IAEA

Safeguards

Emerging Technologies Workshop

Trends and Implications for Safeguards

Workshop Report

13–16 February 2017
IAEA, Vienna

CONTENTS

WORKSHOP TAKEAWAYS: Key challenges and opportunities

- New types of nuclear reactors are advancing and diversifying and will require new or updated safeguards approaches and technologies and greater focus on **'safeguards-by-design'**. Some reactors, including pebble-bed reactors and molten salt reactors, will be particularly challenging for safeguards.
- **Transportable nuclear power plants** will present entirely new safeguards challenges, given difficult-to-access materials in operation for decades in remote locations. They also pose legal questions.
- **Accelerator-driven systems** are being used to treat spent nuclear fuel but require attention as they could enable the misuse of subcritical reactors for the production of direct-use materials for nuclear weapons.
- Commercial **laser systems** are becoming increasingly compact, affordable, powerful, easy to operate and energy efficient. When applied to enrichment, they could pose proliferation challenges due to their dual use nature and widely available expertise, as well as potentially lower cost, space and energy requirements when compared to centrifuge technologies.
- **Additive manufacturing** (3D-printing) may lower technical barriers to proliferation; proliferators could manufacture high-strength structures such as centrifuge parts or advanced materials such as diffusion barriers. The Department should closely monitor developments and assess their impact on acquisition path analyses.
- The world is undergoing an explosion in the amount, speed and variety of available information – a **big data revolution**. The key challenge will be to identify and process what is safeguards relevant and leverage data 'smartly'. Expert/crowdsourcing could be one way of drawing on collective computing power and human knowledge to analyse big data sets.
- The modalities and mechanisms for collecting, integrating, analysing and processing data are constantly being refined and improved. The most important positive potential may lie in the **integration** of multiple data streams, technologies and methods.
- **Artificial intelligence and machine learning** could be ways to achieve further efficiencies and enable analysts to focus on value added tasks, through automation and by reducing repetitive tasks. However, such technologies will not replace inspectors or analysts.
- **Data visualization** helps to focus on the unexpected, better understand data and clearly present and communicate information. It can help analysts to see patterns and recognize anomalies. Visual literacy is key to avoid misrepresenting and misunderstanding facts.
- The transparency and security features of **shared ledger technology** could lend themselves to certain safeguards applications, such as nuclear material accounting reporting, helping to protect confidential data and build confidence.
- The Department will need to monitor developments and **invest in modern technology** to enhance effectiveness and efficiency in its work. **Innovation** is also a matter of organizational culture; it needs to be nurtured.

INTRODUCTION by Therese Renis, Director of the Division of Concepts and Planning

Photo by Jane Hoole

The IAEA Department of Safeguards has successfully been exploiting emerging technologies for many years. In fact, it is a requirement under safeguards agreements to take full account of technological developments, and new technologies have helped improve both the effectiveness and efficiency of the Department.

The Agency will find it increasingly difficult to achieve its safeguards objectives unless, however, an even stronger push for embracing new technologies and innovation is made. New types of power reactors are being developed, including fourth generation nuclear energy systems and transportable nuclear power plants. New enrichment processes, including laser and possibly plasma processes, may emerge alongside, or replace, currently deployed commercial enrichment techniques. Development and construction of geological repositories also presents new challenges for the future of international nuclear safeguards. All of this suggests that the Department must prepare to safeguard new, more advanced and different types of nuclear installations in the future.

In addition, the information age poses challenges; the volume of information is growing exponentially; it comes in a greater variety of formats and spreads faster than ever before. At the same time, it will offer important opportunities, such as artificial intelligence and virtual reality tools. High-speed digital data networks cover increasingly large portions of the globe. Wireless and satellite communication are more ubiquitous. Information fusion and search tools are ever smarter. Storage capacities continue to increase, making the storage of huge volumes of data possible and less expensive. Such advances have the potential to substantially improve the IAEA's technical capabilities and generate efficiencies in the way it works.

The safeguards system must continue to be responsive to such changes in the IAEA's operating environment. Monitoring such changes is an integral part of the strategic planning activities in the Department of Safeguards.

It is against this background that the Department convened a workshop on emerging technologies from 13-16 February 2017. At the workshop, around 100 participants from the Department, the private sector, NGOs, academia and Member States Support Programmes followed the invitation to increase the Department's awareness about and preparedness for addressing the challenges and opportunities of emerging technologies – nuclear and non-nuclear. This report summarises the workshop discussions and will – inter alia – inform the development of the Department's next long-term research and development plan. The plan is part of a suite of strategic planning documents designed to set out the capabilities required to meet its strategic objectives.

I would like to extend my appreciation to all colleagues within the IAEA and our Member States Support Programmes for their support. This workshop would not have been possible without their commitment and generosity.

WELCOMING STATEMENT by Tero Varjoranta, Deputy Director General and Head of the Department of Safeguards

"It is my pleasure to welcome you to the Emerging Technologies Workshop of the IAEA's Department of Safeguards. I am particularly pleased to welcome representatives from the private sector and civil society. We really appreciate your support in carrying out our crucial mission.

Let me start by setting out the broader context of this workshop and the role of safeguards as applied by the IAEA.

The Treaty on the Non-Proliferation of Nuclear Weapons – the NPT, which has achieved almost universal membership, commits over 170 States not to use nuclear energy to make nuclear weapons. This, of course, is the duality of the atom. Nuclear material can be used for peaceful purposes or for making nuclear bombs. To maintain a stable world, we need a global system in which the benefits of nuclear energy can be enjoyed, underpinned by the assurance that nuclear material and technology will not be diverted to weapons of mass destruction.

The IAEA was established 60 years ago in order to provide this assurance – which, of course, needs to be credible. To be effective we need to have a strong technical capability and intrusive verification powers. And effective verification comes largely from the physical presence of IAEA inspectors on the ground. That is why States have accepted through a legal commitment – a safeguards agreement – that the IAEA is given access to their nuclear facilities. In this way, the State demonstrates that it is adhering to its commitment not to develop nuclear weapons.

Ensuring that all the nuclear material under IAEA safeguards remains in peaceful use is a very demanding task. Today, there is enough nuclear material under safeguards to make over 200,000 nuclear weapons. We apply safeguards in over 180 countries in over 1200 nuclear facilities and other locations. And the situation does not stand still. Every day nuclear material sufficient to make 18 more nuclear bombs comes under safeguards. And all the time, more nuclear facilities are coming into operation or being decommissioned. And many of the new facilities are more complex than those previously.

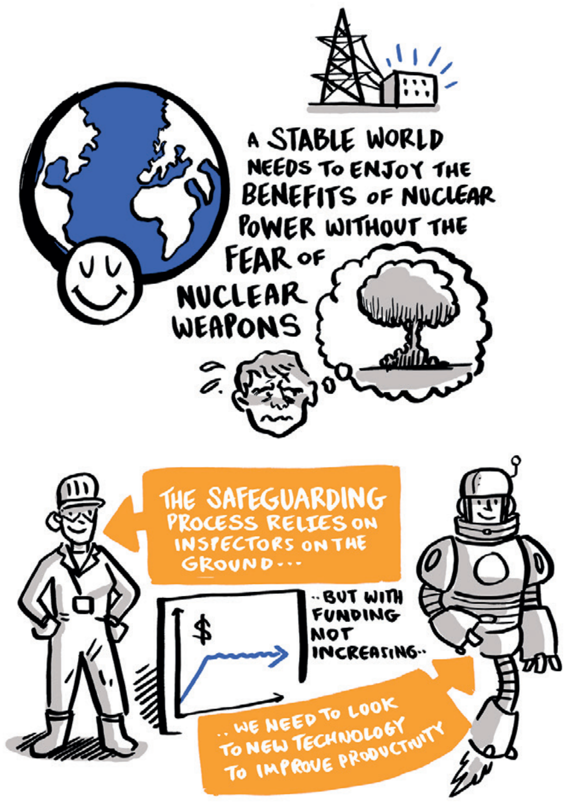
But as the demand on safeguards rises, our budget does not. Consequently, the gap between demand and resources widens. The only way to close that gap is to improve our productivity. And one of the major ways in which we can improve our productivity is to exploit new technologies. Nuclear verification is dependent on technology. The types of technology range from the simple metal seal – to ensure that nobody can access nuclear material in, say, a container drum – to a very sophisticated device capable of identifying minute particles of nuclear material.

And we are introducing new technologies all the time to help us meet our verification challenges. For example, as part of the Iran deal, for the first time we have deployed on-line enrichment monitors. These machines are able to monitor the enrichment level of uranium – in real-time – to ensure that Iran never goes above the limit of 3.67% U-235.

Which brings me back to this week's workshop. It is vital for us to understand where future technology is heading. What are the new capabilities and what are the trends? And, most importantly for us, what are the possibilities to exploit new technologies to serve our safeguards objectives – in ways that enable more effective verification and more efficient use of our resources.

I see that you have an excellent agenda in front of you. We have high expectations that a number of practical ideas and proposals will emerge from your discussions, which we will be able to follow up in the months ahead. Ensuring that declared nuclear material is not diverted from peaceful activities and ensuring that we are able to detect any undeclared nuclear material or activities is vital to global peace and stability.

For us, failure is not an option: safeguards must succeed. I want to thank you once again for your participation, I wish this workshop every success and I very much look forward to positive outcomes."



OPENING SESSION: Identifying global trends in emerging technologies

The opening session of the emerging technologies workshop provided an opportunity to learn about global trends in emerging technologies – nuclear and non-nuclear.

Mr. Mikhail Chudakov, Deputy Director General for Nuclear Energy of the IAEA briefed participants on the status of nuclear power. Most of nuclear growth is in countries expanding their programmes and is currently expected to range between 2% and 56% in total world nuclear generating capacity by 2030. However, much will depend on uranium and other fuel prices, regulations and actions to combat climate change and meet the sustainable development goals. Two thirds of reactors now under construction will continue to be in Asia, particularly in China. Water-cooled reactors will continue to dominate evolutionary designs while innovative designs will include major changes in design approaches, fuels and materials, including small modular reactors with shorter construction times; some will be transportable. Participants also learned that 50% of research reactors are more than 40 years old, requiring replacement or decommissioning and continue to be converted to use low enriched uranium. In uranium production, reactor demands are expected to continue to be met by supply. Spent fuel is accumulating at a fast rate of about 10,000 t(HM)/year. At the back end of the fuel cycle, innovative approaches and technologies could significantly reduce the radiotoxicity of nuclear waste. Accelerator driven systems are being considered by several countries for transmutation of high level waste. Also, many countries are exploring new solutions and final sites for their spent fuel. Fusion remains a technology still in the future, with no major breakthroughs expected in the next coming years.

Briefing on his findings as the chair of the World Economic Forum's council on emerging technologies, Dr. Bernard Meyerson, Chief Innovation Officer at IBM, described the top emerging technologies that could be of relevance to safeguards. Amongst those will be next-generation robotics that could potentially be used for inspection support, and additive manufacturing to increase efficiency of safeguards operations. Autonomous vehicles in turn could prove smart vehicles for transporting nuclear material. Also, Dr. Meyerson saw great value in blockchain technology for tracking nuclear materials. He described the question of complexity and velocity

"Over the next few decades, large water-cooled reactors will continue to provide the bulk of worldwide nuclear electricity generation."

Mr. Mikhail Chudakov,
Deputy Director General for Nuclear Energy, IAEA

"There will be significant growth in decommissioning: both in the number of sites and in the technologies."

