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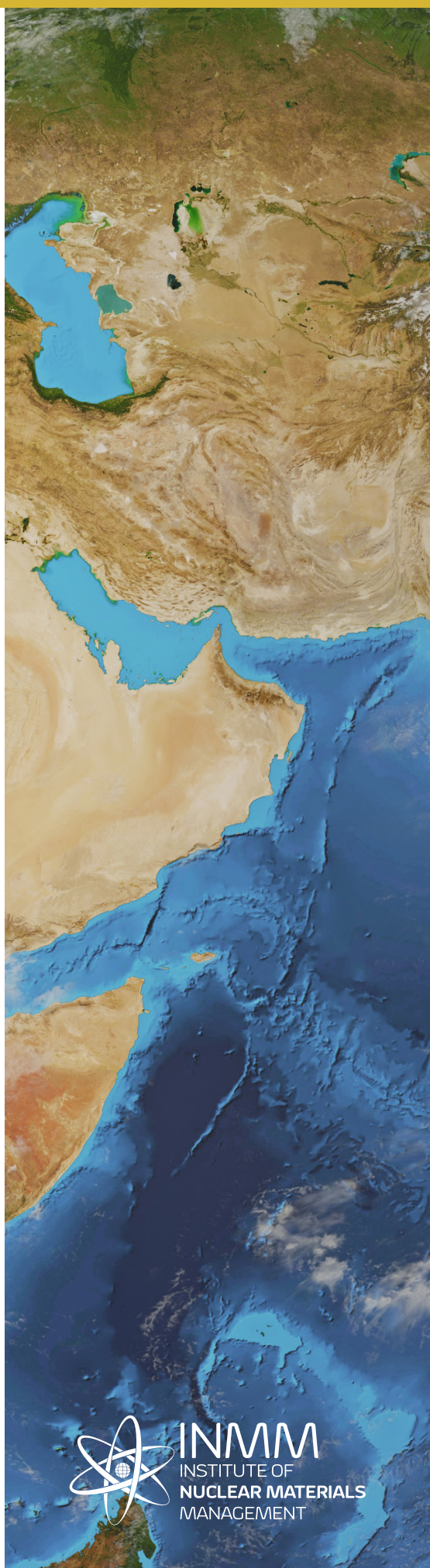

JNMM Journal of Nuclear Materials Management

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Mission Statement

The Institute of Nuclear Materials Management is dedicated to the safe, secure and effective stewardship of nuclear materials and related technologies through the advancement of scientific knowledge, technical skills, policy dialogue, professional capabilities, and best practices.

INMM INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

President's Message

By Corey Hinderstein
INMM President

2018 is an historic year for the nuclear materials management profession. This year marks the 50th anniversary of the opening for signature of the Nuclear Nonproliferation Treaty and, possibly more important, the 60th anniversary of the founding of the Institute of Nuclear Materials Management (INMM). Over the last 60 years, INMM has grown from a handful of American men working on material control and accountability (MC&A) to a diverse, international community that represents the breadth of the nuclear materials management profession. We have nuclear engineers and political scientists; data analysts and transportation logisticians; policy makers and technical innovators. We have chapters across the world, including our student chapters trying to foster the next generation of INMM leaders.

INMM has not ended its evolution. We are looking to foster more diversity in our membership and our technical program. Time after time, studies have shown that diversity increases positive organizational outcomes, so building a diverse membership is not just the right thing to do but it is the smart thing to do.

I would like INMM to end its "diamond anniversary" year stronger and ready to serve the community we represent. In part, that strength will be fueled by our new association management partner, Association Headquarters (AH). AH took over on October 1, 2017 and is helping INMM realize its strategic vision while managing day-to-day operations. Together, we have tried to make the transition as seamless as possible to members and participants in INMM activities. We are still working out the kinks, but I am grateful for AH's professionalism and energy.

The celebration will not end with this year's 60th Birthday – 2019 will mark INMM's 60th annual meeting, and we plan to make it a memorable one. Although we will be back in the desert (come on, it's tradition!) the Technical Program Committee and Executive Committee will make it worth your trip. So while I know all of you have July 22-26, 2018 circled and underlined for the 59th Annual Meeting in Baltimore, don't forget to come back in 2019 to celebrate another INMM milestone!

Corey Hinderstein

PS- If you would like additional insight into INMM's history, please visit https://www.inmm.org/About/History to read about the early days.

The 58th Annual Meeting

By Markku Koskelo
JNMM Technical Editor

As in the past fall Issues, this issue focuses on the INMM Annual Meeting held this past July in Indian Wells, California, USA. See Teressa McKinney's summary of the Annual Meeting for further details.

As has been our tradition for this issue, we have included the transcript of the talks made by our three plenary speakers, Stephanie Cooke, editor, Nuclear Intelligence Weekly, Washington, D.C.; Ambassador Laura Holgate; and Dr. Stephan Lechner, director of Euratom Safeguards, European Commission, Directorate General for Energy, Luxembourg. Each of the talks offered a different viewpoint on "Nuclear Issues Impacting Global Security".

The article on the plenary speeches is followed by an article on the traditional JNMM Roundtable interview of the plenary speakers. The transcript of the Roundtable includes the questions posed by the INMM leadership to the plenary speakers and offers additional candid insight from them on the intersection of nuclear science, technology, and policy with global security.

We have also included two contributed papers related to Japan in this issue. The first one looks at the efforts taken in Japan since the Fukushima nuclear accident in 2011 to educate a new generation of global professionals who are able to tackle globally and cooperatively key challenges such as large-scale nuclear disasters, nuclear terrorism, and nuclear proliferation. The second paper looks at the current status of Japan's commitment of not possessing excessive inventories of plutonium and how that intersects with promoting a comprehensive nuclear fuel-cycle policy and stringent management of plutonium.

In the past, this issue has also included the student paper winners from the Annual Meeting. We intend to publish these papers in a future issue after the papers have been peer reviewed. The peer review takes time and we want to give the students time to address the comments they have received from the reviewers rather than rushing the papers to publication. See the names of the winning authors and the titles of their papers in Teressa McKinney's summary of the Annual Meeting.

Book Review Editor Mark Maiello provides us a comprehensive review of the book, *The Neutron's Long Shadow* by Martin Miller. In this book the author takes readers on a photographic journey of both facilities using U.S. Department of Energy (DOE) archival photos and his own photographs on the legacy of the of the nuclear bomb-making materials. Neutron, the soul of the fission process, does indeed cast a long shadow. In 16,000 years, assuming it is not used, nearly 99.90 percent of the U-235 and about 66 percent of the plutonium produced will still exist. A book well worth looking into.

In his column, "Taking the Long View in a Time of Great Uncertainty— Living in Interesting Times", Jack Jekowski, Industry News Editor and chair of the INMM Strategic Planning Committee, gives us a connection between the daily work of many of the INMM members and the news headlines. It continues to point out how very important the work we all do is.

And last but not least, I would like to offer my sincere thanks and appreciation to Patricia Sullivan, who has stepped down as the Managing Editor of the JNMM in connection with the INMM changing its association management partner from Kellen to Association Headquarters (AH). Patricia taught me how to be a technical editor, and how to organize the review process and a large number of other things that I had never thought of as being part of the job. I will miss having her as my guidance counselor and conscience. I know I can make the transition to the new management company much smoother largely due to the experience I have had with her.

Should you have any comments or questions, feel free to contact me.

JNMM Technical Editor Markku Koskelo can be reached at mkoskelo@aquilagroup.com

Report of the 58th INMM Annual Meeting

Indian Wells, California, USA, July 16–20, 2017

Teressa McKinney, Chair, INMM Technical Program Committee

We are already diligently working on details for the 2018 Annual Meeting, but I hope you had the opportunity to join us at this year's Annual Meeting, which was held at the Renaissance Indian Wells Resort, Indian Wells, California, on July 16–20, 2017. The weather proved to be on target for July in the desert: a mere 106-plus degrees every day, but after all, it's a dry heat!

Kellen staff worked behind the scenes to ensure we had another successful Annual Meeting. I extend my appreciation to Amy Lydic, Sandra Elery, Lyn Maddox, and Patricia Sullivan. Without their hard work, we would not have experienced such a successful event.

The Executive Committee met on Saturday before the Annual Meeting to discuss details that occurred throughout the past year. Sunday was a busy day, too, with many of the committees organizing meetings before the start of the Annual Meeting. All the technical divisions met on Sunday afternoon before the President's Reception. The President's Reception provided an opportunity for all participants to have a meet and greet with our vendors and sponsors. We sincerely appreciate all the vendors and sponsors who participated throughout the week.

Monday morning began with INMM award presentations before the opening plenary speakers. The awardees, all pictured with INMM president Corey Hinderstein, were:

- 2017 INMM Early Career Award: Andreas Enqvist Photo #1
- 2017 Edway R. Johnson Meritorious Service Award: Nancy Jo Nicholas Photo #2 and D. L. Whaley photo #3

Photo 1. Andreas Enqvist

Photo 2. Nancy Jo Nicholas

Photo 3. Dr. Dick Donovan accepting award for D.L. Whaley

Photo 4. Obie Amacker

Photo 5. Martyn Swinhoe

- 2017 Vincent J. DeVito Distinguished Service Award: Obie Amacker photo #4 and Martyn Swinhoe photo #5

Details regarding each of the awards can be found on the INMM's website. Please take a few moments to read about the recipients' outstanding accomplishments. Congratulations to all!

The opening plenary speakers were Stephanie Cooke, editor, *Nuclear Intelligence Weekly*, Washington, D.C.; Ambassador Laura Holgate; and Stephan Lechner, director of Euratom Safeguards, European Commission, Directorate General for Energy, Luxembourg. They gave an informative session titled "Nuclear Issues Impacting Global Security." Keep providing great suggestions for our INMM Annual Meeting opening plenary speakers. We take all suggestions into consideration. Thanks to Steve Mladineo, Larry Satkowiak, and Corey Hinderstein for helping to organize this year's plenary session. A transcript of the opening plenary session and the roundtable discussion with our plenary speakers are published in this issue of *JNMM*.

The technical sessions began immediately following the opening plenary. The

full program included 275 oral presentations and 12 posters during 50 concurrent sessions that included seven panel discussions. We had more than 430 in attendance from 21 countries. I want to thank the Technical Program Committee for pulling together an exceptional technical program. We received many positive comments throughout the week. Thank you to the technical division chairs for your hard work on the technical program:

- Morris Hassler, Facility Operations
- Michael Whitaker, International Safeguards
- Tom Grice, Materials Control and Accountability
- Mona Dreicer, Nonproliferation and Arms Control
- Tom Bonner, Nuclear Security and Physical Protection
- Jeff England, Packaging, Transportation, and Disposition

Tuesday began with papers, followed by the poster session later in the morning. We closed the day with the annual business meeting. The Annual Report to Membership can be found on INMM's website under the INMM Resources tab. I would encourage you to look at the Annual Report, which has a lot of useful information, as well as interesting updates on our chapters.

Closing Plenary

On Thursday, technical sessions were conducted throughout the morning, and in the afternoon we featured our closing plenary session: Using Open Source Information to Identify Nuclear-Related Activities. Bryan Lee, director of the Eurasia Nonproliferation Program at the James Martin Center for Nonproliferation Studies, Middlebury Institute of International Studies at Monterey, Vermont, along with two of his Middlebury students, Ryan Genzoli and Tracy Lee Lyon, gave an information session about utilizing open source information. The session was very well attended, and there were many questions for the team of experts that presented.

After the closing plenary session, INMM President Corey Hinderstein and Vice President Cary Crawford announced the J.D. Williams Student Paper Award winners:

First Place

Nuclear Security and Physical Protection—Paper #255, "Identification of Mixed Sources with an Organic Scintillator-based Radiation Portal Monitor," by Marc Paff from the University of Michigan.

Second Place

Nuclear Security and Physical Protection—Paper #405, "Reexamining the State of Radiological Source Security in Russia," by Alex Bednarek from George Washington University, Washington, DC.

First Place Poster

Poster #380, "Phonon Dispersion Relations of bcc U and Mo from MD Simulations," by Andrea Saltos from the University of Missouri.

Division Winners

Education and Training—Paper #369, "The Benefits of Being Bad: Advancing Nuclear Security Education Through Adversary Based Exercises," by Michael Shattan from the University of Tennessee.

International Safeguards—Paper #207, "Measurement of the U^{235} Induced Fission Gamma-ray Spectrum as an Active Non-destructive Assay of Fresh Fuel," by Sarah Sarnoski from Pennsylvania State University.

Nonproliferation and Arms Control—Paper #393, "Development of Neutron Energy Spectrum Based Nuclear Forensics Attribution Methodology Using Trace Nuclide Ratios in Weapons-grade Plutonium," by Jeremy Osborn from Texas A&M University.

Photo 6. Pictured left to right, INMM Vice President Cary Crawford; INMM Technical Program Chair Teressa McKinney; Tracy Lee Lyon, closing plenary student presenter from the Middlebury Institute of International Studies at Monterey; INMM President Corey Hinderstein; Bryan Lee, Director of the Eurasian Nonproliferation Program at the James Martin Center for Nonproliferation Studies at the Middlebury Institute of International Studies at Monterey. and Ryan Genzoli, another Middlebury student who also spoke in the closing plenary presentation.

