Symposium on International Safeguards

Linking Strategy, Implementation and People

20–24 October 2014
Vienna, Austria

BOOK OF ABSTRACTS, PRESENTATIONS AND PAPERS

IAEA-CN-220

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Version: December 14, 2015

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Colophon
This book has been assembled from the abstract sources submitted by the contributing authors via the Indico conference management platform. Layout, editing, and customized TEX & LATEX macros used to typeset the book were developed by Dr. P. Knowles, LogrusData, Vienna, Austria.

Introduction

Since the 2010 Safeguards Symposium, the IAEA's Department of Safeguards has published STR_375: the Long-Term Research and Development Plan, 2012–2023. The objective of the 2014 Symposium is to foster dialogue, exchange information and promote cooperation with IAEA stakeholders using this R&D plan to make progress towards achieving the Department's strategic objectives.

Message from DDG-Safeguards, Tero Varjoranta

Dear partners and colleagues,

I would like to thank you all for participating in the twelfth Safeguards Symposium taking place at the IAEA here in Vienna.

Since assuming the post of Deputy Director General and Head of the Department of Safeguards one year ago, I have had many opportunities to listen to our partners inside and outside the house.

I have learned that there is a strong common desire to work closely together to meet the growing safeguards challenges posed by an increasingly changing world. In fact, such collaboration is vital to our success.

We see the Symposium as our window to the world — giving us the chance to reflect together on our strategies for implementing safeguards that are effective and efficient and linking with people to make it happen.

With over 300 papers due to be presented during the Symposium, there will be much to nourish the discussion. We have a great opportunity to exchange knowledge and experience from the best experts around the world in the field and improve our collective performance.

I can assure you that everyone in the Department of Safeguards is working hard to make the Symposium a successful event and we all look forward to welcoming you to Vienna.

Tero Varjoranta

Conference Website: 12th Symposium on International Safeguards
http://www.iaea.org/events/symposium-on-international-safeguards-2014

Participation in an IAEA Scientific Meeting

Governments of Member States and those organizations whose activities are relevant to the meeting subject matter are invited to designate participants in the IAEA scientific conferences and symposia. In addition, the IAEA itself may invite a limited number of scientists as invited speakers. Only participants designated or invited in this way are entitled to present papers and take part in the discussions.

Scientists interested in participating in any of the IAEA meetings should request information from the Government authorities of their own countries, in most cases the Ministry of Foreign Affairs or national atomic energy authority.

Conference Location

International Atomic Energy Agency (IAEA)
M–Building
Vienna International Centre (VIC)
1400 Vienna, Austria

Metro, U–Bahn: **U1**: "Kaisermühlen-VIC"

Working Language & Resolutions

Working Language:	English
Resolutions:	No resolutions may be submitted for consideration on any subject; no votes will be taken.

IAEA Publications

All IAEA publications may be ordered from the
Marketing and Sales Unit,
International Atomic Energy Agency,
PO Box 100, 1400 Vienna Austria
Fax: (+43 1) 2600–29302
Feedback
www.iaea.org/publications

Registration

Participants will be issued photo badges by the UN Security and Safety Service (UNSSS), at the Gate One entrance, on Sunday 19 October 2014, 16:00-–18:00 or as of Monday 20 October 2014 throughout the week from 8:00-–16:00. Please bring an official photo identification document. No registration fee is charged.

Information for Participants

For speakers, session chairs, E-Poster presenters, etc, the conference website contains links to many helpful guides:

Guidance for Chairs
Guidance for Oral Presentations
Guidance for E-Posters
Guidance for Contribution Uploads
Practical Information
Follow us on twitter @SGSymp2014
Join our LinkedIn 2014 Safeguards Symposium group

Touch screens located throughout the venue can be consulted for the daily programme as well as the schedule and location of symposium events. Slides and presentation materials can also be viewed once the presentations have been given.

Presentations and Abstracts

This book contains all abstracts accepted by the symposium programme committee. Note that abstracts have been edited only for style uniformity following the IAEA author guidelines. The views expressed remain the responsibility of the named authors and do not necessarily reflect those of the government of the designating Member States. The IAEA cannot be held responsible for any material reproduced in this book.

Presenters should be aware that there are pre-session briefings; please see the guides above, and the floor maps to find your briefing rooms. The duration of oral presentations indicated in the programme already includes discussion time. Speakers are requested to prepare presentations as follows:

Oral: Fifteen (15) minutes presentation and five (5) minutes discussion (total time 20 minutes);

E-Poster: Two (2) minutes introduction followed by viewing and discussions at the E-Poster displays.

E-Poster Awards

Prizes for E-Posters will be awarded by representatives from INMM and ESARDA on Wednesday and Thursday at 18:00 on the technical demonstration stage on the First Floor of the M–Building and on Friday during the closing plenary.

Technical Demonstrations

Various demonstrations of safeguards-related technologies and techniques will be presented on the technical demonstration stage on the First Floor of the M–Building during the coffee breaks. Please see the detailed programme for the titles of each demonstration.

Exhibits

Equipment and services, including commercial products will be exhibited in the C–Building, Rotunda. Side-presentations will take place here at 13:30 where coffee will also be offered.

Displays from the Safeguards Member State Support Programme (MSSP), INMM and ESARDA, as well as universities, institutes and other organizations can be visited in the M– and A–Buildings.

Receptions

Participants are cordially invited to a Welcome Reception on Sunday 19 October 2014 from 16:30–18:00 in the C–Building, Rotunda, as well as an Evening Reception on Tuesday 21 October 2014 from 18:00–20:00 in the M–Building.

Hosted Coffee Breaks

Hosted coffee breaks will be offered from Monday afternoon until Friday morning according to the following schedule:

10:30–11:00 (except Monday) M–Building, Ground Floor, E-Poster Display Area and on the First Floor, Technical Demonstration Stage Area.

13:30–14:00 (except Friday) C–Building, Rotunda.

15:30–16:00 (except Friday) M–Building, Ground Floor, E-Poster Display Area and on the First Floor, Technical Demonstration Stage Area.
NB: On Monday, the coffee is from 16:00–16:30.

Coffee, tea, and snacks can be purchased from the M–Building cafeteria.

Conference Secretariat

IAEA Scientific Secretary:

Subsequent correspondence on scientific matters should be sent to the Scientific Secretary of the symposium and correspondence on administrative matters to the IAEA Conference Services Section.

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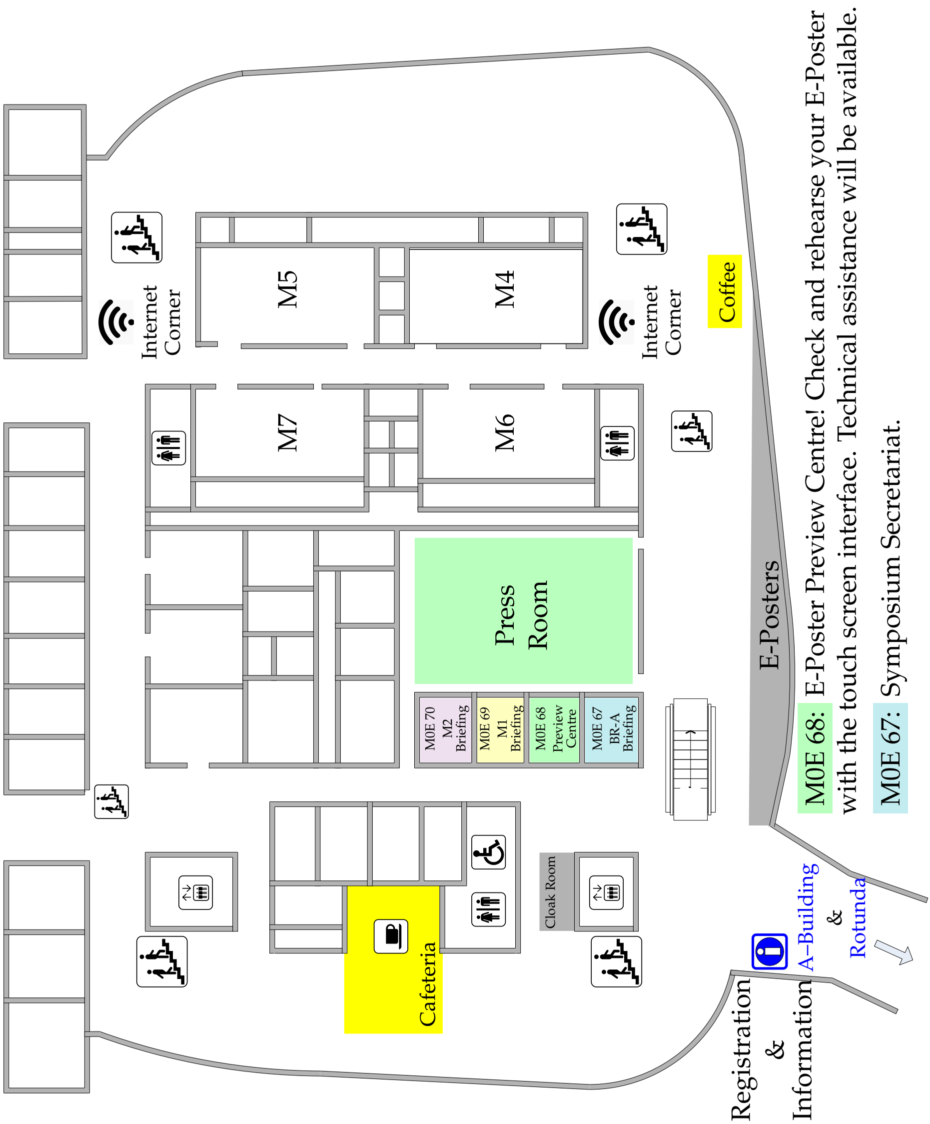
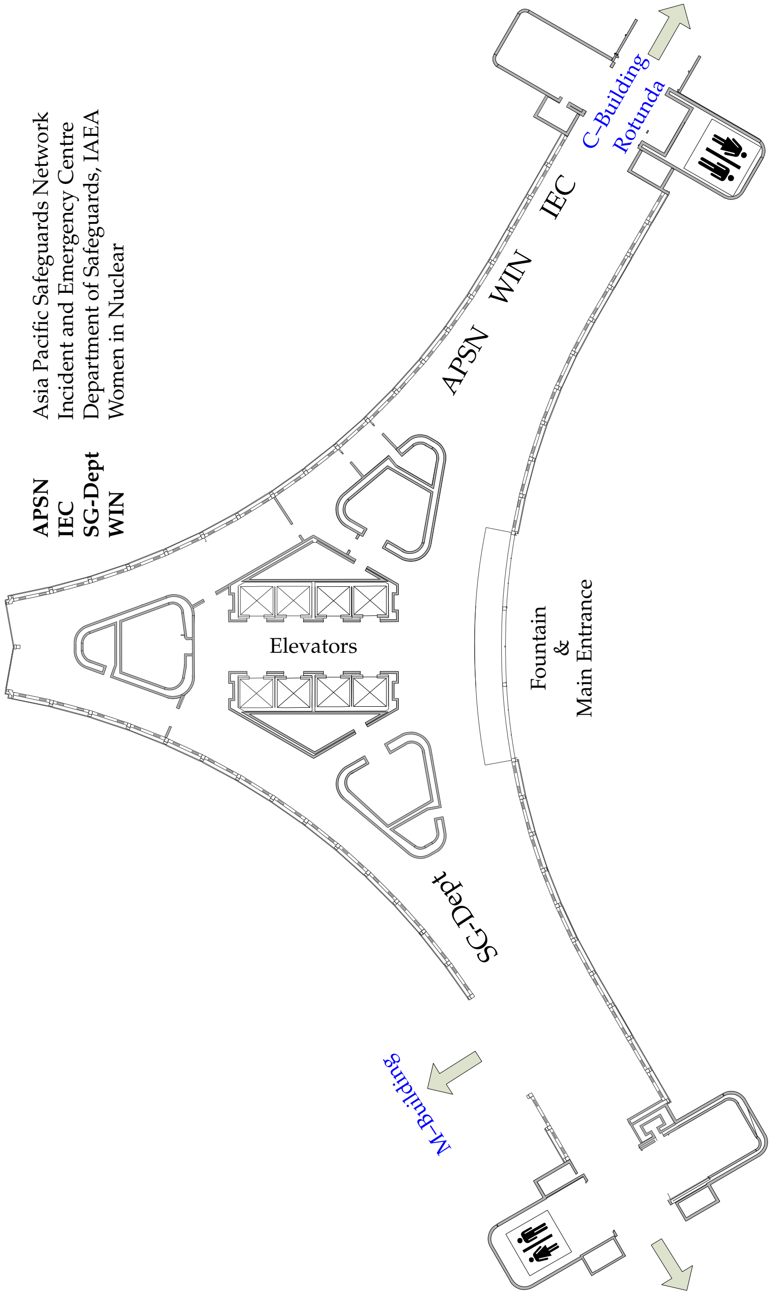
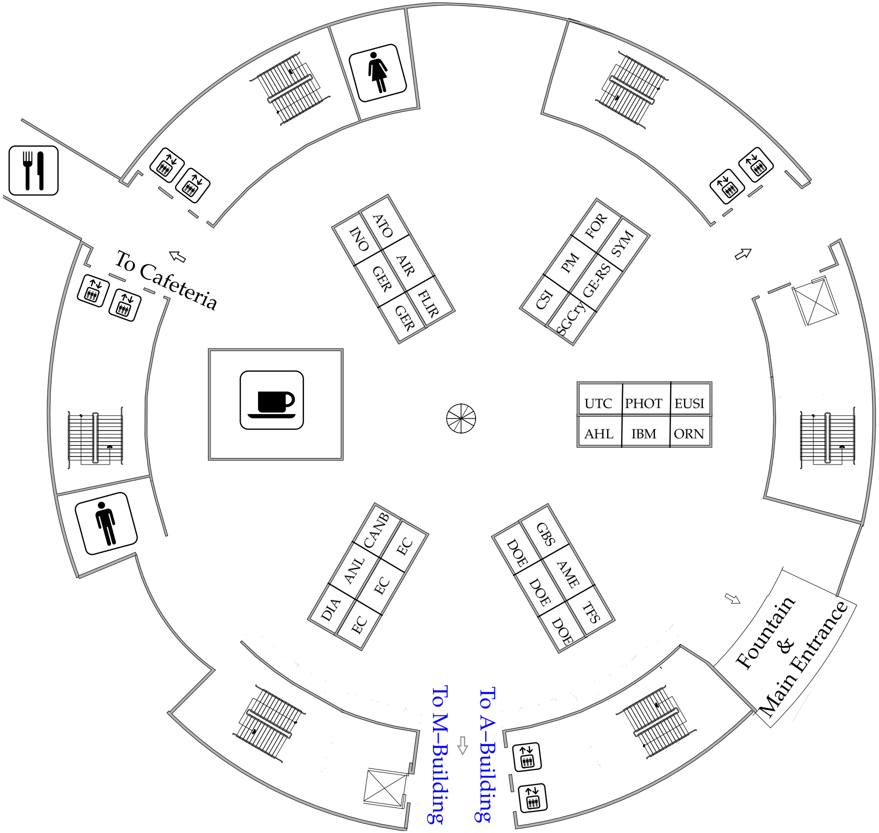
Abbreviations

ABACC	Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials
APSN	Asia Pacific Safeguards Network
CTBTO	Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization
EC	European Commission
ECFA	Egyptian Council for Foreign Affairs
ESARDA	European Safeguards Research and Development Association
EU	European Union
IAEA	International Atomic Energy Agency
INMM	Institute of Nuclear Materials Management
JRC	Joint Research Centre
MSSP	Member State Support Programmes
OPCW	Organisation for the Prohibition of Chemical Weapons
SGAS	Safeguards Analytical Services
SGCP	Safeguards Concepts and Planning
SGIM	Safeguards Information Management
SGIS	Safeguards Information and Communication Systems
SGOA	Safeguards Operations 'A'
SGOB	Safeguards Operations 'B'
SGOC	Safeguards Operations 'C'
SGTS	Safeguards Technical Support
TechSec	Technical Secretary
UNODC	United Nations Office on Drugs and Crime
UNSSS	UN Security and Safety Service
VCDNP	Vienna Center for Disarmament and Non-Proliferation
VERTIC	Verification Research, Training and Information Centre
WIN	Women in Nuclear
WINS	World Institute for Nuclear Security



Internet Corner
M5
M4
Internet Corner
Coffee
M7
M6
Press Room
E-Posters
M0E 70 M2 Briefing
M0E 69 M1 Briefing
M0E 68 Preview Centre
M0E 67 BR-A Briefing
Cloak Room
Cafeteria
Registration & Information
A–Building & Rotunda
M0E 68: E-Poster Preview Centre! Check and rehearse your E-Poster with the touch screen interface. Technical assistance will be available.
M0E 67: Symposium Secretariat.

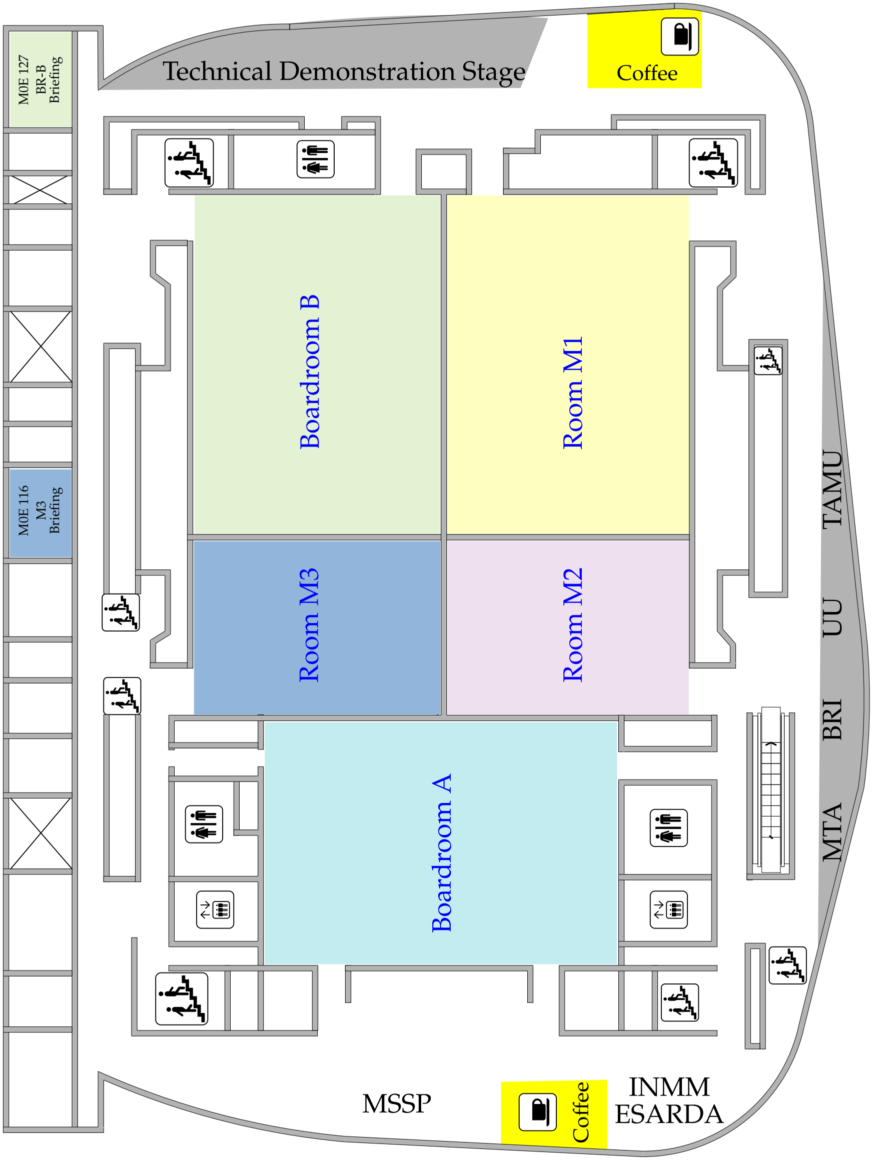

APSN Asia Pacific Safeguards Network
IEC Incident and Emergency Centre
SG-Dept Department of Safeguards, IAEA
WIN Women in Nuclear
C–Building
Rotunda
IEC
WIN
APSN
Elevators
Fountain
&
Main Entrance
SG-Dept
M–Building



AHL	Ahlberg Cameras
AIR	Airbus Defense And Space
AME	Ametek
ANL	Argonne National Laboratory
ATO	Atomtex SPE
CANB	Canberra
CSI	Channel Systems Inc.
DIA	Dialogis
DOE	USA/DOE
EC	European Commission
EUSI	European Space Imaging
FLIR	Flir Systems
FOR	Fortum
GBS	GBS-Electronic
GE-RS	GE Reuter-Stokes
GER	German Support Programme
IBM	IBM
INO	InnoRIID
ORN	Oak Ridge National Laboratory
PHOT	Photonis
PM	Polimaster Ltd.
SGCry	Saint Gobain
SYM	Symetrica
TFS	Thermo Fisher Scientific
UTC	UrtheCast

M–Building, First Floor

BRI	Beijing Research Institute of Uranium
ESARDA	European Safeguards Research and Development Association
INMM	Institute of Nuclear Materials Management
MTA	Hungarian Academy of Sciences
MSSP	Member State Support Programmes
TAMU	Texas A&M University
UU	Uppsala University



Day / Date	Monday 20 October 2014	Tuesday 21 October 2014	Wednesday 22 October 2014	Thursday 23 October 2014	Friday 24 October 2014
09:00 — 10:30	Opening Plenary 10:00–12:30 Chair: T. Varjoranta Boardroom A TechSec: A. Hamilton OP–01: T. Varjoranta (IAEA) OP–02: L. Satkowiak (INMM) OP–03: K. Van der Meer (ESARDA) OP–04: Y. Amano (IAEA) OP–05: V. Šucha (EU) OP–06: G. Berdennikov (Russian Fed.) OP–07: K. Mendelsohn (USA)	Parallel Sessions... Session 01, Session 02, Session 03, Session 04, Session 05	Parallel Sessions... Session 11, Session 12, Session 13, Session 14, Session 15	Parallel Sessions... Session 21, Session 22, Session 23, Session 24, Session 25	Parallel Sessions... Session 31, Session 32, Session 33, Session 34, Session 35
		10:30–11:00 Coffee Break and Technical Demonstration			
11:00 — 12:30		...continued Session 01, Session 02, Session 03, Session 04, Session 05	...continued Session 11, Session 12, Session 13, Session 14, Session 15	...continued Session 21, Session 22, Session 23, Session 24, Session 25	...continued Session 31, Session 32, Session 33, Session 34, Session 35
	12:30– 14:00 Lunch				
14:00 — 15:30	Technical Plenary Boardroom A Chair: S. F. Chin TechSec: A. Catton TP–01: S. F. Chin TP–02: T. Varjoranta TP–03: J. Cooley TP–04: SG Division Directors	Parallel Sessions... Session 06, Session 07, Session 08, Session 09, Session 10	Parallel Sessions... Session 16, Session 17, Session 18, Session 19, Session 20	Parallel Sessions... Session 26, Session 27, Session 28, Session 29, Session 30	Closing Plenary Boardroom A CP–01: M. Whitaker K. Van der Meer CP–02: K. Owen-Whitred CP–03: T. Varjoranta Conference End 16:00
		15:30–16:00 Coffee Break and Technical Demonstration			
16:00 — 17:30	16:00–16:30 Coffee Break Technical Plenary (Continued) TP–05: Panel Discussion	...continued Session 06, Session 07, Session 08, Session 09, Session 10	...continued Session 16, Session 17, Session 18, Session 19, Session 20	...continued Session 26, Session 27, Session 28, Session 29, Session 30	
18:00 — 20:00		Reception M–Building	E-Poster Awards	E-Poster Awards	

Session Titles

Monday 20 October 2014

Tuesday 21 October 2014

Wednesday 22 October 2014

Thursday 23 October 2014

Friday 24 October 2014

Conference Registration

16:00–18:00 Vienna International Centre, Gate One

Welcome Reception

16:30–18:00 C–Building, Rotunda

OP: Opening Plenary

Chair: T. Varjoranta (IAEA)
TechSec: A. Hamilton (IAEA)

Boardroom A
(10:00 – 12:30)

Time	Id	Presenter		Title
10:00	OP–01	T. Varjoranta	IAEA	Opening Remarks
10:20	OP–02	L. Satkowiak	INMM	Welcome from INMM
10:25	OP–03	K. Van der Meer	ESARDA	Welcome from ESARDA
10:30	OP–04	Y. Amano	IAEA	Opening Statement from the IAEA Director General
10:50	OP–05	V. Šucha	EU	Keynote Address
11:10	OP–06	G. Berdennikov	Russian Fed.	Keynote Address
11:30	OP–07	K. Mendelsohn	USA	Keynote Address

TP: Technical Plenary

Chair: S. F. Chin (Singapore)
TechSec: A. Catton (IAEA)

Boardroom A
(14:00 – 17:30)

Time	Id	Presenter		Title
14:00	TP–01	S. F. Chin	Singapore	Welcome and Opening Remarks
14:10	TP–02	T. Varjoranta	IAEA	Keynote Address
14:30	TP–03	J. Cooley	IAEA	Strategic Planning and the Long-term R&D Plan
14:50	TP–04	SG Division Directors		Successes and Future Challenges: Short statements from each of the SG Division Directors (see listing for the Panel below).
16:00	Coffee			
16:30	TP–05	Panel Discussion		Ensuring Non-Discrimination and Consistency in Safeguards Implementation
		G. Dyck	SGOA	
		V. Z. de Villiers	SGOB	
		H. Barroso	SGOC	
		J. Baute	SGIM	
		S. Zykov	SGTS	
		G. Voigt	SGAS	
		F. Moser	SGIS	
		J. Cooley	SGCP	

Tue

S01: Evolving Safeguards Implementation

Chair: W. McCarthy (UK), M. Rasweswe (South Africa) *Boardroom A*
TechSec: T. Renis (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S01–01	J. Cooley	IAEA	Overview of the Development and Discussion on Evolving Safeguards Implementation
09:30	S01–02	P. Burton	Canada	A Canadian Perspective on the IAEA's State-Level Concept
09:50	S01–03	N. Kozlova	Russian Fed.	The IAEA Safeguards System in the XXI Century
10:10	S01–04	D. Trimble	USA	IAEA's Implementation of the State-Level Concept
10:30	Coffee and Technical Demonstration by Virtual Heroes			
11:00	S01–05	Panel Discussion		Evolving Safeguards Implementation
		J. Cooley	IAEA	
		N. Khlebnikov	Russian Fed.	
		G. Terigi	Argentina	
		H. Kumekawa	Japan	
		K. Budlong Sylvester	USA	

S02: Communication with State and Regional Authorities on State Declarations

Chair: K. Owen-Whitred (Canada), P. Szymanski (EU) *Boardroom B*
TechSec: A. Rialhe (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S02–01	F. Queirolo	IAEA	21st Century Declarations
09:30	S02–02	A. Osokina	Russian Fed.	Information Interaction with IAEA on Nuclear Import and Export
09:50	S02–03	F. Sevini	EU	States' Reporting of Annex II Exports (AP) and the Significance for Safeguards Evaluation
10:10	S02–04	K. Gilligan	USA	Transit Matching for International Safeguards
10:30	Coffee and Technical Demonstration by Virtual Heroes			
11:00	S02–05	A. Rialhe	IAEA	Protocol Reporter Update: Scope, User's Requirements, Expectations, Collaborative Work
11:20	S02–06	E. Balter	IAEA	Digital Declarations: The Provision of Site Maps under INFCIRC/540 Article 2.a.(iii)
11:40	S02–07	G. Smith	Canada	Exploiting Spatial Data for Site Declarations
12:00	S02–08	S. Miller	IAEA	Technical Solution for Improved Safeguards/State Cooperation

S03: Safeguards for Reprocessing and Pyroprocessing Facilities

Chair: S. Johnson (USA), S.-H. Park (Korea, Rep. of) *Room M1*
TechSec: M. Hori (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S03–01	S. Bryan	USA	On-Line Monitoring for Process Control and Safeguarding of Radiochemical Streams at Spent Fuel Reprocessing Plants
09:30	S03–02	Y. Lahogue	EU	Developments in the Deployment of Ultrasonic Bolt Seals at the Storage Ponds of a Large Reprocessing Plant
09:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S03–03	R. Plenteda	IAEA	Hardware and Software Upgrade for the Solution Measurement and Monitor System at Rokkasho Reprocessing Plant
	S03–04	M. Åberg Lindell	Sweden	Safeguarding Advanced Generation IV Reprocessing Facilities: Challenges, R&D Needs, and Development of Measurements
	S03–05	P. Richir	EU	Design and Implementation of Equipment for Enhanced Safeguards of a Plutonium Storage in a Reprocessing Plant
	S03–06	B. Cipiti	USA	Improving Materials Accountancy for Reprocessing using hiRX
	S03–07	N. Smith	USA	Application of Laser Induced Breakdown Spectroscopy to Electrochemical Process Monitoring of Molten Chloride Salts
	S03–08	F. Gao	IAEA	Safeguarding Pyroprocessing Related Facilities in the ROK
	S03–09	J. Cazalet	France	Safeguards Considerations for the Design of a Future Fast Neutron Sodium Cooled Reactor
10:30	Coffee and Technical Demonstration by Virtual Heroes			
11:00	S03–10	B. Cipiti	USA	Cost Effective Process Monitoring using UV-VIS-NIR Spectroscopy
11:20	S03–11	M. Hori	IAEA	Proliferation Potential and Safeguards Challenges of Pyroprocesses
11:40	S03–12	S.-H. Park	Korea, Rep. of	Development of a Safeguards Approach for Reference Engineering-Scale Pyroprocessing Facility
12:00	S03–13	C. Pereira	USA	Application of Microfluidic Techniques to Pyrochemical Salt Sampling and Analysis

S04: Innovative Methods for Training

Chair: A. Jraut (Morocco)
TechSec: S. Pickett (IAEA)

Room M2
(09:00 – 12:30)

Time	Id	Presenter		Title
09:10	S04–01	J. G. M. Gonçalves	EU	Virtual Reality Based Accurate Radioactive Source Representation and Dosimetry for Training Applications
09:30	S04–02	T. Patton	VCDNP	Employing 3D Virtual Reality and the Unity Game Engine to Support Nuclear Verification Research
09:50	S04–03	N. Y. Lee	Korea, Rep. of	Training Software for the Bulk Handling Facility
10:10	S04–04	I. Szőke	Norway	Human-Centred Computing for Assisting Nuclear Safeguards
10:30	Coffee and Technical Demonstration by Virtual Heroes			
11:00	S04–05	W. A. M. Janssens	EU	Advanced Safeguards Measurement, Monitoring and Modelling Laboratory (AS3ML)
11:20	S04–06	J. Tackentien	USA	Immersive Environment Development for Training: Opportunities for Cooperation, Coordination, and Cost Savings
11:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S04–07	R. Berndt	EU	Evolution of the Nuclear Safeguards Performance Laboratory PERLA on the Ispra Site of the Institute for Transuranium Elements
	S04–08	S. Bogdanov	Russian Fed.	Practical Results of the Creation of the Non-destructive Assay Measurement Training Laboratory at the Russian Methodological and Training Center
	S04–09	R. Chatelus	EU	Safeguards Export–Import Training: Adapting to Changes in the Department of Safeguards Over 6 Years of Experience
	S04–10	A. Vincze	Hungary	Developing Safeguards Training Material for Management and General Staff of Facilities
	S04–11	L. Holzleitner	EU	Construction of a NDA-Safeguards Training Facility at the ITU Karlsruhe

S05: Assuring Quality in Safeguards Findings

Chair: O. Peixoto (ABACC), C. Everton (Australia) *Room M3*

TechSec: A. Bruno (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S05–01	C. Everton	Australia	Accountability and Transparency: Essential Underpinnings of Quality Safeguards
09:30	S05–02	A. Meyering	Germany	URENCO's Experiences in Safeguards Reporting and in Developing a Nuclear Material Accountancy System
09:50	S05–03	H. Nel	South Africa	Nuclear Material Information Quality Control for Safeguards Purposes in South Africa
10:10	S05–04	K. Robertson	Australia	Deriving, Communicating and Applying Safeguards Conclusions
10:30	Coffee and Technical Demonstration by Virtual Heroes			
11:00	S05–05	Y. Goto	Japan	Japanese Quality Assurance System Regarding the Provision of Material Accounting Reports and the Safeguards Relevant Information to the IAEA
11:20	S05–06	D. Hanks	USA	United States of America Nuclear Regulatory Commission's Approach to Inspections and Quality Control of Data
11:40	S05–07	P. Meylemans	EU	Verification of the Correctness and Completeness of Nuclear Operators' Declarations by Euratom
12:00	S05–08	S. Konecni	IAEA	The Department of Safeguards Quality Management System

S06: Performance Management in Non-profit Organizations

Chair: T. Findlay (Australia) *Boardroom A*
TechSec: S. Shawky (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S06–01	V. Z. de Villiers	IAEA	Strengthening Performance Management in the IAEA Department of Safeguards
14:30	S06–02	R. Howsley	WINS	Effective Strategy Implementation: Best Practice that Really Works
14:50	S06–03	Z. Stefanka	Hungary	Assessing and Promoting the Level of Safeguards Culture in Hungarian Nuclear Facilities
15:10	S06–04	T. Findlay	Australia	Nuclear Safeguards Culture
15:30	Coffee and Technical Demonstration: New Satellite-Based Video Technologies			
16:00	S06–05	Panel Discussion		Performance Management in Non-Profit Organizations
		V. Z. de Villiers	IAEA	
		K. Murakami	Japan	
		S. Dare-Doyen	OPCW	
		K. Owen-Whitred	Canada	
		P. Meylemans	EU	
		J. Dickson	UNODC	

Tue

S07: New Trends in Commercial Satellite Imagery

Chair: M. Hong (Korea, Rep. of), I. Niemeyer (Germany) *Boardroom B*
TechSec: M. Johnson (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S07–01	M. Johnson	IAEA	New and Emerging Satellite Imaging Capabilities in Support of Safeguards
14:30	S07–02	N. Spyropoulos	Canada	UrtheCast: The System of Systems for Dynamic EO Monitoring Content
14:50	S07–03	J. Clark	USA	European Space Imaging & Skybox Imaging
15:10	S07–04	M. Hong	Korea, Rep. of	Alternative Data Source for Monitoring of Nuclear Activity: KOMPSAT Constellation
15:30	Coffee and Technical Demonstration: New Satellite-Based Video Technologies			
16:00	S07–05	J.-M. Lagrange	France	Identification of Nuclear Activities Using Satellite Imaging
16:20	S07–06	M. Canty	Germany	Change Detection with Polarimetric SAR Imagery for Nuclear Verification
16:40	S07–07	P. d'Angelo	Germany	High Resolution 3D Earth Observation Data Analysis for Safeguards Activities
17:00	S07–08	I. Niemeyer	Germany	Advances in the Processing of VHR Optical Imagery in Support of Safeguards Verification

S08: State of the Art Destructive Analysis

Chair: E. Kuhn (Germany), Y. Aregbe (EU) *Room M1*

TechSec: D. Amaraggi (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S08–01	S. Bulyha	IAEA	Implementation of Mass Spectrometry for Bulk Analysis of Environmental and Nuclear Material Inspection Samples
14:30	S08–02	M. Duerr	Germany	Activities at Forschungszentrum Jülich in Safeguards Analytical Techniques and Measurements
14:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S08–03			Withdrawn
	S08–04	A. Knott	IAEA	Production and Characterization of Monodisperse Reference Particles
	S08–05	E. Esbelin	France	Actinide L-line ED-XRF and Hybrid K-edge Densitometer Spectra Processing
	S08–06	D. Roudil	France	Feedback of EQRAIN Uranium and Plutonium Analysis Proficiency Tests for the Evaluation of Method Performance
	S08–07	A. Gorbunova	Russian Fed.	Characterization of Nuclear Materials Using Complex of Non-Destructive and Mass-Spectroscopy Methods of Measurements
	S08–08	C. Barinaga	USA	Towards a Fieldable Atomic Mass Spectrometer for Safeguards Applications: Sample Preparation and Ionization
	S08–09	I. Szalóki	Hungary	Chemical Characterization of Nuclear Materials: Development a New Combined X-Ray Fluorescence and Raman Spectrometer
15:30	Coffee and Technical Demonstration: New Satellite-Based Video Technologies			
16:00	S08–10	C. A. Pickett	USA	Stability of Working Reference Standards for Hybrid K-Edge Densitometer Quality Assurance
16:20	S08–11	D. Guo	China	Analysis of Uranium-Based Materials by Mass Spectrometric Methods
16:40	S08–12	A. Trinquier	Germany	10^{13} Ω Resistor Amplifiers in MC-TIMS for Precise and Accurate U Isotope Analysis
17:00	S08–13	C. Leibman	USA	Field Sample Preparation Method Development for Isotope Ratio Mass Spectrometry

Tue

S09: Training and Education in Nuclear Non-proliferation and Safeguards

Chair: C. Gariazzo (USA), E. Sokova (VCDNP) *Room M2*
TechSec: A. Braunegger-Guelich (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S09–01	A. Braunegger-Guelich	IAEA	IAEA Support for Building-Up a Highly Skilled Workforce Necessary for an Effective State System of Accounting for and Control of Nuclear Material
14:30	S09–02	M. Senzaki	Japan	20 Years of Achievement and Future Challenge for International Capacity Building Regarding Safeguards and SSAC at Japan Atomic Energy Agency (JAEA)
14:50	S09–03	E. Sokova	VCDNP	Synergies between Science and Policy and the Use of New Teaching Tools in the Academic and Professional Development Programs
15:10	S09–04	W. A. M. Janssens	EU	Need for Strengthening Nuclear Non-Proliferation and Safeguards Education to Prepare the Next Generation of Experts
15:30	Coffee and Technical Demonstration: New Satellite-Based Video Technologies			
16:00	S09–05	D. Nikonov	IAEA	Interfacing Nuclear Security and Safeguards through Education and Support Centre Networks
16:20	S09–06	C. Gariazzo	USA	Nuclear Safeguards and Non-Proliferation Education at Texas A&M University
16:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S09–07	V. Kyryshchuk	Ukraine	Ukrainian National System of MC&A Training on Regular Basis at the George Kuzmych Training Center
	S09–08	S. Nilsuwankosit	Thailand	Research Projects at Chulalongkorn University for the Master Degree Programme in Nuclear Security and Safeguard
	S09–09	M. Scholz	USA	Next Generation Safeguards Initiative: Human Capital Development
	S09–10	R. Stevens	IAEA	Member State Outreach: Capitalizing on Synergies for Effective Implementation
	S09–11	S. Lestari	APSN	Promoting Safeguards Best Practice through the Asia-Pacific Safeguards Network (APSN)
	S09–12	J. Gerža	Czech Republic	Safeguards Support Provided by Dukovany NPP
	S09–13	S. Ticevic	IAEA	The Systematic Approach to Training: Analysis and Evaluation in the Department of Safeguards

Tue

S10: Automation and Instrumentation Data Analysis in Safeguards Verification

Chair: Z. Wang (China), A. Anichenko (CTBTO) *Room M3*

TechSec: J. Regula (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S10–01	C. Brunhuber	IAEA	Evolution of RAINSTORM
14:30	S10–02	A. Smejkal	EU	Joint Partnership: a New Software Development Paradigm
14:50	S10–03	C. Versino	EU	Evaluation of a Surveillance Review Software based on Automatic Image Summaries
15:10	S10–04	P. Santi	USA	The Development of Advanced Processing and Analysis Algorithms for Improved Neutron Multiplicity Measurements
15:30	Coffee and Technical Demonstration: New Satellite-Based Video Technologies			
16:00	S10–05	A. Pichan	Australia	Can Nuclear Installations and Research Centres Adopt Cloud Computing Platform?
16:20	S10–06	J. Longo	USA	Sustaining IAEA Neutron Coincidence Counting: Past, Present and Future
16:40	S10–07	E. Lyman	USA	Material Accounting Issues at the U.S. MOX Fuel Fabrication Facility
17:00	S10–08	F. Littmann	EU	Automated Image Acquisition System for the Verification of Copper-Brass Seal Images

S11: Acquisition Path Analysis Methodology

Chair: G. Stein (Germany), A. Vincze (Hungary) *Boardroom A*

TechSec: J. P. Morizot (IAEA) **(09:00 – 12:30)**

Wed

Time	Id	Presenter		Title
09:10	S11–01	T. Renis	IAEA	Opening Remarks
09:30	S11–02	A. Nakao	IAEA	Acquisition Path Analysis as a Collaborative Activity
09:50	S11–03	A. Vincze	Hungary	Effect of State-Specific Factors on Acquisition Path Ranking
10:10	S11–04	C. Listner	Germany	Quantifying Detection Probabilities for Proliferation Activities in Undeclared Facilities
10:30	Coffee and Technical Demonstration: Generation and Analysis of Digitally Emulated Radiation Detector Signals (CAEN SpA)			
11:00	S11–05	K. Budlong Sylvester	USA	Developing State Level Approaches under the State Level Concept
11:20	S11–06	G. G. M. Cojazzi	EU	The Potential of Open Source Information in Supporting Acquisition Pathway Analysis to Design IAEA State Level Approaches
11:40	S11–07	Z. Varga	EU	Identification of Signatures to Detect Undeclared Nuclear Activities at the Front-end of the Fuel Cycle
12:00	S11–08	J. Crowley	USA	Computational Methods for Physical Model Information Management: Opening the Aperture

S12: Preview of New IAEA Guidance: Safeguards Implementation Practice Guides

Chair: N. Y. Lee (Korea, Rep. of) *Boardroom B*
TechSec: C. Mathews (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S12–01	C. Mathews	IAEA	IAEA's Safeguards Implementation Practices Guides
09:30	S12–02	C. Everton	Australia	Implementation Practices in the Asia-Pacific Related to Establishing State Safeguards Infrastructure
09:50	S12–03	E. Martikka	Finland	Implementation Practices of Finland in Facilitating IAEA Verification Activities
10:10	S12–04	R. Maxwell	Canada	Canada's Implementation Practices in Provision of Information to the IAEA
10:30	Coffee and Technical Demonstration: Generation and Analysis of Digitally Emulated Radiation Detector Signals (CAEN SpA)			
11:00	S12–05	Panel Discussion		Preview of New IAEA Guidance: Safeguards Implementation Practice Guides
		V. Cisar	IAEA	
		A. Jraut	Morocco	
		Y. Goto	Japan	
		O. Elkhamri	USA	
		G. Dahlin	Sweden	
		S. Shawky	IAEA	

S13: State of the Art Environmental Sample Analysis

Chair: G. Voigt (IAEA), J. Tushingham (UK) *Room M1*
TechSec: S. Bulyha (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S13–01	Y. Aregbe	EU	Conformity Assessment in Nuclear Material and Environmental Sample Analysis
09:30	S13–02	R. Higgy	IAEA	Detection of Reprocessing Activities Using Environmental Sampling
09:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S13–03	A. Donard	France	Are Polyatomic Interferences, Cross Contamination, Mixing-Effect, etc., Obstacles for the Use of Laser Ablation–ICP-MS Coupling as an Operational Technique for Uranium Isotope Ratio Particle Analysis?
	S13–04	N. Dzigal	IAEA	Laser-Assisted Sampling Techniques in Combination with ICP-MS: A Novel Approach for Particle Analysis at the IAEA Environmental Samples Laboratory
	S13–05	A.-L. Fauré	France	Development of a Methodology to Detect Fluorine in Uranium Bearing Particle by SIMS
	S13–06	V. Khoroshilov	Russian Fed.	Increasing the Accuracy of EPMA of Microparticles Using Lower Energy Electron Beam and FIB Slicing
	S13–07	L. Sexton	USA	Field Testing of Unattended Environmental Sampling Devices and Analysis Results
	S13–08	Y. Stebelkov	Russian Fed.	Dating of Uranium Materials by Using Combination of ICP-MS and SIMS
	S13–09	J. Cliff	Australia	Novel Mass Spectrometric Techniques for the Rapid Characterization and Fingerprinting of Nuclear Fuel Materials
10:30	Coffee and Technical Demonstration: Generation and Analysis of Digitally Emulated Radiation Detector Signals (CAEN SpA)			
11:00	S13–10	U. Admon	Israel	Advancements in Particle Analysis Procedures and their Application to the Characterization of Reference Materials for Safeguards
11:20	S13–11	K. Fiola	Germany	VKTA Rossendorf: Laboratory for Environmental and Radionuclide Analysis
11:40	S13–12	Z. Macsik	IAEA	Validation of Neptune Plus MC-ICP-MS for Bulk Analysis of Environmental Swipe Samples
12:00	S13–13	I. Elantyev	Russian Fed.	Improved Technique for the Determination of Uranium Minor Isotopes Concentrations in Microparticles by Using Secondary Ion Mass-Spectrometer in Multicollection Mode

S14: Safeguards Needs at Geological Repositories and Encapsulation Facilities

Chair: K. Van der Meer (ESARDA), L. Satkowiak (USA) *Room M2*
TechSec: Y. Yudin (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S14–01	O. Okko	Finland	Developing Safeguards for Final Disposal of Spent Nuclear Fuel in Finland
09:30	S14–02	Y. Yudin	IAEA	Safeguards by Design at the Encapsulation Plant in Finland
09:50	S14–03	V.-M. Ammala	Finland	Operator View on Safeguards Implementation for New Type of Facilities (Encapsulation Plant and Geological Repository)
10:10	S14–04	I. Niemeyer	Germany	Safeguarding Geological Repositories: R&D Contributions from the GER SP
10:30	Coffee and Technical Demonstration: Generation and Analysis of Digitally Emulated Radiation Detector Signals (CAEN SpA)			
11:00	S14–05	L. Hildingsson	Sweden	Safeguards Aspects Regarding a Geological Repository in Sweden
11:20	S14–06	S. Tobin	USA	Experimental and Analytical Plans for the Non-Destructive Assay System of the Swedish Encapsulation and Repository Facilities
11:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S14–07	S. Uchtmann	Germany	Radar Monitoring: Modelling of Undeclared Activities
	S14–08	R. Twogood	USA	Secure and Reliable Wireless Communications for Geological Repositories and Nuclear Facilities
	S14–09	R. Haddal	USA	Geological Repository Safeguards: Options for the Future
	S14–10	J. Altmann	Germany	Modelling Seismic Propagation at a Salt Dome: Signals at Potential Monitoring Sites
	S14–11	F. Poidevin	France	“Cigéo”: The French Industrial Project of Deep Geological Repository Developed by Andra
	S14–12	R. Plenteda	IAEA	Study on the Near Real Time (NRT) Impact of Safeguards Measures for the Encapsulation Plant in Finland

S15: New Trends in the Application of Statistical Methodologies for Safeguards

Chair: T. Burr (USA) *Room M3*

TechSec: T. Krieger (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S15–01	C. Norman	IAEA	Outcome and Perspectives from the First IAEA International Technical Meeting on Statistical Methodologies for Safeguards
09:30	S15–02	J. Wuester	IAEA	IAEA Safeguards and GUM-based Measurement Uncertainty Estimation: a Reconciliation
09:50	S15–03	K. Martin	IAEA	The Analysis of Measurement Errors as Outlined in GUM and in the IAEA Statistical Methodologies for Safeguards: a Comparison
10:10	S15–04	T. Krieger	IAEA	Inspections Over Time: The Role of Information
10:30	Coffee and Technical Demonstration: Generation and Analysis of Digitally Emulated Radiation Detector Signals (CAEN SpA)			
11:00	S15–05	T. Shiba	France	Reactor Simulations for Safeguards with the MCNP Utility for Reactor Evolution Code
11:20	S15–06	C. G. Portaix	IAEA	A Computer Simulation to Assess the Nuclear Material Accountancy System of a MOX Fuel Fabrication Facility
11:40	S15–07	S. Richet	IAEA	Near Real-Time Accountancy at JNC-1

S16: Potential Verification Roles

Chair: J. Cooley (IAEA), G. Terigi (Argentina) *Boardroom A*
TechSec: W. J. Kim (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S16–01	T. E. Shea	USA	The Trilateral Initiative: IAEA Verification of Weapon-Origin Plutonium in the Russian Federation and the United States
14:30	S16–02	L. Rockwood	USA	The Trilateral Initiative: The Legal Framework
14:50	S16–03	R. Moul	VERTIC	Building a Simulated Environment for the Study of Multilateral Approaches to Nuclear Materials Verification
15:10	S16–04	L. Persson	EU	Consolidation of NM in the UK: Optimizing the Euratom Approach
15:30	Coffee and Technical Demonstration: Underwater Spectroscopy Measurement Using a New Hermetically Sealed Germanium Probe			
16:00	S16–05	R. Diaz	USA	United States Support Programme (USSP): Lessons Learned from the Management of Complex, Multi-Stakeholder Projects for International Safeguards
16:20	S16–06	A. Dougan	USA	Long Term R&D for Safeguards
16:40	S16–07	Y. Abushady	ECFA	Building-Up the Non-Proliferation Nuclear Trust in the Middle East
17:00	S16–08	H. Sokolski	USA	Is the IAEA's Safeguard Strategic Plan Sufficient?

Wed

S17: Technology Foresight and Emerging Technologies I

Chair: S. Abousahl (EU), N. Khlebnikov (Russian Fed.)

Boardroom B

TechSec: M. Laughter (IAEA)

(14:00 – 17:30)

Time	Id	Presenter		Title
14:10	S17–01	N. Smith	USA	Development of Spectrophotometric Process Monitors for Aqueous Reprocessing Facilities
14:30	S17–02	D. Chernikova	Sweden	A New Approach to Environmentally Safe Unique Identification of Long-Term Stored Copper Canisters
14:50	S17–03	C. M. Kim	Korea, Rep. of	Modeling Nuclear Proliferation for the Purpose of Warning
15:10	S17–04	A. Hubert	France	Improvement of Bulk Analysis of Environmental Samples by Using a Multiple Collector ICP-MS
15:30	Coffee and Technical Demonstration: Underwater Spectroscopy Measurement Using a New Hermetically Sealed Germanium Probe			
16:00	S17–05	T. Martinik	Sweden	Characterization of Spent Nuclear Fuel with a Differential Die-Away Instrument
16:20	S17–06	M. Nangu	South Africa	232Th Mass Determination in a Uranium/Thorium Mixture for Safeguards Purposes
16:40	S17–07	A. Jussofie	Germany	Germany's Accelerated Exit from Nuclear Energy: Challenges and Perspectives with Regard to Safeguards
17:00	S17–08	P. Thompson	UK	The Development of New and Improved Capabilities Applicable to Safeguards

S18: Challenges in Spent Fuel Verification

Chair: S. Zykov (IAEA), S. Tobin (USA) *Room M1*
TechSec: I. Cherradi (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S18–01	R. Rossa	Belgium	A New Approach for the Application of the Self-Interrogation Neutron Resonance Densitometry (SINRD) to Spent Fuel Verifications
14:30	S18–02	Y. D. Lee	Korea, Rep. of	Status of LSDS Development for Isotopic Fissile Assay in Used Fuel
14:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S18–03	A. Borella	Belgium	Advances in the Development of a Spent Fuel Measurement Device in Belgian Nuclear Power Plants
	S18–04	P. Jansson	Sweden	Gamma Transport Calculations for Gamma Emission Tomography on Nuclear Fuel within the UGET Project
	S18–05	V. Ivanovs	Latvia	Performance Evaluation of New Generation CdZnTe Detectors for Safeguards Applications
	S18–06	G. Havrilla	USA	Initial hiRX Performance Characterization of Pu in Nuclear Spent Fuel Matrix
	S18–07	S. Jacobsson Svärd	Sweden	Gamma-Ray Emission Tomography: Modeling and Evaluation of Partial-Defect Testing Capabilities
	S18–08	A. LaFleur	USA	Experimental Assessment of a New Passive Neutron Multiplication Counter for Partial Defect Verification of LWR Fuel Assemblies
	S18–09	Y. G. Lee	IAEA	Development of “Fission Chamber Free” Fork Detector (FDET) for Safeguards Measures on LWR Spent Fuel Assemblies
15:30	Coffee and Technical Demonstration: Underwater Spectroscopy Measurement Using a New Hermetically Sealed Germanium Probe			
16:00	S18–10	Y. Kuno	Japan	Application of Passive Gamma-ray Spectroscopy for Special Nuclear Material Accountancy in Molten Core Material of Fukushima Dai-ichi Nuclear Power Plant
16:20	S18–11	S. Vaccaro	EU	Uncertainty Quantification of Fork Detector Measurements from Spent Fuel Loading Campaigns
16:40	S18–12	T. Honkamaa	Finland	A Prototype for Passive Gamma Emission Tomography
17:00	S18–13	K.-P. Ziock	USA	U and Pu Gamma-Ray Measurements of Spent Fuel Using a Gamma-Ray Mirror Band-Pass Filter

Wed

S19: Advanced Technologies for Safeguards Communications

Chair: F. Moser (IAEA)
TechSec: S. Miller (IAEA)

Room M2
(14:00 – 17:30)

Time	Id	Presenter		Title
14:10	S19–01	J. Garcia	Spain	Mobile Workforce, Mobile Technology, Mobile Threats
14:30	S19–02	M. S. Partee	IAEA	Secure Communications with Mobile Devices During In-Field Activities
14:50	S19–03	M. Gulay	OPCW	The Secure Information Exchange (SIX) Project at the OPCW
15:10	S19–04	J. Sample	Canada	Establishing and Advancing Electronic Nuclear Material Accounting Capabilities: A Canadian Perspective
15:30	Coffee and Technical Demonstration: Underwater Spectroscopy Measurement Using a New Hermetically Sealed Germanium Probe			
16:00	S19–05	A.-M. Eriksson Eklund	Sweden	The STAR System-A Computer Software for Accountancy and Control
16:20	S19–06	S. Negri Ferreira	Brazil	e-Gamma: Nuclear Material Accountancy and Control System in Brazil
16:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S19–07	M. Thomas	USA	Testing The Enhanced Data Authentication System (EDAS)
	S19–08	M. John	IAEA	Next Generation Surveillance System (NGSS): Field Implementation & Associated Developments
	S19–09	F. Nekoogar	USA	An Integrated Passive (Battery-Free) Seals-and-Tag for International Safeguards
	S19–10	L. Persson	EU	Use of Electronic Seals and Remote Data Transmission to Increase the Efficiency of Safeguards Applied in a Static Plutonium Store
	S19–11	S. Lee	Korea, Rep. of	Cyber Security Evaluation of the Wireless Communication for the Mobile Safeguard Systems in Nuclear Power Plants
	S19–12	E. Smith	USA	Front-End Electronics for Verification Measurements: Performance Evaluation and Viability of Advanced Tamper Indicating Measures
	S19–13	H. Smartt	USA	Current Research on Containment Technologies for Verification Activities: Advanced Tools for Maintaining Continuity of Knowledge

S20: Frameworks for Monitoring the Quality of the Operator's Measurement and Accounting Systems

Chair: S. Iso (Japan), S. Ciccarello (EU) *Room M3*

TechSec: C. Norman (IAEA) **(14:00 – 17:30)**

Wed

Time	Id	Presenter		Title
14:10	S20–01	C. Norman	IAEA	Role and Successes of Trilateral Liaison Frameworks (IAEA-SSACs/RSACs- Nuclear Fuel Cycle Facility Operators) in Monitoring the Quality of the Operator's Measurement and Accounting Systems
14:30	S20–02	R. Bencardino	EU	Ensuring Solid, Transparent and Scientifically Sound Material Balance Evaluation (MBE) Practice in the EC through Collaboration between Regulators, Operators and the Scientific Safeguards Community
14:50	S20–03	N. Sato	Japan	Technical Review of Operator's Destructive Analyses at the Rokkasho Reprocessing Plant: Strengthening the Transparency of the Operator's Measurement System
15:10	S20–04	J.-G. Decaillon	IAEA	Continuous Analytical Performances Monitoring at the On-Site Laboratory through Proficiency, Inter-Laboratory Testing and Inter-Comparison Analytical Methods
15:30	Coffee and Technical Demonstration: Underwater Spectroscopy Measurement Using a New Hermetically Sealed Germanium Probe			
16:00	S20–05	Panel Discussion		Frameworks for Monitoring the Quality of the Operator's Measurement and Accounting Systems
		P. Buscaglia	IAEA	
		G. Af Ekenstam	IAEA	
		M. Keselica	IAEA	
		R. Binner	IAEA	
		S. Iso	Japan	
		R. Bencardino	EU	
		S. Fernandez Moreno	ABACC	

S21: IAEA-State Cooperation I

Chair: V. Z. de Villiers (IAEA) *Boardroom A*

TechSec: A. Monteith (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S21–01	S. Abousahl	EU	The Nuclear Safeguards and Security Activities under Euratom Research and Training Programme
09:30	S21–02	H. Kumekawa	Japan	Cooperation in the Implementation of Safeguards at Fukushima Dai-ichi Site
09:50	S21–03	A. Muti	VERTIC	Engagement and Cooperation on IAEA Safeguards Additional Protocol: VERTIC Initiative and Methods
10:10	S21–04	K. Murakami	Japan	The Standing Advisory Group on Safeguards Implementation
10:30	Coffee and Technical Demonstration: Examples of Commercial Off-The-Shelf (COTS) Solutions Considered for SG Implementation			
11:00	S21–05	Panel Discussion		IAEA-State Cooperation
		M. Rasweswe	South Africa	
		M. S. Islam	Bangladesh	
		S. H. Kim	Korea, Rep.	
		C. Everton	Australia	
		M. Marzo	Brazil	

S22: Equipment Security and Considerations for Joint Use

Chair: H. Smartt (USA), P. Gutmann (New Zealand) *Boardroom B*
TechSec: C. Liguori (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S22–01	I. Naumann	IAEA	Security and Risk Analysis of Nuclear Safeguards Instruments Using Attack Trees
09:30	S22–02	G. Baldwin	USA	Authentication Approaches for Standoff Video Surveillance
09:50	S22–03	M. Coram	USA	Key Management Strategies for Safeguards Authentication and Encryption
10:10	S22–04	S. Rocchi	Italy	Use of Specialized Security Techniques to Enhance the Authenticity of Surveillance Data
10:30	Coffee and Technical Demonstration: Examples of Commercial Off-The-Shelf (COTS) Solutions Considered for SG Implementation			
11:00	S22–05	A. Schwier	Germany	The IAEA's Universal Instrument Token
11:20	S22–06	J. Stronkhorst	EU	The Security Plan for the Joint Euratom/IAEA Remote Monitoring Network
11:40	S22–07	T. Nagatani	Japan	JAEA's Contribution to Development of J-MOX Safeguards System

S23: Technical Aspects of Information Collection and Analysis

Chair: J. Oddou (France) *Room M1*

TechSec: W. Hammond (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S23–01	B. Wilson	IAEA	Advances in the Collection and Analysis of Large Volumes of Information on the Nuclear Fuel Cycle from Disparate Sources as a Verification Tool
09:30	S23–02	G. G. M. Cojazzi	EU	Tools for Trade Analysis and Open Source Information Monitoring for Non-proliferation
09:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S23–03	R. Schuler	IAEA	Technical Publications as Indicators for Nuclear Fuel Cycle Declarable Activities
	S23–04	F. Pabian	EU	Open Source Analysis in Support to Nonproliferation Monitoring and Verification Activities: Using the New Media to Derive Unknown New Information
	S23–05	T. Skoeld	IAEA	The Efficacy of Social Media as a Research Tool and Information Source for Safeguards Verification
	S23–06	M. Pericou-Cayère	France	Efficiency and Effectiveness in the Collection and Analysis of S&T Open Source Information
	S23–07	R. Chatelus	EU	Non-Proliferation Community, Do We Really Speak the Same Language?
	S23–08	H. Stefko	Austria	Information Management: Business Vulnerabilities:
	S23–09	S. Kittley	IAEA	Incident and Trafficking Database: New Systems for Reporting and Accessing State Information
10:30	Coffee and Technical Demonstration: Examples of Commercial Off-The-Shelf (COTS) Solutions Considered for SG Implementation			
11:00	S23–10	E. Marinova	IAEA	Analysis of Nuclear Relevant Information on International Procurement and Industrial Activities for Safeguards Purposes
11:20	S23–11	J. Khaled	IAEA	Collection, Analysis, and Dissemination of Open Source News and Analysis for Safeguards Implementation and Evaluation
11:40	S23–12	C. Versino	EU	Pattern Recognition by Humans and Machines
12:00	S23–13	J. Midwinter	UK	Enhancing Safeguards through Information Analysis: Business Analytics Tools

S24: Noble Gas Measurements in Support of Nuclear Safeguards Implementation

Chair: A. Ringbom (Sweden), J. S. E. Wieslander (CTBTO) *Room M2*
TechSec: P. Saey (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S24–01	A. Ringbom	Sweden	Environmental Low-Level Noble Gas Measurements for Nuclear Non-Proliferation Treaty Verification Purposes
09:30	S24–02	C. Schlosser	Germany	Krypton-85 Monitoring at BfS in Germany and Technical Solutions for Safeguards
09:50	S24–03	A. Ringbom	Sweden	Xenon Gas to Identify DPRK's Nuclear Tests
10:10	S24–04	R. Purtschert	Switzerland	Ar-37 in the Atmospheric and Sub-Soil Gases
10:30	Coffee and Technical Demonstration: Examples of Commercial Off-The-Shelf (COTS) Solutions Considered for SG Implementation			
11:00	S24–05	G. Wotawa	Austria	Source Determination and Localization by Atmospheric Transport Modelling
11:20	S24–06	J. S. E. Wieslander	CTBTO	Noble Gas Sampling and Detection Methods for On-Site Inspections in Support of CTBT
11:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S24–07	S. Hebel	Germany	Automated Sampling and Extraction of Krypton from Small Air Samples for Kr-85 Measurement Using Atom Trap Trace Analysis
	S24–08	M. Kohler	Germany	All-Optical Atom Trap Trace Analysis: Potential Use of 85Kr in Safeguards Activities
	S24–09	G. Wotawa	Austria	Source Location of Noble Gas Plumes
	S24–10	P. Saey	IAEA	Radioactive Emissions from Fission-Based Medical Isotope Production and Their Effect on Global Nuclear Explosion Detection
	S24–11	H. Berglund	Sweden	SAUNA: Equipment for Low Level Measurement of Radioactive Xenon
	S24–12	M. Auer	CTBTO	The International Monitoring System's Noble Gas Network

S25: NDA Measurements I: Gamma Spectrometry

Chair: P. Lemaire (France), T. Honkamaa (Finland)

Room M3

TechSec: S. Jung (IAEA)

(09:00 – 12:30)

Time	Id	Presenter		Title
09:10	S25–01	R. Venkataraman	USA	Advanced Mathematical Methods for Gamma-Ray Based Nuclear Safeguards Measurements
09:30	S25–02	J. Dreyer	USA	Next Generation Germanium Systems for Safeguards Applications
09:50	S25–03	V. Danilenko	Russian Fed.	Yields of Gamma- and X-Ray Radiation of Alpha-Decays of 235U
10:10	S25–04	Z. Wang	China	The Distortion-Correction of Transmission-Reconstruction of SGS
10:30	Coffee and Technical Demonstration: Examples of Commercial Off-The-Shelf (COTS) Solutions Considered for SG Implementation			
11:00	S25–05	A. Muehleisen	EU	High-Quality Medium-Resolution Gamma-Ray Spectra from Certified Reference Uranium and Plutonium Materials
11:20	S25–06	A.-L. Weber	France	The Need to Support and Maintain Legacy Software: Ensuring Ongoing Support for the Isotopics Codes
11:40	S25–07	H. Zhang	China	The Measurement of Uranium Decay Daughters by NDA
12:00	S25–08	T. Ruther	EU	Recommendations for Determining Uranium Isotopic Composition by MGAU

S26: Safeguards by Design

Chair: C. Jorant (France), M. Scholz (USA) *Boardroom A*
TechSec: A. Hamilton (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S26–01	S. Poirier	IAEA	IAEA Guidance for Safeguards Implementation in Facility Design and Construction
14:30	S26–02	T. Sampei	Japan	Current Status of J-MOX Safeguards Design and Future Prospects
14:50	S26–03	M. Hämäläinen	Finland	Safeguards by Design: Finnish Experiences and Views
15:10	S26–04	G. Pshakin	Russian Fed.	A Common Approach to Safeguards and Security by Design for Small Modular Reactors
15:30	Coffee and Technical Demonstration: Automated Chemical U/Pu Separation of Inspection Samples			
16:00	S26–05	F.-X. Briffod	France	A Transportable and Subsea SMR: Early Considerations on Safeguarding the Flexblue System
16:20	S26–06	A. Homer	UK	Safeguards by Design as Implemented by Sellafield Limited: Application to a New Nuclear Material Storage Facility
16:40	S26–07	F. Rossi	Italy	Application of the GIF PR&PP Methodology to a Fast Reactor System for a Diversion Scenario
17:00	S26–08	P. Sankaran Nair	India	An Approach to Safeguards by Design (SBD) for Fuel Cycle Facilities

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S27: NDA Measurements II: Gamma and Neutron

Chair: A. Dougan (USA) *Boardroom B*
TechSec: M. Mayorov (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S27–01	M. Ahmed	Egypt	Development of a Portable Tomographic Gamma Scanning System for Safeguards Application
14:30	S27–02	R. Berndt	EU	Neutron Counting and Gamma Spectrometry with MCA-527
14:50	S27–03	K. Amgarou	France	iPIX: A New Generation Gamma Imager for Rapid and Accurate Localization of Radioactive Hotspots
15:10	S27–04	K. Ianakiev	USA	High Count Rate Thermal Neutron Detectors and Electronics
15:30	Coffee and Technical Demonstration: Automated Chemical U/Pu Separation of Inspection Samples			
16:00	S27–05	M. Göttsche	Germany	Neutron Multiplicity Counting for Future Verification Missions: Bias When the Sample Configuration Remains Unknown
16:20	S27–06	J. Zsigrai	EU	Measurement of the Pu Concentration of European MOX Pellets by Neutron Coincidence Counting
16:40	S27–07	E. Branger	Sweden	Towards Unattended Partial-Defect Verification of Irradiated Nuclear Fuel Assemblies Using the DCVD

S28: Safeguards at Enrichment Facilities

Chair: M. Marzo (Brazil), K. Murakami (Japan) *Room M1*

TechSec: A. Lebrun (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S28–01	R. Veldhof	The Netherlands	Overview of Conducted Field Trials at URENCO: An Operator Perspective
14:30	S28–02	K. Miller	USA	A Study of Candidate Non-Destructive Assay Methods for Unattended UF6 Cylinder Verification: Measurement Campaign Results
14:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S28–03	R. McElroy	USA	UF6 Cylinder Imaging by Fast Neutron Transmission Tomography
	S28–04	E. Smith	USA	An Unattended Verification Station for UF6 Cylinders: Development Status
	S28–05	S. Croft	USA	Uncertainty Quantification for Safeguards Measurements
	S28–06	M. Whitaker	USA	How the International Safeguards Regime can Benefit from Efforts to Enhance the Identification Method Used for UF6 Cylinders
	S28–07	J. Ely	IAEA	On-Line Enrichment Monitor (OLEM): Supporting Safeguards at Enrichment Facilities
	S28–08	L. Bai	China	The Design of Integration Device of Neutron and Gamma Ray for Measuring Uranium
15:30	Coffee and Technical Demonstration: Automated Chemical U/Pu Separation of Inspection Samples			
16:00	S28–09	L. Xuesheng	China	Development of an On-Line Uranium Enrichment Monitor
16:20	S28–10	I. I. Badawy Elsamawy	Egypt	Development of a Simple Non-Destructive Assay Technique for Verification of Nuclear Materials in Cylinders
16:40	S28–11	A. LaFleur	USA	Modified Truncated Multiplicity Analysis to Improve Verification of Uranium Fuel Cycle Materials
17:00	S28–12	N. Anheier	USA	A Laser-Based Method for On-site Analysis of UF6 and Environmental Samples at Enrichment Plants

Thu

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S29: IAEA-State Cooperation II

Chair: G. Dyck (IAEA), L. Gerard (France) *Room M2*

TechSec: S. Hambaryan (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S29–01	Y. Al Agbari	United Arab Emirates	The United Arab Emirates Engagement with the International Atomic Energy Agency on Safeguards and Additional Protocol Implementation
14:30	S29–02	P. Boshielo	South Africa	NECSA'S Need to Establish a Nuclear Forensics Specific NDA Facility for On-Site Categorization of Seized Nuclear Materials
14:50	S29–03	P. Sankaran Nair	India	Nuclear Material Accounting and Reporting Software for India
15:10	S29–04	I. A. El-Osery	Egypt	The Egyptian Nuclear Power Project and IAEA Technical Assistance in Supporting the Project and its Nuclear Safeguards
15:30	Coffee and Technical Demonstration: Automated Chemical U/Pu Separation of Inspection Samples			
16:00	S29–05	Y. Kawakubo	Japan	Studies on Enhancing Nuclear Transparency in the Asia-Pacific Region
16:20	S29–06	R. Zarate	Chile	Enhancing IAEA–Chile Cooperation
16:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S29–07	L. Abdulrasaq	Iraq	Sustainability of Safeguard System for Iraqi Facilities
	S29–08	S. Y. Jo	Korea, Rep. of	A New Step for "State–IAEA Cooperation" Based on the Enhanced Cooperation Program
	S29–09	J. Oruru	Nigeria	Creating Material Balance Area for Location Outside Facilities in Nigeria
	S29–10	A. Pawlak	Poland	The 50 Years of Safeguards and Non-Proliferation in Poland
	S29–11	M. Roumié	Lebanon	Safeguards Status in Lebanon as SQP Country and Reinforcement within a Nuclear Law
	S29–12	S. Khan	Pakistan	Safeguards in Pakistan: State-Agency Cooperation
	S29–13	J. Vaclav	Slovakia	Safeguards in Slovakia

S30: Enhancing Safeguards Through Information Analysis

Chair: J. Baute (IAEA), W. A. M. Janssens (EU) *Room M3*

TechSec: M. Ferguson (IAEA) **(14:00 – 17:30)**

Time	Id	Presenter		Title
14:10	S30–01	C. Gazze	IAEA	Enabling Collaborative Analysis: State Evaluation Groups, the Electronic State File, and Collaborative Analysis Tools
14:30	S30–02	G. Christopher	UK	Open Source Information in Support of Safeguards
14:50	S30–03	N. Gillard	UK	Open Source and Trade Data for Non-Proliferation: Challenges and Opportunities
15:10	S30–04	J. Idinger	IAEA	Extraction and Analysis of Information Related to Research & Development Declared Under an Additional Protocol
15:30	Coffee and Technical Demonstration: Automated Chemical U/Pu Separation of Inspection Samples			
16:00	S30–05	Panel Discussion		Enhancing Safeguards through Information Analysis: The Role of Information Analysis in the State Evaluation Process
		M. Ardhammar	IAEA	
		J. Baute	IAEA	
		W. A. M. Janssens	EU	
		G. Anzelon	USA	
		P.-M. Schot	IAEA	

S31: Promoting the Interface Between Nuclear Safety, Security and Safeguards

Chair: E. Martikka (Finland), S. Lestari (Indonesia) *Boardroom A*

TechSec: J. R. Phillips (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S31–01	C. Jorant	France	Nuclear Security and Nuclear Safeguards; Differences, Commonalities and Synergies
09:30	S31–02	N. Y. Lee	Korea, Rep. of	Two Views on Nuclear Material Accounting and Control (NMAC)
09:50	S31–03	E. Susilowati	Indonesia	Exercising Synergy of Safeguards Safety and Security at Facility Level of the GA Siwabessy Multi-Purpose Reactor, Indonesia
10:10	S31–04	E. Haas	Germany	Proliferation Resistance and Safeguards by Design: The Safeguardability Assessment Tool Provided by the INPRO Collaborative Project "INPRO" (Proliferation Resistance and Safeguardability Assessment)
10:30	Coffee and Technical Demonstration: An Innovative Next-Generation Radioisotope Identification Device (RIID) Developed for the Mission Profiles of Safeguards and Nuclear Security			
11:00	S31–05	J. Whitlock	Canada	Status of the Gen-IV Proliferation Resistance and Physical Protection (PRPP) Evaluation Methodology
11:20	S31–06	S. Chirayath	USA	Containment and Surveillance and Physical Protection Updates for Proliferation Resistance Analysis Using PRAETOR
11:40	S31–07	A. Ivasechko	Belarus	Modern Approaches to the Establishment of National Geoinformation Systems as a Means of Combating Nuclear Terrorism and Illicit Trafficking of Radioactive Materials
12:00	S31–08	W. Nimfuehr	Austria	Information Management: Enhancing Information Discovery and Information Availability

S32: NDA Measurements III: Neutron Measurements

Chair: M. Swinhoe (USA), A.-L. Weber (France) *Boardroom B*
TechSec: T. Pochet (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S32–01	M. Boucher	Switzerland	Performance of Boron-10 based Neutron Coincidence Counters
09:30	S32–02	J. Huszti	Hungary	Development of a Pulse-Train Recorder for Safeguards
09:50	S32–03	R. McElroy	USA	Application of 10B Lined Proportional Counters to Traditional Neutron Counting Applications in International Safeguards
10:10	S32–04	G. Dermody	UK	Monte Carlo Modeling and Experimental Evaluation of a 6LiF:ZnS(Ag) Test Module for Use in Nuclear Safeguards Neutron Coincidence Counting Applications
10:30	Coffee and Technical Demonstration: An Innovative Next-Generation Radioisotope Identification Device (RIID) Developed for the Mission Profiles of Safeguards and Nuclear Security			
11:00	S32–05	M. Newell	USA	Development of the Single Chip Shift Register (SCSR) for Neutron Coincidence and Multiplicity Analysis
11:20	S32–06	H. Nakamura	Japan	Development of Advanced MOX Holdup Measurement Technology for Improvement of MC&A and Safeguards
11:40	S32–07	M. Swinhoe	USA	Fresh PWR Assembly Measurements with a New Fast Neutron Collar
12:00	S32–08	J. Newby	USA	Position-Sensitive Organic Scintillation Detectors for Nuclear Material Accountancy

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S33: IAEA-State Cooperation III

Chair: H. Barroso (IAEA), J. G. M. Gonçalves (EU) *Room M1*

TechSec: I. Tsvetkov (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S33–01	P. Schwalbach	EU	Euratom Safeguards: Improving Safeguards by Cooperation in R&D and Implementation
09:30	S33–02	D. Lobach	Belarus	Development of System Regulating and Support for Nuclear Security in Belarus
09:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S33–03	I. Tsvetkov	IAEA	Verification of Spent Fuel Transfers in Germany — Linking Strategy, Implementation and People
	S33–04	J. G. M. Gonçalves	EU	The European Commission Cooperative Support Programme: Activities and Cooperation
	S33–05	A. Jraut	Morocco	Implementation of Safeguards at the Nuclear Studies Centre at La Maâmora
	S33–06	U. Mirsaidov	Tajikistan	Strategic Action Plan and Secure Environment in the Republic of Tajikistan
	S33–07	N. Nakamura	Japan	Japan's Experience on Cooperation with the IAEA
	S33–08	T. Zhantikin	Kazakhstan	Safeguards Implementation in Kazakhstan: Experience and Challenges
	S33–09	T. Korbmacher	Germany	URENCO: A Multinational Contribution to Non-Proliferation
10:30	Coffee and Technical Demonstration: An Innovative Next-Generation Radioisotope Identification Device (RIID) Developed for the Mission Profiles of Safeguards and Nuclear Security			
11:00	S33–10	G. Daniel	France	French Additional Protocol: 10 Years of Implementation
11:20	S33–11	O. Fazly	Ukraine	Integrated Safeguards in Ukraine
11:40	S33–12	M. S. Islam	Bangladesh	Safeguards Practices and Future Challenges for Peaceful Use of Nuclear Energy in Bangladesh
12:00	S33–13	I. Popovici	Romania	Implementation of Safeguards for Romania National LOFs

S34: Technology Foresight and Emerging Technologies II

Chair: D. Chernikova (Sweden) *Room M2*
TechSec: D. Finker (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S34–01	D. Finker	IAEA	Evaluation of an Autonomous Navigation and Positioning System for IAEA-SG Inspectors
09:30	S34–02	D. Schmidt	Germany	Location Intelligence Solutions
09:50	S34–03	S. Chen	Canada	Development of Laser-Induced Breakdown Spectroscopy Technologies for Nuclear Safeguards and Forensic Applications
10:10	S34–04	H. Lemaire	France	Impact of the Pixel Pitch of the Timepix Chip Integrated to the GAMPIX Gamma Camera for Spectrometric and Imaging Performances
10:30	Coffee and Technical Demonstration: An Innovative Next-Generation Radioisotope Identification Device (RIID) Developed for the Mission Profiles of Safeguards and Nuclear Security			
11:00	S34–05	D. F. Mahon	UK	Cosmic-Ray Muon Tomography: Non-Destructive Assay of Illicit Nuclear Material within Shielded Containers
11:20	S34–06	M. Seya	Japan	JAEA-ISCN Development Programmes of Advanced Technologies of Nuclear Material
11:50	Two-minute E-Poster introductions followed by viewing of poster displays			
	S34–07	E. Berruyer	France	MultiSpectrometer: Wide Span and Quick Gamma Detection System
	S34–08	M. Fallot	France	SoLid: Innovative Antineutrino Detector for Nuclear Reactor Monitoring
	S34–09	T. Koeble	Germany	Mobile Techniques for Rapid Detection of Concealed Nuclear Material
	S34–10	A. Letourneau	France	Nuclear Reactor Monitoring with the Nucifer Neutrino Detector
	S34–11	R. de Meijer	The Netherlands	Quest for Very Compact Antineutrino Detectors for Safeguarding Nuclear Reactors
	S34–12	E. Kovacs-Szeles	Hungary	Using LIBS Method in Safeguards
	S34–13			Withdrawn

Fri

S35: Knowledge Management for Safeguards Organizations

Chair: M. Rasweswe (South Africa) *Room M3*
TechSec: S. Konecni (IAEA) **(09:00 – 12:30)**

Time	Id	Presenter		Title
09:10	S35–01	M. Sbaffoni	IAEA	Nuclear Knowledge Management: the IAEA Approach
09:30	S35–02	I. Ogawa	Brazil	Knowledge Management Portal: A Simplified Model to Help Decision Makers
09:50	S35–03	J. Hudson	USA	A Model for Effective Governance of Knowledge Management: A Case Study at the U.S. Nuclear Regulatory Commission
10:10	S35–04	S. Konecni	IAEA	Knowledge Management in the IAEA Department of Safeguards
10:30	Coffee and Technical Demonstration: An Innovative Next-Generation Radioisotope Identification Device (RIID) Developed for the Mission Profiles of Safeguards and Nuclear Security			
11:00	S35–05	Panel Discussion		Knowledge Management for Safeguards Organizations
		M. Rasweswe	South Africa	
		A. Afghan	Pakistan	
		S. Konecni	IAEA	
		J. Martinez	IAEA	
		S. Iso	Japan	

CP: Closing Plenary

Chair: T. Varjoranta (IAEA) *Boardroom A*
TechSec: A. Hamilton (IAEA) **(14:00 – 16:00)**

Time	Id	Presenter		Title
14:00	CP–01	M. Whitaker	INMM	Closing Remarks and Awards
		K. Van der Meer	ESARDA	
14:20	CP–02	K. Owen-Whitred	Canada	Symposium Highlights
15:10	CP–03	T. Varjoranta	IAEA	Closing Statement

Contents

OP: Opening Plenary

Opening Remarks

T. Varjoranta[1]

[1]*International Atomic Energy Agency (IAEA), Vienna, Austria*

Corresponding Author: T. Varjoranta

Good morning and a very warm welcome to everyone. My name is Tero Varjoranta, Deputy Director General and Head of the Department of Safeguards, and the Chair of this Opening Plenary.

