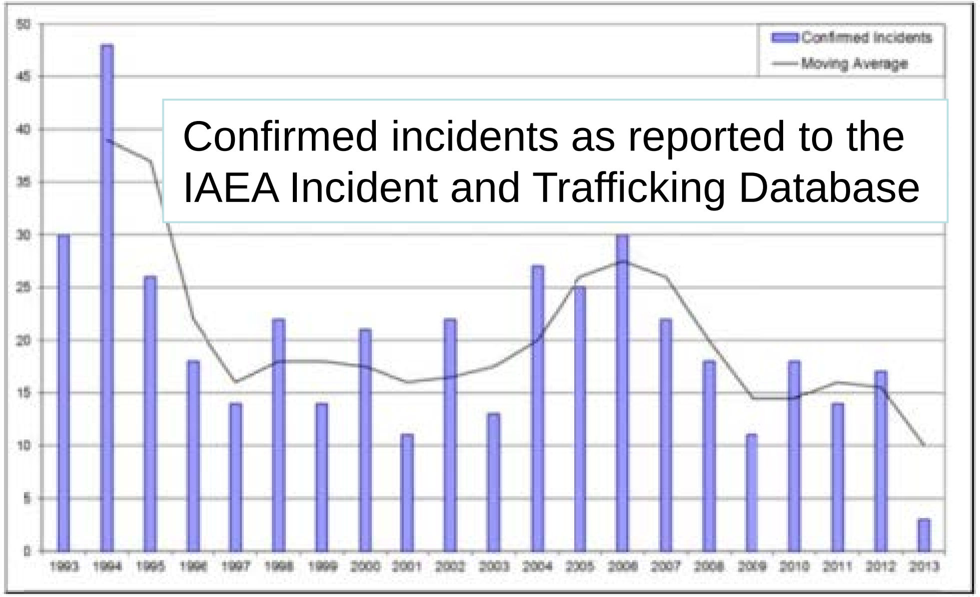
Measures

- Development of tools
- Capacity building
- Implementation support

Stakeholders, Partners and Platforms

Stakeholders:

- Other DG's (DEVCO, HOME, ENER, …)
- IAEA
- EU Member States



Partners:

- Research organizations
- Law enforcement
- US DoE, DHS, DoS

Platforms:

- Border Monitoring Working Group (BMWG)
- Nuclear Forensics International Technical Working Group (ITWG)
- Global Initiative to Combat Nuclear Terrorism (GICNT)

Example of R&D projects in NS

European Commission

Detector Validation, testing and standardization

- ITRAP+10 Phase II: Illicit Trafficking Radiation Detection Assessment Programme)

- SCINTILLA: Improvement of RN detection capabilities by developing and validating innovative solutions

Innovative Detection Technologies

- C-BORD: (effective Container inspection at BORDer control points)
  H2020 Research and Innovation Action
  EU Stakeholders: Universities/Research Centres/Companies/End Users
- Detection of SNM in Containers by Pulsed Neutron Interrogation
  JRC – Collaboration with Israel within an MoU

Joint Research Centre

ITRAP project

European Commission

Detector Validation, testing and standardization

Commercial equipment testing: ITRAP+10

AA DG HOME

Collaboration

US DNDO/DHS, DoE

Family of equipment *31 tested in total in 8 families*	*Standards Reference* *(IEC, ANSI, IAEA)*
RPM for Vehicles *(Radiation Portal Monitors)*	IEC 62244 + IAEA NSS1 (2006 & Rev.1)
SRPM *(Spectrometric Radiation Portal Monitors)*	IEC 62484-FDIS + IEC 6224 + IAEA NSS1 (2006 & Rev.1)
PRD *(Personal Radiation Detectors)*	IEC 62401-FDIS + IAEA NSS1 2006
SPRD *(Spectrometric Personal Radiation Detectors)*	ANSI N42.48
RID *(RadioIsotope IDentifier)*	IEC 62327 + IAEA NSS1 (2006 & Rev.1)
GSD *(highly sensitive Gamma Search Detectors)*	IEC 62533
NSD *(highly sensitive Neutron Search Detectors)*	IEC 62534-FDIS
PRS *(Portable Radiation Scanners – Backpack type)*	ANSI N42.43 + IEC 62327 +IAEA NSS1 Rev.1

Joint Research Centre

Testing of mobile detection equipment (ITRAP+10 Ph. II)

European Commission

- People-carried equipment (Backpacks, P.R. Scanners): tested in ITRAP PhI

- Vehicle-mounted detection equipment:

- Mobile and Transportable Radiation Monitors (MTRM):
  Extensive campaign completed in Jan 2016
- 6 mobile + 3 transportable systems from 5 EU based companies
- All ^{3}He free technologies
- Tests performed in most demanding conditions foreseen in the standards

Other MTRM carriers to be tested in the near future:

- Air (helicopter, airplane, UAV, ...)
- Water (boat, ...)
- Other (cranes, ...)