Materials Control and Accountability—Paper #392, "Variations in AmLi Source Spectra and Their Estimation, Measured Ring Ratios," by Robert Weinmann-Smith from the University of Florida.

Special thanks to Jim André and his team for coordinating this year's Student Paper competition. These volunteers evaluated presentations and posters at the Annual Meeting, along with the many technical readers/graders from the technical divisions who did the initial paper scoring before the Annual Meeting. This is a great opportunity to get involved with INMM. Please contact Jim if you are interested in volunteering. I'm sure he would welcome your participation.

We appreciate your taking the time to provide comments to us about what you liked or disliked about the Annual Meeting. We do take the time to read each of these, and I hope you noticed that we incorporated a few of those suggestions into the Annual Meeting. I look forward to seeing all of you at the 59th Annual Meeting at the Baltimore Marriott Waterfront, Baltimore,

Opening Plenary Session
July 2017

Corey Hinderstein:
I would like to introduce our distinguished speakers for this morning's plenary, who will help frame a discussion of the broader technical, commercial, and international policy issues which will continue to affect the work that we all pursue in the nuclear materials management profession. I'll introduce each of them briefly. They'll join me on the stage, and then we'll have remarks from each one, and then a discussion which will include questions and comments from the audience. So, I encourage you, as our speakers are presenting, to start thinking about your questions and comments, because I will turn to you.

Our first presenter is **Stephanie Cooke**. Stephanie is the editor of *Nuclear Intelligence Weekly*, a part of the Global Energy Intelligence Group with headquarters in London and New York. She is also the author of *In Mortal Hands: A Cautionary History of the Nuclear Age*, and she's based in Washington, DC. Stephanie began her reporting career with the Associated Press. During the 1980s, she began covering the nuclear industry as a reporter, and then she became an editor for *Nucleonics Week*, *Nuclear Fuel*, and *Inside NRC*. So, Stephanie has been following and reporting on and investigating and learning about the nuclear industry for as long as many of us in the room, and we really look forward to her insight.

Ambassador Laura Holgate served as U.S. representative to the Vienna office of the United Nations and International Atomic Energy Agency from July 2016 until January 20, 2017. The United States Mission to international organizations in Vienna works with seven major international organizations of the United Nations system based in Vienna. They include the IAEA [International Atomic Energy Agency], the Preparatory Commission of the CTBTO [Comprehensive Test Ban Treaty Organization] and the Nuclear Suppliers Group. But, also, she had to work on issues of space and crime and all sorts of other fascinating issues.

So, in addition to working on this vast substantive portfolio, Laura also worked tirelessly to promote gender balance in the staff and programming of the Vienna-based international organizations. And part of her legacy is that just recently a gender champions program was launched within the organizations in Vienna, and I know that many of us that work with the organizations there know that there's a lot of pride that they're taking that initiative.

Ambassador Holgate was previously the special assistant to the president and senior director for WMD terrorism and threat reduction at the National Security Council, where she addressed not just nuclear threats but biological and chemical threats. And she was the U.S. Sherpa to the Nuclear Security Summit—all four of them, 2010, '12, '14, and '16—and co-led the President's Global Health Security Agenda.

Before her official career, Ambassador Holgate also held positions at the Nuclear Threat Initiative, and then before that she had come out of the Department of Energy and the U.S. Department of Defense. Ambassador Holgate currently is a member of the Strategic Advisory Group to Oak Ridge National Laboratory.

Finally, **Dr. Stephan Lechner,** based in Luxemburg, is the director of Euratom Safeguards at the European Commission's Directorate General for Energy. Before his appointment to this position in 2016, Dr. Lechner was director of the Institute for the Protection and the Security of the Citizen at the European Commission's Joint Research Centre in Ispra, and that was a position he held for more than eight years. Before this role, he held various management positions and spent more than 18 years in the high-tech sector in private industry and at large international enterprises and in the telecom industry. He managed international expert teams in Germany and China and has more than 25 years of experience in collaborative European projects. Dr. Lechner holds a degree in mathematics and computer sciences, and his doctorate is in cryptography.

Please join me in welcoming our distinguished speakers to the stage, and we will begin in the reverse order that I introduced, so our first comments will be from Stephan Lechner. Thank you.

Stephan Lechner:
Ladies and gentlemen, distinguished guests, President Hinderstein. It's a great honor for me to speak here as representative of the European Commission at the Institute for Nuclear Materials Management's annual conference. Why is that? First, I chose the International Collaboration here very well, and I'm pleased to participate. I'm pleased to also bring a

European angle to the discussion. Second, I appreciate the opportunity to also talk from a Euratom perspective, because in the area of safeguards, we are very operationally responsible on the basis of an international treaty [of] 28 member states. We sometimes fall back a little bit behind in PR behind the International Atomic Energy Agency, and it's kind of not that visible, but there is also an operational European contribution there that is covering quite a large amount of nuclear materials. So, thanks for the opportunity.

The perspective of Euratom this year is a very special year. It has grown for 60 years. So, the Euratom Treaty was established on March 25, 1957. It was exactly 60 years, and there has been an overshadowing again of the Euratom Treaty by the peril signature of the Treaty of the European Union at the very beginning in Rome [on] the very same date. So again, they could not even celebrate that accordingly to the nuclear community, because there was a big, big celebration for the Treaty of the European Union.

So, this is kind of the fate that nuclear and Europe sometimes has, so it's pushed a little bit into the background, and the opportunity here to bring it a little bit to the surface again is highly appreciated.

In 60 years of Euratom, we have received a lot. We have achieved a lot. We have achieved so much that at the end of the day, the nuclear energy and the energy mix of European member states is about a third of the total. But it is not that much acknowledged anymore, because everybody is running for renewables. The European Commission made a strong statement for the illustrative program on nuclear technologies and financing in the future in 2015. And in 2016, only they have issued the whole program on energy, renewable energies. So, they have thought and communicated on nuclear first, which I also appreciated.

Sixty years of nuclear energy have brought us into a situation where it is up to the European member states to choose their mix. And we are currently experiencing a world that has changed from 60 years ago. We have way more nuclear materials around and way more nuclear materials under Euratom safeguards. Euratom safeguards has grown, and it's only a small organization executed by the European Commission as an operational arm. We've got some 130, 135 nuclear inspectors, Euratom inspectors, that are traveling Europe. We have done more than 1,167 on-site inspections, and we have spent more than 4,500 person-days on inspections. The total budget for this is only 20 to 25 million euros, so it might be 25 to 30 million dollars. It's not such a lot.

We have verified, not physically, everything, but also on the continuance surveillance, 99.99% of all nuclear materials in Europe. So, this is quite a big number, and that makes it very difficult to set even better targets than 99.99%. Going to full 100% is never possible.

The world has also changed to adversity, not only a big step ahead for nuclear energy but also a big risk ahead for international terrorism. So, we have seen that in France in Paris, in Belgium, and Germany. And we have also seen potential targets of international terrorism also include nuclear installations. There is little intelligence about that out in the open, but we need to stay alert, and this is why in Europe the European Union is driving an agenda for a European security union, looking into countering threats of international terrorism, countering the currently developing situation.

The situation has changed to the better, catching on with nuclear energy to the verse, and will continue changing. That means for the next years, the operational branch—and this is why I'm talking to the technology community here—has well defined four major priorities where we need technical support. They might not be … those everybody here has in mind, because not all of them are really directly related to nuclear physics.

The first priority is the on-site laboratories that they're running in the UK in Sellafield, and in La Hague in France, where the colleagues of the joint research—and they really are doing a terrific job in supporting us. And a very efficient structure is being built operationally and doing the best for nuclear safeguards. These need to be maintained for the future, and we need to have a continuation of these efficient efforts, and this is baseline operations.

The second thing that goes more into research is new technologies. So, if they're talking about final geological repositories, or perhaps also only about caster loadings, tomography might be a future option to be deployed. Everybody is working on—many people are working on it, but actually, we don't have it now in operational use. And we would really look at these new instruments that would help us do the job in new types of installations.

The third idea that we have looking into the future and being aware of continuous change is a bit of a surprise. It might be looking into the availability and deployability of commercial off-the-shelf technologies. Because in some expert technologies, especially in video surveillance, they're bound to technologies that have been around for 15 years, perhaps even longer. And we are bound to mostly a single supplier of these technologies. So, where is the continuity, where is the risk management should an enterprise, that is providing all of these technologies

or many of these technologies, fail? We might look into also commercial off-the-shelf that has developed in modern technology and digital technologies and smart sensors and miniaturized sensors, which is a lot in the last five to 10 years. But we always try to incrementally improve what we already had, instead of just looking into a side lane where other things are coming along at high speed. I don't say we will have any kind of replacement for existing technologies by commercial off-the-shelf tomorrow, but thinking at five to 10 years, it's worthwhile having a good substantial discussion what is possible and perhaps also what's not possible.

Actually, I discussed [this] yesterday quite a bit, and I found that only a few people are looking into these channels already—people from our perspective to broaden the supplier base in the long run. Therefore, I would encourage the technology community to also give it a thought.

Finally, the fourth priority that we've identified, there's a final one, is data. Because before I deploy a large series of new instruments, and I'm getting an incremental progress in the field, I could also think about deploying [a] data analytics engine on all the different 2 million records that I'm receiving per year in Euratom. And therefore, getting consistency checks and outlier detection and statistical analytics better deployed in the back office—where we got the full control over the data, instead of in the field where the nuclear operators and the day-to-day operations are a little more tedious to address.

So, these four things are a combination of the existing and the new. And this is what is driving us about when considering what the needs [are] in the operational Euratom services.

When we think about the past, when we think about what we've seen in the terror attacks and the development of nuclear energy, then we are so busy and concentrating on what is currently going on, that they're being taken by surprise by effects that we didn't have really on the charts. Brexit. So, all of a sudden, for the very first time in history, we have one member state leaving the Euratom Treaty. It was quite clear to us that the UK was intending on running a referendum of leaving the European Union. But then there was no idea—we have an independent legal basis, a Euratom Treaty, next to the European Union. This is not all tied together. And in the beginning, it was not so clear if the UK also wanted to exit Euratom. So, the story is continuing. We have little information on this now, and the next negotiations will start very soon. But actually, this was a development that nobody really had fully on the radar—perhaps not even the Brexit promoters.

At the end of the speech here, I would like to conclude [by] thanking you for the opportunity to express also some European thoughts here. I would also like to challenge you to pick up on not the standard incremental development, but ongoing new pathways to assuring nuclear safeguards and nuclear security for the future. Thank you very much.

Laura Holgate:

Good morning. I'd like to offer thanks to President Hinderstein for the leadership and vision that you have offered for INMM in your time serving on the leadership team. And also to Cary [Crawford] and Larry [Satkowiak], for the hard work that I know goes into these meetings. I just did the math this morning—I was reminded that the first time I came to INMM was in 1999 to give a keynote address. And in the 18 years that have passed since then, I think I've had the good fortune to attend over a dozen of these such meetings. So, it's a thrill to be back with this group. I always learn, and as Corey said, I am renewed in many ways by the knowledge and the contacts that it's our good fortune to have a chance to make here at this annual meeting.

This is my third keynote address, so obviously I'm glad to know that I occasionally bring worthy thoughts to you all, and hope that today is no exception.

2017 brings more change than continuity in the realm of nuclear security and nonproliferation. And many of these changes will have implications for the experts in this room and for the disciplines in countries that we represent.

Some of these trends were visible a year ago, and many of them stem from policies put forward by the new administration. But the manifestations of these trends have not always been straightforward. And I wanted to talk this morning about six key events or trends that will create new opportunities and challenges for the nuclear materials management community: the Nuclear Weapons Ban Treaty, the Iran deal, nuclear security after the summits, U.S./Russian relations, plutonium disposition, and advanced nuclear reactors.

Perhaps the biggest news this month is the arrival of the Nuclear Weapons Ban Treaty, negotiated over three months and approved by 122 countries, none of whom either have nuclear weapons, with the exception of North Korea, or have a nuclear alliance with another country. And there is much that can be said about the wisdom and efficacy of this treaty, and I won't go into that this morning. But one thing is clear: Neither the countries who negotiated the treaty nor those who chose not to participate are seriously developing

a meaningful verification system for nuclear disarmament.

Some think tanks and "track 1.5" efforts are taking early steps in this direction—for example, Carnegie Endowment [for International Peace's] Firewalls project and the International Partnership for Nonproliferation and Disarmament Verification. But Carnegie's George Perkovich asks several critical questions about the verification of a nuclear weapons ban: "By what means would the world be reassured that a state was not secretly retaining weapons-usable stockpiles? What would be done with nuclear weapons research and development facilities' capabilities and trained personnel? Would researchers in facilities adept at nuclear weapons design and experimentation be monitored including universities—and if so, how? How would the management and safeguarding of civilian fuel cycle facilities and activities need to be revised in order to bolster confidence that no one would cheat on a global disarmament regime?" These and other questions are obviously right at the heart of what this community works on, and how everyone feels about the Ban Treaty as it stands now.