This is the twelfth international Safeguards Symposium, hosted by the IAEA. And once again it is being held in cooperation with the Institute of Nuclear Materials Management and the European Safeguards Research and Development Association. And let me take this opportunity to thank our partners for their support of this event.

Before I introduce the speakers I would like to say a few words about the symposium itself. Our theme is Strategy, Implementation and People. Linking the three core processes of any business — the strategy, its implementation and the people doing the work — determines the success or failure of every organization. And the strength of the link between these three processes determines the degree to which a business is able to deliver what it wants to achieve. The IAEA is no exception.

To achieve our vision, meet our obligations and fulfil the expectation of our Member States requires the careful and successful linking of strategy, implementation and people, and that is what we will all be focusing on during our deliberations this week.

The primary objective of this symposium is to foster dialogue and information exchange between the IAEA and experts from Member States, the nuclear industry and the broader nuclear non-proliferation community.

The global interest in this symposium has been even larger than we had anticipated. There are around 700 registered participants and around 300 oral and poster presentations have been submitted.

We are also pleased to have Non-Governmental and Inter-Governmental organizations represented. And we note the large number of vendors exhibiting their goods and services: this demonstrates the increasing importance of technologies in fulfilling our mission.

All of this increased international response clearly reflects a widespread interest in the work of the Agency and also the efforts of the symposium team to design and promote the event.

Finally, I hope you enjoy the symposium over these five days in Vienna; that you have productive discussions; and I look forward to the Agency working with all of you towards our common goals.

Welcome from INMM

L. Satkowiak[1]

[1]*Institute of Nuclear Materials Management (INMM), Deerfield, IL, USA*

Corresponding Author: L. Satkowiak, satkowiaklj@ornl.gov

Greetings everyone and welcome to Vienna! First, I want to congratulate Tero and his organizing committee for putting together such an impressive symposium and thank him for allowing me to say a few words. I have the honor of serving as the President of the Institute of Nuclear Materials Management (INMM). For those of you who aren't familiar with the INMM, I will describe it briefly.

The INMM is the premier professional society focused on safe and secure use of Nuclear Materials and the related nuclear scientific technology and knowledge. Its international membership includes government, academia, non-governmental organizations and industry, spanning the full spectrum all the way from policy to technology. The Institute's primary role include the promotion of research, the establishment of standards and the development of best practices, all centered around nuclear materials. It then disseminates this information through meetings, professional contacts, reports, papers, discussions, and publications.

The formal structure of the INMM includes six technical divisions:

- Facility Operation
- Materials Control and Accountability
- Nonproliferation and Arms Control
- Nuclear Security and Physical Protection
- Packaging, Transportation and Disposition
- And one most pertinent today, International Safeguards – the chair of the international safeguards division, Michael Whitaker, served on both the Organizing Committee and the Program Committee for this meeting. Thank you Michael!

In addition to the central, main INMM organization, we encourage the formation of regional, local chapters and student chapters where it makes sense to do so. Currently, there are 6 regional chapters in the United States, 11 international chapters, and 16 student chapters (both in US and around the world). I would like to note that we have a strong Vienna Chapter and give a "shout out" to its current president— Carrie Matthews.

The centerpiece of the Institute is its Annual Meeting. The INMM Annual Meeting serves as the primary forum to bring together a diverse group of nuclear material managers, domestic and international, policy and technical, governmental and non-governmental to discuss and develop best practices in nuclear security, nonproliferation, arms control, nuclear transportation, international safeguards, material accounting and control, and facility operations. This year, The 56th Annual meeting of the INMM will be held in Indian Wells, California, July 12th–16th, 2015. I encourage everyone to submit papers and/or attend.

Finally, I want to encourage everyone to take advantage of their time here, attend the technical sessions, interact with your colleagues, and, of course, enjoy the beautiful city of Vienna. Thank you.

Welcome from ESARDA

K. Van der Meer[1]

[1] *European Safeguards Research and Development Association (ESARDA), Ispra, Italy*

Corresponding Author: K. Van der Meer, kvdmeer@Sckcen.Be

Distinguished participants, Ladies and Gentlemen, dear safeguards friends, I would like to thank the IAEA for giving ESARDA as co-organiser of this symposium the opportunity to address you, the participants of this symposium. In my opening address of last year's ESARDA symposium in Bruges, I referred to the European Union as the fundament of a European peace process, set up by forward-thinking European politicians after a devastating second World War. ESARDA, on the one hand being part of that European family and on the other hand working in practice to support peace by the non-proliferation of nuclear weapons, can be considered as a perfect representative of that European peace process.

I am not talking here only to a public of European safeguards researchers, but to the international safeguards community. Going now from the European to the global perspective, peace should be our motivating force and this is also expressed in the basis of safeguards: the non-proliferation Treaty. Several articles of the Treaty deal with not developing nuclear weapons and not supporting the development of nuclear weapons by other countries, and one article (Article VI) deals with the general and complete nuclear disarmament.

What is ESARDA doing in practice? First we provide a forum to exchange scientific information for the benefit of all safeguards stakeholders. The most important forum is the biannual open ESARDA safeguards symposium that will be held next year from 19–21 May in Manchester. Given the low attendance of certain important safeguards stakeholders in the past symposia, I would like to urge you all to attend the Manchester symposium. It promises to be very interesting. I would like to announce that the UK National Nuclear Laboratories offer a free subscription to the best poster of the poster sessions of this symposium on behalf of ESARDA.

Next to the ESARDA symposia, we coordinate European safeguards research via our ESARDA Working Groups. Also non-members are welcome in these WG as observers. JRC Ispra maintains the ESARDA website that also supports exchange of safeguards information. I invite everybody to take a look at it.

Another means of exchange is the publication of the ESARDA Bulletin. I am happy to announce that ESARDA offers free subscriptions of the ESARDA Bulletins to the best posters of each poster session. For the best student poster JRC Ispra offers on behalf of ESARDA a free subscription to the ESARDA Safeguards Course, which is held each year at the JRC Ispra.

Last but not least ESARDA supports scientific exchange by the organisation of Workshops dedicated to one or various subjects. In 2012 ESARDA organised a workshop dedicated to discuss the State Level Concept, while in 2015 ESARDA will organise together with the INMM the 8th INMM–ESARDA workshop in Jackson Hole.

Distinguished participants, Ladies and Gentlemen, to conclude I would like to ask you to keep in mind the ultimate goal of the Non-Proliferation Treaty as expressed in Article VI while doing your daily job as safeguards inspector, safeguards analyst, safeguards R&D specialist or diplomat. With this I would like to express the hope that you will have a fruitful symposium and I would like to thank you very much for your attention!

Opening Statement from the IAEA Director General

Y. Amano[1]

[1]*Director General, International Atomic Energy Agency (IAEA), Vienna, Austria*

Corresponding Author: Y. Amano, www.iaea.org/about/dg/

Good morning, Ladies and Gentlemen.

I am pleased to welcome you all to this 2014 IAEA Symposium on International Safeguards.

The safeguards resolution adopted at the IAEA General Conference last month recognised that "effective and efficient safeguards implementation requires a cooperative effort between the Agency and States."

This cooperative effort takes place every day through the work of our inspectors in the field and our headquarters staff in Vienna, together with their counterparts in the 181 countries in which we implement safeguards.

But this Symposium also has a very important part to play. Every four years, it brings together key interested parties from the Agency and Member States for an in-depth, week-long examination of key issues in nuclear verification.

And, as all of us know, the field of nuclear verification never stands still.

The number of nuclear facilities coming under IAEA safeguards continues to grow steadily — by 12 percent in the past five years alone. So does the amount of nuclear material to be safeguarded. It has risen by around 14 percent in that period.

With 72 nuclear power plants under construction, and many additional countries considering the introduction of nuclear power in the coming years, that trend looks very likely to continue.

And that is just nuclear power. The use of nuclear science and technology in other peaceful applications — in industry, medicine and agriculture, for example — also continues to grow.

Funding for the Agency has not kept pace with growing demand for our services and is unlikely to do so in the coming years. That means we must constantly find ways of working more effectively and more efficiently in all areas of our work, including safeguards.

I will briefly highlight some key developments in the Agency's safeguards activities since the last Symposium in 2010.

Probably the most encouraging news is that our analytical capabilities have significantly improved.

In September 2011, we formally opened the new extension to the IAEA Clean Laboratory at Seibersdorf, near Vienna.

It contains a state-of-the-art Large Geometry Secondary Ion Mass Spectrometer, which greatly improves the Agency's ability to independently analyse environmental samples for safeguards. In fact, it has made us a leader in particle analysis.

The spectrometer is now in routine operation supporting critical safeguards operations.

Two years later, in September 2013, we inaugurated the new Nuclear Material Laboratory for safeguards analysis. Analytical functions are being gradually moved from the old building to the new laboratory, a process which will be completed by the end of this year.

The Nuclear Material Laboratory gives the Department of Safeguards an enhanced set of independent verification capabilities in areas such as the analysis of uranium, plutonium, spent fuel and high-activity liquid waste samples, as well as in archiving samples safely and securely.

This comprehensive modernisation of the safeguards laboratories was one of the most important projects which the Agency has ever undertaken. We are proud that work on both laboratories was completed on schedule and within budget.

As you may know, we have begun an update of the safeguards IT system under a project known as MoSaIc. The system is becoming outdated and it will struggle to cope with the volume of information it is required to manage. The major modernization now underway will improve performance, security and reliability, strengthening the day-to-day implementation of safeguards.

Also on the positive side, the number of States with additional protocols in force continues to rise. It now stands at 124, compared with 102 when the last Safeguards Symposium began.

I urge remaining States to conclude additional protocols as soon as possible. I also ask the 12 States without NPT safeguards agreements in force to bring such agreements into force without delay.

Ladies and Gentlemen,

The Agency continues to implement safeguards through consideration of a State's nuclear activities and related technical capabilities as a whole, rather than on a facility basis. We refer to this as the State-level concept and it has been the subject of extensive dialogue with Member States.

The State-level concept does not entail the introduction of any additional rights or obligations on the part of either States or the Agency, nor does it involve any modification in the interpretation of existing rights and obligations.

It is applicable to all States, but strictly within the scope of each individual State's safeguards agreement.

State-level safeguards approaches have so far been implemented for the 53 States under integrated safeguards. Our focus for the immediate future is on updating these existing approaches. The Agency plans to progressively develop and implement State-level approaches with respect to other States.

We recognize the need to apply State-specific factors objectively, consistently and in accordance with clear and established guidelines, based on technical considerations. We aim to keep the frequency and intensity of routine inspections for States to the minimum level necessary to produce credible safeguards conclusions.

We will continue to consult closely with Member States on safeguards implementation. Discussions during the Symposium this week will be an important part of that process.

Ladies and Gentlemen, Safeguards implementation in the Islamic Republic of Iran remains one of the main issues on the Agency's agenda. In November 2013, the Agency and Iran agreed to cooperate further to resolve all present and past issues under a *Framework for Cooperation*.

Iran has implemented most of the practical measures agreed under the Framework, but not all of them.

Separately, our Board of Governors authorised the Agency to undertake monitoring and verification in relation to nuclear-related measures set out in a *Joint Plan of Action* agreed between the E3+3 and Iran.

This has meant a large additional workload for safeguards staff. In fact, our verification effort in Iran has doubled under the Joint Plan of Action. This has had significant resource implications, not just financially. Many of our most experienced inspectors and analysts are now working on the Iran file full-time, which means they are not available to work on other dossiers.

The Agency continues to verify the non-diversion of nuclear material declared by Iran under its Safeguards Agreement. However, the Agency is not in a position to provide credible assurance about the absence of undeclared nuclear material and activities in Iran, and therefore to conclude that all nuclear material in Iran is in peaceful activities.

In order to resolve all outstanding issues, it is very important that Iran implements, in a timely manner, all practical measures agreed under the Framework for Cooperation, and that it proposes new measures that we can agree upon for the next step.

Ladies and Gentlemen, You have a comprehensive and extremely interesting programme over the next five days. I understand that there will be more presentations at this Symposium than at any time in the past. This is very encouraging.

Safeguards make a vital contribution to international peace and security. I thank all of you for your participation in this Symposium, which I am confident will help all of us to do our jobs more effectively and efficiently. The Agency will continue to engage in open, active dialogue on safeguards matters with Member States.

I wish you every success with your discussions and look forward to learning about the outcome.

Thank you.

Keynote Address

V. Šucha[1]

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Abstract forthcoming.

Keynote Address

G. Berdennikov[1]

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Mr. Chairman, respected participants of the symposium, first of all, I would like to note that Russia was one of the originators of the IAEA safeguards system and throughout the Agency's history consistently supported its effective implementation and development. We always felt that the safeguards system is crucial for the well being of the Non-Proliferation Treaty and the regime build on its foundation. The safeguards system is not something cast in stone or frozen but is a living organism that for its very survival has to change in order to adapt to the changing world and the growing demands placed upon it by the ever more complex requirement of preserving peace and international security in conditions of rapidly developing technologies and changing relationships among nations. However, in the process of such adaptation the system should preserve its core features and functions which have been tested by time. It should remain objective, depoliticised, technically credible, understandable for Member States and based on rights and obligations of the Parties in accordance with Safeguards Agreements they have concluded.

Classic safeguards were fully in line with those principles. They were based on facility-specific approach and were underpinned by technical safeguards criteria that were established for each type of facility or location outside facilities and specified the scope, the normal frequency and the extent of the verification activities required to meet the inspection goals. In other words, verification activities were predetermined by quantity and quality of nuclear material as well as quantity and type of nuclear facilities in a State. This system was by nature resistant to political or other extraneous considerations and generated very little risk in terms of undue interference into the affairs of States unrelated to the nuclear sphere. In addition it was universal in the sense that verification requirements for facilities of certain types were the same for all States with the same type of legal obligations regardless of their affiliation or political system. Member States were assured that any decision by the Secretariat was based on good technical sense and science.

Mr. Chairman, now the situation has become more complicated. A concept of safeguards implementation at State-level (the SLC) has emerged and has been developing by the Secretariat. It had many names, however, the main idea was the same — frequency and intensity of verification should be determined by the Secretariat for each State as a whole, not for each facility type. This should be done on the basis of all available safeguards relevant information including provided by third Parties and using so-called State-specific factors. This concept is claimed to have certain advantages, particularly in terms of achieving some economy of the scarce resources, including human efforts by concentrating on points of real concern. But it also has serious vulnerabilities. First and foremost it makes safeguards implementation prone to politicization. That is why it is essential that Member States are assured that possible modifications in frequency and intensity of safeguards activities in a State are caused by honest technical analysis of facts on the ground and not by individual or collective biased thinking or prejudices. The IAEA should remain an objective mechanism for verifying non-proliferation obligations of States. It should not become an instrument for political pressure against certain countries or a means for rewarding their political loyalty. In recent years Russia, as well as many other IAEA Member States, has taken serious efforts aimed at ensuring that the new safeguards system is equipped with necessary protective mechanisms.

This was not an easy endeavor and it is not over yet. Decades of classic facility-specific safeguards created certain inertia of thinking that resulted in a false impression that safeguards implementation is the Secretariat's exclusive responsibility. It is true that when the IAEA Board of Governors approves a Safeguards Agreement, it authorises the Director General to conclude and subsequently implement the Agreement. But it is also true that nothing limits the right of the IAEA Policy-Making Organs to set core parameters of such implementation. This was done in the past and this becomes especially important in the situation, when safeguards are becoming tailor-made for each State. This logic is becoming more and more acceptable now. The year 2012 witnessed a series of bilateral and multilateral discussions on the SLC. In 2013 a report on the matter was prepared by the Director General following the request by the General Conference. This paper generated a great number of questions and comments by Member States. As a consequence, the request for a further more in-depth report was made by the General Conference in 2013 and seven rounds of detailed open-ended consultations ensued in 2014. Finally, in August this year, Member States received a more detailed report by the Director General on the SLC, which was over 60 pages long. Thus we came a long way to recognise that Member States have the right to know what are the main principles and mechanisms of safeguards implementation.

Mr. Chairman, the 2014 report by the Director General was a significant step in the discussion between Member States and the Secretariat on the SLC. This document contains several important assurances for States.

Firstly, it assures that the SLC will not entail the introduction of any additional rights or obligations on the part of either States or the Agency, nor any modification in the interpretation of existing rights and obligations.

Secondly, it assures that the aim of the whole safeguards reform is to optimise safeguards implementation, not to shift the verification effort from one group of States to another. The Director General stated that the Secretariat will continue to concentrate its verification efforts on the sensitive stages of the nuclear fuel cycle and on nuclear material from which nuclear weapons or other nuclear explosive devices could readily be made. The report also registers that attempts to ensure efficiency in safeguards implementation would not compromise safeguards effectiveness.

Thirdly, the Director General stated that the acquisition path analysis will be focused on nuclear material, not on weaponization. This is in line with obligations under the NPT and will help ensure that the Agency's Secretariat does not inadvertently become a conduit for nuclear proliferation.

Fourthly, it is recognised in the report that to date, customised State-level safeguards approaches for individual States have only been implemented for States under integrated safeguards.

Mr. Chairman, there are some other important aspects in the 2014 report I'd like to highlight. The report says, for instance, that the SLC is not a substitute for an Additional Protocol; it is not designed as a means for the Agency to obtain from a State without an Additional Protocol in force the information and access provided for in this document. It registers that State-specific factors will not include political or other extraneous considerations. It also provides that nuclear material accountancy and its verification in the field will remain at the core of safeguards implementation.

All these assurances are important. They were further stressed in the resolution “Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards” GC(58)/RES/14, adopted by consensus at the 58th session of the General Conference last month.

This resolution made a concrete contribution to developing the SLC. In the 2014 report the nature of bilateral consultations between a State and/or regional authority and the Agency was not sufficiently clarified. This generated legitimate concerns among States that such consultations could turn into some kind of briefings, where the States would be informed by the Secretariat about the details concerning safeguards measures to be implemented on their territory. The 2014 resolution has dealt with this problem. In its paragraph 25 it points out, and I quote, “the development and implementation of State-level approaches requires close consultation and coordination with the State and/or regional authority, and agreement by the State concerned on practical arrangements for effective implementation of all safeguards measures identified for use in the field if not already in place”. This is a serious improvement.

Mr. Chairman, despite all efforts invested, the framework for the SLC implementations is still incomplete. As was pointed out by the Director General in his statement to the session of the Board of Governors on September 15, the release of the 2014 report is part of a continuing process of consultation, not the end. We fully agree with this. I will point out the most important elements, where, in our view, more work is needed most.

Firstly, the Secretariat has the right to use for safeguards implementation all safeguards relevant information available to the Agency about a State. As stated in the 2014 report, this information includes, inter alia, data from open sources and data provided by third parties. It should be noted that third parties include not only States that provide information with regard to another State but also organizations and even private individuals. No proper mechanism that could guarantee the accuracy and authenticity of information used for safeguards purposes is provided for in the 2014 report. In essence it is suggested that all analysis should be done by the Secretariat as decisions on whether certain data can be used for safeguards purposes are left entirely with the Secretariat. Member States according to this approach should simply trust the Secretariat’s choice of information.

The risk here is obvious. False allegations generated by interested parties in order to exercise political pressure on a State unfortunately remain part of current international landscape. They are quite common in many areas, including non-proliferation and one should admit could be very important sometimes involving issues of war and peace. Moreover, the intelligence services of some States may be tempted to use the IAEA as a tool to verify the information they receive via their operative channels. In other words — they may wish to turn the IAEA Department of Safeguards into their branch.

We do not want this to happen. We stress that the right to use all available safeguards relevant information should not be perceived as a blank check that Member States have given to the Secretariat in the area of information handling. The Secretariat remains a technical body of an international organization, which should work with data submitted via official channels or received during performing its statutory functions. The SLC shall not turn the Secretariat into a supranational structure tasked to collect and analyze intelligence information. We think that if the Secretariat decides to use any information, except for data obtained through its own inspection activity, it should duly disclose its origin and be ready to defend its credibility in an open discussion at the Board of Governors. Every State should have the right to publicly defend itself against false allegations and accusations generated by interested third parties or by the media. Moreover, any third party information should be taken on board by the Secretariat in the process of planning and implementing the safeguards measures, as well as of drawing conclusions, only if it is provided to the IAEA in an official and open manner. History of "nuclear dossiers" of different States shows that such measures are essential and urgent for maintaining and strengthening the confidence of Member-States in the safeguards activities performed by the Secretariat.

Secondly, a special procedure has to be introduced to protect Member States with Comprehensive Safeguards Agreements but without an Additional Protocol from arbitrary increase of the safeguards measures intensity under the pretext of checking indicators of undeclared nuclear activities. It is well known that if a State does not have Additional Protocol in force, the Secretariat is not expected to reach the broader conclusion regarding the absence of undeclared nuclear material and activities. The absence of Additional Protocol does not prevent the Secretariat from assessing indications of undeclared activities in such a State. But this process should not turn into the endless quest. It should be clear that if the Secretariat comes across some indications of undeclared nuclear activities, it should first seek clarification from the State concerned. If the clarification does not satisfy the Secretariat, the Secretariat should report on its findings, along with background information including on its discussions with the State concerned, to the Board of Governors for its decision.

Thirdly, a complete list of objective State-specific factors for the SLC is still pending. In the 2014 report the elements of each factor are presented just as examples. This opens the door for different interpretations and even changes to the list that may happen without the approval of the Board. Furthermore, despite the fact that in the 2014 report all factors are called objective not all of them are objective in nature. Factor (v) "the nature and scope of the cooperation between the State and the Agency in the implementation of safeguards" and factor (vi) "the Agency's experience in implementing safeguards in the State" are in our view subjective since they are based on the judgment and opinion of the Secretariat. Factor (ii) "the nuclear fuel cycle and related technical capabilities of the State" is formulated in such a vague way that almost everything can be considered as a related capability. Thus, in our opinion, further work on State-specific factors is needed in order to make them really objective and their list exhaustive.

Mr. Chairman, let me express hope that the Member States together with the Secretariat would continue their efforts aimed at the conceptualization and development of the SLC with a view of further improving the concept and achieving broad international consensus on all its parameters and methods of implementation. The 2014 report is a good working basis for it. The 2014 resolution of the General Conference stated in its paragraph 28 that the focus of the Agency for the immediate future will be on updating existing State-level approaches for 53 States under integrated safeguards. That is a reasonable starting point.

Regular reports of the Director General on this matter will be of great help to all Member States. The 2014 resolution sets a framework for such reporting. Its paragraph 26 provides that on the basis of the 2014 report and its corrigenda, the Secretariat will keep the Board of Governors informed of progress made in the development and implementation of safeguards in the context of the SLC. Paragraph 27 welcomes the intention of the Secretariat to continue to engage in open and active dialogue with States on safeguards matters, and to issue periodic update reports as the Agency and States gain further implementation experience. Paragraph 37 sets a precise timeframe for this by requesting the Director General to report on the implementation of the resolution to the General Conference at its fifty-ninth (2015) regular session.

Russia together with other IAEA Member States will be waiting for this report by the Director General before September 2015, which, as we expect, will have a substantial chapter providing further information and clarifications with regard to the SLC development and describing experience of its implementation in countries with integrated safeguards. We expect that this report will serve as a good basis for future consideration and actions by the Board of Governors and General Conference with regard to the SLC.

Mr. Chairman, we consistently stress the role of IAEA Policy-Making Organs in conceptualization and development of the SLC, as well as in controlling its implementation. Resolutions of the General Conference have become increasingly important in this regard as they express the common will of all the IAEA Member States and give them the right tool to manage and fine-tune the basics of the safeguards system. The contribution of the Board has also become more pronounced. But much work is still before us. We hope that the discussions that we are going to have at this symposium will also help the process of improving the safeguard implementation, thus contributing to the strengthening of the non-proliferation regime and therefore to the maintenance of peace and international security.

Thank you, Mr. Chairman.

Keynote Address

K. Mendelsohn[1]

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I'm delighted to be here this morning, and I welcome the opportunity to speak to you about U.S. efforts to strengthen the IAEA safeguards system.

The United States has long considered the international safeguards system to be a central pillar of the nuclear nonproliferation regime's strategy for preventing the spread of nuclear weapons and ensuring peaceful uses of atomic energy. President Obama re-emphasized the importance of safeguards in his 2009 Prague speech, when he called for "more resources and authority" for international inspections. But nuclear nonproliferation is a global challenge and the entire global community has a major stake in maintaining the effectiveness and credibility of the international safeguards system.

The United States believes it is critically important for Member States to support the Secretariat's efforts to continually improve the effectiveness and efficiency of the IAEA safeguards system. We should continue to work with the Agency to provide resources, technology, expertise, and training to strengthen the Secretariat's capabilities to implement safeguards agreements effectively and efficiently.

The Secretariat went to extraordinary lengths over the last year to explain how safeguards implementation has evolved, particularly at the level of the state as a whole. The United States, like other member states, found the Secretariat's thorough technical briefings and the Director General's Supplementary Document to be extremely valuable.

Now, after discussion of the issue at the September meetings of the Board of Governors and the General Conference, it really is time to let the Secretariat get on with its work. Our task now, especially for the assembled experts here at this Symposium, is to identify options for helping the IAEA as appropriate to find the best possible technologies, procedures, and practices for safeguards implementation.

And like all of you, we look forward to further updates from the Secretariat on future lessons learned in implementing strengthened safeguards.

I would like to spend a little time speaking about how the United States supports the IAEA safeguards system. The United States has the oldest and largest Member State Support Program, and has made many contributions over its 37 year lifespan to strengthen IAEA safeguards and respond to IAEA needs.

As many of you know, the USSP has supported the Agency in the areas of verification and analysis tools and methods, systems studies, information processing, training, quality management, and administrative support. Some of the successful tasks have been carried out as joint tasks with other Members States and the USSP continues to seek such collaborations that build on the unique strengths of each partner. For example, many of the IAEA's surveillance systems and other essential verification tools are products of U.S. and German Support Program collaborations. A U.S.-Belgian training course draws on U.S. training expertise for research reactors and Belgian research reactor facilities that afford a richer learning environment than either support program alone could easily accomplish. The USSP also has joined with other Member States to support Safeguards' largest tasks to date including, the "Enhancing Capabilities of the Safeguards Analytical Services" (ECAS) project to manage the IAEA's safeguards analytical laboratories, and the important project to modernize Safeguards' IT systems and security architecture to enable Safeguards to meet quality and efficiency goals well into the future.

The United States also launched a longer-range program of support for IAEA safeguards, called the Next Generation Safeguards Initiative (NGSI). The primary goal of NGSI is to continually advance the state of the art of international safeguards and develop the policies, concepts and approaches, human capital, technologies, and infrastructure that the IAEA needs to meet its evolving mission.

While NGSI has a U.S. domestic focus intended to ensure that U.S. support for international safeguards continues, its underlying purpose is international. Thus, NGSI cannot succeed as a purely domestic effort; indeed, it is intended to serve as a catalyst for a much broader commitment to international safeguards in partnership with not only the IAEA, but also bilaterally with other countries. Combining U.S. technical and scientific assets with the resources of international partners will allow us to keep pace with the emerging safeguards challenges.

With respect to strategy, the NGSI's Policy and Concepts and Approaches sub-programs work to support the development of technically sound concepts for safeguards implementation. For example, NGSI's recent projects have included work on Safeguards by Design, Acquisition Pathway Analysis, Performance Targets to evaluate the effectiveness of safeguards in achieving safeguards objectives, and advanced concepts for safeguards approaches for gas centrifuge enrichment plants.

In addition to a good strategy, the success of the international safeguards system depends on the talent, knowledge, skills, and commitment of the people who are working on safeguards issues. Today both the United States and the IAEA face a daunting challenge driven by attrition in the field due primarily to significant attrition.

To address the looming human capital crisis, NGSI is taking steps to revitalize and expand the human capital base, with programs to cover the full spectrum of current and emerging safeguard-relevant disciplines. The NGSI Human Capital Development (HCD) program has taken a number of initial steps to implement our action plan to develop and educate the next generation of U.S. international safeguards specialists.

The HCD sub-program has played a key role in recruiting, educating, training and retaining the next generation of safeguards professionals in the United States. The program includes summer internships for undergraduate and graduate students at the National Laboratories; fellowships for PhD candidates in Nuclear Engineering; post-doctorate fellowships at National Laboratories; intensive week-long safeguards courses annually for students and U.S. Government employees; nuclear non-proliferation curriculum development with more than two dozen universities; and programmatic safeguards work for young- and mid-career professionals.

Since its inception in 2008, the HCD program has trained more than 400 student interns from over 100 universities on nonproliferation and safeguards issues, and an impressive 80% of post- doctorate fellows have found follow-on employment at the National Laboratories.

In addition to working to develop the next generation of safeguards experts, we work with the IAEA Secretariat to meet its needs for new safeguards technologies. The NGSI Safeguards Technology Development subprogram supports U.S. national laboratories in the development and application of tools, technologies, and methods that optimize the effectiveness and efficiency of safeguards implementation, particularly by focusing on developing new tools to assist inspectors' nuclear material accountancy efforts. This subprogram focuses on transitioning technologies under development in the laboratory system with potential safeguards application from the laboratory into the field. Focus areas include:

- Advanced nuclear measurement technologies;
- Field-portable, near real-time analysis tools;
- Data integration and authentication applications;
- Improved detector materials; and
- Strengthened technology development infrastructure at the National Laboratories.

These technology developments help to support both the IAEA's and Member States' implementation of their safeguards agreements effectively and efficiently. The development of safeguards technology will help the IAEA increase its productivity and effectiveness in implementing safeguards agreements, particularly in the field. As Deputy Director General (DDG) Varjoranta has said, "The Agency's unique ability and mandate to conduct in-field verification activity is its real added value and will continue to form the bedrock of the Agency's verification effort."

In addition to our efforts to support the development of new concepts, approaches, technologies, and expertise, NGSI cooperates with 25 countries and 2 regional inspectorates, both bilaterally and regionally, on more than 100 technical projects to strengthen the international safeguards system.

NGSI cooperates with nearly a dozen countries that are developing nuclear power for the first time. NGSI provides support to these newcomer countries as they prepare the infrastructure and procedures necessary to provide timely, correct, and complete declarations to the IAEA. In total, NGSI trains more than 500 foreign practitioners each year on international and domestic safeguards.

State and regional authorities are a critical link for strengthening the international safeguards system. NGSI helps increase the effectiveness and efficiency of safeguards implementation in partner countries by supporting projects that directly support the development and improvement of State Systems of Accounting for and Control of nuclear material and build the capacity of State or regional authorities responsible for safeguards implementation.

NGSI also works with partner countries to demonstrate and evaluate next generation safeguards technologies. While many tools and technologies work well in the laboratory, they cannot be accepted for routine use by the IAEA until they are proven to function effectively in real-world situations. NGSI's technology development and demonstration efforts are an important part of the effort to enlarge the toolkit available to the IAEA to safeguard some of the world's most complex nuclear facilities.

As Secretary Moniz said at the General Conference last month: "We must re-dedicate ourselves to reinforcing international organizations and cooperation. We must bolster the nonproliferation regime by respecting its rules and responsibilities. And we must strengthen the IAEA by ensuring it has sufficient financial resources, expertise, legal authorities and political support from its Member States."

I urge you to work together at this Symposium to make real progress on promoting peaceful uses of nuclear energy, strengthening safeguards, and preventing proliferation. My great thanks to the IAEA for pulling this symposium together. Thank you and I wish you a successful symposium.

TP: Technical Plenary

Welcome and Opening Remarks

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Good afternoon, distinguished colleagues, ladies and gentlemen. Welcome back to the 2014 Symposium on International Safeguards. I hope that you have had a good lunch break. I have the honour today to chair the Technical Plenary this afternoon. I hope that we will have a useful exchange of views on several issues of importance to us. Assisting me this afternoon will be Mr Andy Catton, the Technical Secretary.

Just one gentle reminder before we start. This technical plenary is closed to the media. Hence, if there are any journalists in the room, could I kindly invite you to perhaps take some time off to look at the exhibition booths we have outside or just to enjoy the sights and sounds of Vienna.

I see that there are no journalists here, so before we begin I would like to give you an idea of how I intend to organise this afternoon session. As you may have seen from the programme, the first part from now till about 4:00 pm, we will have several presentations by the IAEA Department of Safeguards. After that, I hope that there will be time for questions and answers. I then intend to have a 30-minute coffee break, following which we will engage in a more interactive panel discussion on the topic of “Ensuring Non-Discrimination and Consistency in Safeguards Implementation”. This afternoon’s Technical Plenary is scheduled to end at around 5:30 or 6 pm.

Now, unless there is any objection to how I intend to structure the Technical Plenary, let’s commence with the first part of this afternoon session. As we have a very full programme this afternoon, I hope that all the speakers will stick closely to their allocated time-slot. We begin with a keynote address of around 20 minutes by IAEA Deputy Director General for Safeguards, Mr Tero Varjoranta, followed by a 15-minute presentation by Director of Concepts and Planning, Ms Jill Cooley. Each of the eight Directors at the Safeguards Department will then make some short remarks of around 5 minutes each on their respective area of work.

Without much ado, I now have the honour and the pleasure of inviting DDG Tero Varjoranta to deliver his keynote address. Tero, please…

Thank you, DDG Varjoranta for your keynote address where you highlighted the importance of a good strategy, which is amongst others realistic and flexible enough to adjust to changes in the external environment, sometimes unforeseen and sometimes sudden. A strategy, however, requires effective implementation and in the case of the IAEA it can only be implemented with the assistance of its Member States.

I welcome DDG’s point about the importance of communication, both internal communication within the Secretariat, as well as external communication vis-à-vis the Member States so that the latter are aware of what the Safeguards Department is doing and why.

Last but not least, DDG highlighted that, especially in safeguards, the Secretariat relies on the trust and confidence of its Member States, trust that what the Secretariat is doing is fair and fully consistent with legal agreements in force, and confident that the Secretariat is working objectively in pursuit of independent and soundly-based conclusions.

DDG, we are confident that under your able leadership and earnest efforts, you will open a new chapter of enriched, positive and meaningful cooperation between the Secretariat and Member States on safeguards matters, as well as keeping the credibility of the Agency intact as it has always been.

Next on my list is Director of Concepts and Planning, Ms Jill Cooley, who will elaborate on the IAEA Department of Safeguards strategic planning and its long-term R&D plan which the DDG mentioned in his address a couple of minutes ago. Jill, please… Thank you, Jill.

May I now invite the respective Directors at the Safeguards Department to share with us a summary of their work to-date, the successes as well as the more difficult task at hand. I understand that they will also outline the future challenges they will face. First on my list is :

(i) Director of the Division of Operations A, responsible for inspections in Australasia and East Asia, Mr Gary Dyck.

(ii) Next, may I invite Director of the Division of Operations B, responsible for the Middle East, South Asia, Africa, non-EU states and the Americas, Mr Van Zyl de Villiers.

(iii) Director of the Division of Operations C, responsible for Europe, the Russian Federation and Central Asia, Mr Haroldo Barroso, is next.

(iv) Director of the Division of Information Management, Mr Jacques Baute.

(v) Director of the Division of Technical and Scientific Services, Mr Sergey Zykov.

(vi) Director of the Office of Information and Communication Systems, Mr Frank Moser.

(vii) Director of the Office of Safeguards Analytical Services, Ms Gabi Voigt.

(viii) Last on my list will be Director of the Division of Concepts and Planning, Ms Jill Cooley.

Thank you all eight Directors for highlighting the work under your Divisions including the challenges you are facing. Over the course of this week many of you will have the opportunity to have a more in-depth discussion on some of the issues which have been highlighted during this afternoon's session. In the meantime, perhaps we take advantage of the fact that DDG and all the Directors of the Safeguards Department are present with us here to take some questions from the floor…

Many thanks for your active participation. After sitting here for two hours, I believe that we all deserve a good coffee break. Could I seek your indulgence to return back to this room at 4:30 pm. I would like to begin the second part of this afternoon session promptly at that time.

Welcome back to the second part of this afternoon session where we intend to have a more interactive panel discussion on an issue of importance to many IAEA Member States, namely, "Ensuring non-discrimination and consistency in safeguards implementation".

Now I have the pleasure of having all eight Directors here with me in this very cozy set-up. To help us focus on this discussion and to start the ball rolling, I would like to start with a few comments and a couple of questions before I open it to the meeting for comments and questions.

The IAEA has been entrusted by the international community to conduct verification activities and implement safeguards. The work of the IAEA in this important area contributes to the establishment of a robust global nuclear non-proliferation regime, which is one of the essential elements as we seek to promote peace and security around the world. Being the only international organisation with this special mandate, the integrity and the credibility of the Agency are therefore vital as the international community needs to know that they can trust that the safeguards conclusion for a particular country has been drawn by the Agency only after, amongst others, a meticulous inspection in the field and a thorough and objective evaluation of all safeguards-relevant information, free of all political influence. All these points have also been highlighted by DDG Varjoranta in his keynote address at the beginning of the technical plenary. So, the question is, which is the topic of this panel discussion, how does the IAEA ensure consistency in the area of safeguards? What lessons can be drawn from the past in order to further enhance consistency in safeguards implementation? In light of the changing nuclear landscape, and in particular the increasing complexity of nuclear facilities, what steps may be envisaged to ensure the objectivity and consistency of safeguards implementation?

I am sure many of you will have some comments on this topic. I would like to first invite you to raise any questions or make any comments you would like. Please, if you can limit your intervention to no more than 5 minutes, then I will invite the Directors to answer. Make full use of this opportunity, because we rarely have all eight Directors from the IAEA Safeguards Department with us. The floor is all yours…

Keynote Address

T. Varjoranta[1]

[1]*International Atomic Energy Agency (IAEA), Vienna, Austria*

Corresponding Author: T. Varjoranta

Thank you Madam Chair.

Your excellencies, ladies and gentlemen.

Linking the three core processes of any business — the strategy, its implementation and the people doing the work — determines the success or failure of every organization. And the strength of the link between these three processes determines the degree to which a business is able to deliver what it wants to achieve. The IAEA is no exception.

So, what do we want to achieve?

Our starting point can be taken from the Safeguards Resolution adopted by the General Conference last month. That resolution reconfirmed that the Agency's safeguards are a fundamental component of nuclear non-proliferation and that they promote greater confidence among States by providing assurance that States are complying with their obligations under relevant safeguards agreements. It went on to say that Agency safeguards also contribute to strengthening collective security and help to create an environment conducive to nuclear cooperation.

Further to that statement, I would add my personal vision for the future of Agency safeguards: it is a future in which our Member States and their nuclear industries see us as not as adversaries, but as important partners; a future in which the independence of our work and soundness of our conclusions remains paramount; and a future in which any non-compliance is firmly dealt with.

To achieve this vision, meet our obligations and fulfil the expectation of our Member States requires the careful and successful linking of strategy, implementation and people.

Let me take each of these components in turn.

Strategy:

Essentially, a strategy is a plan for obtaining a specific goal — the means by which aspiration is translated into achievement. The purpose of safeguards strategy is to deliver the overall organizational goal through the pursuit and accomplishment of specific objectives.

However, strategy cannot be a pre-ordained blueprint. Instead, a strategy has to be a system of options. This requires preparation of many plausible outcomes. We need to recognize that safeguards strategy is not made and implemented in isolation: there is a wider context. The nuclear world is changing: as are the political, economic and social worlds — and the Agency interacts within this multi-dimensional context.

Today — right across the world — we see more nuclear facilities and material coming under IAEA safeguards. The use of nuclear power continues to expand: with the geographical focus of these expanding programmes continuing to change. At the same time, many older nuclear plants are being modernized and becoming more technologically sophisticated. Over the past five years alone, the number of nuclear facilities and quantity of nuclear material under safeguards has risen by over 10 per cent. With many more nuclear facilities being built, this global trend looks set to continue. International nuclear cooperation between States is intensifying with an expansion of trade and services in nuclear and related equipment, items and materials. And this is not only a macro-level phenomenon; it is an everyday reality for us in the IAEA.

We also need to be responsive to changes in these domains — changes which are sometimes unforeseen and occurring at very short notice.

For example, if there were to be a comprehensive agreement with Iran over its nuclear programme, or if the IAEA were to be invited back into the DPRK, a large additional verification responsibility would quickly fall on our shoulders. This would have significant resource implications, not just in financial terms but also in terms of staff time. Many of our best and most experienced inspectors and analysts would be needed for such work, meaning that they would not be available to work on other files.

So our strategy must be sufficiently flexible to be able to cope with sometimes dramatic alterations in the external environment, without losing sight of our overall objectives.

Which leads to my second point about strategy: it must be realistic. An astonishing number of business strategies all over the world fail because of a lack of realism and, therefore, the inability of people to implement them. In turn, this leads to disillusionment and the strategy being ignored or forgotten altogether.

A good strategy is one that is easily translatable into implementation plans by people who clearly understand what is expected from them. This means that the strategy should be built on a clear and shared understanding of how our operating environment is changing, where we want to go, why and how.

In the Safeguards Department we recognize the importance of strategic planning. That is why — alone of all the Departments within the IAEA — we have developed a long-term Strategic Plan covering the period 2012–2023. We also adhere to the Agency's Medium-Term Strategy, which is adopted by the Board of Governors. And we have developed a Long-Term R&D Plan within the Department of Safeguards — also covering the period 2012–2023. Indeed, it is that plan that has helped to shape much of the programme of this symposium. The plan identifies the capabilities that the Department needs to achieve its strategic objectives and the key milestones towards achieving those capabilities. In the shorter timeframe, each biennium we also produce a Development and Implementation Support Programme for Nuclear Verification. This programme, which is integrated within the Long-Term R&D Plan, aims to inform Member States and other stakeholders about the Department's short-term development objectives, as well as its projects and plans to support safeguards implementation.

In developing these strategies we have had to be realistic about our current and future working environment and plan accordingly.

As the nuclear world continues to change, the further enhancement of Safeguards implementation becomes a central driver of safeguards' strategy. Through an evolutionary process, consistent with well-established principles and in close consultation with Member States, we are constantly seeking to increase our productivity. There are three main ways in which we can do so:

- Firstly, by optimizing our processes. Doing things more smartly and efficiently in-house and in the field can bring improvements in effectiveness as well as cost savings;
- Secondly, by making better use of modern technology we can identify ways of implementing safeguards most cost-effectively. For example, the use of remote

monitoring technologies can serve to partially reduce the need to for some routine in-field inspection activities; and

- Thirdly, we can improve our productivity by Member States themselves improving their performance in safeguards implementation. Here, I am talking about such matters as ensuring the timeliness and accuracy of reporting, and improvements to the provision of non-discretionary access.

The major challenges currently facing the Department — that our strategy will need to tackle — are numerous, sizeable and varied in nature. They include:

Implementing safeguards in Iran in line with that country's safeguards agreement, the resolutions of the UN Security Council and of the Agency's Board of Governors, the Framework for Cooperation, and the Joint Plan of Action agreed between the E3+3 and Iran. We have already re-directed a significant proportion of our resources to meeting the demands required of us in these respects. As we approach the 24 November deadline, it is too soon to predict the outcome. Whatever happens, will have further implications for — and possibly impose additional demands upon — the Agency.

A second major challenge has involved calibrating how we intend to improve the effective and efficiency of safeguards implementation under the State-level concept, and then explaining what we are doing to our Member States. Following a lengthy and substantive engagement with them, I believe we have now reached a new and broad understanding of the way forward — involving greater cooperation, consultation and transparency. This is very important and we need to keep working at it to ensure that we — the Secretariat — and our Member States remain in step with each other.

A third major challenge involves the modernization of the safeguards information technology system. Many of the various day-to-day activities related to safeguards implementation rely heavily on IT and it is also central to the recording and evaluation of all data and safeguards-relevant information necessary for the drawing of soundly based safeguards conclusions. However, the Agency's safeguards IT system has steadily become outdated and begun to struggle to cope with the volume and complexity of the information it is required to process. In order to improve the effective and efficient implementation of Agency safeguards, it is essential that the Agency modernize its increasingly outdated safeguards IT system. In the absence of remedial action, the Agency faces a number of heightened risks — relating to operational performance, disaster recovery and IT security.

In addition to these three, there are other issues that need to be addressed at the strategic level — including resolving outstanding questions concerning Syria's nuclear programme, remaining on standby for a possible return to the DPRK and coping with the major technological challenge posed by new nuclear plants, such as JMOX.

Implimentation:

Let me turn now to Implementation. Of course, developing a first rate strategy counts for little, unless it is effectively implemented. And that can only happen if those responsible for implementation fully understand the strategy, are given the necessary tools, follow a systematic plan and are held to account for delivering results.

It is all too easy for everyone involved to give a sigh of relief once a grand new strategy has been devised. The danger is that the sense of achievement attaches to the completion of the strategy document, rather than the implementation of the strategy itself. I'm sure that many impressive strategy documents are now sitting in filing cabinets in countless organizations around the world, forgotten and decaying, instead of being living documents that shape organizational direction.

That is why I have instructed the department to re-visit our strategic plan. To give it a health check. See where it needs updating and then, more importantly, ensuring that it is an integral part of the Department's future planning.

To ensure that the strategy is implemented requires implementation plans involving milestones and interim objectives. It requires managers to keep abreast of how the implementation is proceeding and taking remedial action when things stray off course. And it requires accountability of those driving the process to those directing the process.

As far as our long-term R&D plan is concerned, it can only be implemented with the assistance of Member States. The Department relies on Member State Support Programmes.

People:

This brings me to the final, but most important, component of a successful business enterprise — namely, the people who comprise the workforce.

The key characteristics that I look for in the staff of the Department of Safeguards are:

- Competence — can they do the job and do it well?
- Judgement — can they apply their skills in the right way at the right time according to circumstances and context?
- Cooperative spirit — can they work with others to solve problems and produce results.

From my side, I need to provide the tools, the means and the guidance for staff to do their jobs effectively. That includes providing them with the proper training — an area that I take seriously and will seek to develop under my tenure.

For me, management really matters. Managers within the Safeguards Department must not only be leaders, who inspire confidence and instil motivation, but also collaborators, who can work together in pursuit of a streamlined and unified Departmental policy.

I stress the role of communication.

Internal communication is vital in order to keep the workforce informed, on the same page and, therefore, working in the same direction. For the exercise to work, we need all staff to "Buy in" to the plan.

External communication is also vital in order to keep our stakeholders aware of what we are doing and why. Without that support — we cannot succeed. That is why we need to engage, listen, explain and, where necessary, adapt.

Especially in safeguards, we rely on the trust and confidence of our Member States. Trust that what we are doing is fair and fully consistent with the legal agreements in force: and confident that we work objectively in pursuit of independent and soundly-based conclusions. Our credibility is essential to our work, for if we lose it, we are lost too.

All communication needs to be clear, consistent and delivered on a regular basis.

All IAEA staff are international civil servants, not allied to any nation or region, but serving the international community in a common cause.

We are a truly international organization. At the last count, safeguards staff herald from over 80 countries. They conduct inspections, carry out analysis and participate in state evaluation work.

The staff in my own office come from a dozen countries spread all over the world.

The commitment and energy of safeguards staff drives our success. I am very proud of the people working in the Department — at all levels.

Conclusion:

In conclusion, Madam Chair, I emphasize the importance of synchronizing strategy, implementation and people in a way that achieves more "bang for the buck". Higher productivity in the delivery of independent, soundly-based safeguards conclusions.

We have been charged with a heavy responsibility by the international community: to verify the peaceful use of nuclear energy and to prevent the proliferation of nuclear weapons.

Working together — the IAEA with States, regional organizations, the nuclear industry and with civil society — I believe we can uphold that responsibility in the common interests of all humankind.

Thank you.

Strategic Planning and the Long-term R&D Plan

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The Department of Safeguards of the International Atomic Energy Agency implements a structured strategic planning process to ensure that safeguards will continue to be both effective and efficient in the future. This process provides the Department with a comprehensive and coherent planning framework for the short (2 years), medium (6 years) and long (12 years) term. The Department's suite of planning documents includes a long-term strategic plan and an associated long-term research and development plan as well as a biennial development and implementation support programme.

The Department's Long–Term Strategic Plan 2012–2023 addresses the conceptual framework for safeguards implementation, legal authority, technical capabilities (expertise, equipment and infrastructure) and the human and financial resources necessary for Agency verification activities. As research and development (R&D) are essential to meet the safeguards needs of the future, the Department's Long–Term R&D Plan 2012–2023 is designed to support the Long–Term Strategic Plan 2012–2023 by setting out the capabilities that the Department needs to achieve its strategic objectives, and key milestones towards achieving those capabilities for which Member State R&D support is needed. The Long–Term R&D Plan 2012–2023 addresses the Department's R&D requirements in areas such as safeguards concepts and approaches; detection of undeclared nuclear material and activities; safeguards equipment and communication; information technology, collection, analysis and security; analytical services; new mandates; and training. Long–term capabilities discussed in the presentation include deployed systems (e.g., equipment at facilities); analytical (e.g., sample analysis), operational (e.g., staff expertise and skills) and readiness (e.g., safeguarding new types of facilities) capabilities.

To address near–term development objectives and support the implementation of its verification activities as well as to support the attainment of longer term R&D objectives, the Department develops biennially a Development and Implementation Support (D&IS) Programme for Nuclear Verification. The D&IS Programme for Nuclear Verification 2014–2015 identifies 24 projects in such areas as verification technology development, safeguards approaches, information processing and analysis, and training. Its implementation would not be possible without the transfer of technology, funds and expertise provided by Member State Support Programmes.

Successes and Future Challenges Short statements from each of the SG Division Directors.

G. Dyck[1], V. Z. De Villiers[1], H. Barroso[1], J. Baute[1], S. Zykov[1], G. Voigt[1], F. Moser[1], and J. Cooley[1]

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Abstract forthcoming.

S01: Evolving Safeguards Implementation

Overview of the Development and Discussion on Evolving Safeguards Implementation

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An overview of the evolution of safeguards implementation will be described. The state level concept has been further developed and defined through a collaborative process involving the Department of Safeguards and in consultation with Member States. A description of the process and new developments will be elaborated. The status of a recent report on the topic to the IAEA Board of Governors will be reviewed.

A Canadian Perspective on the IAEA's State-Level Concept

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The IAEA has been implementing a State-level approach in Canada since 2005, after Canada first attained the broader safeguards conclusion. The Canadian Nuclear Safety Commission (CNSC), the safeguards regulatory authority in Canada, has nine years of experience in implementing a State-level approach and is thus well-placed to offer thoughts on the IAEA's State-level Concept (SLC). The IAEA is currently in the process of applying the SLC across all Member States, an initiative fully supported by the CNSC as a natural evolution of the safeguards system in response to a 'no real growth' budget, a growing global nuclear industry, and recent cases of undeclared activities.

The IAEA's transition from checklist-based safeguards to the information- and analysis-based SLC stands to enhance the IAEA's ability to deliver effective, efficient, and non-discriminatory safeguards across all States. Under an SLC the IAEA will investigate all safeguards relevant information for all States, providing for more effective safeguards by addressing a weakness in the IAEA's past approach to safeguards. The SLC offers gains in efficiency as it allows for an increase or decrease in safeguards effort where warranted, an effect which has been strongly demonstrated in Canada, where annual IAEA in-field effort under the State-level approach has dropped by seventy percent, without compromising effectiveness. The SLC will, in the CNSC's opinion, enhance the IAEA's ability to implement safeguards in a non-discriminatory manner — allocation of effort to a Member State will be in response to the State-specific Factors relevant to that State as a whole, as opposed to dictated by inflexible, facility-driven criteria. For these reasons Canada has and will continue to support the application of the SLC to all Member States.

The IAEA Safeguards System in the XXI Century

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The report will consider the IAEA safeguards system, established in the 70s in relation to the NPT. It will consider events that influenced development of the system and its reaction; how the changes were implemented. It will designate challenges of today, primarily from the point of view of the world nuclear energy development as no alternatives; allocate important, as considered by the authors, technical and organizational elements of the safeguards system development process and examine their applicability to the situation of today.

The report will consider proposed by the IAEA Secretariat way of the safeguards system evolving — the State Level Concept — and will provide technical reasoning and evaluations of strengths and weaknesses of various elements of the concept. Attention will be paid to information use, sources and reliability confirmation; diversion paths analysis and acquisition paths analysis; and will set out ideas on the role of safeguards criteria, expert judgment and state specific factors, their applicability in the development, implementation and evaluation of safeguards approaches effectiveness.

The report will examine the IAEA and its Member States rights and responsibilities in the area of safeguards, mechanisms that are available for the implementation of safeguards under the Safeguards Agreements and the Additional Protocols thereto. It will discuss, as an important element, the potential way of the maximum use of these mechanisms without making obstacles to the peaceful nuclear activities, economic and technological development of States, and while avoiding undue interference in the State's internal affairs.

In conclusion it will present the authors views and suggestions for further system development and increasing its effectiveness, efficiency and ability to respond to various indicators while mandatory maintaining non-discriminatory, impartial and common approach based safeguards implementation; including considerations and suggestions for safeguards management and broader conclusions drawing practice while avoiding subjectivity in safeguards, including integrated safeguards, assessments.

IAEA's Implementation of the State-Level Concept

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The International Atomic Energy Agency (IAEA) has taken several steps over the years to strengthen its safeguards program, including successfully encouraging more countries to bring an Additional Protocol into force, increasing the number of countries that are subject to a broader range of safeguards measures, and upgrading its safeguards analytical laboratories. IAEA's latest strategy to further improve the effectiveness and efficiency of the safeguards programme is to expand implementation of the "state-level concept" to all countries with safeguards agreements. The state-level concept is an approach in which IAEA considers a broad range of information about a country's nuclear capabilities and tailors its safeguards activities in each country accordingly. IAEA officials have stated that broader implementation of this approach will allow the agency to better allocate resources by reducing safeguards activities where there is no indication of undeclared nuclear activities and to focus its efforts on any issues of safeguards concern. Several member countries, including the United States, support IAEA's plans to broaden implementation of the state-level concept, but other member countries — including some countries with significant nuclear activities — have raised concerns that the agency has not clearly defined and communicated how the state-level concept will be implemented or how it will stay within bounds of the agency's existing legal authorities. In September 2012, the General Conference passed a resolution that included a request for IAEA's Secretariat to report to the Board of Governors on the conceptualization and development of the state-level concept. In August 2013, IAEA released that report to the Board of Governors and started briefing member states on its content. Our paper will discuss (1) IAEA's efforts to clearly define and communicate how IAEA will implement the state-level concept and (2) the status of its implementation.

S02: Communication with State and Regional Authorities on State Declarations

21st Century Declarations

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The IAEA receives and manages information declared by States, as prescribed by the relevant safeguards agreements, and, together with all other safeguards-relevant information, evaluates it as part of the process supporting safeguards implementation. Within the Division of Information Management (SGIM), the Section for State Declared Information Analysis (ISD) plays a key role in the processing of State declared information — from the transmission of information to the Agency to its ultimate use in the context of the State evaluation process and the drawing of safeguards conclusions.

SGIM-ISD handles an increasing variety and volume of these Member State declarations. While the volume of submissions has grown, the submission methods have not kept pace with either the number or the available technology.

The paper and supporting presentation will provide an overview of the variety of declarations and transmission methods. The current paradigm and transmission paths between the State authorities and Agency will be evaluated.

It will also lay out a future paradigm and desired features of a next generation system. As the Department of Safeguards is currently re-engineering its information technology infrastructure, the future paradigm will be placed within the context of these changes.

Information Interaction with IAEA on Nuclear Import and Export

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This paper considers organizational aspects of nuclear import and export interaction between the Russian Federation and the Agency.

Requirements of nuclear import and export in Russia, information submission procedure and forms are determined in RF Government Regulation No 973 from December 15th 2000. Particularly, according to these requirements Russian licenced organizations implementing nuclear import and export submit reports about appointed transfers to State Corporation "Rosatom".

Regulations of State Corporation "Rosatom" entrusted gathering and processing of reporting information and interaction with IAEA to FSUE "SCC of Rosatom". Regulations of reporting information interaction were developed by SCC and approved by State Corporation "Rosatom". Russian organizations send notifications to SCC using regulation electron or paper forms. Regulations determine information security measures in reporting process.

Automated nuclear import and export accounting system developed by SCC provides data entering, keeping and processing, enables to choose and submit requested information in different formats. This system is integrated with State Nuclear Material Control and Accounting System. Also submitted information is regularly compared with customs declarations data to improve reliability and consistency of information.

Generalized nuclear import and export data is using by Departments of State Corporation "Rosatom" and transmitting to Federal Environmental, Industrial and Nuclear Supervision Service of Russia in agreed forms.

Summary information about international nuclear transfers is sending to IAEA according to INFCIRC/207. Reporting information is coordinating. Messaging with IAEA is realized by email using enciphering program.

States' Reporting of Annex II Exports (AP) and the Significance for Safeguards Evaluation

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This paper describes the origin of States' declarations to the Agency of exports of equipment and non-nuclear material specified in Annex II of the Additional Protocol (a list based on an early revision of INFCIRC/254/Part 1) and elaborates on how the reporting of Annex II exports contributes to the consistency analysis of States' declared nuclear activities. The paper also indicates other areas of States' licencing of nuclear-related exports which can bring valuable relevant information to safeguards evaluation — should States be prepared to voluntarily supply such information — as well as the process and prospects for updating Annex II, if and when Member States identify this as a priority.

Transit Matching for International Safeguards

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In 2013 the U.S. Department of Energy / National Nuclear Security Administration Office of Non-proliferation and International Security (NIS) supported a study of the International Atomic Energy Agency's (IAEA) processes and procedures for ensuring that shipments of nuclear material correspond to (match) their receipts (i.e., transit matching). Under Comprehensive Safeguards Agreements, Member States are obliged to declare such information within certain time frames. Nuclear weapons states voluntarily declare such information under INFCIRC/207. This study was funded by the NIS Next Generation Safeguards Initiative (NGSI) Concepts and Approaches program. Oak Ridge National Laboratory led the research, which included collaboration with the U.S. Nuclear Regulatory Commission, the U.S. Nuclear Material Management and Safeguards System (NMMSS), and the IAEA Section for Declared Information Analysis within the Department of Safeguards. The project studied the current transit matching methodologies, identified current challenges (e.g., level of effort and timeliness), and suggested improvements. This paper presents the recommendations that resulted from the study and discussions with IAEA staff. In particular, it includes a recommendation to collaboratively develop a set of best reporting practices for nuclear weapons states under INFCIRC/207.

Protocol Reporter Update: Scope, User's Requirements, Expectations, Collaborative Work

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The Protocol Reporter was developed by the IAEA to assist States in the creation and preparation of declarations pursuant to articles 2 and 3 of the additional protocol (AP), and was designed to be a complete tool for compiling, arranging, editing, managing, and submitting State declarations in support of the AP. Version 1.0 was released in 1999 and version 2.0, the most recent version, was released in December 2008. Both are stand-alone desktop systems that allow users to input data on AP declarable activities and facilities, and to prepare a complete declaration for submission to the IAEA.

Protocol Reporter is currently experiencing compatibility problems with newer 64-bit operating systems. Additionally, the Agency and Member States have identified desirable enhancements not presently available in version 2.0. Development of the next version of the Protocol Reporter is therefore necessary in order to maintain the system's usability. To that end, the Agency has partnered with the United States Department of Energy for support in the development of the next version of AP reporting software.

Since October 2013 the IAEA and DOE have been working to define and document functional requirements and system design specifications. A final draft of the system requirement specification was delivered to the IAEA in March 2014 and, at the time of this submittal, work on the system design specification was in progress. Key differences between version 2.0 and the new version will include increased detail of data, improved methods for States to consolidate and manage declaration data, expanded use of look-up tables, and the ability to attach files directly to an entry, declaration, or submission.

This presentation will report on the collaboration, work, scope, purpose, results to date, and future plans for the Protocol Reporter version 3.0.