Testing RPMs and Handheld Devices at the JRC in Ispra (Italy)

European Commission

For Radiation Portal Monitors (RPM)

Dynamic tests with sources on

- 27 m long coveyor/rail
- 0.02 to 3. m/s
- 10 to 300 cm Height
- with/without moderator

For Handheld Devices

neutron irradiator

Static tests for handheld devices

gamma irradiator

Joint Research Centre

ITRAP Project Conclusions

European Commission

- All families of instruments extensively tested both in EU and US
- Strong collaboration between EU and US to provide the best feedback to the standards
- Ongoing capacity building supported by JRC-Ispra toward sustainable certification in the EU-MS laboratories
- Ongoing development and improvement of the IEC/EN standards for all families of instruments
- Obama's letter of appreciation
- Report to Nuclear Security Summit 2016

European Commission

SCINTILLA project

FP7 project: - 10 partners

- 3.5 MEuro budget
- 3 years (2012-2014)

Aiming to improve RN detection capabilities by developing and validating innovative solutions

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n°285204.

3 SCINTILLA Benchmarks at JRC facilities (2/2013 – 2/2014 – 11/2014)

SCINTILLA results

European Commission

Excellent results for the developed technologies

Vehicle portal with spectrometric PVT and LiZnS neutron module (Symetrica) passed, and in some cases over-performed all the ANSI / IEC requirements; already commercial and under installation in Rotterdam seaport

Vehicle portal with Gd-lined plastic (INFN) passed, and in some cases over-performed all the ANSI / IEC requirements, except sensitivity to strong gamma

Pedestrian portal with NaI gamma and LiZnS neutron modules (Symetrica) passed all ANSI / IEC requirements, except some false positive identifications

Vehicle portals with plastic with PSD (CEA) passed most of the test, failing on false alarm rate, low energy gamma alarm and moderated neutron source

Gamma camera interesting instrument; usage case? Mini-CZT still development to be completed

Joint Research Centre

C-BORD

effective Container inspection at BORDer control points

C-BORD PROJECT – FACT SHEET

- Facts
  - H2020 Research and Innovation Action
  - Only proposal funded under action BES-09-2014 (out of 11)
    - Total of 31 projects out of 338 proposals = 9%
  - Start date: 1 June 2015
  - Duration: 42 months
  - Budget: 11,826,452.50€
  - 100% of eligible costs funded by EU
  - 18 partners from 9 European countries

C-BORD OBJECTIVES

Techniques in C-BORD:

- Improved passive RPM
- Improved X-ray scanner imaging
- Active interrogation with neutron generator (TNIS)
- Active interrogation by photo-fission
- Electronic nose (SNIFFER) for chemicals

Usage cases:

- Large stationary integrated system for major seaports
- Medium-size relocatable system for land borders
- Mobile system

C-BORD PROJECT – PARTNERS

Universities

Bonn-Rhein-Sieg University of Applied Sciences

ESIEE PARIS

MANCHESTER 1824
The University of Manchester

UNIVERSITAS STUDII PADUANI MCCXXII

Research centres

cea list leti CADARACHE

Fraunhofer INT

EK

Narodowe Centrum Badań Jądrowych
National Centre for Nuclear Research
Świerk

European Commission

Companies

ARTTIC INTERNATIONAL MANAGEMENT SERVICES

CAEN Tools for Discovery

smiths detection

symetrica

End users

Douane
Belastingdienst

Nemzeti Adó- és Vámhivatal

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
MINISTÈRE DES FINANCES ET DES COMPTES PUBLICS

Służba Celna
Izba Celna w Gdyni

AGENZIA DELLE DOGANE E DEI MONOPOLI

PUNITA: Pulsed Neutron Interrogation Test Assembly

European Commission

Rationale for Neutron Laboratory & PUNITA:

> ***"Experimental research in non-destructive assay methods and instrumentation for nuclear safeguards and nuclear security applications"***

Current research activities:

Nuclear security

- Methods for detection of Special Nuclear Materials (SNM)
  - Active neutron interrogation - detection of fission signatures
  - Liquid scintillation detectors - pulse shape discrimination – n coincidence events

Nuclear Safeguards

- Active neutron interrogation for fissile mass determination
- Passive and active neutron correlation methods
- Alternatives to 3He neutron detectors