The five nuclear weapons states recognized under the NPT have, in fact, committed to nuclear disarmament. And they, as well as the Ban Treaty advocates, have a responsibility therefore to engage seriously and in good faith with these kinds of questions and the related questions about the circumstances under which disarmament could be achievable. Many of you in this room have expertise and insights that could contribute to such an exercise.

The other major event this month is the two-year anniversary of the Iran deal. And today we expect the second certification by the Trump administration that Iran continues to comply with its commitments made under the joint comprehensive plan of action. This deal consisted of undertakings by Iran that went above and beyond standard safeguards agreements, in keeping with the need to reestablish its compliance status after two decades of cheating on their safeguards obligations under the NPT. The verification of these new types of commitments by the IAEA required the development of new types of inspections and new applications of technology.

In many cases, standard safeguards technologies were applied in new ways, such as tags and seals on materials, equipment, and facilities that were not normally covered by safeguards agreements. In other cases, new approaches such as testing carbon fiber or online monitoring of enrichment activities had to be developed. The degree to which U.S. expertise, particularly at the national laboratories, was relied on in both the negotiations and the implementation of this agreement is, I believe, not well-known, and perhaps that's for the better. But I think this community has much to be proud of in the design and implementation of the JCPOA's verifications methods. And you will certainly be called upon again to support U.S. policymakers and the IAEA as this deal moves forward.

I will be speaking tomorrow afternoon about how the JCPOA's concepts can be applied more broadly, and so I will invite you to join that session to hear more about that topic.

With the end of the Obama-era nuclear security summits last April, attention now turns to the five institutional action plans agreed by the leaders at that final summit. And to the Nuclear Security Contact Group of senior officials tasked with maintaining the momentum generated by the four summits on nuclear materials, countering nuclear smuggling, and preventing nuclear terrorism.

If the year-plus since the last summit is any indication, this will be very tough going. The first few tests of this momentum were not encouraging. First, the annual nuclear security resolution negotiated at last September's IAEA General Conference bore very little resemblance to the IAEA action plan agreed [to] by the leaders just months earlier. And the nuclear security ministerial held at the IAEA in December was also disappointing in the communiqué and in the lack of deliverables. The comprehensive review in New York of U.N. Security Council 1540 resulted in very little incorporation of concepts from the U.N. action plan agreed [to] at the final summit and no proposed updates to the original resolution. And, unfortunately, the contact group so far has proved to be a poor tool to transmit leader-level agreements at summits through the Sherpa community to diplomats on the ground in New York and Vienna.

So, some regrouping is in order. One good sign is that Canada has convened the contact group for a couple of dedicated meetings, which resulted in some concrete efforts regarding the IAEA budget negotiations and upcoming common events of interest and opportunities to push the action plans that were agreed [to] at the summit.

It is also possible that the adoption of the Ban Treaty serves as a relief valve for the incursion of the disarmament discussions into negotiations at the IAEA. The divisiveness created by advocates insisting on disarmament language that was unacceptable to many states wasted time in the negotiating room on a topic that is largely irrelevant to the IAEA's operations and mandate. I hope that having made

their point with the Ban Treaty, these advocates are ready to refocus on the technical work of the agency. If not, this impasse will risk creating the same gridlock in Vienna that has taken hold of the conference on disarmament in Geneva, and that will have much more severe impacts on the day-to-day real-world of work of the IAEA as well as the CTBTO.

That said, there remain multiple opportunities to show progress on nuclear security. One would be for countries inside and outside the summit process to signal their acceptance of INFCIRC 869, through which almost 40 countries have indicated their intent to incorporate the intent of IAEA nuclear security guidance into these national regulations, and to carry out other steps to enhance implementation of nuclear security at the national level. Many other gift baskets from the summit process have been translated into IAEA INFCIRCs and are available as such for any member state to join.

We also have the 2021 review conference for the convention on physical protection that was triggered by the entry into force of the 2005 amendment last year. The nuclear security centers of excellence and nuclear security support centers are also a venue in which the legacy of the summits can continue to be expanded and promoted.

And, finally, the increased threat in addressing the threats posed by activity radioactive sources creates the potential for a new wave of efforts to remove disused or underutilized cobalt … sources to replace them with safer and more effective technologies such as linear accelerators and to enhance security around high-activity sources that remain in use.

This annual meeting has been a bellwether in some ways of the level of U.S./Russian cooperation on nuclear materials issues. Let me just ask for a show of hands—who here is from Russia, is visiting us from Russia? I'm not seeing any hands. I was expecting at least one or two. So, my speech says, it seems significantly lower than in the heyday of U.S./Russian cooperation. But in fairness, this figure has been trending downward for some time. What's new is that the U.S./Russia relationship is in uncharted waters. Until there is clarity on the investigation of Russian attacks on the U.S. electoral process, this relationship is likely to remain at a high level of tension, and apparently without a functional U.S. policy consensus to guide us through this challenging time. It is extremely risky for the U.S. and Russia to be unable to engage in serious discussions of shared security concerns, whether on strategic stability and arms control or on preventing nuclear terrorism. Bilateral technical contacts are at a lower level than during the Cold War.

Fortunately, these tensions have not prevented the U.S. and Russia from working together well on the Iran deal or on the increasingly rare removals of HEU. from third countries. And the U.S. and Russia were united in their efforts to push back on the insertion of disarmament issues in the IAEA and in CTBTO fora. So, that makes it especially critical that we really have to find ways to work together. And this community has an opportunity to work within multilateral institutions to offer a way to maintain the person-to-person connections between U.S. and Russian experts through the work of multilateral institutions. And I really hope that these contacts can provide a future strengthened relationship for the U.S. and Russia over time.

I'll just finalize my comments with a couple of remarks on advanced reactors. Ms. Cooke will talk more about the industry developments, but I want to highlight one specific aspect on the maturation of various advanced or non-light water reactor designs. These efforts are largely driven by two goals: increased safety and decreased or at least more predictable costs. And these goals relate to two of the most obvious concerns relating to the existing reactor fleet or to challenges of new reactor designs.

My observation of these new designs is that they toss around the words "proliferation resistant," or worse, "proliferation proof," without really understanding what they mean. Now is the time to apply the concepts that the INMM community has developed and championed relating to safeguards by design and security by design to these new reactors, while they are still on paper. When combined with the concept of secure fuel cycles, these design criteria are much clearer and more achievable than some subjective notion of proliferation resistance.

And as a strong supporter of nuclear energy's contribution to clean energy and the opportunity that advanced reactors create to establish U.S. leadership in the global nuclear energy marketplace, I believe that the United States design teams should be incorporating and promoting security and safeguard ability as part of their value proposition and their comparative advantage over other designs.

So, these trends are timely reminders of the continued salience of the topics discussed by INMM at its annual meetings, its technical divisions, and within its membership. And I look forward to learning this week what new technical and policy developments are underway that will help us all contribute to a safer and more secure world. Thank you.

Stephanie Cooke:
Good morning. It's really great to be here, and I'd like to thank the Institute and Corey and Teressa for inviting me. As you've just heard, I'm a longtime observer of your industry, and this morning I want to give you an overview of what's going on in it and how and why I think it's changing.

When I started covering the industry for *Nucleonics Week* in 1980, things weren't going so well. It was two years after Three Mile Island and six years before Chernobyl. Reactor orders in the U.S. had dried up before Three Mile Island for other reasons, mainly high borrowing costs and a big drop in demand for electricity, something that is often overlooked.

Much later, in the late '90s, I decided to write a book about this history. And while I was researching the book, I started hearing about nuclear renaissance. I was really puzzled. Had I missed something? What had changed to breathe new life into this industry? A few years later, my book almost complete, in 2007 I was asked to help launch a new newsletter on nuclear—*Nuclear Intelligence Weekly*, to which I hope you all subscribe. Probably not, but maybe sometime later.

Back then, we were writing stories about a lot of new projects that were being planned, 30 or so in the United States. We broke the news of an $18.5 million federal loan guarantee program that was supposed to help these projects get off the ground. We wrote about the uranium market, which was still frothy then, with prices that had climbed to over $100 a pound. But as things turned out, only two projects got off the ground. Then Fukushima happened—or maybe not exactly in that order, but roughly around the same time. And uranium prices are now around $20 a pound, struggling to stay at that level.

Suffice to say, I have a profound sense of déjà vu. History seems to be repeating itself. And I'm asking both myself and others in the industry why. One former government official who started his nuclear career in the 1960s said that part of the problem was that the nuclear leaders back then tried to advance technology too quickly. Back in 1962, even before the big reactor building boom that led to over 100 reactors being built, the then AEC Chairman, Glenn Seaborg—father of plutonium, as you all know—told President Kennedy that the industry was on the threshold of attaining its primary objective of cost-competitive nuclear power. For the country's long-term benefit and for that of the whole world, Seaborg advised Kennedy that it was time we placed relatively more emphasis on the longer-range and more difficult problem of breeder reactors. And he said that only by the use of breeders would we really solve the problem of adequate energy supply for future generations.

It was really heavy stuff, and understandable, but unfortunately this effort to bridge the gap between the infancy and maturity of the civil nuclear effort led the AEC to shortchange efforts to improve safety of conventional light water reactors. For example, the Advisory Committee on Reactor Safeguards worried that the bigger, 1,000-megawatt light water reactors, containments would no longer hold melted fuel during an accident.

But Seaborg didn't want that to slow licensing, so he shifted the emphasis to emergency core cooling, which meant that containments got a little less attention. I wonder, had those scientists taken containment more seriously, would Fukushima have proved so devastating?

Industries dominated by scientists and engineers have always wanted to move their technology forward, and sometimes it's a good idea, and sometimes it works. But in the nuclear industry, the push to breeders was premature, and it led to a tendency to push aside problems with conventional reactors, which were proving more complicated than people anticipated. Arguably, it might have set the industry back.

So, let's fast forward to today. In the United States, only four reactors are under construction, two each in Georgia and South Carolina. And with the bankruptcy of Westinghouse in March, the future of even those projects is uncertain. Europe fares little better. France's state-backed Areva is in the midst of a complex corporate restructuring after a multitude of bad investments and a rocky start to its third-generation offering, the EPR, now under construction in Finland, France, and China.

The delays and cost overruns, particularly in Finland and France, are in part the result of improper planning, and rushing ahead into construction with a very incomplete design. A leading industry person in the United States told me that they basically started with what the engineers call a "cartoon," which is a very preliminary drawing.

Sometimes when you try to move too fast, you end up behind the pack. I'm reminded of the fabled contest between the tortoise and the hare. We all know who won. So, my colleagues and I at *NIW* are interviewing industry executives both here and in Europe to try and understand why we could build so many reactors 40 years ago, and today we're managing barely a handful on both sides of the ocean. This leading industry executive that I referred to earlier told me that with some of those

earlier projects, there were some pretty significant quality assurance failures during construction, and so there was a lot of rework and corrections to be done—and that, of course, led to unforeseen cost increases and more complex designs.

And then he said, "You know"—and he sighed. He said, "I hate to say this, because I'm a big believer in nuclear, but in general we've made these things so complicated that it's getting beyond the capability of normal to be able to produce them." Those are his words, not mine.

Of course, humans can usually solve a problem once they put their minds to it. But, he added, in this case the cost would well be prohibitive. Another problem is shortage of expertise. For example, in the U.S., Westinghouse had engineering and design expertise when it started building the AP1000 reactors in Georgia and South Carolina. But it didn't really know how to manage hardhats on the ground. So, for a while it allowed other firms, particularly Chicago Bridge & Iron, to comanage the two projects. When Westinghouse acquired Stone and Webster from CB&I in 2015, it took over sole project management, apparently thinking Sone & Webster would come to the rescue. But most of the nuclear construction people at Stone & Webster had long since retired or gone elsewhere. So, Westinghouse was in the game, but with a pretty empty hand.

And then in October 2015, when it became sole project manager, it made another fatal mistake: it took on all the financial risk of those two projects. Eighteen months later, in March 2017, Westinghouse declared bankruptcy and left the utility owners of Vogtle and the V. C. Summer projects holding the bag. That's the short version of why we in the U.S. are having trouble building four reactors.

But there are other reasons why Georgia Power won't be building more reactors as it was planning to do only a short while ago—and why we are not likely to see more reactor projects in the U.S. or in some countries in Europe and Asia any time soon. Market realities have changed dramatically since the time these U.S. projects were conceived and approved, and reactors used to be profitable once they were built and paid for. But now the cheap and abundant supplies of natural gas and cheaper, sometimes heavily subsidized renewables, means that some nuclear plants in competitive markets need subsidies to continue operating, which they have now in Illinois and New York.

But with or without subsidies, I think the trend is clear: The cost of renewables is coming down, and nuclear is having a hard time keeping up. In 2015, wind power output globally grew 17%, solar grew by 33%, nuclear 1.3%. That same year China spent $100 billion on renewables compared to $18 billion on nuclear.

Do you see a sea change happening in the industry? Because I do. The primary focus in many countries is shifting away from new builds to the immense challenge of what to do about nuclear waste. More and more reactors are shutting down, and the dense packing of spent fuel pools has become a much bigger issue, especially with the increase in high burnup fuel. This puts politicians in the industry under pressure to come up with more permanent solutions.