Digital Declarations: The Provision of Site Maps under INFCIRC/540 Article 2.a.(iii)

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The modernization of information technology for safeguards is necessary to increase both the availability and the security of safeguards information, a vital asset for Safeguards implementation. The Safeguards Information Management Division's State Infrastructure Analysis Section has initiated several new Member State Support Programme tasks to test and demonstrate how site maps attached to Additional Protocol declarations provided under Article 2.a.(iii) might be submitted to the IAEA in a digital format. This would allow the IAEA to automatically ingest site maps into its Geospatial Exploitation System which would save time and resources as well as result in better, more accurate site maps for the IAEA. The benefits to States include a more well-defined, standardized approach to submitting 2.a.(iii) information. This could mean more consistency across all sites within a country and a simplified annual update process. In addition, creating digital site maps using industry-standard geographically-aware information systems provide tools for data management and data visualization, including temporal changes. The overall verification process would be enhanced since the digital site maps can be easily compared to other data sources, thus enhancing the efficiency and accuracy of verification. Germany, Canada, Finland and Japan have accepted support programme tasks on this subject and agreed to evaluate the provision of digital declaration data on selected nuclear sites. The IAEA will use this opportunity to work with site operators to evaluate what this means to current practices. The IAEA will use the results of these tasks as lessons-learned to evolve and to optimize the process to the benefit of all. A complementary E-poster within this panel section will demonstrate new, more standardized templates and recommended workflows for submission of digital declaration data.

Exploiting Spatial Data for Site Declarations

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The IAEA Department of Safeguards is proposing a spatial data delivery process for state submission of site declaration maps. This new initiative is in support of the Department's Geospatial Exploitation System (GES) which utilizes spatial data from a multitude of sources to enable spatial analysis to verify declarations. Worldwide, many sites deliver declaration maps produced with spatially enabled technologies, such as Geographic Information Systems (GIS), however, the actual spatial data that enables the map production is absent. This paper will present how Bruce Power is using GIS to manage safeguard information for its site and why supporting the digital submission of spatial data to the IAEA, as part of the state declaration, both modernizes and simplifies the submission process while also supporting the objectives of the IAEA GES.

Technical Solution for Improved Safeguards/State Cooperation

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This paper will discuss an information technology solution to allow the IAEA Safeguards Department to improve cooperation with States. The solution will be a portal or hub to integrate the information, processes, and people between Safeguards and States. It will allow for two-way communication and collaboration between Safeguards staff and State representatives. This paper discusses the information security challenges inherent in building such a system. It proposes technical architectures that might allow the existing integration approach (e.g., encrypted email exchange) to be kept, while expanding it to include modern integration technologies (e.g., web services), as well explorer new collaborative web technologies. It looks at current Safeguards processes and approaches to cooperation and discusses efficiencies that could be achieved through the adoption of this technology solution.

Example process areas for improvement include: a) Safeguards Agreements: States are obligated to submit data on their nuclear programme to the IAEA on a periodic basis. Declarations are received through two separate systems using encrypted email. The proposed solution would allow for enhanced exchange of declaration where States can submit any type of declaration using one system. When declarations are received and validated, an acknowledgement would automatically be sent to the State. The solution would provide the Safeguards Department the ability to ask for clarification as well as collaborate on the submitted declarations. Both the question and the response would be recorded in the system. The solution could also integrate tools allowing declarations to be added directly and validated before submission. b) Other areas that could benefit from this solution include declarations from States with small quantities protocol, facility declarations, as well as systems that support extra-budgetary funding (e.g., SPRICS).

S03: Safeguards for Reprocessing and Pyroprocessing Facilities

On-Line Monitoring for Process Control and Safeguarding of Radiochemical Streams at Spent Fuel Reprocessing Plants

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The International Atomic Energy Agency (IAEA) has established international safeguards standards for fissionable material at spent nuclear fuel reprocessing plants to ensure that significant quantities of weapons-grade nuclear material are not diverted from these facilities. Currently, methods to verify material control and accountancy (MC&A) at these facilities require time-consuming and resource-intensive destructive assay (DA). Leveraging new on-line non-destructive assay (NDA) techniques in conjunction with the traditional and highly precise DA methods may provide a more timely, cost-effective and resource-efficient means for MC&A verification at such facilities. Pacific Northwest National Laboratory (PNNL) is developing on-line NDA process monitoring technologies, including a spectroscopy-based monitoring system, to potentially reduce the time and resource burden associated with current techniques. The spectroscopic monitor continuously measures chemical compositions of the process streams including actinide metal ions (U, Pu, Np), selected fission products, and major cold flowsheet chemicals using ultra-violet and visible, near infrared and Raman spectroscopy. This paper will provide an overview of the methods and report our on-going efforts to develop and demonstrate the technologies. Our ability to identify material intentionally diverted from a liquid-liquid solvent extraction contactor system was successfully tested using on-line process monitoring as a means to detect the amount of material diverted. A chemical diversion, and detection of that diversion, from a solvent extraction scheme was demonstrated using a centrifugal contactor system operating with the PUREX flowsheet. A portion of the feed from a counter-current extraction system was diverted while a continuous extraction experiment was underway. The amount observed to be diverted by on-line spectroscopic process monitoring was in excellent agreement with values based from the known mass of sample directly taken (diverted) from system feed solution.

Developments in the Deployment of Ultrasonic Bolt Seals at the Storage Ponds of a Large Reprocessing Plant

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At the ponds of La Hague (F) different types of material are stored awaiting reprocessing:

- Irradiated LEU fuel assemblies,
- Fresh MOX scrap of different origins,
- Irradiated MOX assemblies from research reactors,
- Irradiated L/HEU assemblies from research reactors.

According to the safeguard approach developed by Euratom, irradiated LEU fuel is verified by Cerenkov viewing devices. Other fuel types are verified with a dedicated under water neutron/gamma detector. The measurements are resource intensive for both inspector and operator. In addition one of the measurement points will be decommissioned by 2015. Thus ultrasonic bolt seals (USBS) were identified as a suitable means to keep continuity of knowledge and reduce inspection effort.

The paper describes currently required measurements and related high effort and compares with the effort to place and read USBS. The discussion will focus on the activities required for un-irradiated MOX scrap, which are of particularly high safeguards interest, and will describe the measures implemented to minimize re-measurement needs. The significant savings will be demonstrated.

Under the new approach USBS are placed on all newly arriving baskets, following verification by NDA. Baskets already in the pond will be sealed with USBS step by step. The current status will be discussed.

In order to make this project possible, JRC Ispra supplied a new generation of USBS reading heads, electronics and software. The paper will describe the significant improvements of the technology versus earlier generations.

Hardware and Software Upgrade for the Solution Measurement and Monitor System at Rokkasho Reprocessing Plant

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Rokkasho Reprocessing Plant is the largest reprocessing facility subject to the application of IAEA Safeguards. Within the numerous unattended measurement and monitoring systems (more than 20 NDA detectors), one of the most important and complex is the Solution Measurement and Monitoring System (SMMS). SMMS is applied to the chemical liquid processing part of the plant operation and involves over 90 vessels or extractors. The installed measurement instruments consist mainly of manometers and temperature sensors. The pressure readings from the manometers are used to calculate the density and the mass of the solution in each monitored tank. For the 12 most strategic tanks, IAEA owned manometers are directly connected to the Operator's dip tubes with associated data collection system, (SMMS-I type instruments) aimed at collecting and sending data to a common database. For the remaining tanks/equipment the operator's instruments are used (SMMS-II). The data coming from both types of SMMSs are pre-processed and reviewed by the Solution Monitoring Software (SMS). The software basically provides a calculation of volumes, densities, flow rates in major process vessels, and includes, as well, advanced automatic features to support the inspectorate in the verification activities.

This paper describes the upgrade of the SMMS-I acquisition hardware and the SMMS Operating Software (SOS) at the IAEA local cabinets, for a much more robust and reliable overall system through different levels of redundancy and new features. The software also allows the in situ calibration of manometers using an ad hoc portable calibration system.

Safeguarding Advanced Generation IV Reprocessing Facilities: Challenges, R&D Needs, and Development of Measurements

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Recycling of nuclear fuel will be an essential component of Generation IV (Gen IV) systems. Both the aqueous and electrochemical reprocessing techniques, which comprise the main recycling routes considered for future closed fuel cycles, face challenges related to safeguards implementation. Thus, advancements in the research related to Gen IV cycles call for simultaneous development of safeguards approaches for new types of nuclear facilities.

The feasibility to perform spent fuel measurements in aqueous and electrochemical facilities, respectively, depends heavily on the fuel composition, the chemical processes in operation, and the environments in which they take place. Regardless of reprocessing technique, efficient measures are required in order to conform to the limited resources allocated by the IAEA for safeguards implementation. Remote and online monitoring capabilities at a facility are therefore crucial. At the same time, for establishing and maintaining knowledge of the fuel even in complex bulk handling facilities with high material throughputs, improved accuracy in measurements is desirable.

As part of Sweden's Gen IV research program, financed by the Swedish Research Council, and as one of the safeguards research projects carried out at Uppsala University, a series of physical measurements of solutions containing used nuclear fuel is planned. X-ray and gamma photons emitted from the fuel will be measured at different stages of a laboratory scale GANEX (Group ActiNide EXtraction) aqueous recycling process. Radiation measurements hold a potential for quick, online measurements as a complement to DA (Destructive Assay) sampling. In this paper, results of MCNP simulations performed in preparation of the measurements will be discussed.

Design and Implementation of Equipment for Enhanced Safeguards of a Plutonium Storage in a Reprocessing Plant

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The Nuclear Security unit (NUSEC) of the Institute for Transuranium Elements (ITU, JRC) was entrusted by DG ENER to design and implement equipment in order to achieve enhanced safeguards of a plutonium dioxide storage located on the MAGNOX reprocessing plant in Sellafield (UK). Enhanced safeguards must lead to a win-win situation for all parties involved. In this case the DG ENER inspectorate will save inspection time, manpower and future financial resources and the operator will have the right to access its storage without the need for inspector presence.

To reach this goal, while at the same time taking into account current budget constraints, NUSEC developed applications that use equipment commonly used in the safety and security fields but so far have not been used in safeguards. For instance, two laser scanners are used to detect entry/exit events into and out of the store and to provide the necessary information to an algorithm in order to categorize objects/people passing the scanners, e.g., a Fork Lift Truck, a trolley used to bring in PuO_2 containers, a system used for the dispatch of cans, people, etc. An RFID reader is used to identify equipment duly authorized to access the store. All PuO_2 containers arriving from the production line must be weighed, identified and measured using gamma and neutron detectors before they can be transferred to the store. For this purpose an Unattended Combined Measurement System (UCMS) was designed and manufactured by the JRC in order to do all verification activities using a single instrument.

This paper describes the design features of the equipment and its implementation with the support of the Sellafield Ltd. in the framework of the MAGNOX store project.

Improving Materials Accountancy for Reprocessing using hiRX

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The High Resolution X-ray (hiRX) technology has the potential to replace K-Edge and Hybrid K-Edge Densitometry (HKED) for routine accountability measurements in reprocessing. This technology may significantly reduce plutonium measurement uncertainty in a simpler and less costly instrument. X-ray optics are used to generate monochromatic excitation of a sample and selectively collect emitted X-rays of the target elements. The result is a spectrum with a peak specific to one element with negligible background. Modeling was used to examine how safeguards could be improved through the use of hiRX at existing aqueous reprocessing plants. This work utilized the Separation and Safeguards Performance Model (SSPM), developed at Sandia National Laboratories, to examine how reduced measurement uncertainty decreases the overall inventory difference measurement error. Material loss scenarios were also modelled to determine the effect on detection probability for protracted diversion of nuclear material. Current testing of hiRX is being used to inform the modelling effort, but a 0.1% measurement uncertainty for uranium and plutonium concentration is an optimistic goal based on laboratory results. Modeling results showed that a three-fold improvement in the ability to detect a protracted diversion of plutonium may be possible if the 0.1% uncertainty goal can be achieved. The modelling results will be presented along with a discussion of the current experimental campaign results. In addition, a qualitative cost analysis will be presented to compare the use of hiRX with HKED.

Application of Laser Induced Breakdown Spectroscopy to Electrochemical Process Monitoring of Molten Chloride Salts

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Techniques for in situ, near real-time analysis of molten salt chlorides used in electrochemical fuel treatment processes face several challenges including atmospheric isolation, high radiation fields, corrosive environments and high temperatures. Therefore, techniques that can operate in a stand-off manner will have a definitive advantage for implementation in a fuel treatment facility. Laser induced breakdown spectroscopy (LIBS), an elemental analysis technique, is being pursued as a near real-time process monitor of various process streams. LIBS can operate at stand-off distances and has been used in other industries as a process monitoring technique.

Safeguarding Pyroprocessing Related Facilities in the ROK

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Pyroprocessing technology is being investigated by a number of countries as a promising strategy to the sustainable development of nuclear energy production and management of spent nuclear fuel as one electrochemical recycling process. As one of them, the Republic of Korea (ROK) has been developing technical aspects of pyroprocessing since 1997. To date, the ROK has established three pyroprocessing related facilities at the Korea Atomic Energy Research Institute (KAERI) site.

The IAEA's safeguards system provides the international community with credible assurances regarding a State's fulfilment of its safeguards obligations. Developing safeguards approaches for pyroprocessing facilities in a State is an integrated process consisting of acquisition path analysis (APA), establishment and prioritization of technical objectives (TO) and identification of applicable safeguards measures.

This paper presents the basic principles of safeguards implementation at pyroprocessing related facilities in the ROK which takes into account the specific nature of the process and the nuclear materials involved, and it outlines how new monitoring equipment have been tailored for safeguards purposes. The demands for robust safeguards applied to pyroprocessing facilities require the IAEA to develop new measures/techniques to complement the more traditional safeguards systems such as containment and surveillance (C/S). As an example, a bus bar system has been designed and developed to support evaluation of the facility operators' declarations by monitoring the electrical current supplied to the electro-reduction and the electro-refining equipment.

Safeguards Considerations for the Design of a Future Fast Neutron Sodium Cooled Reactor

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Incorporating safeguards at an early stage of a reactor design is a way to increase the effectiveness and efficiency of safeguards measures minimizing the possibilities of misuse of the plant or nuclear material diversion. It also reduces the impact on the construction and operation cost. At the preliminary phase, the design will integrate: confinement, containment, surveillance features and non-destructive assay equipment. Taking into account these requirements will help the operator in the approval of the plant at the design phase by national and international authorities in charge of Nuclear Material accounting and safeguards.

A large amount of work has been made by the GEN IV International Forum to assess the proliferation resistance of nuclear systems. The IAEA has developed guidelines on “Safeguards by design” describing reference requirements for future nuclear facilities. Based on these studies, this communication details implementation of safeguards in the design of a sodium cooled fast neutron reactor (SFR) currently studied in France. Specificities are the use of MOX fuel with high concentration of plutonium and the potential capacity of breeding. A great attention should be paid to avoid diversion of nuclear material contained in fresh or irradiated fuel. Scenarios of reactor misuse are analyzed.

The identification of diversion pathways and requirements for nuclear material accountancy, leads to an approach of safeguards, specific to SFR: Material Balance Areas (MBA) and some key measurement points (KMP) are characterized. Specific instrumentation assay helping in the identification and/or characterization of fuel elements and the inventory of nuclear material is described.

As concerns the fuel cycle, the safeguards of the reprocessing unit will be progressively increased through the development of materials monitoring and the implementation of these measures at strategic locations of buildings, thus providing real-time information on the distribution and quantities of materials in the process.

Cost Effective Process Monitoring using UV-VIS-NIR Spectroscopy

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UV-VIS-NIR Spectroscopy is a simple and inexpensive measurement technology which has been proposed for process monitoring applications at reprocessing plants. The purpose of this work was to examine if spectroscopy could replace more costly analytical measurements to reduce the safeguards burden to the operator or inspector. Recognizing that the higher measurement uncertainty of spectroscopy makes it unsuited for the accountability tanks, the approach instead was to focus on replacing mass spectrometry for random samples that are taken in a plant. The Interim Inventory Verification and Short Inventory Verification (IIV/SIV) at the Rokkasho Reprocessing Plant utilize random sampling of internal process vessels and laboratory measurement using Isotope Dilution Mass Spectrometry (IDMS) to account for plutonium on a timely basis. These measurements are time-consuming, and the low uncertainty may not always be required. For this work, modelling was used to examine if spectroscopy could be used without adversely affecting the safeguards of the plant. The Separation and Safeguards Performance Model (SSPM), developed at Sandia National Laboratories, was utilized to examine the replacement of IDMS measurements with spectroscopy. Modeling results showed that complete replacement of IDMS with spectroscopy lowered the detection probability for diversion by an unacceptable amount. However, partial replacement (only for samples from vessels with low plutonium content) did not adversely affect the detection probability. This partial replacement covers roughly half of the twenty or so sampling points used for the IIV/SIVȦ cost-benefit analysis was completed to determine the cost savings that this approach can provide based on lower equipment costs, maintenance, and reduction of analysts’ time. This work envisions working with the existing sampling system and performing the spectroscopic measurements in the analytical laboratory, but future work could examine incorporating spectroscopy as a true on-line monitor that does not require sampling.

Proliferation Potential and Safeguards Challenges of Pyroprocesses

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The nuclear industry has continued to evolve technologically in the area of advanced reactors and other advanced fuel cycle facilities. With regard to recycling spent fuel, pyroprocesses have undergone a resurgence of interest in the last decade or so. Considering ongoing development of pyroprocessing technologies worldwide, the IAEA is enhancing its technical knowledge related to pyroprocesses and developing generic safeguards approaches for model pyroprocessing facilities to ensure future facilities will be 'safeguards friendly' allowing for the implementation of effective and efficient safeguards.

The following RnD activities related to the development of safeguards approaches for pyroprocessing facilities are being performed or planned under IAEA Member State Support Programmes:

- Safeguards Approach for Reference Engineering-scale Pyroprocessing Facility (Republic of Korea (ROK))
- Trilateral Safeguards and Security Working Group under the USA/ROK Joint Fuel Cycle Study (ROK, USA)
- Safeguards Technical Report on Pyroprocessing (European Commission, France, Japan, ROK)
- Field Test of Safeguards Measures and Equipment at Pyroprocessing Facilities (under discussion with ROK)

In parallel to the R&D activities, preliminary assessment of the proliferation potential of pyroprocessing technology and a study on generic technical objectives and applicable safeguards measures/activities for pyroprocessing facilities were performed to identify safeguards challenges to be addressed and to guide the direction and focus of the R&D activities.

The assessment of the proliferation potential of the pyroprocess has led to the identification of a number of safeguards challenges, categorized as follows:

- Measurement uncertainties of feed, product, waste and in-process material
- Sampling procedures, destructive analysis and non-destructive analysis for feed, product, waste and in-process materials are not yet established
- Process parameters are not well established
- Signature and indicators of the physical model need to be updated

The paper summarizes the development of concept and technology to meet future safeguards needs of pyroprocessing facilities.

Development of a Safeguards Approach for Reference Engineering-Scale Pyroprocessing Facility

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A Reference Engineering-scale Pyroprocessing Facility (REPF) concept was developed through a Member State Support Programme (MSSP) for the "Support for Development of a Safeguards Approach for a Pyroprocessing Plant". Homogenization process, which was aimed to make the homogenous powder for the nuclear material accountancy, was included in the head end process. Material Balance Area (MBA)s and Key Measurement Point (KMP)s for the REPF were identified, and the nuclear material accounting method of each KMP was specified. A three-level method was proposed to evaluate the nuclear material accountancy by using Near Real Time Accountancy (NRTA). A simulation program, PYroprocessing Material flow and MUF Uncertainty Simulation (PYMUS), was developed to analyze the nuclear material flow in the facility and to calculate the uncertainty of the Material Unaccounted For (MUF). Measurement errors of each KMP were estimated, and the total MUF uncertainties were calculated with the PYMUS. The safeguardability of the REPF safeguards approach was assessed. The result of this study has been reviewed and tested through the following internal collaboration on the safeguards of the pyroprocessing facility.

Application of Microfluidic Techniques to Pyrochemical Salt Sampling and Analysis

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Microfluidic techniques enable production of micro-samples of molten salt for analysis by at-line and off-line sensors and detectors. These sampling systems are intended for implementation in an electrochemical used fuel treatment facility as part of the material balance and control system. Microfluidics may reduce random statistical error associated with sampling inhomogeneity because a large number of uniform sub-microlitre droplets may be generated and successively analyzed. The approach combines two immiscible fluids in a microchannel under laminar flow conditions to generate slug flows. Because the slug flow regime is characterized by regularly sized and spaced droplets, it is commonly used in low-volume/high-throughput assays of aqueous and organic phases. This scheme is now being applied to high-temperature molten salts in combination with a second fluid that is stable at elevated temperatures. The microchip systems are being tested to determine the channel geometries and absolute and relative phase flow rates required to achieve stable slug flow. Because imaging is difficult at the 500°C process temperatures the fluorescence of salt ions under ultraviolet illumination is used to discern flow regimes. As molten chloride melts are optically transparent, UV-visible light spectroscopy is also being explored as a spectroscopic technique for integration with at-line microchannel systems to overcome some of the current challenges to in situ analysis. A second technique that is amenable to droplet analysis is Laser–induced Breakdown Spectroscopy (LIBS). A pneumatic droplet generator is being interfaced with a LIBS system for analysis of molten salts at near-process temperatures. Tests of the pneumatic generator are being run using water and molten salts, and in tandem with off-line analysis of the salt droplets with a LIBS spectrometer.

S04: Innovative Methods for Training

Virtual Reality Based Accurate Radioactive Source Representation and Dosimetry for Training Applications

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Virtual Reality (VR) technologies have much potential for training applications. Success relies on the capacity to provide a real-time immersive effect to a trainee. For a training application to be an effective/meaningful tool, 3D realistic scenarios are not enough. Indeed, it is paramount having sufficiently accurate models of the behaviour of the instruments to be used by a trainee. This will enable the required level of user's interactivity.

Specifically, when dealing with simulation of radioactive sources, a VR model based application must compute the dose rate with equivalent accuracy and in about the same time as a real instrument. A conflicting requirement is the need to provide a smooth visual rendering enabling spatial interactivity and interaction.

This paper presents a VR based prototype which accurately computes the dose rate of radioactive and nuclear sources that can be selected from a wide library. Dose measurements reflect local conditions, i.e., presence of (a) shielding materials with any shape and type and (b) sources with any shape and dimension. Due to a novel way of representing radiation sources, the system is fast enough to grant the necessary user interactivity.

The paper discusses the application of this new method and its advantages in terms of time setting, cost and logistics.

Employing 3D Virtual Reality and the Unity Game Engine to Support Nuclear Verification Research

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This project centres on the development of a virtual nuclear facility environment to assist non-proliferation and nuclear arms control practitioners — including researchers, negotiators, or inspectors — in developing and refining a verification system and secure chain of custody of material or equipment. The platform for creating the virtual facility environment is the Unity 3D game engine. This advanced platform offers both the robust capability and flexibility necessary to support the design goals of the facility. The project also employs Trimble SketchUp and Blender 3D for constructing the model components. The development goal of this phase of the project was to generate a virtual environment that includes basic physics in which avatars can interact with their environment through actions such as picking up objects, operating vehicles, dismantling a warhead through a spherical representation system, opening/closing doors through a custom security access system, and conducting CCTV surveillance. Initial testing of virtual radiation simulation techniques was also explored in preparation for the next phase of development. Some of the eventual utilities and applications for this platform include:

1. conducting live multi-person exercises of verification activities within a single, shared virtual environment,
2. refining procedures, individual roles, and equipment placement in the contexts of non-proliferation or arms control negotiations
3. hands on training for inspectors, and
4. a portable tool/reference for inspectors to use while carrying out inspections.

This project was developed under the Multilateral Verification Project, led by the Verification Research, Training and Information Centre (VERTIC) in the United Kingdom, and financed by the Norwegian Ministry of Foreign Affairs. The environment was constructed at the Vienna Center for Disarmament and Non-Proliferation (VCDNP).

Training Software for the Bulk Handling Facility

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In 2013, the International Atomic Energy Agency, Department of Safeguards, applied safeguards in 180 States with safeguards agreements in force, with implementation of safeguards at over 600 facilities. To support the Department of Safeguards in fulfiling its mission, the training section holds over 100 training courses yearly to help inspectors and analysts develop the necessary knowledge, skills and abilities.

An effective training programme must be able to adapt and respond to changing organizational training needs. Virtual training technologies have the potential to broaden the spectrum of possible training activities, enhance the effectiveness of existing courses, optimize off-site training and activities, and possibly increase trainee motivation and accelerate learning. Ultimately, training is about preparation — being ready to perform in different environments, under a range of conditions or unknown situations. Virtual environments provide this opportunity for the trainee to encounter and train under different scenarios not possible in real facilities.

This paper describes the training software developed for fuel fabrication facilities to be used by both national inspectors and IAEA inspectors. The model includes interactive modules to explain each of the six main fuel fabrication processes. It also includes verification instruments at specific locations with animations that illustrate how to operate the instrument, verify the material and report.

Additionally, the software integrates an evaluation mode to allow the trainee and the instructor to track progress and evaluate learning. Overall, the model can be used for individual training, or integrated into a training course where the instructor can draw on the virtual model to enhance the overall effectiveness of the training.

Human-Centred Computing for Assisting Nuclear Safeguards

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With the rapid evolution of enabling hardware and software, technologies including 3D simulation, virtual reality (VR), augmented reality (AR), advanced user interfaces (UI), and geographical information systems (GIS) are increasingly employed in many aspects of modern life. In line with this, the nuclear industry is rapidly adopting emerging technologies to improve efficiency and safety by supporting planning and optimization of maintenance and decommissioning work, as well as for knowledge management, surveillance, training and briefing field operatives, education, etc.

For many years, the authors have been involved in research and development (R&D) into the application of 3D simulation, VR, and AR, for mobile, desktop, and immersive 3D systems, to provide a greater sense of presence and situation awareness, for training, briefing, and in situ work by field operators. This work has resulted in a unique software base and experience (documented in numerous reports) from evaluating the effects of the design of training programmes and briefing sessions on human performance and training efficiency when applying various emerging technologies. In addition, the authors are involved in R&D into the use of 3D simulation, advanced UIs, mobile computing, and GIS systems to support realistic visualization of the combined radiological and geographical environment, as well as acquisition, analyzes, visualization and sharing of radiological and other data, within nuclear installations and their surroundings.

The toolkit developed by the authors, and the associated knowledge base, has been successfully applied to various aspects of the nuclear industry, and has great potential within the safeguards domain. It can be used to train safeguards inspectors, brief inspectors before inspections, assist inspectors in situ (data registration, analyzes, and communication), support the design and verification of safeguards systems, conserve data and experience, educate future safeguards inspectors on general principles (E-learning materials), etc.

Advanced Safeguards Measurement, Monitoring and Modelling Laboratory (AS3ML)

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Safeguarding declared nuclear facilities is a main duty of the nuclear safeguards inspectorates. Depending upon the amounts of nuclear materials present (and physical/chemical form), a certain inspection approach (and corresponding dedicated techniques and equipment) is developed. This approach will be very different for an item facility compared to a bulk-material handling process, whereby in each case we strive to a maximum efficiency and effectiveness of the safeguards system. Traditionally these safeguards measurements are executed with independent, safeguards approved, measurement equipment, complementary to the existing plant equipment and focusing on a variety of nuclear material diversion scenarios (and statistical considerations).

The innovative aspect of the Advanced Safeguards Measurement, Monitoring and Modelling Laboratory, AS3ML, subject of this paper, is that it aims to complement the above approach by providing an alternative method to monitor the process of sensitive facilities such as Gas Centrifuge Enrichment and Nuclear Fuel Reprocessing plants. It endeavours thus to enhance the "traditional safeguards measures" by the focus on and analysis of (other) process parameters, which a priority each individually might not have a highly significant value, but which, taken all together, might allow to get a very good insight in the proper operation (thrust building measures) or alternatively to the deviations from the "theoretical" values of the behaviour of a facility.

The AS3ML is thus conceived as an R&D location, test bed, demo facility and training centre for innovative safeguards approaches where researchers, inspectors (and operators) can conceive and analyze different approaches (including competing technologies) for safeguarding nuclear facilities. Techniques and approaches, not currently used in routine safeguards applications, will be discussed including a reference to a recent achievement for a fully new way of safeguarding a plutonium storage location which is presented elsewhere in this symposium.

Immersive Environment Development for Training: Opportunities for Cooperation, Coordination, and Cost Savings

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Immersive environments are increasingly demonstrating their utility for a number of nuclear safeguards, nuclear safety, and nuclear and physical security applications. Although training is an obvious use, the immersive (or sometimes called virtual) environment allows the user to “visit” nuclear facilities and sites that might have access restrictions because of security, high radiation or other hazards; are difficult and expensive to visit. An immersive environment can also be reconfigured to study various scenarios, processes, and other what–if situations, which can aid planning and design of new facilities or evaluate safeguards, safety and/or security measures before they are implemented. As the International Atomic Energy Agency, other international organizations, State Authorities, industry, and academia continue development and use of immersive environments and other electronic training technologies, more and more applications can be envisioned. Immersive environments are not a direct or always a desirable replacement for hands-on learning; however, the demand for electronic training media, particularly immersive environments, will grow. The resulting increase of system features and libraries presents opportunities to shorten development time frames, reduce costs and increase availability of immersive environments for a wider audience looking to balance the need for quality training with limited resources. Substantial time and cost savings can be realized by the sharing of raw assets among developers and organizations. This paper will explore potential guidelines, criteria, and mechanisms for such cooperation, including a prototype asset repository website.

Evolution of the Nuclear Safeguards Performance Laboratory PERLA on the Ispra Site of the Institute for Transuranium Elements

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Based upon the experience of many years of operation, the safeguards Performance Laboratory PERLA will be reshaped in the near future (and relocated on the Ispra site such as not to interfere with decommissioning activities). During almost 30 years of successfully operating nuclear facilities in Ispra for supporting nuclear safeguards inspectorates with R&D, equipment development and training for in the meantime more than 1250 trainees, this laboratory is the main work-horse in this field and has functioned very frequently in the last years as easily accessible nuclear laboratory for external users. Even if a constant evolution took place in the last years, and additional facilities like the active neutron laboratory PUNITA or the ITRAP test laboratory for nuclear security R&D, testing and training have been taken in service, this step-change will allow refiguring the laboratory to face also new user expectations. NDA for safeguards continues to be a cornerstone of the measurement capacities complemented by experimental and advanced approaches, such as using active neutron interrogation, automation of measurements, complemented by Monte-Carlo simulations for neutron and gamma radiation. The tendency is also to integrate multiple plant signals (not only NDA measurements) in an overall assessment scheme and we envisage offering training and exercising capabilities for the inspectors also in this direction in the future.

This paper will thus provide some insight in the concepts for the future use of the nuclear facilities on the Ispra site, which is complementary to two other contributions to this symposium, i.e., one describing the activities of our sister unit in Karlsruhe on NDA Safeguards Training and another on the new Advanced Safeguards Measurement, Monitoring and Modelling Laboratory (AS3ML) being built currently in Ispra.

Practical Results of the Creation of the Non-destructive Assay Measurement Training Laboratory at the Russian Methodological and Training Center

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The Russian Methodological and Training Center (RMTC) was created at the Institute of Physics and Power Engineering (IPPE) in Obninsk, Russia as a result of collaborative efforts between the United States, the European Commission and the Russian Federation.

A significant result of the collaboration was the creation of the RMTC's Non-destructive Assay (NDA) Measurement Training Laboratory, where hands-on experience in making NDA measurements can be acquired during conduct of courses.

The NDA laboratory is equipped with standard reference materials, radioactive sources, various gamma-spectrometers for determining uranium and plutonium isotopic composition, active and passive neutron coincidence counters for measurement of U-235 and plutonium mass in containers, waste drum monitors to measure plutonium and U-235 mass in waste, neutron counters, a hybrid K-edge densitometer and a calorimeter. This broad range of equipment provides the opportunity to provide practical training in all aspects of non-destructive measurements needed within the Russian Federation.

The laboratory has a wide spectrum of State Reference Materials (SRM) of uranium oxide and plutonium oxide. State Reference Materials for BN-600, VVER-440 and RBMK fuel elements and fuel assemblies have also been fabricated and certified. The laboratory has equipment models and special uranium samples to conduct courses on measuring uranium and plutonium hold-up in process equipment.

The capability of the lab especially in the field of NDA of plutonium in items and wastes gave the possibility for RMTC to train of IAEA inspectors in advanced plutonium verification techniques.

This paper briefly describes the RMTC NDA laboratory's capabilities and discusses the training course developed by RMTC for IAEA inspectors.

Safeguards Export–Import Training: Adapting to Changes in the Department of Safeguards Over 6 Years of Experience

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Safeguards relevant information encompasses information available to the Agency in exercising its rights and fulfiling its obligations under relevant safeguards agreement(s). It includes information relating to nuclear or nuclear related trade like international transfers of nuclear material, or export (or import upon request by the Agency) of specified equipment described in annex 2 of the Additional Protocol. It may also include information provided by States on a voluntary basis. In 2005, the General Conference (see GC(49)/RES/13) encouraged the provision of information on procurement enquiries, export denials and other nuclear related information. Objectively and independently assessing this information and combining it with other Safeguards data and knowledge requires relevant expertise and well defined processes. Since 2008, the bi-annual Export–Import (EXIM) Training Workshop, jointly run by the IAEA Department of Safeguards and the U.S. Department of Energy, enables SG staff to develop competencies required for collecting, processing and drawing objective conclusions in this area. Over the years, more than 150 SG staff have been exposed to technical information on relevant non-nuclear material and equipment, trade data from different origins, analytical processes, and exercises to use this knowledge in realistic safeguards work scenarios. The EXIM training has also been an opportunity to develop analytical best practices and explore how this analytical work finds it place in the verification process. The paper describes the background and purpose of the EXIM training, how it helps Safeguards to independently collect and analyze relevant trade information to fulfil its obligations. It also touches on the lessons learned from six years of training experience, observing how the Department of Safeguards develops and implements structured processes to collect, process and evaluate safeguards relevant trade information, in order to establish findings and draw safeguards conclusions.

Developing Safeguards Training Material for Management and General Staff of Facilities

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The objective of the European Safeguards Research & Development Association (ESARDA) Working Group on the Implementation of Safeguards (IS WG) is to provide the Safeguards Community with proposals and expert advice on the implementation of safeguards concepts, methodologies and approaches aiming at enhancing the effectiveness and efficiency of safeguards on all levels and serve as a forum for exchange of information and experiences on safeguards implementation.

During the meetings of the IS WG, it was identified that there is a need to enhance the safeguards culture in facilities. Therefore a sub-working group was set up in 2013 in order to develop safeguards training material for the management and for the general staff of these facilities.

The first proposal for the structure of such training was presented in a joint working group during the 36th annual ESARDA meeting in Luxembourg. After the presentation, the feedback from the participants was retrieved and implemented in the proposed structure. Based on this reviewed structure, the sub-working group has elaborated a training material which will be tested by the members of the IS working group in the future. This paper outlines the revised training material

Construction of a NDA-Safeguards Training Facility at the ITU Karlsruhe

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In this paper the newly constructed NDA-Training facility at the Karlsruhe site of the Institute for Transuranium Elements (ITU) is presented. Training courses for nuclear Safeguards inspectors from Euratom and IAEA will be provided. They comprise NDA-techniques for safeguards measurements involving fissile material, e.g., active and passive neutron measurements as well as techniques based on gamma measurements. The laboratory was built as part of the European Nuclear Security Training Centre project (EUSECTRA) which aims at providing security training to prevent the misuse of nuclear material. Nuclear safeguards trainings take place in a specifically dedicated separate lab of this new EUSECTRA facility, where exclusively encapsulated radioactive material is handled. The training courses are embedded in the European Nuclear Safety and Security School (EN3S) of the European Commission, Joint Research Centre and complement NDA safeguards training held at the Ispra site of ITU.

S05: Assuring Quality in Safeguards Findings

Accountability and Transparency: Essential Underpinnings of Quality Safeguards

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The fundamental purpose of IAEA safeguards is to maintain confidence in the international community of the compliance of States with their respective non-proliferation commitments. The safeguards system for ensuring this compliance produces the most important output, the IAEA's compliance findings.

Confidence in the findings of any compliance verification system requires some basic elements such as independence, accountability, transparency, and quality management systems. Quality management systems are an internal set of documents and procedures that, while clearly important, need to incorporate an external communication component in order to engender confidence as to how compliance is being managed and ensured.

This paper will explore the importance of these fundamentals to confidence in IAEA safeguards compliance conclusions, with a focus on the external communication elements of accountability and transparency. Accountability and transparency will be considered with different communication channels through which safeguards implementation matters are explained and reported and at different levels, facility, State, regional, and the IAEA. This will include communications by: the IAEA and State authorities to the general public; State authorities to peers in other national safeguards authorities (regional and beyond); and, the IAEA and State authorities to the international community as represented through the Board of Governors and General Conference. Examples will be presented of good practices in these areas to encourage greater accountability and transparency in the work of safeguards.

URENCO's Experiences in Safeguards Reporting and in Developing a Nuclear Material Accountancy System

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The URENCO Group has operated uranium enrichment plants, using the gas centrifuge technology, for over forty years in Europe. Throughout this period, the plants have been subjected to the Euratom safeguards regime and during the late 1970's the IAEA safeguards regime has been introduced as well. From thereon, the safeguards regimes of Euratom and IAEA have been brought more in line and safeguards inspections were carried out as a so-called Joint Team.

IAEA safeguards for centrifuge enrichment plants developed following the Hexapartite Safeguards Project (HSP) and the introduction of the Additional Protocol (AP) resulted in further refinement of IAEA safeguards for all nuclear facilities. The current IAEA safeguards reporting regime is also applied to the new URENCO facility in the USA.

URENCO has been submitting declarations and reports in compliance with the relevant safeguards regulations and agreements and has been adapting that practice to stay tuned with the changes and modifications in IAEA safeguards.

As a result of the changing demand, developments in office software and the establishment of the URENCO Group, an aligned Nuclear Material Accountancy System (NMAS) has been set up, allowing for the preparation of safeguards reports and declarations with direct use of data collected during plant operations.

The aim of the presentation is to provide the audience insight into the experience gained by URENCO in safeguards reporting and optimization of the NMAS as basis for these reports and declarations.

Nuclear Material Information Quality Control for Safeguards Purposes in South Africa

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The State System of Accounting and Control of Nuclear Material (SSAC) in South Africa comprises a State Inspectorate, Technical Support and Safeguards Information Systems (SIS). SIS is responsible for the quality control and assurance of the Nuclear Material Reports, Additional Protocol declarations and submission to the IAEA.

Monthly reports are received from the facilities where inventory changes took place. Reports are prepared according to a Quality Management Document: Instruction for the Completion of Nuclear Material Accounting Reports. The inventory changes are reported on spreadsheets developed for our system. The Inventory Change Reports (ICR) and General Ledgers (GL) are compared line by line to check for discrepancies, which will be noted on a Control Sheet. The form will be sent to the relevant facility to notify them of corrections needed. The corrected reports will be re-submitted to SIS. A spreadsheet is used in the verification process with columns for all material categories and inventory change codes. The ICR totals of all inventory changes can be reconciled with the GL values. If all the entries are correct the nuclear material totals should be the same as on the GL.

The facility file is checked by the State Inspector responsible for the specific facility as a second round of quality control. The inspector is required to sign the Control Sheet to confirm the completeness and correctness of the reports. The Excel data is then converted into a text (.txt) file, encrypted and then submitted electronically to the Agency.

This paper will present all the steps involved in ensuring the correctness of the reports and the quality control measures in detail used by the South Africa SSAC.

Deriving, Communicating and Applying Safeguards Conclusions

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Safeguards are arrangements for verifying that states are in compliance with international agreements or undertakings relating to the peaceful use of nuclear materials. The IAEA has operated a system of comprehensive safeguards agreements with non-nuclear-weapon states parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) for over forty years. This system has evolved over time in recognition that a progressively broader approach to verification is required to substantiate the IAEA's conclusions.

Current policy debates on the further evolution of safeguards implementation primarily relate to the development of the IAEA's 'state level concept' for safeguards, and the resolution of compliance or performance issues in several countries. Safeguards experts acknowledge that the identification and clarification of principles for determining safeguards priorities and for deriving safeguards conclusions will be a crucial step in strengthening the non-proliferation regime.

This paper recommends the development of a procedure by which the IAEA Secretariat would issue standardized notices to the Board of Governors in situations where anomalies in safeguards implementation remain unresolved for a prescribed period of time. These 'Automatic Notices' are designed to assist the Secretariat with the structured communication of technical information about state compliance.

The procedure would enhance the transparency of the operation of the IAEA, the credibility of the verification assurance, and the timeliness of identification of potential non-compliance. It also provides states, whether acting through the Agency's Board of Governors or otherwise, with opportunities to craft effective solutions to potential proliferation crises. Furthermore, the existence and number of these 'Automatic Notices' would provide one transparent and objective basis for differentiating between states in future allocation of safeguards resources. This paper will address the manner in which Automatic Notices could be phased in and their relationship with the annual Safeguards Implementation Report.

Japanese Quality Assurance System Regarding the Provision of Material Accounting Reports and the Safeguards Relevant Information to the IAEA

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The provision of the safeguards relevant reports and information in accordance with the comprehensive safeguards agreement (CSA) and the additional protocol (AP) is the basis for the IAEA safeguards.

The government of Japan (Japan Safeguards Office, JSGO) has believed that the correct reports contribute to effective and efficient safeguards therefore the domestic quality assurance system for the reporting to the IAEA was already established at the time of the accession of the CSA in 1977. It consists of Code 10 interpretation (including the seminars for operators in Japan), SSAC's checks for syntax error, code and internal consistency (computer based consistency check between facilities) and the discussion with the IAEA on the facilities' measurement system for bulk-handling facilities, which contributes to the more accurate reports from operators. This spirit has been maintained for the entry into force of the AP. For example, questions and amplification from the IAEA will be taken into account the review of the AP declaration before sending to the IAEA and the open source information such as news article and scientific literature in Japanese is collected and translated into English, and the translated information is provided to the IAEA as the supplementary information, which may contribute to broadening the IAEA information source and to their comprehensive evaluation.

The other safeguards relevant information, such as the mail-box information for SNRI at LEU fuel fabrication plants, is also checked by the JSGO's QC software before posting. The software was developed by JSGO and it checks data format, batch IDs, birth/death date, shipper/receiver information and material description code.

This paper explains the history of the development of the Japanese quality assurance system regarding the reports and the safeguards relevant information to the IAEA.

United States of America Nuclear Regulatory Commission's Approach to Inspections and Quality Control of Data

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In recent years, the International Atomic Energy Agency (IAEA) has benefited greatly from an increased number of data sources along with enhanced capabilities to assist safeguards inspectors who analyze this new data. However, the quality and reliability of State declared information used by the IAEA to draw safeguards conclusions remains critically important. Each State or Regional Authority has the responsibility to ensure reports provided to the IAEA are correct and complete. This paper describes the United States Nuclear Regulatory Commission's (US NRC) approach to quality control of safeguards declarations provided to the IAEA and how this process supports fulfilment of the United States' international obligations. The US NRC's audit-based approach to domestic inspections will be reviewed along with the advantages and challenges of such an approach to the quality control of information. Furthermore, examples of quality control of safeguards-relevant information at facilities, the national nuclear materials database, and the NRC will be cited and used to show how each step helps build confidence in the final declaration provided to the IAEA.

Verification of the Correctness and Completeness of Nuclear Operators' Declarations by Euratom

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We present the Euratom nuclear safeguards system, a supranational system used to verify the operators' and States' (when required by the Additional Protocol) declarations. The verifications performed by the European Commission serve to conclude on the non-diversion of the civil stocks of nuclear materials in the territories of EU Member States (Article 77a Euratom Treaty) and to fulfil obligations stemming from nuclear cooperation agreements with third States and international organizations such as the IAEA (Article 77b).

In line with multilateral safeguards agreements and their respective additional protocols, as well as under the New Partnership Approach, Euratom works closely with the IAEA in order to avoid unnecessary duplication of efforts while maintaining the ability of both organizations to reach independent conclusions.

In our paper the focus lies on the verifications performed before transmitting data to the IAEA. Starting from the sheer volume of data we describe checks and other operations performed (e.g., format adaptations) on the nuclear material accountancy (NMAC) data and Additional Protocol declarations; including quality assurance measures. We also present some statistics on the related workload, including answering queries from the IAEA.

We describe the IT tools developed by Euratom for nuclear operators to submit their declarations and which are subsequently verified by Euratom before being transmitted to the IAEA. Moreover, we present support activities aiming at improving the operators' NMAC systems such as audits (including audits of measurement systems).

We conclude by presenting the challenges lying ahead and ways to address them to further strengthen and improve the quality of the Euratom work and cooperation with the IAEA.

The Department of Safeguards Quality Management System

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The International Atomic Energy Agency (IAEA) Department of Safeguards quality management system (QMS) provides the framework for all activities that support the Agency's commitment to providing soundly-based safeguards conclusions regarding the peaceful use of nuclear material. The focus of the QMS is to enhance the effectiveness and efficiency of safeguards implementation through defined, documented processes, routine oversight and continual improvement initiatives. In accordance with QMS principles, the high-level business processes representing the Department's activities are defined in procedures, guidelines and policies that are maintained in the Safeguards Document Manager. These processes form the basis for Department operations for drawing safeguards conclusions regarding State's compliance with their safeguards obligations. Oversight is provided through internal quality audits. These audits are targeted at processes selected by Senior Management with a focus on procedure compliance as well as customer expectations. Best practices and areas for improvement are assessed through continual improvement. Noncompliance and conditions that are adverse to quality are identified and analyzed in the Condition Report System. Root cause analysis and the implementation actions to eliminate the cause reduce the chance of condition recurrence. Through continual process improvement, processes are measured and analyzed to reduce process and administration waste. The improved processes improve efficiency while providing the desired results. Within the scope of the QMS, these tools support the performance of Departmental processes so that Safeguards products achieve the intended purpose. This paper describes how the various elements of the Department's QMS support safeguards implementation.

S06: Performance Management in Non-profit Organizations

Strengthening Performance Management in the IAEA Department of Safeguards

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This paper will describe an initiative to develop a management support tool to improve performance management in the IAEA Department of Safeguards. The envisaged mechanism should enable the Department to (a) plan, assess and report on the achievement of its objectives and (b) to improve its performance on a continuous basis. The performance management tool should be aligned with related processes in the Department and the IAEA as a whole such as strategic planning, programming and budget, the result-based management approach and various reporting mechanisms. It should be integrated with existing and planned information and other management systems.

The initially, departmental working group that was established for this initiative focussed on two aspects: confirmation of the overall and specific objectives to be achieved by the Department of Safeguards, and compiling an inventory of indicators of activities, outputs and outcomes that were being used in the Department. This exercise confirmed that alignment and prioritization of activities relating to assessment of, and reporting on, performance could be improved. A value creation map was subsequently developed to assist in focussing the performance management tool to identified needs of stakeholders.

Other activities of the working group included the determination of the desired characteristics of a hierarchy of performance indicators to be used to drive desired behaviour across organizational levels. Complexities to be handled included the following:

- reflecting the appropriate component of the results chain (such as activities, outputs, outcomes and impact);
- maintaining the linkages between objectives and performance indicators across organizational levels;
- developing a balanced set of performance indicators (e.g. reflecting in-field and Headquarters activities, incorporating all main components of Departmental processes and balanced scorecard perspectives, measurable vs qualitative indicators); and
- distinguishing between performance of the Secretariat and the safeguards system as a whole.

Effective Strategy Implementation: Best Practice that Really Works

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The application of Business Performance Management (BPM) was traditionally associated with the Balanced Scorecard developed by Keppler and Norton over 20 years ago and used primarily in commercial organizations where Shareholder value was the priority. The presentation describes how this approach has evolved to focus on Stakeholder priorities rather than profit, how it has been applied successfully to the management of nuclear security performance and how it can be applied to any organization whether in the public or private sector. Strategy Mapping clarifies organizational priorities, allows staff to understand their role and contribution much more clearly and has a significant motivational impact on most organizations to which it is applied.

Assessing and Promoting the Level of Safeguards Culture in Hungarian Nuclear Facilities

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The Hungarian SSAC has introduced a comprehensive domestic safeguards verification system consisting of regular comprehensive SSAC verifications in the whole lifetime of the facilities. The main goals of the comprehensive verification system are:

(i) to assess the facility's safeguards system compliance with the relevant national legislation and recommendations,

(ii) to assess the activities of the facility aimed at maintaining and further developing its safeguards system, and,

(iii) to revise validity of data and information previously provided by the facility subject to safeguards licencing procedures.

The maintenance level of the system as well as the available knowledge on the possible needs for change reflect the top management's awareness of this issue and is a good indicator of the present and future effectiveness of the facility level safeguards system and the level of safeguards culture. The structure, preparation, conduction, documentation and initial experiences of the comprehensive safeguards verification system is introduced in the paper. Additionally, HAEA has just introduced a safeguards indexing method for evaluation the safeguards culture at Hungarian nuclear facilities. The main goal of indexing method and the evaluated parameters are also shown in the paper.

Nuclear Safeguards Culture

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The paper will consider safeguards culture both at the IAEA and among member states. It will do so through the lens of organizational culture theory and taking into account developments in safeguards since the Iraq case of the early 1990s. The study will seek to identify the current characteristics of safeguards culture and how it has evolved since the 93+2 programme was initiated, as well as considering the roles of the most important purveyors of such culture, including member states and their national safeguards authorities, the General Conference and Board of Governors, the Director General, the Secretariat as a whole, the Safeguards Department and the inspectorate. The question of what might be an optimal safeguards culture at the Agency and among member states will be investigated, along with the issue of how such a culture might be engendered or encouraged.

S07: New Trends in Commercial Satellite Imagery

New and Emerging Satellite Imaging Capabilities in Support of Safeguards

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This abstract is focused on new and emerging commercial satellite imagery (CSI) capabilities. For more than a decade, experienced imagery analysts have been exploiting and analyzing CSI in support of the Department of Safeguards. As the remote sensing industry continues to evolve, additional CSI imagery types are becoming available that could enhance our ability to evaluate and verify States' declarations and to investigate the possible presence of undeclared activities. A newly available and promising CSI capability that may have a Safeguards application is Full Motion Video (FMV) imagery collection from satellites. For quite some time, FMV imagery has been collected from airborne platforms, but now FMV sensors are being deployed into space. Like its airborne counterpart, satellite FMV imagery could provide analysts with a great deal of information, including insight into the operational status of facilities and patterns of activity. From a Safeguards perspective, FMV imagery could help the Agency in the evaluation and verification of States' declared facilities and activities. There are advantages of FMV imaging capabilities that cannot be duplicated with other CSI capabilities, including the ability to loiter over areas of interest and the potential to revisit sites multiple times per day.

Additional sensor capabilities applicable to the Safeguards mission include, but are not limited to, the following sensors:

- Thermal Infrared imaging sensors will be launched in late 2014 to monitor operational status, e.g., heat from a transformer.
- High resolution Short Wave Infrared sensors able to characterize materials that could support verification of Additional Protocol declarations under Article 2.a(v).
- Unmanned Aerial Vehicles with individual sensors or specific sensor combinations.

The Safeguards Symposium provides a forum to showcase and demonstrate safeguards applications for these emerging satellite imaging capabilities.

UrtheCast: The System of Systems for Dynamic EO Monitoring Content

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UrtheCast is a multinational industrial initiative that tasks, downloads, processes and commercially exploits a medium resolution multispectral sensor and high-resolution wide area motion colorful video camera.

UrtheCast's Earth Observation imaging system includes a pair of multispectral color cameras installed on the ISS. The High-Resolution Camera (HRC-Iris) is mounted on a pointing platform and captures 1 m-class high-definition (HD), full color motion imagery of areas measuring approximately 5.5×3.6 km^2. The nadir pointing, push-broom Medium-Resolution Camera (MRC-Theia) produces a continuous ribbon of 4-channel, multispectral 6 m-class imagery. The acquired data are downlinked to a global network of antennas and backhauled to the UrtheCast cloud-based processing system and dissemination services. The resulting imagery and video are streamed in near-real time to the UrtheCast web platform or delivered to customers as special order products.

UrtheCast daily MRC collection capability is $\sim$29 million km^2 while the HRC capacity is envisaged to generate approximately 2.5 terabytes of data per day, the equivalent of about 270 full resolution $\sim$90 second movies.

The UrtheCast new Generation cameras include a dual Optical sensor (video & push-broom focal planes) and dual-band (X and L) Synthetic Aperture Radar payload. Video will be of half-metre colour (0.40 m after super-imposition) and push-broom will be 1 m of 6-band multispectral. SAR payload will simultaneously record in both L and X bands, with the L-band in full quad pole (HH, HV, VH, VV, at 5 m) and the X-band in single pole (HH or VV, at 1.5 m or at $<$1 m in spotlight mode).

The new system will be installed at NASA's Node 3 segment in late 2016.

ISS is flying at 400 km, orbiting the earth 15 times/day and covering areas fallen into a geographic zone from 51.5 degrees north to 51.5 degrees south.

European Space Imaging & Skybox Imaging

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Skybox and European Space Imaging have partnered to bring timely, Very High-Resolution imagery to customers in Europe and North Africa. Leveraging Silicon Valley ingenuity and world-class aerospace expertise, Skybox designs, builds, and operates a fleet of imaging satellites. With two satellites currently on-orbit, Skybox is quickly advancing towards a planned constellation of 24+ satellites with the potential for daily or sub-daily imaging at 70–90 cm resolution.

With consistent, high-resolution imagery and video, European customers can monitor the dynamic units of human activity — cars, trucks, shipping containers, ships, aircraft, etc. — and derive valuable insights about the global economy. With multiple imaging opportunities per day, the Skybox constellation provides unprecedented access to imagery and information about critical targets that require rapid analysis.

Skybox's unique capability to deliver high-definition video from space enables European customers to monitor a network of globally distributed assets with full-motion snapshots, without the need to deploy an aircraft or field team. The movement captured in these 30–90 second video windows yield unique insights that improve operational decisions.

Skybox and EUSI are excited to offer a unique data source that can drive a better understanding of our world through supply chain monitoring, natural resource management, infrastructure monitoring, and crisis response.

Alternative Data Source for Monitoring of Nuclear Activity: KOMPSAT Constellation

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Very High Resolution (VHR) satellite images are used to verify the correctness and completeness of declarations provided by member States, and to generate preparatory information for on-site inspections and technical visits. VHR satellite images are also used for collect data for nuclear monitoring in inaccessible areas of interest. Most satellites acquire image in the morning, and the better resolution requires higher costs.

This presentation is focused on introduction of alternative VHR satellite images: KOMPSAT (KOrean Multi-Purpose SATellite) constellation. KOMPSAT-2 (1.0 m resolution) and KOMPSAT-3(0.7 m resolution) provides VHR optical images and KOMPSAT-5 (1.0 m resolution) provides VHR SAR images as well and those make it possible to look into the situation more accurately and promptly. KOMPSAT-3 has highest quantization with 14 bits per pixel, which contains more information than any other optical satellite. SI Imaging Services offers further VHR optical satellite data such as DubaiSat-2 and Deimos-2 which provide 1m resolution optical image. Shorter revisit time on a specific target can be achieved by combination of KOMPSAT-2, -3, -5, DubaiSat-2, and Deimos-2.

KOMPSAT constellation provides not only unique combination of optical and SAR but also unique imaging time combination, namely 06:00, 10:50, 13:30, and 18:00. Using this constellation, event related monitoring over a specific target can be achieved and change detection within one day can be performed.

Data continuity for both optical and SAR data is guaranteed by long-term government commitment followed by KOMPSAT-3A (Optical and IR) and KOMPSAT-6 (SAR). This unique combination can provide advanced data sets to analysts by enhancing collection capability and enabling integrated analysis for important assignments.

Identification of Nuclear Activities Using Satellite Imaging

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Satellite imagery is now a very performing tool for the monitoring of human and industrial activity. Due to the multiplicity of modalities, its scope is very broad and it participates actively in the monitoring of proliferation activities. In this paper, we focus on quantitative or pseudo quantitative exploitation of indicators or afferent signatures of these activities extracted from various type of satellite images.

We have developed automatic algorithms for the detection of changes, in complement to visual examination of time series, which provide information on modifications of buildings or vehicle positions and on the ground. Such algorithms can be applied to visible or RADAR imaging, this latter being operational in all weather or illumination conditions. We first describe a technique based on 3D changes analysis applied first to an urban environment and then to the estimation of volumes of material dredged from digged underground galleries. We also present the possibilities brought by RADAR imagery from acquisitions in interferometric mode; in this case, the amplitude signal is analyzed.

Upstream of the nuclear cycle, monitoring of the production of uranium or other materials of interest is affordable by hyperspectral imaging. This latter, due to the richness of analysis on fine and densified spectral bands, allows quantifying emissions of gaseous effluents and categorizing mineral deposits; we illustrate examples of both applications in the paper.

Change Detection with Polarimetric SAR Imagery for Nuclear Verification

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This paper investigates the application of multivariate statistical change detection with high-resolution polarimetric SAR imagery acquired from commercial satellite platforms for observation and verification of nuclear activities. A prototype software tool comprising a processing chain starting from single look complex (SLC) multitemporal data through to change detection maps is presented.

Multivariate change detection algorithms applied to polarimetric SAR data are not common. This is because, up until recently, not many researchers or practitioners have had access to polarimetric data. However with the advent of several spaceborne polarimetric SAR instruments such as the Japanese ALOS, the Canadian Radarsat-2, the German TerraSAR-X, the Italian COSMO-SkyMed missions and the European Sentinal SAR platform, the situation has greatly improved. There is now a rich source of weather-independent satellite radar data which can be exploited for Nuclear Safeguards purposes. The method will also work for univariate data, that is, it is also applicable to scalar or single polarimetric SAR data.

The change detection procedure investigated here exploits the complex Wishart distribution of dual and quad polarimetric imagery in look-averaged covariance matrix format in order to define a per-pixel change/no-change hypothesis test. It includes approximations for the probability distribution of the test statistic, and so permits quantitative significance levels to be quoted for change pixels. The method has been demonstrated previously with polarimetric images from the airborne EMISAR sensor, but is applied here for the first time to satellite platforms. In addition, an improved multivariate method is used to estimate the so-called equivalent number of looks (ENL), which is a critical parameter of the hypothesis test.

High Resolution 3D Earth Observation Data Analysis for Safeguards Activities

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This paper provides an overview of the investigations performed in the last three years at DLR and highlights the application of SAR and optical data for 3D analysis in the context of Safeguards. The Research Center Jülich and the adjacent open cut mines were used as main test site, and a comprehensive stack of ascending and descending TerraSAR data was acquired over two years. TerraSAR data acquisition was performed, and various ways to visualize stacks of radar images were evaluated. Building height estimation was performed using a combination of ascending-descending radar images, as well as height-form-shadow, height-from-layover. A tutorial on building signatures from SAR images highlighted the sensor specific imaging characteristics. These topics were particularly relevant in safeguards activity with a "small-budget" as only a single image — or a couple — were employed. Interferometric coherence map interpretation allows the detection of used dirt roads.

Digital surface models (DSM) were generated from TanDEM-X interferometric data and from optical VHR data. Sub-meter Worldview-2 and GeoEye-1 data was processed into highly detailed DSM with a grid spacing of 1 m, showing building structures. 3D change and volume detection was performed with both optical and radar DSMs. The TanDEM-X DSMs proved useful for volume change detection and computation in mining areas, and down to building level with optical data. Virtual fly-through were found to be a good tool to provide an intuitive understanding of site structure and might be useful for inspector briefing. Tools for most of the above mentioned tasks have been developed for the ENVI environment and can be used by IAEA internally.

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Advances in the Processing of VHR Optical Imagery in Support of Safeguards Verification

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Under the Additional Protocol of the Non-Proliferation Treaty (NPT) complementing the safeguards agreements between States and the International Atomic Energy Agency, commercial satellite imagery, preferably acquired by very high-resolution (VHR) satellite sensors, is an important source of safeguards-relevant information. Satellite imagery can assist in the evaluation of site declarations, design information verification, the detection of undeclared nuclear facilities, and the preparation of inspections or other visits. With the IAEA's Geospatial Exploitation System (GES), satellite imagery and other geospatial information such as site plans of nuclear facilities are available for a broad range of inspectors, analysts and country officers. The demand for spatial information and new tools to analyze this data is growing, together with the rising number of nuclear facilities under safeguards worldwide. Automated computer-driven processing of satellite imagery could therefore add a big value in the safeguards verification process. These could be, for example, satellite imagery pre-processing algorithms specially developed for new sensors, tools for pixel or object-based image analysis, or geoprocessing tools that generate additional safeguards-relevant information. In the last decade procedures for automated (pre-) processing of satellite imagery have considerably evolved. This paper aims at testing some pixel-based and object-based procedures for automated change detection and classification in support of safeguards verification. Taking different nuclear sites as examples, these methods will be evaluated and compared with regard to their suitability to (semi-) automatically extract safeguards-relevant information.

S08: State of the Art Destructive Analysis

Implementation of Mass Spectrometry for Bulk Analysis of Environmental and Nuclear Material Inspection Samples

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In the frame of the ECAS project (Enhancing Capabilities of Safeguards Analytical Services) the IAEA Office of Safeguards Analytical Services has implemented the latest-generation inductively coupled plasma mass spectrometers, or ICP-MS, for (i) bulk analysis of uranium and plutonium isotopes in environmental inspection samples and (ii) impurity analyzes in uranium samples. The measurement accuracy for n(U-235)/n(U-238) ratios has been improved by approximately five times with the new multi-collector ICP-MS equipment. Use of modern ICP-MS enabled also an improvement of instrumental detection limits for U-233 and U-236 and Pu isotopes by at least one order of magnitude in comparison to the values, which had been achieved with the previously used methods. The improved accuracy and precision for isotope ratio measurements is mainly due to the higher sensitivity and the possibility to simultaneously detect several U isotopes with a multi-collector detector block. Implementation of the ICP-MS has also demonstrated a possibility for an increased sample throughput. In parallel to the implementation of the ICP-MS, a new version of the "modified total evaporation" (MTE) method has been developed for isotopic analysis of uranium samples by multi-collector thermal ionization mass spectrometry (TIMS). The MTE method provides a measurement performance which is, in particular for minor uranium isotopes, by several orders of magnitude superior compared to the commonly used "total evaporation" method. The new mass spectrometric techniques significantly improve the capability of the IAEA safeguards laboratories to detect the presence of non-natural uranium and plutonium isotopes in environmental swipe samples and to identify previously imperceptible differences in nuclear "signatures". Thus, they enhance the IAEA's ability to obtain independent, timely and quality-assured safeguards-relevant data and ensure that important nuclear and chemical signatures are identified.

Activities at Forschungszentrum Jülich in Safeguards Analytical Techniques and Measurements

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The application of safeguards by the IAEA involves analytical measurements of samples taken during inspections. The development and advancement of analytical techniques with support from the Member States contributes to strengthened and more efficient verification of compliance with non-proliferation obligations. Since recently, a cooperation agreement has been established between Forschungszentrum Jülich and the IAEA in the field of analytical services. The current working areas of Forschungszentrum Jülich are:

(i) Production of synthetic micro-particles as calibration standard and reference material for particle analysis,

(ii) qualification of the Forschungszentrum Jülich as a member of the IAEA network of analytical laboratories for safeguards (NWAL), and

(iii) analysis of impurities in nuclear material samples.

With respect to the synthesis of particles, a dedicated setup for the production of uranium particles is being developed, which addresses the urgent need for material tailored for its use in quality assurance and quality control measures for particle analysis of environmental swipe samples. Furthermore, Forschungszentrum Jülich has been nominated as a candidate laboratory for membership in the NWAL network. To this end, analytical capabilities at Forschungszentrum Jülich have been joined to form an analytical service within a dedicated quality management system. Another activity is the establishment of analytical techniques for impurity analysis of uranium-oxide, mainly focusing on inductively coupled mass spectrometry. This contribution will present the activities at Forschungszentrum Jülich in the area of analytical measurements and techniques for nuclear verification.

Production and Characterization of Monodisperse Reference Particles

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Individual particle analysis of nuclear materials is an important tool in nuclear safeguards and nuclear forensics. Particles in the sub-micrometer to micrometer range are investigated routinely for nuclear safeguards analysis. Different techniques are utilized for particle discrimination and characterization, including scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM/EDX) for identification of the particles of interest and mass spectrometric methods such as (laser ablation-) multi-collector inductively coupled plasma mass spectrometry ((LA)-MC-ICP-MS), large geometry secondary ionization mass spectrometry (LG-SIMS), and thermal ionization mass spectrometry (TIMS) for the determination of their isotopic composition.

The quality control of analytical methodologies, including instrument and method validation, as well as the assurance of the quality of the reported results, requires the use of suitable reference materials. The availability of such reference materials with precisely defined characteristics such as the number of uranium or plutonium atoms per particle, size, density, chemical form, elemental and isotopic composition is very limited.

Monodisperse particles with uranium content can be produced using a Vibrating Orifice Aerosol Generator (VOAG). The particle production is an integrated two-step process: (1) generation of monodisperse aerosols using the VOAG and (2) subsequent drying and calcination of those aerosols to the corresponding oxides.

An important follow up operation is the sampling and subsequent transfer of particles to appropriate substrates for further analysis. This project also addresses these issues. Depending on the subsequent analysis that is being performed with those reference particles, different substrates and sample preparation techniques have to be applied. This paper describes the experimental setup for production of monodisperse particles and discusses the issues related to sampling and handling of individual particles depending on their future application and analysis with the use of analytical techniques such as SEM/EDX and LG-SIMS.

Actinide L-line ED-XRF and Hybrid K-edge Densitometer Spectra Processing

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The analysis laboratory in the CEA Atalante complex at Marcoule (France) performs numerous R&D studies carried out in glove-boxes or in hot cells. Most of the samples are measured in liquid phase, aqueous or organic. The concentration of the main actinides of interest (U, Np, Pu, Am and Cm) are determined by XRF in a hot cell via their L-line X-ray between 13 and 15 keV. In order to limit the counting rate of many radioactive emitters (X-ray and gamma emitters) in the analysis solution and the continuous spectrum, a graphite monochromator is placed between the sample and detector. Commercial or free, the software packages available for processing X-ray spectra are designed and dedicated to a specific instrument and/or do not take into account the specific feature of our system, in other words, the presence of a monochromator. Therefore, a new X-ray analysis software programme was developed for this particular system which takes into account matrix effects corrections. For sample with U and/or Pu in high concentrations, the hybrid K-edge densitometer is used. A new software programme was also developed. For K-edge densitometry spectra processing, no calibration process is used. Spectra processing is based on theoretical equation and uses XCOM database for mass attenuation coefficients. Measured spectra on K-edge densitometer of Rokkasho Safeguards Analytical Laboratory were processed with this software and a very good agreement was found with IDTIMS results. The new graphical user interface allows to manually correct the defined edge. For the XRF spectra processing, new algorithms are used to define the base line and to find/integrate peaks. With these two analytical devices in laboratory, U and Pu concentrations can be measured from 0.5 mg/ℓ to several hundred of g/ℓ.

Feedback of EQRAIN Uranium and Plutonium Analysis Proficiency Tests for the Evaluation of Method Performance

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Analytical approaches are validated by demonstrating that they are suitable for their intended objectives and meet particular requirements of each unit. In this context of analytical validation, included in its main mission of promotion of good analytical practices, the CEA's Committee for the Establishment of Analysis Method (CETAMA) has implemented the programme known as "quality Assessment of Analysis Results in the Nuclear Industry" (EQRAIN) since 1987. This programme has organized regularly interlaboratory comparisons concerning the elemental analysis of uranyl and plutonium nitrate solutions.

The EQRAIN U and Pu interlaboratory comparisons are basically proficiency tests although they are not performed directly for the purpose of qualifying the laboratories. They are closely related to nuclear material accountancy in the fuel cycle and are relatively complementary of the IMEP programme organized by IRMM and the NML IAEA's program.

The specifications of a new comparison are defined at meetings of uranium or plutonium working group. The preparation step, including fabrication, packaging and reference values determination are conducted by the nuclear material laboratory (LAMMAN) located in the Atalante facility of CEA Marcoule (DRCP/SERA/LAMM).

For each ampoules analyzed, the interpretation of the results is based on the ISO 13528 and ISO 5725 standards.

This paper will present the compiled results of the last five EQRAIN U and Pu comparisons. It provides an interesting opportunity to discern the trends in this type of analysis and to compare the accuracy and reproducibility of the main methods employed either material balance inspection methods or process control methods. This statistic data processing highlights the progress of laboratories in evaluating their measurement uncertainties.

This intrinsic performance of measurement methods evaluation is compared to the measurement uncertainties values established by IAEA for nuclear material balance (ITV2010).

Characterization of Nuclear Materials Using Complex of Non-Destructive and Mass-Spectroscopy Methods of Measurements

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Information and Analytical Centre for nuclear materials investigations was established in Russian Federation in the February 2 of 2009 by ROSATOM State Atomic Energy Corporation (the order #80). Its purpose is in preventing unauthorized access to nuclear materials and excluding their illicit traffic. Information and Analytical Centre includes analytical laboratory to provide composition and properties of nuclear materials of unknown origin for their identification.

According to Regulation the Centre deals with:

- identification of nuclear materials of unknown origin to provide information about their composition and properties;
- arbitration analyzes of nuclear materials;
- comprehensive research of nuclear and radioactive materials for developing techniques characterization of materials;
- interlaboratory measurements;
- measurements for control and accounting;
- confirmatory measurements.

Complex of non-destructive and mass-spectroscopy techniques was developed for the measurements. The complex consists of:

- gamma-ray techniques on the base of MGAU, MGA and FRAM codes for uranium and plutonium isotopic composition;
- gravimetrical technique with gamma-spectroscopy in addition for uranium content;
- calorimetric technique for plutonium mass;
- neutron multiplicity technique for plutonium mass;
- measurement technique on the base of mass-spectroscopy for uranium isotopic composition;
- measurement technique on the base of mass-spectroscopy for metallic impurities.