Support to nuclear decommissioning / waste characterization

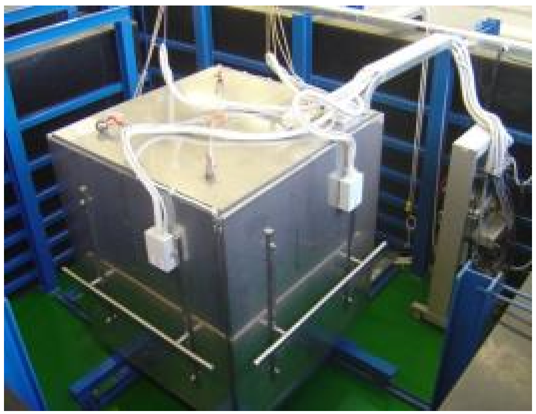
- Passive/active waste drum counter for Pu assay
- Free release waste measurement systems

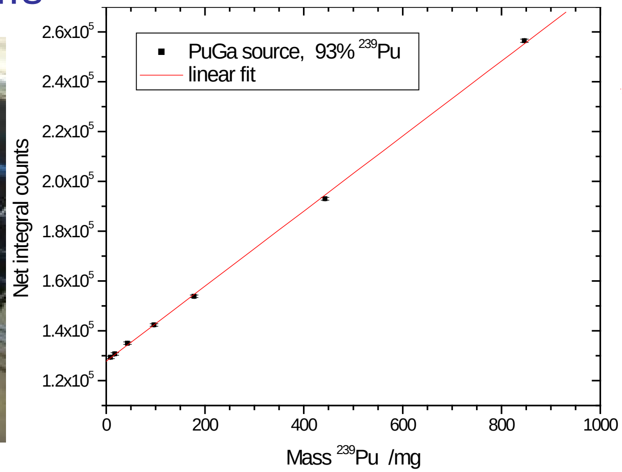
Pulsed Neutron Interrogation Test Assembly (PUNITA Facility)

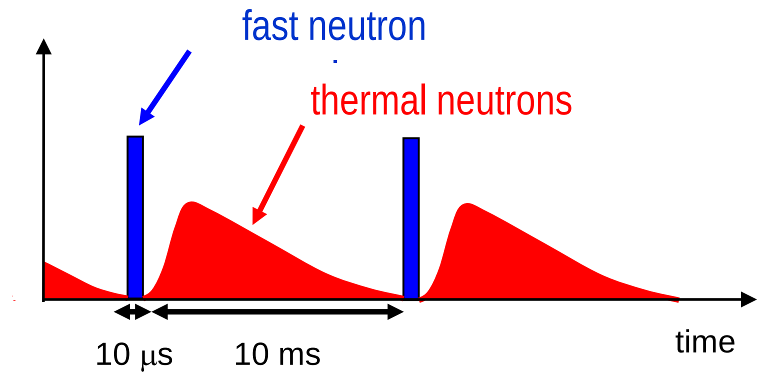
European Commission

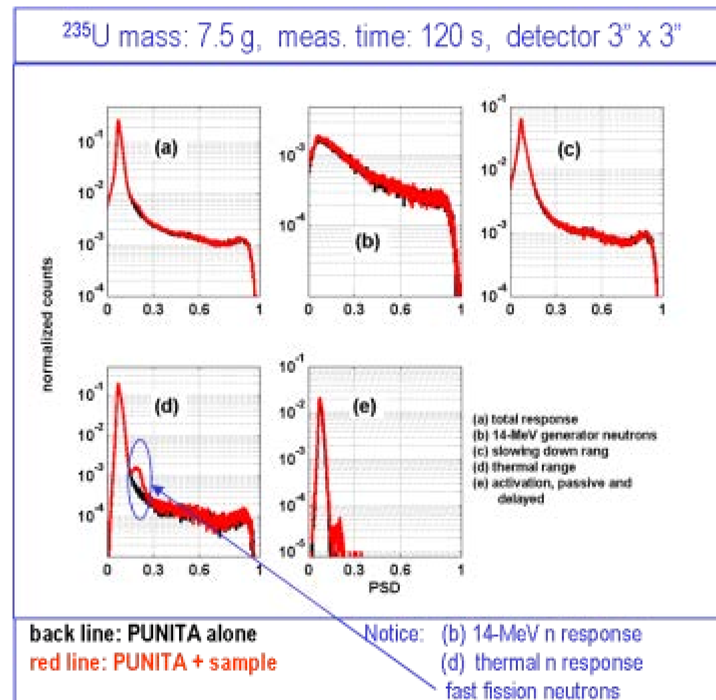
Nuclear Safeguards Application:

Mass determination of small quantities of fissile materials in huge drums









Nuclear Security Application:

Detection of special nuclear materials by fission signatures in large containers

Support to nuclear decommissioning / waste characterization

Detection of Special Nuclear Materials

European Commission

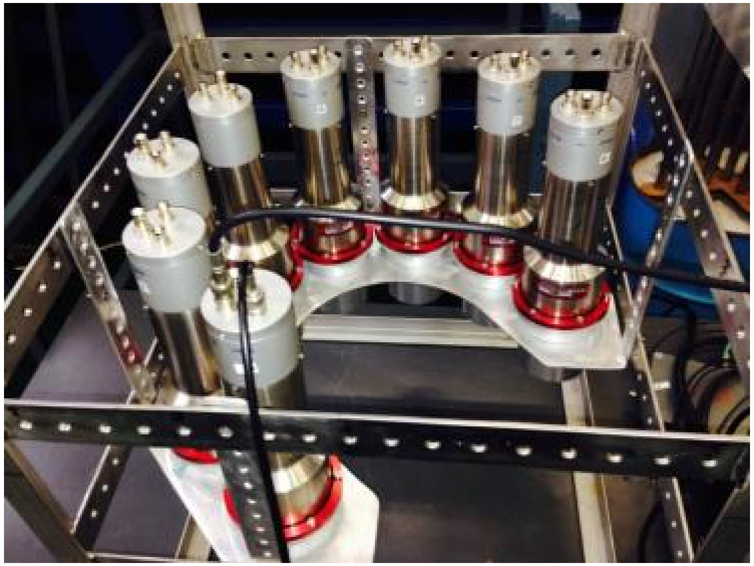
Objective: Detection of Special Nuclear Material for Nuclear Security applications

Application:
- detection of SNM in shielded containers

Physics principle:
- induce fission by epi-thermal/thermal neutrons (pulsed neutron source)
- fission signatures are the evidence for presence of SNM:
  - only fast prompt fission neutrons appear in PSD peak
  - neutron coincidences in short gates of 10-40 ns.

Technical implementation issues:
- high count rates in neutron/photon mixed fields
- fast neutron detection at high efficiency
- good neutron/photon separation necessary

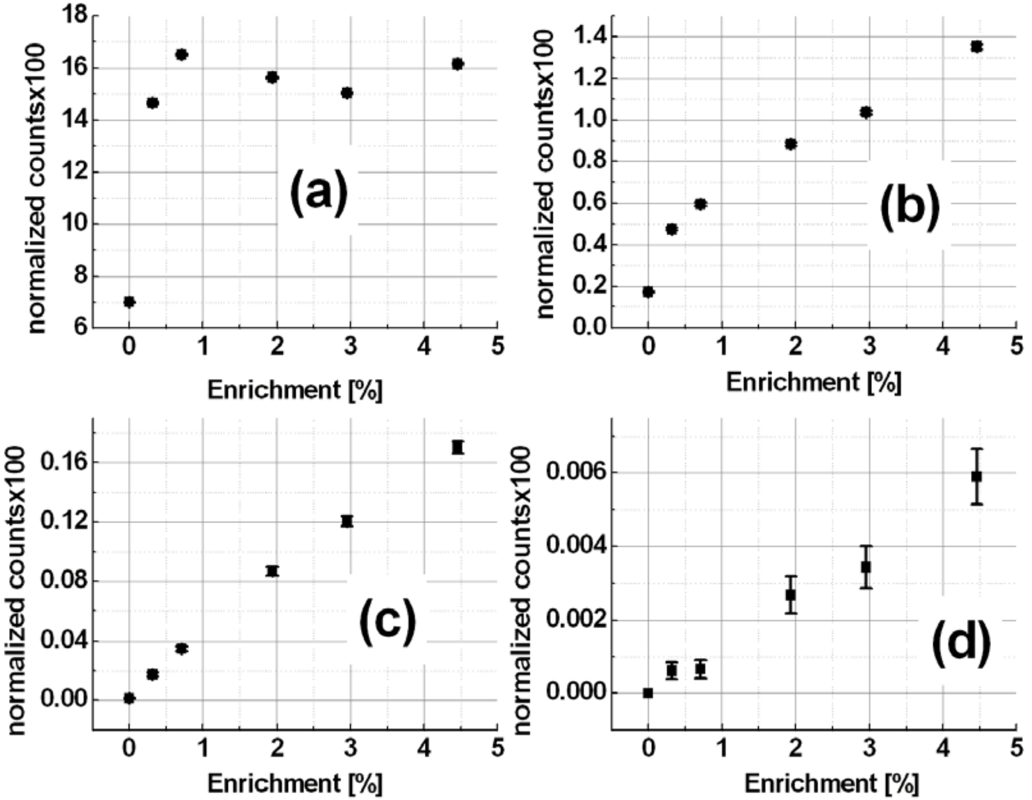
Technical/scientific implementation:
- 8x 3”x3” EJ-309 liquid scintillation detectors
- signal analyzing hardware (fast digitizers)
- (online interpretation (PSD) in FPGA hardware)