The problem is there was never an acceptable plan for cleaning up after the party, and few took time to think about the morning after. In 1976, a report in England concluded there should be no further large-scale nuclear development without a solution to the issue of how radioactive waste could be permanently safely stored. The report also warned against breeders, because they would be expensive, crowd out other energy options, and present a proliferation risk. The report was written by a royal commission made up of leading experts on soil, oceans, and the atmosphere, and it was led by a top industry official, Brian Flowers, who told me that he was very conflicted by it because he was a big believer in breeders. He said it took him a long time, and he used the words emotionally, to accept plutonium as waste.

Few now remember that report, though it made a big impact at the time. Yet instead of heeding its advice, Britain's energy establishment basically ignored it. But the tab for this failure in every country with a nuclear program keeps growing, and now the costs, so far as anyone can reasonably estimate them, are eye-popping. For example, a recent report by the European Union guesses it will cost at least 400 billion euros to clean up and store most of the continent's spent fuel and radioactive waste. In the U.S., estimates for an underground repository are upwards of $100 billion, maybe another $100 billion needed to repackage it for storage underground and transport it. Japan just announced [that] a decommissioning [of] the relatively small Tokaimura reprocessing plant will cost 1 trillion yen, almost $9 billion U.S. dollars. This is not exactly pocket change. This means that very important choices must be made about where in the nuclear industry money gets allocated.

In the United States, with the largest spent fuel inventories in the world, nuclear plants have become de facto waste sites. Meanwhile, the U.S. Nuclear Regulatory Commission has taken pressure off the situation by okaying storage onsite in pools or dry casks effectively for up to 120 years.

The NRC allows utilities to load these pools at much higher densities than they

were originally designed for. The Agency admits a spent fuel pool fire would cause widespread contamination and the relocation of millions. But it may actually be underestimating the consequences. According to a recent science magazine article, one of the authors of which I believe is sitting here today, such a fire would force 20 million people to relocate, with damages reaching as high as $2 trillion, which is 10 times the estimated damages from radioactivity at Fukushima.

It's difficult to imagine citizens sitting easily beside such dangers, and yet that is the situation across the country in communities that host reactors. Removing that waste even to an interim site presents enormous hurdles. Packaging, transport, and legal arrangements with the Energy Department have to be worked out, and new, well-crafted legislation will be needed. Given our present fractured politics, it's hard to see how progress will be easily made in this country. And if some of the legislation currently on offer in Congress does get passed, it might end up delaying things further.

For example, a bill in the House aimed at revising Yucca seems to ignore key recommendations of the Blue Ribbon Commission—in particular, for consent-based siting. A bipartisan Senate bill that would incorporate many of the BRC recommendations is supposed to be reintroduced this year, but we haven't seen it so far. I hope the bill and the BRC's recommendations don't suffer the same fate as the Flowers report, because I believe that over the long term, it would delay things only further.

I don't have a crystal ball about the industry's longer-term future. It's hard to predict. But I think it would take some as-yet-unforeseen technical advance, the kind Laura was talking about, or a dramatic change in market economics, to reverse the downward slide we are seeing in many countries right now. I talked earlier about the tendency to shortchange the present in a rush to get to the future. That was about the race to start breeders. With waste, it might be just the opposite. Because if we fail to properly address the issue now, aren't we shortchanging the future for ourselves, our children, and our children's children?

Many of you are working to come up with answers, and I have to say that listening to the people, the jobs you all do during the awards ceremony, I'm just amazed at the collective intelligence [and skill] in this room. It's so good to hear how many of you are working with younger people to pass on your knowledge. I just wanted to mention that.

Anyway, keep us in the media and the public informed about your progress to the extent you can. We really appreciate it. I wish you well, and I hope the meeting this week provides many opportunities and inspiration for progress. Thanks.

Hinderstein:
Thank you to all of our speakers. There was so much there. I was scribbling notes the whole time. I'm going to start by asking a few questions, picking up on some of the ideas that were presented during the remarks. But we're going to go to questions and comments from the audience. There was a lot that was new to me and a lot that might be controversial. I love those kinds of remarks. I hope that we'll have good responses. I'll give you a warning when I'm reaching my last question, and I'll ask that people go ahead and line up at the microphones in the aisles so we can be prepared to take questions and comments for all of our speakers.

I wanted to start in kind of reverse order. Stephanie, thank you for the compliment for the people in the room. You do *Nuclear Intelligence Weekly*—I think we're nuclear intelligence daily in our job. You talked a lot about the need to learn from history. One of the things I picked up from your remarks is that—and thank you for bringing such insight into the nuclear commercial, nuclear power industry, because that's not something we focus a lot on, although a lot of our work is definitely affected by and affects it.

Companies didn't seem in your kind of retelling of history to be structured correctly, to be oriented correctly to meet the challenges. I wonder as you look toward the need to address, as you mentioned, long-term storage, which requires packaging, transportation, disposition, words that are familiar to a lot of people in our audience, do you think companies, the commercial nuclear companies, are structured correctly to meet these demands?

Cooke:
For the waste?

Hinderstein:
Exactly.

Cooke:
I think that's happening now. I think there's some restructuring going on in the industry. One thing I will observe, though, is that you look at Hanford, you look at Whip. There are management problems and project management problems, a lot of them. There have been reports about that that the DOE needs to improve that. And I think that's critical. I would say there's room for improvement, for sure.

Hinderstein:
Laura, you mentioned the political dynamics in Vienna. And, certainly, it's something

that many of us who interact in Vienna, having seen change over the years be kind of injection of the unhelpful political and block dynamics that go on in other cities, that have kind of appeared in Vienna in the last handful of years. I wonder if you could expand on the point that you made about whether the Ban Treaty might have either created a release valve for some of those approaches, where some countries want to bring disarmament into the conversation on every nuclear issue, even where it's not necessarily connected. Release valve or kind of fuel to the fire—where do you see that?

Holgate:
I really think that is the critical question. It's hard for me to say because I haven't been in Vienna in the last couple of weeks since the Ban Treaty, the negotiations were completed and the treaty was adopted.

When you look at how it keeps getting injected into discussions at the Board of Governors, into negotiations around other issues that are not specifically related to disarmament, and recognizing that disarmament is not within the mandate of the International Atomic Energy Agency, now, that would be a worthy discussion. If the advocates want to say, "Okay, now there's a treaty." There's been this amorphous—what is it, Central International Authority or some kind of name which has the unfortunate initials of CIA. It's embedded in the treaty whether or not the conversation in Vienna—can and should the IAEA play that role? And if so, what would need to be changed about its mandate and its structure and its funding, and the responsibilities of member states and so on?

But that big question has not yet been called in an appropriate way. And so instead it's skirmishes on things that actually really matter to the day-to-day operation of the Agency. That really creates problems in both the time and attention of member states on helping guide the agency and explain and express their expectations of the Agency on certain issues. But it also creates this very negative dynamic in which hostages are being taken for things that are seen to be cared about more by one party than the other, where that could actually lead to just a complete breakdown.

And when you think about [how] most of the advocates of the Ban Treaty are actually the strongest beneficiaries of that large portion of the IAEA budget that supports technical cooperation and nuclear applications, this could be actually a self-inflicted wound for them. If they create a constipation, pardon the word, in Vienna on the Agency's business, then you're going to have actual impacts on lives being lost because we don't have countries that have effective nuclear medicine capabilities, on opportunities being missed to advance agriculture and public health in connection with nuclear technologies. Those are real downsides for the very countries that are that vocal in the advocacy of the Ban Treaty. I think it's a bad thing for everybody if that argument prevents progress, prevents the Agency from doing its own important day-to-day business.

Hinderstein:
Thank you. Stephanie mentioned she doesn't have a crystal ball. Yours is broken. I wonder what good are we, any of us? Stephan, let me try to force you to predict the future a little bit. I want to connect two points you made in your remarks. You identified early on that European countries are moving more toward renewables. We heard some of the data on growth from Stephanie as well. You also mentioned you have significant technical priorities—maintaining laboratory capability, exploring new technology like tomography, commercial technology and data utilization and analysis. What is the impact on your organization and on that really robust R&D and technical development agenda of a region that is moving away from nuclear? Are you seeing, or do you expect to see, continued support for that technical agenda because of the long-term stewardship of nuclear materials? Or is it at risk if the focus is moving more toward renewables?

Lechner:
It's very clear that even if they are moving away partially from nuclear energy in Europe, like Germany moving out of nuclear energy—just France having communicated seven years ago that they will move from 75% nuclear share to 50%. Then we're not moving away from nuclear materials.

So, we're moving within the fuel cycle toward the back end of the fuel cycle. They should not assess that, on the very long-living nuclear materials stewardship, as you mentioned, we can just get out of the responsibility together with the operational core generation being downsized in nuclear terms.

Predictions: I'm pretty much with Niels Bohr that predictions are difficult, especially if it's about the future. But we can see that the responsibility will remain. There are different ways to address it. German nuclear operators have been very smart. Just earlier this year, they bought themselves out of the responsibility for long-term storage for a total amount of 23 billion euros, which is about $25 to 28 billion U.S. dollars, and, therefore, moved the whole responsibility to the German government in this one approach. The government will then have to follow up in the future.

Areva currently is economically struggling. This is correct. So, good management of the operational responsibilities under the official regulations that are in force is key, and therefore the Euratom Treaty with all the different reporting obligations for operators will prevail. The nuclear material will stay where it is or move inside the borders of the new territory, and the nuclear safeguards will be with it.

Hinderstein:
Thank you for that. I think where you started your response to my question is something that we count on for the Institute of Nuclear Materials Management, which is that our job is not going away anywhere in our lifetimes or any generation.

Holgate:
I was going to say, if anything, more resources should be shifting in that direction. And with the other questions you were asking, I wanted to say that the same thing applies on the back end that applied on the front end. Don't rush. Get it right before you start throwing the waste underground and have happen 20 years from now. You have to get it right, and [it's] worth spending time and devoting resources to that.

Hinderstein:
Thank you. Yes, responsible safe securities are all words that we feel need to guide our profession and our work. And that needs to be filtering at all levels, from regulatory oversight policymaking and commercial operation.

Lechner:
[A] comment here, very quickly. Technology and knowledge are one of our main concerns, because we are an operational agency. There is an operational institution, and I hope that we will be able to maintain the competence. If I'm looking into [curriculum] of universities in Europe, hardly anybody is investing into new [curriculum] and nuclear anymore. This is a big concern for the future, because it's not that attractive on the general trend, and therefore, the know-how might phase out.

Hinderstein:
That plays right into a question I was going to ask later. I'll jump up, which is we have our extensive student chapter network here at INMM. We have a lot of students from not just our chapters but many parts of the world, and a lot of young professionals. Maybe I'd ask each of you. I'll start with Laura. If there was one area where you're talking to young people, either students or young professionals, and you want to say if you want job security, if there's a growth area where we know we need really good thinking going forward, what would you think? Where in the nonproliferation nuclear security policy arena do you want to start bringing these great young minds?

Holgate:
I wasn't going to pick one. But in my remarks, I mentioned a number of areas where, in the nonproliferation world, where the mission of the INMM and the professionals that are associated with it have extensive experience, knowledge, and opportunities to add to the future needs, whether it's the Iran deal, whether it's verification of disarmament, whether it's the bilateral regional international nuclear security mechanisms that exist. Or in influencing the development and design of advanced reactors.

But I'll just mention one thing I didn't have a chance to talk about, which is the thing that I actually came here to talk about 18 years ago with my very first keynote address, was plutonium disposition and the commitment that Secretary [Ernest] Moniz made last December to invite the IAEA to provide oversight and monitoring of the U.S. disposition of excessive weapons, plutonium, through the dilute-and-dispose technology. That's never been done before, so that's again another new area where the expertise in this room and all of your colleagues are going to be critical to add to that conversation.

Hinderstein:
Excellent. Thank you. Stephan, what do you think? What's the area that you want us to turn all of our great young minds toward?

Lechner:
It's difficult to tell if I'm supposed to choose only one area. On our operational requests, we are seeing that they have a very solid basis of nuclear physics of measurement and chemical analysis that should be maintained.

I would like to address rather the information technology side, where it is difficult to apply business analytics engines to nuclear data, because they are particular. They have specific characteristics. They're sensitive. And if you just carry over intelligent data assessment topics from information technologies to nuclear, there will probably not be a right way applicable. So, we need somebody or also a workforce that has an intelligent understanding of the nuclear fuel cycle, an in-depth understanding of nuclear technologies and issues, and then also have a complementary knowledge in data analytics and modern

information tools to be applied there. This is what I see just emerging, and I would like to have it here or have it in the future to help us a little bit in our central offices to analyze better than we're doing today.

Hinderstein:
I'm looking at Teressa. Let's make mental notes for an interdisciplinary action there. I think that could be extremely important in a place where we could contribute. Stephanie, what do you think?

Cooke:
I feel underqualified to address this issue. But I would just say that I agree with what the other two speakers said, and add that, to me, to finding somebody to marry these two worlds, basically. Academically. And to maybe create specialties in the universities. My son, for example, is studying computer science. And I keep telling him, "There could be a career for you here." It's just finding ways to take all that technology. And I wonder, is that true in all industries, that each industry has a different set of characteristics and then you take basic computer science you learn, or is it much harder in nuclear?