Complex satisfies the state regulation requirements of ensuring the uniformity of measurements including the Russian Federation Federal Law on Ensuring the Uniformity of Measurements #102-FZ, Interstate Standard GOST R ISO/IEC 17025-2006, National Standards of Russian Federation GOST R 8.563-2009, GOST R 8.703-2010, Federal Regulations NRB-99/2009, OSPORB 99/2010. Created complex is provided in reference materials, equipment end certificated techniques. The complex is included in accredited analytical laboratory of JSC "VNIINM's" nuclear materials account and control system.

Towards a Fieldable Atomic Mass Spectrometer for Safeguards Applications: Sample Preparation and Ionization

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The International Atomic Energy Agency's (IAEA) long-term R&D plan calls for the development of new methods to detect misuse at nuclear fuel cycle facilities such as reprocessing and enrichment plants. At enrichment plants, for example, the IAEA's contemporary safeguards approaches are based on a combination of routine and random inspections that include collection of UF6 samples from in-process material and selected cylinders for subsequent destructive analysis (DA) in a laboratory for isotopic characterization, and environmental sampling (ES) for subsequent laboratory elemental and isotopic analysis (both typically by MS). One area of new method development includes moving this kind of isotope-ratio analytical capability for DA and ES activities into the field. Reasons for these developments include timeliness of results, avoidance of hazardous material shipments, guidance of additional sample collecting, etc. However, there are several reasons why this capability does not already exist, such as most lab-based chemical and instrumental methods rely on laboratory infrastructure (highly trained staff, etc.) and require significant amounts of consumables (power, compressed gases, etc.). In addition, there are no currently available, fieldable instruments for atomic or isotope ratio analysis. To address these issues, Pacific Northwest National Laboratory (PNNL) is studying key areas that limit the fieldability of isotope ratio mass spectrometry for atomic ions: sample preparation and ionization, and reducing the physical size of a fieldable mass spectrometer. PNNL is seeking simple and robust techniques that could be effectively utilized by non-technical inspectors. In this report, we present and describe the preliminary findings for three candidate techniques: atmospheric pressure glow discharge, laser ablation/ionization MS at atmospheric pressure, and matrix assisted laser desorption ionization MS. Potential performance metrics for these techniques will be presented, including: detectability, response, isotope ratio accuracy and precision, and ease of use.

Chemical Characterization of Nuclear Materials: Development a New Combined X-Ray Fluorescence and Raman Spectrometer

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New mobile analytical device based on combination of X-ray fluorescence and Raman spectrometer has been developed for prompt and quantitative characterization of chemical component from Al to U in nuclear waste or undeclared materials. The excitation source of the X-ray fluorescence spectrometer is an air-cooled X-ray tube with Ag transmission anode. For collection of secondary X-ray photons and data processing, a compact Amptek X-ray detector system is applied with silicon drift X-ray detector. The XRF system operates in confocal mode with focal volume around 1–4 mm^3. Varying the geometrical position and orientation of the sample optional part of its surface can be analyzed. The Raman unit includes thermoelectrically cooled laser source having 500 mW power at wavelength 785 nm. In order to obtain spectral information from sample surface a reflection-type probe is connected by optical fibres to the Raman spectrometer. A mini focusing optics is set up to the sensor-fibre that provides the system to operate as confocal optical device in reflection mode. The XRF spectrometer with X-ray detector, Raman probe and X-ray tube are mechanically fixed and hermetically connected to an aluminium chamber, which can be optionally filled with helium. The chamber is mounted on a vertical stage that provides moving it to the sample surface. A new model and computer code have been developed for XRF quantitative analysis which describes the mathematical relationship between the concentration of sample elements and their characteristic X-ray intensities. For verification of the calculations standard reference alloy samples were measured. The results was in good agreement with certified concentrations in range of 0.001–100 w%. According to these numerical results this new method is successfully applicable for quick and non-destructive quantitative analysis of waste materials without using standard samples.

Stability of Working Reference Standards for Hybrid K-Edge Densitometer Quality Assurance

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The relatively short working life of aqueous solution standards of actinides for the calibration and quality control of Hybrid K-Edge Densitometer (HKED) measurements necessitates the development of a stable matrix material less susceptible to degradation. Degradation in the form of evaporation, radiolysis, settling, sloshing, and sediment formation can all reduce the reliability and working life of an aqueous standard. These factors make aqueous solutions inadequate for long-term quality assurance measurements designed to detect weak or subtle trends in system performance. Epoxy, studied here, is an alternative matrix material that may be less vulnerable to degradation. An additional benefit of epoxy is that standards can easily be characterized as sealed sources which allows for simplified administrative controls during shipping and storage. The stability of working reference standards consisting of U_3O_8 in an epoxy matrix for use in the HKED has been tracked for over three years through repeated X-ray Fluorescence (XRF) and K-Edge (KED) measurements. A set of six epoxy standards ranging in concentration from 1 g/ℓ to 76 g/ℓ uranium were determined to be stable, within the expected accuracy of the system, over the period of analysis. During this time, no effort was made to enhance the stability of the epoxy standards; the radial measurement position was not controlled and in the middle of the analysis period the HKED system and standards were shipped from the vendor's factory to the customer. Epoxy standards afford numerous benefits over those created from aqueous solutions and should be considered when developing HKED standards for quality assurance measurements. The stability of the epoxy allows the development of working standards of a stability and robustness sufficient for use in a proposed international round-robin exercise based on the exchange of such standards.

Analysis of Uranium-Based Materials by Mass Spectrometric Methods

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The well-developed TIMS with high precision and accuracy for determination of uranium isotopes, ICP-MS with low detection limits and high throughput for determination of impurities, LI-TOF-MS equipped with 193 nm excimer laser and orthogonal-reflection time-of-flight mass spectrometer for identification of specific isotopes, ions, and clusters in full mass range, have been used to analysis of uranium samples originated from nuclear industry, and paid an important role in nuclear safeguards. The laboratory has implemented those mass spectrometric methods in analysis of uranium-based materials. Details will be presented at this symposium.

10^{13} Ω Resistor Amplifiers in MC-TIMS for Precise and Accurate U Isotope Analysis

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Accurate and precise uranium isotopic analysis in nuclear safeguards is challenged by the extreme range of relative U isotopic abundances, limitations in analyte quantities, applicable instrumental mass fractionation methods, and requirements for certified isotopic reference materials.

The present study on a Thermo Scientific™ TRITON Plus™ mass spectrometer is aimed at investigating the level of accuracy and precision obtainable for extreme U isotopic ratios by using, for the first time, 10^{13} Ω amplifiers for U analysis on a TIMS instrument. Accordingly, the IRMM-187 standard with certified U isotope ratios of 234U/238U= $0.000071965(39)$ and 236U/238U= $0.00038700(16)$[1] was selected. Sample loads of 1 μg were run following the modified total evaporation protocol developed by the New Brunswick Laboratory, the Safeguards Analytical Services of the International Atomic Energy Agency, the Institute for Transuranium Elements, and the Institute for Reference Materials and Measurements, combining 10^{11} Ω amplifiers on major U ion beams, and the newly developed 10^{13} Ω amplifiers on 234U, 236U ion beams and the 233.7, 234.4, 235.7 and 236.4 half masses. Mean 234U and 236U ion beams were $\leqslant 10$ mV. Each measurement comprised three ion beam cup-settings, thus allowing analysis of U isotopes and a per mass cycle subtraction of half-masses, for optimized correction of peak tailing effects from the major U isotopes. The internal uncertainty obtained was 0.17‰ on 234U/238U and 0.59‰ on 236U/238U (2RSE). Measurement performance, expressed as the sum of the absolute deviation of the measured relative to the certified value (2RSD) plus the absolute measurement uncertainty (2RSE) is 5×10^{-7} for both 234U/238U and 236U/238U, in line with the IAEA requirement of better than 10^{-6}.

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Field Sample Preparation Method Development for Isotope Ratio Mass Spectrometry

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Non-proliferation & International Security (NA-241) established a working group of researchers from Los Alamos National Laboratory (LANL), Pacific Northwest National Laboratory (PNNL) and Savannah River National Laboratory (SRNL) to evaluate the utilization of in-field mass spectrometry for safeguards applications. The survey of commercial off-the-shelf (COTS) mass spectrometers (MS) revealed no instrumentation existed capable of meeting all the potential safeguards requirements for performance, portability, and ease of use. Additionally, fieldable instruments are unlikely to meet the International Target Values (ITVs) for accuracy and precision for isotope ratio measurements achieved with laboratory methods. The major gaps identified for in-field actinide isotope ratio analysis were in the areas of:

1. sample preparation and/or sample introduction,
2. size reduction of mass analyzers and ionization sources,
3. system automation, and
4. decreased system cost.

Development work in 2 through 4, numerated above continues, in the private and public sector.

LANL is focusing on developing sample preparation/sample introduction methods for use with the different sample types anticipated for safeguard applications. Addressing sample handling and sample preparation methods for MS analysis will enable use of new MS instrumentation as it becomes commercially available. As one example, we have developed a rapid, sample preparation method for dissolution of uranium and plutonium oxides using ammonium bifluoride (ABF). ABF is a significantly safer and faster alternative to digestion with boiling combinations of highly concentrated mineral acids. Actinides digested with ABF yield fluorides, which can then be analyzed directly or chemically converted and separated using established column chromatography techniques as needed prior to isotope analysis. The reagent volumes and the sample processing steps associated with ABF sample digestion lend themselves to automation and field portability. Work to date, on this and other sample type processing method development will be presented.

S09: Training and Education in Nuclear Non-proliferation and Safeguards

IAEA Support for Building-Up a Highly Skilled Workforce Necessary for an Effective State System of Accounting for and Control of Nuclear Material

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The need for highly qualified and well trained experts in the area of nuclear safeguards and non-proliferation has been emphasized at several International Atomic Energy Agency (IAEA) General Conferences and Board of Governors' meetings. To meet this need, the IAEA has developed a training programme dedicated to assisting Member States in building-up knowledge, skills and attitudes required for the sustainable establishment and maintenance of an effective State system of accounting for and control of nuclear material.

The IAEA training programme in the area of nuclear safeguards and non-proliferation is designed for experts in governmental organizations, regulatory bodies, utilities and relevant industries and is provided on a regular basis at the regional and international level and, upon request, at the national level. It is based on training needs assessed, inter alia, during relevant IAEA advisory services and is updated periodically by applying the Systematic Approach to Training (SAT). In the framework of this human resources assistance programme, the IAEA also facilitates fellowship programmes for young professionals, regularly hosts the IAEA safeguards traineeship programme and supports safeguards related outreach activities organized by donor countries, universities or other institutions.

This paper provides an overview of the IAEA's efforts in the area of nuclear safeguards and non-proliferation training and education, including assistance to Member States' initiatives and nuclear education networks, focusing on the development and delivery of nuclear safeguards training and academic courses. Further, it discusses the important role of IAEA advisory missions and other mechanisms that significantly contribute to the continuous improvement of the IAEA Member States training in the area of nuclear safeguards and non-proliferation. Finally, it outlines the forthcoming eLearning module on Safeguards that will complement the existing training programme and is part of an interactive e-learning series explaining the IAEA's Milestones Approach to introducing a nuclear power programme.

20 Years of Achievement and Future Challenge for International Capacity Building Regarding Safeguards and SSAC at Japan Atomic Energy Agency (JAEA)

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Developing human resources in the fields of nuclear non-proliferation and safeguards is critical to promote the peaceful use of nuclear energy. The shortfall of human resources in such fields presents a serious challenge. It has, therefore, become important to urgently develop human resources and thereby to ensure. With a long experience in practicing Japan's nuclear non-proliferation policy, JAEA has been contributing since the 1990s to international human-resource development. More than 300 people from about 40 countries have joined the training courses organized by the Integrated Support Center for Nuclear Non-proliferation and Nuclear Security (ISCN) of JAEA. These courses use lectures, workshops, group discussions, and facility tours to teach knowledge of the basic concepts of IAEA safeguards, SSAC requirements, and safeguards tools to government officials who are responsible for safeguards implementation and to operators who are engaged in nuclear-material accounting and control.

Based on Japan's statement at the 2010 Nuclear Security Summit, ISCN was established in December 2010. ISCN places top priority on providing support for the development of future leaders, the development of legal and regulatory infrastructure, and the fostering of nuclear non-proliferation culture. For further advancement, ISCN also examines the current situations of the Asian nations that ISCN supports, based on discussions made between the Japanese government and the IAEA. It works on formulating new training courses that focus on specific themes, such as NDA training and table-top exercises for CA under the AP, identified through needs surveys. ISCN is committed to the development of human resources in the field of safeguards and work closely with governmental organizations in Japan and with other Asian countries, the IAEA, US DOE, European Commission, FNCA, and APSN.

Synergies between Science and Policy and the Use of New Teaching Tools in the Academic and Professional Development Programs

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The James Martin Center for Non-proliferation Studies (CNS) at the Monterey Institute of International Studies has been providing academic coursework and professional development training in nuclear non-proliferation, nuclear safeguards and security issues to graduate students and professionals for over two decades. Since 2011, the CNS also managers the Vienna Center for Disarmament and Non-Proliferation (VCDNP) in Vienna, Austria, an international non-governmental organization established at the initiative of the Austria Foreign Ministry. The VCDNP offers professional development courses on nuclear non-proliferation and disarmament to diplomats and other practitioners, primarily from the developing countries, as well as conducts a variety of awareness and outreach programmes.

International safeguards and non-proliferation verification feature prominently in the CNS and VCDNP educational and training programmes. The Centers offer cutting edge courses and programmes that prepare specialists with relevant competences and skills for a range of the safeguards-related jobs, particularly in the area of open source information analysis. These programmes utilize both traditional and new tools and methods, offer curricula that combine science and policy, encourage regular interaction with the IAEA experts, other practitioners, as well as academic and professional networks.

The proposed paper will offer an overview of best practices and lessons learned from key programmes and tools used by CNS and VCDNP in education and training, with particular attention paid to the use of negotiation simulations, on-line courses and modules, and virtual reality simulations. The paper will examine the role of internships, on-the-job training, academic and professional exchanges and discuss the role of partnerships among different stakeholders, including in training specialists from developing and newcomer countries.

Need for Strengthening Nuclear Non-Proliferation and Safeguards Education to Prepare the Next Generation of Experts

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Although nuclear non-proliferation and safeguards are a continuous concern of the international community and discussed frequently at international fora and conferences, the academic world is not really on board with these topics. What we mean by this is that nuclear non-proliferation and safeguards is only very seldom part of a university curriculum. In the few cases where it does appear in the curriculum, whether in a nuclear engineering course or a political sciences master programme, it is typically covered only partially.

Nuclear non-proliferation and safeguards are multidisciplinary and embrace, inter alia, historical, legal, technical, and political aspects. This is perhaps the reason why it is challenging for a single professor or university to develop and implement a comprehensive academic course or programme in this area.

Professional organizations in this field, like the European Safeguards Research and Development Association (ESARDA) and the Institute for Nuclear Materials Management (INMM), have made first steps to address this issue by implementing specific educational activities. However, much more needs to be done. Therefore, ESARDA, INMM and the International Atomic Energy Agency (IAEA) are in the process of joining efforts to identify key elements and priorities to support universities in establishing appropriate and effective academic programmes in this area.

This paper will share best practices, achievements and lessons learned by ESARDA, INMM and the IAEA in providing education and training to develop and maintain the expertise of nuclear non-proliferation and safeguards professionals. In addition, it will suggest potential ways on how to assist universities to get prepared for building-up the next generation of experts able to meet any future challenges in the area of non-proliferation and safeguards.

Interfacing Nuclear Security and Safeguards through Education and Support Centre Networks

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This paper presents the work of the International Nuclear Security Education Network (INSEN) and the International Nuclear Security Training and Support Centre Network (NSSC) as the means to achieve sustainable human resource development in member states. The paper also examines how both security and safeguards can benefit from collaborative and coordinated activities when such networks focus on practical achievements.

Nuclear Safeguards and Non-Proliferation Education at Texas A&M University

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The MS degree in Nuclear Engineering — Non-proliferation at Texas A&M University is administered by the Nuclear Security Science and Policy Institute (NSSPI). The oldest and largest of its kind in the US, 45 M.S. and 15 Ph.D. students conducted technical research in relevant areas: safeguards, nuclear security, non-proliferation, and arms control. In addition to focusing on graduate education with a wide combination of internationally-recognized talent, NSSPI faculty lead research and service activities in safeguarding of nuclear materials and reducing nuclear threats. Texas A&M Nuclear Engineering students take relevant non-proliferation and safeguards courses (within the College of Engineering and the Texas A&M Bush School of Government) as well as conduct their research under competent experts. The complete educational experience here is unique because of the strong research and educational support NSSPI provides. This paper will detail these endeavors and convey contributions from NSSPI for developing next-generation safeguards experts via practical experiences and strong affiliations with real-world practitioners.

The safeguards and non-proliferation education programme blends historical, legal, technical and policy aspects that is unique for a technical university such as Texas A&M. Beyond classroom lectures, NSSPI provides opportunities for students ranging from asynchronous learning modules to practical experiences. Publicly-available self-paced, online course modules in basic and advanced safeguards education have been developed by NSSPI as supplemental nuclear education for students and professionals. By leveraging NSSPI's contacts, students participate in exchange programmes with international institutions as well as partake in experiences like engaging safeguards practitioners at nuclear fuel cycle facilities around the world, conducting experiments at internationally-renowned laboratories, and representing their communities at workshops worldwide (e.g., Japan, Norway, etc.). The practical experiences at Texas A&M are valuable in the students' educational development and will be discussed in this paper.

Ukrainian National System of MC&A Training on Regular Basis at the George Kuzmych Training Center

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The George Kuzmych Training Center (GKTC) was created at the Kyiv Institute for Nuclear Research as a result of collaborative efforts between the United States and Ukraine in 1998. Later the European Commission (EC) and Sweden joined the USA supporting MC&A aspects of the GKTC activity. The GKTC was designated by the Ukrainian Government to provide the MPC&A training and methodological assistance to nuclear facilities and nuclear specialists.

In order to increase the efficiency of State MC&A system an essential number of new regulations, norms and rules was developed demanding regular and more intensive MC&A experts training from the Regulatory Body of Ukraine and all nuclear facilities. For this purpose ten training courses were developed by the GKTC under the EC contract taking into account both specifics of Ukrainian nuclear facilities and expertise level of their personnel.

Along with the NDA training laboratory created with the US DOE financial support and methodological assistance in 2003, a new surveillance and containment laboratory was created under the EC contract and with US DOE financial support as well. Moreover, under the EC contract the laboratory was equipped with the state-of-the-art and most advanced means of surveillance and containment strengthening even more the GKTC training opportunities. As a result, the MC&A experts from all nuclear facilities and Regulatory Body of Ukraine can regularly be trained practically on all MC&A issues.

This paper briefly describes the practical efforts applied to improve Ukrainian MC&A systems both at the State and facility levels and real results on the way to develop the National System for MC&A regular training at the GKTC, problems encountered and their solution, comments, suggestions and recommendations for the future activity to promote and improve the nuclear security culture in Ukraine.

Research Projects at Chulalongkorn University for the Master Degree Programme in Nuclear Security and Safeguard

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The Department of Nuclear Engineering, Faculty of Engineering, Chulalongkorn University, Thailand, began its master degree programme in nuclear security and safeguard in November 2013 with the support from the CBRN-Center of Excellence, European Union. This programme was planned as a way to raise the awareness of various local agencies in ASEAN countries regarding the threat of CBRN events. In the long run, the programme will also serve as the platform to develop the human resource and to provide the professional assistance required to counter such threat in the region. The programme closely follows the guideline as given by the IAEA and employs its materials as the main source of references. The first batch of 20 students came from countries in the ASEAN community. Due to the nature of the program, each student is required to conduct the research and a thesis based on such research is to be submitted as part of the requirement for the graduation. Currently, the research subjects that are readily available to the students can be classified into 5 categories:

1. subjects with neutron generator,
2. subjects with nuclear electronics and instruments,
3. subjects with industrial applications,
4. subjects with computer simulations, and
5. subjects with policy research.

Next Generation Safeguards Initiative: Human Capital Development

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Since 2008, the Human Capital Development (HCD) subprogramme of the U.S. National Nuclear Security Administration's (NNSA) Next Generation Safeguards Initiative (NGSI) has supported the recruitment, education, training, and retention of the next generation of international safeguards professionals to meet the needs of both the International Atomic Energy Agency (IAEA) and the United States. Specifically, HCD's efforts respond to data indicating that 82% of safeguards experts at U.S. Laboratories will have left the workforce within 15 years. This paper provides an update on the status of the subprogramme since its last presentation at the IAEA Safeguards Symposium in 2010. It highlights strengthened, integrated efforts in the areas of graduate and post-doctoral fellowships, young and mid-career professional support, short safeguards courses, and university engagement. It also discusses lessons learned from the U.S. experience in safeguards education and training as well as the importance of long-range strategies to develop a cohesive, effective, and efficient human capital development approach.

Member State Outreach: Capitalizing on Synergies for Effective Implementation

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At a time when the nuclear programmes of many States are expanding and the resources of the IAEA remain static, it is more important than ever to maximize the efficiency with which the Agency cooperates with Member States to ensure the effective implementation of safeguards. The Training Section of the Department of Safeguards is working to optimize training and outreach through coordinating with the efforts of other departments of the IAEA and Member States to reach as large an audience as possible within budget constraints.

This paper will describe some of the efforts undertaken in 2014 that highlight this collaboration strategy, which include: support to the Division of Nuclear Security in training on Nuclear Material Accounting and Control; partnering with the Department of Technical Cooperation and the Member State Support Programme of Finland to hold a training course for nuclear power newcomers on the regulatory aspects of safeguards, security, emergency response and safety; and support to the Department of Nuclear Energy in the Integrated Nuclear Infrastructure Review Missions (INIR) to assess the readiness of States' nuclear infrastructure in those States that are implementing new nuclear power programmes. In all three of these venues, the presentation of safeguards obligations and good practice were emphasized, although none of these events was exclusively dedicated to safeguards training. In fact, given the broader attendance of these forums, safeguards objectives and their relation to the objectives of related programmes will reach a wider audience in a more expansive context than traditional training methods. It is to be expected that this model will continue, ensuring that training and guidance for safeguards will benefit from the synergies of related training efforts well into the future.

Promoting Safeguards Best Practice through the Asia-Pacific Safeguards Network (APSN)

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There is a growing international focus on effective regulatory oversight of nuclear energy across the three pillars of nuclear safety, security and safeguards. Regarding nuclear safeguards, States in the Asia-Pacific region recognize the importance of cooperation and sharing of experiences to ensure that this is implemented to high international standards. For this reason the Asia-Pacific Safeguards Network (APSN) was formed in 2009 — an informal network of departments, agencies and regulatory authorities with safeguards responsibilities from some 15 countries across the Asia-Pacific region.

The objective of APSN it to bring States in the region together to develop practical measures for enhancing effective safeguards implementation, through workshops, sharing experiences and other safeguards projects. APSN works closely with the IAEA to achieve these objectives.

This paper will outline the role and objectives of APSN and provide examples of how APSN work together to enhance safeguards effectiveness and raise awareness. The paper will also explore how this model of a broad community of States working together on safeguards could enhance implementation and awareness in other regions of the world.

Safeguards Support Provided by Dukovany NPP

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NPP Dukovany is the closest nuclear power plant to IAEA Headquarters in Vienna. Its location together with specific design features of VVER 440 plant give perfect condition for close cooperation. Several tasks within the IAEA Support Programme are being performed at Dukovany NPP. Besides these activities, the IAEA authorized the plant operator to perform spent fuel cask seals attachment by specified procedure without presence of inspectors.

The paper gives information about the mentioned activities.

The Systematic Approach to Training: Analysis and Evaluation in the Department of Safeguards

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In applying a systematic approach to training (SAT), identifying the learning needs is the first step — a learning needs analysis allows the organization to identify the competencies required to perform a particular job. A systematic approach can provide a clear structure for training and education programme development as well as the necessary evaluation and feedback so that the organization can adjust the development accordingly and deliver the optimal learning experience. In this presentation we will describes two key elements of a SAT used in the Safeguards Training Section in the Department of Safeguards: Analysis and Evaluation.

Analysis is the first part of a SAT needed to define competencies for Safeguards staff in order to improve training development within the Department. We describe the training needs analysis used to capture and articulate the various competencies required for safeguards implementation based upon an analysis of tasks and activities carried out by staff members in the Department. Firstly, we highlight the different qualitative methods used to gather information from staff and the process of evaluating and organizing this information into a structured framework. Secondly, we describe how this framework provides the necessary reference to specify learning objectives, evaluate training effectiveness, review and revise training offerings, and select appropriate training paths based on identified needs.

In addition, as part of the SAT, evaluation is performed to identify the usefulness of course outcomes and improvements for future offerings based on lessons learned, to ensure that appropriate knowledge and skills are being taught and to demonstrate the value of training by meeting the organization’s needs. We present how the Kirkpatrick four–level evaluation model has been implemented by Safeguards Training Section in order to evaluate course effectiveness after the training has been completed, and discuss how the current evaluation mechanism has benefitted the Section´s approach to training development and implementation.

S10: Automation and Instrumentation Data Analysis in Safeguards Verification

Evolution of RAINSTORM

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The IAEA began using remote monitoring in 1997 as a means of optimizing inspection efforts while simultaneously improving the timeliness of safeguards information. Use of remote monitoring has gradually expanded over the last 15+ years. To manage the complexity of this vast network of diverse instruments, in 2012 the IAEA Department of Safeguards initiated an effort to define a set of requirements for Real-time And INtegrated STream-Oriented Remote Monitoring (RAINSTORM). In 2013, "Remote Monitoring Requirements for the Development of IAEA Safeguards Equipment" was published, which defines the data interface and data security requirements for all new remote-monitoring capable safeguards instruments.

The data interface requirements centre on the Hypertext Transfer Protocol (HTTP) [RFC 2616]. HTTP is an extremely simple, yet ubiquitous protocol (used many billions of times per day). HTTP also boasts a feature set that is well-suited to remote monitoring, e.g., range retrieval and on-the-wire compression. Several sample software implementations are available with a BSD 3-Clause Licence.

The data security requirements centre on public-key infrastructure (PKI) and the public-key cryptography standards (PKCS). PKI provides far superior encryption/authentication security than pre-shared keys. The Agency has selected a Universal Instrument (cryptography) Token (UIT) that will provide greater private key protection and allow instruments to offload the CPU-intensive private-key operations. An ultralight platform-independent software driver and a sample software implementation are available with a BSD 3-Clause Licence.

Currently there are several instruments under development or in field testing that are "RAINSTORM compliant", including the Remote Monitoring Sealing Array (RMSA from Canberra/SNL), On-Line Enrichment Monitor (OLEM from ORNL/LANL), Laser Mapping for Containment Verification (LMCV from ISPRA) and Next Generation Adam Module (NGAM from Bot). The Next Generation Surveillance System (NGSS) is also RAINSTORM compatible.

Looking forward, we see increasing need for real-time data collection from safeguards instruments in the field. HTTP is well-suited for that task, particularly the HTTP version 2 protocol, which is currently in draft form.

Joint Partnership: a New Software Development Paradigm

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A joint development partnership between Euratom and the IAEA was established in 2013 for the standard software iRAP (Integrated Review and Analysis Program), an automated analysis tool for Non-Destructive Analysis data. The application includes a database system which allows inspectors to perform an efficient, easy and quick review of huge amounts of safeguards relevant data especially in large facilities. iRAP (formerly know as CRISP) analyzes measured data in a multi-sensor system and compares the results with item movement declarations provided by the plant operator. A considerable number of evaluation algorithms are already integrated into the iRAP system. They are the core of the application and can be either developed in-house (e.g., Pu Mass Calculation) or integrated as a third party development into the system.

The licence agreement which provides the legal basis for the joint development shares Intellectual Property (IP) rights, costs for development, and combines features that are beneficial to both inspectorates. Instead of starting a new costly software development, the Agency can leverage already existing code and make smaller investments into tailoring the application to the needs of IAEA inspectors. Much of the system's integrity depends on the requirements gathered. A joint development partnership involves more users in the development life cycle; more users will define their requirements. This ensures that the system developed satisfies the actual needs of safeguards inspectors of both organizations. A joint software development allows as well for an efficient use of financial and human resources.

Within the frame of the agreement, a Change Control Board (CCB) with members of both organizations has been established. The CCB meets regularly in order to bring developers, users and technicians together in the very early phase of a development cycle, to define the scope and requirements of projects, to avoid potential conflicts among different user groups and to review new releases. This enhances communication and relationship between inspectors and technical personnel of both organizations. A first release of iRAP is expected in July 2014. It will be handed over to a user group of selected IAEA inspectors who will be in charge of testing the software in compliance with IAEA requirements. Euratom is in charge of regression testing in order to determine if new faults have been introduced to existing functionalities of iRAP.

Evaluation of a Surveillance Review Software based on Automatic Image Summaries

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Surveillance streams from safeguards instruments contain thousands of images. Inspectors review them in order to find safeguards-relevant events. Statistically a very small fraction of the images is expected to be safeguards-relevant. For this reason inspectors need a tool which helps them to focus their attention directly to the relevant parts of the surveillance stream.

The current approach for surveillance review makes use of scene change detection within areas of interest (AOIs). The data reduction provided can be effective for the review of regular processes, and requires specific knowledge of the process/environment under review for the proper setting of the AOIs.

The VideoZoom approach, developed by the European Commission Joint Research Centre-Institute for Transuranium Elements (JRC-ITU), detects scene changes on the whole image plane. Changes are then summarized and rendered at different levels of abstraction in four layers of summaries, each one revealing more information about the image changes. By means of a zooming interface, the reviewer is able to navigate the summary layers and decide which are to be examined with full photographic detail or skipped because they are clearly not safeguards-relevant. In this way reviewers can make best use of their time by investigating what really requires their attention.

VideoZoom was evaluated by a group of IAEA inspectors on a benchmark of image reviews, with promising results in terms of identification of safeguards-relevant events, efficiency and usability. Following the positive results collected during the preliminary benchmark, the IAEA initiated a task under the European Commission Support Programme (EC SP), aimed at the research, development, and evaluation of surveillance review software based on VideoZoom and compatible with surveillance streams produced by NGSS cameras, the current safeguards surveillance technology deployed by the IAEA.

This paper provides a description of the VideoZoom approach to surveillance reviews, presents results of the evaluation performed by IAEA inspectors, and reports about the current development status.

The Development of Advanced Processing and Analysis Algorithms for Improved Neutron Multiplicity Measurements

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One of the most distinctive and informative signatures of special nuclear materials is the emission of correlated neutrons from either spontaneous or induced fission. Because the emission of correlated neutrons is a unique and unmistakable signature of nuclear materials, the ability to effectively detect, process, and analyze these emissions will continue to play a vital role in the non-proliferation, safeguards, and security missions. While currently deployed neutron measurement techniques based on 3He proportional counter technology, such as neutron coincidence and multiplicity counters currently used by the International Atomic Energy Agency, have proven to be effective over the past several decades for a wide range of measurement needs, a number of technical and practical limitations exist in continuing to apply this technique to future measurement needs. In many cases, those limitations exist within the algorithms that are used to process and analyze the detected signals from these counters that were initially developed approximately 20 years ago based on the technology and computing power that was available at that time. Over the past three years, an effort has been undertaken to address the general shortcomings in these algorithms by developing new algorithms that are based on fundamental physics principles that should lead to the development of more sensitive neutron non-destructive assay instrumentation. Through this effort, a number of advancements have been made in correcting incoming data for electronic dead time, connecting the two main types of analysis techniques used to quantify the data (Shift register analysis and Feynman variance to mean analysis), and in the underlying physical model, known as the point model, that is used to interpret the data in terms of the characteristic properties of the item being measured. The current status of the testing and evaluation of these advancements in correlated neutron analysis techniques will be discussed.

Can Nuclear Installations and Research Centres Adopt Cloud Computing Platform?

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Cloud Computing is arguably one of the recent and highly significant advances in information technology today. It produces transformative changes in the history of computing and presents many promising technological and economic opportunities. The pay-per-use model, the computing power, abundance of storage, skilled resources, fault tolerance and the economy of scale it offers, provides significant advantages to enterprises to adopt cloud platform for their business needs. However, customers especially those dealing with national security, high end scientific research institutions, critical national infrastructure service providers (like power, water) remain very much reluctant to move their business system to the cloud. One of the main concerns is the question of information security in the cloud and the threat of the unknown. Cloud Service Providers (CSP) indirectly encourages this perception by not letting their customers see what is behind their virtual curtain. Jurisdiction (information assets being stored elsewhere), data duplication, multi-tenancy, virtualisation and decentralized nature of data processing are the default characteristics of cloud computing. Therefore traditional approach of enforcing and implementing security controls remains a big challenge and largely depends upon the service provider. The other biggest challenge and open issue is the ability to perform digital forensic investigations in the cloud in case of security breaches. Traditional approaches to evidence collection and recovery are no longer practical as they rely on unrestricted access to the relevant systems and user data, something that is not available in the cloud model. This continues to fuel high insecurity for the cloud customers.

In this paper we analyze the cyber security and digital forensics challenges, issues and opportunities for nuclear facilities to adopt cloud computing. We also discuss the due diligence process and applicable industry best practices which shall be considered before deciding to adopt cloud computing for the organizational ICT needs.

Sustaining IAEA Neutron Coincidence Counting: Past, Present and Future

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Los Alamos National Laboratory's IAEA Neutron Coincidence Counting (INCC) code is the standard tool for neutron coincidence counting measurements. INCC software and its' predecessors were originally implemented in the 1970s. The measurement and analysis techniques perfected in the code arise from many years of laboratory and field experience by nuclear engineers and physicists. Covering the full arc of INCC's lifecycle, we discuss the engineering approaches used for conception, original development, worldwide deployment of the stand-alone Windows application, more than a decade of sustained maintenance support, and our recent work to carry INCC successfully into future applications.

We delve into the recent re-architecture of the INCC code base, an effort to create a maintainable and extensible architecture designed to preserve the existing INCC code base while adding support for new analyzes and instruments (e.g., List Mode PTR-32 and the List Mode Multiplicity Module). INCC now consists of separate modules implementing attended instrumentation control, data file processing, statistical and Pu mass calculation and analyzes, list mode counting and analyzes, reporting functions, and a database support library. Separating functional capabilities in this architecture enables better testing, isolates development risk and enables the use of INCC features in other software systems. We discuss our approach to handling divergent data and protocol support as a result of this re-architecture. INCC has complex testing requirements; we show how the testing effort was reduced by breaking the software into separate modules.

This new architecture enables integration of INCC analysis into the IAEA's new Integrated Review and Analysis Programme (iRAP) data review system. iRAP is based on the respected Euratom Comprehensive Review Inspector Software Package (CRISP) software framework, and is expected to be the future data review system for IAEA and Euratom inspectors and analysts. Neutron measurement data collected from fielded instrumentation is processed and analyzed by iRAP's INCC plug-in and the results are preserved in a relational database for inspection reporting. Isolating the functionality of the INCC analyzes libraries allows iRAP to customize the user interface of its software while still using the time-tested algorithmic core of the INCC software. The INCC iRAP integration is the first substantial external algorithmic and feature addition to iRAP, and its software interface implementation will be used as a guide for future integration of other algorithms.

Material Accounting Issues at the U.S. MOX Fuel Fabrication Facility

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The Mixed Oxide Fuel Fabrication Facility (MFFF) is under construction in the United States. The plant is being licenced by the U.S. Nuclear Regulatory Commission (NRC), which as the U.S. SSAC regulates both domestic MC&A and compliance with international safeguards (where applicable). Among the NRC's MC&A requirements for Category I fuel cycle facilities are programmes for item and process monitoring. The NRC also has requirements for timely resolution of alarms and assessment of the validity of alleged thefts. NRC's item monitoring requirement specifies that the operator must be able to verify the "presence and integrity" of items, with the goal of detecting the loss of items containing 2 kilogrammes of plutonium within certain time periods. The requirements for resolution of alarms and assessment of alleged thefts also generally require some capability to locate and verify items on demand. However, to the extent these regulations mandate that individual items be physically located and verified by hand, they can be difficult (or impossible) to meet for facilities with large numbers of items. The MFFF design was based largely on French facilities that were not subject to similar requirements. Consequently, the applicant proposed a novel item monitoring approach that relies on the data within the plant's computerized inventory and process control systems. This proposal was challenged in July 2010 by intervenors, raising questions such as whether computer systems could be used as the sole means for verification, given the potential for data to be compromised. In February 2014, the NRC's Atomic Safety and Licencing Board issued a decision upholding the applicant's plan, but one of the three judges issued a dissent, citing concern about cyberterrorism. This paper will discuss the issues argued during the hearing and their broader relevance.

Automated Image Acquisition System for the Verification of Copper-Brass Seal Images

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This paper describes a system for the verification of copper-brass seals realized by JRC according to DG ENER requirements.

DG ENER processes about 20,000 metal seals per year. The verification of metal seals consists in visually checking the identity of a removed seal. The identity of a copper-brass seal is defined by a random stain pattern realized by the seal producer together with random scratches engraved when the seals are initialized (‘seal production’). In order to verify that the seal returned from the field is the expected one its pattern is compared with an image taken during seal production. Formerly, seal initialization and verification were very heavy tasks as seal pictures were acquired with a camera one by one both in the initialization and verification stages. During the initialization the Nuclear Safeguards technicians had to place one by one new seals under a camera and acquire the related reference images. During the verification, the technician had to take used seals and place them one by one under a camera to take new pictures. The new images were presented to the technicians without any preprocessing and the technicians had to recognize the seal.

The new station described in this paper has an automated image acquisition system allowing to easily process seals in batches of 100 seals. To simplify the verification, a software automatically centres and rotates the newly acquired seal image in order to perfectly overlap with the reference image acquired during the production phase. The new system significantly speeds up seal production and helps particularly with the demanding task of seal verification. As a large part of the seals is dealt with by a joint Euratom-IAEA team, the IAEA directly profits from this development. The new tool has been in routine use since mid 2013.

S11: Acquisition Path Analysis Methodology

Opening Remarks

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An overview of the recent development work that has been done on acquisition path analysis, implementation of the methodologies within the Department of Safeguards, lessons learned and future areas for development will be provided.

Acquisition Path Analysis as a Collaborative Activity

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In the International Atomic Energy Agency, acquisition path analysis (APA) is indispensable to safeguards implementation. It is an integral part of both State evaluation process and the development of State level safeguards approaches, all performed through ongoing collaborative analysis of all available safeguards relevant information by State evaluation groups (SEG) with participation of other contributors, as required.

To perform comprehensive State evaluation, to develop and revise State-level safeguards approaches, and to prepare annual implementation plans, the SEG in its collaborative analysis follows accepted safeguards methodology and guidance. In particular, the guide "Performing Acquisition Path Analysis for the Development of a State-level Safeguards Approach for a State with a CSA" is used.

This guide identifies four major steps of the APA process:

1. Consolidating information about the State's past, present and planned nuclear fuel cycle-related capabilities and infrastructure;
2. Identifying and visually presenting technically plausible acquisition paths for the State;
3. Assessing acquisition path steps (State's technical capabilities and possible actions) along the identified acquisition paths; and
4. Assessing the time needed to accomplish each identified technically plausible acquisition path for the State.

The paper reports on SEG members' and other contributors' experience with APA when following the above steps, including the identification of plausible acquisition pathways, estimation of time frames for all identified steps and determination of the time needed to accomplish each acquisition path. The difficulties that the SEG encountered during the process of performing the APA are also addressed. Feedback in the form of practical suggestions for improving the clarity of the acquisition path step assessment forms and a proposal for software support are also included.

Effect of State-Specific Factors on Acquisition Path Ranking

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The "directed graph analysis" has been shown to be a promising methodology to implement acquisition path analysis by the IAEA to support the State evaluation process. Based on this methodology a material flow network model has been developed under the Hungarian Support Programme to the IAEA, in which materials in different chemical and physical form can flow through pipes representing declared processes, material transports, diversions or undeclared processes [1, 2, 3]. The ranking of the resulting acquisition paths of the analysis is a key step to facilitate the determination of technical objectives and the planning of safeguards implementation on State-level. These are determined by the attributes of the processes included into the graph and different state-specific factors. In this paper different set of attributes, State-specific factors and their functional combination will be tested for hypothetical case studies.

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Quantifying Detection Probabilities for Proliferation Activities in Undeclared Facilities

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International Safeguards is currently in an evolutionary process to increase effectiveness and efficiency of the verification system. This is an obvious consequence of the inability to detect the Iraq's clandestine nuclear weapons programme in the early 90s. By the adoption of the Programme 93+2, this has led to the development of Integrated Safeguards and the State-level concept. Moreover, the IAEA's focus was extended onto proliferation activities outside the State's declared facilities.

The effectiveness of safeguards activities within declared facilities can and have been quantified with respect to costs and detection probabilities. In contrast, when verifying the absence of undeclared facilities this quantification has been avoided in the past because it has been considered to be impossible. However, when balancing the allocation of budget between the declared and the undeclared field, explicit reasoning is needed why safeguards effort is distributed in a given way.

Such reasoning can be given by a holistic, information and risk-driven approach to Acquisition Path Analysis comprising declared and undeclared facilities [1]. Regarding the input, this approach relies on the quantification of several factors, i.e., costs of attractiveness values for specific proliferation activities, potential safeguards measures and detection probabilities for these measures also for the undeclared field.

In order to overcome the lack of quantification for detection probabilities in undeclared facilities, the authors of this paper propose a general verification error model. Based on this model, four different approaches are explained and assessed with respect to their advantages and disadvantages: the analogy approach, the Bayes approach, the frequentist approach and the process approach. The paper concludes with a summary and an outlook on potential future research activities.

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Developing State Level Approaches under the State Level Concept

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With the pursuit of the State-Level Concept (SLC), the IAEA has sought to further evolve the international safeguards system in a manner which maintains (or improves) the effectiveness of the system in an environment of expanding demands and limited resources. The IAEA must not remain static and should continuously examine its practices to ensure it can capture opportunities for cost reductions while adapting to, and staying ahead of, emerging proliferation challenges. Contemporary safeguards have been focused on assessing the nuclear programme of the State as a whole, rather than on the basis of individual facilities. Since the IAEA's integrated safeguards program, State-level Approaches (SLAs) have been developed that seek to optimally combine the measures provided for by the Additional Protocol with those of traditional safeguards. This process resulted in facility specific approaches that, while making use of a State's broader conclusion, were nonetheless prescriptive. Designing SLAs on a State-by-State basis would avoid the shortcomings of a one-size-fits-all system. It would also enable the effective use of the Agency's information analysis and State evaluation efforts by linking this analysis to safeguards planning efforts. Acquisition Path Analysis (APA), along with the State Evaluation process, can be used to prioritize paths in a State in terms of their attractiveness for proliferation. While taking advantage of all safeguards relevant information, and tailoring safeguards to individual characteristics of the State, paths of the highest priority in all States will necessarily meet the same standard of coverage. Similarly, lower priority paths will have lower performance targets, thereby promoting nondiscrimination. Such an approach would improve understanding of safeguards implementation under the SLC and the rational for safeguards resource allocation. The potential roles for APA and performance targets in SLA development will be reviewed and assessed.

The Potential of Open Source Information in Supporting Acquisition Pathway Analysis to Design IAEA State Level Approaches

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International Atomic Energy Agency (IAEA) safeguards designed to deter nuclear proliferation are constantly evolving to respond to new challenges. Within its State Level Concept, the IAEA envisions an objective-based and information-driven approach for designing and implementing State Level Approaches (SLAs), using all available measures to improve the effectiveness and efficiency of safeguards. The main Objectives of a SLA are a) to detect undeclared nuclear material or activities in the State, b) to detect undeclared production or processing of nuclear materials in declared facilities or locations outside facilities (LOFs), c) to detect diversion of declared nuclear material in declared facilities or LOFs. Under the SLA, States will be differentiated based upon objective State-Specific Factors that influence the design, planning, conduct and evaluation of safeguards activities. Proposed categories of factors include both technical and legal aspects, spanning from the deployed fuel cycle and the related state's technical capability to the type of safeguards agreements in force and the IAEA experience in implementing safeguards in that state. To design a SLA, the IAEA foresees the use of Acquisition Path Analysis (APA) to identify the plausible routes for acquiring weapons-usable material and to assess their safeguards significance. In order to achieve this goal, APA will have to identify possible acquisition paths, characterize them and eventually prioritize them. This paper will provide an overview of how the use of open source information (here loosely defined as any type of non-classified or proprietary information and including, but not limited to, media sources, government and non-governmental reports and analyzes, commercial data, satellite imagery, scientific/technical literature, trade data) can support this activity in the various aspects of a typical APA approach.

Identification of Signatures to Detect Undeclared Nuclear Activities at the Front-end of the Fuel Cycle

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Several parameters of the nuclear materials can be used to verify their sources and the declared origin for safeguards purposes, such as chemical composition, nuclear material content, impurities or the isotopic compositions of major or trace-level constituents. Combining these parameters (also known as signatures) enables the verification of the safeguarded materials at high confidence, and also allows detecting the use of undeclared nuclear materials. Moreover, several signatures can be used not only as a comparative indicator against another samples or datasets, but also permits to reveal the possible origin of the undeclared feed material without any prior knowledge on the provenance. The measurable signatures, however, have different strength and require diverse analytical techniques, thus the knowledge of their variations throughout the complex production processes is of vital importance to use them for safeguards.

The aim of the present study is to investigate the behaviour and relevance of as many signatures for safeguards as possible in a respective uranium ore concentrate production process. Within the framework of the European Commission Support Programme A 1753 the production of uranium ore concentrate from uranium ore was followed and sampled at each stage. By the comprehensive analysis of the samples (major and minor constituents, molecular structure, morphology, rare-earth elemental pattern, trace-level organic residues, age measurement, isotopic study of S, Pb, Sr, Nd and Th), together with the process information, the role and applicability of the various signatures can be assessed. By this means the appropriate and relevant safeguards parameters can be identified, their advantages and limitations can be revealed.

Computational Methods for Physical Model Information Management: Opening the Aperture

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The volume, velocity and diversity of data available to analysts are growing exponentially, increasing the demands on analysts to stay abreast of developments in their areas of investigation. In parallel to the growth in data, technologies have been developed to efficiently process, store, and effectively extract information suitable for the development of a knowledge base capable of supporting inferential (decision logic) reasoning over semantic spaces. These technologies and methodologies, in effect, allow for automated discovery and mapping of information to specific steps in the Physical Model (Safeguard's standard reference of the Nuclear Fuel Cycle).

This paper will describe and demonstrate an integrated service under development at the IAEA that utilizes machine learning techniques, computational natural language models, Bayesian methods and semantic/ontological reasoning capabilities to process large volumes of (streaming) information and associate relevant, discovered information to the appropriate process step in the Physical Model. The paper will detail how this capability will consume open source and controlled information sources and be integrated with other capabilities within the analysis environment, and provide the basis for a semantic knowledge base suitable for hosting future mission focused applications.

S12: Preview of New IAEA Guidance: Safeguards Implementation Practice Guides

IAEA's Safeguards Implementation Practices Guides

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Implementation of IAEA safeguards benefits greatly from effective cooperation among the IAEA, State or regional authorities (SRAs), and operators of facilities and other locations. To improve such cooperation, the IAEA has produced numerous safeguards guidance documents in its Services Series publications. The IAEA also provides assistance, training and advisory services that are based on the published guidance. The foundation of the IAEA's safeguards guidance is the Guidance for States Implementing Comprehensive Safeguards Agreements and Additional Protocols (IAEA Services Series 21) published in March of 2012. The large majority of States have concluded CSAs and therefore will benefit from this guidance. Many States with CSAs also have concluded small quantities protocols (SQPs) to their CSAs. In April of 2013, the IAEA published the Safeguards Implementation Guide for States with SQPs (IAEA Services Series 22). Other guidance focuses on specific topics such as preparing additional protocol declarations and nuclear material accounting. This paper will describe a recent effort to produce a "Safeguards Implementation Practices" (SIP) series of guides that will provide additional explanatory information about safeguards implementation, and share the practical experiences and lessons learned of States and the IAEA over the many decades of implementing safeguards. The topics to be addressed in four SIP guides include: 1) Facilitating IAEA Verification Activities; 2) Establishing and Maintaining State Safeguards Infrastructure; 3) Provision of Information to the IAEA; and 4) Collaborative Approaches to Safeguards Implementation. The SIP Guides build upon the content of IAEA Services Series 21. Because the SIP Guides are intended to share implementation practices and lessons learned of States, a number of experienced State experts have participated in the development of the documents, through a joint Member State Support Programme task. Nineteen States have accepted the task.

Implementation Practices in the Asia-Pacific Related to Establishing State Safeguards Infrastructure

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Over 2013 and 2014 the IAEA in cooperation with safeguards specialists from several Member States has been developing a series of Safeguards Implementation Practices (SIP). These are guides for States that will provide additional explanatory information about safeguards implementation and will share the practical experiences and lessons learnt by States and the IAEA through implementing safeguards.

One of these SIP guides under development is on establishing State safeguards infrastructure. This is a topic that lends itself well to incorporating the direct experiences and lessons learnt from a range of States. Using such examples helps provide context and practicality for other States using such a guide to help prepare their own safeguards infrastructure. The development of this SIP guide has drawn from examples from the Asia-Pacific Safeguards Network (APSN). Comprising such a broad community of States, APSN provided a diverse range of experiences from States; those with very limited nuclear infrastructure through to States with very substantial nuclear infrastructure. Guidance on good practices in safeguards infrastructure was a subject APSN also had some experience in having published the guide "Fundamentals and Good Practices of Safeguards Regulatory Authorities" (INFCIRC/845).

This paper will draw examples from some implementation practices from the Asia-Pacific region and explain how these have contributed to the SIP guide on establishing safeguards infrastructure.

Implementation Practices of Finland in Facilitating IAEA Verification Activities

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The Member States provide the information to the IAEA according to the Safeguards Agreements and Additional Protocols. For example, the requirements to provide the reports and declarations are very general and there are no explanation what the IAEA is looking for from that information. It is important for the States to understand how their efforts to collect and provide information, and to facilitate IAEA verification activities, contribute to the achievement of objectives and finally to draw conclusions on the exclusively peaceful use of nuclear materials in a State. The IAEA is producing a new series of guidance called Safeguards Implementation Practices, SIP, guides, which are shedding light on the requirements and sharing the good practices of States. It is hoped that the SIP Guides will create a better understanding of the needs of the IAEA and the important role of States and facility operators in achieving safeguards objectives. The guides are also important for the States to share their lessons learned and good practices for the benefit of other States that might be developing their capabilities or enhancing their processes and procedures.

The way is very wide and long, when a State decides to start up a new nuclear programme. At first there is a need for legislation, regulatory body, contact point, international agreements and then finally practical implementation of the safeguards in the nuclear facilities. There are a lot of issues to be prepared in advance to facilitate the IAEA's implementation of verification activities successfully, effectively and with the good quality. Using the structure of the IAEA's draft SIP Guide on Facilitating Verification Activities as a framework, this paper will describe the most relevant implementation practices and experiences in Finland.

Canada's Implementation Practices in Provision of Information to the IAEA

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The information required by the IAEA to implement safeguards in Canada can be categorized into six main areas: operational, nuclear material accounting, design information, voluntary reporting, Additional Protocol, and responding to IAEA questions and inquires. This information is provided to the IAEA by mail, email, secure mailbox and hopefully in the future by electronic data submission.

The requirements for the reporting and submission of this information are found in Canada's Subsidiary Arrangements, Facility Attachments and in the IAEA safeguards procedures for Canadian facilities. These requirements are incorporated into regulatory requirements through regulations, licences and regulatory documents. Licencees then implement a safeguards programme that demonstrates their ability and commitment to meet the relevant regulatory requirements.

As Canada moved to a State-level integrated safeguards approach the volume of information provided to the IAEA increased, mostly in the provision of additional monthly and weekly advanced notifications and declarations to support the short notice random and unannounced inspections, and the provision of near-real-time nuclear material accounting reports. As the IAEA, CNSC and licencees gained experience in providing this information, the amount of information submitted was streamlined. This information gives the IAEA comprehensive knowledge of the flow of nuclear material (imports, exports and transfers between Material Balance Areas) as well as the location of nuclear material in Canadian facilities at any point in time.

Using the structure of the IAEA's draft Safeguards Implementation Practices Guide on Provision of Information to the IAEA as a framework, this paper will describe the relevant implementation practices and experiences in Canada.

S13: State of the Art Environmental Sample Analysis

Conformity Assessment in Nuclear Material and Environmental Sample Analysis

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Safeguards conclusions are based to a large extent on comparison of measurement results between operator and safeguards laboratories. Measurement results must state traceability and uncertainties to be comparable. Recent workshops held at the IAEA and in the frame of the European Safeguards Research and Development Association (ESARDA), reviewed different approaches for Nuclear Material Balance Evaluation (MBE). Among those, the "bottom-up" approach requires assessment of operators and safeguards laboratories measurement systems and capabilities. Therefore, inter-laboratory comparisons (ILCs) with independent reference values provided for decades by JRC-IRMM, CEA/CETAMA and US DOE are instrumental to shed light on the current state of practice in measurements of nuclear material and environmental swipe samples. Participating laboratories are requested to report the measurement results with associated uncertainties, and have the possibility to benchmark those results against independent and traceable reference values. The measurement capability of both the IAEA Network of Analytical Laboratories (NWAL) and the nuclear operator's analytical services participating in ILCs can be assessed against the independent reference values as well as against internationally agreed quality goals, in compliance with ISO 13528:2005. The quality goals for nuclear material analysis are the relative combined standard uncertainties listed in the ITV2010. Concerning environmental swipe sample analysis, the IAEA defined measurement quality goals applied in conformity assessment. The paper reports examples from relevant inter-laboratory comparisons, looking at laboratory performance according to the purpose of the measurement and the possible use of the result in line with the IUPAC International Harmonized Protocol. Tendencies of laboratories to either overestimate and/or underestimate uncertainties are discussed using straightforward graphical tools to evaluate participants' results, e.g., "Naji plots". Finally, we explore the possibility to evaluate laboratories' performances over time and to use conformity assessment to support the safeguards "bottom-up" MBE approach.

Detection of Reprocessing Activities Using Environmental Sampling

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Being able to detect and identify undeclared reprocessing activities involving the extraction of plutonium from irradiated fuel remains a major nuclear non-proliferation concern and challenge to international Safeguards. One tool the International Atomic Energy Agency uses for detecting possible undeclared reprocessing activities is environmental sampling (ES).

The reprocessing of irradiated nuclear fuel enables the separation and extraction of uranium and plutonium for further use. In the conventional power generation fuel cycle, the recovered uranium can be converted, re-enriched or re-fabricated into new fuel. However, plutonium can also be extracted from irradiated fuel for weapons purposes, particularly if the burnup of fuel in the reactor is optimized to ensure that the maximum yield of plutonium-239 is achieved without significant degradation by plutonium-240. Recovery of plutonium from irradiated fuel is one approach to obtaining fissile material for a weapon other than the alternative, uranium enrichment.

Typically, ES involves taking swipe samples from the facilities of a known or suspected nuclear site in order to detect trace materials associated with nuclear-related activities, in the case of reprocessing a chemical operation that separates plutonium and uranium from irradiated spent fuel. This paper discusses and provides examples of the nuclear signatures detectable through ES that can be used to identify the reprocessing activities beyond just the detection of plutonium. It will also examine the potential signatures that could be used to distinguish between aqueous and non-aqueous reprocessing methods.

Are Polyatomic Interferences, Cross Contamination, Mixing-Effect, etc., Obstacles for the Use of Laser Ablation–ICP-MS Coupling as an Operational Technique for Uranium Isotope Ratio Particle Analysis?

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Analysis of "environmental samples", which consists in dust collected with cotton clothes wiped by inspectors on surfaces inside declared nuclear facilities, is a key tool for safeguards. Although two methods (fission tracks-TIMS and SIMS) are already used routinely to determine the isotopic composition of uranium particles, the laser ablation-inductively coupled plasma mass spectrometry (LA-ICP-MS) coupling has been proven to be an interesting option thanks to its rapidity, high sensitivity and high signal/noise ratio. At CEA and UPPA, feasibility of particle analysis using a nanosecond LA device and a quadrupole ICP-MS has been demonstrated. However, despite the obvious potential of LA-ICP-MS for particle analysis, the effect of many phenomena which may bias isotope ratio measurements or lead to false detections must be investigated. Actually, environmental samples contain many types of non-uranium particles (organic debris, iron oxides, etc.) that can form molecular interferences and induce the risk of isotopic measurement bias, especially for minor isotopes (234U, 236U). The influence of these polyatomic interferences on the measurements will be discussed. Moreover, different uranium isotopic compositions can be found in the same sample. Therefore, risks of memory effect and of particle-to-particle cross-contamination by the deposition of ablation debris around the crater have also been investigated. This study has been conducted by using a femtosecond laser ablation device coupled to a high sensitivity sector field ICP-MS. Particles were fixed onto the discs with collodion and were located thanks to their fission tracks so that micrometric particles can be analyzed separately. All uranium isotope ratios were measured. Results are compared with the ones obtained with the fission tracks-TIMS technique on other deposition discs from the same sample. Performance of the method in terms of accuracy, precision, and detection limits are estimated.

Laser-Assisted Sampling Techniques in Combination with ICP-MS: A Novel Approach for Particle Analysis at the IAEA Environmental Samples Laboratory

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Researchers have found many applications for lasers. About two decades ago, scientists started using lasers as sample introduction instruments for mass spectrometry measurements. Similarly, lasers as micro-dissection tools have also been increasingly on demand in the fields of life sciences, materials science, forensics, etc. This presentation deals with the interception of these aforementioned laser-assisted techniques to the field of particle analysis.

Historically, the use of a nanosecond laser to ablate material has been used in materials science. Recently, it has been proven that in the analysis of particulate materials the disadvantages associated with the utilization of nanosecond lasers such as overheating and melting of the sample are suppressed when using femtosecond lasers. Further, due to the length of a single laser shot, fs-LA allows a more controlled ablation to occur and therefore the sample plasma is more homogeneous and less mass-fractionation events are detected.

The use of laser micro-dissection devices enables the physical segmentation of micro-sized artefacts previously performed by a laborious manual procedure. By combining the precision of the laser cutting inherent to the LMD technique together with a particle identification methodology, one can increase the efficiency of single particle isolation. Further, besides the increase in throughput of analyses, this combination enhances the signal-to-noise ratio by removing matrix particles effectively.

Specifically, this contribution describes the use of an Olympus+MMI laser micro-dissection device in improving the sample preparation of environmental swipe samples and the installation of an Applied Spectra J200 fs-LA/LIBS (laser ablation/laser induced-breakdown spectroscopy) system as a sample introduction device to a quadrupole mass spectrometer, the iCap Q from Thermofisher Scientific at the IAEA Environmental Samples Laboratory are explored. Preliminary results of the ongoing efforts for the eventual automation of sample preparation procedures for routine safeguards sample analyses by using the laser micro-dissection technology are discussed.

Development of a Methodology to Detect Fluorine in Uranium Bearing Particle by SIMS

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The isotopic analysis of micrometer-size uranium bearing particles, released from nuclear facilities, has been proven to be an efficient tool for safeguard purposes. The French atomic energy agency has developed analytical techniques to detect traces of uranium in these micrometric particles. However, isotopic measurements are not always sufficient for identifying specifically some crucial nuclear operations, like uranium conversion, which are most of the time carried out with natural uranium. Conversion and enrichment activities may lead to releases to the atmosphere of particulate UF4 and/or UO2F2 material. So, the detection of a significant amount of fluorine in such uranium particles is a proof that uranium has been converted at one point before the sampling. Therefore, CEA developed a methodology to detect and analyze by SIMS (secondary ion mass spectrometry) micrometer-size particles that contain both uranium and fluorine as an indicator of this conversion activity. Following the particle detection, which is performed automatically, individual particle are analyzed in microbeam conditions to measure both a precise uranium isotopic composition and the relative amount of fluorine. The methodology was applied to uranium particles coming from the fuel cycle upstream the enrichment step. This study demonstrated that, contrary to uranium isotopic measurements, the measurement of the relative amount of fluorine allowed discriminating between uranium-ore concentrate particles and particles coming from a conversion plant. Moreover, the results, obtained on particles collected five years ago in the surroundings of a conversion plant, showed that fluorine is a persistent indicator of a conversion activity. The analysis of these particles enabled to establish a database, which was successfully used to draw conclusions from the analysis of unknown real-life environmental samples.

Increasing the Accuracy of EPMA of Microparticles Using Lower Energy Electron Beam and FIB Slicing

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Technique for increasing the accuracy of energy probe microanalysis (EPMA) of particles is proposed. EPMA with scanning electron microscope (SEM) and energy dispersive X-ray spectrometer is reasonable express method to search and analyze microparticles of nuclear materials. Accuracy of elemental analysis of uranium microparticles could be low if results are calculated with pre-installed commercial software. Such software provides good accuracy only for polished beam-perpendicular sample. The size this sample should be larger than free pass of incident electrons. Microparticles are not such samples.

Traditional technique of EPMA is to place microparticles on a planchet randomly and to analyze them by using electron beam with energy about 20–30 keV. In this case results of analysis have not good accuracy. Measured concentrations of uranium for the set of microparticles manufactured of the same UO2 sample differ by more than 10%. Moreover systematic error of measure of elemental composition depends on a size of a particle. At the same time the difference of measured concentrations for individual particle could be up to 10% due to relative orientation of the particle, electron beam and X-ray detector.

Using lower electron beam energy (5–8 keV) higher accuracy for the same particles obtained. Difference of measured concentrations is less 10% regardless of the particle size if this size is larger $0.5\ \mu$m.

Most modern SEM equipped with focused ion beam (FIB). Preparing of particles surface with FIB allows to get even higher accuracy of microanalysis. Particles of UO2 with the smallest size of $2\ \mu$m were sliced by using 30 kV Ga^+ beam. Difference of measured concentrations for individual sliced particle decreases down to 1%. For the set of sliced particles this difference decreases down to 2%.

Field Testing of Unattended Environmental Sampling Devices and Analysis Results

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Researchers at Savannah River National Laboratory (SRNL) and Oak Ridge National Laboratory (ORNL) have been developing a tamper resistant/tamper indicating aerosol contaminant extractor (TRI-ACE) to be used for unattended environmental sampling in support of safeguards applications. Environmental sampling has become a key component of International Atomic Energy Agency (IAEA) safeguards approaches by supporting conclusions concerning the absence of undeclared nuclear material or nuclear activities in a State. Swipe sampling is the most commonly used method for the collection of environmental samples from bulk handling facilities. However, augmenting swipe samples with an air monitoring system, which could continuously draw samples from the environment of bulk handling facilities, could improve the possibility of the detection of undeclared activities. Continuous, unattended sampling offers the possibility to collect airborne materials before they settle on surfaces which can be decontaminated, taken into existing duct work, filtered by plant ventilation, or escape via alternate pathways. The TRI-ACE system will allow for such collection in a manner that ensures sample integrity. The TRI-ACE prototype, which was completed in early 2013, has many features which could indicate possible tampering events that may have occurred during unattended collection.

In 2013, a team traveled to a U.S. facility to field test the TRI-ACE alongside a standard ACE unit. The goals of the field trial were to evaluate the effectiveness of the TRI-ACE system in unattended monitoring of airborne particulate, and to establish the effectiveness of ACE collection versus swipe collection. The samples collected were processed using various techniques, including mass spectroscopy. If the collection plates and swipes provided accurate analysis, the system could potentially be deployed by the IAEA at uranium-handling facilities as a safeguards measure. This paper will discuss the field trial results found by the team from SRNL and ORNL.

Dating of Uranium Materials by Using Combination of ICP-MS and SIMS

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The age of nuclear and some other radioactive materials can be determined undoubtedly by using ICP-MS techniques. But it can be correct if only one nuclear or another radioactive material is presented in analyzed sample and no isotope-chronograph presented in background particles in significant quantities.

For particle analysis, which can be implemented by using SIMS, these restrictions are not valid. Practically one particle always characterizes only one material and does not contain background isotopes-chronographs. But age determination is based on the result of measuring of the content ratio of Th230 and U234. The difference of ionization coefficients of uranium and thorium and dependence of these coefficients on composition of particle does not allow using this method directly for age determination.

Nevertheless SIMS is useful for dating of uranium materials, especially if the sample can contain small amounts of different materials. In this case the analysis of different fragments of materials by SIMS can confirm or not confirm the result, had been obtained by ICP-MS. If all detected and analyzed particles and fragments will have the same ratio of ion currents of Th230 and U234, the result of ICP-MS is true. If particles and fragments will have different ratios the result of ICP-MS cannot be related to any of presented materials.

But in the last case the ages of different materials can be still estimated if different fragments have different ages, but the same elemental composition. The "age" had been determined by ICP-MS can be correlated with the average ratio of ion currents of Th230 and U234 had been determined by SIMS for all analyzed particles or fragments. This correlation determines the ratio of ionization coefficients of uranium and thorium, which should be the same for particles with the same elemental composition.

Novel Mass Spectrometric Techniques for the Rapid Characterization and Fingerprinting of Nuclear Fuel Materials

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This paper explores two somewhat novel mass spectrometric analysis techniques to characterize nuclear safeguards materials. The first uses Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) to perform rapid elemental analyzes of trace components in uranium-bearing particles. We demonstrate this approach by measuring trace elements in eight different samples containing uranium-bearing particles, including three uranium oxide reference materials, two uranium doped glass reference materials, two actual IAEA swipe samples, and an ore sample. Principal component analysis was used to classify particles based on relative abundance of 16 elemental peaks or molecular peaks. Five principal components explained 86% of the total variance between samples and all samples could be distinguished using some combinations of the principal component scores. Analysis of loading factors indicated which elements were important in distinguishing different samples. Of particular interest is the fact that the two IAEA swipe samples could be distinguished from one another based on relative abundance of strontium and barium suggesting different processes or trace contaminants might be used in fingerprinting specific facilities or processes. High mass resolution analysis of the positive spectrum from the uranium-bearing polymer from one of the IAEA swipe samples revealed that the particle was comprised largely of nylon 66. A second technique employs oxygen isotope analyzes using large geometry SIMS (LG-SIMS)to potentially distinguish geographical location of production. Preliminary data indicate that 18O/16O ratios of one-micron-sized particles can be estimated with a precision of about one part in a thousand. This precision is adequate for the analyzes to be useful for establishing provenance. We will discuss the utility of the techniques, potential pitfalls and the work that needs to be achieved to move forward.

Advancements in Particle Analysis Procedures and their Application to the Characterization of Reference Materials for Safeguards

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Two approaches may be employed in the preparation of Reference Materials (RMs) for use in micro analytical techniques: placement of characterized micro artefacts in bulk materials and characterization of certain classes of individual particles in existing materials. In November 2013, a collaborative project was launched with the aim of adding information about such individual particles in existing RMs. The motivation behind this project was to investigate and characterize micro-artefacts present in certain commercially available RM, making them available and fit for use in safeguards and several other nuclear applications. The implementation and development of new techniques for particle characterization in bulk materials are also part of this project.

The strategy for that approach includes the following steps:

1. Sample preparation: Dispersion of particles on stubs and planchets by an in-house shock-wave device.
2. Particle-of-Interest identification and characterization:
   (a) Fission Track (FT) route: Mosaic imaging of detectors containing FT stars; Applying automatic pattern recognition and localization of FT stars in detectors; Using Laser Micro-Dissection (LMD) for retrieval of individual particles; Preparation of sampled particles for SEM observation and other analytical techniques.
   (b) Alpha Track (αT) route: Direct particle identification and localization using position sensitive detectors (instrumental auto-radiography).
   (c) The advanced SEM route: Integration of analytical SEM techniques for characterization of individual particles of interest: EDS, mass spectrometry, FIB, micro-Raman.

Preliminary results of the ongoing efforts will be reported. Utilization of these hyphenated techniques and instruments represents an innovative approach to particle characterization for Safeguards applications.

VKTA Rossendorf: Laboratory for Environmental and Radionuclide Analysis

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The VKTA (Nuclear Engineering and Analytics Inc.) is charged by the Free State of Saxony with the decommissioning and waste management of the nuclear installations at the research site Dresden-Rossendorf. This task includes the safe management and disposal of fissile material and radioactive wastes.

The acquired expertise and our solution-oriented way of working are the basis for a varied range of services especially the environmental and radionuclide analyzes.

The Laboratory for Environmental and Radionuclide Analysis is accredited according to DIN EN ISO/IEC 17025 and provides a sound range of analytical and metrological services including their coordination and management. The personnel and the rooms, measuring and technical equipment are particularly designed for our special field, the measuring of radioactivity. We are focussed on measuring artificial and natural radionuclides in a wide range of activity and in different sample matrices (e.g., urine, faeces, metals, soil, concrete, food, liquids). With the flexible accreditation of the radionuclide analytics the Laboratory is able to react shortly to changing requirements in decommissioning, environmental monitoring and radiation protection. Essential chemical and radiochemical methods are e.g.:

- Alpha particle spectrometry,
- Liquid scintillation counting,
- gamma ray spectrometry, including Ultra-Low-Level,
- High-resolution ICP-MS,
- Chromatographic methods such as ion chromatography, gas chromatography, HPLC,
- Electrochemical measuring methods such as potentiometry, voltammetry.

The Laboratory offers analytical services to the research site Dresden-Rossendorf and national and international customers adapting its analytical procedures to the special needs of customers.

The presentation demonstrates on the basis of examples the work of Laboratory within the scope of decommissioning of nuclear facilities, especially at a research site, from radiological preliminary investigation to declaration of waste.

Validation of Neptune Plus MC-ICP-MS for Bulk Analysis of Environmental Swipe Samples

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As part of the ECAS (Enhancing Capabilities of Safeguards Analytical Services) project a new generation multi-collector inductively coupled plasma mass spectrometer (MC-ICP-MS) has been installed in the Environmental Sample Laboratory of the IAEA's Safeguards Analytical Laboratories for the bulk analysis of environmental swipe samples. Several analytical procedures have been validated for bulk analysis of environmental swipe samples. During the validation study the chemical sample preparation procedure has also been further improved.