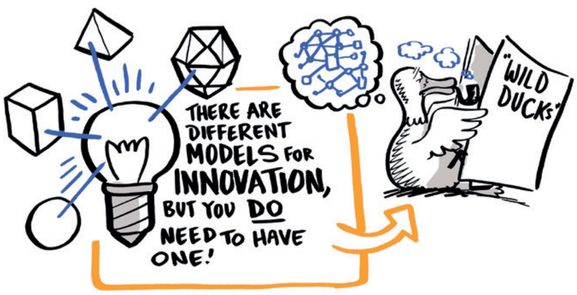
Mr. Mikhail Chudakov,
Deputy Director General for Nuclear Energy, IAEA

"Bureaucracy is failure, time kills deals."

Mr. Bernard Meyerson,
Chief Innovation Officer, IBM

of data as the main challenge of modern information systems, and stressed that cognitive systems and artificial intelligence can help organisations deal with this complexity – working in partnership with humans. The main breakthrough is not that cognitive systems are more intelligent than humans but that they are able to process a much larger set of data. According to him, more data equals more accurate analysis. Finally, Dr. Meyerson described how organizations can drive innovation, offering a set of questions to prepare them do so.

During the discussion, participants noted the difference between the pair of nuclear and non-nuclear technologies: the nuclear sector is characterised by slow moving technology while information technology is an extremely fast moving technology. Dr. Meyerson acknowledged that there were two types of innovation – radical and continuous – and that both were of value. He saw the computer industry as being at an important juncture where the architecture of computing is changing and bringing about a new era of computing power. During the discussion participants also touched upon the kinds of measures organizations can take to ensure that they make optimal use of innovations. Besides deliberately investing resources and taking the time to monitor the operating environment and technology developments, panellists stressed that innovation is a matter of organizational culture – the idea of accepting change and even allowing occasional failures in experimenting with technology. Organisations also need to watch out that bureaucracy does not kill innovation. Instead, they need to allow innovation to take root and nurture it so it can grow.



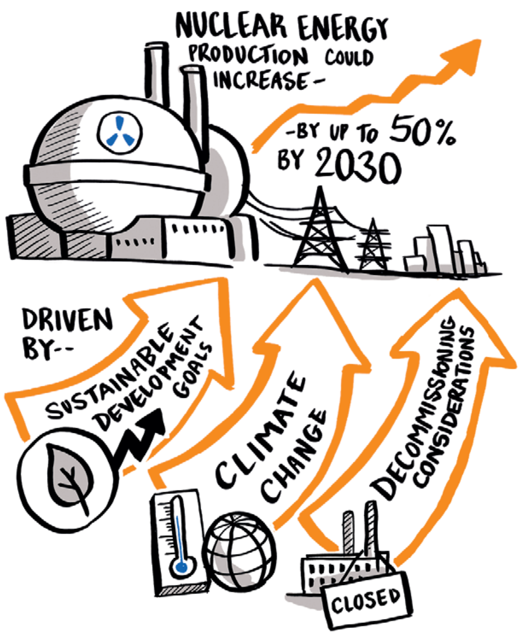
Chair:

Ms. Therese Renis, Director, Division of Concepts and Planning, Department of Safeguards, IAEA

Keynote Speakers:

Mr. Mikhail Chudakov, Deputy Director General and Head of Department of Nuclear Energy, IAEA

Mr. Bernard Meyerson, Chair of the Future of Advanced Materials Council, World Economic Forum and Chief Innovation Officer, IBM



BUSINESS INTELLIGENCE: Being smart about 'Big Data'

The Department for Safeguards operates in a big data world and the amount of data is growing rapidly. The session addressed the question how data can support the Department in gathering, storing, analysing and providing access to data so that it can gain better insights and make fact-based decisions.

Mr. Bernard Marr, Founder and CEO, Advanced Performance Institute, described the huge increase in the amount of available data and how organizations are making use of this big data revolution to (1) make better decisions, (2) improve their operations, and (3) understand their stakeholders. The common challenge, according to him, is not to 'get lost' in all the data but process and analyse the vast amounts of data to produce insights that are useful for the organization. To help with this, organizations are resorting to, e.g., text analytics, predictive analytics, artificial intelligence and machine learning. He emphasised that the key to strategically collecting data is using a SMART model – start with strategy, measure the metrics, apply analytics, report results, and transform the organisation.

The speaker also described the issue of diminishing privacy given that every virtual activity leaves a digital trail. Currently there are over fifteen billion networked objects interacting with one another. Companies, such as mobile phone providers, collect data on users both individually and as organizations. From the GPS usage and tracking for example, data on an individual's daily travel information and buying habits are collected. Along the same lines, internet and telephone habits leave a data trail that is impossible to hide. This data trail paints a fairly complete picture of a person or organization with the cost of collecting this information being relatively inexpensive.

During the discussion, participants posed questions on the implications for safeguards such as the question whether companies or organizations would be able to localize individuals such as inspectors on unannounced inspections. They also discussed sparse data and data cleaning as challenges that are expected to become easier to deal with by using machine learning.

Key Takeaways

- In recent years, the world has witnessed an explosion in the amount and variety of data, requiring also new, more automated ways of processing, analysing and storing data.
- The challenge is to process and analyze the data so that it produces useful insights.
- Given the expected continued data expansion, organizations need to be strategic and selective about the data they collect; in other words, be 'smart' about big data.
- With the use of electronic devices and collection of data from them comes also reduced privacy and increased transparency.

Facilitator:

Mr. John Patten, Section Head, Performance and Quality Section, Department of Safeguards, IAEA

Panellist:

Mr. Bernard Marr, Founder and CEO, Advanced Performance Institute

ARTIFICIAL INTELLIGENCE: Increasing efficiency through automation

Artificial intelligence (AI) and machine learning (ML) are transforming society, organizations and businesses in ways that is being compared to the changes brought on by the industrial revolution. The goal of the artificial intelligence and machine learning session was to understand how these technologies could be applied in the Department of Safeguards.

The first speaker was Ms. Jane Zavalishina, CEO of Yandex Data Factory. Ms. Zavalishina talked about the industrial applications of artificial intelligence and how these technologies are being applied to industries such as manufacturing. She explained a series of analytical questions that machine learning can support, i.e. what happened (descriptive), why it happened (diagnostic), what will happen (predictive) and how to make it happen (prescriptive). By going through these steps analysts can increase their understanding of an issue and get better at fact-based decision making. At the same time there are opportunities to increase efficiencies through automation along these steps.

Mr. Andreas Ebert, Regional Technology Officer for Western Europe, Microsoft, then made a distinction between general artificial intelligence, which is a futuristic scenario where a computer is giving advice to a human, and narrow artificial intelligence, which addresses specific tasks such as language translations, self-driving cars or image recognition. Mr. Ebert was of the opinion that any discussion should center around narrow artificial intelligence. He also touched upon the potential challenges involved with AI, such as employment issues, access to data and ethnical concerns.

As part of the discussion, participants posed the question how much time it will take for investments in AI to be recoverable. Ms. Zavalishina stated that the investment costs in AI would be recoverable within the same year. She talked about the "democratization of AI" in bringing the costs down. According to her, the cost and time issues will not be a decisive factor, but rather the need to change people's perspectives on AI. She argued for the need of a scientific approach and to start where there are already metrics in place. Artificial intelligence does not need to be implemented everywhere, but only to the processes that make sense to be automated. The key was to identify measurable outcomes.

On the question of getting too confident in machines, it was stated that the machines' algorithms are very complex and cannot be processed by humans. The only way to challenge their efficiency is by constantly measuring the outcomes. Mr. Ebert advised that machines' intelligence should not stop humans from constantly questioning things. He argued that there is a big difference in having a "feeling" about data and "predicting" data. As decisions become more important it is important to increase the level of scrutiny.

Key Takeaways

- Modalities and mechanisms for collecting, integrating and analyzing large amount of information are constantly being refined and improved.
- Artificial intelligence and machine learning could be ways to achieve further efficiencies and enable analysts to focus on value added tasks, through automation and by reducing repetitive tasks. However, such technologies will not replace inspectors or analysts.
- It is important to apply artificial intelligence strategically where it can benefit operations the most and where metrics are already in place.

Facilitator:

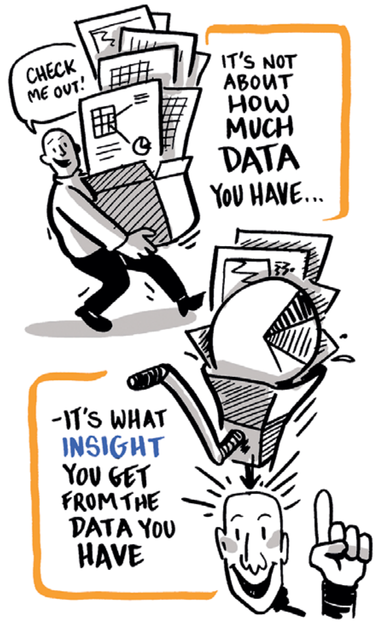
Mr. Scott Miller, Section Head, Office for Information and Communication Systems, Department of Safeguards, IAEA

Panellists:

Mr. Andreas Ebert, Regional Technology Officer for Western Europe, Microsoft

Ms. Jane Zavalishina, Chief Executive Officer, Yandex Data Factory

PANEL DISCUSSION: Leveraging smart data and new technologies for Safeguards



The panel discussion brought together the speakers of the day to tie in their expertise with Safeguards needs and to discuss with the audience which next steps need to be taken.

Panellists acknowledged that the Department is already faced with a large amount of 'big' data. The challenge is to focus on the data that is most significant to safeguards in order to meet its objectives. And to unlock the significant value of this data. Participants agreed that artificial intelligence (AI) and machine learning can be one tool to support this and ensure greater consistency in safeguards work. The idea is to leverage artificial intelligence to reduce repetitive tasks and ensure that safeguards staff can use time more wisely. At the same time, it will not remove the need for people to think critically. Speakers also advised not to apply AI to everything, but consider carefully the safeguards processes and identify the areas where the Department thinks they are most applicable: where Safeguards needs it and can apply it to improve operations. One such example could be the detection of anomalies.

However, there are also challenges associated with the new technologies. Speakers stressed that the Department need to continue ensuring that the data received is valid, so that it can be trusted and not be altered. One measure that the panellists highlighted was the need for large data sets including meta data in this regard. Participants also pointed to issues of data security. Shared ledger technology was highlighted as one solution, one which can help also build transparency. In addition it might help Member States leapfrog technological innovations when e.g. moving from fax-based submission to blockchain technology.

Overall, the speakers emphasised that the range of technological applications and opportunities has grown and will continue to expand, in some cases at a very rapid pace. The question now is which technologies to integrate into safeguards operations and how, because potential proliferators certainly will make use of it for their purposes. Some speakers called it a race the Department was already in. In this regard, it was pointed out that safeguards has one key advantage on its side: it is much harder to hide something than discover it in today's world – something the Department can make use of.

Moderator:

Ms. Laura Rockwood, Executive Director, The Vienna Center for Disarmament and Non-Proliferation

Panellists:

Mr. Bernard Meyerson, Chair of the Future of Advanced Materials Council, World Economic Forum and Chief Innovation Officer, IBM

Mr. Andreas Ebert, Regional Technology Officer for Western Europe, Microsoft

Ms. Jane Zavalishina, Chief Executive Officer, Yandex Data Factory

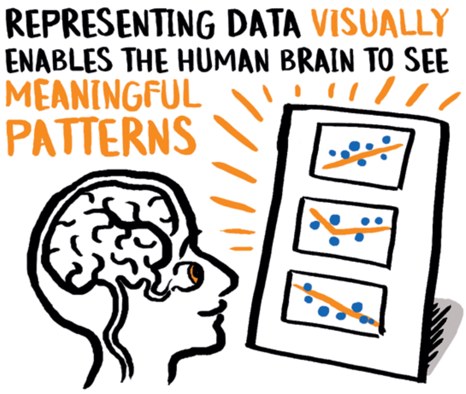
Mr. John Coyne, Director, Office for Information and Communication Systems, Department of Safeguards, IAEA

"We do not want to become IT people but we want IT to help us."