Lechner:
Answering questions both ways now. It's really for nuclear, it is specific and it's more difficult. Because we're living 20 years behind the recent developments and information technologies. We have a very security-sensitive community. We have a very conservative community. Whereas on the fast-living internet telecommunications chapters, they're moving along with a whole industry into the digital wave, and we're enjoying it. And nuclear always is tied with one leg in the old conservative, hardcore engineering world, and cannot completely sidestep the digital wave. So, actually, the split is getting bigger.

Cooke:
It's a catch-up job, is what you're talking about. A huge catch-up job. There's a little story I was going to tell before just about on the construction side. But it's similar not in that it relates to information technology, but the specifics that nuclear requires. For example, they have this company called Shaw [that] was working on the project. And Shaw set up a factory to build modules for the reactors, and these were supposed to save costs. But Westinghouse year after year would go down and say, "No, it's not acceptable." Because I guess in pipe manufacturing, it's okay if you say point-five, if it comes out at point-seven, it's okay. But in nuclear it's not okay. It has to be absolutely exact. I don't understand why they couldn't get it right, that's something I don't understand. But that's an example, kind of, another example of nuclear.

Hinderstein:
The nuclear industry is conservative, but it's conservative for a reason. And the reasons are what you highlighted in the beginning of your talk, which is when you fail, the world is at risk, as opposed to there are some other industries where that risk tolerance is more acceptable, because the consequences are potentially not so grave.

Warning to the audience: I'm going to ask one more question approximately, each, and then I'd love to have questions from the audience. So, please at this time you can start lining yourself up at the microphones, and we'll turn to you in just a minute.

Did you want to add something quickly, Stephan, at this point?

Lechner:
Stephanie, I think they do not have to request for catching up long distance from being anchored in very conservative thinking. As you say, we are rightfully anchored in conservative thinking, and we should stay there. So, it's just covering the big split that we are experiencing moving into the challenge. But not moving the traditional junk into the new world in a way.

Hinderstein:
On that point, I wanted to come to the topic of nuclear security—which, Laura, you highlighted a lot for good reason in your remarks. Stephan, you had mentioned that there is a new initiative in the EU to develop a nuclear threat combined effort. Could you describe briefly what the thinking is there?

Lechner:
This initiative. The European Security Union is not tailored to nuclear all alone. It is tailored to all the different security threats that they're currently experiencing. And 28 different member states have just put their heads together to develop concepts [for] how they could work on this security union together. We have an internal European market. We have other concepts for agricultural subsidies that we're sharing. Two years ago, we also [took] up the first thinking with the current European Commission to come together in a security union. So, the security union is made up of different elements. There is a monthly review under the British Commissioner currently on the progress. Some of the monthly review topics are taking a look at borders and immigration. Some are taking a look at cybersecurity. Some are taking a look at nuclear nonproliferation. So, this is an integrated concept at the European level for security.

Hinderstein:
So, Laura, you mentioned your disappointment in some of the post-summit initiatives, and while many of the elements still have promise, not all of them have maybe realized that promise. I've seen a chart that you've shown at previous talks of the architecture, and one of the boxes that you've always noted as not quite filled out is the regional approaches. I wonder if you could react to what Europe is doing and talk about the potential benefit of a regional approach versus these broad international or global approaches.

Holgate:
Well, I think they each have their own niche to play. The thing about the European community, and I say that with a small "c," is that they can take action together. They have a legal framework and a way of working through the governance bodies in Brussels to do joint work. Almost no other regional structure has that kind of decisional ability. That gives them a leg up, but also a responsibility to live out those potential areas.

Threats are regional, but they are also not regional. And so there's challenges—I mean, you can't over-regionalize these things. Each thing has its role to play. One of the things that I hope we could develop as a regional concept coming out of the Nuclear Security Summit were these concepts that we were observing just by looking at the map—that we have entire regions of the world that have no highly enriched uranium. None in Latin America. None in Eastern Europe. None in Southeast Asia. And that there are ways that these accomplishments can be recognized that create perhaps not only a recognition and a commitment of those countries in those regions not to have material that could be used in a nuclear weapon, but also a deterrent affect for terrorists who might be looking for where they think they might be able to acquire such materials. There's a whole swath of the globe that they don't even need to look at. So, I do think that there are special niche roles for regional organizations to process.

Hinderstein:
So, my final point along this nuclear security chain, Stephanie—and I know it's not an area that you've focused [on] heavily, but maybe you've observed. The role of the industry in the course of the Nuclear Security Summit has changed over time from an extremely reluctant and defensive participant, I would say, in 2010 to an active and forward-looking role in 2016, with a commitment to actually continue. Have you seen evidence that the nuclear industry is owning their nuclear security responsibility beyond just meeting their regulatory obligations?

Cooke:
That's a very good [question]—I actually had a reporter who is no longer with us do a story on that. And he was having a really hard time getting people to tell him what they were actually doing. So, I'm not sure—it's like screaming out at me with examples. The other thing, of course, that's worrying is on the nuclear side of these utilities, with all this cost-cutting. The financial strains they're under. I fear that security might be lower in the priority list. But I don't have documented evidence of that. [It's] something we should be looking into.

Hinderstein:
We have lots of questions, which is great. I'm going to take one question from each microphone in one group. I'll ask folks to respond to whichever piece that they'd like to, and then we'll do a couple of rounds. Let's start on the right.

Audience Questions

Andrew Worrall, Oak Ridge National Laboratory:
First of all, thanks for the probing discussion there, because I think there's a lot of challenging questions that have been raised. So, I'd just like to address a particular one from Laura. Thank you, Laura, for the comments about the advanced reactors and things. We met during the year at one of the advanced reactor summits and conversations about how these new technologies do introduce new challenges, should we say.

One of the things I'd just like to underline with is that the community at large may not be aware. The advanced reactor community has very much switched on to the necessity for the needs for safeguards and security. But I think it's an important point to recognize [that] it probably isn't their number-one priority right now, because these designs are still on the drawing board. But one thing I would just like to flag in that regard is that they are being looked at. So, for example, we at Oak Ridge already have several projects and programs underway to address exactly that. Without going into the details. I'd be happy to talk later. So, that's the first thing to underline. It isn't being forgotten, it's being worked on, whether it's modern salt reactors or anything else.

But the thing I'd like to just offer. In my role at Oak Ridge National Lab, I've recently been appointed as the deputy director of the GAIN initiative. So, [for] those people who may not be aware, this is the DOE Office of Nuclear Energy Initiative, called the Gateway to Accelerated Innovation in Nuclear. And this is the way that the DOE and the national labs can support the industry going forward with

their advanced technologies. So, in that context, this is a huge multi-, multi-, tens of millions of dollars of opportunity that they're looking to leverage from the DoE national labs to support those nuclear programs.

In conversations last night, I heard a lot of misinformation, misunderstanding, as to what's going on. So, what I'd like to do on behalf of the GAIN initiative and me as deputy director, I would like to offer to be a conduit between the two communities to ensure that there is not that lack of information or that misinformation. And, also, if I can offer to facilitate any exchanges, so maybe at next year's event to INMM to have a session on that kind of exchange on the programs that are underway, what DOE office [does], what GAIN's doing. It's an offer rather than a question. But I'd like to address this misinformation that's out there today. And I think it's important as two communities [that] we underline them and fix that.

Hinderstein:
Thank you, Andy. We appreciate that. Let's go to Mark.

Mark Goodman, Department of State:
My question is also for Laura. You've been working with the Russians for, I won't say how many years, but quite a few. And you've seen the trends in our ability to cooperate with the Russians. I'm wondering if you have any assessment of their motivations now. Is it mostly opposition to the United States? I'm thinking particularly in the Vienna context, where they're making things difficult on nuclear security and sometimes on safeguards. [I'm] wondering if there are ways to, in thinking about their interests, find more confluence of interest, common ground.

One area where we have had common interest is in the proposed role of the IAEA in the Ban Treaty, where both governments have been opposed. But then I wonder if this is a constructive area for cooperation, because it tends to exacerbate the split. In June, there was a discussion on this, and the Board was split right down the middle on whether the IAEA should or shouldn't have a role.

Jack Jekowski, ITP, Albuquerque:
Many years ago, Graham Allison from Harvard did a study on the economic impact of a nuclear event in lower Manhattan, to the tune of 2 trillion dollars, and then used the DoD model to evaluate what should be the investment in nonproliferation. You mentioned earlier the stocking of fuel ponds and the risks associated with the storage onsite. My question is: Is anybody really working on the risk model and looking at the cost of such an event in order to identify how much really should be invested in long term storage?

Hinderstein:
So, we had comments from Andy, which I will take as a comment and an offer on addressing GAIN. And if the speakers would like to address it, you're welcome. But we had a specific question from Mark on Russia to Laura—and then to any panelist who would like to address Jack's question about special storage risk and cost.

Holgate:
Well, I will just make a remark on the GAIN issue, and that is to observe that that provides—to my knowledge, it hasn't been utilized yet. But it could be a tool for these advanced reactors to take advantage of the safeguards and security expertise that exist in national labs in addition to the kinds of material science, fuel design, safety analysis, code development, and so on that has been the primary goal for that. But I look forward to having conversation with Andy and learning more about that.

As for the Russian motivations—like any large country, there is no monolithic Russian opinion. I think the policy level of discussions that take place at the Board of Governors and the IAEA and other governance forums in Vienna, it is very much a political thing. If the U.S. is for it, then the Russians are going to be against it. They are concerned and feel in some ways disadvantaged by the strong presence and quality of U.S. personnel within these institutions and organizations. And they worry about what influence that might be providing on the work of the secretariat of these organizations.

Now, part of that has to do with the Russian vision. And we all know that when Russians show up as the CFE or as a staff member in Vienna, they're not working only for the IAEA, they are also working for their country. And the U.S. has a very different approach. When we send our staff and our experts to the Agency to take up roles in the secretariat, we expect them to be serving the Agency. So, there's a misconception, I think, of the mirror imaging that is not true in how the Russians think about the presence of U.S. personnel and expertise within the organization.

I do believe, however, that at the technical level, there are Russians who are interested in continuing and even deepening joint work with the U.S., and that there are opportunities within the IAEA, whether it's through joint participation of U.S. and Russian experts on IAEA review missions; whether it's participation in the kind of coordinated research projects that the Agency manages and sponsors; whether it's the work in training that happens through the Centers of

Excellence and supported by the IAEA, and so on. And so I think there are ways to keep those human-level contacts warm, and I think there's interest on both sides in that. And I really want to give credit—and I see Leon [Ratz] is about up for his turn at the mic—to the joint work of NTI and Anton Khlopkov's organization in Moscow on looking at the future opportunities for how U.S. and Russia can get back to a collaborative set of work on U.S. and Russian joint efforts.

I think one other point to motivation I should just mention is that the Russians are really interested—their prioritization is on nuclear energy and other types of technology cooperation, not on the nuclear security and nonproliferation. Since the current U.S. policy limits U.S. support for U.S./Russian nuclear energy cooperation because of the competitive nature of Rosatom and the role that it's playing in the global fuel markets, the Russians have decided if we're not going to work with them on their priority, they're not going to work with us on our priority. So, I think we really need to find corners of this nuclear space where we have common perspective. Keep the work going. Waiting for a more salutary political environment across the world.

Hinderstein:
Thank you. Stephanie, did you want to address Jack's question?

Cooke:
I can try. As far as I know, there aren't any studies like the one you suggested. I'd also observe that the NRC's budget is going down and that the NRC, as I understand, doesn't have regulations to govern high burn-up fuel. So, there's a lot of shortcomings right now on the whole system of spent fuel, and I think it's an area that spent fuel pools in general need to be looked at a lot more seriously. Beyond that, I would defer to Ed Lyman, who is here and knows a lot more about [that] than I do.

Hinderstein:
Thank you, Stephanie. I realize we're already over time, and the discussion is really so great I don't want to cut it off. So, we're going to take the questions of the folks at the mic. I ask you to be please be succinct in your question, knowing that all of our speakers are going to be around and available for hallway discussions and everything else after. And then we'll give our speakers one last chance to respond to everything. So, Mark?

Mark Schanfein, Pacific Northwest National Laboratory:
Stephanie, you mentioned about the dire straits of these four new bills in the U.S. These large LWRs. About a year ago, I was in NuScale and saw a level of enthusiasm for this company, who wants to build small modular reactors. I'm curious if you see that as a path forward, possibly, in the U.S.

Hinderstein:
Thank you for that very direct question. Leon?

Leon Ratz, NTI:
My question is for Laura and for Stephanie. I was wondering if you could comment a little bit on the president's budget request and your thoughts on implications for this community and how this community might best respond to these kinds of cuts. We've seen organized industry responses in a couple of other fields, particularly diplomacy, and I'm wondering if you have some thoughts on how we ought to respond as a community. And a similar question to Corey, whether the Institute has given any thoughts on a response to the president's budget request. Thanks.

Hinderstein:
Thank you. Will?

Will Steinberger, PhD student, University of Michigan:
My question is for Dr. Lechner, if you could comment on how France's reprocessing system affects their spent fuel storage later on.

Hinderstein:
Great questions. Let's go [in] reverse order, starting with James, and we'll go back across.