The U and Pu isotope ratio measurements and the Pu isotope dilution analysis are performed with ThermoFisher Scientific Neptune Plus MC-ICP-MS coupled to a high-efficiency sample introduction system (Aridus II). Mass bias correction, background / memory effect correction, hydride formation correction, yield correction of the multi-collector ion counters, ion counter non-linearity and dead time correction, and peak-tailing correction are performed for isotope ratio measurements. The effect of potential molecular interferences is assessed by the screening of concentrations of interfering elements in uranium fractions.

The new procedures allow the determination of n(U-235)/n(U-238) with relative expanded uncertainties lower than 0.2%, allow achieving detection limits below 5×10^{-7} for n(U-233)/n(U-238) and below 1×10^{-7} for n(U-236)/n(U-238) in swipe samples, and allow achieving detection limits for the determination of 239Pu, 240Pu, 241Pu, and 244Pu amounts lower than 1 femtogramme per aliquot.

Improved Technique for the Determination of Uranium Minor Isotopes Concentrations in Microparticles by Using Secondary Ion Mass-Spectrometer in Multicollection Mode

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Traditional method of the analysis implies simultaneous measuring of secondary ion currents of isotopes $234U^+$, $235U^+$, $238U^+$, ions with mass 236 amu ($236U^+$ and $235UH^+$) and hydride ions $238UH^+$ by using mass-spectrometer Cameca IMS1280 in multicollection mode. Calculating of uranium isotopic composition is performed using the results of 40 successive measurements of those currents (cycles). Duration of each measurement is 8 s. Small amounts of uranium minor isotopes are limitation for precise determination of their concentrations. To prevent the damage of the secondary ions detector the intensity of ion current should be no more than 5×10^5 s^{-1}. This limitation does not allow setting a higher primary ion current for the increasing of minor uranium isotopes ions emission because of the signal of ions $238U^+$ gets too high.

New technique is developed to improve the accuracy of determination of uranium minor isotopes concentrations. Process of measurement is divided on two steps. First step is a measurement of ion currents during 20 cycles by five detectors. The second step implies the elimination of ions $238U^+$ hitting to the detector and 10 times increasing of primary ion current.

The ratio 235U/238U is calculated from the first step results, so uncertainty of determination of this value is 1.4 times bigger than with duration of 40 cycles of the measurement. The ratios 234U/235U and 236U/235U are calculated during the second step. This technique allows to determine content of 234U and 236U with 3 and 5 times less uncertainties respectively, but with different degree of the sputtering particles. Moreover the duration of each cycle was set less (1 second) to use data more efficient. The technique accordingly with every second counting provides uncertainty of determination 236U concentration 4 times less than traditional method at the same degree of sputtering particles.

S14: Safeguards Needs at Geological Repositories and Encapsulation Facilities

Developing Safeguards for Final Disposal of Spent Nuclear Fuel in Finland

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Final disposal of spent nuclear fuel brings new types of safeguards concerns. The non-verifiability and non-accessibility of the disposed fuel create a challenge in creating and preserving reliable knowledge about the nuclear material and its location. Therefore, a verified information package consisting of spent fuel characterization and site investigation data shall be generated for future generations. Also the assurance that the continuity of knowledge is maintained from the fuel verification to the final emplacement position is to be documented. With these data, future generations are able to formulate their role in maintaining the safeguards and security for the disposal site as long as needed.

As a national authority in Finland, STUK has taken the position that the collection, dissemination and storage of above-mentioned data packages are required in such a way that also international inspectorates can use it to create knowledge for their independent safeguards conclusions. This position is shown on practical level in STUK regulations.

In practical terms this means that final verification of spent fuel should be as comprehensive as feasible. Designing an optimized C/S system to maintain continuity of knowledge during the operation of the final disposal facility needs careful planning and development in the spirit of the SbD and 3 S concepts. Design Information Verification and Containment/Surveillance for the underground part of the repository is another area where new practical and reliable approaches and procedures need to be taken into use.

STUK has a central role in negotiations with the operator and international inspectorates. The discussions are taking place in national regulatory meetings, international technical meetings and official trilateral meetings with Finland, EC and IAEA. Various Member State Support Programme tasks conduct R&D for final disposal. The goal is to set up a robust and cost effective safeguards system.

Safeguards by Design at the Encapsulation Plant in Finland

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Finland has launched a spent fuel disposition project to encapsulate all of its spent fuel assemblies and confine the disposal canisters in a deep geological repository. The construction of the underground premises started several years ago with the drilling, blasting and reinforcement of tunnels and shafts to ensure the safe deep underground construction and disposal techniques in the repository, while the design of the encapsulation plant (EP) enters the licencing phase preliminary to its construction. The spent fuel assemblies, which have been safeguarded for decades at the nuclear power plants, are going to be transported to the EP, loaded into copper canisters and stored in underground tunnels where they become inaccessible after backfilling. Safeguards measures are needed to ensure that final spent fuel verification is performed before its encapsulation and that no nuclear material is diverted during the process. This is an opportunity for the inspectorates to have the infrastructure necessary for the safeguards equipment incorporated in the design of the encapsulation plant before licencing for construction occurs.

The peculiarity of this project is that it is going to run for more than a century. Therefore, significant changes are to be expected in the technical capabilities available for implementing safeguards (e.g., verification techniques and instruments), as well as in the process itself, e.g., redesign for the encapsulation of future fuel types. For these reasons a high degree of flexibility is required in order to be able to shift to different solutions at a later stage while minimizing the interference with the licencing process and facility operations. This paper describes the process leading to the definition of the technical requirements by IAEA and Euratom to be incorporated in the facility's design.

Operator View on Safeguards Implementation for New Type of Facilities (Encapsulation Plant and Geological Repository)

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The Finnish solution for the geological disposal of spent nuclear fuel is based on a facility complex consisting of an above ground encapsulation plant and an underground disposal facility that are connected by a vertical shaft transferring the encapsulated fuel into the repository. The schedule was outlined in 1983, when the Government decided on the objectives and programme for the nuclear waste management. According to that schedule the disposal site was selected in 2001 and the construction licence application for the facilities was filed in 2012. The construction licence application is based on the multi-disciplinary research and development carried out during the three decades. The knowledge of the site has been confirmed by constructing the underground rock characterization facility ONKALO starting in 2004. ONKALO is designed and constructed considering that the future repository can benefit of the infrastructure and underground premises. Currently ONKALO serves as in situ testing and demonstration facility for the development of the disposal operations. The construction of the encapsulation plant and further excavations for the repository are expected to start in 2015.

Implementation of the safeguards control started together with the excavations at the site. The control ensures that ONKALO is excavated as declared and that any other works compromising the integrity of the geological containment do not exist. In the context of the construction licence application, the first comprehensive basic technical characteristics (BTC) for the facilities were provided together with the site declaration. The encapsulation plant and geological repository both are new type of facilities. The fit for purpose design information provided in the BTC and development of the safeguards concept for the new facilities have required interactive communication between the international and national regulators and the operator. This work continues presumably at least until the operation of the facilities starts in about 2022.

Safeguarding Geological Repositories: R&D Contributions from the GER SP

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Germany has contributed actively to R&D related to safeguarding geological repositories since 1980, first on the national level, since 1990 also through the SAGOR (II) and ASTOR group of experts, and other German Support Programme (GER SP) tasks. While earlier studies identified issues of essential relevance (aspects of retrievability, need for Design Information Verification (DIV), definition of physical boundaries) and developed safeguards approaches for geological repositories and encapsulation plants, R&D more recently has focused on technologies for safeguarding geological repositories: i) Satellite imagery: In a joint task with the Finnish, Japanese, and Canadian SPs, the GER SP demonstrated the potential of synthetic aperture radar (SAR) data acquired by remote sensing satellites. ii) Geophysical methods: Measurement campaigns at the Gorleben exploratory mine showed the applicability of seismic and acoustic measurement methods to detect clandestine underground mining activities. Based on the results, a follow-up project is modelling the propagation of seismic waves from different sources in the salt and surrounding sediments. Another project is investigating the applicability of underground radar technology as a directive and wide ranging technology. Active radar systems could probably be used to set up a protective screen around a geological repository. iii) Autonomous navigation and localization: The GER SP has recently started a feasibility study on simultaneous localization and mapping (SLAM) systems for safeguards verification purposes. Results achieved during field tests have indicated several possibilities and challenges for using indoor navigation and mapping technologies in support of geological repositories safeguards. In the near future, more attention will be paid to the impacts of (geophysical) safeguards measures on the operation and long-term safety of geological repositories. The paper presents the lessons learnt from the earlier studies and gives an overview of the results and implications of recent and on-going projects for safeguarding geological repositories.

Safeguards Aspects Regarding a Geological Repository in Sweden

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Swedish spent nuclear fuel will be deposited in a geological repository after having been encapsulated in copper canisters. The Swedish Nuclear Fuel and Waste Management Company (SKB) has applied for licences to build an encapsulation plant in Oskarshamn and a geological repository at Forsmark. The encapsulated fuel will be transported by ship in specially constructed transport containers from Oskarshamn to Forsmark (450 km).

The Swedish concept is close to that assumed by the IAEA for defining model safeguards approaches for such facilities. However, there are certain differences; one being that the encapsulation plant will be directly connected to the spent fuel interim storage (CLAB). This, to an extent, complicates the the monitoring of movements of spent fuel. Another difference is that the transport casks for copper canisters will be removed underground in the geological repository.

Informal meetings are being held with Euratom and the IAEA on the preliminary designs of the encapsulation plant and the geological repository.

This paper will discuss challenges that we can expect at the encapsulation, transportation and deposit stages. These are, for example, spent fuel verification techniques, CoK during encapsulation and transport and canister identification. Verification of the design of the geological repository is essential and should be done mainly by in situ observation using, for example, laser techniques. This can be combined with other techniques such as satellite imaging. Geophysical monitoring can be made redundant through the proper use of AP measures such as Complementary Access and extended Information Analysis.

Experimental and Analytical Plans for the Non-Destructive Assay System of the Swedish Encapsulation and Repository Facilities

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The Swedish Nuclear Fuel and Waste Management Company (SKB), European Atomic Energy Community (Euratom), two universities and several U.S. Department of Energy Laboratories have joined in a collaborative research effort to determine the capability of non-destructive assay (NDA) techniques to meet the combined needs of the safeguards community and the Swedish encapsulation and repository facilities operator SKB. These needs include partial defect detection, heat quantification, assembly identification (initial enrichment, burnup and cooling time), and Pu mass and reactivity determination. The experimental component of this research effort involves the measurement of 50 assemblies at the Central Storage of Spent Nuclear Fuel (Clab) facility in Sweden, 25 of which were irradiated in Pressurized Water Reactors and 25 in Boiling Water Reactors. The experimental signatures being measured for all assemblies include spectral resolved gammas (HPGe and LaBr3), time correlated neutrons (Differential Die-away Self Interrogation), time-varying and continuous active neutron interrogation (Differential Die-away and an approximation of Californium Interrogation Prompt Neutron), total neutron and total gamma fluxes (Fork Detector), total heat (assembly length calorimeter) and possibly the Cerenkov light emission (Digital Cerenkov Viewing Device). This paper fits into the IAEA's Department of Safeguards Long-Term R&D Plan in the context of developing "more sensitive and less intrusive alternatives to existing NDA instruments to perform partial defect test on spent fuel assembly prior to transfer to difficult to access storage," as well as potentially supporting pyrochemical processing. The work describes the specific measured signatures, the uniqueness of the information contained in these signatures and why a data mining approach is being used to combine the various signatures to optimally satisfy the various needs of the collaboration. This paper will address efficient and effective verification strategies particularly in the context of encapsulation and repository facilities.

Radar Monitoring: Modelling of Undeclared Activities

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A feasibility study in the framework of the German Support Programme investigates the applicability of the 3D radar method for the monitoring of a geological repository. The aim of technical solution is the detection and localization of clandestine underground mining activities. The radar system should form a kind of protective shield around a repository to detect and localize possible activities in an early stage and in a sufficient distance.

To date radar monitoring in the context of geotechnical engineering is restricted to few applications, mainly in form of repetitive linear measurements. Repetitive surveys out of boreholes or drifts are conducted with disadvantages concerning safeguards requirements as high maintenance and positioning inaccuracies. In this study a static radar system is selected to omit these disadvantages. A monitoring system consisting of an array of static radar probes could probably be realized as a highly accurate, durable and low-maintenance automatic early warning system.

In the past decade DMT has developed an unique 3D borehole radar used for the exploration in salt mines, at cavern sites and in limestone quarries. The knowledge of DMT can be used for a further development of a direction sensitive radar monitoring system. With the additional information of the direction, possible activities in the mine could not only be detected but also localized in 3D space.

The detectability of different possible clandestine mining activities is investigated by simulations of radar wave propagation. The simulations involve the influence of baseline conditions and known activities to the data. The detectability of mining activities is analyzed by comparing different geometries of the activities, different layouts of the radar probes and accounts for different probe parameters.

Secure and Reliable Wireless Communications for Geological Repositories and Nuclear Facilities

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There is an important need to develop new generation robust RF communication systems to support wireless communications and instrumentation control in geological repositories and nuclear facilities, such as nuclear power plants. Often these facilities have large metallic structures with electromagnetic (EM) transients from plant equipment. The ambient EMI/RFI harsh environment is responsible for degrading radio link bandwidth. Current communication systems often employ physical cables that are not only expensive to install, but deteriorate over time and are vulnerable to failures. Furthermore, conventional high-power narrowband walkie-talkies sometimes upset other electronics. On the other hand, high-quality reliable wireless communications between operators and automated control systems are critical in these facilities, as wireless sensors become more and more prevalent in these operations. In an effort to develop novel wireless communications systems, Dirac Solutions Inc. (DSI) in collaboration with Lawrence Livermore National Laboratory (LLNL), has developed high-quality ultra-wideband (UWB) hand-held communications systems that have proven to have excellent performance in ships and tunnels. The short pulse UWB RF technology, with bandwidths of many hundreds of MHz's, are non-interfering due to low average power. Furthermore, the UWB link has been shown to be highly reliable in the presence of other interfering signals.

The DSI UWB communications systems can be adapted for applications in tunnels and nuclear power facilities for voice, data, and instrumentation control. In this paper we show examples of voice communication in ships with UWB walkie-talkies. We have developed novel modulation and demodulation techniques for short pulse UWB communications. The design is a low-power one and in a compact form. The communication units can be produced inexpensively in large quantities. A major application of these units might be their use by IAEA inspectors and facility operators.

Geological Repository Safeguards: Options for the Future

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Challenges for safeguarding a geological repository of spent nuclear fuel pose at least three high-level opportunities. First, being a relative late-comer among the various types of nuclear facilities subject to safeguards, the geological repository is an ideal candidate for applying “safeguards by design” (SBD). Moreover, a repository is an especially good example facility where the sometimes conflicting objectives of safeguards, security, and safety (3S) in fact can align harmoniously. And finally, a repository is unlike all other nuclear facilities such that containment and surveillance (C/S) arguably should constitute the primary safeguards approach, rather than material accountancy. Several states have already invested many years and resources toward implementing final disposal of spent nuclear fuel in a geological repository. The critical, precedent-setting decisions about the best approaches for safeguarding nuclear material destined for and emplaced within a geological repository are already beginning to take shape. We consider the unfolding safeguards consideration of geological repositories from the perspectives of SBD, 3S, and C/S. If done mindfully, the prospects are good for an effective and cost-efficient safeguards solution likely to facilitate, rather than hinder, the future worldwide growth of civil nuclear energy.

Modelling Seismic Propagation at a Salt Dome: Signals at Potential Monitoring Sites

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Tasked by the German Support Programme for the IAEA we are doing research for safeguards for underground final repositories for spent nuclear fuel in geological formations. The task is to detect potential access, during and in particular after the emplacement phase. During the latter phase geophysical methods offer possibilities of monitoring the repository from the outside, without sensors or cables in or close to the repository volume. To learn about the strengths and other properties of seismic signals produced by different mining activities, a first project (2010–2012) was devoted to acoustic and seismic measurements in the exploratory mine in the Gorleben salt dome in Germany[1].

The present project is to model the propagation of seismic signals caused by mining activities to potential monitoring sites, mostly underground, close to and within the salt dome. Due to the complicated geological structure this is done by numerical modelling in three dimensions, using the open-source programme SpecFEM3D. The structure is represented by a somewhat simplified model of the salt dome and its surrounding rock. Attenuation is incorporated using constant quality factors for the different media. The mesh is built using the commercial programme Trelis/Cubit. Computation uses the LiDO cluster of TU Dortmund that provides several hundred cores.

For relevant activities such as drilling and blasting, source strengths and time courses are used as input. Signal strengths are computed at various potential sensor sites. At the surface and in the salt dome they can be compared with measured data. For statements on the detection capability, amplitudes and spectral content are compared to the characteristics of typical background noise.

References

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"Cigéo": The French Industrial Project of Deep Geological Repository Developed by Andra

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Andra is a publicly owned industrial and commercial body, set up by the French radioactive waste management and research Act of 1991. It is responsible for the study and the design of Cigéo, the future industrial deep geological repository devoted to the French high and intermediate level waste. It will also be the future operator of the repository. The licence application of Cigéo is currently being prepared and the first operations should start in 2025.

The inventory of Cigéo covers conditioned waste originating from the activities and the dismantling of 50 years of operations of the French nuclear installations licenced to date. In agreement to French policy, irradiated fuel is being reprocessed. As a result, the licence application of Cigéo will not include the disposal of fuel assemblies.

Safeguards have been integrated as an early stage in the industrial project according to safeguards by design approach:

- Participation of Andra and French Authorities to international working groups (ASTOR, ESARDA, . . .);
- First official contact with Euratom in 2014 in order to launch a regular technical exchange process. The idea is to identify potential difficulties and introduce specific control needs as soon as possible in the project.

The technical important specificities to take into account are:

- The mass of nuclear material in the packages are declared to Andra by waste producers;
- Cigéo does not extract any nuclear material from the waste;
- Once a waste package has been emplaced in the underground disposal facility, it cannot be retrieved without being detected;
- The exact location and movement of all waste packages is permanently known;
- Information on the inventory disposed of is kept with no duration limit (at least several centuries).

Study on the Near Real Time (NRT) Impact of Safeguards Measures for the Encapsulation Plant in Finland

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An encapsulation plant is being co-located with the long term spent fuel geological repository under construction in Finland. Here, spent fuel (SF) coming from different temporary storage in the same country will be encapsulated and moved underground for final disposal. The scope of the planned safeguards measures is to verify the characteristics of the declared SF (using the best methods available) prior to their encapsulation, as from that point on the fuel will be inaccessible for future verification. Once this verification is performed, other measures aim to maintain the continuity-of-knowledge of the SF until the entrance to the final repository; no internal tracking of the SF for safeguards purposes is expected inside the repository, due to its inaccessible nature.

Many options have been considered with regard to the SF verification site(s) and the methods used, starting from the most appealing one: the verification at the Encapsulation Plant itself, as it is the closest to the final repository and an obvious common path for all SF. The demanding process nature of the Encapsulation Plant places stringent near-real-time (NRT) requirements on the Inspectorate to confirm the declared characteristics of the SF, and notify the operators that they may proceed with the encapsulation process. Non-fulfilment of these requirements would lead to extra costs and effort for all involved parties, especially when considering the expected 100 year operational life of the facility. These requirements have led to choose a different location (initially at the encapsulation plant) for the final re-verification of the SF.

This paper describes the study on NRT impact on the different verification options, in terms of the cost, risks, and effort from the standpoints of both the inspectorate and the facilities operator.

S15: New Trends in the Application of Statistical Methodologies for Safeguards

Outcome and Perspectives from the First IAEA International Technical Meeting on Statistical Methodologies for Safeguards

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Statistical and probabilistic methodologies have always played a fundamental role in the field of safeguards. In-field inspection approaches are based on sampling algorithms and random verification schemes designed to achieve a designed detection probability for defects of interest (e.g., missing material, indicators of tampering with containment and other equipment, changes of design). In addition, the evaluation of verification data with a view to drawing soundly based safeguards conclusions rests on the application of various advanced statistical methodologies.

The considerable progress of information technology in the field of data processing and computational capabilities as well as the evolution of safeguards concepts and the steep increase in the volume of verification data in the last decades call for the review and modernization of safeguards statistical methodologies, not only to improve the efficiency of the analytical processes but also to address new statistical and probabilistic questions. Modern computer-intensive approaches are also needed to fully exploit the large body of verification data collected over the years in the increasing number and diversifying types of nuclear fuel cycle facilities in the world.

The first biennial IAEA International Technical Meeting on Statistical Methodologies for Safeguards was held in Vienna from the 16 to 18 October 2013. Recommendations and a working plan were drafted which identify and chart necessary steps to review, harmonize, update and consolidate statistical methodologies for safeguards. Three major problem spaces were identified: Random Verification Schemes, Estimation of Uncertainties and Statistical Evaluation of Safeguards Verification Data for which a detailed list of objectives and actions to be taken were established.

Since the meeting, considerable progress was made to meet these objectives. The actions undertaken and their outcome are presented in this paper.

IAEA Safeguards and GUM-based Measurement Uncertainty Estimation: a Reconciliation

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In response to its specific need to assess the statistical significance of declared and observed nuclear material accounting differences shipper-receiver difference (SRD), material unaccounted for (MUF), operator-inspector difference (D), inspector's estimate of MUF (IMUF), the safeguards community in the 1970s and 1980s developed a methodology to estimate measurement error variances. This has been applied by the IAEA to date and is currently undergoing review and enhancement. The terminology associated with this approach attributes observed variances to sources of error.

Since the first publication in 1995 of the 'Guide to the Expression of Uncertainty in Measurement' (GUM), safeguards laboratories are converging in their treatment of measurement results towards this international metrological standard. GUM models the analytical process from the ground up via cause-and-effect and accounts for and propagates uncertainties at each point of the process up to the measurand via the low of error propagation. In contrast, the safeguards methodology estimates uncertainties from the top down by applying estimation routines to paired measurement data and attributing the resulting variance to operator/inspector and random/short-term systematic components. Differences in both approach and terminology complicate communication between communities in need of close co-operation: IAEA safeguards data evaluators and safeguards laboratory analysts.

The authors wish to reconcile the IAEA methodology with the GUM-based uncertainty estimation. In a first step, the features of both approaches are introduced and compared. After resolution of purely terminological differences, the divergences in approach caused by differences in the underlying problems to be solved become clearly visible. We do not expect the approaches to become unified because the deliverable of a laboratory is a measurement result whereas the deliverable of material balance evaluation is an assessment of the statistical significance of observed balance statistics, but we identify potential benefits and recommend specific steps towards convergence in areas of overlap.

The Analysis of Measurement Errors as Outlined in GUM and in the IAEA Statistical Methodologies for Safeguards: a Comparison

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We compare the definitions and propagation of measurement errors as outlined in GUM (Guide to the expression of Uncertainty in Measurement) and in the IAEA statistical methodologies for safeguards. Measurement errors are not observable. Based on a correct mode of error propagation, we can estimate the variances of measurement errors. In order to do so, we have to first define a mathematical measurement error model. Based on this model, we can then carry out propagation of errors with the aim to determine realistic estimates of the variance of measurement errors. For illustration purposes, we use the mathematical error model describing the measurement errors associated with a linear calibration. We can demonstrate that the mathematical error model for any calibration, which always consists of a random and systematic component, is subsumed in the mathematical error model used in the IAEA statistical methodology for safeguards. The goal of this paper is to describe the mode of propagation of measurement errors as outlined in GUM and in the IAEA statistical methodology for safeguards and to compare the mathematical error model used for a linear calibration with the model used for the evaluation of paired data. Paired data are obtained by measuring the same item with two different measurement methods and are used by the IAEA to estimate the measurement error variances of plant operators and inspectors in order to inform the material balance evaluation (MBE) process. Adequate methods of error propagation are of paramount importance to draw soundly based conclusions from material balance evaluation at bulk-handling facilities.

Inspections Over Time: The Role of Information

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When inspections in nuclear plants are planned over time it has to be decided if the time points of all inspections are fixed at the beginning of the reference time interval, e.g., one year, or if they are fixed sequentially. In the latter case the time point for the second inspection is fixed only after the first one has been performed, the third after the second one, and so on. For that decision, not only organizational aspects have to be taken into account but also the role of information: Will the Inspectorate in the latter case be able to draw an advantage from the fact that after the first inspection it may know what the plant Operator´s behaviour was so far? Vice versa, the same holds for the Operator in case he plans to start an undeclared activity in the course of the reference time interval.

In this paper two general inspection schemes are analyzed: The Operator behaves sequentially in both cases, whereas the Inspectorate behaves sequentially in the one, and non-sequentially in the other case. It is shown that both schemes lead to the same optimal expected detection time which means that the Inspectorate may do what is easier from organizational and financial points of view. These results are discussed from the point of view of information which both parties may gain in the course of the inspection over time. With some care the essential arguments may also be applied to more complicated, i.e., realistic inspection schemes which cannot be analyzed quantitatively until now.

Reactor Simulations for Safeguards with the MCNP Utility for Reactor Evolution Code

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To tackle nuclear material proliferation, we conducted several proliferation scenarios using the MURE (MCNP Utility for Reactor Evolution) code. The MURE code, developed by CNRS laboratories, is a precision, open-source code written in C++ that automates the preparation and computation of successive MCNP (Monte Carlo N-Particle) calculations and solves the Bateman equations in between, for burnup or thermal-hydraulics purposes. In addition, MURE has been completed recently with a module for the CHaracterization of Radioactive Sources, called CHARS, which computes the emitted gamma, beta and alpha rays associated to any fuel composition.

Reactor simulations could allow knowing how plutonium or other material generation evolves inside reactors in terms of time and amount. The MURE code is appropriate for this purpose and can also provide knowledge on associated particle emissions.

Using MURE, we have both developed a cell simulation of a typical CANDU reactor and a detailed model of light water PWR core, which could be used to analyze the composition of fuel assemblies as a function of time or burnup. MURE is also able to provide, thanks to its extension MURE-CHARTS, the emitted gamma rays from fuel assemblies unloaded from the core at any burnup.

Diversion cases of Generation IV reactors have been also developed; a design of Very High Temperature Reactor (a Pebble Bed Reactor (PBR), loaded with UOx, PuOx and ThUOx fuels), and a Na-cooled Fast Breeder Reactor (FBR) (with depleted Uranium or Minor Actinides in the blanket). The loading of Protected Plutonium Production (P3) in the FBR was simulated.

The simulations of various reactor designs taking into account reactor physics constraints may bring valuable information to inspectors. At this symposium, we propose to show the results of these reactor simulations as examples of the potentiality of reactor simulations for safeguards.

A Computer Simulation to Assess the Nuclear Material Accountancy System of a MOX Fuel Fabrication Facility

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SimMOX is a computer programme that simulates container histories as they pass through a MOX facility. It performs two parallel calculations:

- the first quantifies the actual movements of material that might be expected to occur, given certain assumptions about, for instance, the accumulation of material and waste, and of their subsequent treatment;
- the second quantifies the same movements on the basis of the operator's perception of the quantities involved; that is, they are based on assumptions about quantities contained in the containers.

Separate skeletal Excel computer programmes are provided, which can be configured to generate further accountancy results based on these two parallel calculations.

SimMOX is flexible in that it makes few assumptions about the order and operational performance of individual activities that might take place at each stage of the process. It is able to do this because its focus is on material flows, and not on the performance of individual processes. Similarly there are no pre-conceptions about the different types of containers that might be involved.

At the macroscopic level, the simulation takes steady operation as its base case, i.e., the same quantity of material is deemed to enter and leave the simulated area, over any given period. Transient situations can then be superimposed onto this base scene, by simulating them as operational incidents. A general facility has been incorporated into SimMOX to enable the user to create an "act of a play" based on a number of operational incidents that have been built into the programme. By doing this a simulation can be constructed that predicts the way the facility would respond to any number of transient activities.

This computer programme can help assess the nuclear material accountancy system of a MOX fuel fabrication facility; for instance the implications of applying NRTA (near real time accountancy).

Near Real-Time Accountancy at JNC-1

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The JNC-1 site in Japan includes four large Pu/MOX bulk handling facilities for which standard plutonium accountancy would not be sufficient to give high confidence in the timely detection of diversion. Other safeguards measures are needed to strengthen the ability for early detection, and Near Real Time Accountancy (NRTA) provides the capability of performing a short-term evaluation of material accountancy in the field as well as at Headquarters.

NRTA was introduced at the main JNC-1 facilities on a facility-by-facility basis, starting at the MOX fuel fabrication plant (Plutonium Fuel Production Facility, PFPF) in 1999, followed by the reprocessing plant (Tokai Reprocessing Plant, TRP) in 2000, the MOX fuel fabrication and R&D facility (Plutonium fuel centre, Plutonium Fuel Facility, PPFF) in 2007, and finally at the conversion facility (Plutonium Conversion and Development Facility, PCDF) in 2014. In all four facilities, the main process areas are covered.

This paper summarizes the experience gained with NRTA in PFPF, TRP, and PPFF since it was introduced in the respective facilities and describes the development work performed in implementing it in the last facility, PCDF. The key NRTA signatures which help guide the analysts' decisions on possible follow-up activities, i.e., the early detection of changes in parameters toward which NRTA is geared, are described based on the experience gained over the years.

Furthermore, the paper describes the basis of the algorithms used in NRTA and the important relationships and dependencies between vessel calibrations, the determination of calibration curves and the associated uncertainty matrices on one side and the implemented structure and algorithms employed in the software on the other side. These algorithms were developed using Oracle SQL PLUS, MS Excel and Visual Basic, and batch commands.

S16: Potential Verification Roles

The Trilateral Initiative: IAEA Verification of Weapon-Origin Plutonium in the Russian Federation and the United States

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One year following the indefinite extension of the NPT, the IAEA, the United States and the Russian Federation entered into a cooperative effort aimed at creating a verification system under which the IAEA could accept and monitor nuclear warheads or nuclear warhead components in relation to the Article VI commitments of both States. Over a six year period, through 98 trilateral events, substantial progress was made on verification arrangements and technologies that could enable the IAEA to carry out such a mission, without gaining access to design or manufacturing secrets associated with nuclear weapons. Substantial progress was made on defining the approaches at lead facilities in the two States. The Board of Governors was looking forward to having the Agency undertake such a mission, and the 2000 NPT Review Conference called for the completion and implementation of the Trilateral Initiative. Then elections changed the leadership in both States and the incoming Administrations decided to end the effort, call it a success, and walk away. This presentation will summarize the creation, history, accomplishments, unresolved issues, consider the legacy and suggest four steps that might now be taken.

The Trilateral Initiative: The Legal Framework

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The Trilateral Initiative was a six-year effort undertaken by the IAEA, the United States and the Russian Federation between 1996 to 2002 to identify verification arrangements and technologies for IAEA verification of classified forms of Pu and HEU from nuclear warheads or components. As part of that Initiative, between 1999 and 2001, the parties succeeded in negotiating a model agreement for such verification (the Model Agreement). Although the Trilateral Initiative ended in 2002, the Model Agreement produced as a result of those negotiations could still serve as the basis for bilateral agreements between the IAEA and nuclear-weapon States wishing to demonstrate, in a verifiable manner, the release of weapon origin and other fissile material from defence programmes. This presentation will describe the legal framework for the Model Agreement and the major issues addressed during its negotiation.

Building a Simulated Environment for the Study of Multilateral Approaches to Nuclear Materials Verification

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Verification research can be resource-intensive, particularly when it relies on practical or field exercises. These exercises can also involve substantial logistical preparations and are difficult to run in an iterative manner to produce data sets that can be later utilized in verification research. This paper presents the conceptual framework, methodology and preliminary findings from part of a multi-year research project, led by VERTIC. The multi-component simulated environment that we have generated, using existing computer models for nuclear reactors and other components of fuel cycles, can be used to investigate options for future multilateral nuclear verification, at a variety of locations and time points in a nuclear complex. We have constructed detailed fuel cycle simulations for two fictional, and very different, states. In addition to these mass-flow models, a 3-dimensional, avatar-based simulation of a nuclear facility is under development. We have also developed accompanying scenarios — that provide legal and procedural assumptions that will control the process of our fictional verification solutions. These tools have all been produced using open source information and software. While these tools are valuable for research purposes, they can also play an important role in support of training and education in the field of nuclear materials verification, in a variety of settings and circumstances.

Consolidation of NM in the UK: Optimizing the Euratom Approach

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As part of the UK strategy to consolidate nuclear material (NM) allowing for declassification of a number of UK facilities, transfer of un-irradiated NM from Dounreay to Sellafield is envisaged. Dounreay will therefore construct a facility to condition and characterize most of the NM before shipment. On the Sellafield site, construction of a dedicated storage facility for material arriving in cans is in progress, whereas assemblies will be stored in an existing assembly store.

Both operators and ONR Safeguards (the national safeguards authority) have voluntarily engaged with Euratom safeguards earlier than legally required in order to facilitate the implementation of safeguards and reduce project risks. This early engagement followed by regular interaction between the parties has been crucial when addressing challenges encountered associated with logistics, security and a very tight time schedule and has played a major role in the process of optimizing the approach.

This paper describes the safeguards approaches developed for the two UK sites and how they aim to optimize the use of resources. For example, NM will be characterized for safeguards purposes at one site only. The location chosen for characterization of the material depends on the need for the Dounreay operator to obtain knowledge of the NM, the need for Euratom to maintain safeguards knowledge of the material once verified using containment and surveillance (C/S), instrument requirements, flexibility of operations, requirements for inspector presence, etc. Remote data transmission will be a crucial aspect of the verification approach at both sites.

United States Support Programme (USSP): Lessons Learned from the Management of Complex, Multi-Stakeholder Projects for International Safeguards

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This paper will review USSP experiences, lessons learned, and proposed future strategies on the management of complex projects including the Universal Non-Destructive Assay Data Acquisition Platform (UNAP) instrument development task. The focus will be on identifying lessons learned to formulate strategies to minimize risk and maximize the potential of commercial success for future complex projects. Topics planned for inclusion are:

1. Initial agreement amongst all stakeholders on the justification of the need of the development including market studies of existing/near term future COTS technology capabilities;
2. Initial confirmation that there is a market for the product other than the IAEA to reduce investment risk;
3. Agreement on an accelerated initial project schedule from request acceptance to commercial unit production including per unit cost and quantities;
4. During product development, obtaining periodic customer reaffirmation of the need and quantities for the product per the existing schedule and per unit price.

Long Term R&D for Safeguards

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Within the Office of Defense Nuclear Non-proliferation Research and Development (DNN R&D), the Nuclear Weapons and Material Security Team conducts research to develop advanced detection and source technologies for the purposes of detecting and characterizing special nuclear materials (SNM); international safeguards and radiological source replacement; nuclear arms control treaty monitoring and verification; and supporting interdiction and nuclear security efforts across NNSA. Our safeguards-specific goal is to develop and demonstrate new technologies and capabilities to cooperatively quantify and track SNM in the nuclear fuel cycle and detect any diversion of these materials for illicit purposes. Our goals and objectives align with a technology goal of the International Atomic Energy's Long Term Strategy for 2012-2023 "to improve the Department's technical capabilities by making use of scientific and technological innovation, and to enhance its readiness to safeguard new nuclear technology and support new verification missions." Toward that end, we work closely with the US Department of Energy's Next Generation Safeguards Initiative and the US Support Programme to meet their specific long term needs.

In this talk we will give a brief overview of current research efforts and specifically describe several helium-3 replacement technologies, advanced spent nuclear fuel characterization methods, and upcoming tags and seals technologies. We will present additional research into cross cutting enabling technologies such as advancements in detector materials, electronics, and sources, and basic physics measurements that support long term safeguards R&D.

Building-Up the Non-Proliferation Nuclear Trust in the Middle East

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This paper is aiming to address different proposals to overcome the lack of trust in the use of nuclear energy for peaceful applications among the Middle East (ME) States. By building-up and strengthen the non-proliferation nuclear trust in the ME region, a wider use of nuclear energy for peaceful applications will be promoted. To achieve this target, two proposals are here addressed. The first proposal is to form a Regional Safeguard (SG) organization (called MEATOM), which should be formed by all or a number of the ME States and should avoid the political influence posed on other international organizations. The new proposed Safeguards organization should establish a technical cooperation with the IAEA Safeguards to fulfil its functions which would be in lines with the functions of the two other known regional organizations, mainly Euratom and ABACC. The second proposal is to establish a regional cooperation in the installation and use of nuclear fuel cycle facilities at different ME States. By considering these two proposals in sincere and serious manner, it is believed that each ME state would provide more transparency and gain more trust in nuclear non-proliferation and consequently would permit wider use of nuclear energy for peaceful applications.

Is the IAEA's Safeguard Strategic Plan Sufficient?

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IAEA safeguards have much improved and the Safeguards Department is commendably planning to further its technical capabilities and to make full use of its authority. Will this be enough to keep countries from exploiting nuclear power programmes to develop nuclear weapons, or to be in a position to do so rapidly should they so decide? Depending on nuclear programmes developments worldwide, especially on expansions in enrichment and reprocessing, and on how international affairs unfold, the answer may well be no.

The fundamental limitations on the Department's ability to prevent proliferation are not technical, but conceptual. The Department is clearly motivated to carry out its technical activities competently. Yet it takes a relatively passive view of its role in the worldwide development of nuclear power—whatever technology comes into use, and whoever deploys it, the Department promises to exert its best effort to safeguard. In our view the Department should be more open about what it can or cannot realistically safeguard, and therefore what technology is permissible for deployment in national programmes.

The Department's Strategic Plan says at the outset that its verifications assist the Agency to fulfil its statutory objective to "accelerate and enlarge the contribution of atomic energy. . . " The Department should judge itself by how well it promotes international security, not by its contribution to expanding nuclear power use.

The Department's Vision includes advancing toward a nuclear weapons free world. That vision should include keeping states from deploying technologies that put them within easy reach of nuclear weapons. Our paper will suggest how the Department might supplement its current plan to best accomplish this.

S17: Technology Foresight and Emerging Technologies I

Development of Spectrophotometric Process Monitors for Aqueous Reprocessing Facilities

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The safeguards envelope of an aqueous reprocessing plant can be extended beyond traditional measures to include surveillance of the process chemistry itself. By observing the concentration of accountable species in solution directly, a measure of real time accountancy can be applied. Of equal importance, select information on the process chemistry can be determined that will allow the operator and inspectors to verify that the process is operating as intended. One of the process monitors that can be incorporated is molecular spectroscopy, such as UV-Visible absorption spectroscopy.

Argonne National Laboratory has developed a process monitoring system that can be tailored to meet the specific chemistry requirements of a variety of processes. The Argonne Spectroscopic Process monitoring system (ASP) is composed of commercial-off-the-shelf (COTS) spectroscopic hardware, custom manufactured sample handling components (to meet end user requirements) and the custom Plutonium and Uranium Measurement and Acquisition System (PUMAS) software.

Two versions of the system have been deployed at the Savannah River Site's H-Canyon facility, tailored for high and low concentration streams. The design, development and potential application of these systems will be discussed.

A New Approach to Environmentally Safe Unique Identification of Long-Term Stored Copper Canisters

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A new approach to environmentally safe unique identification of long-term stored copper canisters is suggested in this paper. The approach is based on the use of a tungsten-based insert placed inside a copper cask between a top iron lid and a copper lid. The insert/label is marked with unique code in a form of binary number, which is implemented as a combination of holes in the tungsten plate. In order to provide a necessary redundancy of the identifier, the tungsten label marked with few identical binary codes. The position of code (i.e., holes in tungsten) corresponds to a predefined placement of the spent fuel assembles in the iron container. This is in order to avoid any non-uniformity of the gamma background at the canister surface caused by a presence of iron-filled spaces between spent nuclear fuel assembles. Due to the use of the tungsten material gamma rays emitted by the spent fuel assembles are collimated in a specific way because of strong attenuation properties of tungsten. As a result, the variation in the gamma-counting rate in a detector array placed on the top of copper lid provides the distribution of the holes in the tungsten insert or in other words the unique identifier. Thus, this way of identification of copper cask do not impair the integrity of the cask and it offers a way that the information about spent nuclear fuel is legible for a time scale up to a few thousands years.

Modeling Nuclear Proliferation for the Purpose of Warning

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Can nuclear proliferation risk of a country be calculated? If the answer is yes, future challenges of nuclear proliferation could be better dealt with. Currently estimation of nuclear proliferation risk of a country is made based on human judgments. Signs of nuclear proliferation are derived by experts by collecting and processing massive amount of information. This process is human resource intensive and potentially subject to human biases. Quantitative modelling of state's nuclear proliferation risk can be useful in this process. Such a modelling work can aid human decision, and, if reliable, can serve to provide warning for the international community to take necessary preventive actions. Past efforts have shown the possibility of developing such model. The purpose of this study is to develop quantitative models to estimate proliferation risk of states based on open source information. The work is based on the understanding of determinants of nuclear proliferation for both supply and demand sides. Based on examining how a country specific situation leads to specific scenarios of nuclear proliferation, relevant variables are developed along with the supporting data. Utility of the quantitative model is examined based on historical data.

Improvement of Bulk Analysis of Environmental Samples by Using a Multiple Collector ICP-MS

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The CEA is a member of the NWAL since 2001 for both bulk and particles analysis of environmental samples. Bulk analysis consists in the measurement of U and Pu isotopes in environmental samples (generally cotton "swipe" samples). Most of the samples received by our laboratory contain extremely low amount of U (below 1 μg) and Pu (below 1 ng). Until recently U isotopic measurements were performed using a quadrupole ICP-MS (X-series II, ThermoScientific), and Pu isotopes were measured by means of a single–collector sector–field ICP-MS (Element XR, ThermoScientific). The latter is equipped with various devices which enhance its sensitivity. Although these instruments are very sensitive and have very low detection limits, in the femtogramme range for Pu, reproducibility for isotopic ratio measurement is limited as all isotopes are measured sequentially with the single detector available. For instance, relative standard deviation for 235U/238U ratio measurements is at best of 0.5%.

A multiple–collector ICP-MS (Neptune Plus, ThermoFisher), equipped with a large array of Faraday cups and ion counters, has been purchased and is now installed in the laboratory. Performance of this new instrument, in terms of accuracy, reproducibility, and detection limits, both for U and Pu measurements, will be compared to the ones obtained with the other instruments.

Characterization of Spent Nuclear Fuel with a Differential Die-Away Instrument

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The Differential die-away technique (DDA) is currently being investigated within the Next Generation Safeguards Initiative Spent Fuel project as one of the non-destructive assay techniques for spent nuclear fuel characterization and verification. This technique is based on active interrogation of the spent fuel assembly (SFA) by neutrons from an external, off-the-shelf, neutron generator. As the interrogating neutrons penetrate the SFA that is submerged in water, they thermalize and induce fission preferentially on the fissile content of the SFA, typically 235U, 239Pu and 241Pu. The strength and dynamic properties of the signal from the induced fission reflect the isotopic content of the SFA and makes it possible to determine various general characteristics of the SFA such as its total Pu content, initial enrichment, burn-up and possible existence of partial defects.

Following promising results of initial simulations, our research currently focuses on the design of a prototype instrument capable of characterization of the SFAs in Sweden, which consist of Boiling Water and Pressurized Water Reactor fuel assemblies. According to the requirements of the Swedish Nuclear Fuel and Waste Management Company, the instrument is being customized to perform test measurements of 50 different SFAs in the Swedish central interim storage facility (CLAB). At the future encapsulation facility (CLINK), an instrument is required to reliably characterize more than 50 000 SFAs with wide range of characteristic parameters.

In addition, within the scope of the IAEA objective of "development of more sensitive and less intrusive alternatives to existing non-destructive assay instruments," we will present our reasoning that this instrument, developed for a specific purpose (CLAB+CLINK), has the potential to become a more universally applicable tool installable or deployable to other sites as a standardized safeguards tool.

232Th Mass Determination in a Uranium/Thorium Mixture for Safeguards Purposes

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In nuclear safeguards it is required that thorium content in safeguarded material should be quantified and reported as appropriate. As such the South African State System of Control and Accounting (SSAC) on discovering a number of safeguarded waste drums which contained considerable quantities of thorium decided to initiate a project to properly quantify their thorium content using a high purity germanium detector and In Situ Object Counting System (ISOCS) efficiency calibration software.

These metal waste drums are contained inside overpacks which for health reasons cannot be opened and thus giving rise to the challenge of determining the exact fill heights and the density of the material. Fill heights determined using transmission sources and the material density calculated from them together with the geometry used for the overpacks could be used to further refine the ISOCS calibration geometry and thus improving the quantitative result. In order to have confidence on the ISOCS measurements, it was decided to also validate the ISOCS results through the preparation of similar density standards that would be used for the efficiency calibration in the determination of the 232Th activity in the material.

In addition, MGAU v4.2, which was used to determine uranium enrichment in a measured material, also provides an approximate 232Th abundance relative to uranium content. ISOCS measurements of 232Th masses in waste drums were compared to MGAU results. Results of these studies are presented in this paper.

Germany's Accelerated Exit from Nuclear Energy: Challenges and Perspectives with Regard to Safeguards

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Germany's current situation of nuclear power supply and SF management derives from two decisions that are now embodied in the German legislation: (1) 13th Amendment of 6th August 2011 to the Atomic Energy Act. Germany's decision to phase out nuclear energy until end of 2022 led to an enforced shut-down of 8 from a total of 17 nuclear power plants. (2) Law on Site Selection from 23rd July 2013 for a repository to store heat-generating radioactive waste. It determines no preference for a specific host rock type and a designation of the final repository site until 2031. The shift in German energy policy is a challenge for Safeguards (SG). The defueling of nuclear power plants generates an extra workload for the operators and the two inspectorates of IAEA and Euratom due to the temporary increase of cask loadings per year. To tackle this challenge, an approach is the cask sealing by the operator in the absence of Euratom and IAEA. An EOSS seal interface was developed to guide the operator through the sealing procedure and confirm its successful termination as a storable message. According to the law of site selection, the operation of the repository might start in 2055 and cease in 2095. Therefore an extension of the dry interim storage period that is currently limited to 40 years will become necessary. This timeline emphasizes the importance of dry interim storage for SF management and the need for long-term reliable unattended Safeguards measures in order to maintain continuity of knowledge. Remote transmission of SG data from the dry storage facilities in Germany to Euratom and IAEA can be regarded as a reasonable step towards this goal. The experiences gained so far with these SG measures will be presented from the German operators' point of view.

The Development of New and Improved Capabilities Applicable to Safeguards

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AWE provides technical expertise to the UK Ministry of Defence (MoD) on the verification of nuclear-related treaties or arms control agreements. This Nuclear Treaty Verification programme is divided into two parts: an element that monitors for nuclear testing in support of the Comprehensive Test Ban Treaty Organization; and an element that conducts research to provide advice on the verification of potential future nuclear-related treaties or agreements.

Under the first programme element, AWE provides the UK's national capability to monitor, analyze and advise on possible nuclear explosions, using radiochemical analysis and forensic seismology. The former in particular is relevant to Safeguards applications: as a thermal ionization mass spectroscopy (TIMS) laboratory, AWE has been a member of the IAEA Network of Analytical Laboratories (NWAL) since 1996; and more recent capability developments at AWE in the fields of secondary ionization mass spectroscopy (SIMS) and scanning electron microscopy (SEM) may in the future lead to an expanded contribution to NWAL. The second element of the Nuclear Treaty Verification programme, which looks to possible future verification requirements, provides advice to MoD on the options for conducting verification activities in future, and develops methods and technologies to support those activities. As with AWE's radiochemistry capability, some or all of these methods and technologies may be transferrable to Safeguards applications.

This paper outlines AWE's views on some the most significant challenges associated with nuclear treaty verification, along with potential solutions that might meet those challenges. It also highlights some of the research activities within the AWE programme that are aimed at delivering particularly high priority capabilities. Our view on necessary areas for future research is discussed.

S18: Challenges in Spent Fuel Verification

A New Approach for the Application of the Self-Interrogation Neutron Resonance Densitometry (SINRD) to Spent Fuel Verifications

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The verification of spent nuclear fuel is one of the activities performed by the International Atomic Energy Agency (IAEA), and the development of innovative non-destructive assays (NDA) is one of the fields of research in the safeguards community.

In this framework the Belgian nuclear research centre SCK-CEN started the investigation of the Self-Interrogation Neutron Resonance Densitometry (SINRD). SINRD is a NDA technique that aims at the direct quantification of the residual 239Pu content in a spent fuel assembly. The technique is proposed in the framework of the Next Generation Safeguards Initiative (NGSI) and is also being studied by Los Alamos National Laboratory (LANL). SINRD relies on detecting the neutron flux attenuation by 239Pu around the 0.3 eV neutron resonance by measuring the neutron flux with detectors covered with Gd and Cd filters. Since it was found that this signature is significantly affected by the presence of water around the fuel elements, a new approach has been proposed within our work.

This contribution starts from the results of a previous feasibility study aimed at a better understanding of the technique. We first compare the performance of different detector types that can be used for the SINRD measurements and from these considerations an optimal range for the thickness of the Gd and Cd filters is identified. The results obtained with these simulations will be used for the assessment of the neutron count rate that can be obtained with realistic measurement conditions, and they will guide the planning of the future benchmark experiments.

Status of LSDS Development for Isotopic Fissile Assay in Used Fuel

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Because of the large amount accumulation of spent fuel, a research to solve the spent fuel problem is actively performed in Korea. One option is to develop the SFR linked with the pyro process to reuse the existing fissile materials in spent fuel. Therefore, an accurate isotopic fissile content assay becomes a key factor in the reuse of fissile material for safety and safeguards purpose. There are several commercial non-destructive technologies for nuclear material assay. However, technology for direct isotopic fissile content assay in spent fuel is not developed yet.

Internationally, a verification of special nuclear material in spent fuel, mainly U-235, Pu239, Pu241, is very important for the safeguards objective. These fissile materials can be misused for nuclear weapon purpose, not for peaceful use. As a future nuclear system is developed,, improved safeguards technology must be developed for an approval of fissile materials. A direct measurement of fissile materials is very important to provide a continuous of knowledge on nuclear materials.

LSDS (Lead Slowing Down Spectrometer) has an advantage to assay an isotopic fissile content directly, without any help of burnup code and history. LSDS system is under development in KAERI (Korea Atomic Energy Research Institute) for spent fuel and recycled fuel. A linear assay model was setup for U235, Pu239 and Pu241. The dominant individual fission characteristic is appeared between 0.1 eV and 1 keV range. An electron linear accelerator for compact and low cost is under development to produce high source neutron effectively and efficiently.

The LSDS is also applicable for optimum design of spent fuel storage and management. The advanced fissile assay technology will contribute to increase the transparency and credibility internationally on a reuse of fissile materials in future nuclear energy system development.

Advances in the Development of a Spent Fuel Measurement Device in Belgian Nuclear Power Plants

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One of the research lines at SCK-CEN is focussed on the investigating experimental methods for the burnup determination of spent fuel elements. In the past a version of the so-called Fork Detector has been designed and built at SCK-CEN and is in use at the Belgian Nuclear Power Plant of Doel. The Fork Detector relies on passive neutron and gamma measurements for the assessment of the burnup and Safeguards verification activities. In this assessment, certain information like initial enrichment of the fuel element, the irradiation history and material composition are supposed to be known operator declared data.

An industry sponsored project is on-going to design and build a measurement system which includes both neutron detectors and a medium resolution gamma rays spectrometer, e.g., a Cadmium Zinc Telluride detector. The response of these two detectors can then be used for the determination of the average and axial burnup, relying less on operator declared data.

This paper summarizes the main findings of the projects and the conclusions that have been reached so far on the design of the new measurement device. In particular the used approach based on MCNP calculations and their optimization to reduce the computation time are discussed.

Gamma Transport Calculations for Gamma Emission Tomography on Nuclear Fuel within the UGET Project

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The unattended gamma emission tomography (UGET) for spent nuclear fuel verification is an on-going project in the IAEA member states' support program. In line with the long term R&D plan of the IAEA Department of Safeguards, it is anticipated that this effort will help develop "more sensitive and less intrusive alternatives to existing NDA instruments to perform partial defect test on spent fuel assembly prior to transfer to difficult to access storage".

In the first phase of the project, gamma transport calculations and modelling of existing and proposed new designs of tomographic instruments is performed. In this paper, a set of Monte Carlo calculations regarding modelling of various tomographic devices are presented, including two existing tomographic instruments previously used for spent fuel measurements; one instrument based on scintillator detectors, developed by Uppsala University, and another based on CdTe detector arrays, developed by the JNT 1510 collaborative effort (Hungary, Finland). Detailed models of the tomographic instruments, including structural materials, and the measured fuel assemblies are used in the simulations. The calculated results are compared to the experimentally measured data to provide a benchmark for the simulation procedure.

The developed modelling capabilities are also used for evaluation of the partial-defect detection capabilities of the tomographic technique based on a proposed GET instrument design.

Performance Evaluation of New Generation CdZnTe Detectors for Safeguards Applications

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Cadmium zinc telluride detectors (CdZnTe) have found a wide application in non-destructive assay measurements in the IAEA's verification practice. It is because of their form factor, usability, sensitivity and good spectral characteristics that they are extensively used for fresh and spent fuel attribute test measurements. Until now, the series of CdZnTe detectors utilized in the IAEA have covered the range of 5 mm^3, 20 mm^3, 60 mm^3 and 500 mm^3 of sensitive volume. Recently, new CdZnTe detectors with improved spectroscopic characteristics and significantly bigger active volume have become available, owing to advances in crystal and detector manufacturing and signal processing technologies. The distinctive feature of this new technological development is the application of a low-intensity monochromatic optical stimulation with infrared (IR) light. The use of IR illumination with a properly chosen wavelength close to the absorption edge of the CdZnTe can significantly improve the performance of the detectors. Recognizing potential benefits of these detectors in safeguards applications, the IAEA has performed an evaluation of their performance characteristics. Under evaluation were several new detectors with sensitive volumes of 500 mm^3, 1500 mm^3 and 4000 mm^3, as well as all-in-one 60 mm^3, 500 mm^3 and 1500 mm^3 integrated micro-spectrometers available from RITEC, Latvia. In addition to the standard performance characteristics, such as energy resolution, peak shape, efficiency, linearity, throughput and temperature stability, the potential use of the detectors for safeguards specific measurements, such as uranium enrichment with infinite thickness method, was of particular interest. The paper will describe the advances in the CdZnTe detector technology and present the results of their performance evaluation.

Initial hiRX Performance Characterization of Pu in Nuclear Spent Fuel Matrix

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A new prototype instrument, hiRX (high resolution X-ray), offers a paradigm shift for plutonium assay in nuclear spent fuel. This new approach offers direct, active, non-destructive interrogation of nuclear spent fuel for plutonium content. This instrument is based upon technology known as monochromatic wavelength dispersive X-rayfluorescence (MWDXRF) which utilizes two doubly curved crystal (DCC) optics. The DCC optics provides monochromatic transmission of X-rays through the crystal. The MWDXRF technology uses one DCC optic for excitation and another for detection of the target analyte, in this case plutonium. The advantage of using monochromatic optics reduces the background and employs selective X-ray energy detection resulting in a high signal-to-noise ratio. The high signal-to-noise ratio offers low detection limits, elimination of radiation background and high selectivity detection for Pu. This highly selective and sensitive method offers a new capability for plutonium quantitative characterization in nuclear spent fuel matrices. This technology has been developed into a prototype production instrument. The prototype instrument offers enhanced safety by using only a 4 microlitre sample of nuclear spent fuel solution. This low amount of solution significantly reduces the radiation exposure for the operator as well as reducing the amount of waste which needs to be disposed. A measurement can be obtained within 10 minutes of receiving the sample which is achieved by simply pipetting the volume into a disposable plastic sample cell. The operation is straightforward with results displayed in g/ℓ of uranium. The expected uncertainty performance of the hiRX prototype instrument is around 5%. The ultimate uncertainty goal is less than 1% which can be achieved through further refinement and development of improved hardware and software. LA–UR–14–22443

Gamma-Ray Emission Tomography: Modeling and Evaluation of Partial-Defect Testing Capabilities

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Gamma emission tomography (GET) for spent nuclear fuel verification is the subject for IAEA MSP project JNT1955. In line with IAEA Safeguards R&D plan 2012-2023, the aim of this effort is to "develop more sensitive and less intrusive alternatives to existing NDA instruments to perform partial defect test on spent fuel assembly prior to transfer to difficult to access storage". The current viability study constitutes the first phase of three, with evaluation and decision points between each phase. Two verification objectives have been identified; (1) counting of fuel pins in tomographic images without any a priori knowledge of the fuel assembly under study, and (2) quantitative measurements of pin-by-pin properties, e.g., burnup, for the detection of anomalies and/or verification of operator-declared data.

Previous measurements performed in Sweden and Finland have proven GET highly promising for detecting removed or substituted fuel rods in BWR and VVER-440 fuel assemblies even down to the individual fuel rod level. The current project adds to previous experiences by pursuing a quantitative assessment of the capabilities of GET for partial defect detection, across a broad range of potential IAEA applications, fuel types and fuel parameters. A modelling and performance-evaluation framework has been developed to provide quantitative GET performance predictions, incorporating burn-up and cooling-time calculations, Monte Carlo radiation-transport and detector-response modelling, GET instrument definitions (existing and notional) and tomographic reconstruction algorithms, which use recorded gamma-ray intensities to produce images of the fuel's internal source distribution or conclusive rod-by-rod data. The framework also comprises image-processing algorithms and performance metrics that recognize the inherent tradeoff between the probability of detecting missing pins and the false-alarm rate. Here, the modelling and analysis framework is described and preliminary results are presented.

Experimental Assessment of a New Passive Neutron Multiplication Counter for Partial Defect Verification of LWR Fuel Assemblies

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The development of non-destructive assay (NDA) capabilities to improve partial defect verification of spent fuel assemblies is needed to improve the timely detection of the diversion of significant quantities of fissile material. This NDA capability is important to the implementation of integrated safeguards for spent fuel verification by the International Atomic Energy Agency (IAEA) and would improve deterrence of possible diversions by increasing the risk of early detection. A new NDA technique called Passive Neutron Multiplication Counter (PNMC) is currently being developed at Los Alamos National Laboratory (LANL) to improve safeguards measurements of Light Water Reactor (LWR) fuel assemblies. The PNMC uses the ratio of the fast-neutron emission rate to the thermal-neutron emission rate to quantify the neutron multiplication of the item. The fast neutrons versus thermal neutrons are measured using fission chambers (FC) that have differential shielding to isolate fast and thermal energies. The fast-neutron emission rate is directly proportional to the neutron multiplication in the spent fuel assembly; whereas, the thermal-neutron leakage is suppressed by the fissile material absorption in the assembly. These FCs are already implemented in the basic Self-Interrogation Neutron Resonance Densitometry (SINRD) detector package. Experimental measurements of fresh and spent PWR fuel assemblies were performed at LANL and the Korea Atomic Energy Research Institute (KAERI), respectively, using a hybrid PNMC and SINRD detector. The results from these measurements provides valuable experimental data that directly supports safeguards research and development (R&D) efforts on the viability of passive neutron NDA techniques and detector designs for partial defect verification of spent fuel assemblies.

Development of "Fission Chamber Free" Fork Detector (FDET) for Safeguards Measures on LWR Spent Fuel Assemblies

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As a part of light water reactor (LWR) spent fuel verification technology improvement, the IAEA developed a Fork Detector (FDET) in which neutron detectors were changed from fission chambers (FCs) to boron-10 (B-10) lined proportional counters in order to avoid the difficulties in the transportation and deployment of fission chambers containing fissile materials.

The validation experiment to investigate the features and performance of a prototype FDET with B-10 counters was carried out at the pressurized water reactor (PWR) spent fuel storage pond of Ulchin nuclear power plant (NPP) in the Republic of Korea in June 2011 in the framework of Member State Support to the IAEA, and the results promised that FDET with shielded B-10 counters could be applied for neutron detection of PWR spent fuel assemblies cooled over three years.

The IAEA is currently applying B-10 counter based FDET(B10) for the implementation of safeguards measures on the LWR spent fuel assemblies during the transfer campaign prior to loading into the transfer cask to move from wet to dry storage at the commercial NPP. The traditional fission chamber based FDET(FC) is continuously used as a safeguards measure to resolve core fuel anomalies because the extremely high gamma dose of freshly discharged core fuel assemblies exceeds the application limit of FDET(B10).

Application of Passive Gamma-ray Spectroscopy for Special Nuclear Material Accountancy in Molten Core Material of Fukushima Dai-ichi Nuclear Power Plant

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For the nuclear material accountancy of molten core material in Fukushima Daiichi unit 1, 2 and 3, feasibility studies of variety of technologies are being performed in JAEA. As one of the technologies, feasibility study of passive gamma spectroscopy of low-volatile fission products (FPs) for nuclear material accountancy in molten core material has been performed with reviewing TMI-2 experience, and the correlation of actinides and FPs inventory in BWR spent fuel was reported, considering the sensitivity of axial neutron spectrum, void, burnup, enrichment distribution unique to BWR fuel.

In the present paper, numerical simulation of leakage gamma-ray from molten core materials in hypothetical canister is dealt with for determination of radioactivity of low-volatile high-energy emission FPs, which could be utilized for special nuclear material (SNM) quantity estimation coupling with SNM/FPs ratio derived from core inventory calculation. The model of canister is assumed based on the fuel type one in used TMI-2 for gamma-ray leakage calculation, with 3 main geometrical regions; canister, surrounding water/air and shielding/collimator for detectors. Homogeneous loading model of molten core material and water/air is taken as a reference model as same as TMI-2 core bore cases, and patterns of loading model are also evaluated, and the effectiveness of several attenuation correction techniques and the detector applicability are compared.

The coexistence of SNM and index FP is essential condition in case of using this methodology. As a consideration, even with their low-volatility of, for example, lanthanides such as cerium and europium, small but non-zero volatility, local migration inside debris and dissolution to cooling water must be considered.

Uncertainty Quantification of Fork Detector Measurements from Spent Fuel Loading Campaigns

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With increasing activities at the end of the fuel cycle, the requirements for the verification of spent nuclear fuel for safeguards purposes are continuously growing. In the European Union we are experiencing a dramatic increase in the number of cask loadings for interim dry storage. This is caused by the progressive shut-down of reactors, related to facility ageing but also due to politically motivated phase-out of nuclear power. On the other hand there are advanced plans for the construction of encapsulation plants and geological repositories. The cask loading or the encapsulation process will provide the last occasion to verify the spent fuel assemblies.

In this context, Euratom and the US DOE have carried out a critical review of the widely used Fork measurements method of irradiated assemblies. The Nuclear Safeguards directorates of the European Commission's Directorate General for Energy and Oak Ridge National Laboratory have collaborated to improve the Fork data evaluation process and simplify its use for inspection applications. Within the Commission's standard data evaluation package CRISP, we included a SCALE/ORIGEN-based irradiation and depletion simulation of the measured assembly and modelled the fork transfer function to calculate expected count rates based on operator's declarations. The complete acquisition and evaluation process has been automated to compare expected (calculated) with measured count rates. This approach allows a physics-based improvement of the data review and evaluation process. At the same time the new method provides the means for better measurement uncertainty quantification.

The present paper will address the implications of the combined approach involving measured and simulated data to the quantification of measurement uncertainty and the consequences of these uncertainties in the possible use of the Fork detector as a partial defect detection method.

A Prototype for Passive Gamma Emission Tomography

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Combined efforts of multiple stakeholders of the IAEA Support Programme task JNT 1510: "Prototype of passive gamma emission tomograph (PGET)", resulted in the design, manufacturing and extensive testing of an advanced verification tool for partial defect testing on light water reactor spent fuel. The PGET has now reached a proven capability of detecting a single missing or substituted pin inside a BWR and VVER-440 fuel assemblies.

The task started in 2004 and it is planned to be finished this year. The PGET head consists of two banks of 104 CdTe detectors each with integrated data acquisition electronics. The CdTe detectors are embedded in tungsten collimators which can be rotated around the fuel element using an integrated stepping motor mounted on a rotating table. All components are packed inside a toroid watertight enclosure. Control, data acquisition and image reconstruction analysis is fully computerized and automated. The design of the system is transportable and suitable for safeguards verifications in spent fuel ponds anywhere.

Four test campaigns have been conducted. In 2009, the first test in Ringhals NPP failed collecting data but demonstrated suitability of the PGET for field deployments. Subsequent tests on fuel with increasing complexity were all successful (Ispra, Italy (2012), Olkiluoto, Finland (2013) and Loviisa, Finland (2014)).

The paper will present the PGET design, results obtained from the test campaigns and mention also drawbacks that were experienced in the project. The paper also describes further tests which would allow evaluating the capabilities and limitations of the method and the algorithm used. Currently, the main technical shortcoming is long acquisition time, due to serial control and readout of detectors. With redesigned electronics it can be expected that the system would be able to verify a VVER-440 assembly in five minutes, which meets the IAEA user requirements.

U and Pu Gamma-Ray Measurements of Spent Fuel Using a Gamma-Ray Mirror Band-Pass Filter

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We report the use of grazing incidence gamma-ray mirrors as narrow band-pass filters for advanced non-destructive analysis of spent nuclear fuel. The mirrors limit radiation reaching an HPGe detector to narrow spectral bands around characteristic emission lines from fissile isotopes in the fuel. Ideally, these emissions could be used to determine the fuel's fissile content, but they are normally masked by the overwhelming radiation emitted by short-lived fission by-products. These latter emissions raise the overall background, making direct observation of the fuel with HPGe detectors virtually impossible. Such observations can only be performed using precise collimators that restrict the detector's field of view to very small solid angles. This results in impracticably long dwell times for safeguards measurements targeting the weak isotopic lines of interest. In a proof-of-concept experiment, a set of simple flat gamma-ray mirrors was used to observe the atomic florescence lines from U and Pu from a spent nuclear fuel pin. For the measurements, the mirrors were placed at the egress of an access port in a hot cell wall. A coarse collimator in the port restricted radiation from a fuel pin placed in front of the port to fully illuminate the front surface of the mirror assembly (0.5×3.8 cm^2). The mirrors, consisting of highly polished silicon substrates deposited with WC/SiC multilayer coatings, were successfully used to deflect the lines of interest onto an HPGe detector while the intense primary radiation from the spent fuel was blocked by a lead beam stop. The gamma-ray mirror multilayer coatings used here at $\sim$100 keV, have been experimentally tested at energies as high as 645 keV, indicating that direct observation of nuclear emission lines from 239Pu should be possible with an appropriately designed optic.

S19: Advanced Technologies for Safeguards Communications

Mobile Workforce, Mobile Technology, Mobile Threats

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Mobile technologies' introduction into the world of safeguards business processes such as inspection creates tremendous opportunity for novel approaches and could result in a number of improvements to such processes. Mobile applications are certainly the wave of the future. The success of the application ecosystems has shown that users want full fidelity, highly-usable, simple purpose applications with simple installation, quick responses and, of course, access to network resources at all times. But the counterpart to opportunity is risk, and the widespread adoption of mobile technologies requires a deep understanding of the threats and vulnerabilities inherent in mobile technologies.

Modern mobile devices can be characterized as small computers. As such, the threats against computing infrastructure apply to mobile devices. Meanwhile, the attributes of mobile technology that make it such an obvious benefit over traditional computing platforms all have elements of risk: pervasive, always-on networking; diverse ecosystems; lack of centralized control; constantly shifting technological foundations; intense competition among competitors in the marketplace; the scale of the installation base (from millions to billions); and many more.

This paper will explore the diverse and massive environment of mobile, the number of attackers and vast opportunities for compromise. The paper will explain how mobile devices prove valuable targets to both advanced and persistent attackers as well as less-skilled casual hackers. Organized crime, national intelligence agencies, corporate espionage are all part of the landscape.

Secure Communications with Mobile Devices During In-Field Activities

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One of the classic problems in information security is how to exchange confidential information securely in uncontrolled environments. There have been innumerable academic and commercial hours spent resolving this question. In traditional practice, securing communications meant investing in satellites, specialized hardware, rigorous security engineering and testing, and expending a lot of resources. For this reason, smaller organizations have often been unable to secure communications.

The widespread adoption of mobile communications and the modern mobile device has brought about unprecedented abilities to stay connected with colleagues during work activities. As connectedness has increased, so have the opportunities for information compromise. The enormous mobile landscape, with competing ecosystems, large research and product development budgets, proliferating devices, and rapidly-shifting technical foundations prove to be a tremendous source of both opportunity and risk.

With the reality of shrinking budgets and increasing threats, many organizations, commercial enterprises, and product vendors are looking for new ways to utilize existing resources for secure communications and mobile work capabilities. Keeping communications private and secure using the infrastructure of the world's telecommunications network and standard computing and mobile devices is the challenge.

This paper will examine some methods for communicating securely using consumer mobile products and evaluate the risk such tools can present to an organization in the context of inspection work in the field.

The Secure Information Exchange (SIX) Project at the OPCW

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The Chemical Weapons Convention (CWC) entered into force in 1997 and the member states of the Organisation for the Prohibition of Chemical Weapons (OPCW) have obligations for making declarations under various articles of the convention. These declarations could contain confidential information and until recently the only mechanism to submit confidential information to the OPCW Technical Secretariat was through physical delivery by the permanent representatives of the member states which introduced delays in the exchange of information in general.

In 2012, the Technical Secretariat initiated a strategic project to establish a secure electronic transmission channel that could be used as an alternative option for the exchange of information between the Technical Secretariat and the member states. The Secure Information Exchange (SIX) Project has been given priority by the Director-General and it received support from the member states. A core project team comprising representatives of the main business unit, the office of legal affairs, IT security and implementation teams were established. Following a feasibility study and with continuous communication with the representatives of the member states, the pilot phase of the project was completed successfully in 2013. In the near future, the project will go live and the member states and the Technical Secretariat will benefit from this key initiative.