"Artificial intelligence is to make our analysts more effective, reduce repetitive tasks and use their time more wisely."

"It is much harder to hide something than discover it."

VISUALISATION OF DATA: Getting insights through visualisation



The amount of qualitative and quantitative data to be interpreted by Safeguards information analysts increases steadily. The capacity of the human brain to extract useful and relevant information and identify inconsistencies from large volumes of text and figures is very quickly exceeded. Data visualization can help recognize relationships, signals and possible dissonances that could otherwise remain undetected. However, it can also be used in a deceptive way.

Two data visualization professionals presented their insights to the audience. Mr. Robert Kosara, Senior Research Scientist, Tableau Software, and Ms. Christina Versino, data analyst, Joint Research Centre, European Commission. Mr. Kosara in his presentation explored how humans can use their cognitive abilities to understand data. According to him, the main goals of visualization should be to see patterns, to focus on the unexpected, to understand what the data shows, and to present and communicate.

Making extensive reference to the 'Truthful Art' framework for data visualization as defined by Alberto Cairo, Ms. Versino's lecture focussed on the qualities of great visualisations, with some illustrative examples. A great visualisation requires four charachteristcs: (1) Truthful: Since data visualization can be truthful to various degrees there is a truth continuum, between the absolutely untrue and the absolutely true. The analysts' work is to approach the absolute truth insofar as possible. (2) Functional: The visualization is functional when it constitutes an accurate depiction of the data, and is built in a way that allows people to do meaningful operations based on it. (3) Insightful: The visualization should reveal evidence that would have been difficult to detect otherwise, and (4) Enlightening: This quality is largely the consequence of the first four. According to Ms. Versino, this means two different things: work on things that matter, and secondly the added value is when you understand something new.

During the subsequent discussion, the question of how to deal with a truth that is a moving target was adressed. Ms. Versino explained that the analysis should be continuous and that one should not be driven by expectations. Panelists then shared their experience on ways visualization can be used to deceive or distort the intended message, e.g. by using truncated bars, scaled axes, bubbles with a radius out of scale with background maps or scaling objects instead of repeating them. A question about the resources and technology needed to implement visualization tools was posed. In that regard, the bar is not so high since tools are now readily available to assist users in extracting data from the databases and establishing the desired statistics, which previously was the primary barrier for most data visualization. Visual literacy is however desirable and this can be achieved with limited resources.

Key Takeaways

- The implementation of data visualization can support analysts in focusing on the unexpected, and being able to clearly present and communicate rationales and conclusions.
- The tools needed for data visualization are readily available and there is no technological obstacle to implementing and disseminating them right now.
- The main prerequisite for analysts to use these tools is to acquire a basic level of visual literacy, i.e. knowledge of good visualization practices combined with a sound critical sense to avoid misrepresenting facts.

Facilitator:

Ms. Claude Norman, Section Head, Division of Information Management, Department of Safeguards, IAEA

Panellists:

Mr. Robert Kosara, Senior Research Scientist, Tableau Software

Ms. Cristina Versino, data analyst, Joint Research Centre, European Commission

NEW MEDIA, NEW METHODS: Integrating multiple data sources for increased effectiveness

The new media, new methods session aimed to explore how alternative and emerging sources of data and information, including from social media, and new methods of organizing collaborative activities, such as crowdsourcing, may offer new opportunities and challenges for Safeguards.

The session opened with a presentation on “Active crowdsourcing for Safeguards” that was delivered on behalf of Ms. Kari Sentz, Intelligence and Space Research Division, Los Alamos National Laboratory, USA. Crowdsourcing is a method for drawing on the computing power and collective knowledge of many human minds working in parallel to gather and analyse data and to solve problems. Through planned and focused distribution of workloads, including gathering and analysing larger data sets, problems can be solved more efficiently or effectively. In real and simulated crowdsourcing experiments, researchers have found that misinformation and disinformation are present as well as valuable and otherwise unattainable quantities of high-value accurate information. For these and other reasons, crowdsourcing tasks need to be carefully planned and implemented under controls to avoid unintended negative consequences. Two measures that may have application for IAEA safeguards are relying on selected pools of experts rather than larger groups of laypersons, and on structuring methods of cross-validation such as peer ranking in order to identify and encourage factual accuracy and sound analytic judgements.

“Three safeguards-relevant approaches to non-proliferation research” was presented by Ms. Melissa Hanham, Senior Research Associate, Middlebury Institute of International Studies at Monterey. Ms. Hanham briefed participants about Geo4Nonpro, a limited-access crowdsourcing project to identify and cross-check locations and features in satellite imagery that may be relevant to non-proliferation issues. Invited participants, who include satellite imagery analysts, engineers and non-proliferation analysts, can tag and offer comments on specific locations for review and possible further elaboration by other experts. The project found that eliciting participation from a larger group including non-specialists led to the identification of some locations and features not previously recognised. Ms. Hanham further explained that a new commercial satellite imagery provider

(Planet Labs) offers medium-resolution images with a high revisit rate. While not substituting for high resolution commercial images, these mini-satellite services offer new and potentially more timely possibilities for change detection in monitoring high-interest locations.

Mr. Joshua Rutkowski, Staff Researcher, Institute of Energy and Climate Research, Forschungszentrum Jülich, presented on trends in remote sensing and geospatial information. There is an increasing range of technical capabilities for remote sensing potentially relevant for nuclear safeguards verification, including through an increasing number of satellites, commercial vendors, variety of platforms, types of sensors, and resulting data streams. In some cases, ground-based and aerial platforms can be used to complement these remote sensing capabilities to provide increased resolution and capabilities for nearer to real-time change detection. According to Mr. Rutkowski, this increasing volume of images and other sensor data should be processed through machine learning to assist and complement the work of the analysts.

During the discussion, participants confirmed that crowdsourcing has already proven an effective mechanism in the IAEA’s Technology Challenge to improve digital image processing for the Improved Cerenkov Viewing Device. Key challenges in applying crowdsourcing to other areas relevant to IAEA safeguards were identified. These include (1) maintaining confidentiality of information and IAEA independence in reaching conclusions, (2) eliciting participation from a sufficiently large group of relevant technical experts, (3) providing appropriate incentives to motivate participants, and (4) pre-screening participants, encouraging 'self-policing' and providing ongoing monitoring to address risks of possible deliberate disinformation.

Participants also discussed the increasing volume of unstructured textual and image data available in social media and how it may offer opportunities to further widen the IAEA's use of open sources of information to complement State-declared and IAEA in-field verification data. Challenges in using social media information may include going through the increasing volumes of data to identify and assess only the relatively very small volume of information that is potentially relevant to nuclear safeguards; and employing image forensics and other technical and analytic measures to identify deliberately manipulated information or misinformation.

Finally, the increasing volume of satellite imagery offers considerable opportunities for change detection and feature identification relevant to nuclear facilities and related locations. Due to the growing number of mini-satellites and their higher frequency of revisit rates, it may become increasingly difficult to hide the construction of nuclear facilities with distinctive observable features. Challenges include employing new technologies such as machine learning effectively to automate basic processing of satellite imagery to prioritise images for expert analysts to review, and to continue efforts to identify the means by which nuclear-related purposes of physical installations may be concealed or disguised.

Key Takeaways

- The Department was advised to continue to explore (1) new data sources such as social media, (2) new technologies such as medium-resolution frequent-revisit imagery from mini-satellites and and (3) new methods such as crowdsourcing with expert technical communities.
- Two key challenges will be coping with the increasing volume of data to identify and process only the relatively very small volume of information that is relevant for IAEA safeguards, and implementing effective measures to guard against inaccurate information and possible deliberate misinformation.
- Opportunities to use machine learning should be actively explored for partial processing of textual and multimedia information and other sensor data, to assist and empower inspectors and analysts in implementing the IAEA's verification mission.
- The most important positive potential may lie in the integration of multiple data streams, technologies and methods; any single data source or technology alone will not offer a radical advance in applications for safeguards, but the effective combination of multiple data types and methods may enable the IAEA to realize considerable increases in efficiency and effectiveness.

Facilitator:

Mr. Michael Barletta, Senior Safeguards Analyst, Division of Information Management, Department of Safeguards, IAEA

Panellists:

Ms. Melissa Hanham, Senior Research Associate, Middlebury Institute of International Studies at Monterey

Mr. Joshua Rutkowski, Staff Researcher, Institute of Energy and Climate Research, Forschungszentrum Jülich

NOISE REDUCTION AND DATA VALIDATION: Addressing security concerns and adding transparency through shared ledger technology

The session on noise reduction and data validation provided a look at the potential techniques needed to deal with verifying the accuracy of all safeguards relevant information collected from various sources. The fundamental premise was that the volume of information available in all forms of media continues to expand in both number and type. In addition, as the volume increases concerns continue to grow about the accuracy of the information and the consequent reduction in the signal to noise ratio.

The session opened with the screening of a TED talk by Mr. Eli Pariser, called “Beware online filter bubbles”. He described the phenomena engendered by the emergence of smart applications. As software applications increase their customization and their initial utilization of artificial intelligence, many have been designed to tailor their content delivery to specific users’ previous patterns. His contention is that this customization creates a “filter bubble” that distorts the information that the applications deliver. The affected applications cover the gamut of what is available electronically; social media, news aggregators, search engines, and even media outlets. A user’s unique universe of online information is not fully selected by the user but also by the underlying algorithms that may be based on a variety of unknown drivers ranging from economics to political considerations. Objectivity and a variety of ethical concerns of note were not necessarily yet part of the underlying algorithms that determine what electronic information users see.

Turning towards the topic of shared ledger, Ms. Sarah Frazar, Nonproliferation Specialist, Pacific Northwest National Laboratory presented information on the underlying technology. A blockchain is an encoded digital ledger that is stored on multiple computers in a public or private network. It comprises data records, or “blocks.” Once these blocks are collected in a chain, they cannot be changed or deleted by a single actor; instead, they are verified and managed using automation and shared governance protocols. Blockchain technology can increase transparency and trust without sacrificing confidentiality. It provides a unique value added on top of traditional secure databases. A few types of shared ledger technology exist, all of which have the following five characteristics: consistency, validity, uniqueness, immutability and authentication (all transactions are tied to an individual). Two of the major features that were highlighted were the fact that multiple levels of encryption provide excellent security and the immutability of the encrypted data provides confidence in the fact that entries have not been tampered with.

Although the technology is still under development, participants during the discussion proposed that there were safeguards activities that could benefit from shared ledger approaches, such as nuclear material accounting, transit matching and a dynamically updated Safeguards Implementation Report. It was noted that Member States could use this approach to provide encrypted data to the Agency that could be visible to other entities. This would enhance confidence in the reporting of the participating parties while maintaining a high level of data protection and confidentiality. On the question whether this type of technology would lead to the potential elimination of certain Agency activities it was stated that the main intent of using shared ledger technology was to improve the efficiency, security, and transparency of Agency safeguard activities.

Key Takeaways

- The increasing customasation of web content creats “filter bubbles” that may distort information.
- The transparency and security features of shared ledger technology could lend themselves to certain safeguards applications such as nuclear material accounting reporting.
- There are a number of blockchain tools and technologies that can be implemented immediately to protect critical data and improve the management of confidential records.