James Larkin, University of the Witwatersrand, South Africa:
It's not actually a question, it's more of comment and some good news. You were talking about where we should be going in terms of education and things. Well, there is a project coming out of the IAEA, the nuclear management section, where we are looking at developing a couple of education programs in nuclear management. And, certainly, Texas A&M is involved, as well as Tokyo University, Manchester University. And we're in the process at the moment of looking at these courses and going through an international peer review. We have heard what the industry is saying in terms of, "We need some skills," and these programs are very much aimed at sort of nuclear technologists … and teaching them management processes. It's been recognized, and this whole thing is moving forward. If you want to talk to me about it, I'll give you a card. I can put you in contact with a couple of people as well, both at Texas A&M [and] elsewhere in the world. So, it's a global initiative, and it's coming along nicely.

Hinderstein:
A good news story is a great way to come to the end of our session. Thank you for sharing that.

Kayla Mattucci:
I'm a student intern at Sandia Labs. My question is about future prospects for arms control. Last year, I saw an address at Sandia by Gary Samore saying that—if you agree with this comment, I'm curious to know. But he thinks that all the low-hanging fruit in arms control has sort of been plucked already from the tree, and you talked a little bit about prospects for cooperation and disposition in areas like that. And especially with talk of some areas in the nuclear industry winding down, do you think that's more possible now than it was even a year ago?

Hinderstein:
Thank you, Kayla. Our final question or comment.

Karen Hope, National Security Complex:
You all kind of touched on the idea … that we approach these challenges with novel approaches and novel methodology as opposed to kind of incremental changes. However, you also all noted the fact that we work in this slow, understandably conservative, international community. And we heard a couple of the comments that people said are examples of it, but I'm wondering if you had any additional kind of tangible ways of doing that. Perhaps examples of a successful initiative in the past of implementing creative methodology or best practices for us.

Hinderstein:
Thank you, Karen. I'm going to go in the reverse order of our speakers, and just feel free to respond to any of the points that were made.

Cooke:
I would just say on the SMRs, it's again a question of economics. If you can bring them in at a cost that can compete with renewables and cheap gas, fine. But make sure you get it right before you do, and don't oversell.

Secondly, the question about what to do about the administration's budget cuts in research: that's a tough one. My observation, our observation at *NIW*, it's extremely frustrating covering politics right now because of this administration and its quirks, or whatever you want to call them. I would focus on Congress, totally focus on Congress. George Will - came out with a column. He basically called for isolating President Trump politically. I think he was saying go to Congress, you're going to have to depend on Congress, for better or for worse.

Holgate:
Well, just picking up on that point. There are some points of light within the president's budget that I hope Congress maintains, which was at least flat funding, no cuts for the accounts in the State Department that typically fund a lot of the voluntary contributions and a lot of the nonproliferation work that is done by the U.S. or in cooperation with other countries. The budget for the nonproliferation work at the National Nuclear Security Administration also seems to be relatively stable. I will say that is stability at a level that was significantly lower than it was at the beginning of the Obama administration, and there's a lot of conversations that could be had about that. But there were not cuts to that. But there are other cuts elsewhere in the R&D mission space, the nuclear energy mission space, in possibly the dues that the U.S. pays to international organizations including the IAEA. That is still a question mark as to whether the U.S. is going to actually pay its dues. Too many moments of that not happening completely remove our voice from that venue, which is in no one's interest. And because of the way the color of money works, the voluntary contributions resources that do seem to have been protected cannot be applied to paying our dues, and so this is something really that needs to be watched.

I welcome the administration's rhetorical support for nuclear energy, but their diagnosis of the problems of nuclear energy is just dead wrong. And so, that's leading them to do things like cutting the NRC, because they see regulations as the big barrier. That leads them to walk away from things like a carbon tax, which is the most valuable way that you could create a level of economic playing field. You see them undermining the resources that the Department of Energy has to support advanced reactor technologies and the new challenges that are going to be facing the existing fleet. And so those are issues that I worry very much about in terms of the long-term future of nuclear energy.

Lechner:
I would like to answer two questions. One from Will on the French reprocessing system just impacting the spent fuel storage later on. And the final one on the new methodologies, new technologies, the tangible example of Kelly.

So, the first question for us at a European level—this is a tricky one, because reprocessing and then storage and final storage is something that the European

Union is not as unified as it could be. If I'm taking a look at 27 different nation states having to build a final repository because national law says you cannot export nuclear waste, then in principle, this is not very efficient. Otherwise, if we wanted to put it all to Finland, which would be a nice idea, then we'd dump our problem on somebody way up in the north, and we have long transport routes to get there. So, this is an ongoing discussion now, and there is no unified market on long-term storage and disposal ready in the European Union.

The French position currently, and the French position all alone with a lot of reprocessing going on, is a long-term concentration as well, but currently it's a French situation that they need to leave to the French state, and we will safeguard whatever state the material is. It's not so relevant at a European level.

The interesting thing is that if material is being exported and all of a sudden, it's getting out of our territory, this is something where then according to the Euratom Treaty, Euratom Safeguards ceases If now France might export material to Hinkley Point C in the UK, then all of a sudden that will not be the European Union anymore. And that might also have some influence over the question, which is by no means straightforward. We might discuss later on, but if you see it from the European perspective, there is a lot of political work to be done to determine common concepts in the European Union about storage and final storage. We currently were on our model united in diversity, but this isn't on diversity.

The second question of new ways to combine not incremental progress on technologies but new ideas, would be probably something, Corey, that I can give to you. Because this is exactly what INMM is good for, having a platform for getting people together. We've talked off mic, I felt that data analytics is a need. But the business case for it is somewhere between Google and Facebook, and is not so much in the nuclear area so that will be a challenge. But the competence that these guys have would definitely be enough to cover also nuclear needs.

Hinderstein:

Thank you. I will take that baton, and we can think about how we can contribute. I have already failed at my first job this morning, miserably [ending on time]. I actually appreciate that some people who had to get up and leave have gone and left. I know that we will have a chance to have a quick coffee before our session starts, but please—thank you. Join me in thanking our presenters for a really stimulating discussion.

JNMM Roundtable

July 17, 2017

Opening Plenary Speakers

Stephanie Cooke
Editor, *Nuclear Intelligence Weekly*
Washington, DC, USA

Ambassador Laura S. H. Holgate
Senior Fellow (nonresident), Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University
Arlington, Virginia, USA

Stephan Lechner
Director, Euratom Safeguards, European Commission Directorate General for Energy
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INMM Immediate Past President

Patricia Sullivan
JNMM Managing Editor

Taken at the JNMM Roundtable, pictured are: Corey Hinderstein, INMM President; Stephanie Cooke, Editor, *Nuclear Intelligence Weekly*; Stephan Lechner, Director of Euratom Safeguards, European Commission Directorate General for Energy; Ambassador Laura Holgate, Senior Fellow, and Teressa McKinney, INMM Technical Program Chair.

Each year, the *Journal of Nuclear Materials Management* hosts a roundtable interview of the opening plenary speakers at the INMM Annual Meeting. The following is a transcript of the 2017 *JNMM* Roundtable.

Markku Koskelo: Thank you all for participating in this discussion today. There was a comment that Dr. Lechner made during the morning session that I wanted to expand on, and that is not about Brexit per se but the recent terrorist events in Europe. There have been quite a number of them that have made the news. How does that affect your operations of sending inspectors or worrying about the possibility of nuclear facilities becoming targets for terrorists?

Stephan Lechner: This question has actually two perspectives. Number one is nuclear security, on which the European Commission legally has very limited competence. Nuclear security altogether is part of the competences of the European member states—these competences did not pass to the European federal level in the Lisbon Treaty in 2010. So, the EU has maintained an independence of its member states on their national security, including antiterror activities and nuclear security. But it doesn't mean that there could not be collaboration. So, the European position is between our member states where everybody has a national stake and where the national competence is undisputed. Nevertheless, there is a need for collaboration because we have seen terrorists attacking France and moving over to Belgium and other terrorists who had been attacking in Germany were finally found and shot in Italy.

So, the exchange of information about what's going on is really, really essential, and on the European level there, we have established the concept of a Security Union where we can discuss collaboration also on topics related to national security without any federal power to propose European legislation.

The operational part of the question relates to sending inspectors into nuclear installations, which has become more difficult after some terror attacks. This does not mean that there has been a change in access rights; our rights are undisputed and unchanged, and we have very good collaboration in our member states. But in contrast to the International Atomic Energy Agency, we are overseeing operators, not states, so we are dealing with private companies. These private companies are subject to national legislation of all types. So, if national security is tightened after terror attacks, or if there is, for example, a decree that says from now on certain documents need to be double checked, then also the procedures for our inspectors to enter and to access might become more tedious. We cannot even complain that the rights that are enshrined in the Euratom Treaty would not be respected by the member states. It is just that the procedures have become more complex and that operators have to respect national legislation and Euratom legislation simultaneously. So, the situation has become more complex. There is no dispute; it's always good collaboration but of course operators cannot overstep national legislation, and they still need to adhere to the European one.

Corey Hinderstein: There is another element to this that I hadn't thought of until hearing Markku's question. What about the process by which you vet the actual Euratom inspectors whom you are sending to facilities, since many of the issues related to terrorist activities in Europe have involved European citizens? Have the requirements of the Commission, or your internal requirements, changed as far as your vetting of inspectors?

Lechner: No. This vetting procedure is formally established for all security clearances at the European level, so there's a fixed process, and even the Euratom community does not do it. It is the same process of security clearance as in other

areas, for example, for handling classified information in the financial crisis. This is a general system at the European Union level, but I need to refer to what I said on national security: It goes back to the EU member states.

So, if we want to get a security clearance for a new inspector of a particular European citizenship, then we first request a Euratom security clearance, which is done at a central service of the European Commission. The European Commission, of course, checks the file and passes it on to the country of origin of the particular inspector. It might then be the case that on average in country A the security clearance takes longer than in country B. But it all goes back to the national competence on national security, which then feeds into the European process. I have little understanding [of] how well national security checks and security clearances are harmonized. In principle, they should follow the same logic. But I need to underline that the details of national vetting procedures are not fully open and transparent. When the security clearance is issued by the member states we will only get the final result.

The main drawback in this procedure is it takes quite a long time to get a new inspector security vetted. But we can use the time well: new inspectors need to spend roundabout 42 training days just to be fit for the job. Then we issue inspector passports, which need to be acknowledged by all EU member states. For this purpose, we issue formal notices. But, unfortunately, we cannot do the final step until the security clearance has been completed in the member state of the inspector. Some cases have taken up to two years, so we need to plan our staff well ahead.

Larry Satkowiak: Actually, this is a question that's somewhat directed toward Laura, but I appreciate any answer that anybody else might have. Laura, [you] mentioned that you've lived through four Nuclear Security Summits, and after the fourth one there was this lack of direction in terms of what to do next. And during those four summits, you got to meet a lot of the Sherpas from the different countries. In your perspective, is there still political will internationally to carry on some of the things that they tried to accomplish under the Nuclear Security Summits? Or is the lack of U.S. leadership in this area causing a problem?

Laura S. H. Holgate: This is a good, complicated question. We did actually have a plan for how to keep the Sherpa family together. It's called the Nuclear Security Contact Group, which was intended to do two things. One is to try to maintain the relationships that had been created by the summit process of these, I would call, "senior empowered individuals." Now those individuals had different positions within each government. When we initially started the summit process, we'd ask leaders to name Sherpas who were similar to what we were on the U.S. side within the White House, where you had senior people with direct access to their leaders and if not authority, at least influence over all the relevant agency players in each government.

That was not matched in many cases because not every country has a national security council or similar body. Certainly, the British and the French were the closest, and they did in fact represent Sherpas out of either the cabinet office or out of the presidential staff in France.

But many countries represented out of their diplomatic corps or out of the regulators. But what made it nice was that it was a diverse group. It wasn't like meeting with like. We each had responsibilities for representing our national interest across the agencies and for preparing for leader participation. And that empowered the Sherpas to be able to get things done within their own governments that they would not normally have been able to do if all they had was their normal bureaucratic role.

We hoped to maintain some of that through this Nuclear Security Contact Group, which involved many countries that were part of the summit process, but not all. But it was also specifically designed to be open to new countries as a way to kind of lance the boil that had become this concern of exclusivity, where why do 52 and why not others and especially within the European Union, this is very complicated because there were some EU members who were not part of the summit process. The EU itself was there. There were maybe a dozen really vocal countries that would talk about this exclusivity. So, the theory was, okay, if you want to be part of like leadership on nuclear security, join the contact group—it's open to you to do that if you want to work on the terms of reference that the contact group identified.

That was kind of the people part, and then of course the functional part is these action plans. The five action plans that the leaders agreed [to] coming out of the last summit said [that] within the five main institutional structures that work on nuclear security, these are the things that we're going to do collectively as members of those organizations and initiatives and to promote through the decision-making bodies that belong to them. So, there was a pretty clear path forward. But I think what we underestimated is how much momentum would be lost by the loss of access to the leaders. Those Sherpa-level

people became disempowered when they weren't prepping for their leader to show up in another country and represent. They lost connectivity to other parts of their government. And the other thing that we learned is that Sherpas were not strongly connected to their diplomatic counterparts in Vienna and in New York.