Detection of Special Nuclear Materials

European Commission

Detection of triple coincidences using CBNM U_3O_8 standards
thermal interrogation (250µs to 40000µs)



Kinds of three-fold coincidences:

(a) γγγ
(b) γγn
(c) γnn
(d) nnn

Detection of Special Nuclear Materials

Scale-up of experimental results to industrial size (preliminary results)

PUNITA simulations:

- To compare experiments to MCNP model we apply the following figure of merit (FOM):
  FOM = [thermal n-flux] x [detector n-efficiency]
  in order to optimize both parameters individually.

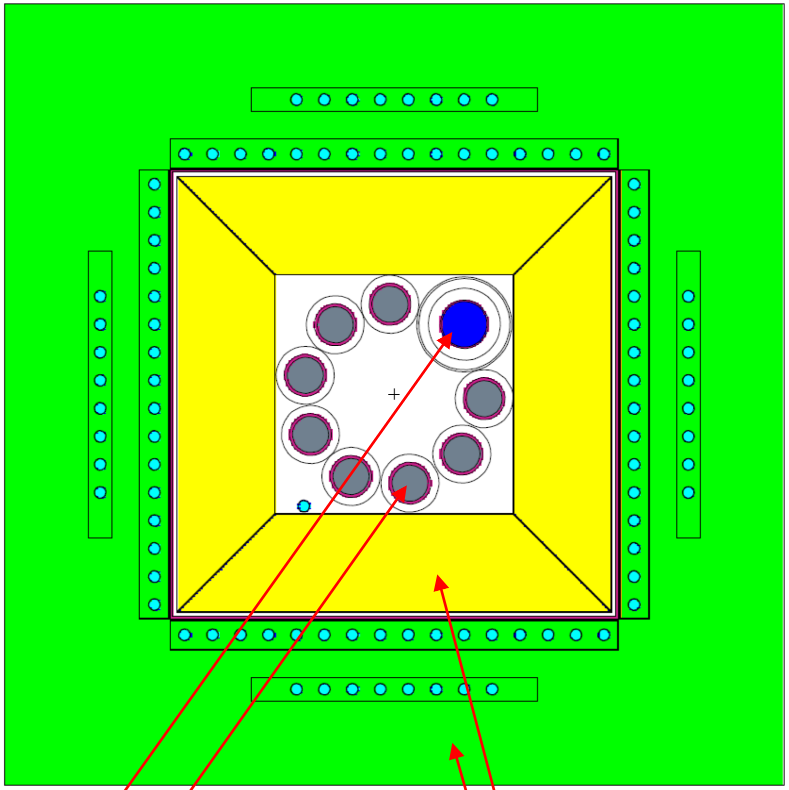
- Due to generator pulsing (100 Hz) we integrate n-flux over 10 ms period:

$$\varphi_{th} = 224891 \text{ cm}^{-2}$$

- As a measure of fission neutron detection efficiency we define recoil protons with E_{kin} > 700 keV as a neutron detection event:

$$\varepsilon_n = 6.07 \pm 0.30 \%$$

MCNP model of PUNITA setup

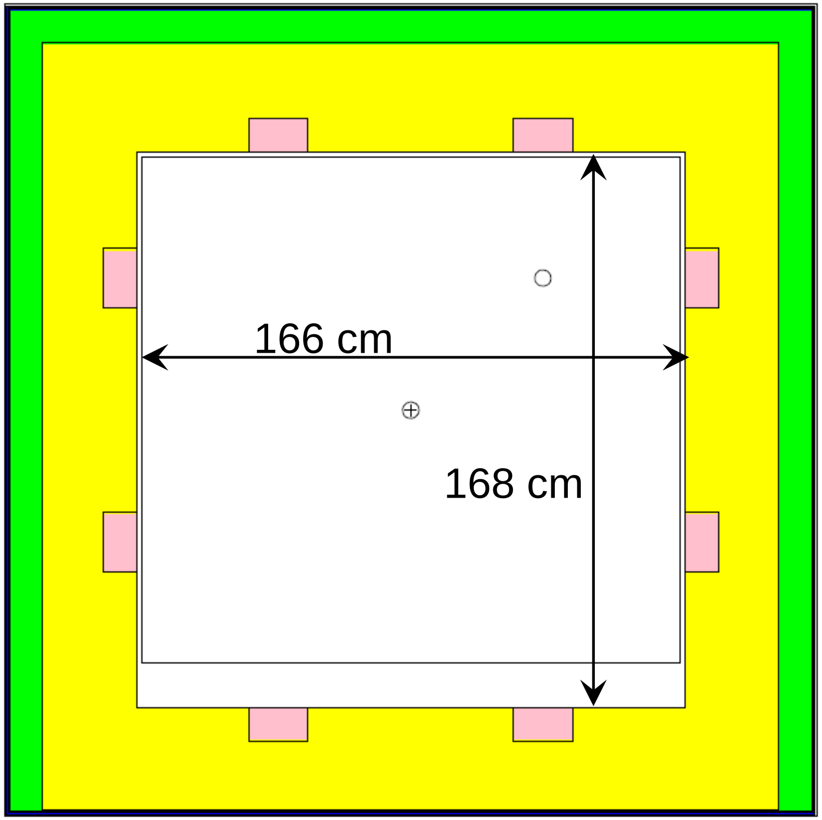


Detection of Special Nuclear Materials

European Commission

Scale-up of experimental results to industrial size (preliminary results)

Assay device as implemented in 20-foot container (view from entrance) showing:
detector positions, n-generator position



Standard ULD as applied for air cargo

Detection of Special Nuclear Materials

European Commission

Scale-up of experimental results to industrial size (preliminary results)

Geometry comparison "ULD device / PUNITA":

moderator volume ratio	11.9	
• sample cavity size ratio	31.7	
• detector volume ratio	21.8	
• neutron generator	same	(1x 10^8 /sec, 100 Hz pulsing)

Preliminary simulation results "ULD device / PUNITA":

thermal n-flux ratio, centre pos.	$\varphi_{th,ULD\ device} / \varphi_{th,PUNITA}$ =	0.0061 ± 0.0002
fission neutron det. efficiency	$\varepsilon_{n,\ ULD\ device} / \varepsilon_{n,\ PUNITA}$ =	$0.379 \pm 9.94 \cdot 10^{-4}$
FOM ratio		$1/436 \pm 1/11065$

Based on the (conservative) estimate of a detection limit in the PUNITA configuration of 0.52 g ^{235}U in a 100 second measurement when using the 3-fold neutron coincidences as signature, the detection limit of the "ULD device" described above would be approximately a factor 436 higher, or LOD = 228 g ^{235}U.

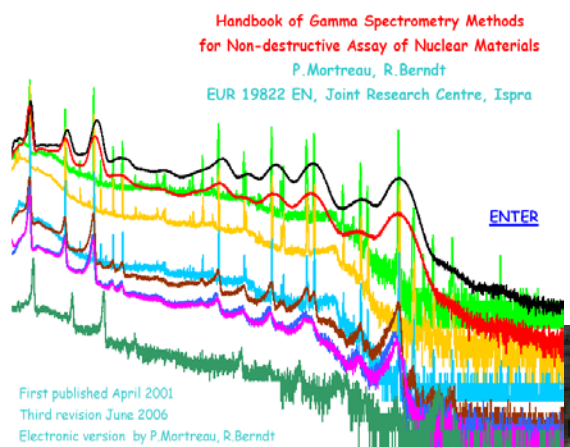
Joint Research Centre

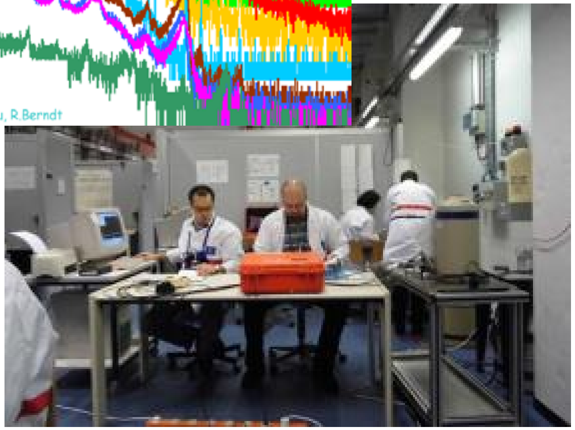
Safeguards and non proliferation courses