This paper aims to provide an overview of the project: the solution approach, data gathered in order to assess the delays in communication through traditional means, IT security and implementation issues as well as the legal considerations.

Establishing and Advancing Electronic Nuclear Material Accounting Capabilities: A Canadian Perspective

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Under safeguards agreements that the Government of Canada has with the International Atomic Energy Agency (IAEA), and nuclear cooperation agreements with other states, the Canadian Nuclear Safety Commission (CNSC) is required to track the inventory and movement of all safeguarded material. As safeguards programmes evolve, including the implementation of Integrated Safeguards, the scope of the reporting requirements for facilities within Canada has also increased. At the same time, ensuring the secure transmission of the associated data continues to be an overarching factor. The changes that are occurring in the nuclear material accounting (NMA) landscape have necessitated a modernization of Canada's accounting and reporting system, with the objective of creating a more effective and efficient system, while at the same time maintaining the security of prescribed information. After a review of the environment, the CNSC embarked on a project that would encourage facilities to transition away from traditional modes of NMA reporting and adopt an electronic approach. This paper will discuss how the changes to Canada's NMA infrastructure were identified and implemented internally to allow for optimized electronic reporting. Improvements included the development of the regulatory and guidance documents, the overhaul of the reporting forms, the upgrade of the CNSC's NMA database, and the development of an electronic reporting platform that leveraged existing technologies. The paper will also discuss the logistics of engaging stakeholders throughout the process, launching the system and soliciting feedback for future system improvements. Special consideration will be given to the benefits realized by both the CNSC and facilities who have voluntarily embraced electronic reporting. The final objective of this paper will be to identify the challenges that were faced by the CNSC and the nuclear industry as the system changes were implemented and to highlight how these obstacles were overcome or will be addressed.

The STAR System-A Computer Software for Accountancy and Control

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The development of the STAR system started within the Swedish support programme for NIS countries. Improvements to the system have been made and the family of STAR software now includes software for SSAC as well as software nuclear power plants, research reactors, bulk handling facilities, storages and LOFs. The programmes are developed for use on PC and are designed for usage in a network.

The systems are usually tailored according to the needs of a specific country and/or facility and contain additional functions that a state authority require in addition to reporting to the IAEA. The reporting module is able to report to the IAEA in Code 10 labelled format but can also report in fixed format depending on agreement.

General Features:

- Generic design,
- Module Built to be able to easy add new functions and specific needs,
- Menu driven System,
- Minimum data entering requirements,
- Data bases are automatically updated,
- Advanced QC System,
- Powerful Filter Functions (Enhanced SQL type),
- Possibility to export/import data from other languages,
- Data easy to access for other applications,
- Possibility to easily make correction records,
- Automatic creation of necessary documents,
- Designed for Advanced Electronically communication,
- Built-in backup system.,
- Fuel maps can be generated for NPP's and storages.

Reports for inspection purposes, design features: The programmes have been designed to be a powerful working tool for the user and are designed to be extremely easy to handle and at the same time give the operator the maximal power of searches, calculations and reports that a modern advanced system can produce. The programme is designed for a multi-user environment in a network with different access levels. A special designed system, covering just the SSAC part and LOFs, can be provided to make the reporting very easy for states without an extensive nuclear program.

e-Gamma: Nuclear Material Accountancy and Control System in Brazil

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The Brazilian Nuclear Energy Commission (CNEN) is the government organization responsible for regulating all nuclear activities in Brazil and for ensuring that international safeguards are implemented according to the international agreements.

In 2006 CNEN initiated a project aiming at the development and implementation of a web based system (e-Gamma) for on line nuclear material accountancy and control. In January-2014, after three years of beta testing, e-Gamma finally became the official nuclear material accountancy system in Brazil. e-Gamma is a web system hosted in a dedicated server under a secure environment maintained at CNEN headquarters. Secure access is provided by the use of Digital Client Certificate and internal user pre-authorization for login as well as multiple access profiles each one with specific function menus.

The System operation is based on source documents for each inventory change prepared and updated by the MBA operators with the help of specific forms with strong validations. After the document conclusion the System records the inventory change in a general ledger. Monthly the officers of CNEN analyzes the general ledgers of each MBA and generates the applicable reports through the System [Inventory Change Reports (ICR), Physical Inventory List (PIL), and Material Balance Report (MBR)].

The System allows the running of managerial queries and has brought to CNEN much more control and traceability of the inventory changes and significant reduction in typing errors, costs and inspection efforts. Therefore, more efficient accountancy verification procedures at national and international levels are expected, as well as remote accountancy verification previous to an inspection.

The proposed paper will describe the e-Gamma System, its main features and the oral presentation will contain a brief demonstration of some functionalities through the use of a local version installed on a notebook.

Testing The Enhanced Data Authentication System (EDAS)

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The Enhanced Data Authentication System (EDAS) is a secure branching concept that provides a safeguards inspectorate a copy of measurement data from operator instrumentation. Both safeguards inspector and facility operator requirements for secure branching have been established in previous work. These dictated the design and development of EDAS hardware and software. This paper presents the test plan for the EDAS prototypes, which need to demonstrate performance against the identified requirements.

Sandia National Laboratories (SNL), Directorate-General for Energy (DG-Energy) in Luxembourg, and the Joint Research Centre (JRC) in Ispra will each perform different tests on the EDAS prototypes. Sandia, the developer, will perform comprehensive testing of functionality, robustness, and reliability. The JRC, as an independent technical organization, will evaluate electrical safety and other environmental factors important to facility operator acceptance. The JRC is also able to simulate field trial conditions using equipment similar to what will be used in the field trial. DG-Energy will confirm the Sandia tests and also test the interface of the EDAS prototype to the RADAR data acquisition and analysis system used by the Euratom inspectorate.

The EDAS prototypes will be tested in a comprehensive field trial at the Westinghouse Springfields facility in a collaboration between Euratom inspectors and the facility operator. The field trial will support barcode and weight measurements taken related to the movements of nuclear material items entering and exiting the facility. One EDAS prototype will branch barcode scanner data, while the other will branch facility weight scale data. The branched data will be sent securely to an inspector computer, accessible to a Euratom inspector for data analysis. The field trial will test operational factors and environmental conditions. A critical outcome will be to ascertain whether the inspectorate gains an accurate picture of the facility operation via the branched information channel.

Next Generation Surveillance System (NGSS): Field Implementation & Associated Developments

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The NGSS is the product of more than five years of development between the IAEA, other Inspectorates, Member State Support Programmes, and commercial vendors. The product of these efforts has now matured into the field implementation stage. This paper details the goals, achievements and challenges experienced during the implementation phase and associated developments of the project.

NGSS procurement was subject to the IAEA's stringent procurement policies involving independent third party assessments to assure supplier reliability and competitive pricing controls. More than 1200 surveillance cameras currently installed in facilities worldwide will be replaced by NGSS within the next 4 to 5 years. Joint use procedures have been established taking advantage of the technical capabilities integrated within the design of the NGSS which allow for multiple inspectorates and States to securely and independently share and review data.

Utilization of outdated facility infrastructure poses many challenges to implementation efforts; these were met with innovative technical solutions to take advantage of cost-benefits allowed in its re-utilization. New partnerships were established with Member States, regulatory bodies and nuclear power plant operators for new nuclear facilities under construction, to address infrastructural requirements spanning the next half century.

The utilization of the IAEA's well-established PKI infrastructure enhances data security features and usability with regard to data sharing, key management and joint use of the NGSS system data. Embedded inventory reporting capability aids electronic inventory verification of safeguards equipment, simplifying accountability, configuration control and troubleshooting of installed systems.

Current developments ongoing within the project include the design of hardware and software components for use of the system in special applications (e.g., underwater and outdoor installations, mechanism to authenticate external sensors). The lessons learned within the project can contribute a great deal to future developments and continued implementation efforts.

An Integrated Passive (Battery-Free) Seals-and-Tag for International Safeguards

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The ability to reliably and securely automate the monitoring of SNM is an important goal in Safeguards. Although item level monitoring of SNM requires both seal and tag technologies, the two technologies thus far have been developed more or less independently, and had been a lack of an integrated compact system. An integrated seal-and-tag approach not only aids inspectors to perform their tasks effectively, this approach also allows real-time inspection in large scale facilities. A typical facility could be the size of a large warehouse with hundreds or thousands of items that need to be sealed and monitored in real-time.

Previously we reported on advanced secure RF passive (battery-less) tags with special features including, long-range interrogation of passive tags, communicating with passive tags with strong encryption and dynamic authentication features, and the ability to place the tags directly on metal objects. In this paper, we report on a novel secure passive tag integrated with fibre optics seal that allows real-time monitoring of items through secure wireless communications that employs AES encryption and dynamic authentication. Furthermore, the devices can be networked for large scale operations.

The proposed passive seal has the same capabilities as active seals in that it allows real-time monitoring. However, the battery lifetimes of conventional active seals are limited or unpredictable. As the long-term storage of SNM might last for several years, these passive seals having been integrated with passive RF tags, extends the lifetime of the physical seals and tags indefinitely, while getting the same performance of active seals and tags. The integrated seal-and-tag is transformational in addressing a critical need in Safeguards area for long-term real-time monitoring.

Use of Electronic Seals and Remote Data Transmission to Increase the Efficiency of Safeguards Applied in a Static Plutonium Store

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The Pu timeliness has been the deciding factor for determining the frequency of inspections at static Pu stores. The scope of these inspections concerns, mainly, seals replacements and video review. Using electronic seals together with remote data transmission (RDT) can significantly reduce the need for the physical presence of inspectors on site.

For a static Pu store in Sellafield, jointly inspected by the EC and the IAEA, special covers were developed which prevent inadvertent damage to the group sealing array which has now been attached to the channel charge face. Electronic (EOSS) and Cobra group seals were applied that ensure minimal loss of knowledge in the event of any individual seal failures. At present, the EOSS seals are verified from Luxembourg once a week with seal status data forwarded to the IAEA. Surveillance images can be used to investigate any issues with seals data. If an issue cannot be resolved by performing a video review, a physical inspection will be necessary to perform verification activities as needed.

Under the new safeguards approach, the operator announces all planned visits to the store for maintenance and other planned work well in advance by sending an email to an agreed mailbox. This gives the inspectorates the possibility to participate in case they are present on site for other activities or in case they see a need.

The use of RDT makes it possible for the regulators to replace monthly inspections with seal data checks at their respective HQ, supplemented by periodic design information verification, at low frequency to ensure the continuing integrity of the system. It is expected that the overall efficiency gain will be substantial for both inspectorates, while for the operator the burden of physical inspections is reduced leading to savings in terms of personnel resources and increased operational flexibility.

Cyber Security Evaluation of the Wireless Communication for the Mobile Safeguard Systems in Nuclear Power Plants

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This paper introduces cyber security evaluation results and a design of the wireless communication technology to apply to safeguard systems in nuclear power plants. While wireless communication technologies can generally make mobility and efficiency on plant operation, those have seldom been installed on the nuclear I&C systems due to the negative concern of unexpected outcomes that stem from electromagnetic interference and cyber attack. New design of advanced digital safeguard and I&C systems uses computer-based systems for the safeguard and safety functions. On the other hand, those are being exposed to various types of new and existing cyber threats, vulnerabilities and risks which significantly increase the likelihood that those could be compromised. In order to employ the wireless communication technology in safeguard function, licencees assess and manage the potential for adverse effects on safeguard and safety functions so as to provide high assurance that critical functions are properly protected cyber attack. It is expected that the safeguard function, specifically on the area of real-time monitoring, logging, can be enhanced by employing the mobile safeguard devices (: smart phone, laptop, smart pad, etc). In this paper, we deal with the cyber security evaluation, which consists of threat analysis, vulnerability test, establishment of security plan, and design solutions for the wireless communication on the basis of IEEE 802.11(Wi-Fi) protocol. Proposed evaluation and design solution could be a basis for the design of wireless communication and mobile safeguard systems in nuclear power plants.

Front-End Electronics for Verification Measurements: Performance Evaluation and Viability of Advanced Tamper Indicating Measures

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The International Atomic Energy Agency (IAEA) continues to expand its use of unattended, remotely monitored measurement systems. An increasing number of systems and an expanding family of instruments create challenges in terms of deployment efficiency and the implementation of data authentication measures. A collaboration between Pacific Northwest National Laboratory (PNNL), Idaho National Laboratory (INL), and Los Alamos National Laboratory (LANL) is working to advance the IAEA's capabilities in these areas. The first objective of the project is to perform a comprehensive evaluation of a prototype front-end electronics package, as specified by the IAEA and procured from a commercial vendor. This evaluation begins with an assessment against the IAEA's original technical specifications and expands to consider the strengths and limitations over a broad range of important parameters that include: sensor types, cable types, and the spectrum of industrial electromagnetic noise that can degrade signals from remotely located detectors. A second objective of the collaboration is to explore advanced tamper-indicating (TI) measures that could help to address some of the long-standing data authentication challenges with IAEA's unattended systems. The collaboration has defined high-priority tampering scenarios to consider (e.g., replacement of sensor, intrusion into cable), and drafted preliminary requirements for advanced TI measures. The collaborators are performing independent TI investigations of different candidate approaches: active time-domain reflectometry (PNNL), passive noise analysis (INL), and pulse-by-pulse analysis and correction (LANL). The initial investigations focus on scenarios where new TI measures are retrofitted into existing IAEA UMS deployments; subsequent work will consider the integration of advanced TI methods into new IAEA UMS deployments where the detector is separated from the front-end electronics. In this paper, project progress on both the prototype evaluation and the exploration of advanced TI measures are described.

Current Research on Containment Technologies for Verification Activities: Advanced Tools for Maintaining Continuity of Knowledge

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The U.S. National Nuclear Security Administration (NNSA) Office of Non-proliferation and Verification Research and Development currently funds research on advanced containment technologies to support Continuity of Knowledge (CoK) objectives for verification regimes. One effort in this area is the Advanced Tools for Maintaining Continuity of Knowledge (ATCK) project. Recognizing that CoK assurances must withstand potential threats from sophisticated adversaries, and that containment options must therefore keep pace with technology advances, the NNSA research and development on advanced containment tools is an important investment. The two ATCK efforts underway at present address the technical containment requirements for securing access points (loop seals) and protecting defined volumes.

Multiple U.S. national laboratories are supporting this project: Sandia National Laboratories (SNL), Savannah River National Laboratory (SRNL), and Oak Ridge National Laboratory (ORNL). SNL and SRNL are developing the "Ceramic Seal," an active loop seal that integrates multiple advanced security capabilities and improved efficiency housed within a small-volume ceramic body. The development includes an associated handheld reader and interface software. Currently at the prototype stage, the Ceramic Seal will undergo a series of tests to determine operational readiness. It will be field tested in a representative verification trial in 2016. ORNL is developing the Whole Volume Containment Seal (WCS), a flexible conductive fabric capable of enclosing various sizes and shapes of monitored items. The WCS includes a distributed impedance measurement system for imaging the fabric surface area and passive tamper-indicating features such as permanent-staining conductive ink. With the expected technology advances from the Ceramic Seal and WCS, the ATCK project takes significant steps in advancing containment technologies to help maintain CoK for various verification regimes, including international nuclear safeguards.

S20: Frameworks for Monitoring the Quality of the Operator's Measurement and Accounting Systems

Role and Successes of Trilateral Liaison Frameworks (IAEA-SSACs/RSACs- Nuclear Fuel Cycle Facility Operators) in Monitoring the Quality of the Operator's Measurement and Accounting Systems

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Two of the three generic objectives of safeguards under a comprehensive safeguards agreement (CSA) are to detect any undeclared production or processing of nuclear material in declared facilities and locations outside facilities (LOFs) and to detect any diversion of declared nuclear material at facilities and LOFs. The effectiveness and efficiency of the IAEA in reaching these objectives strongly relies on the quality of the State or regional system of accounting for and control of nuclear material (SSAC/RSAC) which in turn depends on the nuclear fuel cycle facility operators' capabilities to establish accurate and precise estimates of the inventories and flow of nuclear material.

To monitor the performance of the State's nuclear fuel cycle facilities' accounting and measurement systems in a collaborative way, the IAEA initiated yearly trilateral liaison meetings with relevant State or regional authorities and bulk handling facilities' operators to review material balance evaluation results for the elapsed material balance period and their trends over the facility lifetime. During these meetings, trends of concern are examined and the IAEA proposes remedial actions, drawing on its expertise and experience of observations in similar facilities.

Pilot trilateral meetings held in Japan over the past years demonstrate the benefits of this collaborative framework. Biases in material balance variables are identified, their causes determined and a set of recommendations is drawn to implement remedial actions before they become a safeguards concern. In the margins of these meetings, workshops are also organised to foster exchanges in the fields of measurement and analytical methods as well as statistical methodologies used to determine their uncertainties and assess the sensitivity of material balances to these uncertainties. In the context of its strategy to enhance cooperation with States, reinforce mutual trust and pursue further efficiencies though collaboration and synergy, the IAEA hopes to extend these trilateral exchanges to all SSACs/RSACs.

Ensuring Solid, Transparent and Scientifically Sound Material Balance Evaluation (MBE) Practice in the EC through Collaboration between Regulators, Operators and the Scientific Safeguards Community

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The European Commission (COM) and the International Atomic Energy Agency (IAEA) have a long-standing and well-established cooperation based on multilateral comprehensive Verification Agreements. The two organisations' inspectorates coordinate the implementation of EURATOM and international safeguards in the territory of the European Union (EU) as well as their communication with operators and State authorities in the EU with regard to safeguards performance.

In this paper, the elements of Material Balance Evaluation (MBE) as practiced by the European Commission are presented. The use of a facility-tailored flexible approach to evaluate the main material balance evaluation parameters combined and strengthened with elements of audit methodologies are further elaborated upon. An outline on how IT (and especially the dedicated EURATOM inspection software 'VARO') can help to ensure a coherent implementation, documentation, evaluation, effective follow-up, and data input from the operators is also included.

The paper emphasizes the consultative element between EURATOM, the IAEA and nuclear operators as well as the importance of a comprehensive debriefing following independent evaluation by both regulators. A description of the legal framework, the core processes, and the interaction between EURATOM, the IAEA and operators for arriving at appropriate safeguards conclusions sets the context for the MBE.

Technical Review of Operator's Destructive Analyses at the Rokkasho Reprocessing Plant: Strengthening the Transparency of the Operator's Measurement System

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The Rokkasho Reprocessing Plant is a large-scale nuclear facility in Japan. For the purposes of process control, product management and nuclear material accountancy for safeguards purposes, the laboratory of the facility operator analyzes thousands of samples from various process streams and with a multitude of matrices. Transparency of operational procedures, quality control measures and sample analytical results among the facility operator and state and international safeguards authorities are required to assess the facility operator's measurement system, and thus to assure a credible safeguards approach. The facility operator, Japan Nuclear Fuel, Limited (JNFL), is engaged in continuous improvement of its nuclear material analyzes. For the declarations to the inspectorates, it is important that JNFL and the safeguards authorities be able to confirm that the analytical methods used by JNFL are reliable and meet the latest version of the International Target Values. Since 2012 JNFL, the IAEA and the SSAC have carried out several technical reviews of the destructive analysis (DA) processes as a means of strengthening the transparency of the DA measurement systems. The goal of the DA technical reviews is to (1) assess past commitments of the JNFL plan for analytical improvement, (2) review the JNFL Quality System by means of documentation reviews and in-field demonstrations, and (3) review the analytical performance of the JNFL lab through its own results or from inter-laboratory comparison exercises. Throughout this process, subject-matter experts from all organizations met with JNFL laboratory staff and discussed analytical concerns and solutions. The outcome of these technical reviews was a series of recommendations to JNFL for strengthening its plan for continuous improvement. This paper presents the methodology of the DA technical reviews, the communication scheme and some examples of the outcome for JNFL to improve its DA methods and analytical performance.

Continuous Analytical Performances Monitoring at the On-Site Laboratory through Proficiency, Inter-Laboratory Testing and Inter-Comparison Analytical Methods

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Since 2008, as one measure to strengthen its quality management system, the On-Site Laboratory for nuclear safeguards at the Rokkasho Reprocessing Plant, has increased its participation in domestic and international proficiency and inter-laboratory testing for the purpose of determining analytical method accuracy, precision and robustness but also to support method development and improvement. This paper provides a description of the testing and its scheduling. It presents the way the testing was optimized to cover most of the analytical methods at the OSL. The paper presents the methodology used for the evaluation of the obtained results based on Analysis of variance (ANOVA). Results are discussed with respect to random, systematic and long term systematic error.

S21: IAEA-State Cooperation I

The Nuclear Safeguards and Security Activities under Euratom Research and Training Programme

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Nuclear safeguards and security are absolute priorities for the EU. At technical level, the Joint Research Centre (JRC) as the European Commission's in-house science service plays an important role in the field of nuclear research, training and education that include nuclear safety, safeguards and security. The JRC's nuclear research activities are defined in a Council Regulation on the research and training programme of the European Atomic Energy Community.

The JRC works closely with EC safeguards authority, whose mission is to ensure that nuclear material within the EU is not diverted from its intended use according to Euratom treaty. Technologies, methodologies and trainings are developed according to the Euratom Safeguards inspectorate's needs.

In the area of nuclear security, the JRC contributes to the development of specific expertise in the field of nuclear forensics and border security detection as well as related training efforts for first front-line responders and national experts. The JRC provides its expert support for the implementation of internal EU action plans mainly in the field of radiological and nuclear security.

At an international level, the JRC cooperates with the IAEA mainly through the EC support programme on the control of nuclear materials and facilities in order to avoid proliferation or diversion. Close cooperation with IAEA nuclear security is developed through the recent signature of a dedicated practical arrangement. Key partnerships have also been developed in the field of safeguards and security with the US-DoE, Russia, Japan and China.

In addition, JRC contributes significantly to the EU nuclear safeguards and security outreach activities implemented under the Instrument for Nuclear Safety Cooperation and Instrument contributing to Stability and Peace.

In this paper we will highlight some of the JRC contributions to the enhancement of nuclear safeguards and security at EU and international levels.

Cooperation in the Implementation of Safeguards at Fukushima Dai-ichi Site

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The accident at Fukushima Dai-ichi Nuclear Power Station caused by the Great East Japan Earthquake and tsunami in March 2011 had a major impact on the safeguards situation at the site. JSGO, NMCC, TEPCO and JAEA are tackling the challenges posed by the accident jointly with the IAEA and in cooperation with the US Department of Energy (DOE).

From the day of the earthquake, JSGO and the IAEA have shared information on decommissioning activities and discussed how to deal with this difficult issue. In May 2012, the Fukushima Task Force was established. Its objective is to develop a holistic approach to safeguards implementation measures for the site, to monitor the re-establishment of safeguards, to facilitate discussion of relevant issues, and to consider possible approaches to longer-term safeguards challenges.

All the fuels in spent fuel ponds in Units 5 and 6 and Common Spent Fuel Storage have been successfully re-verified. Re-verification of fuels kept in spent fuel pond in Unit 4 is underway. A special arrangement called SNOS (Short Notice Operational Support Activities) has been introduced to confirm non-diversion of declared material at Fukushima Dai-ichi site. Based on extensive information exchange, proactive discussions on safeguards approaches are being held for near-term issues.

The damaged core material in Units 1-3 will pose extreme difficulties in longer-term. A special sub-group has been established under the task force to address the issues. Although lessons learned from past nuclear accidents resulting in damage of core material have some relevance, none of them can be directly applicable for Fukushima. Thus a foresighted and creative approach is needed. Close coordination with the IAEA and support from technically competent institutions in Japan and from abroad, such as DOE, are also essential to tackle the issues.

Engagement and Cooperation on IAEA Safeguards Additional Protocol: VERTIC Initiative and Methods

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When considering ratification and implementation of safeguards agreements, States typically need to examine their legislative, regulatory and institutional frameworks to identify what changes or additions they may need to make. To assist in this endeavour, VERTIC runs an initiative offering cooperation and technical engagement on legislative and related arrangements to States interested in bringing the IAEA additional protocol into force and in identifying effective approaches to implementation. This paper explains the activities carried out under this initiative and provides observations on safeguards implementation as well as questions that States may encounter when considering taking up the protocol. The initiative includes familiarization activities for States; presenting guidance on legislative and institutional implementation; reviewing legislation and institutional arrangements in States currently without the protocol and providing tailored regulatory assistance. In addition, the project runs a knowledge base on State practice in implementing the protocol. The purpose of this practical resource is to allow States to learn from each other's experience and approaches, and identify new and potentially more efficient approaches to implementation. The tool consists of a database of State legislation, regulation and institutional practice in applying safeguards and the additional protocol. The information is categorized into each area that the protocol covers. The search functions generate results forms showing an index of one State's approach to implementation across all categories, or alternatively, display how a range of States have implemented one or more categories. The database includes information on States' legal traditions and fuel cycle activities allowing examples of countries with similar profiles to be identified for enhanced experience sharing. Where possible, the database includes information on the evolution of States' safeguards and fuel cycle activities to pinpoint key factors determining the approach chosen by the country.

The Standing Advisory Group on Safeguards Implementation

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The Standing Advisory Group on Safeguards Implementation (SAGSI) is an advisory group to the IAEA Director General that was established in 1975. SAGSI provides advice on a wide range of technical topics related to the objectives and implementation parameters of IAEA safeguards. SAGSI plays a particularly important role during times of significant developments in safeguards implementation, such as in the formulation of the Safeguards Criteria that formed the basis for the frequency and intensity of safeguards, and its subsequent revision in the early 1990's; in the Programme 93+2 which culminated in the model Additional Protocol; and in the development of the conceptual framework for integrated safeguards.

SAGSI is comprised of up to 20 members reflecting the diversity of the IAEA's Member States. Members of SAGSI function in their personal capacity, and each is a recognized expert in the field of IAEA safeguards. This paper, authored by the current Chair of SAGSI, briefly discusses the history of SAGSI, its work practices, and summarizes the issues that have been addressed in the recent past.

S22: Equipment Security and Considerations for Joint Use

Security and Risk Analysis of Nuclear Safeguards Instruments Using Attack Trees

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The IAEA's nuclear safeguards instruments must be frequently evaluated against attack vectors, which are extremely varied and, at first approximation, may seem inconsequential, but are not. To accurately analyze the impact of attacks on a multi-component system requires a highly structured and well-documented assessment. Tree structures, such as fault trees, have long been used to assess the consequences of selecting potential solutions and their impact on risk. When applied to security threats by introducing threat agents (adversaries) and vulnerabilities, this approach can be extremely valuable in uncovering previously unidentified risks and identifying mitigation steps.

This paper discusses how attack trees can be used for the security analysis of nuclear safeguards instruments. The root node of such a tree represents an objective that negatively impacts security such as disclosing and/or falsifying instrument data or circumventing safeguards methods. Usually, this objective is rather complex and attaining it requires a combination of several security breaches which may vary on how much funding or what capabilities are required in order to execute them. Thus, it is necessary to break the root objective into smaller, less complex units. Once a leaf node describes a reasonably comprehensible action, it is the security experts' task to allocate levels of difficulty and funding to this node. Eventually, the paths from the leaf nodes to the root node describe all possible combinations of actions necessary to carry out a successful attack. The use of a well-structured attack tree facilitates the developer in thinking like the adversary providing more effective security solutions.

Authentication Approaches for Standoff Video Surveillance

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Video surveillance for international nuclear safeguards applications requires authentication, which confirms to an inspector reviewing the surveillance images that both the source and the integrity of those images can be trusted. To date, all such authentication approaches originate at the camera. Camera authentication would not suffice for a "standoff video" application, where the surveillance camera views an image piped to it from a distant objective lens. Standoff video might be desired in situations where it does not make sense to expose sensitive and costly camera electronics to contamination, radiation, water immersion, or other adverse environments typical of hot cells, reprocessing facilities, and within spent fuel pools, for example. In this paper, we offer optical architectures that introduce a standoff distance of several metres between the scene and camera. Several schemes enable one to authenticate not only that the extended optical path is secure, but also that the scene is being viewed live. They employ optical components with remotely-operated spectral, temporal, directional, and intensity properties that are under the control of the inspector. If permitted by the facility operator, illuminators, reflectors and polarizers placed in the scene offer further possibilities. Any tampering that would insert an alternative image source for the camera, although undetectable with conventional cryptographic authentication of digital camera data, is easily exposed using the approaches we describe.

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Key Management Strategies for Safeguards Authentication and Encryption

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Management of cryptographic keys for the authentication and encryption of safeguards data can be the critical weak link in the practical implementation of information security. Within the safeguards community, there is the need to validate that data has not been modified at any point since generation and that it was generated by the monitoring node and not an imposter. In addition, there is the need for that data to be transmitted securely between the monitoring node and the monitoring party such that it cannot be intercepted and read while in transit. Encryption and digital signatures support the required confidentiality and authenticity but challenges exist in managing the cryptographic keys they require.

Technologies developed at Sandia National Laboratories have evolved in their use of an associated key management strategy. The first generation system utilized a shared secret key for digital signatures. While fast and efficient, it required that a list of keys be maintained and protected. If control of the key was lost, fraudulent data could be made to look authentic. The second generation changed to support public key / private key cryptography. The key pair is generated by the system, the public key shared, and the private key held internally. This approach eliminated the need to maintain the list of keys. It also allows the public key to be provided to anyone needing to authenticate the data without allowing them to spoof data. A third generation system, currently under development, improves upon the public key / private key approach to address a potential man-in-the-middle attack related to the sharing of the public key. In a planned fourth generation system, secure key exchange protocols will distribute session keys for encryption, eliminating another fixed set of keys utilized by the technology and allowing for periodic renegotiation of keys for enhanced security.

Use of Specialized Security Techniques to Enhance the Authenticity of Surveillance Data

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In 2013, the IAEA started testing a commercial application-specific integrated circuit (ASIC) from LiveWire technology for its ability to monitor changes in wiring systems in real time. This technology is useful in specific situations where digital video signal authentication cannot be used due to analog cameras used in high radiation level (e.g., hot cells, reading spent fuel identification numbers), dimensional requirements, or when an analog signal has to be shared with a facility's built-in camera. The LiveWire ASIC can be used for tamper indication with resulting cost savings by eliminating the need for specifically manufactured tamper indicating conduits. This technology can also be integrated within the Next Generation Surveillance System (NGSS) camera module, coupled with the upcoming implementation of the analogue video input, for the protection of analog video signals provided by an external camera head.

Digital camera identification based on sensor pattern noise analysis is another technique under investigation at the IAEA. Sensor pattern noise is unique to a device and can be used as a distinct identification "fingerprint". This technique is increasingly being employed for camera identification and in-image authentication & video forensics by commercial software suites. Interest in this technique for use in safeguards applications is justified by the need to own specific forensic tools and the requirement to verify the authenticity of surveillance streams acquired in analog video input configurations where the camera head is external to the NGSS camera module). Preliminary tests have been performed on surveillance data acquired by NGSS cameras and post-processed with commercial forensic software. The promising results obtained encourage further development efforts and tests to be conducted to fully assess the potential capabilities this technology offers.

This paper will focus on these two applications recently addressed by the IAEA, detailing the theory of operation and preliminary test results.

The IAEA's Universal Instrument Token

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The IAEA currently seeks to improve the harmonization of security approaches across safeguards equipment. The protection of digital safeguards data is based on several principles: a) the signing of data in measurement devices using standard public/private-key-based signature generation, b) the storage of secret keys on certified, tamper-protected cryptographic devices, and c) well-established cryptographic algorithms and protocols based on global standards and internationally recognized cryptographic libraries. This paper discusses a cryptographic token, the Universal Instrument Token, which constitutes the core element of the architecture for signing safeguards data. This architecture supports the above principles and is compliant with the IAEA's information security policies and guidelines. An important side-condition is that the UIT must be implemented across a wide range of operating systems and hardware architectures, which mandates the use of open-source software for all software-related parts involved.

The UIT is permanently connected to the measuring device (usually via the USB port) and requires complex hardware drivers and middleware components. Identifying open-source based, mature and ready-for-use smart card drivers and tools that are compatible with a range of operating systems was a major challenge. Reliable and well-established cryptographic libraries reside at the core of every information-security application. Different types of review software, typically software products used at IAEA headquarters in Vienna but occasionally also in the facilities, need to contain some specific software modules in order to verify the digital signatures attached to the data. Finally, also required are enrollment tools which generate private keys and certify their corresponding public counterparts using the IAEA's internal Certification Authority.

In 2014, the roll-out of the UIT has raised the security of IAEA instrument data signing to a level which is currently considered to be impractical to defeat, provided that the correct procedures are followed.

The Security Plan for the Joint Euratom/IAEA Remote Monitoring Network

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The European Commission and the IAEA have installed surveillance systems in all larger civil European nuclear facilities. The monitoring data is gathered by optical surveillance systems, electronic sealing systems and numerous measuring devices. The on-site joint Euratom/IAEA monitoring networks operate in general completely isolated from the operator's IT systems. To largely improve data security and reliability, remote data transmission (RDT) is installed on a growing number of sites, and the inspection data is daily transferred to the Data Collect Servers in Luxembourg and Vienna.

A growing number of RDT connections and a growing number of security threats require an IT security policy that is pro-active as well as reactive in an efficient way.

The risk based approach used in setting up the security plans assesses all elements of the monitoring network, from the implemented technical solution and the assessment of the security needs and threats, up to the incident handling and lessons learned. The results of the assessments are, for each individual RDT connection, described in the technical paragraphs and annexes, including system descriptions, network plans and contact information.

The principles of secure data handling as implemented in the shared Euratom /IAEA monitoring network can apply to a broad range of industrial monitoring systems, where human interaction is in general the largest security risk.

JAEA's Contribution to Development of J-MOX Safeguards System

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Safeguards systems are under development for a large scale LWR MOX fuel fabrication plant (J-MOX) being constructed by Japan Nuclear Fuel Limited. Development of the systems is shared by Secretariat of Nuclear Regulation Authority (NRA) and International Atomic Energy Agency (IAEA). NRA has developed NDA systems including Advanced Fuel Assembly System (AFAS) and Advanced Verification for Inventory sample System (AVIS). These systems were designed and manufactured by Los Alamos National Laboratory under contract with NRA. The AFAS is a NDA system for verification of the LWR MOX fuel assembly and it applies a new technology to measure active lengths of the assembly by neutron detectors without inspector's attendance. The AVIS is a NDA system for verification of MOX bulk material and it is expected to make measurements with bias defect level for many verification samples in short order due to J-MOX's large throughput. Because the AFAS applies the new technology and the AVIS requires bias defect level accuracy, inspectorate recognizes the importance of demonstrating system performance before the installation to J-MOX and confirming effectiveness of safeguards approach. Plutonium Fuel Development Center of Japan Atomic Energy Agency (JAEA) has developed various NDA systems to quantify the plutonium in MOX samples such as pellet and assembly in MOX fuel fabrication facilities. JAEA has knowledge and experiences obtained through the development of the NDAs and testing fields to demonstrate system performance of AFAS and AVIS. Based on the commission from NRA and Nuclear Material Control Center (NMCC), JAEA has conducted the demonstration test of the AFAS and AVIS by using MOX materials at JAEA's MOX fuel fabrication facilities. Through the test, JAEA has contributed to development of J-MOX safeguards systems by demonstrating that the system performance of the AFAS and AVIS satisfies requirements by IAEA.

S23: Technical Aspects of Information Collection and Analysis

Advances in the Collection and Analysis of Large Volumes of Information on the Nuclear Fuel Cycle from Disparate Sources as a Verification Tool

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The Department of Safeguards seeks to provide the international community with credible assurances that States are fulfiling their Safeguards obligations in that all nuclear materials remains in peaceful use and that there are no undeclared nuclear activities. To this end declarations by States to the Agency are verified for correctness and completeness. This verification process involves the collection of Safeguards relevant information from a wide and disparate range of sources, independent from the States' declarations.

In the years since the last Safeguards Symposium, the Department of Safeguards further developed its sources to obtain a reliable, broad coverage of all aspects of the nuclear fuel cycle, as well as methodologies to query and collate this information. In addition, analytical techniques have been developed, supported by implementation of a new analytical platform that can handle the vast amount of information and data now available.

This enables the IAEA to map information collected on all aspects of the nuclear fuel cycle in any State to the Physical Model, the internal Agency standard technological reference, combining diverse, disparate and multiple sources into one analytical model in a reliable way.

In this paper the authors will describe the types of data sources used, methodologies of collection and analysis and how information is collated. The authors will also describe the environment used for such work and the information analysis platform that is being established. They will briefly touch on the use of this work in relation to the State level-concept, the analytical framework that is in use in the Department. The paper will illustrate the work performed through an example.

Tools for Trade Analysis and Open Source Information Monitoring for Non-proliferation

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The new state level approach being proposed by IAEA envisions an objective based and information driven safeguards approach utilizing all relevant information to improve the effectiveness and efficiency of safeguards. To this goal the IAEA makes also use of open source information, here broadly defined as any information that is neither classified nor proprietary. It includes, but is not limited to: media sources, government and non-governmental reports and analyzes, commercial data, and scientific/technical literature, including trade data.

Within the EC support programme to IAEA, JRC has surveyed and catalogued open sources on import-export customs trade data and developed tools for supporting the use of the related databases in safeguards. The JRC software The Big Table, (TBT), supports i.a.: a) the search through a collection of reference documents relevant to trade analysis (legal/regulatory documents, technical handbooks); b) the selection of items of interests to specific verifications and c) the mapping of these items to customs commodities searchable in trade databases.

In the field of open source monitoring, JRC is developing and operating a "Nuclear Security Media Monitor" (NSMM), which is a web-based multilingual news aggregation system that automatically collects news articles from pre-defined web sites. NSMM is a domain specific version of the general JRC-Europe Media Monitor (EMM). NSMM has been established within the EC support programme with the aim, i.e., to streamline IAEA's process of open source information monitoring.

In the first part, the paper will recall the trade data sources relevant for non-proliferation and will then illustrate the main features of TBT, recently coupled with the IAEA Physical Model, and new visualization techniques applied to trade data. In the second part it will present the main aspects of the NSMM also by illustrating some of uses done at JRC.

Technical Publications as Indicators for Nuclear Fuel Cycle Declarable Activities

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The Department of Safeguards aims to provide credible assurances to the international community that States are fulfiling their safeguards obligations in that all nuclear material remains in peaceful use. It does so in part by developing and implementing methodologies for early detection of undeclared activities or misuse of nuclear material or technology, based on large and diverse sources of information.

Analyzing scientific, technical and patent information allows analysts in the Department to understand the technology available to a State, to forecast possible technical developments, to map collaborative research activities within and across States, and compare that information with declarations received by the State for completeness and correctness. Furthermore, with regard to patent information, scientists or companies want to make sure their intellectual property is protected; accordingly, patents are frequently filed before the information is published elsewhere, making patent information also an early indicator of relevant activities.

Dealing with such large information sources requires the use of an innovative methodology conducting analysis. The Department has recently begun to examine the efficacy of link analysis tools to help carry out its mission. Using the link analysis platform Palantir, the authors conducted several case studies with the aim of deriving sound analytical results from large amounts of technical information within a reasonable time frame. The authors used data sets of bibliographic references from the IAEA International Nuclear Information System (INIS), Web of Science, Science Direct and data on worldwide patents from the European Patent Office (EPO). Based on these case studies, the authors are developing methodologies for the efficient application of link analysis to scientific and technical information, thus strengthening the Department's information collection and analysis capabilities and the overall process of State evaluation.

Open Source Analysis in Support to Nonproliferation Monitoring and Verification Activities: Using the New Media to Derive Unknown New Information

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This paper will describe evolving techniques that leverage freely available open source social media venues, sometimes referred to as the "New Media," together with geospatial tools and commercial satellite imagery (with its ever improving spatial, spectral, and temporal resolutions), to expand the existing nuclear non-proliferation knowledge base by way of a review of some recent exemplar cases. The application of such techniques can enhance more general data mining, as those techniques can be more directly tailored to IAEA Safeguards monitoring and other non-proliferation verification activities to improve the possibility of the remote detection of undeclared nuclear related facilities and/or activities.

As part of what might be called the new "Societal Verification" regime, these techniques have enlisted either the passive or active involvement of interested parties (NGOs, academics, and even hobbyists) using open sources and collaboration networks together with previously highlighted geospatial visualization tools and techniques. This paper will show how new significant, and unprecedented, information discoveries have already been made (and published in open source) in the last four years, i.e., since the last IAEA Safeguards Symposium.

With respect to the possibility of soliciting active participation (e.g., "crowd-sourcing") via social media, one can envision scenarios (one example from open source will be provided) whereby a previously unknown nuclear related facility could be identified or located through the online posting of reports, line drawings, and/or ground photographs. Nonetheless, these techniques should not be viewed as a panacea, as examples of both deception and human error will also be provided.

This paper will highlight the use of these remote-means of discovery techniques, and how they have shed entirely new light on important nuclear non-proliferation relevant issues in limited access, and even denied access, areas.

The Efficacy of Social Media as a Research Tool and Information Source for Safeguards Verification

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The IAEA Department of Safeguards aims to provide credible assurances to the international community that States are fulfiling their safeguards obligations in that all nuclear material remains in peaceful use. In order to draw a soundly-based safeguards conclusion for a State that has a safeguards agreement in force with the IAEA, the Department establishes a knowledge base of the State's nuclear-related infrastructure and activities against which a State's declarations are evaluated for correctness and completeness. Open source information is one stream of data that is used in the evaluation of nuclear fuel cycle activities in the State. The Department is continuously working to ensure that it has access to the most up-to-date, accurate, relevant and credible open source information available, and has begun to examine the use of social media as a new source of information.

The use of social networking sites has increased exponentially in the last decade. In fact, social media has emerged as the key vehicle for delivering and acquiring information in near real-time. Therefore, it has become necessary for the open source analyst to consider social media as an essential element in the broader concept of open source information. Characteristics, such as "immediacy", "recency", "interractiveness", which set social networks apart from the "traditional media", are also the same attributes that present a challenge for using social media as an efficient information-delivery platform and a credible source of information. New tools and technologies for social media analytics have begun to emerge to help systematically monitor and mine this large body of data.

The paper will survey the social media landscape in an effort to identify platforms that could be of value for safeguards verification purposes. It will explore how a number of social networking sites, such as Twitter, Facebook and LinkedIn, might be relevant in the context of overall State evaluation. The paper will further survey the tools available in the public domain that improve the monitoring of, searching for and extraction of safeguards-relevant information. The paper will conclude with an assessment of the value of social media and social media analytics as a component of the open source analyst's safeguards verification toolbox.

Efficiency and Effectiveness in the Collection and Analysis of S&T Open Source Information

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While looking for information in scientific database, we are overwhelmed by the amount of information that we encounter. In this big data collection, getting information with added-value could be strategic for nuclear verification.

In our study, we have worked about "best practices" in collecting, processing and analyzing open source scientific and technical information. First, we were insistent on working with information authenticated by referees such as scientific publications (structured information). Analysis of this structured data is made with bibliometric tools. Several steps are carried out: collecting data related to the paradigm, creating a database to store data generated by bibliographic research, analyzing data with selected tools.

With analysis of bibliographic data only, we are able to get:

- a panoramic view of countries that publish in the paradigm,
- co-publication networks,
- organizations that contribute to scientific publications,
- countries with which a country collaborates,
- areas of interest of a country, ...

So we are able to identify a target. On a second phase, we can focus on a target (countries for example).

Working with non-structured data (i.e., press release, social networks, full text analysis of publications) is in progress and needs other tools to be added to the process, as we will discuss in this paper.

In information analysis, methodology and expert analysis are important. Software analysis is just a tool to achieve our goal. This presentation deals with concrete measures that improve the efficiency and effectiveness in the use of open source S&T information and in the management of that information over time. Examples are shown.

Non-Proliferation Community, Do We Really Speak the Same Language?

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The non-proliferation community, with its many different stakeholders, has issues with a number of terms and concepts which have different meanings, not only in different national languages but also for scientists, diplomats, engineers, law enforcement people, IAEA safeguards staff, and many others. The consequences are not only relevant for translators and seminar participants. This confusion of terms may create misunderstandings with legal, diplomatic and operational consequences. A number of terms, used because of their meaning in English are “false friends” in other languages, i.e., they are used because they sound close, but their meaning may be different. The nuances may be about the fact that they cover a narrower, broader, or slightly different concept in another national or professional language. The emblematic example is the English word control, written the same way in many languages but with different connotations. Other examples include terms which have a precise legal definition for some communities whereas other stakeholder see it as generic terms (e.g., technology, transit); terms that are not explicit but have different implicit contents related to the context like outreach or declaration; terms which are distinct in one language but translated into one word in others like specially and especially designed; terms which cover different realities for different work communities like counter-proliferation, analysis; terms which are widely used and hardly defined anywhere like dual-use; or terms which refer to a specific legal or moral reference framework which is not always explicated like illegal, legitimate. This paper will explore issues related to some of these terms used in Western languages, and argue the necessity to take into account these sometimes subtle language differences, realizing the difficulties they may create for practitioners of non-proliferation. Improvements might include revising official reference documents like glossaries or other agreed sources.

Information Management: Business Vulnerabilities:

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Sophisticated cybercrimes and advanced persistent threats are occurring at an alarming rate. Aided by new attack techniques, increased financial support and the ease of exploiting social connections, attackers are having more success than ever before. Traditional security solutions are no longer sufficient to defend against these escalating threats.

IBM® Security QRadar® uses big data capabilities to help keep pace with advanced threats and prevent attacks before they happen. It helps uncover hidden relationships within massive amounts of security data, using proven analytics to reduce billions of security events to a manageable set of prioritized incidents.

Forward-leaning organizations are exploring custom analytics that use additional big data technologies on a variety of unstructured data sources including email, social media feeds, business transactions and full network packet payloads. To meet this demand, IBM is integrating industry-leading security intelligence capabilities with the world-class analytics capabilities of IBM InfoSphere® BigInsights™ and related big data software and services. The combination offers a comprehensive solution — a security intelligence platform designed to detect and prioritize threats in real time, together with a mature Hadoop- based solution for custom data mining and analytics.

Incident and Trafficking Database: New Systems for Reporting and Accessing State Information

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The IAEA's Incident and Trafficking Database (ITDB) is the Agency's authoritative source for information on incidents in which nuclear and other radioactive material is out of national regulatory control. It was established in 1995 and, as of June 2014, 126 States participate in the ITDB programme. Currently, the database contains over 2500 confirmed incidents, out of which 21% involve nuclear material, 62% radioactive source and 17% radioactively contaminated material.

In recent years, the system for States to report incidents to the ITDB has been evolving — moving from fax-based to secure email and most recently to secure on-line reporting. A Beta version of the on-line system was rolled out this June, offering a simple, yet secure, communication channel for member states to provide information. In addition the system serves as a central hub for information related to official communication of the IAEA with Member States so some communication that is traditionally shared by e-mail does not get lost when ITDB counterparts change. In addition the new reporting system incorporates optional features that allow multiple Member State users to collaboratively contribute toward an INF.

States are also being given secure on-line access to a streamlined version of the ITDB. This improves States' capabilities to retrieve and analyze information for their own purposes. In addition, on-line access to ITDB statistical information on incidents is available to States through an ITDB Dashboard. The dashboard contains aggregate information on number and types of incidents, material involved, as well some other statistics related to the ITDB that is typically provided in the ITDB Quarterly reports.

Analysis of Nuclear Relevant Information on International Procurement and Industrial Activities for Safeguards Purposes

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Through the use of information on trade and industry, analysts in the Department of Safeguards create an understanding of relevant technological capabilities available to States with safeguards agreements in force and the nuclear related equipment and materials they can make use of either through indigenous manufacture or import. This information gives a valuable independent input into the consistency analysis of States' declarations and may identify inconsistencies or provide indicators of possible undeclared activities.

Information on procurement attempts of potential safeguards relevance is made available to the Department through the voluntary support of several Member States. These provide complete and original primary details on enquiries that reach expert suppliers of nuclear relevant goods in the respective Member States, enquiries that may not adequately declare the intended end use of the goods.

Information on export/import activities (EXIM) is collected from a variety of publicly available statistical trade databases. These provide details on trade flows of commodities between States. The information is categorized according to the World Customs Organization's universal product nomenclature: the Harmonized System (HS). Querying relevant HS codes allows analysis of EXIM information for indicators of safeguards relevance, providing insight into potential safeguards relevant capabilities, resources or activities.

Surveys of nuclear relevant manufacturing capabilities of States are performed by collecting information from publicly available business directories. Such information is then further refined by identifying the actual activities of the individual manufacturers and suppliers of interest. This survey provides valuable knowledge on the technical capabilities of States.

This paper will discuss the most important types of information used, clarify why they are relevant, describe the methodologies now routinely used in the Department of Safeguards to collect, collate and analyze the information, and identify areas where further work can be done to improve the process.

Collection, Analysis, and Dissemination of Open Source News and Analysis for Safeguards Implementation and Evaluation

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Analysis of all safeguards-relevant information is an essential component of IAEA safeguards and the ongoing State evaluation underlying IAEA verification activities.

In addition to State declared safeguards information and information generated from safeguards activities both in the field and at headquarters, the IAEA collects and analyzes information from a wide array of open sources relevant to States' nuclear related activities. A number of these open sources include information that could be loosely categorized as "news": international, regional, and local media; company and government press releases; public records of parliamentary proceedings; and NGO/academic commentaries and analyzes.

It is the task of the State Factors Analysis Section of the Department of Safeguards to collect, analyze and disseminate news of relevance to support ongoing State evaluation.

This information supports State evaluation by providing the Department with a global overview of safeguards-relevant nuclear developments. Additionally, this type of information can support in-depth analyses of nuclear fuel cycle related activities, alerting State Evaluation Groups to potential inconsistencies in State declarations, and preparing inspectors for activities in the field.

The State Factors Analysis Section uses a variety of tools, including subscription services, news aggregators, a roster of specialized sources, and a custom software application developed by an external partner to manage incoming data streams and assist with making sure that critical information is not overlooked.

When analyzing data, it is necessary to determine the credibility of a given source and piece of information. Data must be considered for accuracy, bias, and relevance to the overall assessment. Analysts use a variety of methodological techniques to make these types of judgments, which are included when the information is presented to State Evaluation Groups.

Dissemination of news to appropriate stakeholders within the Agency is a key component of the process. Timely dissemination of news can enable the Department to better allocate resources, identify trends, and quickly react to emerging issues.

This paper provides an overview of current practices across the analytical cycle, the role this information plays in ongoing State evaluation, and efforts to overcome key challenges associated with analyzing this specific set of information.

Pattern Recognition by Humans and Machines

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Data visualization is centred on new ways of processing and displaying large data sets to support pattern recognition by humans rather than by machines. The motivation for approaches based on data visualization is to encourage data exploration and curiosity by analysts. They should help formulating the right question more than addressing specific predefined issues or expectations. Translated into IAEA's terms, they should help verify the completeness of information declared to the IAEA more than their correctness.

Data visualization contrasts with traditional information retrieval where one needs first to formulate a query in order to get to a narrow slice of data. Using traditional information retrieval, no one knows what is missed out. The system may fail to recall relevant data due to the way the query was formulated, or the query itself may not be the most relevant one to be asked in the first place.

Examples of data visualizations relevant to safeguards will be illustrated, including new approaches for the review of surveillance images and for trade analysis. Common to these examples is the attempt to enlarge the view of the analyst on a universe of data, where context or detailed data is presented on-demand and by levels of abstraction.

The paper will make reference to ongoing research and to enabling information technologies.

Enhancing Safeguards through Information Analysis: Business Analytics Tools

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For the past 25 years the IBM i2 Intelligence Analysis product portfolio has assisted over 4,500 organizations across law enforcement, defense, government agencies, and commercial private sector businesses to maximize the value of the mass of information to discover and disseminate actionable intelligence that can help identify, investigate, predict, prevent, and disrupt criminal, terrorist, and fraudulent acts; safeguarding communities, organizations, infrastructures, and investments. The collaborative Intelligence Analysis environment delivered by i2 is specifically designed to be:

- scalable: supporting business needs as well as operational and end user environments
- modular: an architecture which can deliver maximum operational flexibility with ability to add complimentary analytics
- interoperable: integrating with existing environments and eases information sharing across partner agencies
- extendable: providing an open source developer essential toolkit, examples, and documentation for custom requirements

i2 Intelligence Analysis brings clarity to complex investigations and operations by delivering industry leading multidimensional analytics that can be run on-demand across disparate data sets or across a single centralized analysis environment. The sole aim is to detect connections, patterns, and relationships hidden within high-volume, all-source data, and to create and disseminate intelligence products in near real time for faster informed decision making.

S24: Noble Gas Measurements in Support of Nuclear Safeguards Implementation

Environmental Low-Level Noble Gas Measurements for Nuclear Non-Proliferation Treaty Verification Purposes

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The measurement of radioactive noble gases has been used since the Manhattan Project in the 1940s and later during the Cold War to monitor other countries' nuclear programmes and progress. In more recent times, it plays an important role as a tool in international nuclear verification regimes.

Various noble gases are created as fission products in nuclear processes such as burn-up of nuclear fuel in nuclear reactors, target irradiation for medical isotope production, and nuclear accidents and explosions. Being chemically inert, noble gases will not react with the ambient environment or deposit on the ground once entered into the atmosphere, but will only disappear due to radioactive decay. They are, therefore, very good tracers for revealing specific nuclear activities and can help in verifying non-proliferation treaties.

Radioxenon isotopes as well as Krypton-85 are anthropogenic isotopes produced through fission of uranium or plutonium. The analysis of krypton in the atmosphere could help in verifying compliance with the Nuclear Non-Proliferation Treaty by monitoring nuclear fuel re-processing activities. The detection of the radioxenon isotopes could give indications, e.g., on illicit nuclear fission experiments, a nuclear explosion, clandestine nuclear reactors or other violations of non-proliferation treaties.

Argon-37 is an anthropogenic isotope produced when fission neutrons react with calcium in rock. Its identification in the lower troposphere or in soil gas can be an indication for the detonation of a nuclear device. Other noble gases like argon-41 and various short-lived krypton isotopes may be used for nuclear safety monitoring or reactor operation surveillance.

This paper will describe how these noble gases are created and measured, the history of their use for nuclear verification, and the most modern advancements in the measurement technology and data interpretation.

Krypton-85 Monitoring at BfS in Germany and Technical Solutions for Safeguards

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The radioactive noble gas isotope krypton-85 with a half-life of 10.76 years is produced by nuclear fission. The main source of krypton-85 in the atmosphere are releases from reprocessing plants for nuclear fuel in the Northern Hemisphere. This volatile isotope is not retained in such plants and thus a very good indicator for the processing of irradiated nuclear fuel. This includes reprocessing for military purposes. Additionally, Kr-85 could be used as tracer for the validation of Atmospheric Transport Models.

The German Federal Office for Radiation Protection (BfS) operates a noble gas laboratory and a global network which continuously monitors the krypton-85 activity concentrations in ground level air since the 1970s. The atmospheric activity concentration has continuously been increasing since the installation of reprocessing plants for nuclear fuels in the early 1950s until 2003. In the first decades it came mostly from military applications and later from civil reprocessing. Since 2003 the atmospheric krypton-85 background level in the Northern Hemisphere is nearly constant with a value of around 1.5 Bq/m^3 in Central Europe. The baseline is superimposed by spikes as a result from discharges of two European reprocessing plants of nuclear fuel, Sellafield and La Hague. The laboratory of the BfS and the techniques used will be presented. Long time series will be discussed and the use of ATM for source location demonstrated.

Xenon Gas to Identify DPRK's Nuclear Tests

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The presence of radioactive xenon in the atmosphere is a unique signature that nuclear fission occurred. The last decade, sensitive radioxenon measurement systems and analysis techniques intended to detect and locate underground nuclear tests have developed rapidly. The new methods were used to detect and analyze airborne xenon isotopes from DPRK's first and third nuclear tests, conducted in 2006 and 2013. The analysis of these events consists of several parts, including analysis of measured activity concentrations in relation to historical data, comparison of isotopic ratios with calculated release scenarios, as well as atmospheric transport modelling. Using the DPRK detections as examples, these methods will be presented and discussed.

Ar-37 in the Atmospheric and Sub-Soil Gases

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On-site inspection of the radioactive noble gas isotope 37Ar is a definitive and unambiguous indicator of an underground nuclear explosion. 37Ar is produced underground by neutron activation of calcium by the reaction 40Ca(n,α)37Ar. In the atmosphere, 37Ar is produced by the spallation reaction 40Ar(n,4n)37Ar. Periodic measurements over the last six years on air collected in Bern revealed a background level in the order of 1–5 mBq/m^3 air in agreement with former findings and theoretical calculations. Those calculations also indicated that the intrusion of stratospheric air masses may lead to elevated tropospheric 37Ar concentrations up to 8–10 mBq/m^3 air. Selected samples taken up to now in the vicinity of nuclear power plants revealed no significant deviation from the natural background. In order to distinguish between natural and artificially elevated 37Ar the location-specific 37Ar activity range in soils, rocks and the atmosphere were identified. From CARIBIC flights, a passenger aircraft with a special air freight container filled with scientific equipment in the cargo compartment, tropospheric air samples were analyzed for 37Ar and 85Kr. The natural 37Ar production in soils and the rock basement underlying the alluvium is investigated by means of in situ measurements of different isotopes, theoretical calculations and irradiation experiments on selected rock samples. This will help resolve the temporal evolution and/or constancy of the natural 37Ar background and allow for an interpretation in terms of the identification of clandestine nuclear explosions.

Source Determination and Localization by Atmospheric Transport Modelling

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Monitoring of noble gases, in particular Krypton-85, can be used to detect signatures from undeclared plutonium production and reprocessing activities. Based on Atmospheric Transport Modelling, it is possible to localize sources and, if a source localization hypothesis already exists, to determine the strengths of the releases.

In the last decade, the methods have been very much improved, especially by introducing Lagrangian modelling systems. Eulerian gridded approaches required the introduction of adjoint models, which is technically demanding, and the adjoint model simulations are CPU time consuming. In the Lagrangian world, the adjoint model is the same as the normal model, only the integration is performed with a negative time step. The introduction of so-called source-receptor sensitivity fields allowed separating the ATM calculations from the source localization task, making computations less demanding from the CPU perspective.

SRS fields can be used in different ways to investigate sources, either with simple trial and error schemes where emission scenarios are tested, or using inverse modelling algorithms. Such methods have been tested in various applications, including the detection of the nuclear tests of DPRK, the source estimates for the Fukushima nuclear accident 2011 or the Eyjafjallajökull volcano eruption in 2010. In all cases, results were promising. Also in more complicated domains, for example the assessment of complex emissions of air pollutants, it was shown that inverse modelling schemes work properly and accurately. Depending on the application, emission estimates are accurate at least on the order of magnitude. Also in the IAEA application area, source localization/determination methods were already investigated, and found to be very useful to investigate reprocessing activities.

In the presentation, atmospheric and backtracking methods are explained, and examples for their application are shown. In particular, there will be a reference to the applicability in the IAEA safeguards domain.

Noble Gas Sampling and Detection Methods for On-Site Inspections in Support of CTBT

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The On-Site Inspections (OSI) constitutes the final verification measure under the CTBT, and are conducted to verify States Parties' compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT). An on-site inspection is launched to establish whether or not a nuclear explosion has been carried out and during such an inspection, facts might also be gathered to identify a possible violator of the Treaty.

The Treaty lists all activities and techniques that are permitted and one of these is the environmental sampling of noble gases (NG) in the air and underground, which can be deployed at any time during an OSI. The CTBT relevant isotopes are Xe-133, 133m, 131m, 135 and Ar-37. The samples are primarily to be analyzed on-site, although the treaty also allows off-site analysis in designated laboratories if necessary. Stringent procedures ensure the security, integrity and confidentiality of the samples throughout the sampling and analysis process — all taking place in the field.

Over the past decade the techniques for NG sampling, processing and analysis of both atmospheric and subsoil NG samples have been developed further in order to fit to the conditions and requirements during an OSI. This has been a major international effort with a global set of collaborators. Especially during the past three years the efforts intensified in order to finalize the scientific and technical developments for the Integrated Field Exercise, November 2014 (IFE14). This presentation will provide an overview of the current status of the OSI NG sampling regime and the OSI NG Field Laboratory to be deployed in IFE14, together with more technical descriptions of methods and equipment as well as a short discussion on potential future developments and alternative applications as applicable.

Automated Sampling and Extraction of Krypton from Small Air Samples for Kr-85 Measurement Using Atom Trap Trace Analysis

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Atom-Trap-Trace-Analysis (ATTA) provides the capability of measuring the Krypton-85 concentration in microlitre amounts of krypton extracted from air samples of about 1 litre. This sample size is sufficiently small to allow for a range of applications, including on-site spot sampling and continuous sampling over periods of several hours. All samples can be easily handled and transported to an off-site laboratory for ATTA measurement, or stored and analyzed on demand. Bayesian sampling methodologies can be applied by blending samples for bulk measurement and performing in-depth analysis as required.

Prerequisite for measurement is the extraction of a pure krypton fraction from the sample. This paper introduces an extraction unit able to isolate the krypton in small ambient air samples with high speed, high efficiency and in a fully automated manner using a combination of cryogenic distillation and gas chromatography.

Air samples are collected using an automated smart sampler developed in-house to achieve a constant sampling rate over adjustable time periods ranging from 5 minutes to 3 hours per sample. The smart sampler can be deployed in the field and operate on battery for one week to take up to 60 air samples.

This high flexibility of sampling and the fast, robust sample preparation are a valuable tool for research and the application of Kr-85 measurements to novel Safeguards procedures.

All-Optical Atom Trap Trace Analysis: Potential Use of 85Kr in Safeguards Activities

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Sensitive measurement techniques for the detection of anthropogenic tracers demand measurement resolutions down to single atoms, as it has been demonstrated by the first atom trap trace analysis experiments. However, technical limitations had lowered the sample throughput to about 200 per year per machine. We have developed an all-optical apparatus which allows higher sample throughput and small sample sizes at the same time.

Krypton-85 as anthropogenic isotope is an ideal tracer for nuclear activities since the only relevant source term is fission. An increased 85Kr concentration in an air sample indicates, that a plume was passing by during sampling. In practice, however, its applicability may be limited by the global and regional background concentrations caused by the emissions of nuclear fuel reprocessing plants.

The potential of 85Kr monitoring for safeguards applications has been discussed extensively. Among these is the short range detection of elevated concentrations of 85Kr in the vicinity of reprocessing plants. Our ATTA technique needs sample sizes of about 1 ℓ of air only and thus for the first time will allow simple environmental sampling of 85Kr with high spatial and temporal resolution. The design of such a study including local sampling and tracer transport modelling in proximity to a reprocessing plants is outlined. In addition, such a study could be used also for validating near-field atmospheric dispersion models if the 85Kr source term is known. The potential of environmental analyzes of 85Kr during an IAEA short-notice access is discussed. It is shown that it crucially depends on the emission dynamics after shut-down of fuel dissolution which needs further study.

Source Location of Noble Gas Plumes

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In radionuclide monitoring, one of the most significant challenges from a verification or surveillance perspective is the source location problem. Modern monitoring/surveillance systems employ meteorological source reconstruction — for example, the Fukushima accident, CRL emissions analysis and even radon risk mapping. These studies usually take weeks to months to conduct, involving multidisciplinary teams representing meteorology; dispersion modelling; radionuclide sampling and metrology; and, when relevant, proper representation of source characteristics (e.g., reactor engineering expertise). Several different approaches have been tried in an attempt to determine useful techniques to apply to the source location problem and to develop rigorous methods that combine all potentially relevant observations and models to identify a most probable source location and size with uncertainties. The ultimate goal is to understand the utility and limitations of these techniques so they can transition from R&D to operational tools.

Radioactive Emissions from Fission-Based Medical Isotope Production and Their Effect on Global Nuclear Explosion Detection

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The use of medical isotopes, such as Tc-99m, is widespread with over 30 million procedures being performed every year, but the fission-based production of isotopes used for medical procedures causes emissions into the environment.

This paper will show that gaseous radioactive isotopes of xenon, such as Xe-133, are released in high quantities, because they have a high fission cross section and they are difficult to scrub from the processes used to produce the medical isotopes due to their largely unreactive nature. Unfortunately, the reasons that large amounts of radioactive xenon isotopes are emitted from isotope production are the same as those that make these isotopes the most useful isotopes for the detection of underground nuclear explosions. Relatively recently, the nuclear explosion monitoring community has established a provisional monitoring network for the Comprehensive Nuclear-Test-Ban Treaty (CTBT) that includes radioactive xenon monitoring as a major component. This community has discovered that emissions from medical isotope production present a more serious problem to nuclear explosion monitoring than thought when the network was first conceived. To address the growing problem, a group of scientists in both the monitoring and the isotope production communities have come together to attempt to find scientific and pragmatic ways to address the emissions problems, recognizing that medical isotope production should not be adversely affected, while monitoring for nuclear explosions should remain effective as isotope production grows, changes, and spreads globally.

SAUNA: Equipment for Low Level Measurement of Radioactive Xenon

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Today, more than 25 SAUNA Systems are installed around the world, operated by national and international organizations.

The activity measurement of the four xenon isotopes, 133Xe, 131mXe, 133mXe, and 135Xe is performed using the very sensitive beta gamma coincidence technique allowing high sensitivity also for the meta-stable states resulting in MDC's of 0.3, 0.3, 0.3 and 0.7 mBq/m^3 respectively.

In the SAUNA Systems product portfolio there are systems for; continuous monitoring, in-field sampling, and reanalysis of archived samples. We also have a container solution for continuous monitoring with all infrastructure integrated.

The SAUNA systems in the network are now being upgraded with the latest developments; memory free detector cells, new digital detector electronics, in house developed high voltage supply, new data acquisition software, new safety solutions, and a new sample archive.

The International Monitoring System's Noble Gas Network

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The International Monitoring System (IMS) is a unique global network for surveillance of the Comprehensive Nuclear-Test-Ban Treaty. A major component of the IMS is the radionuclide monitoring network since, among all IMS technologies, it can provide the most unequivocal evidence for a nuclear explosion. The radionuclide monitoring component is unprecedented in its combination of global coverage, sensitivity, network density and temporal resolution. In particular for the detection of underground or underwater nuclear tests, forty of the eighty radionuclide stations will eventually be equipped with sensors to measure the Xenon isotopes Xe-131m ($\tau_{1/2} = 11.8$ d), Xe-133 ($\tau_{1/2} = 5.25$ d), Xe-133m ($\tau_{1/2} = 2.2$ d) and Xe-135 ($\tau_{1/2} = 9.14$ h). These are among the isotopes with the highest yields in fission of uranium or plutonium with half-lives long enough to be detected at large distances from the point of emission. As of today, 31 noble gas systems have been installed and are sending data to the International Data Centre. The noble gas systems installed at the stations are automated and sample Xenon continuously from atmospheric air for 12 or 24 hours at an air flow of 0.5 to several m^3/h by absorption of Xenon on activated charcoal. Detection of the Xenon isotopes is either by high resolution gamma spectrometry or by beta-gamma coincidence spectrometry. With the currently available equipment, detection limits of 0.2 mBq/m^3 can be achieved. An overview on the existing technology and future developments as well as on the interpretation of measurement results is given.

S25: NDA Measurements I: Gamma Spectrometry

Advanced Mathematical Methods for Gamma-Ray Based Nuclear Safeguards Measurements

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Working in close collaboration with the IAEA, Canberra Industries has developed an analysis tool that yields self-consistent radionuclide activities or masses contained in items commonly encountered in nuclear safeguards measurements. The tool, known as Advanced-ISOCS, is based on Canberra's In Situ Calibration Software (ISOCS) and automatically adjusts source geometry parameters to yield an efficiency calibration that is a best match for the given measurement. Canberra worked with the IAEA at every stage of the project. The final deliverables were tested thoroughly by Canberra as well as the IAEA. The advanced-ISOCS project was funded by the US Support Program. (USSP Task USA A 1607 "Development of ISOCS Self Modelling Capabilities" A.267).

Advanced-ISOCS reduces the total measurement uncertainty (TMU) and improves the accuracy of radionuclide quantification in safeguards measurement. The capability of the ISOCS Uncertainty Estimator (IUE), a tool already present in ISOCS, has now been extended to adjust the efficiency calibration by benchmarking the efficiency shape and magnitude to the data available in the analyzed gamma ray spectra. The benchmarks include isotopic results from MGA, MGAU, FRAM analysis, or declared information, the consistency of line activities from a given multiple-line nuclide, the consistency between measured and modelled uranium or plutonium mass, and the consistency of activities from multiple measurements of the same item.

Since IAEA inspectors face many measurement and time challenges in the field, an additional achievement of the development was a utility that enables measurement setup and analysis parameters to be pre-defined in advance of field measurements. The utility, called "Field ISOCS", greatly facilitates the inspectors' quantitative analysis of measured items in the field and the comparison of results with declarations.

An overview of the methodology and functionality of the Advanced-ISOCS software and recent performance results are presented.

Next Generation Germanium Systems for Safeguards Applications

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We are developing the latest generation of highly portable, mechanically cooled germanium systems for safeguard applications. In collaboration with our industrial partner, Ph.D.s Co, we have developed the Germanium Gamma Ray Imager (GeGI), an imager with a 2π field of view. This instrument has been thoroughly field tested in a wide range of environments and have performed reliably even in the harshest conditions. The imaging capability of GeGI complements existing safeguards techniques by allowing for the spatial detection, identification, and characterization of nuclear material. Additionally, imaging can be used in design information verification activities to address potential material diversions. Measurements conducted at the Paducah Gaseous Diffusion Plant highlight the advantages this instrument offers in the identification and localization of LEU, HEU and Pu holdup. GeGI has also been deployed to the Savannah River Site for the measurement of radioactive waste canisters, providing information valuable for waste characterization and inventory accountancy. Measuring $30 \times 15 \times 23$ cm and weighing approximately 15 kg, this instrument is the first portable germanium-based imager. GeGI offers high reliability with the convenience of mechanical cooling, making this instrument ideal for the next generation of safeguards instrumentation.