Many of the Vienna-based ambassadors had participated in the summit process, but not all of them. We had huge differentials in levels of engagement, in levels of helpfulness in some cases, between the Sherpa from a country and their Vienna ambassador, for example. Because of my role, I had a chance to see this on both sides. We tried during the negotiations of the IAEA [International Atomic Energy Agency] nuclear security resolution in September and then again during the IAEA nuclear security ministerial to actually use the mailing list for the contact group to whip support, to try to say, "OK guys, remember your president signed up for this, your king, your Prime Minister, whatever. And this is the moment, this is when we try to get this done, and so we need you to be speaking up. We can't always have it be the same five predictable countries that are advocating for things that have their roots in the action plans." And that was not very useful.

What it really proved is that in many, many countries, the Vienna-based ambassadors—and I think it's even more true for New York, because I think those ambassadors are going to be even more powerful—they are disconnected from their foreign ministry, and they're disconnected especially from their leaders. So, that's been a hard lesson to learn, but I think it's a reality that we need to design around in future efforts to keep this moving.

I think the agenda remains clear. The action plans remain available for action. That's a menu of things that can be done in New York, in Vienna, in Lyon, with Interpol, the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction, the Global Initiative for Combatting Nuclear Terrorism. And those things should continue to animate those organizations and initiatives.

Now, the other thing we did with the contact group that turned out to be, I think, a bad idea—or at least the implementation has been a bad idea. And I really don't want to blame the Canadians for this. They've been leading the contact group, and they've been awesome. But, the notion of doing the contract group on the margins of the IAEA General Conference sounded like a good idea. But it turned out to be a terrible idea, because nobody has time to dedicate the amount of time you really need to do tactical organization. "Here's this paragraph," or "Here's a way we could change it to make it be more supportive of the action. Make sure everybody chimes in." Make sure we're showing a volume of interest around one position so we can overwhelm the volume of antipathy coming from the other side. Those are just basically the international diplomatic ground game. The contact group has not been able to really use that well. I think we still need to develop that now that it's really a multilateral diplomacy thing. And I hope that the team can get that.

As for U.S. leadership, the April 2016 summit was designed to be the end of the summit process. It was designed to have the contact group and the action plans to carry it forward. It was designed to be resistant to lack of knowledge at the last summit of who was going to be the next U.S. president. And President Obama was very explicit about this. He said, "I don't want the decision to continue or not continue to the summit by my successor to become a political thing. So, we will just draw it to a natural close, and then they can do whatever they want to do to support nuclear security. So, it doesn't have to be like I'm taking over this thing from my predecessor or I'm stopping this thing from my predecessor." I think that was a very wise decision. I think it is fair to say there was some fatigue at the leader level, so as much as we lost from not having leaders meet, I'm not sure that we would have gotten the same kind of high-quality, high-level participation for the fifth or sixth or seventh or twelfth summit.

In some ways, we incurred this momentum problem at the best time, when we had the most momentum, and we're still struggling, I think, to figure out how to bring that momentum forward.

The one hope I have in terms of U.S. government leadership is that Chris Ford—who has a leadership role in the office that I had at the White House on these issues—in a speech where every question he was asked, his answer was, "It's under review," he was asked a question about nuclear security. He said, "The summits were a great thing. The action plans are an excellent forward path, and IAEA is a critical player in nuclear security." It was the only definitive thing he said in the whole speech. So, I have some hope for that. I think we'll have to look at how the U.S. position on paying its assessed dues for the IAEA is going to sort out to know whether there's actual meat behind that. But I certainly do not expect that there will be anything close to a presidential level of leadership on this issue under the current administration. And what worries me, as capable as the deputy chiefs of mission are in UNVIE, [is] that without a U.S. ambassador there who is active and empowered to move this, there will be a leadership gap in Vienna. I think that will be to the

detriment of the nuclear security legacy.

Chris Pickett: First, I want to thank our plenary speakers for providing such interesting and engaging talks this morning. This question is for everyone. Many of you mentioned [that] the need to capture and preserve knowledge will be very important going forward. This is something I've heard many times over my career, but I haven't seen any effective implementation. So, I'd like to ask each of you, what needs to happen for effective knowledge capture and preservation to occur?

Lechner: Let me try to start with this: Organizations are always concerned about losing knowledge due to experienced people going into retirement. This year, 57 percent of our Euratom inspectors are having between 15 and 20 years of experience on the job. So, they are comparably senior, as an inspector typically enters the European service between age 35 and age 45.

Inspectors with 20 years of experience are normally approaching retirement.

This means we have a very experienced workforce, and there are always concerns of this experience fading away without being replaced. But frankly spoken, we are just looking at a very normal turnover procedure. There are periods where more people are going into retirement, and there are periods when less people are going into retirement. For us, it is important to attract a sufficient number of qualified young people, such that the average experience of the service remains strong enough to perform Euratom safeguards. So, I think we are tending to overemphasize on the concerns that our very good collaborators will fade away naturally over time. And we forget that we are getting very good young colleagues as well who will pick up from them. In addition, we do not consider that we are having persons from the second row who can be team leaders or lead inspectors as well. They are the ones who can step into the shoes of the ones who have to leave. We tend to forget that also our experienced colleagues were young when they started. Altogether, I think we do not have to be seriously concerned that the operational know-how would fade out.

What I see, in turn, is the funding at universities being under pressure, and that European research organizations and universities are turning towards renewables as the long-term future of energy. Nuclear research has a general tendency that is reflected, for example, by the recent French decision to cut down their nuclear power share from 75 to 50 percent: it is less and less attractive. We have a decision that Germany wants to abandon nuclear altogether. We really do not see any strong efforts on nuclear new builds in Europe. So, why should the technology and research community invest into an area where they are getting little funding, while they see right in front of their nose the appealing idea of going into wind and solar and renewables altogether? And with a smart grid and the implied dynamic balancing between decentralized production and consumption, that big block of nuclear somehow does not seem too appealing for future research anymore.

So, my main concern is that, in the long run, the universities, at least in Europe, might not supply enough graduates anymore for the nuclear sector. Nuclear engineering might stay a particular niche, but the nuclear community has been developed over 60 years, and most of the time—let's say for 50 years—the community was growing. Now, after 10 years of stagnation, we are experiencing a period where, all of a sudden, the future is not so rosy anymore. As far as maintaining nuclear knowledge is concerned, I am worried, [because] fresh young university graduates will all have many other opportunities in the energy sector than going into nuclear, and even high school graduates will be mostly drawn into other energy-related faculties of the universities.

Stephanie Cooke: I'd like to step in for a minute. I thought about this a lot when I was writing my speech. I thought, "Wow, how do you draw in people when it's not like the '50s when nuclear was the go-to area for students?" That's a real problem.

One of the things I was saying is that I think you have to make a choice about how you allocate resources. You also have to make a choice as an industry about how you broadcast this to the public. I almost think that this area of security and safety and decommissioning needs to be separated from the effort to promote clean nuclear energy. I think it has to be pitched and positioned in the university community you were talking about, but to the broader public, too, so that they understand the challenges. People who get into this field are guardians of the planet. They are guardians of the planet's future safety and security. And their work is vital. It doesn't matter what you think about nuclear power. It matters that there is a job to do, and it will never go away. It's there basically for the long term.

Holgate: The other thing I would add to that is the concept of demonstrable competence. And this is a commitment that a number of summit countries made in the context of the "implementing nuclear security" gift basket. And organizations like WINS [the World Institute for Nuclear Security] are making a dent in it by trying to create a transferable certification program for nuclear knowledge. I know about that from the WINS perspective, and I'd be really interested to know about

it from an operator perspective or from a regulator perspective or someone who is actually hiring these people who have gone through that kind of a certification process: has that been an effective way to transfer knowledge?

I've got to believe that there are models or examples or evidence-based programs from other fields about knowledge transfer that can be brought into the nuclear security community. It's not a field in which I'm [an] expert, but this can't be the only community that has faced that problem, and hopefully there are other parts of technology, society, however broad you want to cast it, that's able to do that knowledge-capture process.

Lechner: Interestingly, in Europe you have another problem at the national level: If you're running nuclear installations in Eastern Europe, you need to have engineers who speak the national language—for example, Czech. Also, official letters we are writing to the Czech authorities are better understood in Czech, so we often need to translate them. Occasionally we write in English, occasionally we write in the national language. But if you want to work in the national system itself, you need to speak the local language and be educated to the national standards on top of any European regulations. Smaller countries cannot harvest from a large offer nuclear education and nuclear training in their national language, like in the United States. We have limited central means to provide central efforts, but these will not necessarily help, for example, local Slovak engineers.

Jack Jekowski: Thank you for coming today and sharing your wisdom with us. This is directed more toward Laura, but I'd like to hear other comments as well. And it builds on the question I asked this morning at the plenary session, if anybody has done a risk analysis of spent fuel pond scenarios and the potential cost of an incident, and then extrapolated that into what the investment should be to mitigate the possibility. If you go to a higher level of analysis, Graham Allison is leaving Belfer this month and Ash Carter is taking his place. He brings with him, of course, his knowledge of the U.S. Department of Defense modeling that's done in terms of investments that need to be made for R&D to mitigate significant events.

We have the Price Anderson Act, which limits the liability of nuclear operators, I think, to about $12 billion, and then the U.S. government picks up the rest. But if you consider beyond design-basis accidents, which now has become a very popular topic, particularly after Fukushima, one can envision developing a number of scenarios about spent fuel ponds and the projected cost of those events, much like Graham Allison did with a nuclear device going off in lower Manhattan, and then extrapolating from that with the DoD model what the actual investment should be to preclude as much as possible that event.

The first question I'm asking is: Is there a way that we can ensure that the work that Graham Allison had done can be picked up and extrapolated to other beyond design-basis accidents, like the spent fuel pond one? But secondly, when you think about doing that, is there a danger when that information is released, or that analysis is released, that people say it's not worth investing in nuclear because of the cost of the risks associated with them? So, it's a double-edged sword. I don't even know if there's an answer to that.

Holgate: No. First of all, in terms of what Belfer might be doing, I would refer you to Matt Bunn. I'm there four days a year and kibitzing. I have no influence on their prospective research, as it may change with the arrival of Ash Carter. I'm going to challenge the premise of the question a little bit, which is to suggest that the cost of a post-event dealing with it is in any way related to the cost of preventing. The only relationship is as a motivator. Because it's going to cost what it's going to cost to do the right thing after the fact. And whether it's however many trillion, or five times that in terms of impact, it's still going to cost what it's going to cost to fix it.

I've never been an advocate of really detailed economic analysis of the impact of risk when it is that large. We can't even conceive—well, our mathematician friend probably can conceive a trillion, but we can't conceive a trillion, and we can't conceive the difference between 1 trillion and 10 trillion and upwards of that. Refining the edges of that analysis, I don't find very interesting or, frankly, very motivating.

The real question is what would it cost to actually buy down 50 percent of that risk, 25 percent of that risk, whatever. And what is it that those investments would go toward, and how do you present that in a way that in a democracy is supported by the citizens and policymakers who act on their behalf?

The other question you're asking is about the accident scenarios, which, for better or for worse, the safety community is one, the security community is another, so I would be surprised frankly if Belfer were going to do a lot of work on accidents that don't have some kind of security origin, because that's kind of their meat and potatoes. So, the question is, who would be? If you did want to have some work done on these broader issues that are more safety oriented, what's the right place for some of that work to be done? And maybe Stephanie has some thoughts on that.

Cooke: I was just going to answer the part of your question that had to do with the question of how do you publicize your work in a way that wouldn't that be damaging to the nuclear industry? I kind of feel that you have to get away from that mentality, because the risks are so great. You have to think beyond all of that and think about addressing the here and now risks that aren't going to go away, and not really couple that to worrying about bad publicity for the industry, because the industry will carry on the way it is. Publicizing, debating, or discussing your work does not mean that reactors are all going to shut down tomorrow, the ones that are operating. And as for the future, there's just so many other dynamics in play that it's much better to be seen [as] trying to improve nuclear security and blowing your horn about that than it is to worry about not blowing your horn about it and then having something awful happen.

Holgate: I think that's right, too, but I was listening to—that when you look at climate, those are creeping threats that are real. There is no way to reach carbon reduction targets that does not have some component of nuclear energy. If you're really worried about those costs and those risks, then nuclear has to be part of it.

But I absolutely agree with you. I think all that the nuclear industry does on safety, security, appropriate stewardship of legacy issues has to be an affirmative case and not one that the industry is afraid of taking on or speaking eloquently toward. Or recruiting, back to Chris's point, the next generation of technical stewards to do that with the quality and attention that it needs.

Lechner: Being addressed as a mathematician, I can tell you that in risk management, there is always difficult consideration about things that you don't have on the radar. Having worked in the industry and in security for 18 years, I can tell. Implementing safety and security, everyone needs to look into the inherent costs that a certain level of protection will require. But all of a sudden, we might be struck by a security issue that we did not plan for. And then we frantically try to do everything [to] cover also these new risks. We learn from the past and try to avoid issues like Fukushima in the future. But the next security issue can again be different: We might see a terror attack on a nuclear installation carried out by a drone, and we might not be prepared everywhere. Finally, we need to understand we cannot have 100 percent security, because the bill would go to an infinite amount. No limit there.