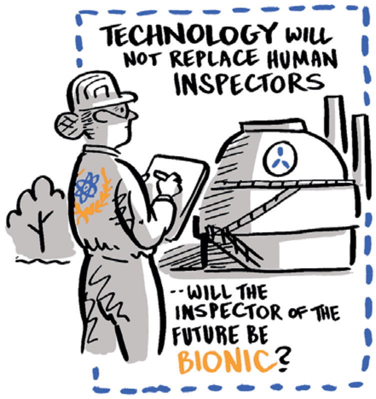
Facilitator:

Mr. Brian Aubert, Section Head, Division of Information Management, Department of Safeguards, IAEA

Panellist:

Ms. Sarah Frazar, Nonproliferation Specialist, Pacific Northwest National Laboratory

PANEL DISCUSSION: Towards an integrated approach to new technologies



The panel discussion at the end of the second workshop day focussed on the impact of new technologies on Safeguards and how these technologies will change the Department’s activities. Panel members emphasised that the Department’s approach to addressing and incorporating new technologies has to be integrated. The number of large datasets is expected to grow, and the level of the Departments’ digital and image data literacy will have to rise accordingly. The challenge will be how to deal with increasing masses of data while also improving productivity.

On the question whether the new technologies could help to bridge the growing gap between demands and available resources, the panellists were of the opinion that there will be better tools available but also more data to analyse. A large challenge will thus be storing, securing and analysing the data. They were of the opinion that new technologies will become integrated throughout the Department. At the same time, technology will not replace human inspectors. In fact, the ability to deploy inspectors to be on the ground was seen as the comparative advantage of the Department. Moreover, if new tools and work processes can more fully integrate data in headquarters and in the field, IAEA inspectors will become ever more effective in conducting their verification activities. Another opportunity will be to automate repetitive tasks and have inspectors and analysts focus on more challenging value-added tasks.

New technologies will also necessitate an examination of budget allocations and non-compliance processes of Safeguards. Along the same lines, it will be important to prioritise investments into new technologies. There are many lines of research of relevance to the Department, but it is important to choose wisely and to have a balance between issues the Department would like to do and can do. The focus should be on applying the right tools to the right outcomes with measurable results.

On the question of partnerships and collaboration, the panellists highlighted the need for the Department to engage more closely with industry players, e.g. for blockchain, as well as with NGOs and civil society.

“The ability to have inspectors on the ground is the comparative advantage of Safeguards.”

“New tools can be used to automate repetitive activities and focus on more challenging tasks.”

“The approach to new technologies has to be integrated.”

Moderator:

Mr. Frederik Dahl, Section Head, Multimedia and Public Outreach Section, IAEA

Panellists:

Mr. Robert Kosara, Research Scientist, Tableau Research

Ms. Cristina Versino, Joint Research Centre, European Commission

Ms. Melissa Hanham, Senior Research Associate, Middlebury Institute of International Studies at Monterey

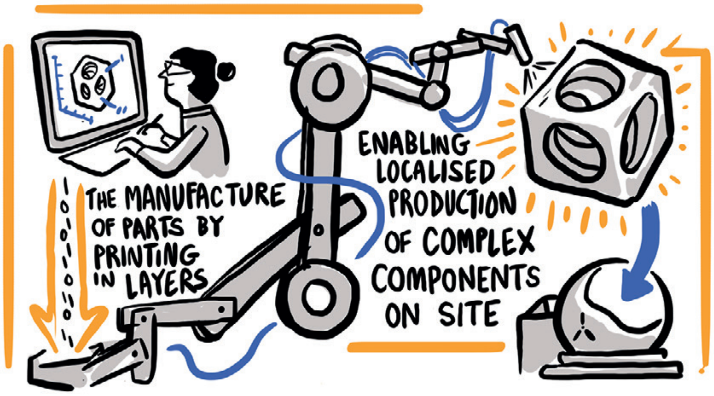
Mr. Joshua Rutkowski, Staff Researcher, Institute of Energy and Climate Research, Forschungszentrum Jülich

Ms. Sarah Frazar, Nonproliferation Specialist, Pacific Northwest National Laboratory

Mr. Jacques Baute, Director, Division of Information Management, Department of Safeguards, IAEA

ADDITIVE MANUFACTURING: Learning about and preparing for 3D Printing

Additive manufacturing, colloquially referred to as 3D printing, is the fabrication of complex structures via the stacking of 2D layers to construct a 3D object. Of particular interest to safeguards is whether 3D printing may one day enable the manufacture of high-strength structures for use in nuclear fuel cycle, such as centrifuge parts, advanced materials such as diffusion barriers, or complex components such as nuclear weapon parts by circumventing traditional barriers.

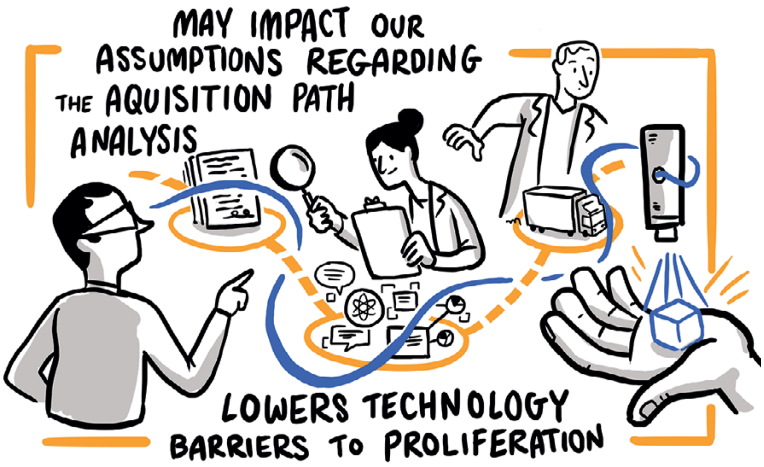


Mr. Grant Christopher, Research Fellow, International Centre for Security Analysis, King's College, London, and Mr. Marco Fey, Research Associate, Peace Research Institute Frankfurt, briefly described four different additive manufacturing (AM) processes. The most relevant to safeguards were direct energy deposition, where feed material (e.g., metal wire) is fused with an electron beam, and powder bed fusion, where a bed of solid powder material is melted by a light source (to produce metal, ceramic or plastic parts). Advantages of the technology, according to them, include accelerated product development (years to months), less material required per unit, and the combining of manufacturing and assembly steps.

Current technical barriers of 3D printing include size limits of commercially available machines, long time required to print each part, varying quality of raw materials, varying performance of commercial machines (General Electric spent months adjusting each commercial printer for its jet engine parts), anisotropic material properties (weakness in the build direction), and inadequate understanding of the underlying physics. However, there is a chance that this technology could evolve to a stage where the know-how is not necessary anymore to produce a high-tech component, but one just needs the design file. This could increase unauthorized technology transfers and affect time considerations in acquisition path analysis (APA). In addition, new materials might be possible to be printed, e.g., making graphene structures, and amorphous metals (so-called "metallic glass", which has no crystalline structure).

As regards export controls, the speakers mentioned that some of the powders used in AM have potential properties that would fall within the Nuclear Supplier Group's (NSG) dual use list. However, to date metal powders have not been controlled in practice. They also advised that designs must be secured against unauthorized theft or tampering, and that there is a near- to mid-term expectation for innovation along the entire manufacturing chain, leading to the development of integrated post process solutions, and the improvement of material properties.

During the discussion, participants focussed on a number of challenges that the technology could pose to the Department. The first challenge discussed was the question of centrifuge rotors potentially being printed through AM. The speakers thought it was currently not possible, as the microstructures and mechanical properties of the finished product cannot be controlled to the required level yet. It was generally thought that nothing currently printed through AM would achieve the strict tolerances needed for centrifuges, though one speaker thought post-processing (e.g. polishing) might allow targets to be reached. Another participant observed that limitations in strength of materials might be bypassed by modifying the design. Participants thought that countries with high-tech manufacturing bases would probably not choose AM to make centrifuges; AM would be more interesting for actors that currently



do not have access to traditional manufacturing technologies/materials.

On the question of APA and the potential for AM to reduce development cycles, some participants thought that AM could enable vertical proliferation. Regarding export controls, the speakers thought materials should be prioritized over printers for now. They also observed that reviews of NSG dual use lists would be preceded by reviews of lists in conventional weapons agreements, and this has not yet taken place. Another challenge was whether complex materials like diffusion barriers might one day be more easily engineered using AM than through traditional R&D. Finally, the potential to replicate complex or random patterns used to authenticate Agency metal or glass seals was discussed.

The discussion also centred around potential opportunities that AM could present to the Department. These included the possibility of prototype sealing arrangements, unique enclosures with hidden features, as well as, ad-hoc spare parts for Agency equipment.

Key Takeaways

- Additive Manufacturing could pose challenges to the Department, as proliferators could manufacture high-strength structures such as centrifuge parts, advanced materials such as diffusion barriers, or complex components such as nuclear weapon parts.
- The Department should monitor technology developments in this area, paying attention to advances in printing higher-strength, larger-geometry parts; mass production; learning curves and commissioning times; design security; changing needs for specialized expertise; and the evolution of export controls.
- In particular, analysis should be done to understand how path step time estimates in APA might be shortened by AM.
- State evaluation groups may need to think differently about how they track and estimate capabilities as AM technology advances, as well as how AM indicators might differ from those associated with traditional manufacturing.
- Vulnerabilities in sealing systems from AM should be considered.

Facilitator:

Mr. Christopher Gazze, Section Head, Division of Operations A, Department of Safeguards, IAEA

Panellists:

Mr. Marco Fey, Research Associate, Peace Research Institute Frankfurt

Mr. Grant Christopher, Research Fellow, International Centre for Security Analysis, King's College, London

LASER TECHNOLOGIES: Dual-use technologies and associated proliferation risks

Laser technologies are rapidly developing. The coherency, high monochromaticity, and ability to reach extremely high powers allow for specialized laser applications. The IAEA has also been introducing laser systems to improve IAEA safeguards efficiency and effectiveness. For example, recently deployed 3D laser range finder instruments allow inspectors to scan a location to mm accuracy for use when undertaking design information verification visits. On the other hand certain applications of laser technologies may pose threats for IAEA safeguards e.g. using lasers for uranium enrichment.

Mr. Andreas Otto, Professor, Institute for Production Engineering and Laser Technology, TU Vienna, in his presentation briefed the audience on current applications of laser technologies including hand-operated laser-cutting for nuclear decommissioning, laser drilling, laser additive manufacturing and laser weapon systems. He also highlighted trends for commercial high power laser systems. They are becoming more and more compact, cheaper, extremely powerful, easy to operate and highly energy efficient.

Mr. Ryan Snyder, Visiting Research Fellow, Arms Control Association, in his presentation focused on using lasers for uranium enrichment. He described different laser isotope separation methods, including Atomic vapor laser isotope separation (AVLIS) and Molecular laser isotope separation (MLIS). According to Mr. Snyder, commercialization of these methods was abandoned due to expensive reprocessing chemistry, materials corrosion, inefficient laser excitation, and problems with low laser pulse repetition rates. He then provided background on 3rd generation laser enrichment technologies of which SILEX (separation of isotopes by laser excitation) may be one. He was of the opinion that these 3rd generation technologies have lower capital and operating costs, require smaller space and are more energy efficient than centrifuges. In addition, laser expertise is more widely available worldwide. Mr. Snyder concluded that SILEX technologies may potentially be attractive for weapons production, but other experts in the audience noted that it was not yet proven that SILEX could make HEU at scale and were also sceptical whether SILEX for HEU would have a smaller footprint than centrifuges.