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Yields of Gamma- and X-Ray Radiation of Alpha-Decays of 235U

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Precise knowledge of gamma- and X-rays emission probabilities of uranium isotopes is vital for accurate gamma-spectrometric determination of the isotopic composition and quantity of uranium. The peak intensity ratio methods employing high resolution gamma-spectrometry and intrinsic efficiency calibration approach are known to provide most accurate and reliable isotopic information. When applied to unshielded and moderately shielded material, these methods largely benefit from de-convolution of the 90–100 keV narrow spectral interval, which contains intense gamma- and X-ray lines of major uranium isotopes 235U and 238U. These are the 92.37 keV and 92.79 keV gamma-rays of 238U/234Th, and the 93.35 keV ThKα1 X-rays from alpha-decay of 235U. Although the emission probability ratios of these lines were accurately established, their absolute yields are still lacking accuracy. For instance, as resulted from recent study [1], the yields of 234Th lines become corrected by 30%, compared with their previous values. This consequently raised a question regarding validity of the yield data for the 93.35 keV line of 235U and triggered the present experimental study. This study was later extended to the reexamination of emission probabilities of other 235U gamma-lines with energies above 205 keV. The experimental data used in the current work was collected using SRM 969 and CRM 146 reference uranium samples.

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The Distortion-Correction of Transmission-Reconstruction of SGS

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In this paper, the correction of the linear attenuation coefficient was discussed.

The coefficient used for self-absorption correcting of the emission data was reconstructed based on the transmission measurement data. Unlike the basic assumption of reconstruction, the data was measured from cone-like beam instead of the liner beam. The deviation of the coefficient reconstructed has contributed to the deviation of the final result of SGS. The correction technique was developed to reduce the deviation of coefficient by using the Monte Carlo simulation. An iterative process was used to narrow the difference between the coefficient reconstructed and real value by minimizing the difference of the penetration between measurement and simulation.

The technique was used to improve the accuracy of final result of SGS and supported by experimental data.

High-Quality Medium-Resolution Gamma-Ray Spectra from Certified Reference Uranium and Plutonium Materials

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The Institute of Transuranium Elements (ITU) has made an effort to record a collection of medium resolution gamma-ray spectra from well-characterized U and Pu certified reference materials CRM-171 (also known as SRM-969), CBNM-271, and Harwell PIDIE standards. The goal of this exercise was twofold: (i) to complement the international database of reference gamma-ray spectra with high-quality data for medium resolution spectrometers, and (ii) to feed Phase I of the U/Pu isotopic inter-comparison exercise that is being jointly organized by the ESARDA NDA Working Group and IAEA. Phase II of the exercise will be fed by similar spectra recorded by Institute for Radiological Protection and Nuclear Safety (IRSN).

These activities are supported through a joint Member State Support Programmes (MSSP) task and aimed at delivering reliable methodologies for the determination of U/Pu isotopic composition using medium resolution gamma-spectrometers. The latter have obvious benefits for in-field applications, amongst which are better usability, portability and maintainability. As the spectra will be made available online for software developers and end users, ultimately this will also contribute to sustainability as well as the improved and validated performance of existing U/Pu isotopic codes.

The spectra were recorded using the IAEA's standard Lanthanum Bromide (LaBr3(Ce)) (2.0″×0.5″) and Cadmium Zink Telluride (CdZnTe) (500 mm^3) detectors and acquisition electronics. Aiming to acquire the highest quality reference data, the spectra were measured for long acquisition times, ensuring very good counting statistics across potentially useful spectral intervals — up to 1 MeV for the CdZnTe and up to 2.6 MeV for the LaBr3(Ce) detectors. Great attention was also paid to ensure that the measurement geometry was stable and reproducible, and the spectra had minimum influence from background radiation and pile-up effects.

The paper will briefly discuss challenges of U/Pu isotopic analysis using medium resolution gamma-spectrometers and provide complete information about the sample properties and conditions of measurements, as will be needed for future use of the collected reference spectra.

The Need to Support and Maintain Legacy Software: Ensuring Ongoing Support for the Isotopics Codes

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Since about four decades, gamma evaluation codes for plutonium and uranium isotope abundance measurements are a key component of international, regional and domestic safeguards inspections. However, the development of these codes still relies upon a very limited number of experts. This led the safeguards authorities to express concerns, and to request continuity of knowledge and maintenance capability for the codes.

The presentation describes initiatives undertaken in the past ten years to ensure ongoing support for the isotopic codes. As a follow-up to the 2005 international workshop, the IAEA issued a roadmap for future developments of gamma codes, followed by a request for support in this field to several MSSP's (namely JNT A 01684). The international working group on gamma spectrometry techniques for U and Pu isotopics (IWG-GST) was launched by the European, French and US MSSPs in 2007, to respond to the needs expressed by the IAEA and other national or international inspectorates. Its activities started with the organization in 2008 of a workshop on gamma spectrometry analysis codes for U and Pu isotopics. The working group is currently developing an international database of reference spectra that will be made available to the community of users and developers. In parallel, IRSN contributes to the JNT A 01684 by advising the IAEA on establishing a procedure for validating a new version of isotopics codes compared to the previous version. The most recent initiative, proposed by the IAEA, consists in organizing an inter-comparison exercise to assess the performances of U and Pu isotopics and mass assay techniques based on medium resolution gamma spectrometry (MRGS).

All these initiatives contributed to the continuity of knowledge and maintenance of the gamma isotopic codes, but further efforts are needed to ensure the long-term sustainability of the codes.

The Measurement of Uranium Decay Daughters by NDA

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The abundances of daughters of Uranium is important information to disclose the producing time of Uranium material but also to deduce if the Uranium material had been melted. But the abundance of those daughters is ultra trace, low to several 10–20%. It is difficult to analysis so far as to mass spectrum. For daughters such as 231Th and 211Bi, the emitted measurable γ-ray, can be used to analysis their abundance accurately. Firstly the abundance of 234U, 235U and 238U can be acquired by MGAU code. Secondly a relative efficiency curve form 121 keV to 1001 keV can be fitted in combination with the areas of U isotopes full energy peak. Therefore the abundances of those daughters relative to U isotopes are possible to measured by their γ-ray. For the daughters which could not emit measurable γ-rays, their abundance can be given by principle of cascade decay balance.

Recommendations for Determining Uranium Isotopic Composition by MGAU

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The study deals with testing the versions 4.0 and 4.2 of the Multi-Group Analysis for Uranium (MGAU) software. MGAU is used for determining uranium isotopic composition by gamma spectrometry. The aim of the study was to determine the optimal measurement conditions needed to get the MGAU results as accurate as possible. The optimal number of total counts and the optimal count rate were determined. The study also shows how the accuracy of MGAU depends on the 235U-enrichment for various total numbers of counts.

The testing procedure is based on using simulated spectra generated from real spectra of certified reference materials and well characterized fuel pellets. The simulated spectra are generated by randomly sampling data from real ones by Cambio software. This approach allows producing a large number of spectra having different number of total counts to obtain statistically relevant data. More than 7000 spectra have been used in the study. The results of this work can help to appropriately set up a gamma-spectrometric measurement of the uranium isotopic composition.

S26: Safeguards by Design

IAEA Guidance for Safeguards Implementation in Facility Design and Construction

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One of the IAEA's statutory objectives is to seek to accelerate and enlarge the contribution of nuclear energy to peace, health and prosperity throughout the world. One way the IAEA works to achieve this objective is through the publication of technical series that can provide guidance to Member States. These series include the IAEA Services Series, the IAEA Safety Standard Series, the IAEA Nuclear Security Series and the IAEA Nuclear Energy Series.

The Nuclear Energy Series is comprised of publications designed to encourage and assist research and development on, and practical application of, nuclear energy for peaceful purposes. This includes guidance to be used by owners and operators of utilities, academia, vendors and government officials. The IAEA has chosen the Nuclear Energy Series to publish guidance for States regarding the consideration of safeguards in nuclear facility design and construction.

Historically, safeguards were often applied after a facility was designed or maybe even after it was built. However, many in the design and construction community would prefer to include consideration of these requirements from the conceptual design phase in order to reduce the need for retro-fits and modifications. One can then also take advantage of possible synergies between safeguards, security, safety and environmental protection and reduce the project risk against cost increments and schedule slippage.

The IAEA is responding to this interest with a suite of publications in the IAEA Nuclear Energy Series, developed with the assistance of a number of Member State Support Programmes through a joint support programme task [1]:

- International Safeguards in Nuclear Facility Design and Construction (NP-T-2.8, 2013),
- International Safeguards in the Design of Nuclear Reactors (NP-T-2.9, 2014),
- International Safeguards in the Design of Spent Fuel Management (NF-T-3.1, tbd),
- International Safeguards in the Design of Fuel Fabrication Plants (NF-T-4.7, tbd),
- International Safeguards in the Design of Conversion Plants (NF-T-4.8, tbd),
- International Safeguards in the Design of Enrichment Plants (NF-T-4.9, tbd),
- International Safeguards in the Design of Reprocessing Plants (NF-T-3.2, tbd),

The presentation will address how these publications can be shared and promoted. It will include lessons learned and suggestions how to affect the new facility bidding process in a constructive way.

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[1] Argentina, Belgium, Brazil, Canada, China, the European Commission, Finland, France, Germany, Japan, the Republic of Korea, the United Kingdom, and the United States of America.

An Approach to Safeguards by Design (SBD) for Fuel Cycle Facilities

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Implementation of safeguards in bulk handling facilities such as fuel fabrication facilities and reprocessing facilities are a challenging task. This is attributed to the nuclear material present in the facility in the form of powder, pellet, green pellet, solution and gaseous. Additionally material hold up, material unaccounted for (MUF) and the operations carried out round the clock add to the difficulties in implementing safeguards. In facilities already designed or commissioned or operational, implementation of safeguards measures are relatively difficult. The authors have studied a number of measures which can be adopted at the design stage itself. Safeguard By Design (SBD) measures can help in more effective implementation of safeguards, reduction of cost and reduction in radiological dose to the installation personnel. The SBD measures in the power reactors are comparatively easier to implement than in the fuel fabrication plants, since reactors are item counting facilities while the fuel fabrication plants are bulk handling type of facilities and involves much rigorous nuclear material accounting methodology. The safeguards measures include technical measures like dynamic nuclear material accounting, near real time monitoring, remote monitoring, use of automation, facility imagery, Radio Frequency Identification (RFID) tagging, reduction of MUF in bulk handling facilities etc. These measures have been studied in the context of bulk handling facilities and presented in this paper. Incorporation of these measures at the design stage (SBD) is expected to improve the efficiency of safeguardability in such bulk handling and item counting facilities and proliferation resistance of nuclear material handled in such facilities

Safeguards by Design: Finnish Experiences and Views

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Safeguards by design (SbD) promotes consideration of safeguards requirements and obligations as an integral part of planning and construction of a new nuclear facility or planning and modification of an existing facility.

One important step in introducing safeguards into facility design requirements was to include safeguards into the IAEA safety standards on "Safety of Nuclear Power Plants: Design". Safety standards stipulate that safety and security measures and arrangements for nuclear material control shall be designed and implemented in an integrated manner, so that they do not compromise one another. In practise, necessary safeguards measures shall be incorporated into the facility design and the implementation of these measures must be fulfiled so that safety and security are not jeopardized.

In Finland, SbD is a part of the national 3 S approach which aims at fulfiling international and national requirements. In Finland, new nuclear facilities are under planning and one nuclear power plant unit is under construction at the Olkiluoto NPP. Experiences gained from TVO's Olkiluoto 3 plant unit project have been influential in developing a concept for managing and combining safeguards, security and safety in an optimal manner. The main objective of SbD is that the facility is planned, designed, constructed and operated so that safeguards, security and safety are supporting each others. TVO has incorporated the lessons learned during the construction of Olkiluoto 3 plant unit into the requirements for the bidding process for the new Olkiluoto 4 plant unit. This paper describes both national regulatory authorities and plant operator's experiences and views on facilitating the SbD approach in Finland.

A Common Approach to Safeguards and Security by Design for Small Modular Reactors

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Small Modular Reactors (SMR) with power levels significantly less than the currently standard 1000 to 1600 MWe reactors have been promoted as having a simpler, more standardized, and safer modular design by using factory built and easily transportable components. Because many SMRs designs are still conceptual and consequently not yet fixed, designers have a unique opportunity to incorporate updated design bases threats and emergency preparedness requirements, and more completely integrate safety, physical security, and safeguards/material control and accounting (MC&A). Through the U.S. — Russia Civil Nuclear Energy Working Subgroup activities, collaborative efforts have been focused on developing a common approach to safeguards and security by design (SSBD) for SMRs. To date, this common approach has been concerned with identifying the most relevant set of requirements and guidelines for security, MC&A, and international safeguards that influence SSBD for SMRs. Following identification of the relevant set of requirements and guidelines, evaluation of their applicability for global export of SMRs will be considered.

We report here the identification of commonalities and differences between U.S. and Russian domestic requirements for security and MC&A, and compare these commonalities and differences with IAEA guidance for security and MC&A. Additionally, international (IAEA) safeguards are reviewed for their applicability to SMRs, regardless of their siting location throughout the world. Applicability of the relevant set of requirements for global export of SMRs may be considered with respect to the international export regime, to include the Nuclear Suppliers Group. Results from this study may help guide future U.S. — Russian collaborations related to SSBD for SMRs.

A Transportable and Subsea SMR: Early Considerations on Safeguarding the Flexblue System

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The Flexblue system is an innovative concept that consists in a small size transportable nuclear power plant to be sited on a flat sea bottom together with on shore command and control as well as fuel loading/unloading facilities. Although it is only at an early design phase, it seems appropriate to share some considerations on the specificities that this model may entail from an international safeguards perspective.

This presentation will first describe the main features, both technical and organizational of the concept, as well as the milestones and schedule envisaged for its development. It will then outline some safeguards relevant characteristics of TNPPs in general and of the Flexblue concept more particularly and investigate both implementation issues and legal aspects based on IAEA/INPRO's preliminary study (2013). It will assess to what extent these characteristics should facilitate safeguards from the operator or from the importing state point of view but also from the IAEA's perspective. It will point out some possible technical challenges that may arise and stimulate exchanges on the ways to overcome such situations.

In the course of the presentation some more general issues will be discussed. For instance a case study of export from a NWS to A NNWS will illustrate the need for strengthened cooperation between States and with the IAEA, the prospect for broader cooperation with the industry to better integrate safeguards friendly features in the design and contribute to alleviate the burden of safeguards while preserving their effectiveness.

Launching the reflection on safeguards issues at this early stage not only responds to the Agency's call for safeguards by design attitude but it will also allow the IAEA to take into account needs for innovative technical solutions and provide for R&D efforts within the long term R&D plan.

Safeguards by Design as Implemented by Sellafield Limited: Application to a New Nuclear Material Storage Facility

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Safeguards-by-design is defined as the consideration of safeguards throughout the lifetime of a facility, from conceptual design to decommissioning. A new nuclear material storage facility has been designed and is in the process of being constructed on Sellafield site as part of the UK strategy for consolidating nuclear material from other UK facilities to allow for their declassification. The design work started in 2012, construction is ongoing, and the first receipt of nuclear material is due to arrive in late 2014. The store has been designed for long term storage of a variety of plutonium and highly enriched uranium bearing materials, as well as Prototype Fast Reactor mixed-oxide fuel assemblies.

Although safeguards-by-design has not introduced any new safeguards requirements to the project, it has presented an opportunity for Sellafield Limited to engage voluntarily with DG ENER earlier than legally required in order to reduce project risk. It has been in the interests of both Sellafield Limited and DG ENER to cooperate in order to facilitate the implementation of safeguards in terms of enhancing understanding of the facility capability, its suitability for safeguards implementation, as well as keeping costs low and the project to schedule.

This paper describes the Sellafield Limited process for application of safeguards-by-design commencing at the conceptual design stage. In order to meet the safeguards requirements, a close dialogue was established between key stakeholders and early contact initiated prior to and during the design stages has facilitated the inclusion of safeguards instrumentation into the overall design and facility construction. Detailed discussions at the early stages of design have raised the profile of nuclear material accountancy and safeguards within the wider Sellafield community.

Application of the GIF PR&PP Methodology to a Fast Reactor System for a Diversion Scenario

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The Generation IV International Forum Proliferation Resistance and Physical Protection Working Group has developed a methodology for the PR&PP evaluation of the next generation Nuclear Energy Systems. Following this methodology the main objective of this work is not only to apply the methodology, but to show an example of how the results could be used by designers to improve the PR of the system. In this study, a hypothetical and commercial sodium-cooled fast nuclear reactor system (SFR) was used as the target for the application of the methodology. The design is based on the layout of the Japanese Sodium Fast Reactor with a safeguards design based on the safeguards approach of the prototype Monju. In this paper, the attention was focused on a diversion scenario involving the SFR. Moreover, the present work will focus within the reactor site.

The methodology was first applied to the SFR to check if this system meets the target of PR as described in the GIF goal; secondly, a comparison between the SFR and a reference system was performed to evaluate if and how it would be possible to improve the PR&PP of the SFR. As a reference system, a light water reactor (LWR), based on the layout of the European Pressurized Water Reactor with an open fuel cycle, was taken. The comparison was implemented according to the following example development target: achieving proliferation resistance to material diversion similar or superior to domestic and international advanced LWR. Three main actions were performed: implement the evaluation methodology based on its assumptions; characterize the PR&PP for the nuclear energy system applying the methodology to the SFR; and identify recommendations for system designers through comparing the SFR with the reference system.

Current Status of J-MOX Safeguards Design and Future Prospects

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The construction of JNFL MOX Fuel Fabrication Plant (J-MOX) is proceeding toward active test using uranium and MOX in July 2017, and completion of construction in October 2017. Although the construction schedule is largely impacted by progress of licencing, according to domestic law, JNFL is making every effort to get necessary permission of business licence and authorization of design and construction method as soon as possible.

On the other hand, it is desirable that integrated safeguards approach is effective, efficient and consistent with J-MOX facility features. Discussion about the approach is going on among IAEA, Japan Safeguards Office (JSGO) and JNFL, and IAEA is planning to introduce the measures into the approach such as application of Near Real-Time Accountancy with frequent declaration from operator, Containment/Surveillance measures to storages, internal flow verification with 100%, random interim inspection (RII) and so on.

RII scheme is intended to increase efficiency without compromising effectiveness and makes interruption of facility operation minimum. Also newly developed and improved safeguards equipment will be employed and it is possible to realize to increase credibility and efficiency of inspection by introduction of unattended/automatic safeguards equipment. Especially IAEA and JSGO share the development of non-destructive assay systems which meet the requirements from both parties. These systems will be jointly utilized at the flow verification, RII and PIV.

JNFL will continue to provide enough design information in a timely manner toward early establishment of safeguards approach for J-MOX. Also JNFL will implement the coordination of installation and commissioning of safeguards equipment, and Design Information Verification activities for completion of construction in October 2017.

S27: NDA Measurements II: Gamma and Neutron

Development of a Portable Tomographic Gamma Scanning System for Safeguards Application

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Characterization and verification of Nuclear Material (NM) are important activities for nuclear material accounting and control. In order to characterize or verify NM many factors have to be measured or estimated. These factors may include some bulk properties like material distribution, homogeneity, geometry and volume. Such information might not be detectable using the traditional gamma ray spectroscopy. Also, in some cases the measured item could not be easy opened. Tomographic gamma scanning is an important technique that could be effectively employed to overcome such difficulties.

The objective of this work is to develop a Portable Tomographic Gamma Scanning System for safeguards applications (PTGSS). The system is designed and developed in such away it could be easily installed and operate in field. It is consisted of a NaI (7×7 cm) gamma ray spectroscopy. The measured sample is scanned in 3D and rotates via three motors controlled by a predesigned computer code to reconstruct 3D image.

The reconstruction software code was developed using Visual Basic. Also, the reconstruction has been done using Filtered Back Projection (FBP) and Algebraic Reconstruction Technique (ART). The reconstructed images were validated using MCNP. Many factors affecting the reconstructed image have been studied analyzed, including scanning time, used γ-ray energy and collimator diameter.

Neutron Counting and Gamma Spectrometry with MCA-527

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The digital MCA527 was developed by GBS as follower instrument for the MiniMCA-166, which cannot be produced any more due to missing electronic chips. The instrument was successfully tested for use by IAEA and Euratom safeguards inspectors [test report].

In the course of the tests it was understood that this same piece of hardware can be used for correlated and multiplicity counting as well. A dedicated firmware version and user software, WinTimeStamps, were developed by the instrument provider. Test results for this application show that the instrument, operated in its basic mode ("EDGE" mode) fulfils the requirements for correlated neutron counting. Due to the fact that the MCA527 is not a dedicated neutron counter but a multichannel analyzer it is slower than established neutron counting devices; however this is of no real relevance for most of the safeguards inspection applications.

Further study of the signal flow resulted in the development of a new signal evaluation method which integrates rather than counts TTL signals. The method is implemented as "Advanced High Count Rate" mode ("AHCR" mode). In this mode the MCA527 is faster than the other established neutron counters. The paper presents some relevant measurement results.

iPIX: A New Generation Gamma Imager for Rapid and Accurate Localization of Radioactive Hotspots

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A next generation gamma imager, with improved characteristics in terms of portability, sensitivity and angular resolution, has been recently developed in our facilities for an accurate localization of radioactive hotspots. This device, called iPIX, consists of an advanced photon detector based on a pixilated readout CMOS, a coded mask aperture and a mini CCD camera. The iPIX gamma imager is currently under the industrialization process with a primary focus on the decontamination and decommissioning (D&D) purposes.

The observed performance with an industrial prototype were very encouraging as it can significantly help in finding radioactive sources whose associated dose rates are only several nSv/h (at the measurement points) in less than a minute. Other applications, such as the radiological safety in the whole nuclear industry and Homeland Security, have been already explored and deployed to seek for potential benefits this challenging technology. This talk will present the main features of the iPIX gamma imager.

High Count Rate Thermal Neutron Detectors and Electronics

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He3 proportional counters and analog electronics are the backbone of neutron detection systems. 1″ He3 tubes have been used with classical electronics for over three decades. The major challenge for short dead time and operation in high gamma fields, including spent fuel measurement, are difficult to address by simply changing the gas admix and tweaking the shaper time constants, resulting in thick shielding with added size and cost. Those small gains are adequate for spent fuel measurements of some lower burnup LEU assemblies, but not for MOX fuel or advanced fast reactor fuel, where the neutron source term is even greater. In this paper we report the Next Generation Safeguards Initiative's (NGSI) and GE Reuter Stokes systematical efforts to develop the next generation of thermal neutron detectors and front-end electronics addressing that technology gap:

- A cost-performances metric of tube diameter and gas pressure has been developed.
- New tubes with redesigned electrodes (reduced tube diameter and increased anode diameter) for better use of He3 gas, improved time response and gamma resistance.
- New front-end electronics with double pulsing filtering and dual channel architecture expanding many times the measurement capabilities over current technology.
- In-field calibration and status of health instrumentation for thermal neutron detectors.

The He3 and 10B tubes with new electronic package allows the operation at higher count rates and in higher gamma fields, as well as offering the possibility of more efficient use of He3. These devices, which are being commercialized, can also be used by themselves to upgrade conventional detector systems, enabling possible solution to measure spent nuclear fuel with high neutron efficiency previously not possible in systems that used 235U fission counters in the past.

Neutron Multiplicity Counting for Future Verification Missions: Bias When the Sample Configuration Remains Unknown

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Passive neutron multiplicity counting to determine plutonium mass is used nowadays inter alia in Safeguards applications. As opposed to total neutron rate counting, it can determine plutonium mass also in oxides and samples with induced fission processes if the isotopic composition is known. Neutron multiplicity counting may be helpful for other missions. These may include CBRN response related to nuclear trafficking, and verification of nuclear material, including the nuclear fuel cycle and military stocks under potential future regimes. Sometimes, the exact sample configuration may remain unknown.

Despite the technique's clear advantages, limitations require further study. Besides the influence of possible shielding between sample and detector, the assay results are dependent on the configuration, in particular geometry, of the fissile material. Assay bias for highly multiplicative samples has already been studied to some extent which lead to the introduction of corrections to the point model which is usually used to calculate the fissile mass. This paper presents MCNPX PoliMi simulation results of different plutonium sample and shielding configurations to critically evaluate eventual bias occurring with the point model. In addition, correction methods will be evaluated.

Measurement of the Pu Concentration of European MOX Pellets by Neutron Coincidence Counting

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A neutron-coincidence counter was calibrated for the non-destructive measurement of Pu concentration of mixed oxide (MOX) fuel pellets produced in Europe. The aim was to implement a non-destructive procedure for verifying the declared Pu inventory which can be used either by analysts in the lab or by safeguards inspectors in field.

A set of 6 MOX pellets taken from a MOX fuel fabrication facility and transported to the laboratory was used for the calibration. An older set of 5 pellets from the same facility was used to validate the calibration and to check the performance of the method. After recording gamma spectra and doing neutron measurements, both sets of pellets were characterized by destructive methods.

Two different calibration curves were prepared. For one of them the effects of sample self-multiplication were corrected for by using a simple correction factor. For the other one these effects were ignored. The bias between Pu concentrations obtained from neutron measurements and from isotope-dilution mass-spectrometry was calculated. It was found to be between 1 and 3% depending on the calibration curve and on the source of isotopic data used for calculation.

This accuracy may be sufficient for a quick preliminary assessment of the Pu inventory in MOX pellets by in-field instruments to immediately spot possible Pu diversion. However, for material balance evaluation purposes the smaller uncertainties associated with destructive assay remain preferable.

Towards Unattended Partial-Defect Verification of Irradiated Nuclear Fuel Assemblies Using the DCVD

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The Digital Cherenkov Viewing Device (DCVD) is a tool for verifying irradiated nuclear fuel assemblies in wet storage by means of measuring the Cherenkov light generated by the fuel. The DCVD is currently used in attended mode to verify the presence of irradiated fuel material, so-called gross defect verification, as well as to verify that part of the fuel material has not been diverted, so-called partial defect verification.

To further enhance the capabilities of the DCVD, image analysis techniques can be applied to the DCVD data to enhance image quality and to extract more information about the fuel. In this report, we both describe how general image analysis techniques can be applied, and we discuss specific methods applicable to DCVD data from PWR fuel assemblies. Based on our findings, we suggest some improvements to the current DCVD data acquisition procedures, and suggest methods for analyzing DCVD data.

We also elaborate on how the methods presented may form a basis for unattended verification of irradiated fuel assemblies. Unattended verification is of interest when large quantities of irradiated fuel assemblies are to be verified at one specific measurement site during a long time period. This development of the DCVD capabilities are in line with the IAEA's Department of Safeguards Long-Term R&D Plan goal of developing "more sensitive and less intrusive alternatives to existing NDA instruments to perform partial defect test on spent fuel assembly prior to transfer to difficult to access storage".

S28: Safeguards at Enrichment Facilities

Overview of Conducted Field Trials at URENCO: An Operator Perspective

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Field trials are an important instrument to test new safeguards equipment or methods if the new systems work in operational environment as foreseen. Circumstances can be much different in real facilities than laboratory surroundings. Also company policies (e.g., IT security) can give limitations to the implementation of new systems.

URENCO recognizes its responsibility for international safeguards and therefore supports safeguards authorities on a voluntary basis. Field trials, however, can only be carried out within the organizational, operational and security boundaries in order to avoid unnecessary interference in production or with security obligations. Beyond that, URENCO as operator needs to be convinced about the benefit of a particular field trail: Does the equipment/method to be tested deliver:

- direct benefits for URENCO operations?
- potential for reduction of safeguards efforts from an operator standpoint? or
- obvious potential for enhancing safeguards systems?

Several field trials have already been carried out on URENCO sites until today. Some of them have led to practical implementation; others are still under development.

This contribution will focus on the field trials conducted over the years at the URENCO Group. Some examples will be given; e.g., loadcells, mailbox approach, enrichment monitors, NDA equipment. The author will give his operator perspective to questions on:

- how successful were the trials?
- have they led to implementation?
- were there any constraints?
- how was the cooperation?

A Study of Candidate Non-Destructive Assay Methods for Unattended UF6 Cylinder Verification: Measurement Campaign Results

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Verification of uranium hexafluoride (UF6) cylinders is one of the key components of enrichment plant safeguards, and in recent years, the International Atomic Energy Agency (IAEA) has explored the possibility of developing an Unattended Cylinder Verification Station (UCVS) to provide 100% verification of cylinders within an enrichment facility while reducing the need for routine measurements and sampling during on-site inspections. In 2011, the U.S. Department of Energy (DOE) and the European Atomic Energy Community (Euratom) signed an Action Sheet for the exchange of recent findings and a joint measurement campaign to advance the capabilities of both parties in the area of non-destructive assay (NDA) methods for UF6 cylinder verification. The measurement campaign occurred in May 2013 at URENCO's gas centrifuge enrichment plant in the Netherlands and included participants from Pacific Northwest National Laboratory (PNNL), Los Alamos National Laboratory (LANL), the Joint Research Centre (JRC) in Ispra, the EC's Nuclear Safeguards Directorate, and an observer from the IAEA. Over five days at the site, the participants measured a total of 45 cylinders. Included in the population were typical 30B and 48Y cylinders containing feed, product, and tails and, in order to stress test the NDA systems, a smaller subset of atypical cylinders containing reprocessed (i.e., uranium derived from reactor recycle), non-homogenized, or very old UF6. The joint measurement campaign allowed for the direct comparison of mature handheld gamma-ray detectors that are in regular use by Euratom inspectors with two emerging NDA technologies for UF6 cylinder verification, namely the Hybrid Enrichment Verification Array (HEVA) and the Passive Neutron Enrichment Meter (PNEM). This paper provides an overview of the Action Sheet, background on the two emerging NDA techniques, a summary of the measurement campaign results, and the implications for a potential UCVS.

UF6 Cylinder Imaging by Fast Neutron Transmission Tomography

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The common use Non-Destructive Assay techniques for the determination of 235U enrichment and mass of UF6 cylinders used in the production of nuclear reactor fuel require prior knowledge of the physical distribution of the UF6 within the cylinder. The measurement performance for these techniques is typically evaluated based on assumed bounding case distributions of the material. However, little direct data such as radiographic or tomographic images, regarding the distribution of the UF6 within the cylinder is available against which to judge these assumptions. We have developed and tested a prototype active neutron tomographic imaging system employing an Associated Particle Imaging (API) neutron generator and an array of pixelated neutron scintillation counters. This system has been successfully used to obtain the 3-dimensional map of the distribution of UF6 within a type 12B storage cylinder. Results from these measurements are presented and the potential performance and utility of this technique with larger 30B and 48Y cylinders is discussed.

An Unattended Verification Station for UF6 Cylinders: Development Status

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In recent years, the International Atomic Energy Agency (IAEA) has pursued innovative techniques and an integrated suite of safeguards measures to address the verification challenges posed by advanced centrifuge technologies and the growth in separative work unit capacity at modern centrifuge enrichment plants. These measures would include permanently installed, unattended instruments capable of performing the routine and repetitive measurements previously performed by inspectors. Among the unattended instruments currently being explored by the IAEA is an Unattended Cylinder Verification Stations (UCVS) that could provide independent verification of the declared relative enrichment, U-235 mass and total uranium mass of all declared cylinders moving through the plant, as well as the application and verification of a "Non-destructive Assay Fingerprint" to preserve verification knowledge on the contents of each cylinder throughout its life in the facility. As IAEA's vision for a UCVS has evolved, Pacific Northwest National Laboratory (PNNL) and Los Alamos National Laboratory have been developing and testing candidate non-destructive assay (NDA) methods for inclusion in a UCVS. Modeling and multiple field campaigns have indicated that these methods are capable of assaying relative cylinder enrichment with a precision comparable to or substantially better than today's high-resolution handheld devices, without the need for manual wall-thickness corrections. In addition, the methods interrogate the full volume of the cylinder, thereby offering the IAEA a new capability to assay the absolute U-235 mass in the cylinder, and much-improved sensitivity to substituted or removed material. Building on this prior work, and under the auspices of the United States Support Programme to the IAEA, a UCVS field prototype is being developed and tested. This paper provides an overview of: a) hardware and software design of the prototypes, b) preparation for field trials, and c) status of the UCVS prototype development.

Uncertainty Quantification for Safeguards Measurements

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Part of the scientific method requires all calculated and measured results to be accompanied by a description that meets user needs and provides an adequate statement of the confidence one can have in the results. The scientific art of generating quantitative uncertainty statements is closely related to the mathematical disciplines of applied statistics, sensitivity analysis, optimization, and inversion, but in the field of non-destructive assay, also often draws heavily on expert judgment based on experience. We call this process uncertainty quantification, (UQ). Philosophical approaches to UQ along with the formal tools available for UQ have advanced considerably over recent years and these advances, we feel, may be useful to include in the analysis of data gathered from safeguards instruments. This paper sets out what we hope to achieve during a three year US DOE NNSA research project recently launched to address the potential of advanced UQ to improve safeguards conclusions.

By way of illustration we discuss measurement of uranium enrichment by the enrichment meter principle (also known as the infinite thickness technique), that relies on gamma counts near the 186 keV peak directly from 235U. This method has strong foundations in fundamental physics and so we have a basis for the choice of response model — although in some implementations, peak area extraction may result in a bias when applied over a wide dynamic range. It also allows us to describe a common but usually neglected aspect of applying a calibration curve, namely the error structure in the predictors. We illustrate this using a combination of measured data and simulation.

How the International Safeguards Regime can Benefit from Efforts to Enhance the Identification Method Used for UF6 Cylinders

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Improvements to the current methods used by industry to identify uranium hexafluoride (UF6) cylinders would benefit International Atomic Energy Agency (IAEA) safeguards, inspectorates, and regulatory authorities, as well as facility operators. A move towards a standardized UF6 cylinder identifier is gaining momentum within industry. A National Nuclear Security Administration (NNSA) team has analyzed how a cylinder identification and monitoring system could be useful to IAEA safeguards and has also engaged industry stakeholders to seek feedback on concepts related to unique cylinder identification and monitoring. The IAEA supported a feasibility test that would demonstrate a practicable, cost-efficient approach to uniquely identifying cylinders for safeguards purposes. During a UF6 cylinder stakeholders meeting hosted by NNSA in April 2014, the IAEA shared ideas on how a unique cylinder identifier used throughout industry could be most valuable and could offer safeguards benefits. A unique cylinder identifier, when combined with sufficient tamper-proofing and authentication, could provide greater functionality for the IAEA and create new opportunities to increase the efficiency and effectiveness of safeguards measures applied at facilities at the front end of the nuclear fuel cycle. This paper explores the various benefits that a unique cylinder identifier could provide to the IAEA and potentially other inspectorates. While industry initiative is central to developing a system for identifying UF6 cylinders, the IAEA has been monitoring the maturation of identification/tracking technologies in support of possible safeguards use. An industry working group has recently been formed to establish an industry-wide identification format for uniquely identifying UF6 cylinders and to investigate methods of making the unique identifier machine readable (e.g., barcode) and independently verifiable by the IAEA. Increasing benefits can be incrementally realized as implementation of the unique identifier spreads across industry and capabilities to use it are tested, proven, accepted, and implemented.

On-Line Enrichment Monitor (OLEM): Supporting Safeguards at Enrichment Facilities

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The On-Line Enrichment Monitor (OLEM) is a system designed to provide continuous enrichment measurements at gaseous centrifuge enrichment plants. In addition to results of recent research carried out internationally, it incorporates lessons learned from the design, operation, and maintenance of systems such as the Continuous Enrichment Monitor (CEMO) and the Cascade Header Enrichment Monitor (CHEM) to provide an improved system for unattended use. The OLEM system, designed to measure process gas at feed and take-off piping level, allows for more efficient implementation of enrichment monitoring at large scale facilities, and provides a significant contribution to the goal of improving the uranium-235 mass balance. The OLEM design is however flexible and modular enough to be easily adaptable to any piping. OLEM additional contribution is also bringing permanent assurance that the declared features of UF6 handling are operated as declared and in particular are not used for highly enriched uranium (HEU) production. The OLEM design incorporates the latest IAEA methods and approaches for physical and data security, while minimizing the impact on facility operations. The OLEM system provides inspectors with precise measurements to allow effective monitoring of enrichment levels. Recently, a field trial of OLEM prototype systems has been conducted, and the OLEM design and measurement approach, along with feedback from the field trial, will be presented.

The Design of Integration Device of Neutron and Gamma Ray for Measuring Uranium

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In this paper, the integration device of neutron and gamma ray was designed for measuring barreled uranium material which is the after-product in fuel element plant.

For barreled uranium with middle and low density matrix, the device used segment gamma ray scan technology and Monte Carlo imitation method to analysis the mass of uranium. For high density material, it added a neutron half-collar, and used total neutron technology to get the mass.

The measurement results of the device will act as support data for accounting balance in nuclear fuel element plant.

Development of an On-Line Uranium Enrichment Monitor

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An on-line enrichment monitor was developed to measure the enrichment of UF6 flowing through the processing pipes in centrifuge uranium enrichment plant. A NaI(Tl) detector was used to measure the count rates of the 186 keV gamma ray emitted from 235U, and the total quantity of uranium was determined from thermodynamic characteristics of gaseous uranium hexafluoride. The results show that the maximum relative standard deviation is less than 1% when the measurement time is 120 s or more and the pressure is more than 2 kPa in the measurement chamber. There are two working models for the monitor. The monitor works normally in the continuous model, When the gas's pressure in the pipe fluctuates greatly, it can work in the intermittent model, and the measurement result is very well. The background of the monitor can be measured automatically periodically. It can control automatically electromagnetic valves open and close, so as to change the gas's quantity in the chamber. It is a kind of unattended and remote monitor, all of data can be transfer to central control room. It should be effective for nuclear materials accountability verifications and materials balance verification at uranium enrichment plant by using the monitor to monitor Uranium enrichment of gaseous uranium hexafluoride in the output end of cascade continuously.

Development of a Simple Non-Destructive Assay Technique for Verification of Nuclear Materials in Cylinders

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The present work is a case study that describes a laboratory experimental method for estimating the U-235 mass content and/or enrichment in nuclear material bearing samples. A non-destructive assay technique has been developed for the verification of nuclear materials in cylinders. The technique is based on measuring the Gamma-rays counting rate emitted from a sample and calculating the absolute efficiency of a Gamma-ray detector system at a specific full energy peak for samples of nuclear material in cylinders with specific configuration and source-detector distance. Calculations are performed using a Monte Carlo Simulation Code [MC-4B] to achieve optimal agreement between experimental detector system efficiency and calculation values. The estimated value of U-235 mass content and/or enrichment in Uranium-bearing materials in cylinders with similar configuration and source-detector distance could be obtained for the assayed samples with accuracy in the range 7.1–10.8%. The present method may be considered simple and rapid for the verification of nuclear materials in cylindrical form. Also, it may be implemented in real field cases and for the purposes of nuclear material safeguards.

Modified Truncated Multiplicity Analysis to Improve Verification of Uranium Fuel Cycle Materials

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Accurate verification of 235U enrichment and mass in UF6 storage cylinders and the UO2F2 holdup contained in the process equipment is needed to improve international safeguards and nuclear material accountancy at uranium enrichment plants. Small UF6 cylinders (1.5″ and 5″ diameter) are used to store the full range of enrichments from depleted to highly-enriched UF6. For independent verification of these materials, it is essential that the 235U mass and enrichment measurements do not rely on facility operator declarations. Furthermore, in order to be deployed by IAEA inspectors to detect undeclared activities (e.g., during complementary access), it is also imperative that the measurement technique is quick, portable, and sensitive to a broad range of 235U masses. Truncated multiplicity analysis is a technique that reduces the variance in the measured count rates by only considering moments 1, 2, and 3 of the multiplicity distribution. This is especially important for reducing the uncertainty in the measured doubles and triples rates in environments with a high cosmic ray background relative to the uranium signal strength. However, we believe that the existing truncated multiplicity analysis throws away too much useful data by truncating the distribution after the third moment. This paper describes a modified truncated multiplicity analysis method that determines the optimal moment to truncate the multiplicity distribution based on the measured data. Experimental measurements of small UF6 cylinders and UO2F2 working reference materials were performed at Los Alamos National Laboratory (LANL). The data were analyzed using traditional and modified truncated multiplicity analysis to determine the optimal moment to truncate the multiplicity distribution to minimize the uncertainty in the measured count rates. The results from this analysis directly support nuclear safeguards at enrichment plants and provide a more accurate verification method for UF6 cylinders and uranium holdup in high background environments.

A Laser-Based Method for On-site Analysis of UF6 and Environmental Samples at Enrichment Plants

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The International Atomic Energy Agency's (IAEA) long-term R&D plan calls for more cost-effective and efficient safeguard methods to detect and deter misuse of gaseous centrifuge enrichment plant (GCEPs). The IAEA's current safeguards approaches at GCEPs are based on a combination of routine and random inspections that include environmental sampling (ES) and destructive assay (DA) sample collection from UF6 in-process material and selected cylinders. Samples are then shipped off-site for subsequent laboratory analysis. On-site analysis could provide timely screening of ES samples, and help to meet challenges in transportation and chain of custody for UF6 DA samples. PNNL's development of the Laser Ablation, Laser Absorbance Ratio Spectrometry (LAARS) method is aimed at these two applications. For both ES and DA samples, a LAARS analysis instrument could be temporarily or permanently deployed in the IAEA control room of the facility, for example in the IAEA data acquisition cabinet. Sample collection concepts include a PNNL-designed handheld DA sampler with a small sampling planchet to collect microgrammes of adsorbed UF6 gas directly from a process line tap and potentially, from a cylinder headspace. The sample planchet could then be assayed on-site by LAARS; some portion of the sample could be reserved for laboratory analysis (low sample activity should mitigate shipping restrictions). A second sampling concept collects aerosol particles from facility surfaces using a small backpack aerosol collector based on a PNNL rotating drum impactor design, which offers the possibility of sample segregation by sampling location and particle size. Some portions of the collector drums could be characterized on-site by LAARS to provide early sample screening and to guide additional sampling. The remaining drum samples could be transported to off-site laboratories for comprehensive analysis need to confirm or refute initial on-site findings.

S29: IAEA-State Cooperation II

The United Arab Emirates Engagement with the International Atomic Energy Agency on Safeguards and Additional Protocol Implementation

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In its approach to the development of a peaceful nuclear energy program, the UAE is committed to complete operational transparency, the highest standards of non-proliferation and to working directly with the IAEA. A strategy of continuous cooperation has been adopted in order to leverage the experience and recommendations of the IAEA early in the process of facility (reactor) construction and the establishment of the UAE Safeguards Structure. This strategy of early and continuous engagement since 2009 has proven to be of significant value. Reduced costs, reduced manpower requirements, and integration of safeguards into construction plans are all advantages realized with regard to generating and executing the safeguards approach for the UAE's nuclear program. Additional advantages include increased transparency, increased rapport between the IAEA and UAE and increased bilateral cooperation with other states. Challenges included establishing the appropriate information pathways while the program was still in formation. The conclusion is that early, continuous engagement with the IAEA for States beginning or expanding their peaceful nuclear programmes is strongly advised.

NECSA'S Need to Establish a Nuclear Forensics Specific NDA Facility for On-Site Categorization of Seized Nuclear Materials

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The increase of nuclear material that are out of regulatory control is becoming a serious concern and threat and thereby continuously seeking urgent interventions and counteractions from the international community aspiring effective control over all nuclear material and peaceful uses of nuclear technologies globally. In South Africa the nuclear forensics initiative approach and its execution have been adopted, established and managed by the South African Nuclear Energy Corporation (NECSA) to support the country's nuclear safeguards system and nuclear security investigations plan to fight against the illicit trafficking of nuclear and radioactive materials.

On this nuclear forensics initiative approach adopted by Necsa, the development and later execution of a Non-Destructive Analyses (NDA) facility capability for quick categorization of any seized nuclear material by law-enforcement agencies is currently envisaged as a critical initiative to comprehend nuclear forensics Laboratory analytical or characterization techniques. The main objective for this NDA facility is planned to be used for performing nuclear material screening process for material categorization purposes to generate information and results which will be open to law enforcement agencies for prosecution processes and also for the safeguards reporting to the IAEA (ITDB).

The NDA technique is therefore found to be a critical tool needed at NECSA as an Early-Checking-Point or first-line material check point for all seized nuclear materials in determining some characteristics of the materials and collection of data without having to destroy or changing the morphology of the material.

Nuclear Material Accounting and Reporting Software for India

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India has an item specific Safeguards Agreement, INFCIRC/754 with the IAEA and a nuclear material accounting system which generates the monthly reports for the Agency promptly. Subsequent to entry into force of subsidiary arrangements to INFCIRC/754 and as a part of implementation of new reporting Structure, India is developing new software to cater to its NUMAC reporting requirement. This paper gives the details of the software wherein the requirement of reporting for each of its facility to the Nuclear Controls & Planning Wing (NCPW) and the State level report to IAEA. The software is being developed on Linux (Ubuntu) OS, Mysql database and PHP. All the components are based on open source software and is developed as a two module system. The first module is for facility and the second one is for State level reports. The application has multi-level security for both the modules. Additionally, the facility level module is hardware interlocked. The facility reporter module generates a pdf file for the facility authority to sign, authenticate and hard copy filing. It can generate another xml file with an encryption, which can be sent to the State authority. In the State level module, the State authority generates reports for the Agency from xml file so received (after decryption and verification with the facility after receiving the signed hard copy) and also appends to its national database with all the information. The National database has all the information whereas the facility database has local information. The State module, in turn generates a pdf file, authenticate the same with signature of the authorized signatory (either in hardcopy form or in electronic form with PGP encryption as required by IAEA) and sends the same to the Agency. All the necessary security precautions to protect the entire NUMAC and safeguards information.

The Egyptian Nuclear Power Project and IAEA Technical Assistance in Supporting the Project and its Nuclear Safeguards

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The paper presents the potential of the Egyptian Nuclear Power Project and its importance to Egypt for electric energy security and diversity as well as the nuclear project role to achieve the economical and social development of the country. The former historical three efforts to implement the project would be presented. The main features of the project Bid Invitation Specifications (BIS) would be highlighted including the nuclear reactor type and the financial issues as well as the challenges especially that regarding public acceptance and local industry participation. The presentation highlights the role of the IAEA in providing the technical assistance in support of the project implementation throughout its history as related to the feasibility study, electric grid requirements, site selection, training, and other aspects.

Studies on Enhancing Nuclear Transparency in the Asia-Pacific Region

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Nuclear transparency is defined as "a cooperative process of providing information to all interested parties so that they can independently assess the safety, security, and legitimate management of nuclear materials" by Sandia National Laboratories (SNL). Since the Asia-Pacific region has a broad spectrum of nuclear development underway and planned in the future, nuclear transparency is recognized as essential to provide additional assurance and enhance confidence building in this area. It is expected that elevated nuclear transparency should also supplement International Atomic Energy Agency (IAEA) safeguards.

With this recognition, JAEA has committed various studies and activities for enhancing regional nuclear transparency mainly with U.S. Department of Energy (DOE) and its national laboratories. The efforts include concept study, development of secure data transmission technologies at the Experimental Fast Reactor "Joyo" for the use of regional nuclear transparency, and support for Council for Security and Cooperation in Asia Pacific (CSCAP) to develop internet-based transparency tools. JAEA also organized several workshops to discuss with stakeholder organizations to build acceptance for transparency tools and activities.

Based on the past studies, JAEA, jointly with SNL, Korea Institute of Nuclear Nonproliferation and Control (KINAC) and Korea Atomic Energy Research Institute (KAERI), initiated a new phase of study in 2011 to design and establish an Information Sharing Framework (ISF) which was defined as "a communication platform on which nuclear nonproliferation experts can provide and/or receive relevant information in a practical and sustainable manner". During the period of two-year study, partner organizations identified essential elements to establish ISF and developed the requirements. Currently, JAEA and KINAC are planning to implement demonstration of ISF under Asia Pacific Safeguards Network (APSN) as the next step.

This paper describes the past studies and activities in JAEA for enhancing regional nuclear transparency and discusses the future prospect.

Enhancing IAEA–Chile Cooperation

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Our country, has demonstrated its commitment with the nuclear non-proliferation regime. Consequently, during the past few years, the IAEA got to a broader conclusion that all of the nuclear material in the State had been placed under safeguards and remained in peaceful nuclear activities. In this matter, Chile has signed, ratified and is an active member of the following international conventions and treaties: "Statute of IAEA" (1960), Treaty of Tlatelolco on February (1967), NPT (25 May 1995), Compressive Safeguards Agreements (1995), the Additional Protocol (2002). Considering that the country has achieved the IAEA's safeguards obligations, the IAEA has implemented (2008) integrated safeguards in Chile.

Moreover, Chile is aware of the relevance of protecting their nuclear facilities against unauthorized removal of nuclear material or acts of sabotage and preventing nuclear and radioactive materials from being lost, stolen and misused. Therefore, the "Convention on the Physical Protection of Nuclear Materials" 27 April 1994 (Decree No. 1121, issued on 17 October 1994) and later 2008 the "Amendment to the Convention on the Physical Protection of Materials Nuclear" incorporating the "Nuclear Facilities" has been subscribed by the Government of Chile, and appropriate actions has been taken in collaboration with the IAEA, such the IPPAS mission (2003) and INSServ mission (2013) to evaluate the nuclear security infrastructure. Finally, an Integrated Nuclear Security Support Plan (INSSP) has been developed supported by the IAEA aimed to identify and consolidate the nuclear security needs of Chile.

For all the above we can infer that our country has a clear understanding and commitment of its international non-proliferation obligations and its safeguards agreement with IAEA, which reinforce the understanding of the inherent effects in the use of nuclear energy

Sustainability of Safeguard System for Iraqi Facilities

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- Constitution of Iraq, Implementation Commitment
- Law of National Monitoring Authority on Non-Proliferation of Nuclear, Chemical and Biological Weapons No. (48) for the year 2012
- Safeguards Application in Iraq, National Procedures for Nuclear non-proliferation system in Iraq
- Governmental supported the INMA's missions to implement Iraqi SC, AP obligations
- Establishing a National State System of Accounting for and control of Nuclear Materials in Iraq and maintained System for Accounting and Monitoring Nuclear Materials to identify nuclear material positions in and out of the nuclear facilities under Safeguards System.
- Provide official permissions to use nuclear source materials inside the nuclear facilities (such as reactor, fuel fabrication) and outside nuclear facilities (universities, research centres).
- INMD identified locations and sites which are involved in AP declaration according to our national verification.
- INMD prepared national information lists of AP articles to be distributed to all ministries so as to fill them with information required. (Industry, Higher Education, Science and Technology)
- Making inspection visits to the previous Iraqi nuclear facilities to verify their current activities.
- Establishing the information system for all nuclear activities and Materials related to Non-Proliferation Regime.
- Issuing the regulation for using, handling and transportation of The nuclear material under safeguards and Additional protocol.
- Making arrangements for the prompt notifications of losses, unauthorized use, removal of nuclear material. facilities of Iraqi Nuclear past programme monitoring and verification related to Additional protocol.
- Ensure efficient physical protection for the nuclear materials.
- Prepare design information for the nuclear facilities that are under Safeguards System as well as identify the name, occupation, address, geographical site, general description, objective and capacity of the facility.
- Hold physical inventory procedures for the inventory change report.
- Identify records' type and container and monitoring devices.

A New Step for "State–IAEA Cooperation" Based on the Enhanced Cooperation Program

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Since joining the IAEA comprehensive safeguards agreements, the ROK has made some exemplary case of implementing the IAEA's safeguards policy in a State. It's the results of the ROK Government's persistent effort for nuclear transparency to maintain its peaceful nuclear activities which is indispensible in Korea. The history of the ROK SSAC development can be reflected on the trajectory of the evolution of the IAEA safeguards. The ROK SSAC has achieved technical capabilities required for IAEA safeguards, which was not possible without cooperation programme with the IAEA. The first memorable moment of the ROK-IAEA cooperation is the enhanced cooperation program for the ROK LWRs in 2001, introducing remote monitoring systems and some changes in interim inspections. The next chance for leveling the ROK SSAC up came with IS implementation. Two parties consulted what should be prepared for efficient implementation of IS through seven times working group meetings. The WG put out IS approaches which have been being applied for the ROK nuclear facilities since 2008. The IS implementation, which is based on the state level approach, allowed the ROK SSAC to get opportunities to improve more its technical capabilities about support for IAEA safeguards activities, developing verification devices and safeguards approaches for pyroprocessing related facilities. The IAEA and the ROK are putting strenuous efforts for strengthening safeguards cooperation based on the Enhanced Cooperation Arrangements which was signed in 2012, discussing the SSAC role in IAEA safeguards activities, joint use equipment, etc. Besides, two parties are considering introducing unannounced inspections at LWRs after several rehearsals. In this paper, the implication and importance of State-IAEA cooperation is presented based on the ROK's experience with summarizing the brief history of SSAC development and cooperation with the IAEA.

Creating Material Balance Area for Location Outside Facilities in Nigeria

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Nigeria signed the Comprehensive Safeguards Agreement and its Additional Protocol which came into force on 29th February 1988 and 4th April 2007 respectively. In fulfilment of Article 2(a)(ii) of INFCIRC/358/Add.1 of the Agreement between the Federal Republic of Nigeria and the Agency on the application of Safeguards in connection with the Treaty on Non-proliferation of Nuclear Weapons (the Agreement), Nigeria through the NNRA embarked on a Survey of Depleted Uranium (DU) used as shielding in various locations in Nigeria based on the IAEA reporting requirements. The preliminary survey was executed by two inspectors each in the south (SS), south-west (SW) and north-west (NW) part of Nigeria from 12–23 December 2011. The major survey was carried out by a total number of twenty-four inspectors from 18–22 November 2013 and a total number of eighteen inspectors from 3–7 February 2014 for Phase I and II, respectively, in the six geopolitical zones of Nigeria. Both surveys were by physical inventory.

The purpose of the survey was to ensure radiation protection planning and management of safety, security and safeguards of sources material used for shielding. The result of the survey is the database of depleted uranium in different parts of Nigeria which had been appropriately reported under the above Agreement.

Depleted Uranium was found in 31 facilities in the NW, SS and SW region. The NNRA is also consulting with the Agency on appropriate reporting of these findings. In this regard, an update report on the Depleted Uranium Survey was sent to the Agency on 22nd February 2014 for advice and further processing.

The 50 Years of Safeguards and Non-Proliferation in Poland

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Milestones of safeguards and non-proliferation activities are presented. Poland has declared its compliance with non-proliferation regime by ratification of Treaty of Non-proliferation of Nuclear Weapons in 1969. Poland concluded in 1972 Agreement with IAEA for application of safeguards — INFCIRC/153. Next steps in implementation of international safeguards were: ratification of Additional Protocol and introduction of Integrated Safeguards.

After accession to European Union, Poland fulfils its safeguards obligations according to following international legal instruments: Treaty establishing Euratom, Agreement between Poland, European Commission and International Atomic Energy Agency in connection with implementation of Article III of Treaty of Non-proliferation of Nuclear Weapons — INFCIRC/193 and Additional Protocol to this Agreement — INFCIRC/193 Add.8.

Detailed safeguards requirements are established by domestic Act of Parliament of 29th November 2000 — Atomic law and European Union's Regulations of Commission (Euratom) No 302/2005 on application of Euratom safeguards and the Commission Recommendation on guidelines for the application of Regulation (Euratom) No 302/2005.

SSAC was established in 1972 as required by CSA. Activities related to accounting for and control of nuclear material were conducted from 1970s till 1990s by Central Laboratory for Radiological Protection and National Inspectorate for Radiation and Nuclear Safety. Currently, NAEA is responsible for collecting and maintenance of accounting data and safeguards inspections at all MBAs.

Around 30 routine inspections/year are performed by the NAEA, Euratom and IAEA. In addition, usually 2 unannounced inspections/year under framework of Integrated Safeguards are conducted.

In accordance with implementation of Global Threat Reduction Initiative seven shipments of high enriched nuclear fuel from research reactor to Russian Federation under supervision of safeguards inspectors from NAEA, Euratom and IAEA were successfully completed in years 2009–2014.

Inspections performed by NAEA, Euratom and IAEA showed that there are no diversion of nuclear material in Poland.

Safeguards Status in Lebanon as SQP Country and Reinforcement within a Nuclear Law

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As SQP State, the Lebanese Atomic Energy Commission LAEC, as regulatory authority, was assigned by the Lebanese government to deal with all issues related to safeguards within the small quantities protocol. Consequently, the State System of Accounting for and Control of Nuclear Material (SSAC) was established within the LAEC and linked to the Nuclear Security Department. In this regard, an initial report was submitted to the IAEA, followed by a first inventory on nuclear materials existing in Lebanon.

In the initial report, it was declared that there are no nuclear facilities in Lebanon (power plant, reactor, nuclear fuel fabrication, nuclear fuel processing) and no mining activities related to nuclear materials, therefore, there is no nuclear material used for the above mentioned purposes. However, in the first inventory it was reported on the existing of nuclear materials, commonly for non-nuclear use, and they are mainly located in hospitals, industries, universities and research institutes. In this inventory report, we have included information about these materials such as type, quantity, form, location and exact use, in compliance with the inventory form attached to the SQP guidance document. During the inventory preparation, it was noticed some synergy between nuclear safety, nuclear security and safeguards. However, this inventory should be upgraded soon.

A nuclear law is prepared by LAEC with the technical assistance of IAEA. The first draft is already available and waiting to be promulgated to the Lebanese parliament. In this law, the IAEA-SSS concept (safety, security and safeguards) is covered in a comprehensive way.

Safeguards in Pakistan: State-Agency Cooperation

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Implementation of IAEA Safeguards in Pakistan dates back to March, 1962 when a trilateral safeguards agreement (INFCIRC/34) was signed for the supply of Pakistan Research Reactor-1 (PARR-1), under the "Atoms for Peace program". At that time there were few nuclear facilities under IAEA safeguards around the globe. Since then Pakistan has concluded several safeguards agreements with the Agency. All the safeguards agreements concluded by Pakistan are governed under the Safeguards Document INFCIRC/66/Rev.2. Under this model, an item-specific or facility-specific safeguards is applied which employs diverse approaches and, from some aspects, is more stringent than Comprehensive Safeguards approach. However, Pakistan believes in strong State-Agency cooperation for successful implementation of safeguards. Throughout the history of safeguards in Pakistan since 1962, the atmosphere of coordination and cooperation with Agency in safeguards implementation has been exceptional. Pakistan has been extending its utmost cooperation with the Agency in resolving the emerging safeguards issues at its safeguarded facilities. KANUPP remained involved in the Agency project on "Development of In situ Verification for CANDU Spent Fuel Bundles" as well as in performance evaluation of bundle counters. KANUPP has been providing analytical services for heavy water samples and various manufacturing services on Agency's requests. Pakistan is participating in voluntary reporting scheme established by the Agency regarding any export of separated neptunium (Np) and americium (Am) to any of the Comprehensive Safeguards Agreement (CSA) State since 2000. Various emerging issues of safeguards implementation have been resolved with the Agency by agreeing to a number of Safeguards Approaches with the Agency. Recently this number has been increased to 36. We intend to maintain this spirit of cooperation with the Agency in future regarding safeguards implementation in Pakistan.

Safeguards in Slovakia

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The use of nuclear power started in former Czechoslovakia in early seventies in previous century. Czechoslovakia was party to Safeguards Agreement since 1973. After the split of Czechoslovakia in 1993, Slovak government fully adopted the Safeguards Agreement. After accession to the EU Slovakia ratified INFCIRC/193 and its Protocol Additional. Finally, in 2009, integrated safeguards regime has been implemented in Slovakia.

After reaching highest standards in safeguards implementation we focused our effort on strengthening synergistic effects of safeguards, nuclear safety and nuclear security. The implementation and awareness of concept of 3S became our task. The Nuclear Regulatory Authority of the Slovak Republic (UJD) has started systematic effort of explanation of usefulness of implementation of 3S concept in our nuclear facilities. After the Chernobyl accident the nuclear safety became very important issue. Fukushima accident has further increased the importance of highest level of nuclear safety in our nuclear installations. Although the level of nuclear security and nuclear safeguards is very high, the awareness of importance of nuclear security and safeguards is not at the same level as awareness of nuclear safety.

UJD organized several activities with aim to increase the overall understanding of the concept of 3S. In last years we organized workshops on nuclear safety and nuclear security culture, we also discuss the issue with our operators in order to find ways on how to implement and utilize the benefits of synergy of 3S.

It is quite difficult to change the way the people think. The change will be a long process and we are at the beginning of it.

S30: Enhancing Safeguards Through Information Analysis

Enabling Collaborative Analysis: State Evaluation Groups, the Electronic State File, and Collaborative Analysis Tools

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The timely collection and analysis of all safeguards relevant information is the key to drawing and maintaining soundly-based safeguards conclusions. In this regard, the IAEA has made multidisciplinary State Evaluation Groups (SEGs) central to this process. To date, SEGs have been established for all States and tasked with developing State-level approaches (including the identification of technical objectives), drafting annual implementation plans specifying the field and headquarters activities necessary to meet technical objectives, updating the State evaluation on an ongoing basis to incorporate new information, preparing an annual evaluation summary, and recommending a safeguards conclusion to IAEA senior management.

To accomplish these tasks, SEGs need to be staffed with relevant expertise and empowered with tools that allow for collaborative access to, and analysis of, disparate information sets. To ensure SEGs have the requisite expertise, members are drawn from across the Department of Safeguards based on their knowledge of relevant data sets (e.g., nuclear material accountancy, material balance evaluation, environmental sampling, satellite imagery, open source information, etc.) or their relevant technical (e.g., fuel cycle) expertise.

SEG members also require access to all available safeguards relevant data on the State. To facilitate this, the IAEA is also developing a common, secure platform where all safeguards information can be electronically stored and made available for analysis (an electronic State file). The structure of this SharePoint-based system supports IAEA information collection processes, enables collaborative analysis by SEGs, and provides for management insight and review. In addition to this common platform, the Agency is developing, deploying, and/or testing sophisticated data analysis tools that can synthesize information from diverse information sources, analyze diverse datasets from multiple viewpoints (e.g., temporal, geospatial, and process-centric), and document results, including intermediate analytical products. The electronic platform and analysis tools are described.

Open Source Information in Support of Safeguards

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Open source techniques are an increasingly important tool for in safeguards. From social networking sites, such as Linkedin, to B2B portals like Alibaba, there are large open source databases that touch all aspects of the nuclear fuel cycle, from goods to scientists. This is in addition to the wealth of more traditional open source tools such as search engines.

In this paper we focus on the potential of B2B sites to provide dual use goods for use in the nuclear fuel cycle. We will discuss the availability of these items as well as the frequency and content of tenders.

As many of the largest sites—by traffic and content—are in Asia we will examine the potential of these sites to provide goods used in the nuclear fuel cycle.

Open Source and Trade Data for Non-Proliferation: Challenges and Opportunities

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This paper explores what more systematic exploitation of trade data can contribute to the state evaluation process. The paper begins by setting out a typology of trade data, which groups the data into five categories:

- Government Declared Data, which is prepared and submitted by States to an international authority for non-proliferation purposes.
- Government Recorded Data, which includes information collected by the state for its own purposes, and which is not routinely submitted to international authorities for non-proliferation purposes. It includes (some) export licencing data, customs data, and business registration information.
- Business-held data, which includes information on a company's own products and customers, but also "market intelligence".
- Intelligence and Enforcement Derived Information, which can include information on specific procurement attempts, networks, or procurement requirements.
- Procurement Requirements Information, which can include information released by a programme for the purpose of seeking goods or services.

Challenges and opportunities related to further exploitation of trade data sources in each category are then explored, as are factors related to accessibility (both in terms of mandates and more practical considerations), reliability (including presentation of a typology), completeness, and duplication in data.

Next, the paper explores how the IAEA can systematically collect, integrate and analyze the various sources of trade data given the considerations outlined above. In particular, this section focuses on how data in variable structures can be integrated into the state evaluation process.

In concluding, the paper will describe how the newly formed "Collaboration on Open Source and Trade Analysis for Non-proliferation" (COSTA-NP) is seeking to develop each of the categories of trade data.

The paper links to research objectives 1.3, 1.4, 2.1, 2.3, and 2.4 of the IAEA research plan.

Extraction and Analysis of Information Related to Research & Development Declared Under an Additional Protocol

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The additional protocol (AP) provides important tools to strengthen and improve the effectiveness and efficiency of the safeguards system. Safeguards are designed to verify that States comply with their international commitments not to use nuclear material or to engage in nuclear-related activities for the purpose of developing nuclear weapons or other nuclear explosive devices. Under an AP based on INFCIRC/540, a State must provide to the IAEA additional information about, and inspector access to, all parts of its nuclear fuel cycle. In addition, the State has to supply information about its nuclear fuel cycle-related research and development (R&D) activities. The majority of States declare their R&D activities under the AP Articles 2.a.(i), 2.a.(x), and 2.b.(i) as part of initial declarations and their annual updates under the AP.

In order to verify consistency and completeness of information provided under the AP by States, the Agency has started to analyze declared R&D information by identifying interrelationships between States in different R&D areas relevant to safeguards.

The paper outlines the quality of R&D information provided by States to the Agency, describes how the extraction and analysis of relevant declarations are currently carried out at the Agency and specifies what kinds of difficulties arise during evaluation in respect to cross-linking international projects and finding gaps in reporting. In addition, the paper tries to elaborate how the reporting quality of AP information with reference to R&D activities and the assessment process of R&D information could be improved.

S31: Promoting the Interface Between Nuclear Safety, Security and Safeguards

Nuclear Security and Nuclear Safeguards; Differences, Commonalities and Synergies

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Reference to the three S's in the nuclear world is recurring and much has been said about the need to build on synergies to reinforce safeguards, safety and security. In practice, the 3S's communities are seldom interconnected even though some interaction can be observed between safety and security and security and safeguards. Ensuring a better understanding between those three sectors about their scope, requirements, implementation methods and tools would stimulate cooperation.

The second Nuclear Security Summit and particularly the industry related event stressed the synergies between safety and security. The first IAEAs Security Conference organized in July 2013 did not address specifically nuclear safeguards and security relations. Last Security Summit took place in The Hague in March 2014 and this type of issue was not really raised either.

The safeguards Symposium provides a timely opportunity to tackle possible enhanced cooperation between safeguards and security communities and assess the prospect for addressing such issue at the next and allegedly last security summit in 2016.

This presentation will analyze the differences and commonalities between those two sectors, in particular with regards to the objectives and actors, the organization and technicalities, or to the conceptual approaches (DBT and APA/SLC, attractiveness/accessibility). It will then assess the possible synergies or cooperation between both communities. It will discuss the merits of a global and comprehensive involvement of the different actors, (State, industry and international bodies including the NGOs) and of exchanges on good practices to contribute to a common understanding and references while allowing for an adaptable and national approach. Indeed the need to reassure the stakeholders, including the general public, that security, as well as safeguards are addressed in a consistent manner worldwide is of utmost importance for building future nuclear energy programmes on a strong and confident basis.

Two Views on Nuclear Material Accounting and Control (NMAC)

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Under the NPT, most of the states concluded comprehensive safeguards agreement with the Agency for the peaceful use of nuclear energy. Nuclear Material and Control (NMAC) is one of the most important measures of the safeguards to detect the diversion of the nuclear material by the state actor. Meanwhile, NMAC plays an important role in detection of the theft by the non-state actor. Therefore, the NMAC is used as a measure for the security purpose. Since the 3S concept was introduced, relations, synergies and interfaces of the safety, security and safeguards were discussed. NMAC is one of the items representing security-safeguards interface. Most of the non-weapon states have well established NMAC system. Physical inventory of the nuclear material and their verification would be performed periodically by the Agency, which makes it less vulnerable to the insider threat in view of security. It will be useful for the newcomer countries to have NMAC system with consideration of security feature. The states with well established NMAC system can utilize the existing NMAC system for the security purpose, or strengthen their security system. In this research, we will discuss what needs to be considered to get synergies both for safeguards and security of the NMAC system. It will include technical aspects as well as legislation point of view.

Exercising Synergy of Safeguards Safety and Security at Facility Level of the GA Siwabessy Multi-Purpose Reactor, Indonesia

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Safeguards, safety and security (3Ss) constitute as essential elements for successful development of nuclear technology in the life time of nuclear installation. All 3Ss need to be coordinated due workers, the public and the environment require protection from plant malfunction, human error, malicious acts and proliferation of nuclear materials and technologies. Then the importance of the 3Ss was deemed valuable, particularly to a country having willingness to expand to nuclear power reactor such as Indonesia that in the near future plans to build small experimental power reactor. This paper is aimed to discuss synergy among safeguards, safety and security which will have opportunity been exercising at the GA Siwabessy Reactor (RSG-GAS), Indonesia. Synergy among safeguards, safety and security offers much opportunity for cost savings and enhance efficiency. Discussion is carried out by first investigating common values and conflicts exist among 3S. Up to now each of them was accomplished separately by different division and using different equipment due lack of coordination among them. The objective of this exercise is to develop more efficient and effective 3Ss infrastructures and also to support skill and knowledge of human resources. Benefitting from synergy between safeguards and security such as management of nuclear material and non proliferation; safeguards and safety such as management of nuclear material and waste management; safety and security such as prevent radiological release and also tension among them if any are discussed. It is expected that outcome of this exercise will able to develop a role model of infrastructures to the up-coming small experimental power reactor in Indonesia.