Training and Education programme

European Commission

- Pu isotopic composition by gamma spectrometry
- Uranium enrichment determination by gamma spectrometry
- Passive neutron assay
- Active neutron interrogation
- JRC CANDU sealing systems
- 3D laser based verification systems
- Video zoom : tool for image review
- Tank calibration
- Process Monitoring
- Data Analysis and Interpretation
- Advance hands on RADAR/CRISP/XSEAT
- Complementary access (APEX)





- Export Control seminars & courses
- Upon request trainings on JRC Trade Analysis and Open Source Tools: TBT and NSMM

European Commission

EUSECTRA

Nuclear Security Training Centre:
- established under AA with DG HOME
- Ispra facility operational since 2009
- Karlsruhe facility inaugurated 2013

Topics:

- Detection at borders/nodal points
- Train the Trainers
- Mobile Expert Support Teams
- Reach back
- Response plans
- Nuclear Forensics
- Management of radiological Crime scene
- Nuclear security awareness for management and decision makers
- Sustainability & Maintenance issues
- Other on-demand courses

Target audience:

- Front Line Officers
- Trainers/future trainers
- Experts
- Management/Decision Makers

European
Commission

High Level EU Scenario-Based Exercise on Nuclear Security – Apex Europa

- ✓ The EU is organising the first High Level EU Scenario-Based Exercise on Nuclear Security

- ✓ The Apex Europa will bring together high officials from EU Member States for one day of scenario analysis planned for 23 November 2016 in the unique facilities of the European Commission's Joint Research Centre in Karlsruhe, Germany. The participants will also experience live demonstrations and become acquainted with, among others, specialised nuclear detection laboratories, the nuclear security training centre (EUSECTRA) and nuclear forensics laboratories.

APEX

Knowledge Management

ESARDA
European SAfeguards Research and Development Association

A very lively membership:

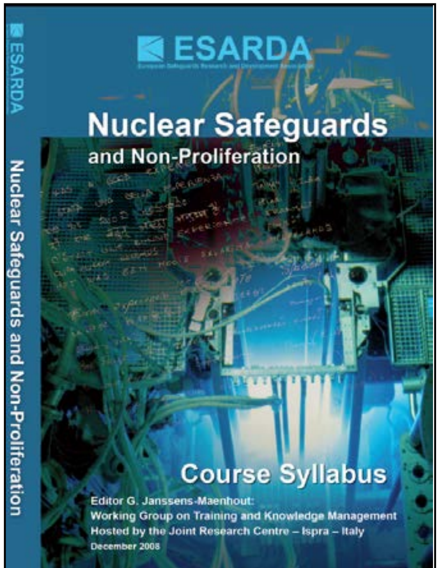
30 Parties, 7 Associated Members from USA, Norway, Switzerland, 8 individual members and 1 Observer (DG ENER)

A de facto knowledge center hub with active involvement in a number of WGs: NDA, DA, C/S, NA/NT, VTM, EXP…

A managerial effort

- Steering Committee and Executive Board meetings
- Editorial of Bulletin and review of papers
- Chairmanship of a number of WG committees
- Technical documentation with more than 200 active contributors

15th edition of ESARDA Course Nuclear Safeguards and Non-Proliferation, 11-15 April 2016



Chairman: Kamel Abbas, JRC-ITU Nuclear Security Unit, Ispra

Monday 11 April 2016	
09:00-09:30	Welcome and opening of the course, *Maria Betti, Director of JRC-ITU* Introduction of the JRC-ITU, Course and students *Willem Janssens, Head of Unit, JRC-ITU Ispra*
09:30-10:30	History of Non-Proliferation, *Thomas Jonter, Stockholm University*
10:30-10:45	*Coffee break and group picture*
10:45-11:45	International Law and Concepts on the Physical Protection of Nuclear Material and on Nuclear Security, *Odette Jankowitsch-Prevor, Consultant*
11:45-12:45	Nuclear Material Subject to Safeguards, *Greet Maenhout, JRC Ispra & Gent University*
12:45-13:45	*Lunch*
13:45-15:15	Visit to JRC Ispra Laboratories
15:15-16:15	Monitoring Containment/Surveillance, *Pierre Funk, IRSN*
16:15-16:30	*Coffee break*
16:30-17:15	Inspection on site, *Peter Schwalbach, EC DG-ENER*
17:15-18:00	Physical Protection, *Carry Crawford, ORNL*
18:00-18:15	***Wrap-up***
18:30	*Cocktail & Evening presentation ", Willem Janssens, HoU, JRC-ITU Ispra*