During the discussion a question was posed on potential other uses of lasers. Additive manufacturing was mentioned as one option; one that might potentially pose a challenge for safeguards since lasers are easy to access and the footprint is rather small. Participants also raised questions on cost and scaling issues for laser enrichment. At the same time, participants agreed that possible use of AVLIS and MLIS technologies for uranium enrichment requires the IAEA to remain ready to safeguard such facilities as well. Participants also discussed a necessity of clarifying legal issues related to export control of laser technologies, and also a potential update of INFCIRC/540 Annex I Para 5.7 to cover SILEX technology.

Key Takeaways

- Commercial high power laser systems are becoming more and more compact, cheaper, extremely powerful, easy to operate and highly energy efficient.
- Laser enrichment technologies could pose proliferation challenges due to widely available expertise and potentially lower cost, space and energy required compared to centrifuge technologies.
- The potential use of laser technologies in decommissioning activities should be further studied.
- Legal issues related to laser technologies need to be addressed.

Facilitator:

Ms. Stephanie Poirier, Team Leader, Division of Technical and Scientific Resources, Department of Safeguards, IAEA

Panellists:

Mr. Andreas Otto, Professor, Institute for Production Engineering and Laser Technology, TU Vienna

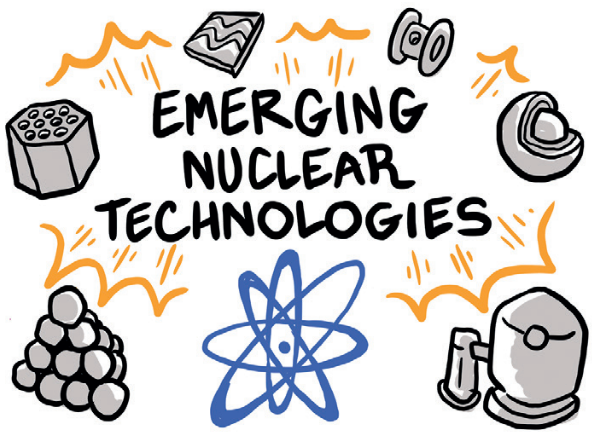
Mr. Ryan Snyder, Visiting Research Fellow, Arms Control Association

TRENDS IN NUCLEAR TECHNOLOGIES: What are potential Safeguards challenges?

The 'Trends in Nuclear Technologies' session opened the section of the workshop that focused on nuclear technologies. The session highlighted some of the biggest safeguards challenges posed by emerging nuclear technologies. and started the conversation on what the Department should do, both now and in coming years, to prepare to effectively and efficiently safeguard these technologies.

Mr. Mark Hibbs, Senior Fellow at the Carnegie Endowment for International Peace, in his presentation focused on forthcoming, previously non-deployed nuclear technologies (all reactors and pyro-processing), their drivers, and probable challenges to IAEA safeguards. This picture was presented through the lens of nuclear development plans in China, which is nearly certain to be the first and possibly largest implementer of new technology in this area. Mr. Hibbs delved into particular technologies he considers to be both particularly likely to emerge soon and are known to be challenging from a safeguards perspective. Amongst these are transportable reactors (access, liability, continuity of knowledge), pyro-processing (diversion scenarios), pebble-bed reactors (continuity of knowledge), as well as, molten-salt reactors (liquid fuel, continuously refuelled, in an opaque coolant). Mr. Hibbs noted that the political and organizational drivers for these technologies are not primarily concerned with pressing, as-yet-unresolved safeguards issues. At the same time the 'lead time' to resolve some of these difficult, technically complex challenges is quite large, necessitating a start as early as possible with relevant experts.

Participants during the discussion agreed on the key differences that Mr. Hibbs highlighted between safeguardability and proliferation resistance. Specific technologies/ projects are often focussed heavily on proliferation resistance when explaining the merits of a given technology, but many notionally proliferation resistant features actually make the implementation of safeguards more difficult. One workshop participant stressed that, in forthcoming discussions and definitions in appropriate forums, there will be a significant effort from the IAEA to ensure that safeguardability is specifically included as a major component of the concept of proliferation resistance. Participants further agreed that 'safeguards by design' remains essential in order to ensure the IAEA is prepared for the future. Finally, Mr.



Hibbs suggested the establishment of a mechanism/ forum to continually evaluate the status of relevant technologies as well as specific measures and approaches to facilitate the application of safeguards.

Key Takeaways

- Amongst the range of emerging nuclear technologies transportable reactors, pyro-processing, pebble-bed reactors and molten salt reactors will be particularly challenging for safeguards.
- For many proponents of these technologies, the primary concern is not safeguardability but rather cost, safety and proliferation resistance.
- Some nuclear energy technologies may not be satisfactorily safeguardable (further study required).

Facilitator:

Mr. David Peranteau, Division of Concepts and Planning, Department of Safeguards, IAEA

Panellist:

Mr. Mark Hibbs, Senior Fellow, Nuclear Policy Program, Carnegie Endowment for International Peace

TRANSPORTABLE NUCLEAR POWER PLANTS: Safeguarding remote and difficult to access facilities

Transportable nuclear power plants (TNNPs) and specifically the marine based water cooled small modular reactors (SMRs) are integral pressurized water reactor (PWR) concepts. The aim of the session on transportable NPPs was to discuss challenges the Department could potentially face, such as safeguards obligations of the host or supplier state, the application of safeguards to a light water reactor and safeguarding a factory fuelled and shipped reactor.

Mr. Hadid Subki, Department of Nuclear Energy, IAEA, provided an overview of deployment schedules and the market and viability of SMRs for transportable use. Mr. Subki noted that SMRs have unique design features in underground and marine based deployment. Underground deployment provides better protection against the impacts of severe weather, better seismic strength, enhanced protection against fission product release and improved physical security. Marine based deployments offer an infinite heat sink (sea) and site flexibility. One of the key issues was that these technologies are coming in the next decade to the grid and the Department must be prepared to address them.

Representing the Canadian Nuclear Laboratories, Mr. Bryan Van Der Ende, Physicist, Canadian Nuclear Laboratories, briefed on issues in deployment and use of transportable reactors and the siting of test/prototypes and timescale of deployment. He noted that in the far north of Canada, Very Small Modular Reactors (VSMRs) provide an opportunity for simple dependable long-running power sources. He noted that VSMRs challenge the safeguards regime with low refuelling frequency requiring significant excess reactivity and burnable absorbers and can tolerate target material irradiation, a potential diversion pathway. However, VSMRs can mitigate those issues with IAEA pre-operation design verification and reliable sealing and surveillance measures with a focus on safeguards by design.

Mr. Vladimir Galitskikh, Head of Bureau, and Ms. Nadezhda A. Salnikova, Specialist, OKBM Afrikantov Enterprise, presented on questions relating to building, transporting and operating a barge reactor. The speakers noted that potential customer states are interested in receiving electricity while minimising their responsibilities at the stage of TNPP operation, including those related to placing TNPP under IAEA safeguards and providing compliance with international requirements in the field of non-proliferation. The speakers stated that the most preferable business-model is 'Build Own Operate' (BOO), without refuelling at the operation site. The supplier State is responsible for TNPP construction, transportation and operation in order to provide the Customer State with electricity. Moreover, the speakers briefed about some proposed engineering solutions on sealing the reactor and the control room, installing sensors and monitoring devices.

Key Takeaways

- The deployment of SMRs is expected within the next decade to the grid and the IAEA must be prepared to address them.
- Technical safeguards on SMRs, including TNPPs, will need consideration by the Department to cover difficult-to-access materials in operation for decades in remote places, verification of a reactor at the factory, and maintenance of continuity of knowledge for up to decades prior to refuelling and reverification.
- The proposed "build, own, operate" model for the safeguards regime that has the supplier State taking all safeguards obligations and operating the facility off-shore should be carefully examinated.

Facilitator:

Mr. Brian Boyer, Safeguards Analyst, Department of Safeguards, IAEA

Panellists:

Mr. M. Hadid Subki, Nuclear Engineer, Division of Nuclear Power, Department of Nuclear Energy, IAEA

Mr. Vladimir Galitskikh, Head of Bureau and **Ms. Nadezhda Salnikova**, Specialist, OKBM Afrikantov Enterprise

Mr. Bryan van der Ende, Physicist, Research and Development, Canadian Nuclear Laboratories Ltd.

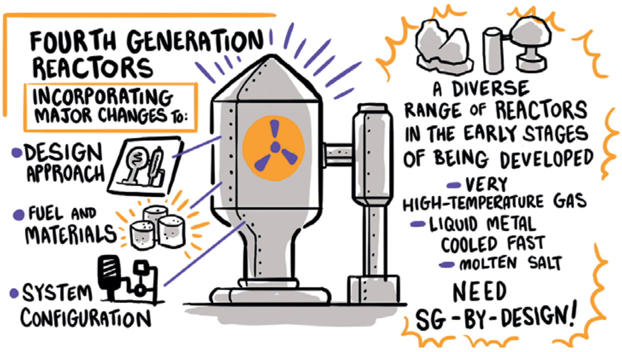
GENERATION IV REACTORS: Preparing to safeguard innovative reactor designs

The sessions on Generation IV reactors and associated fuel cycles provided an overview of new types of reactors currently being developed.

Mr. Stefano Monti, Section Head, Division of Nuclear Power, IAEA, stated that the current fleet of reactors [Generation II] is largely made up of commercial power plants built since the 1970s and that are still operating today. With the expected life time extension, a large fleet of these reactors is expected to remain in operation until 2050, and most probably also well beyond. However, advanced nuclear reactor designs are being developed and implemented. These can be divided into evolutionary and innovative designs: evolutionary designs [Generation III and III+] achieve improvements over existing designs through small to moderate modifications, with a strong emphasis on maintaining proven design features to minimize technological risks. Their development requires at most engineering and confirmatory testing. In contrast, innovative designs [Generation IV] incorporate major changes in design approaches, fuel and materials, or system configuration in comparison with existing practice. Although first of a kind design and deployment of innovative reactors presently requires substantial R&D as well as industrial demonstration through the realization and operation of experimental, demonstration or prototype reactors it is required to explore safeguards challenges to be brought by new types of reactors.

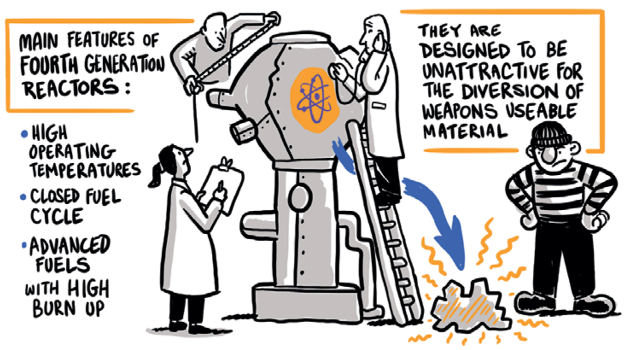
Mr. Monti briefed the audience on the main features of innovative reactors that might be of relevance for safeguards, including high operating temperatures, closing the fuel cycle and advanced fuels with high burn-up (mixed U-Pu, MA-based, Th). He also pointed out that one of the goals of developing advanced reactors is to increase the assurance that they are very unattractive and the least desirable route for diversion or theft of weapons-usable materials.

Out of the multitude of Generation IV reactors under development, the Generation IV International Forum, in 2002 and again in 2012, announced the selection of six reactor technologies which they believe represent the future shape of nuclear energy. The systems selected are the Sodium-cooled Fast Reactor, Very High Temperature Reactor, Lead-cooled Fast Reactor, Supercritical Water-Cooled Reactor, Gas-cooled Fast Reactor, and Molten Salt Reactor. These types of reactors were discussed separately during the subsequent three sessions of the workshop.