Proliferation Resistance and Safeguards by Design: The Safeguardability Assessment Tool Provided by the INPRO Collaborative Project "INPRO" (Proliferation Resistance and Safeguardability Assessment)

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Since the INPRO Collaborative Project on Proliferation Resistance and Safeguardability Assessment Tools (PROSA) was launched in 2011, Member State experts have worked with the INPRO Section and the IAEA Department of Safeguards to develop a revised methodology for self-assessment of sustainability in the area of proliferation resistance of a nuclear energy system (NES). With the common understanding that there is "no proliferation resistance without safeguards" the revised approach emphasizes the evaluation of a new "User Requirement" for "safeguardability", that combines metrics of effective and efficient implementation of IAEA Safeguards including "Safeguards-by-Design" principles. The assessment with safeguardability as the key issue has been devised as a linear process evaluating the NES against a "Basic Principle" in the area of proliferation resistance, answering fundamental questions related to safeguards: 1) Do a State's legal commitments, policies and practices provide credible assurance of the exclusively peaceful use of the NES, including a legal basis for verification activities by the IAEA? 2) Does design and operation of the NES facilitate the effective and efficient implementation of IAEA safeguards? To answer those questions, a questionnaire approach has been developed that clearly identifies gaps and weaknesses. Gaps include prospects for improvements and needs for research and development. In this context, the PROSA approach assesses the safeguardability of a NES using a layered "Evaluation Questionnaire" that defines Evaluation Parameters (EP), EP-related questions, Illustrative Tests and Screening Questions to present and structure the evidence of findings. An integral part of the assessment process is Safeguards-by-Design, the identification of potential diversion, misuse and concealment strategies (coarse diversion path analysis), and the identification of safeguards tools and measures to meet facility or activity specific safeguards objectives. The usefulness of this approach has been preliminary tested and demonstrated in a case study performed by KAERI.

Status of the Gen-IV Proliferation Resistance and Physical Protection (PRPP) Evaluation Methodology

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Methodologies have been developed within the Generation IV International Forum (GIF) to support the assessment and improvement of system performance in the areas safeguards, security, economics and safety. Of these four areas, safeguards and security are the subjects of the GIF working group on Proliferation Resistance and Physical Protection (PRPP). Since the PRPP methodology (now at Revision 6) represents a mature, generic, and comprehensive evaluation approach, and is freely available on the GIF public website, several non-GIF technical groups have chosen to utilize the PRPP methodology for their own goals. Indeed, the results of the evaluations performed with the methodology are intended for three types of generic users: system designers, programme policy makers, and external stakeholders. The PRPP Working Group developed the methodology through a series of demonstration and case studies. In addition, over the past few years various national and international groups have applied the methodology to inform nuclear energy system designs, as well as to support the development of approaches to advanced safeguards. A number of international workshops have also been held which have introduced the methodology to design groups and other stakeholders. In this paper we summarize the technical progress and accomplishments of the PRPP evaluation methodology, including applications outside GIF, and we outline the PRPP methodology's relationship with the IAEA's INPRO methodology. Current challenges with the efficient implementation of the methodology are outlined, along with our path forward for increasing its accessibility to a broader stakeholder audience – including supporting the next generation of skilled professionals in the nuclear non-proliferation field.

Containment and Surveillance and Physical Protection Updates for Proliferation Resistance Analysis Using PRAETOR

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The Proliferation Resistance Analysis and Evaluation Tool for Observed Risk (PRAETOR) software code assesses the proliferation resistance (PR) of nuclear fuel cycle (NFC) systems. The Nuclear Security Science and Policy Institute (NSSPI) at Texas A&M University developed PRAETOR based on the well-established multi-attribute utility analysis (MAUA) methodology. MAUA methods facilitate compiling multiple PR characteristics into tiered PRAETOR output PR metrics enabling easier decision making at the analyst, program manager, and policy maker levels. PRAETOR uses intrinsic and extrinsic PR attributes to evaluate NFC systems. The PRAETOR 1.0 code originally had 63 attribute inputs representing the NFC system. The attribute input values assigned by the user are mapped to a utility value between 0 and 1 using utility functions. Each attribute has an associated weight obtained through a survey. Larger PRAETOR utility values indicate higher NFC system PR.

An updated version of PRAETOR (Version 2.0) added seven more attribute inputs representing the nuclear security PR aspects of: (1) physical protection systems (PPS) and (2) containment and surveillance (C&S). The applicability of PRAETOR is demonstrated through a set of case studies. Two cases of Pressurized Water Reactor (PWR)used fuel assemblies with different cooling times were considered in this paper: (a) non-cooled fuel assemblies, and (b) 30-year cooled fuel assemblies. The case studies consider the new PPS and C&S attributes with low and high utility values. The PR results for the case studies with the updated PRAETOR were compared with those without the PPS and C&S attributes. The new attributes increased overall PR value by about 10% for case (a) and decreased it by about 3% in case (b). The importance of adding new attributes capturing physical protection and containment & surveillance is established.

Modern Approaches to the Establishment of National Geoinformation Systems as a Means of Combating Nuclear Terrorism and Illicit Trafficking of Radioactive Materials

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The report deals with the approaches to the establishment of National geoinformation systems as a means of combating nuclear terrorism and illicit trafficking of radioactive materials (hereinafter National geoinformation systems), which represent the integration of already existing and brand-new hardware and software into a single system for illicit trafficking control. It illustrates the model of transition from current operation system, which is based on engagement of different resources used by governmental agencies, to network solutions enabling to automatize and optimize the process of radiation control, to organize on-line radiological information exchange, thus, enhancing efficiency of reacting on illicit trafficking of nuclear or other radioactive materials.

The report also describes operational algorithm of National geoinformation systems and experience of implementation of modern radiological network based equipment, which enables to indicate location, to take measurements and transfer results to the remote expert centre on-line using different data transmission means.

Web-application of National geoinformation systems enables to automatize processing of radiological information, which is transferred from different users to a single server, to display the location on the map, to maintain the database of illicit trafficking of nuclear and other radioactive materials, and to exchange information between concerned member-states and IAEA contact points.

In general, the suggested system combines new possibilities, which allow to integrate a number of devices into a single network, to display radiological data with GPS-location marks, to give access to the experts for estimating the results of the radiological measurements, to manage the actions of different users from a single remote expert centre and, if necessary, to render on-line expert assistance.

The described in the report National geoinformation system has been adopted by a number of users, has turned out to be efficient and is recommended for use in IAEA member-states.

Information Management: Enhancing Information Discovery and Information Availability

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IBM Security Intelligence with Analytics of massive data provides exceptional threat and risk detection, combining deep security expertise with analytical insights on a massive scale. For forward-leaning organizations seeking advanced insight into security risks, the IBM solution — Security Intelligence Platform for massive data — provides a comprehensive, integrated approach that combines real-time correlation for continuous insight, custom analytics across massive structured and unstructured data, and forensic capabilities for irrefutable evidence. The combination can help you address advanced persistent threats, fraud and insider threats.

The IBM solution is designed to widening the scope and scale of investigation, enabling analyzes of any kind of data in any format, such as DNS transactions or full packet capture data to find malicious activity hidden deep in the masses of an organization's data.

IBM Watson Explorer provides a unified view displaying all of security relevant information in a portal-like UI. The information analytics system is built around AQL (Annotated query language), a declarative rule language with a familiar SQL-like syntax. AQL supports the paradigm describing data for data with an optional data governance catalogue for massive volumes of data supporting individual views in addition to the pre-defined Document view that holds the textual and label content.

An underlying Role-Based Access Control that data protection rules are strictly enforced within the whole architecture. Security at the document, sub-document and record level is built into Watson Explorer. When Watson Explorer security is implemented, users cannot see information that they would be prohibited from seeing if they were directly logged into the target system.

S32: NDA Measurements III: Neutron Measurements

Performance of Boron-10 based Neutron Coincidence Counters

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Helium-3 gas-filled detectors have been used in neutron coincidence counting for non-destructive assay for over 30 years. With the current shortage of 3He gas, GE's Reuter-Stokes business developed a 10B lined proportional counter and a 10B hybrid coincidence counter, in which a small amount of 3He is added to a 10B detector to enhance the neutron sensitivity.

GE's Reuter-Stokes business modelled, designed, built and tested prototype coincidence counters using the 10B lined detectors and the 10B hybrid detectors. We will present these systems and their applications for non-destructive assay.

Development of a Pulse-Train Recorder for Safeguards

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A list-mode pulse-train recorder, PTR-32HV has been developed by the Hungarian Centre for Energy Research. The hardware has been authorized by the IAEA for safeguards applications. The finished unit provides 32 input channels, high voltage output, low-voltage output and is controlled over a USB port. Each input channel can be used independent or in sum for neutron multiplicity analysis. Independently used channels can replace several parallel working conventional shift registers. The hardware can be controlled by the INCC software package used by the IAEA or by software provided by the vendor.

The vendor software provides four distribution views including follow-up time, multiplicity, Rossi-alpha and impulse rate. There are several channel related and other utility functions like merging, unfolding, deleting and chopping. We have recently expanded the data analysis software to include conventional signal-triggered shift-register multiplicity analysis and Feynman variance-of-the-mean analysis in addition to incorporating fast-accidentals sampling (FAS). We have also expanded the available error analysis to include the calculated standard deviation, Dytlewski-Ensslin theoretical error calculation and a new variance analysis technique applicable to FAS and Feynman analysis.

This work has been supported by the Hungarian Support Programme to the IAEA

Application of 10B Lined Proportional Counters to Traditional Neutron Counting Applications in International Safeguards

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Many neutron detection techniques are under consideration as replacement for 3He proportional tube in international safeguards applications. The traditional 10B-lined proportional tube is a commercial off the shelf (COTS) technology for neutron detection that pre-dates the development of 3He detectors. This long history of use of these detectors in neutron counting facilitates modelling, design and testing of assay systems based this alternative detection technique. In comparison to the 3He tube, the 10B-lined detector meets or exceeds all relevant criteria (e.g., stability, resistance to gamma-ray exposure, etc.) with the exception of neutron detection efficiency per unit volume. Boron coating thickness and the active detection area per unit volume limit the measurement performance ultimately achievable with these detectors, however, assay systems based on the 10B-lined proportional detector can be constructed with sufficient measurement performance to achieve the International Target Values for a subset of traditional safeguards counting applications. Additionally, these detectors are well suited to a number of active neutron interrogation applications such as the differential die-away and 252Cf Shuffler techniques. We have examined the performance of a set of commercially manufactured neutron slab counting assemblies configured as a neutron coincidence collar, a passive neutron coincidence well counter, and as the detector assembly within a large cavity 252Cf Shuffler. Measurement performances are presented and compared with that of the standard 3He based counting systems. These performance levels present a baseline of what can be achieved using COTS neutron counting with no significant development required against which the anticipated performance of a potential alternative technology and the additional portion of the safeguards application space it could address.

Monte Carlo Modeling and Experimental Evaluation of a 6LiF:ZnS(Ag) Test Module for Use in Nuclear Safeguards Neutron Coincidence Counting Applications

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This paper summarizes the Monte Carlo modelling, prototype construction, calibration and characterization of a 3He-free neutron detection test module consisting of several compact 6LiF:ZnS(Ag) thermal neutron absorbers in a moderating slab configuration. In order to determine the suitability of the test module for implementation in a nuclear safeguards coincidence counter, safeguards-relevant detection parameters, such as intrinsic efficiency, die-away time, gamma sensitivity, and dead time effects, are evaluated experimentally using a 252Cf spontaneous fission neutron source and 137Cs gamma sources. The 6LiF:ZnS(Ag) test module performance will be assessed systematically in comparison to other alternative 3He technologies which have already been investigated. The design of coincidence and multiplicity counters based on this technology will then be discussed.

Development of the Single Chip Shift Register (SCSR) for Neutron Coincidence and Multiplicity Analysis

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The Single Chip Shift Register (SCSR) is designed to be a very simple, low cost, and very robust data acquisition circuit board that can be used with any neutron coincidence or multiplicity counter. Safeguards systems used in neutron detection presently require a detector/amplifier combination along with a data acquisition system that converts pulse streams into histogrammes of correlated pulses, commonly referred to as a shift register. The current state of digital electronics now makes it possible to incorporate the shift register into the detector/amplifier system and allow direct USB or Ethernet connection to the detector from a laptop. Inclusion of the shift register into the detector head will eliminate the need for the agency to purchase expensive and often not readily available shift register systems, i.e., AMSRs and JSR15s. The setup and operation of attended instrumentation will be simpler and more reliable. External HV or signal cabling will be unnecessary. The SCSR is a modification of the existing derandomizer circuit board which is normally located in the detector head. The modification includes the addition of the shift register circuitry, HV supply, USB port and Ethernet port.

Development of Advanced MOX Holdup Measurement Technology for Improvement of MC&A and Safeguards

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The Distributed Source-Term Analysis (DSTA) technique has been used in a variety of safeguards applications to determine location and quantity of material contained within large sample volumes. The DSTA method can provide user with knowledge of the location of neutron-producing materials and magnitude of the localized activity. By applying this method, JAEA developed two different neutron measurement techniques to improve own material accountancy and control (MC&A) in PCDF.

The first technique is a Glove Box Cleanout Assistance Tool (BCAT). It is used by operator during cleanout to increase recovered material, to decrease unmeasured inventory, and to perform the cleanout activity effectively. In order to identify holdup locations in a multiple gloveboxes qualitatively, we have designated 57 representative neutron measurement positions distributed individually throughout area of interest (53 areas). The BCAT is being introduced to the actual cleanout since 2011.

The second technique is a dynamic cross-talk correction (DCTC) method. The DCTC can obtain actual doubles signal cross-talk between multiple gloveboxes. In order to improve own MC&A in the holdup, it was necessary for operator to improve the current holdup measurement system (HBAS; passive neutron-coincidence based NDA). Because we had historically used a simple fixed-value for cross-talk correction although holdup amount varies according to the facility operation. After introduction of DCTC, by using a response matrix (6×6) between each detector position and glovebox determined from MCNPX model, cross-talk corrected doubles rates which is equivalent to the holdup amount can get correctly. We implemented an improved HBAS system using DCTC at the 2011PIT with authorization by inspectorate. The DCTC improves own MC&A by eliminating the double-counting of material that stems from cross-talk in the holdup assay data and eliminates this source of bias in the assay results.

Fresh PWR Assembly Measurements with a New Fast Neutron Collar

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The primary tool for the physical verification of LWR fresh fuel assemblies is the neutron collar [1]. In order to minimize the dependence on the operator's declaration for poison fuel rods, it can be operated in fast mode. Until now, measurements in this mode were time-consuming, taking ∼1 hr for reasonable precision. In order to improve this performance a new collar for PWR assemblies, still based on 3He tubes, but with better performance, was designed using simulations [2]. This paper reports on the experiments undertaken to demonstrate that the performance of the new collar, as fabricated, corresponded to the modelling predictions. Measurements have been made with the same PWR mock-up assembly that was used for the original collar calibration work [1]. These measurements have shown that the experimental performance of the new collar is very similar to the simulated performance. The U235 content of a 4.5% enriched fuel assembly can be determined with an uncertainty of ±2% in a total measurement time (active plus passive) of less than 1000 s. The effect of poison pins was also determined. The results show that the size of the poison pin effect agrees with the simulated predictions, reducing the effect of 12 pins with 5.2% Gd from over 20% in thermal mode to 3.6%. Experimental tests were also made on the response of the detector to changes in the location of the fissile material within the assembly.

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Position-Sensitive Organic Scintillation Detectors for Nuclear Material Accountancy

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Recent years have seen renewed interest in fast organic scintillators with pulse shape properties that enable neutron-gamma discrimination, in part because of the present shortage of He3, but primarily because of the diagnostic value of timing and pulse height information available from such scintillators. Effort at Oak Ridge National Laboratory (ORNL) associated with fast organic scintillators has concentrated on development of position-sensitive fast-neutron detectors for imaging applications. Two aspects of this effort are of interest. First, the development has revisited the fundamental limitations on pulse-shape measurement imposed by photon counting statistics, properties of the scintillator, and properties of photomultiplier amplification. This idealized limit can then be used to evaluate the performance of the detector combined with data acquisition and analysis such as free-running digitizers with embedded algorithms. Second, the development of position-sensitive detectors has enabled a new generation of fast-neutron imaging instruments and techniques with sufficient resolution to give new capabilities relevant to safeguards. Toward this end, ORNL has built and demonstrated a number of passive and active fast-neutron imagers, including a proof-of-concept passive imager capable of resolving individual fuel pins in an assembly via their neutron emanations. This presentation will describe the performance and construction of position-sensing fast-neutron detectors and present results of imaging measurements.

S33: IAEA-State Cooperation III

Euratom Safeguards: Improving Safeguards by Cooperation in R&D and Implementation

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Euratom Safeguards, implemented on the basis of the Euratom Treaty by the European Commission's Directorate Nuclear Safeguards, is the largest Regional Safeguards System and involved in many R&D activities of its own, often in close cooperation with external partners. Most of the results of these activities are shared with or offered to the IAEA. The work described in this paper is complementary to the projects run by the European Commission Cooperative Support Programme (ECSP) to the IAEA. The ECSP activities will be described elsewhere at this conference.

The present paper will provide an overview on R&D activities run in addition to the ECSP, and will attempt to link them to the capabilities discussed by the IAEA in the Long Term R&D Plan. The range of topics will include work on unattended data acquisition systems (hard- and software), advanced data analysis tools, news from seals related technology, containment and design verification applications of 3D lasers, activities to keep standard measurement technologies sustainable etc. Work done with the IAEA in preparation of new facilities and facility types will be discussed briefly. The paper will also highlight some current challenges and make suggestions how to address them.

Development of System Regulating and Support for Nuclear Security in Belarus

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A safeguards strengthening in Belarus is realized as complex for measures of legal authorities building, advance staff education and international cooperation. The main scope of complex coordinated activities is to provide the sustainable development of national regulatory system and support for current and future challenges in a more globalized world to assure relevant safeguards measures and implements, to get the sustainable international and regional cooperation. Collected and implemented information and knowledge, analytical thinking of involved specialists will improve cooperation between IAEA and States to optimize technical support and experience exchange.

Some authorities are responsible in regulating and oversighting for nuclear security in Belarus. The main challenge of national system development is realization the conception of effective coordination. The nuclear regulatory authority (the Ministry for Emergency Situations/ Gosatomnadzor) has the responsibility either to build up own technical capabilities for detailed review and assessment of processes and activities of the NPP operator or to make sure that a technical support organization equipped with sufficient knowledge and structural capabilities is involved in assessment and analysis of processes at all phases of the NPP use.

There is developed the conception for creation of analytical and technical support laboratory including both stationary and mobile equipment and techniques for nuclear security prevention and control measures and arrangements. It is actually the realization of conception the Joint Center for Nuclear Security Competence in Belarus for national and cooperational purposes.

The implementation of strengthening plans and put-up arrangements will lead to integrated regulatory activities in order to allow practical optimization of the resources to get benefits from exchange of experience and issues from safety analysis and oversighting as synergy effect.

Verification of Spent Fuel Transfers in Germany — Linking Strategy, Implementation and People

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Following the decision of the German Government to completely phase out nuclear energy by 2022, the Agency is facing an increasing number of spent fuel (SF) transfers from nuclear power plants (NPP) to dry SF storage facilities. Verification of these transfers in the period 2015–2016 would have required about 1000 additional calendar-days in the field by inspectors. To meet the verification requirements with the available resources, the Agency together with the European Commission (EC) designed an innovative approach. The approach is making full use of safeguards cooperation with the EC and Germany's NPP operators to reduce the inspector's efforts, while fully adhering to the Agency's safeguards policy and requirements.

The approach includes verification for partial defect test using digital Cerenkov viewing device (DCVD) of all SF assemblies in a reactor pond(s) before and after a SF loading campaign; during the SF loading campaign all SF in pond(s) is maintained under continuous surveillance, while the containment measures on SF casks, i.e., fibre-optic and electronic seals, and corresponding fibre-optic cables, are applied by the NPP operator in accordance with the agreed procedure.

While the above approach allows for substantial reduction of the Agency inspector presence during the SF cask loading campaign, it can only be implemented when good cooperation exists between the Agency, the facility operator, and, as in the case of Germany, the regional safeguards authority.

The European Commission Cooperative Support Programme: Activities and Cooperation

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The International Atomic Energy Agency (IAEA) bases its technical and scientific programme on voluntary contributions from Member States, constituting the Member States Support Programme (MSSP). The European Commission Cooperative Support Programme (EC-SP) started in 1981 to support IAEA activities in the field of nuclear safeguards.

Since its beginning, the EC-SP has been operated by the European Commission's Joint Research Centre in close collaboration and coordination with the European Commission's Directorate General for Energy — Directorate Nuclear Safeguards implementing the Euratom treaty. EC-SP tasks provide technology and expertise in technical areas related to the effective implementation of safeguards verification measures including the detection of undeclared materials, activities, and facilities.

The EC-SP fosters cooperation with Support Programmes from European Union Member States, as well as with non-EU states with which the European Commission has specific research and development agreements, e.g., the United States Department of Energy, ABACC. Information on the research and development activities under these frameworks is shared with the IAEA and complements core EC-SP work.

The paper describes the EC-SP, its modus operandi, collaborations, and main activities, namely, (a) the specific R&D work as part of tasks with well-defined milestones and deadlines, (b) training activities; (c) the technical support in establishing Safeguards guidelines and approaches and (d) the technical consultancy support to IAEA meetings and expert groups.

Implementation of Safeguards at the Nuclear Studies Centre at La Maâmora

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Morocco entered into force its Comprehensive Safeguards Agreement in 1976 and its Additional Protocol in 2011.

The Moroccan National Centre of Nuclear Energy, Sciences and Technologies (CNESTEN) has been licenced to operate the Nuclear Studies Centre at La Maâmora (CENM), including a 2MW TRIGA Research Reactor, since January 2009. This reactor is mainly used for training, basic and applied research, neutron activation analysis and radioisotope production.

In May 2006 and before performing the hot commissioning of the TRIGA RR, a training had been organized by the IAEA for CNESTEN staff in charge of accountancy for and control of nuclear material in this reactor. This training had been supported by some practical examples with regard to the preparation of accountancy reports and the conduct of inspections.

For the implementation of AP at CENM, CNESTEN had signed an Action Sheet with the US/DOE on "Technical Assistance in Implementation of the Additional Protocol". This Action Sheet allowed CNESTEN to enhance its capabilities to meet the requirements set forth in the AP concerning the preparation of declarations and the conduct of IAEA complementary access activities.

This paper focuses mainly on the approach developed by CNESTEN to fulfil the national safeguards commitments applicable to CENM.

Strategic Action Plan and Secure Environment in the Republic of Tajikistan

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National legislation related to remediation of uranium legacy sites is described. National functions of regulator and operator are described. Theoretical and practical training provided to laboratory personnel on operation of delivered equipment under IAEA, ISTC and NATO projects during project implementation is described.

Solution of the following problems for development of monitoring program:

1. spectrum analyzing equipment of wide range and gamma spectrometers for better monitoring quality;
2. the vehicle is required for carrying out field monitoring works;

is pending and awaits implementation of national and regional projects in the country.

Inter-agency council activities established by RT Governmental Decree #471 dated 2 December 2005 with the purpose of projects and coordination works management on radiation safety issues and functions are described. Involvement of Mass Media for remediation activities is described.

In order to improve significantly the radio-ecological situation in Central Asian countries and to bring it in compliance with IAEA and other international organizations' objectives and recommendations, it is proposed:

- To establish works coordination Committee on uranium legacy management in CA countries;
- To develop and implement projects on safe management of uranium legacy in Northern Tajikistan;
- Gafurov tailing: to remediate and hand over to national economy;
- Degmay tailing: to close tailing's beach by local soil from adjoining hills;
- Taboshar tailing: to facilitate in implementing the EurAsEC project on remediation;
- Adrasman tailing: redeploy residues to safe place;
- Khujand tailing: to apply advanced technology for purification of mine uranium waters.

Experience of national operator on remediation of radiation-dangerous sites is provided. RT Governmental contribution for criteria system development allowing determination danger degree of radiation sites and their remediation chain depending on danger level from 2009 till present is presented. Study of tailings and close-by territories radiation and ecological condition is presented.

Japan's Experience on Cooperation with the IAEA

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Cooperation between International Atomic Energy Agency (IAEA) and State System of Accounting for and Control of nuclear material (SSAC) is essential for effective and efficient IAEA's safeguards implementation. JSGO (Japan Safeguards Office), NMCC (Nuclear Material Control Center) and Facility Operators play a key role of SSAC in Japan. Trilateral liaison meetings among IAEA, JSGO/NMCC and Operator are a fundamental element to facilitate IAEA's safeguards activities.

Especially, cooperation from facility operators largely contribute to the improvement of IAEA's safeguards implementation because operator has basic responsibility in pursuance of real operation. Meeting including facility operators enable the smooth introduction of new safeguards approach, procedure or equipment.

This paper introduce following typical cooperation in Japan.

1. Trials for development for new safeguards approaches: Under traditional safeguards, Short Notice Random Inspection (SNRI) for Low Enriched Uranium Fabrication Facility (LEUFF) was introduced for improving the coverage of nuclear material flow. Under IS, Random Interim Inspection (RII) for each facility was also developed under the cooperation between IAEA and SSAC. Trials under WGs always play important roles for the development of new safeguards approaches in Japan.
2. Safeguards by design at plutonium handling facilities: Plutonium handling facility installed a lot of non-destructive measurement equipment which can be used for not only operator but also IAEA or JSGO/NMCC in 1980s and 1990s. This type of co-operation has continued for the development of safeguards approaches for large-scale facilities.
3. Joint-use equipment between IAEA and JSGO/NMCC: Surveillance camera and NDA equipment have been jointly developed and used for the IAEA and Japan's SSAC since 1990s. Discussions between IAEA and SSAC are one of the best practice for cooperation.

Safeguards Implementation in Kazakhstan: Experience and Challenges

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Experience of Kazakhstan joined the NPT in 1993, just after desintegration of USSR, and enforced Safeguards Agreement in 1995 can be interesting in implementation of safeguards in non-standard cases. Having weapon materials and test infrastructure legacy, the country together with IAEA and several donor countries found acceptable approaches to meet NPT provisions. One of challenges was to provide protection of sensitive information that could be accidentally disclosed in safeguards activities.

With support of several weapon countries in close cooperation with the IAEA Kazakhstan liquidated test infrastructure in Semipalatinsk, implemented projects on elimination and minimization of use of HEU in civil sector, decommissioning of BN-350 fast breeder reactor. Now the IAEA LEU Bank is going to be established in Kazakhstan, and more challenges are coming in implementation of safeguards. Some technical and organizational details will be described from the experience of Kazakhstan in these projects.

URENCO: A Multinational Contribution to Non-Proliferation

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URENCO was founded in 1970 following the signing of the Treaty of Almelo by the governments of Germany, the Netherlands and the UK. The fundamental principles for effective supervision of URENCO's technology and enrichment operations with respect to non-proliferation issues have been laid down in this treaty.

In order to enable the construction of a URENCO enrichment facility in the USA and to permit the transfer of classified information into the USA, another treaty has been concluded in 1992. The US government entered into the Treaty of Washington together with the governments of Germany, the Netherlands and the UK to ensure that the same conditions that had been agreed in the Treaty of Almelo would also apply to the US.

To allow for the completion of the joint venture with Areva regarding the URENCO Group's technology business ETC, the Treaty of Cardiff has been signed on 12 July 2005 by the governments of Germany, the Netherlands, the UK and France. Through this treaty, France is obliged to adhere to the principles of the Treaty of Almelo.

For each treaty, control bodies have been formed with representatives of the governments of the signatory countries. These committees exercise the role of effective supervision of the technology and operations with respect to non-proliferation issues. They also consider all questions concerning the safeguards system (as established by IAEA/Euratom), classification arrangements and security procedures, exports of the technology and enriched uranium, as well as other non-proliferation issues.

The presentation describes how the multinational structure of URENCO contributes to Non-Proliferation on the basis of the above mentioned treaties. Beyond that, the international cross linking of operational working groups and committees within the URENCO Group structure is explained. This structure implies an additional assurance to achieve the safeguards goals set.

French Additional Protocol: 10 Years of Implementation

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This paper will start by an historical overview on why and how the AP has been implemented in France from 2004 to 2014 and the context associated to its implementation, considering the previous obligations and the role played by Euratom.

Next, the technical organization put in place will be described by using a typical example and appropriate information about size of the declaration. The feedback concerning the challenges associated to the collection of information to ensure their correctness and completeness will be addressed, including the understanding of the AP by the industrials when contacted about their activities. Available means to respond to an Agency request for clarification or complementary access will be briefly described.

Considering the previous parts, the future of the French AP will be addressed: especially using the IT to improve the quality of the declaration by way of a new web portal. The feedback given by the Agency and evolution request will be detailed and the way France does its utmost to respond favourably.

At last, this paper will point out the interest of implementing safeguards such as AP in a nuclear weapon state in order to help the Agency on its mission: facilitate the detection of undeclared nuclear activities in a non-nuclear-weapon State and, to this end, allow complementary accesses on French territory.

Integrated Safeguards in Ukraine

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Integrated safeguards are being implemented in Ukraine since 2012. Integrated safeguards are the optimum combination of all safeguards measures available to the IAEA under Comprehensive Safeguards Agreement and Additional Protocol to achieve maximum effectiveness and efficiency in meeting the safeguards obligation within available resources. The implementation of integrated safeguards has provided both advantages and disadvantages for Ukraine. It will be discussed.

The concept of unannounced inspections under the integrated safeguards compared to traditional safeguards is the one of the major issues. The use of unannounced inspections, i.e., inspections for which no advance notification regarding inspection activities or location in accordance with paragraph 84 of Safeguards agreement. Ukrainian state inspectors organize and take part in each IAEA inspection and complementary access. Analysis of the quantity and type of IAEA inspections and complementary accesses will be made. Also, a short presentation of software for support of IAEA inspections will be made.

After due consideration of the LOF's information, the results of last inspections carried out and non-nuclear use of the depleted uranium, State Nuclear Regulatory Inspectorate of Ukraine decided to send to IAEA the exemption requests for nuclear material of LOF's according to Article 36(b) of the Safeguards Agreement.

In conclusion, the development and building of a strong and effective SSAC is never completed. Our plans of SSAC development (legislation, training activities) will be presented.

Safeguards Practices and Future Challenges for Peaceful Use of Nuclear Energy in Bangladesh

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Nuclear material and different category of radiation sources are being used in industries, R&D & education purposes. All of them are used for human welfare and economic uplift of the country. Prior to use, Bangladesh has firmly committed for the peaceful use of nuclear energy in a safe, secured and non-proliferation manner. Bangladesh has regularly provided credible assurance about the non-diversion of nuclear material as well as the absence of undeclared material and activities to the international community by fulfiling the obligations under the NPT and Comprehensive Safeguards Agreements (CSA) over the last 35 years. IAEA approved the State Level Safeguards Approach (SLA) for Bangladesh on 1 December, 2006 and consequently Bangladesh entered into the Integrated Safeguards (IS) regime on 1 January, 2007. The Government of Bangladesh enacted a comprehensive nuclear law titled "Bangladesh Atomic Energy Regulatory (BAER) Act-2012" and under this act established "Bangladesh Atomic Energy Regulatory Authority (BAERA)" in February 2013 to regulate all nuclear activities and to fulfil its international obligations. Furthermore, Bangladesh has signed agreements with Russia for setting up two 1000 MWe generation-III VVER type power reactors. During the INIR missions conducted by IAEA, the team identified some gaps and then recommended to develop, implement and to enforce of safeguards framework including strengthening the SSAC's oversight capability embarking the first nuclear power program in the country. Bangladesh is working on legal and regulatory requirements in adopting the VVER technology into the BAER Act-2012 related to safeguards. The purpose of this paper is to present an overview of country's practices in implementing the IAEA safeguards and also to provide with an in-depth look at the legislations, regulations and facility procedures for strengthening the safeguards infrastructure and to identify future challenges for international cooperation.

Implementation of Safeguards for Romania National LOFs

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The safe deployment of nuclear activities in Romania is provided by Law no. 111/1996. The Law was republished based on the provisions of Article II of Law no. 63/2006 for the amendment and addition and was modified and completed by the Law no. 378/2013.

The competent national authority in the nuclear field, which has responsibilities of regulation, authorization and control as stipulated in this Law, is the National Commission for Nuclear Activities Control (CNCAN).

According to art. 2c), provisions of the Nuclear Law shall apply to production, sitting and construction, supply, leasing, transfer, handling, possession, processing, treatment, use, temporary storage or final disposal, transport, transit, import and export of radiological installations, nuclear and radioactive materials, including nuclear fuel, radioactive waste and ionizing radiation generating devices.

With regards to the small holders of nuclear materials, the Romanian legislation takes into account the following safeguards objectives:

- Establishing provisions governing the possession, use, transfer, import and export of nuclear materials;
- Ensuring the implementation of the safeguards system for accountancy and control of nuclear materials:
- Ensuring that all nuclear materials are reported under the provisions of the Safeguards Agreement;
- Ensuring that all nuclear activities are declared under the provisions of the Additional Protocol;
- Developing and implementing nuclear material accounting and control procedures at all small holders of nuclear materials;
- Ensuring training for safeguards staff at all small holders.

Based on the provision of Law no. 111/1996 CNCAN has issued a Guidelines for applying of the safeguards by the small holders of nuclear materials from Romania. The guidelines provide specific regulations regarding the movement of the nuclear materials, the accountancy and control of nuclear materials, the containment and surveillance systems for small holders of nuclear materials, and so on.

S34: Technology Foresight and Emerging Technologies II

Evaluation of an Autonomous Navigation and Positioning System for IAEA-SG Inspectors

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Documenting visual observations and other data taken during field missions such as inspections, complementary accesses and design information verification is a time-consuming process which requires considerable effort from the inspectors in the field. To streamline their work in the field, IAEA inspectors would benefit from being able to position themselves and navigate inside vast and complex sites. Automated positioning of the inspector will result in more accurate and complete documentation of the measurements and data that they collect. While outdoor positioning using GPS is a mature technology, an autonomous system providing ubiquitous positioning without relying on any infrastructure is still an emerging technology.

This paper will present the results of the Technology Evaluation Workshop that was conducted in 2014 by the Department of Safeguards to assess the readiness level of existing technologies, identify gaps, and validate the identified operational needs. Potential implementation of the technology will be envisioned, and the presentation will highlight how they could benefit the efficiency of IAEA safeguards activities in the field and at Headquarters. Finally, it will be shown how the process of organizing technology evaluation workshops can be systematized to accelerate technological development and lower the risks associated with their deployment.

Location Intelligence Solutions

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Location Intelligence (LI) means using the spatial dimension of information as a key to support business processes. This spatial dimension has to be defined by geographic coordinates. Storing these spatial objects in a database allows for attaching a "meaning" to them, like "current position", "border", "building" or "room". Now the coordinates represent real-world objects, which can be relevant for the measurement, documentation, control or optimization of (parameters of) business processes aiming at different business objectives.

But LI can only be applied, if the locations can be determined with an accuracy (in space and time) appropriate for the business process in consideration. Therefore the first step in any development of a LI solution is the analysis of the business process itself regarding its requirements for spatial and time resolution and accuracy. The next step is the detailed analysis of the surrounding conditions of the process: Does the process happen indoor and/or outdoor? Are there moving objects? If yes, how fast are they? How does the relevant environment look like? Is technical infrastructure available? Is the process restricted by regulations? As a result, a proper Location Detection Technology (LDT) has to be chosen in order to get reliable and accurate positions of the relevant objects.

At the highly challenging conditions of the business processes IAEA inspectors are working with, the chosen LDTs have to deliver reliable positioning on "room-level" accuracy, even if there is no location enabling infrastructure in place, the objects (people) mostly are indoors and have to work under strong regulations.

The presentation will give insights into innovative LI solutions based on technologies of different LDT providers. Pros and cons of combinations of different LDT (like multi-GNSS, IMU, camera, and human interaction based positioning) will be discussed from the perspective of the IAEA inspectors' specific requirements.

Development of Laser-Induced Breakdown Spectroscopy Technologies for Nuclear Safeguards and Forensic Applications

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Under the IAEA Task A1855, the Canadian Safeguards Support Program (CSSP) undertook the development of laser-induced breakdown spectroscopy (LIBS) technologies for safeguards applications. Collaboration between the Canadian Nuclear Safety Commission (CNSC), the National Research Council Canada, and the IAEA has demonstrated that the LIBS technique combined with chemometrics can determine the origins of yellowcake, identify maraging steels, aluminium alloys, and magnesium alloys, among other materials involved in the nuclear industry; and determine heavy water content as well as the isotope ratios of other actinides. As part of the task, the CSSP has developed a portable LIBS system to enable inspectors to characterize specific nuclear and non-nuclear material during complementary access and inspections. This device was recently tested by the IAEA in both Vienna and Siebersdorf for various metals and uranium bearing materials. The laser source proved to be stable and the chemometrics software was able to identify various materials. The device is ready for further in-depth testing.

The chemometrics algorithm that has been developed for LIBS can also be adapted to nuclear forensics for the querying database. Multi-stage pattern recognition algorithms can reliably identify unknown materials among database populations (e.g., identify origins of yellowcake). Further work in this field is being undertaken as part of the CNSC's National Nuclear Forensics Library (NNFL) development activities for the Canadian National Nuclear Forensics Capability Project (CNNFCP).

The paper will provide an overview of the LIBS techniques being developed for safeguards and forensic applications, and of progress in integrating all components into a compact unit.

Impact of the Pixel Pitch of the Timepix Chip Integrated to the GAMPIX Gamma Camera for Spectrometric and Imaging Performances

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Spatial localization and identification of radioactive sources is a main issue interesting Homeland Security. Gamma imaging allows reaching this need. A new gamma camera, GAMPIX, has been designed by the French Atomic Energy Commission (CEA). GAMPIX enables spatial localization of hot spots on a large energy range. Sensitivity, portability (2 kg) and ergonomics were improved in comparison with previous industrial systems. The detection system is based on the 1.4 cm side Timepix pixelated readout chip developed by CERN and hybridized to a 1 mm thick CdTe substrate. Pixel size of the Timepix chip is 55 μm or 110 μm. Ongoing developments concern the addition of a spectrometric capability to the existing system. The challenge is the optimization of spectrometric performances while maintaining imaging performances. Our work intends to assess the impact of pixel pitch by means of simulations and experimental validation.

A large range of pixel pitch and energies were tested by MCNPX simulations. Fluorescence impact depending on pixel pitch was demonstrated. Pixel pitch impact on imaging performances was also studied. The purpose is to preserve the angular resolution of the GAMPIX gamma camera, i.e., the ability to separate radioactive sources spatially close.

Energy calibration of Timepix detectors is crucial for the optimization of spectrometric performances. The small pixel size compared to the substrate thickness induces charge depositions in several pixels, called clusters, and the shift between spectra due to different cluster sizes degrades the energy resolution. The energy calibration of our Timepix detectors was carried out in the SOLEX tunable monochromatic X-ray source (CEA).

Our developments show that the replacement of the 55 μm pixelated Timepix chip currently used in the GAMPIX gamma camera by a 110 μm pixel pitch would lead to a significant improvement in terms of spectrometric performances without degrading imaging abilities.

Cosmic-Ray Muon Tomography: Non-Destructive Assay of Illicit Nuclear Material within Shielded Containers

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Tomographic imaging techniques using the Coulomb scattering of cosmic-ray muons are increasingly being exploited for the non-destructive assay of shielded containers in a wide range of applications. One such application is the characterization of legacy nuclear waste materials stored within industrial containers. The design, assembly and performance of a prototype muon tomography system developed for this purpose are detailed in this work. This muon tracker comprises four detection modules, each containing orthogonal layers of 2 mm-pitch plastic scintillating fibres. Identification of the two struck fibres per module allows the reconstruction of a space point, and subsequently, the incoming and Coulomb-scattered muon trajectories. These allow the container content, with respect to the atomic number Z of the scattering material, to be determined through reconstruction of the scattering location and magnitude. On each detection layer, the light emitted by the fibre is detected by a single MAPMT with two fibres coupled to each pixel via dedicated pairing schemes developed to ensure the identification of the struck fibre. The PMT signals are read out to standard charge-to-digital converters and interpreted via custom data acquisition and analysis software.

The design and assembly of the detector system are detailed and presented alongside results from performance studies with data collected after construction. Images reconstructed from a test configuration of materials have been obtained using software based on the Maximum Likelihood Expectation Maximization algorithm. The results highlight the high spatial resolution provided by the detector system. Clear discrimination between the low, medium and high-Z materials assayed is also observed.

JAEA-ISCN Development Programmes of Advanced Technologies of Nuclear Material

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JAEA-ISCN(Integrated Support Center for Nuclear non-proliferation and Nuclear Security) has been implementing basic development programmes of the following NDA technologies.

1. NRF (Nuclear resonance fluorescence) NDA technology using laser Compton scattered (LCS) gamma-rays (intense mono-energetic gamma-rays).
2. Alternative to 3He neutron detection technology using B2O3/ZnS ceramic scintillator.
3. NRD (Neutron resonance densitometry) using NRTA (Neutron resonance transmission analysis) and NRCA (Neutron resonance capture analysis).

Technology (1) is for future NDA systems using NRF reaction for precise quantitative selective measurement of 239Pu (and any actinide isotopes) in spent fuel assemblies, debris of melted fuel with using an LCS gamma-ray source based on a superconducting energy recovery linac (ERL). NRF NDA could be used for nuclear security (non-destructive detection of NM hidden behind very thick shielding material in containers) if the LCS gamma-ray source is achieved. Basic demonstrations of LCS gamma-ray generation are planned in the end of 2014JFY.

Technology (2) is for NDA systems (instead of current safeguards NDA systems with 3He tubes) of neutrons from NMs. The present activities are developing ZnS/B2O3 ceramic scintillator and demo-NDA systems using ZnS/B2O3 ceramic scintillator detectors. Comparative measurements between the demo-NDA systems with the same kind of 3He NDA system are planned.

Technology (3) is for a precise NDA system of nuclear material in particle-like debris (in a thin disc container) of melted fuel. NRTA is for determining Pu/U isotopic compositions. NRCA is for determining neutron absorbing elements such as 10B in the target by analyzing gamma-rays specific to neutron absorbing elements. Demonstrations of NRD detectors at a beam line of GELINA of JRC-IRMM are planned in the end of 2014JFY.

MultiSpectrometer: Wide Span and Quick Gamma Detection System

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The MultiSpectrometer is a photonic spectrometry device which targets to quickly and precisely detect gamma photon inside fluids.

The poster will rely on:

- presentation of 3 inline industrial application (nuclear plant);
- features and performances of the system;
- spectrum examples acquired on production line (nuclear workshops);
- explanation on its ability to well suit to particular application.

SoLid: Innovative Antineutrino Detector for Nuclear Reactor Monitoring

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The detection of antineutrinos emitted in the decay chains of the fission products in nuclear reactors associated with accurate simulations could provide an isotopic tomography of the core. Nevertheless, their extremely low interaction probability makes the shielding of antineutrinos, practically impossible. In conclusion, such kind of technique could detect a change occurring in the reactor core composition, thus it could be used for non-proliferation purposes. For a declared isotopic composition of the reactor core, the information coming from the antineutrino flux is valuable for the electricity companies which run the reactors in order to increase the precision of the power measurement.

In order to be used as a potential safeguard tool, the antineutrino detectors should be a good compromise between detection performances and design constrains related to safety, low cost and size reduction. An example of such detector is SoLid, which will be installed and will take data at SCKCEN/BR2 research reactor, in Belgium. SoLid uses a Lithium-6 based composite scintillator which provides by design a high degree of safety. The design of the detector provides also high detection efficiency as well as maximum robustness against potential background which could fake the antineutrino signal. In consequence, the dimensions of the detector can be reduced without lowering its performances. The combination of Lithium-6 and high segmentation provides ways of imaging the composition of cores, unreachable with a traditional liquid scintillator.

A $20 \times 20 \times 20$ cm^3 prototype of the SoLid detector has been developed in order to validate the new technology and it takes data at BR2 reactor since August 2013. A larger scale demonstrator able to monitor the reactor in real time will be installed at mid 2015. First results from the prototype system as well as expected performance for the large system will be presented at this symposium.

Mobile Techniques for Rapid Detection of Concealed Nuclear Material

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To prevent the diversion of nuclear material as well as illicit production, transport and use of nuclear material we investigated in mobile techniques to detect and identify such material in the field as early as possible. For that purpose we use a highly sensitive gamma measurement system installed in a car. It consists of two large volume plastic scintillators, one on each side of the car, each scintillator with 12 ℓ active volume, and two extreme sensitive high purity Germanium detectors with 57 cm^2 crystal diameter, cooled electrically. The measured data are processed immediately with integrated, appropriate analysis software for direct assessment including material identification and classification within seconds. The software for the plastic scintillators can differentiate between natural and artificial radioactivity, thus giving a clear hint for the existence of unexpected material. In addition, the system is equipped with highly sensitive neutron detectors. We have performed numerous measurements by passing different radioactive and nuclear sources in relatively large distances with this measurement car. Even shielded as well as masked material was detected and identified in most of the cases. We will report on the measurements performed in the field (on an exercise area) and in the lab and discuss the capabilities of the system, especially with respect to timeliness and identification. This system will improve the nuclear verification capabilities also.

Nuclear Reactor Monitoring with the Nucifer Neutrino Detector

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The detection of electron antineutrinos emitted in the decay chains of the fission products in nuclear reactors associated with accurate simulations provides an efficient method to assess both the thermal power and the evolution of the core fuel composition. This information could be used by the International Agency for Atomic Energy for safeguarding civil nuclear reactors in the future. The Nucifer experiment aims to demonstrate the concept of "neutrinometry" at the pre-industrialized stage. A novel detector has been designed to meet IAEA requirements and it has been deployed at 7 m away from the Osiris research reactor at CEA-Saclay. We report the detector performances and the first detection of neutrinos compared to backgrounds. We discuss the ability of the Nucifer detector to detect a possible non-standard operation of a nuclear reactor.

Quest for Very Compact Antineutrino Detectors for Safeguarding Nuclear Reactors

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Monitoring the status of a reactor and its fissile content in a continuous mode using antineutrinos is one of challenging topics for safeguarding. Detectors deployed thus far require volumes of several cubic metres. In our search for a very compact antineutrino detector we have investigated an indirect method for antineutrino detection. In a first test of this hypothesis de Meijer *et al.*, we found an upper limit of $\delta\lambda/\lambda = (-1 \pm 1) \times 10^{-4}$ at a flux change of 2.5×10^{10} cm^{-2}s^{-1} at the 2 MW reactor at Delft, NL.

We continued our search for effects on β^+-decay at the nuclear power plant Koeberg, South Africa. Here we report on two sets of measurements, one in 2011, another from December 2012 — February 2014. In the first experiment a LaBr3 detector was used. La has a natural radioactive isotope, decaying by either β^- or EC, hence the effect of reactor-status change could be measured during background measurements: no effect was observed. With a 22Na source an effect in the count rate was observed between reactor-OFF and reactor-ON which was not considered to be reliable, since an amplifier broke down and had to be replaced during the ramp-up of the reactor.

In the recent measurement a $0.4\ \ell$ NaI detector coupled via a PMT to a PMT-base MCA was used. After overcoming a number of technical problems a stable condition has been reached. Again an effect has been observed in the count rate during two reactor changes. Provided that this effect is only due to antineutrinos affecting β^+-decay, this result would correspond to a change in decay constant $\delta\lambda/\lambda = (-0.52 \pm 0.11) \times 10^{-4}$ at a flux change of 1.0×10^{13} cm^{-2}s^{-1}. We are in the process to investigate instrumental effects as alternative explanations.

Using LIBS Method in Safeguards

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Laser-Induced Breakdown Spectroscopy (LIBS) is a type of atomic emission spectroscopic technique which is capable to detect almost all the elements from the periodic table in different sample types (solid, liquid or gas). Other advantage of the technique is that a LIBS analysis is much faster than a conventional laboratory technique. Beside the easy usability and fastness of the system the main advantages of the technique is that portable systems are also available. Using a so-called 'backpack' version in-field analysis can be carried out. Therefore, LIBS is a more and more popular technique also e.g., in the nuclear analytics due to its several advantages. It is also tested for Safeguards purposes as a novel technology.

In this work development and test of a portable LIBS system is discussed in detail. Detector system with higher resolution and specific software for evaluation of uranium isotope composition has been developed. Different kind of uranium fuel pellets with various enrichments was analyzed as test samples. Concerning the test measurements the developed LIBS instrument was found well-applicable for analysis of Safeguards samples and determination of higher enrichment of uranium in-field. The method is rapid and simple enough for short in-field sample analysis.

S35: Knowledge Management for Safeguards Organizations

Nuclear Knowledge Management: the IAEA Approach

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Knowledge in an organization is residing in people, processes and technology. Adequate awareness of their knowledge assets and of the risk of losing them is vital for safe and secure operations of nuclear installations. Senior managers understand this important linkage, and in the last years there is an increasing tendency in nuclear organizations to implement knowledge management strategies to ensure that the adequate and necessary knowledge is available at the right time, in the right place.

Specific and advanced levels of knowledge are clearly required to achieve and maintain technical expertise, and experience must be developed and be available throughout the nuclear technology lifecycle. If a nuclear organization does not possess or have access to the required technical knowledge, a full understanding of the potential consequences of decisions and actions may not be possible, and safety, security and safeguards might be compromised. Effective decision making during design, licencing, procurement, construction, commissioning, operation, maintenance, refurbishment, and decommissioning of nuclear facilities needs to be risk-informed and knowledge-driven.

Nuclear technology is complex and brings with it inherent and unique risks that must be managed to acceptably low levels. Nuclear managers have a responsibility not only to establish adequate technical knowledge and experience in their nuclear organizations but also to maintain it. The consequences of failing to manage the organizations key knowledge assets can result in serious degradations or accidents.

The IAEA Nuclear Knowledge Management (NKM) sub-programme was established more than 10 years ago to support Nuclear Organizations, at Member States request, in the implementation and dissemination of the NKM methodology, through the development of guidance and tools, and by providing knowledge management services and assistance.

The paper will briefly present IAEA understanding of and approach to knowledge management, applied in and to nuclear organizations.

Knowledge Management Portal: A Simplified Model to Help Decision Makers

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The aim of this work is to present a simplified model that could help the nuclear industry to keep the expertise of safeguards professionals in touch with the state of the art, and also to have available information in the Portal of Knowledge Management.

It can also provide indicators and general data for decision makers. Authors have developed the concept based on their own experience through systems running in hydroelectric and gas fired plants, and one exclusive system that manage all courses in one University.

It is under development a Portal of Knowledge Management for NPP dealing with information obtained of Strategic Plans, Budgets and Economics, Operation Performance, Maintenance and Surveillance Plans, Training and Education Programs, QA Programs, Operational Experience, Safety Culture, and Engineering of Human Factors. This model will provide indicators for decision makers.

Training and education module is prepared according to profile of each individual and his attributes, tasks and capabilities, and training and education programmes. The system could apply self-assessment questionnaires; immersive learning using media (video) classes, and test applications using questions randomly selected from data bank, as well as could make applications to certificate people. All these data are analyzed and generate indicators about strongest and weakness points. Managers could have indication of individual's deficiency even though in training programmes on a real time basis.

Another tool that could be applied to the model is the remote operation of supervision equipment. The model is developed using web-based tools, like ASP.NET encrypted by 128 bits, and web site https. Finally, it is important to stress that the model can be customized according to industry preference.

A Model for Effective Governance of Knowledge Management: A Case Study at the U.S. Nuclear Regulatory Commission

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Many organizations struggle to achieve an effective Knowledge Management (KM) program. One contributing reason is ineffective governance. The U.S. Nuclear Regulatory Commission (NRC) possesses a robust KM Program. A major reason for NRC's success in KM is due to its system of governance. This paper describes the U.S. NRC's KM programme with a focus on its system of governance, roles, and responsibilities.

Knowledge Management in the IAEA Department of Safeguards

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Knowledge management is the discipline of enabling individuals and teams to collectively and systematically create, share and apply knowledge. The most important assets in the IAEA Department of Safeguards are people and their knowledge. The focus of the Department is to create an environment within which people share, learn and work together.

The efforts to manage the knowledge leaving the Department have been focused on helping the supervisor of the departing staff member to identify what critical knowledge needs to be retained, and how to retain that knowledge.

The Safeguards Knowledge Management team developed a person-centred approach. This approach involves interviews with the staff member, co-workers and/or customers to identify the critical knowledge to be transferred. Although time consuming we have found that this method is most effective to capture the needed knowledge. This approach has four steps:

- Identify the critical knowledge to be retained;
- Select the knowledge transfer methods;
- Apply the knowledge transfer methods; and
- Assess and refine the transfer process.

The paper will describe the person-centred approach and lessons learned from implementing this programme in the Department over several years.

CP: Closing Plenary

Closing Remarks and Awards

M. Whitaker[1], K. Van der Meer[2]

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M. Whitaker:

Good afternoon everyone. On behalf of the Institute of Nuclear Materials Management, we are grateful for the opportunity to support this symposium. The number of symposium events — presentations, posters, technical demonstrations, panel discussions, and receptions — has been completely overwhelming and truly impressive. My compliments to the IAEA organization staff for a spectacular event. I have gained a much better appreciation for why these are only once every four years.

This symposium has provided an important opportunity to reengage with friends and colleagues from around the globe to discuss international safeguards topics. The theme this year is very appropriate. So much of our work relies upon people. Together we work to develop the strategies that ensure that international safeguards are effectively implemented to provide the world the assurances that they expect from us.

Thank you for this opportunity to share in the organization and execution of this symposium.

K. Van der Meer:

It is my pleasure to give the last poster awards. We have had two award ceremonies already this week on Wednesday and Thursday to recognize the best posters in those sessions. Today it will be two parts. First we will give the award for the best posters for this morning's sessions, and then we have four special awards: Gold, Silver, Bronze and the New Generation Symposium Award. These are the awards for the best posters for the whole week. The New Generation Symposium Award is for recognition of a younger participant and the prize is also for a younger participant. The full list of award winners is available under the symposium website.

The IAEA recognizes the generous donations by INMM and ESARDA of the following prizes given as awards for the best posters:

- Best e-poster advertisement per session: free subscription to the ESARDA Bulletin;
- Best e-poster per session: free membership in INMM;
- Best poster of the week "Bronze": free registration for the 8th INMM/ESARDA Joint Workshop;
- Best poster of the week "Silver": free registration for the 2015 ESARDA Symposium;
- Best poster of the week "Gold": free registration for the 2015 INMM Annual Meeting;
- Best poster of the week "New Generation Symposium Award": free participation in the 2015 ESARDA Safeguards course.

Symposium Highlights

K. Owen-Whitred[1]

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Introduction:

Good afternoon everyone. As you can see, I am not Rob Floyd. My name is Karen Owen-Whitred and I'm the Director of the International Safeguards Division with the Canadian Nuclear Safety Commission.

I was asked to be rapporteur for the Symposium just over one week ago. I said yes, clearly, based largely on my own lack of understanding of what is expected of a rapporteur.

What I have to offer you today is therefore reflective of my view of a rapporteur's function, which is not to provide a session-by-session summary of the past week or attempt to summarize positions that have been presented by various representatives of the Secretariat or Member States or industry or other organizations. Instead, I will try to pull together some highlights of the Symposium, I will provide my thoughts on some of the themes that I saw emerging over the course of the week that can hopefully help provide some context for the individual experiences we all had. Finally, I want to close with some thoughts on "what next" — how can we make use of the connections and relationships — the linkages — we've all made here as we go back to our daily work and as we look ahead to the next Symposium, four years away.

Spoiler Alert: that's the first of many references to "linking" that I will be using throughout my presentation.

Overview/Highlights:

To begin, I'd like to take a moment to highlight some of the novel elements of this Symposium as compared to those that have been held in the past.

For the first time ever, this Symposium was organized around five concurrent sessions, covering over 300 papers and presentations. These sessions were complemented by an active series of exhibits put on by vendors, universities, ESARDA, INMM, and Member State Support Programmes.

We also had live demonstrations throughout the week on everything from software to destructive analysis to instrumentation, which provided the participants the opportunity to see recent developments that are ready for implementation.

I'm sure you all had a chance to observe — and, more importantly, interact with — the electronic Poster, or ePoster format used this past week. This technology was used here for the first time ever by the IAEA, and I'm sure was a first for many of us as well. The ePoster format allowed participants to interact with the subject matter, and the subject matter experts, in a dynamic, engaging way. In addition to the novel technology used here, I have to say that having the posters strategically embedded in the sessions on the same topic, by having each poster author introduce his or her topic to the assembled group in order to lure us to the poster area during the breaks, was also a novel and highly effective technique.

A final highlight I'd like to touch on in terms of the Symposium organization is the diversity of participation.

This chart shows the breakdown by geographical distribution for the Symposium, in terms of participants. There are no labels, so don't try to read any, I simply wanted to demonstrate that we had great representation in terms of both the Symposium participants in general and the session chairs more specifically — and on that note, I would just mention here that 59 Member States participated in the Symposium.

But what I find especially interesting and encouraging is the diversity in terms of representation from the Secretariat, Member States, and operators — and this is something I'm going to come back to later in my remarks.

Linkages:

Next I want to turn to the idea of linkages. And for those of you keeping score, that's reference two.

We all know that the three themes or components of the Symposium are strategy, implementation, and people. The DDG touched on these in his opening comments and offered some interesting thoughts on each of the individual components and their importance in any organization, but particularly in the world of safeguards. What I'd like to do now is focus, not on the components themselves, but on the intersections among them.

First let me caveat the following comments by noting that these linkages are simply the mental constructs dreamed up by myself and some very talented people I worked with to help me pull together my thoughts for this presentation. I don't claim that these constructs would hold up as a Ph.D. thesis. But without pushing the metaphor too far, my intent is to use the concept of linkages as a useful lens through which to highlight some specific content of the Symposium.

Strategy and Implementation:

The first connection I want to talk about is the link between strategy and implementation, which is what I'm framing as the intersection between ideas and action, between the concepts of safeguards and the "how to".

Wednesday's session on the Safeguards Implementation Practice Guides, or SIP Guides, fits particularly well within this category.

For those of you who weren't able to attend this session, the SIP Guides, which are still in draft form but should be published soon, have been developed through collaboration between the IAEA and professionals from several Member States. The guides help States understand the legal text and requirements of safeguards, to help them move from concepts to good practices, and they include powerful examples to add clarity.

Three individual guides — covering safeguards infrastructure, verification activities, and the provision of information — were described by different Member States during the session, using examples from their own experiences. This was followed by a panel discussion that touched on the benefits of exchanging information and best practices, and the value of documenting some basic safeguards guidance, whether for emerging State authorities, for new staff, or for operators who may not be familiar with day-to-day safeguards requirements.

The success of this project demonstrates the natural and vital connection between strategy and implementation.

Implementation and People:

Now I'd like to turn to the linkage between implementation and people. This can be thought of in terms of "on the ground" activities and, in my mind, covers many of the more technical sessions from the past week. It represents the practical, concrete techniques and tools being put in the hands of the people in order to actually do the work.

There are a large number of sessions that I would group under this category — from communication technology to measurement techniques to analytical methodology. What's interesting about all of these sessions is that they typically stimulated very lively discussions, which speaks to both the knowledge level of the Symposium participants as well as their engagement with "practical safeguards".

These sessions also highlighted the collaborative nature of much of the ongoing technical work — I would reference, just to take one example, the poster covering cooperation between the US and the Republic of Korea on experimental assessment to improve partial defect verification of spent fuel assemblies.

In addition to the more highly technical work, the link between implementation and people is also about getting safeguards professionals out in the field for practical experience — this is another area where collaboration is key, such as that described in a poster from the Czech Republic describing how the support programme from that country consistently offers access to its nuclear power plant for the hands-on training of IAEA safeguards inspectors.

Finally, and this was specifically explored by some of the ePosters on this topic, it was clear that the advanced technologies that are being developed still often require a skilled human to interpret the data — satellite analysis is a good example of this.

In other words, no matter how good the tool, we still need the right people to make use of it.

People and Strategy:

Finally, let me touch on the concept of people linked with strategy. For me, this link is all about mobilizing people in pursuit of an organization's strategic goals. The sessions on performance management and training are particularly relevant to this intersection. There were three sessions that explored these topics explicitly, and a number of others that referred to them indirectly.

I really enjoyed the ideas and range of perspectives in the Performance Management session (particularly since I was a panellist). A key message coming out of that session was the importance of clearly and transparently reporting on results. There's an obvious link here to the safeguards system and the Safeguards Implementation Report, but this also applies to all of us in our respective organizations.

We need to give our stakeholders the confidence that we're fulfilling our goals — whether you're an operator focused on ensuring the high quality of material measurements within your facility, a State regulator evaluating the performance of your national industry, or the Agency drawing conclusions on the implementation of safeguards commitments. We're all striving to do a good job, but we can't forget the importance of demonstrating that we're doing a good job.

In a sense, this is about bringing strategy back down to the "people level": "You said you were going to do this, but now show me that you did."

Themes:

I've spent some time talking about a few individual sessions; now I'd like to turn to some overarching themes that I saw emerge over the past week. Once again, I'm going to preface these remarks by reminding you that these are my own thoughts. You may disagree with the themes I identified, or you may have additional ones to add to the list, but these are the themes that spoke to me, personally.

"New Blood":

First off, the acquisition, training, and management of the next generation of safeguards experts, is a theme that jumped out at me from the opening plenary and was an undercurrent throughout the week. Without giving away my age, I think I'm safe in saying that I'm closer to the beginning of my career than the end, and so this is a topic that is near and dear to my heart. I'm not saying anything new when I note that we are, collectively, facing the reality of an aging workforce and a corresponding need to introduce "new blood" into the community.

At the same time, safeguards is a field that requires some unique and specialized expertise: technical knowledge, certainly, of fuel cycle activities, of advanced statistics, of nuclear material accountancy, of measurement techniques, of data analysis; but also the less tangible skills of judgement, discretion, mediation, insight, the ability to synthesize large amounts of complex information and arrive at objective conclusions. And, I would add to that, a passion for, and dedication to, this important job that we all do. These are not things that can be easily taught through manuals or even classrooms — they require a commitment to on-the-job mentoring and the opportunity to gain experience through action.

These twin realities — a large group of experienced staff nearing retirement on the one hand and the need for highly skilled and motivated newer staff on the other — highlight the importance of knowledge retention, knowledge transfer, and training. The sessions on these specific subjects offered us some good starting points of how to address these issues.

One main take-away from the Symposium for me under this theme is: do not take these next generation experts for granted. All of us in our respective organizations need to put in the sincere effort to find them, train them, and strive to motivate and inspire them so that they will have both the abilities and the desire to contribute to the field of safeguards.

Innovation:

There's a nice segue from the theme of next generation staff to next generation technology. On that note, innovation is another clear theme that I think we would all agree featured in this Symposium There were some fascinating presentations and posters throughout the week touching on some borderline futuristic technology and methodology. Virtual environments for training, cloud computing, "attack trees", video imaging from space,. . . , the list goes on!

There were a few particularly interesting take-aways from all of this, such as the ability to use emerging technologies from a diversity of (non-safeguards) disciplines for safeguards purposes, and especially the value of Member State Support Programmes in advancing safeguards R&D.

I would also note that there were a number of projects or technologies presented through the week that are still in the very early, or even conceptual stages, accompanied by acknowledgements that much work remains to be done.

The session on Spent Fuel Verification, for instance, noted that this issue continues to be a major challenge for the safeguards system and offered an overview of the current status of R&D in this field, particularly noting the need to follow up with ongoing experiments.

UF6 cylinder tracking, the digitization of site maps and State declarations in general, the growing use of Electronic State Files within the Agency, these are other examples of interesting and emerging projects that were presented here this week and for which we are all, I'm sure, eagerly awaiting updates.

That means we can all look forward to hearing about progress in these areas in four years at the next Symposium.

Cooperation:

The final overarching theme I want to discuss is one of cooperation.

Not only were there three separate sessions dedicated explicitly to IAEA-State cooperation, but the concepts of partnerships, joint endeavours, and collaboration ran through many of the sessions, from the very technical to the more policy-oriented. The importance of close cooperation within the safeguards community was discussed in sessions as diverse as advanced communication technology, instrumentation data analysis, and evolving safeguards implementation.

This theme goes hand in hand with one of open and clear communication — this links to the importance of clearly defining the roles and responsibilities of all parties involved in implementing safeguards, and the value of proactive communication in managing day-to-day safeguards issues.

So, as I said, there were three sessions specifically on IAEA-State cooperation — and I would explicitly add Regional Authorities to that list as well — and these were really valuable in providing a diversity of viewpoints on this topic. From the perspective of "newcomer" States, meaning new to safeguards, we saw for example a poster from Nigeria describing how the interaction between the IAEA and the Member State during the surveys and preparation of initial declarations is critical to smooth initiation of safeguards activities in those States.

There was a really interesting session on Frameworks for Monitoring the Quality of the Operator's Measurement and Accounting Systems that described the trilateral liaison meetings — involving the State, the operator, and the Agency — that have been held in Japan for over ten years, and how those meetings have contributed significantly to the implementation of safeguards in that country. That same session also touched on the consultative nature of Euratom safeguards throughout the verification cycle. I can say that we have a similar mind-set in Canada and I'm sure there are many other such examples from other Member States around the world.

What's Next?:

So that's what happened this week, as I saw it. But what happens next?

I alluded at the beginning of my remarks to the importance of all three major stakeholders in our safeguards community: the IAEA, the State or Regional Authorities, and the operators. There seems to be an ever-growing acknowledgement of and appreciation for the importance of cooperation between the first two on this list: the Agency and the Safeguards Authority. What I've heard from colleagues, and as I've already touched on here, this relationship has been really well represented at this Symposium.

Where I believe there's opportunity for further discussion is on the role of the third stakeholder on my list: the operator. Over the past week we've had a few presentations from members of industry, and I was fortunate to hear some really valuable interventions from operators in the audience in certain session. I believe it was in the session on Assuring Quality of Safeguards Findings that acknowledged the fact that the quality of the entire system of safeguards data, analysis, and evaluations begins with the facility operator. That one session had presentations from URENCO, the Australian National University, the European Commission, and State regulators from South Africa, Japan, and the United States, which I think shows an amazing diversity of perspectives on this issue.

But there's more that can be done. In the lead up to the next Symposium, I think we should all consider the vital role of the operator in the success of the safeguards system and how we can seek to more meaningfully engage operators in the conversations we have in this forum. I would love to hear from other Member States how they encourage operator involvement, as appropriate, within the safeguards system in their countries, and I would love to hear more directly from operators themselves.

I'd like to close my remarks with an acknowledgment that, although we're all heading home today or tomorrow, this Symposium is not meant to end here. The links that were made throughout the week — be they relationships between colleagues, or inspiration gained through the intersection of ideas and technology — should be kept alive after we go back to our respective countries and responsibilities.

Conclusion:

In conclusion: the world is changing. Therefore safeguards must continue to evolve. We cannot know for certain what challenges the future will bring. What we do know is that we, meaning the full "we", are taking the necessary steps now to develop and maintain a dynamic, well-trained workforce, devise robust and forward-looking technology, and foster the open, collaborative, genuine relationships that are needed to meet the challenges that come our way. Remember, we are all in this together. We may have different perspectives on certain issues, we may have different ways of doing things, but we're all working together towards the common goal of preventing the proliferation of nuclear weapons. And that's a pretty worth-while goal.

Thank you.

Closing Statement

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Excellencies, friends and colleagues,

For me, this week has been a success. I have been impressed with the range and depth of discussion that has taken place, not only in the formal sessions, but also in the coffee breaks, over lunch and into the evening.

When we placed an international call for papers earlier this year, we did not expect that we would receive 400 abstracts and end up arranging 237 oral presentations and 91 poster sessions. There have been over 600 participants originating from 54 Member States and 11 invited organizations.

A wealth of information and analysis arising from this week's deliberations is now available on the Agency website. This provides you with the chance to catch up on any presentations that you may have missed the first time, as well as providing a resource for future research and application.

If you recall, the purpose of the symposium was to foster dialogue and exchange of information involving Member States, the nuclear industry and members of the broader nuclear non-proliferation community, including civil society. I believe we have succeeded on that score.

We are living in a rapidly changing world and the nuclear world is no exception. More nuclear material and facilities are coming under safeguards all the time. International nuclear cooperation between States is intensifying with an expansion of trade and services in nuclear and related equipment, items and materials. Also, technologies are changing. Many older nuclear plants are being modernized and becoming more technologically sophisticated. The geographical focus of these expanding programmes also continues to change.

Yet, our budget remains static.

This means that the only way we can maintain our effectiveness in the face of rising demand for our services, is to become more productive. That is the backdrop to this symposium.

The overarching theme was to link strategy, implementation and people: the three core processes of any business. As I said on Monday, the strength of the link between these three processes determines the degree to which a business is able to deliver what it wants to achieve.

Devising a strategy that is realistic, flexible and widely understood; Ensuring that implementation is carried out, kept on course and implementers are held to account; and that the people involved are properly trained, motivated and work well as a team.

I believe that this symposium has served the purpose of forging some new linkages as well as strengthening existing ones. I very much hope that these will now be developed in the months and years ahead to the benefit of safeguards around the world.

Having listened to the debates myself, and having heard feedback from the sessions I could not attend, I know we have achieved our objectives.

Organizing any large meeting is hard work, but a meeting with so many sessions and such a variety of sessions is a considerable challenge. In that regard, I would like to express my gratitude to those Agency staff responsible for organizing the symposium the scientific secretary, Andy Hamilton, and his team — comprising Stephanie Poirier, Tom Killeen, Meg Furnish and Janette Donner.

And especial thanks again to Karen Owen-Whitred for standing in at such short notice as our rapporteur.

Thank you also to session chairs, panel members, and secretaries: to all of you who presented here this week - as well to those working behind the scenes. I'm sure you will join me in congratulating all of them.

Thank you also to our co-organisers INMM and ESARDA. And to our sponsors — who, of course, come here to promote their products — but who provide important financial support to enable this event to proceed.

My gratitude also to all of you, who have participated in this event with such enthusiasm and commitment: for the expertise that you brought to bear on the challenges we face, and the ideas and proposals that you have aired.

Let me end by saying that I hope to see you in 2018, for what will be the thirteenth safeguards symposium.

More immediately, I wish you a safe journey home.

I hereby declare the 2014 Safeguards Symposium closed.

Thank you all.

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