Tuesday 12 April 2016	
09:00-09:45	Nuclear Material account and control principles, *Nick Edmonds, Sellafield*
09:45-10:30	Statistical Accounting, *Raffaele Bencardino, EC DG-ENER*
10:30-10:45	*Coffee break*
10:45-11:45	Legal Instruments Implementing NPT, *Laura Rockwood, VCDNP*
11:45-12:45	Group Exercise 2, *Laura Rockwood, VCDNP*
12:45-13:45	*Lunch*
13:45-15:15	Visit to JRC Ispra Laboratories
15:15-16:15	The Nuclear Fuel Cycle, *Luc Van Den Durpel, Nuclear-21.Net*
16:15-16:30	*Coffee break*
16:30-17:45	Presentation of Group Exercise 2, *Laura Rockwood, VCDNP*
17:45-18:00	***Wrap-up***

Wednesday 13 April 2016	
09:00-09:45	Non Destructive Assay: neutron detectors, *Paolo Peerani, Head of Unit, JRC Ispra*
09:45-10:30	Non Destructive Assay: gamma spectrometers, *Reinhard Berndt, JRC Ispra*
10:30-10:45	*Coffee break*
10:45-11:30	Destructive Analysis, *Yetunde Aregbe, JRC Geel*
11:30-12:15	Group Exercise 1 & Presentations, *Luc Van Den Durpel, Nuclear-21.Net*
12:15-12:45	JAEA's Safeguards, *Noriko Miyaji, JAEA*
12:45-13:45	*Lunch*
13:45-15:15	Visit to JRC Ispra Laboratories
15:15-16:15	Nuclear Forensic, *Maria Wallenius, JRC Karlsruhe*
16:15-16:30	*Coffee break*
16:30-17:15	Case study, *Noriko Miyaji, JAEA*
17:15-18:00	How to Combat Illicit Trafficking, *Kamel Abbas, JRC Ispra*
18:00-18:15	***Wrap-up***

External cooperation benefits

European Commission

JRC integration at international level

- Close coordination with US SLD, IAEA and EU Council SG at the ***Border Monitoring Working Group****.*

- Created in 2006 under the auspice of the IAEA to share relevant information in border monitoring activities and coordinate international support programs in the field

- Core members: IAEA, US DoE and EC

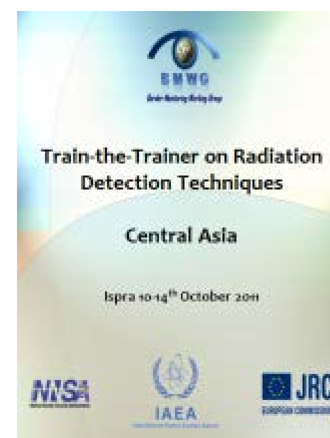
BMWG
Border Monitoring Working Group

Coordinated Technical Approach

- Joint Assessment missions
- Coordinated equipment deployment
- Joint Training and Seminars

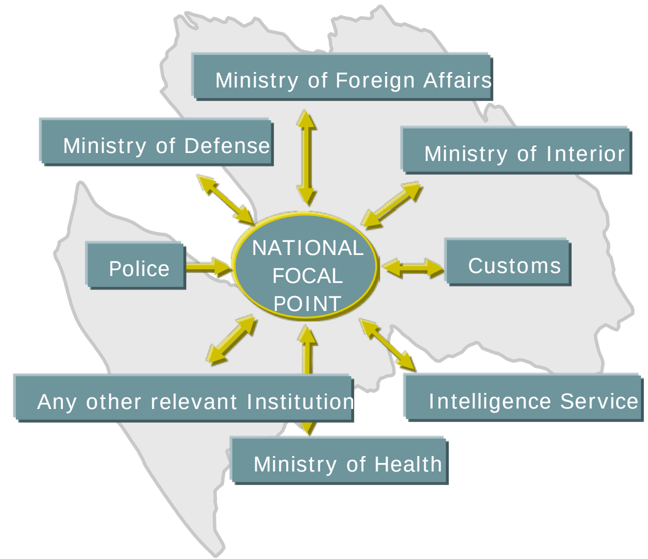
Coordinated Training Approach

- Joint Training curricula for FLO and Train-the-Trainer
- Joint Training sessions



Role of JRC in the implementation of the EU CBRN Risk Mitigation Centre of Excellence Initiative (CBRN CoE)

CBRN Centres of Excellence
An initiative of the European Union



JRC tasks:

CBRN CoE structure and communication strategy

Implementation of the CoE cycle of activities

- *Needs Assessment, National Action Plans*
- *TOR writing, projects ranking/prioritisation*
- *Evaluation of projects implementation*
- *Quality Control*
- *Sustainability of the initiative*
- *Incl. International Coordination / follow-up*

Thank you

For further information or questions
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