Key Takeaways

- Advanced nuclear reactor designs have significant improvements over the current fleet. Depending on the amount of modifications implemented, they can be divided into evolutionary and innovative designs, with SMRs in both categories.
- Worldwide nuclear electricity generation with evolutionary designs will continue to be dominated by large water-cooled reactors over the next decades.
- Innovative Designs incorporate major changes in design approaches, fuel and materials, or system configuration in comparison with existing practice. They promise to further increase efficiency and sustainability, in particular through higher operating temperatures and closing the fuel cycle.



Presenter:

Mr. Stefano Monti, Section Head, Division of Nuclear Power, IAEA

Very high-temperature gas reactors

Among the Gen IV reactors, very high temperature reactors (VHTRs), especially pebble-bed modular reactors (PBMR), are those which are the closest to be available commercially, with China leading the way. Currently, beside its research PBMR, China has started building a 250MwTh unit and is planning additional units.

Mr. Fredrik Reitsma, Nuclear Engineer, Department of Nuclear Energy, IAEA, provided a brief history of various PBMR programs and their achievements, paying attention to international cooperation and the status of various technological challenges. High-temperature gas reactors (HTGRs) allow flexibility of operation by switching between electricity and process heat. And they are ready for commercial deployment. The presentation was complemented by Dr. Li Fu, Deputy Chief Engineer, Institute of Nuclear and New Energy Technology, China, who presented on the first commercially licensed PBMR plant, its layout and characteristics. Professor Fu put forth some potential safeguards challenges, including the fact that the PBMRs would include large numbers of pebbles that would be challenging to safeguard. On the other hand they will be challenging to divert from as well.

The subsequent discussion centered around two issues, i.e. reprocessing and diversion of nuclear material. As for reprocessing, although the PBMR and its associated fuel were developed to be proliferation resistant and to abolish the need for reprocessing, professor Li Fu made it clear that in China, in order to obtain a license, it is essential to show that a closed fuel cycle can be achieved with any type of reactors. Furthermore, Mr. Reitsma also pointed out that a Swiss company, in cooperation with a research center had developed a machine capable of breaking up the PBMR fuel. However, to date no test on irradiated fuel has been carried out. Regarding the diversion of nuclear material, it was stressed that the high number of PBMR fuel pebbles necessary to operate the reactor, together with being extremely difficult to access and handle poses a challenge to safeguard. More than likely a new generation of non-destructive assay and counting equipment will need to be developed.

Key Takeaways

- The high number of PBMR fuel pebbles necessary to operate the reactor, together with being extremely difficult to access poses a challenge to safeguards.
- VHTRs rate high on technology viability with fifty years of operational experience. Their enhanced safety characteristics have been demonstrated with severe accidents practically excluded (no core melt down or massive fission product release are possible even in extreme conditions).
- The construction of a commercial PBMR demonstration plant (operation expected to begin in 2017) is currently ongoing in Shandong province, China.

Facilitator:

Mr. Ghislain Berthelot, Nuclear Safeguards Inspector, Division of Operations A, Department of Safeguards, IAEA

Panellists:

Mr. Frederik Reitsma, Nuclear Engineer, Department of Nuclear Energy, IAEA

Mr. Li Fu, Deputy Chief Engineer, Institute of Nuclear and New Energy Technology, China

Liquid metal fast reactors

Among the Gen IV reactors, liquid metal cooled (sodium) reactors are part of the most advanced ones. Demonstrators of such reactors have already been built and operated successfully and first safeguards approaches were implemented, even though there is currently no such reactor in operation in a nonnuclear weapon State (NNWS).

Mr. David Wootan, Nuclear Engineer, Pacific Northwest National Laboratory, focussed his presentation on the question of safeguards by design of TerraPower and other New Liquid Metal Cooled Reactors. He highlighted the importance of moving safeguards by design from a concept to an industrial practice and identified challenges with sodium-cooled fast reactors (SFRs), i.e. the opaque and pyrophonic coolant while many IAEA technics rely on containment and surveillance (C/S) measures. Ultrasonic metrology for sodium inspection is still in the research and development phase. In addition, existing SFRs under safeguards rely on C/S using optical systems and unattended monitoring systems using radiation sensors. He then presented TerraPower with the idea of a fuel using exclusively low enriched uranium, no plutonium and the absence of any refuelling. The demonstrator of such a reactor is foreseen to be built in China starting in 2018.

Mr. Fredric Nguyen, Physicist, French Alternative Energies and Atomic Energy Commission (CEA), briefed participants about sodium cooled fast reactors and eelated nuclear fuel cycles. He reminded participants that such a cycle would imply large quantities of plutonium and reprocessing capabilities. These reactors can be used as breeders or transuranic burners or for iso-generation, and would lead to high burnups of the fuel. The deployment of SFR cycle in parallel with the current PWR was presented, highlighting the synergy between the two types of cycles before the nuclear fuel cycle becomes completely closed with SFRs only. For French SFRs, the reprocessing is seen as co-management of uranium and plutonium therefore such a cycle would not imply any separation of plutonium at any point of the process. However, this type of reactor needs near real time control on the nature and concentration of material flows: there is a need to proceed to simulations and confront their results with operational data.

The subsequent discussion highlighted challenges raised by SFRs but also, to a large extent by the other Gen IV reactor designs and accelerator driven systems. First, the question on how to handle the ^{237}Np generated in large amounts in such reactors was raised: ^{237}Np is fissile but does not fall into the definition of nuclear material. In addition, the question of the joint use of ultrasonic devices was raised. The ultrasonic devices would belong to the operators and it seems difficult to have the Agency use its own independent device. Therefore, this tool should be thought of as a joint use tool by design and measures to trust the results of such devices should be sought for in advance. Thirdly, due to the high burnups reached by these reactors, the uncertainties on crucial parameters such as evolution in time of the inventory of the main nuclei of interest (fissile, minor actinides), delayed neutron fractions, residual power are large and require simulation tools and more and improved nuclear data. From a safeguards standpoint such reactors offer a wide range of misuse and/or diversion scenarios, and only a simulation tool would allow to study their feasibility, their fingerprint and to evaluate the capability of current detectors used by the Agency.

Key Takeaways

- Sodium cooled fast reactors are among the most advanced projects in the Gen IV family, some are already in use in nuclear weapon States, and demonstrators are currently being built.
- Safeguards by design for such reactors should be a high priority and taken from the conceptual to the implementation stage.
- The high burnups and innovative fuels/fuel cycle require having a simulation tool to study the feasibility of diversion/misuse scenarios in order to either verify the capability of the current detectors or to specify the needs for new detectors.
- The high burnups imply the build-up of significant inventories of 237Np which is fissile but does not fall into the definition of nuclear material.
- The type of equipment needed to safeguard these reactors, where fuel is not visible (due to liquid metal as a coolant) should be sought.

Facilitator:

Ms. Sandrine Cormon, Nuclear Safeguards Inspector, Division of Operations C, Department of Safeguards, IAEA

Panellists:

Mr. David Wootan, Nuclear Engineer, Pacific Northwest National Laboratory

Mr. Frédéric Nguyen, Physicist, French Alternative Energies and Atomic Energy Commission (CEA)

Molten salt reactors

Molten Salt Reactors (MSR) are one type of the Generation IV reactors that are currently under development. Apart from increased efficiency in power generation, the development of Generation IV reactors is being driven by a trinity of requirements: Passive safety, waste management and process heat production. All types of current Generation IV reactor concepts have at least one of these requirements, but it is only the MSRs that are able to achieve all three requirements. MSRs are therefore likely to be a popular reactor type in the coming years. In fact, China is planning to deploy the first MSR in the mid-2020s, and Terrestrial Energy (Canada and US based) intend to submit a license application in 2019, both targeting the export market that consists mostly of non-nuclear weapon States.

Mr. Andrew Worrall, Fuel Cycle Technology R&D Leader, Oak Ridge National Laboratory, in his presentation provided a definition of MSRs. According to Mr. Worall, any reactor that employs a molten salt to perform a significant function in the reactor is a molten salt reactor. MSRs have two primary sub-classes: salt-fuelled and salt-cooled. The fuel can therefore be solid (looking very similar in form to a high temperature gas reactor, kernel based fuel in blocks), or mixed in a liquid form with the salt itself.

MSRs are further characterised by on-load refuelling and mechanical (non-chemical) removal of some of the fission products, rare earth elements, and noble metals. This removal is often a “passive” process, hence will happen naturally, but has to be controlled for operational and safety reasons, including for long term reactivity control. They do not have to have fissile material separations, and in fact the majority of modern MSR designs only have mechanical fission product removal, with no separations and recycle of fissile material; this is contrary to the very first and early generation of MSR concepts. Finally, MSRs are capable of delivering on a number of fuel cycles, including open using LEU, closed/full recycle, U/Pu, and U/Th.

The presentation further provided a history of the origins and evolution of MSR concepts, emphasizing the very wide range of designs, as opposed to Generation-II reactors that are essentially of one generic design per reactor type.

It was also clear that unlike the types of reactors currently under safeguards, MSRs will not be exclusively item facilities; they will most likely be mostly bulk facilities (at least for those using liquid fuels) .

The Agency will be challenged on how to implement nuclear material accountancy, and how to deal with material unaccounted for (MUF); especially considering that there may be as many accounting strategies as there are MSRs potentially. On-load refuelling and and in some cases the use of online fuel processing in MSRs provides these reactors with the capability to produce weapons grade plutonium or uranium-233.

Following the presentation, participants engaged in a discussion about different features of MSRs. It became clear that the removal of fission products (FP) from the flow stream of the MSR is not reprocessing in the normally understood sense of chemical reprocessing via solvent extraction. It is a mechanical process based on techniques such as sparging or cold traps. Reprocessing in the commonly understood sense means the separation of fissile material, and that is not what happens in the majority of the new generation of MSRs.

Furthermore, the fact that FPs are not fully removed from the bulk fuel stream would mean that safeguards non-destructive assay (NDA) verification based on gamma rays and neutrons will be difficult to carry out because of interference from FP emissions. Concepts and approaches, MBAs, and safeguards technology needs are all yet to be determined for modern MSRs. Non-traditional instruments may be more appropriate i.e., not those that traditionally rely on gamma or neutron measurements alone.

Participants also discussed the questions about how the IAEA will address the MUF issue, in MSRs that are bulk facilities. The first challenge would be to determine how to establish nuclear material accountancy (NMA) – via key measurement points – in the first place, and then to figure out how to estimate MUF in nuclear material that is always mixed with fission products having similar nuclear characteristics. Large volumes of material in the system will require a high degree of precision in any measurements being taken. There may be the necessity for destructive analysis (DA) as well as NDA measurement options.

Considering the wide variety of possible MSR designs, it would be important for the IAEA to establish safeguards by design as soon as possible. Getting involved with designers and manufacturers as early as the conceptual phase, and developing a greater understanding and initiating the early dialogue now.

Noting that all Generation-IV reactors tend to advertise themselves by stressing their proliferation resistant characteristics, it was pointed out that proliferation resistance and ease to verify (safeguard-ability) are not interchangeable; and most of the features lending proliferation resistance to Generation-IV reactors actually make safeguards nuclear material accountancy more difficult.

Key Takeaways

- The safeguards inspection regimes of today are not truly valid for proposed MSR designs and the associated fuel cycles.
- There is a lack of safeguards technology, as well as, approaches and technical measures for the different MSR designs.
- A US/Canadian and a Chinese MSR are due for deployment in 2020–2025, there is a need to urgently understand the design of the MSRs and to develop safeguards approaches in case the reactors are exported to NNWS.
- The fact that MSR designs come with so many possibilities may make the development of generic safeguards approaches impossible. It may be necessary to develop a different type of safeguards approach for each MSR variant.
- Safeguards by design for Gen-IV reactors, especially MSRs, should start at the conceptual stage.

Facilitator:

Mr. Enobot Agboraw, Senior Inspector for Implementation Coordination, Division of Operations C, Department of Safeguards, IAEA

Panellist:

Mr. Andrew Worrall, Fuel Cycle Technology R&D Leader, Oak Ridge National Laboratory

ACCELERATOR DRIVEN SYSTEMS: Safeguarding an innovative approach to the treatment of spent nuclear fuel

Accelerator Driven Systems (ADS) are an emerging technology where a high energy and high intensity proton accelerator is coupled to a subcritical nuclear reactor to produce energy and/or transmute minor actinides.

Mr. Hamid Aït Abderrahim, Deputy Director-General International Relations and Director MYRRHA project, focussed on the technical particularities of ADS as well as the associated safeguards challenges. Among those of high relevance are the non-transparent medium (Lead-Bismuth for example), the target design, the actual accelerator parameters and the large amount of fuel in storage and fissile material in the core are.

The question of the potential misuse of ADS for tritium production and/or the potential production of weapon grade plutonium was stressed by Mr. Per Andersson, Deputy Research Director, Swedish Defence Research Agency. According to him, an ADS-system has many positive properties, such as security, transmutation and flexibility. On the other hand it can be "dangerously" good for the production of strategic materials, particularly, Plutonium and Tritium. With the ADS technology, the proliferator has a powerful neutron source. The idea is to place a lithium blanket around the spallation target, with no need to enrich the lithium or use core space. He further explained that any diversion of the beam would be a very important indicator when looking for signs of potential misuse of ADS. As for other indicators, the panellists explained that – since the energy is linked to the equipment set-up – the beam intensity could be a reliable indicator.

Key Takeaways

- High power accelerators in connection with a sub-critical or critical reactor can pose challenges to Safeguards. Care has to be taken regarding the large amount of nuclear material that is considered as direct use material for nuclear weapons (weapon grade plutonium, tritium production).
- The inaccessibility of nuclear material, atypical fuel assembly form and fuel composition and the power monitoring aspect have to be considered.
- Aspects that can play a positive role in proliferation resistance (e.g. in MYRRHA) is the fact that it is an item facility where the items can be verified rather easily by inspectors.

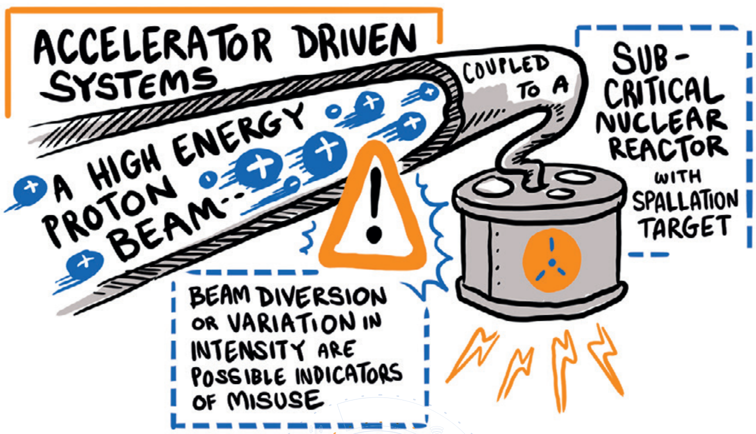
Facilitator:

Mr. Sébastien Richet, Safeguards Information Analyst (Nuclear Material Accounting), Division of Information Management, Department of Safeguards, IAEA

Panellists:

Mr. Hamid Aït Abderrahim, Deputy Director-General International Relations and Director MYRRHA project, SCKCEN

Mr. Per Andersson, Deputy Research Director, Swedish Defence Research Agency



CLOSING SESSION: Highlights and next steps

During the closing session, Ms. Therese Renis, Director for Safeguards Concepts and Approaches, IAEA, provided her views on some highlights of the workshop, and touched upon some of the themes that she saw emerging over the course of the week. She began by highlighting some of the novel elements of the workshop. First, the workshop was a joint effort of the whole Department. Second, it was a true learning event. The sessions were all very interactive benefiting not only from the external expertise but also from knowledge and experience of the Agency's own staff. The sessions were complemented by an active series of live demonstrations. She then turned to some of the overarching themes emerging over the past few days.

First, **'smart data'** was the focus during the first two days and was an undercurrent throughout the workshop. It became even clearer that the safeguards objectives cannot be met without a strong push for smart data and technologies. The challenge is to focus on the data that is most significant, in order to meet the safeguards objectives, and to unlock the significant value of this data. It is important to extract the relevant data and present and visualise it in a digestible way so that effective use can be made of it. And to continue to ensure that the data received is valid, so that it can be trusted and that it cannot be altered. Participants also recognized that artificial intelligence and machine learning can create 'filter bubbles,' but if implemented effectively can help overcome human biases, complexity and ensure greater consistency in the Department's work. The idea is to leverage it to reduce repetitive tasks and ensure that staff can use their time more wisely. At the same time, AI will not remove the need for people to think critically. Speakers also advised not to apply AI to everything, but consider carefully the safeguards processes and identify the areas most applicable. Visualisation was mentioned as a powerful tool to see patterns, to focus on the unexpected and to understand what the data means. Participants also often pointed to issues of security. Shared ledger technology was highlighted throughout the week as one solution, one which can help also build transparency. Overall, the speakers briefed that the range of applications and opportunities has grown and will continue to expand, in some cases at a very rapid pace. The question for the Department is which technologies to integrate into its operations and how – something that will require further consideration and which will be explored in the context of the Department's next R&D plan.

Innovation is another theme that featured prominently during the workshop. Participants learned what

organizations do to ensure they do not stay behind and make use of innovation. Besides deliberately investing resources and taking time to monitor the operating environment and technology developments – which safeguards does as part of its strategic planning efforts. It is a matter of organizational culture – the idea of accepting change and even allowing occasional failures in experimenting with technology. And it is important to find, train and motivate the next generation of experts to contribute to the field of safeguards, experts that have literacy in these new technologies.

The third overarching theme is the **duality of new technologies**. 3D printing for example is transforming access to components used for the nuclear fuel cycle. It is thereby potentially opening up additional acquisition paths. Similarly, development and knowledge of laser technology in general is accelerating and is expected to have an impact in the nuclear field as well. The department realised that participants were not immediately able to identify indicators, i.e. signals to look for. In addition, the international community has to clarify the legal frameworks when it comes to additive manufacturing or laser technologies.

Fourth were the topic of **nuclear technologies** and questions of: how soon, how different, how challenging will trends in nuclear technologies be for the Department of Safeguards. Mobile reactors, for example, are already being deployed now. There was also a discussion on the question of the implementation of safeguards to international commercial TNPP projects. The question was not so much about the technology, but rather the operating model for safeguards with questions of liability, oversight and access. On the upcoming new research designs the need for early safeguards by design was highlighted several times.

The workshop was part of the Department's strategic planning efforts as it was designed to inform and start the process of updating its next research and development plan. The key takeaways will be consolidated and priority areas for action that require R&D be identified. As a next step, the Department and the Member States Support Programmes will be consulted to identify actions within the priority areas that require external support. In addition, select outcomes of the workshop will further be reflected in the updated strategic plan of the Department, as well as, the next Safeguards Symposium in 2018.

DEMONSTRATIONS

The workshop sessions were complemented by an active series of live demonstrations to provide some examples of how the Department applies technology in its work.

Instrument Records Integrator for Safeguards (IRIS)

The organization and reporting of visual observation, instrument data, and notes collected by SG inspectors during in-field activities is a non-standard and time-consuming process – but only when performed manually. The IRIS software which was demonstrated during the workshop streamlines the process, makes it visual and interactive, and capitalizes on the inspector's geo-location information when it is available. In particular, IRIS supports an inertial tracking sensor to achieve accurate results when GPS is not available.

IAEA 3D-Printing Capabilities

3D printing, also known as additive manufacturing, is a process by which physical objects are created by depositing materials in layers based on a digital model. All 3D printing processes require software, hardware, and materials to work together. 3D printing technology can be used to create everything from prototypes and simple parts to highly technical final products such as airplane parts, eco-friendly buildings, life-saving medical implants, and even artificial organs using layers of human cells. During the workshop a demonstration of how 3D printing is being used in Safeguards was provided.

Results of Technology Challenge on Digital Image Processing

When spent fuel is stored under water, it emits a characteristic blue glow with strong ultraviolet (UV) spectral components called the Cerenkov effect. IAEA inspectors are able to verify the spent fuel declarations of the operator using a Cerenkov Viewing Device, which magnifies the image, filters out the visible light and intensifies the UV light. While this appears simple, in practice the images seen by the inspector are noisy, feeble and depend on the vertical alignment. The IAEA recently organized a crowdsourcing event to improve the quality of images collected with the Cerenkov Viewing Device. More than 2 million people visited the web sites, and 130 of them registered to propose image processing algorithms. A demo was presented during the workshop on the most interesting results that were generated.

Surface Hub

The Surface Hub is an interactive whiteboard that brings people together to collaborate and communicate to create shared understanding and generate ideas. In line with one theme of the Emerging Technology Workshop, i.e. "to generate insight from data", the Surface Hub is a tool for teams to come together, visualize and interact with their data. During the workshop, demos were held to show these features. The first one was on Sand Dance, a web based application that enables teams to more easily explore, identify, and communicate insights about data. The second demo was on surface hub as a collaborative device. Colleagues showcased collaboration with a remote team around satellite imagery data.

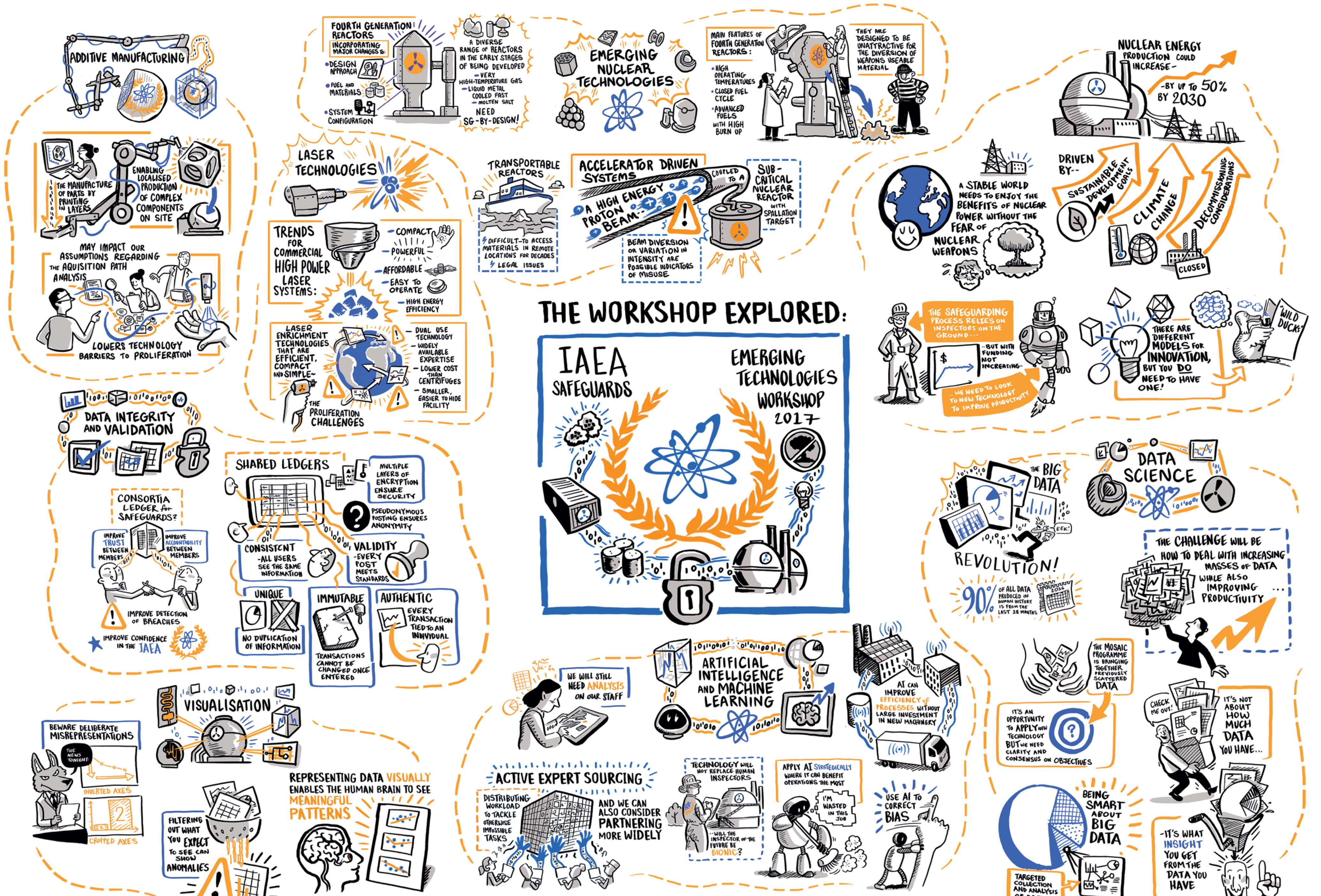
ANNEX 1:
Workshop agenda

Monday, 13 February 2017	
09:30-11:00	**I. OPENING SESSION**, Room M2 **Chair**: Ms. Therese Renis, Director, Division of Concepts and Planning, Department of Safeguards, IAEA **Welcoming Remarks**: Mr. Tero Varjoranta, Deputy Director General and Head of the Department of Safeguards, IAEA **Keynotes**: • Mr. Mikhail Chudakov, Deputy Director General and Head of Department of Nuclear Energy, IAEA • Mr. Bernard Meyerson, Chair of the Future of Advanced Materials Council, World Economic Forum and Chief Innovation Officer, IBM **Discussion**
11:00-11:30	**BREAK** **DEMO**: Microsoft Surface Hub
11:30-13:00	**II. BUSINESS INTELLIGENCE**, Room M2 **Facilitator**: Mr. John Patten, Section Head, Performance and Quality Section, Department of Safeguards, IAEA **Speaker**: • Mr. Bernard Marr, Founder and CEO, Advanced Performance Institute **Implications for Safeguards – Discussion**
13:00-14:30	**BREAK**
14:30-16:00	**III. ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING**, Room M2 **Facilitator**: Mr. Scott Miller, Section Head, Office for Information and Communication Systems, Department of Safeguards, IAEA **Speakers**: • Mr. Andreas Ebert, Regional Technology Officer for Western Europe, Microsoft • Ms. Jane Zavalishina, Chief Executive Officer, Yandex Data Factory **Implications for Safeguards – Discussion**
16:00-16:30	**BREAK** **DEMO**: Microsoft Surface Hub
16:30-18:00	**PANEL DISCUSSION**, Room M2 **Moderator**: Ms. Laura Rockwood, Executive Director, The Vienna Center for Disarmament and Non-Proliferation **Participants**: • Mr. Bernard Meyerson, Chair of the Future of Advanced Materials Council, World Economic Forum and Chief Innovation Officer, IBM • Mr. Bernard Marr, Founder and CEO, Advanced Performance Institute • Mr. Andreas Ebert, Regional Technology Officer for Western Europe, Microsoft • Ms. Jane Zavalishina, Chief Executive Officer, Yandex Data Factory • Mr. John Coyne, Director, Office for Information and Communication Systems, Department of Safeguards, IAEA

Tuesday, 14 February 2017	
09:00-10:30	**IV. VISUALIZATION OF DATA**, Room M2 **Facilitator**: Ms. Claude Norman, Section Head, Division of Information Management, Department of Safeguards, IAEA **Speaker**: • Mr. Robert Kosara, Senior Research Scientist, Tableau Software • Ms. Cristina Versino, Data Analyst, Joint Research Centre, European Commission **Implications for Safeguards – Discussion**
10:30-11:00	**BREAK** **DEMO**: IRIS system (Instrument Records Integrator for Safeguards)
11:00-12:30	**V. NEW MEDIA, NEW METHODS**, Room M2 **Facilitator**: Mr. Michael Barletta, Senior Safeguards Analyst, Division of Information Management, Department of Safeguards, IAEA **Speakers**: • Ms. Melissa Hanham, Senior Research Associate, Middlebury Institute of International Studies at Monterey • Mr. Joshua Rutkowski, Staff Researcher, Institute of Energy and Climate Research, Forschungszentrum Jülich **Implications for Safeguards – Discussion**
12:30-14:00	**BREAK** **DEMO:** Results of Technology Challenge on Digital Image Processing for the ICVD
14:00-15:30	**VI. NOISE REDUCTION AND DATA VALIDATION**, Room M2 **Facilitator**: Mr. Brian Aubert, Section Head, Division of Information Management, Department of Safeguards, IAEA **Speakers**: • Ms. Sarah Frazar, Nonproliferation Specialist, Pacific Northwest National Laboratory **Implications for Safeguards – Discussion**
15:30-16:00	**BREAK** **DEMO**: Microsoft Surface Hub
16:00-17:30	**PANEL DISCUSSION**, Room M2 **Moderator**: Mr. Frederik Dahl, Section Head, Multimedia and Public Outreach Section, IAEA **Participants**: • Mr. Robert Kosara, Research Scientist, Tableau Research • Ms. Cristina Versino, Joint Research Centre, European Commission • Ms. Melissa Hanham, Senior Research Associate, Middlebury Institute of International Studies at Monterey • Mr. Joshua Rutkowski, Staff Researcher, Institute of Energy and Climate Research, Forschungszentrum Jülich • Ms. Sarah Frazar, Nonproliferation Specialist, Pacific Northwest National Laboratory • Mr. Jacques Baute, Director, Division of Information Management, Department of Safeguards, IAEA

Wednesday, 15 February 2017	
09:00-10:30	**VII. ADDITIVE MANUFACTURING (E.G. 3D-PRINTING)**, Room M2 **Facilitator**: Mr. Christopher Gazze, Section Head, Division of Operations A, Department of Safeguards, IAEA **Speakers**: • Mr. Marco Fey, Research Associate, Peace Research Institute Frankfurt • Mr. Grant Christopher, Research Fellow, International Centre for Security Analysis, King's College, London **Implications for Safeguards – Discussion**
10:30-11:00	**BREAK** **DEMO**: Additive Manufacturing for the IAEA Safeguards Systems
11:00-12:30	**VIII. LASER TECHNOLOGIES**, Room M2 **Facilitator**: Ms. Stephanie Poirier, Team Leader, Division of Technical and Scientific Resources, Department of Safeguards, IAEA **Speakers**: • Mr. Andreas Otto, Professor, Institute for Production Engineering and Laser Technology, TU Vienna • Mr. Ryan Snyder, Visiting Research Fellow, Arms Control Association **Implications for Safeguards – Discussion**
12:30-14:00	**BREAK**
14:00-15:00	**IX. TRENDS IN NUCLEAR TECHNOLOGIES**, Room M2 **Facilitator**: Mr. David Peranteau, Team Leader, Division of Concepts and Planning, Department of Safeguards, IAEA **Speaker**: • Mr. Mark Hibbs, Senior Fellow, Nuclear Policy Program, Carnegie Endowment for International Peace **Implications for Safeguards – Discussion**
15:00-15:30	**BREAK** **DEMO**: Additive Manufacturing for the IAEA Safeguards Systems
15:30-17:30	**X. TRANSPORTABLE NUCLEAR POWER PLANTS, INCLUDING FLOATING AND SEABED-BASED SMALL MODULAR REACTORS**, Room M2 **Facilitator**: Mr. Brian Boyer, Safeguards Analyst, Division of Concepts and Planning, Department of Safeguards, IAEA **Speakers**: • Mr. M. Hadid Subki, Nuclear Engineer, Department of Nuclear Energy, IAEA • Mr. Vladimir Galitskikh, Head of Bureau, and Ms. Nadezhda Salnikova, Specialist, OKBM Afrikantov Enterprise • Mr. Bryan van der Ende, Physicist, Research and Development, Canadian Nuclear Laboratories Ltd. **Implications for Safeguards – Discussion**

Thursday, 16 February 2017	
09:00-10:30	**XI. GENERATION IV REACTORS AND RELATED NUCLEAR FUEL CYCLES**, Room M5 **Introductory Remarks**: Mr. Stefano Monti, Section Head, Division of Nuclear Power, IAEA
10:30-10:45	**XI (ctd). VERY HIGH-TEMPERATURE GAS REACTORS**, Room M5 **Facilitator**: Mr. Ghislain Berthelot, Nuclear Safeguards Inspector, Division of Operations A, Department of Safeguards, IAEA **Speakers**: • Mr. Frederik Reitsma, Nuclear Engineer, Department of Nuclear Energy, IAEA • Mr. Li Fu, Deputy Chief Engineer, Institute of Nuclear and New Energy Technology, China **Implications for Safeguards – Discussion**
10:45-11:15	**BREAK** **DEMO**: Microsoft Surface Hub
11:15-12:30	**XI (ctd). LIQUID METAL COOLED FAST REACTORS**, Room M5 **Facilitator**: Ms. Sandrine Cormon, Nuclear Safeguards Inspector, Division of Operations C, Department of Safeguards, IAEA **Speakers**: • Mr. David Wootan, Nuclear Engineer, Pacific Northwest National Laboratory • Mr. Frédéric Nguyen, Physicist, The French Alternative Energies and Atomic Energy Commission (CEA) **Implications for Safeguards – Discussion**
12:30-14:00	**BREAK**
14:00-15:15	**XI (ctd). MOLTEN SALT REACTORS**, Room M5 **Facilitator**: Mr. Enobot Agboraw, Senior Inspector for Implementation Coordination, Division of Operations C, Department of Safeguards, IAEA **Speaker**: • Mr. Andrew Worrall, Fuel Cycle Technology R&D Leader, Oak Ridge National Laboratory **Implications for Safeguards – Discussion**
15:15-15:30	**BREAK** **DEMO**: Microsoft Surface Hub
15:30-17:00	**XII. TRANSMUTATION INCLUDING ACCELERATOR DRIVEN SYSTEMS**, Room M5 **Facilitator**: Mr. Sébastien Richet, Safeguards Information Analyst (Nuclear Material Accounting), Division of Information Management, Department of Safeguards, IAEA **Speaker**: • Mr. Hamid Aït Abderrahim, Deputy Director-General International Relations and Director MYRRHA project – SCK•CEN • Mr. Per Andersson, Deputy Research Director, Swedish Defence Research Agency **Implications for Safeguards – discussion**
17:00-17:30	**XIII. CLOSING**, Room M5 **Closing Remarks**: Ms. Therese Renis, Director, Division of Concepts and Planning, Department of Safeguards, IAEA



THE CONTENTS EXPRESSED ON THIS POSTER DO NOT REFLECT THE VIEWS OF THE IAEA OR ITS MEMBER STATES; THEY WERE QUESTIONS RAISED BY WORKSHOP SPEAKERS AND PARTICIPANTS.

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