We need to also understand that if we are asking for too much, the economic analysis will always come up with a number of trillions that nobody will be able to invest. The question is rather: What can we realistically afford, and how would we most efficiently distribute the financial burden, the workload, and the total efforts to get it done? This is typically how big security problems are addressed. If someone is looking into damaging the nuclear industry, publishing figures for 100 percent safety and security would serve the purpose, but this holds for any security-relevant area.

Cooke: One thing I wanted to mention too concerns the danger of spent fuel pools, which the U.S. Department of Homeland Security is looking at. But the regulator is the U.S. Nuclear Regulatory Commission (NRC), and the NRC has a special relationship with the industry. I mean, the industry basically funds the NRC. If the NRC takes a less conservative view of spent fuel pool risks than people who are advising Homeland Security, I'm wondering if there should be more weight given to agencies outside the NRC in the way we manage these risks. I don't know how it would be done, but maybe we need to look at the whole area of how these kinds of risks are governed and regulated to make sure that they aren't ignored.

Glenn Abramczyk: Thank you for your interesting opening plenary. I'm following up on what Chris was asking earlier. And in the scenario you put forth was that renewables are replacing nuclear. I propose the alternate scenario that it's natural gas that's putting out pretty much everything else. But natural gas isn't renewable either. So, when it goes away, the need for nuclear could either rise or at least stay level to where it was before. So, you still need the brain drain. You still need to encourage those people who are either going to continue that industry or improve that industry, and if not, the other alternate to the scenario is that it does kill off nuclear. You still have the legacy material that needs to be addressed in some publicly palatable fashion.

Cooke: I was going to say that, interestingly, I'm trying to dig more into how the actual grid operates. The plants that Exelon had that are most in trouble, they're at certain key parts of the grid. Wind coming in from the Midwest is killing plants like Quad Cities [in] western Illinois.

But in the case of another Exelon plant in Illinois, the utility built a transmission line to push more of that wind further east, and then the plant's economics suddenly changed. The point is that nuclear problems aren't always gas related. And when they are, such as in Pennsylvania, and you start talking about subsidies, the fossil fuel industry comes after the nuclear industry, as they did with the state subsidies in New York and Illinois. There is quite a clash in the courts over nuclear subsidies.

I know what you're saying about gas and nuclear. But the key thing is that there's also a lot of improvement going on with efficiency and with the grid. I can't see nuclear becoming economically competitive anytime soon. It may happen, but in the meantime, there are all these other issues within the nuclear industry that have to be dealt with. That's the reason I was saying I see the industry changing shape. And all of these things, there's an awful lot of work to be done on these. And there's only a certain amount of money. So, we have to make decisions.

Mona Dreicer: I have two questions. One is for Laura. I was planning to ask you this question before you went through the lessons learned after the Nuclear Security Summit, but I'll ask anyway: If you were in a position to create the next forum of what we can do to carry nuclear security forward—recognizing that there is [that] fatigue at the head-of-state level—what would you do?

While you are thinking of the answer, another question that comes to mind while listening to the discussion about the future is: I keep hearing that we're assuming that nuclear technology is going to provide energy needs in the future. I want to challenge whether it's really a given that this is the case, taking into account economics, safety, dual-use issues, and security.

More than 20 years ago, I worked on a project in Europe called ExternE. It was working to assess the external costs of energy for different options and integrate those costs into energy decision-making. I actually don't know if it ever really got implemented. It was such a hard problem, and that was before terrorist actions and all of the security-related issues that we're faced with today needed to be taken into account.

So, I guess I want to challenge whether nuclear is the future. We are always going to have the legacy issues, we're going to need safety and security; We have to deal with decommissioning. It's a long-term issue. But is nuclear energy really going to be a viable source in the future? If so, it might be just in certain parts of the world, and maybe not in Europe and the United States. What are your thoughts?

Cooke: I'll take a crack at it. It's certainly there in China, India, and Russia, and to some extent there's a lot of talk about it in certain countries in the Middle East. There's always talk about it in South Africa, and a little bit in South America. So yes, it's not going away. It's not going as any of these countries had hoped. Russia a few years ago talked about 38 new reactors by, I think, the year 2030. And India just came out with a new forecast. China has definitely been dialing back. Fukushima had a big impact on that program-—on their construction approvals.

They stopped approving any reactors in 2016. That was because of the problems at Sanmen, where the AP1000 was being built. They had a lot of problems, most notably with the circulation pumps that had to be sent back two or three times to the U.S. and reengineered and replaced. In Beijing, they look very carefully at this, and they are worried about safety.

So, all of these countries that want to go ahead in nuclear, they are going ahead, but they're going ahead more slowly than they originally said they would. So, what you say about, yes, there's going to be more nuclear in some parts of the world than others. That's what I see happening. I see the U.S. and Europe pretty much dialing back. And I see in Asia more going forward, mainly in China, but more slowly. And also, the same in Russia and India to some extent. India is notorious for coming out with forecasts and never achieving them. It's all going to go a lot slower. But it's going to go ahead. At least that's the outlook from my perch at the moment.

Lechner: The European position is a bit tricky, because the Paris climate agreement does not mention nuclear. According to my knowledge, there were diplomatic efforts to get nuclear power acknowledged as climate-friendly technology. But finally, these did not succeed. Currently, we are somewhere in the middle between knowing that we still have a significant nuclear contribution now and a long-term objective toward renewables. In between, we might still need a baseload generation for a certain amount of time, but this need might disappear sooner or later, depending on how future energy storage develops and how well the dynamics of the smart grid will work.

If I take a look at the European Union, the nuclear perspective is very straightforward: The numbers are going down. We will formally lose a lot of nuclear energy contributions in the EU in the year 2019, when the UK will be exiting. That's just by mere calculation. After this, the main player remaining is France, who have just issued plans to reduce the nuclear share in its energy mix as well. Germany, another big country, will be abandoning nuclear power completely in 2022. So, the trend in Europe is quite clear, but I need to underline that this does not mean we will not need nuclear safeguards anymore.

Cooke: And Switzerland and Sweden.

Lechner: Just to underline, Switzerland is not a member state of the European Union.

You are right with the legitimate question, "Will there be a future for nuclear power generation?" The European Commission has issued a plan for clean energy for all Europeans, which is the energy package of December 2016, driving us

into the future of a climate agreement. The word nuclear doesn't appear there, because investment into nuclear at the European level is mostly about safety, security, waste management, and safeguards, and a respective illustrative program of the European Commission had been issued already before. So, along these lines, we are really not seeing a lot of indications that nuclear power generation will be the big thing for the future of Europe. But the safeguards and related concerns will be always with us.

The U.S. are planning—as far as I recall—a stable future nuclear energy share of around 19 percent to 21 percent. There might be a slight increase, even. Look at China, and it is again different. So, we see different regions in the world having different strategies with respect to their future energy mix. Globally, we might have nuclear energy production around for another 50 to 100 years—just how much and where exactly is hard to tell.

Koskelo: We are just about out of time. Laura, a last few words.

Holgate: Well, as you've observed, I laid out the plan that exists, and since I was part of building that plan, I really have some sadness about the less-than-fabulous implementation of those plans. But I couldn't come up with anything better. I'll just go back to what I said a lot during the summit process: The summits were a sprint in the middle of a marathon. The marathon still has to be run. It's boring. It's hard. It's waking up every day and having the right diplomats and the right technical people and the right people in various secretariats and the various institutions trying to create the environment in which they can do the right thing. One hopes that in this moment where the U.S. leadership on this issue is going to be perhaps less visible, that just gives the chance to spread the leadership. We had, just from the summit process, Australia, Jordan, and the Netherlands coming to the forefront as being real champions of nuclear security, with knowledgeable diplomats and experts and the willingness to take risks and take leadership roles in various institutions, and so on. That can grow.

So, I think it's just the hard slog of keeping focus, having specific actions that you can aim toward [that] are in the action plans, and gauging progress against those and just working the problem. I think at some point there will be a logical moment for another kind of leader-level summit process. Let's hope that's not after a major event that proves what we've all been saying about the vulnerabilities in the system. But I think the path is set, and we've just got to do it.

Koskelo: With that, let me thank our panelists for their answers and comments. And thank all of you for taking the time to ask all of the questions. I hope you got some answers. Thank you, everyone.

Nuclear Safety and Security Education Program at Tokyo Tech

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Abstract

Tokyo Institute of Technology established the Academy for Global Nuclear Safety and Security Agent in 2011 to develop global nuclear human resources, educate excellent graduate students, and foster the next generation of global leaders with communication skills and social literacy in nuclear safety, security, and safeguards. The academy established the Global Nuclear Safety and Security Dojo Program to prepare students to play leading roles internationally in the academic, industrial, and governmental sectors. The program provides them with special living quarters in a nuclear-safety-and-security interest house, an incentive scholarship, and a well-rounded curriculum of academic study and field experience. The program combined five sets of specially designed courses from multiple disciplines with existing nuclear engineering courses. The academy hosts an annual international symposium and seminar to provide students with a customized forum for discussions with leading experts to build up their global connections and understanding, as well as their professional competence. Students also take advantage of domestic and overseas internship opportunities for extensive study. The academy expands the opportunities for them to enhance learning experiences in a wider variety of out-of-class settings through the overseas educational training tour program in the United States, Europe, Russia, and Asia. The academy had the first graduates of the Global Nuclear Safety and Security Dojo Program in 2017. Mentoring programs also provide students with professional preparation for entry into fields of work. This paper describes the objectives and curriculum of the Global Nuclear Safety and Security Dojo Program.

Introduction

After the Fukushima nuclear accident, it has been recognized that it is necessary to tackle globally and cooperatively key challenges such as large-scale nuclear disasters, nuclear terrorism, and nuclear proliferation. Global professionals need to cope with the difficult consequences of such crises and find solutions. They need the capacity to communicate with society and manage the aftermath of theses crises, as well as be specialized in nuclear safety, security, and safeguards.

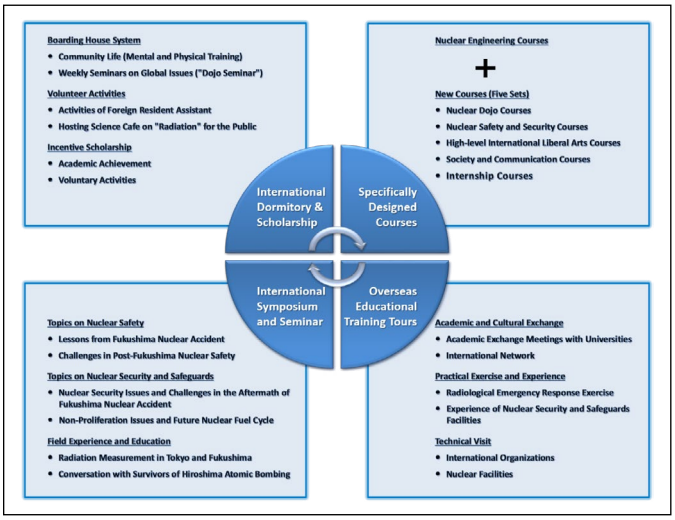

Figure 1. Overview of the Global Nuclear Safety and Security Dojo Program

The Academy for Global Nuclear Safety and Security Agent was established to develop such global nuclear human resources at the Tokyo Institute of Technology (Tokyo Tech) in 2011, as an initiative of the Program for Leading Graduate Schools supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan. The academy aims to educate excellent graduate students and foster the next generation of leaders who will play leading roles internationally in the academic, industrial, and governmental sectors with communication skills and social literacy in nuclear safety, security, and safeguards.

Building on Tokyo Tech's nuclear engineering program, which has existed since 1956, the academy program, called the *Global Nuclear Safety and Security Dojo Program* (hereafter referred to as the Dojo Program) is a five-year master's and doctoral program. Figure 1 shows an overview of the Dojo Program. It provides a special living option of a nuclear-safety-and-security interest house, an incentive scholarship, and a comprehensive education for master's and doctoral students selected from the Department of Nuclear Engineering. Dojo students live and learn together under the leadership of supervisors in an international interest house dormitory. Specially designed courses,

international symposiums and seminars, and overseas educational training tours were developed to create a well-rounded education of academic study and field experiences.

This paper describes the objectives and curriculum of the Dojo Program. Section 2 will provide an outline of the required courses involved in the Dojo Program and a brief description of the new courses developed for nuclear safety and security. Section 3 will introduce the main components of the international symposium and seminar. Section 4 will cover the mission and values of the overseas educational training tours. Finally, Section 5 contains a summary of the value of this program to nuclear materials management.

Courses

Figure 2 shows the outline of the Dojo Program's courses. The existing nuclear engineering courses offer primarily traditional nuclear engineering disciplines, such as reactor physics and fuel cycle studies, as well as focusing on the general fundamentals of nuclear safety, security, and safeguards. Five sets of customized courses from across multiple disciplines were developed and combined with the nuclear engineering courses. These five sets are Nuclear Dojo, Nuclear Safety and Security, Society and Communication, high-level International Liberal Arts, and Internship.

The Nuclear Dojo courses discuss global security issues, nonproliferation, safety culture and risk management, and emergency response and crisis management for global experts and leaders. The Nuclear Safety and Security courses offer simulation and/or field exercises of severe nuclear accidents, radioactive nuclide dispersion, physical protection, and environmental radiation measurement.

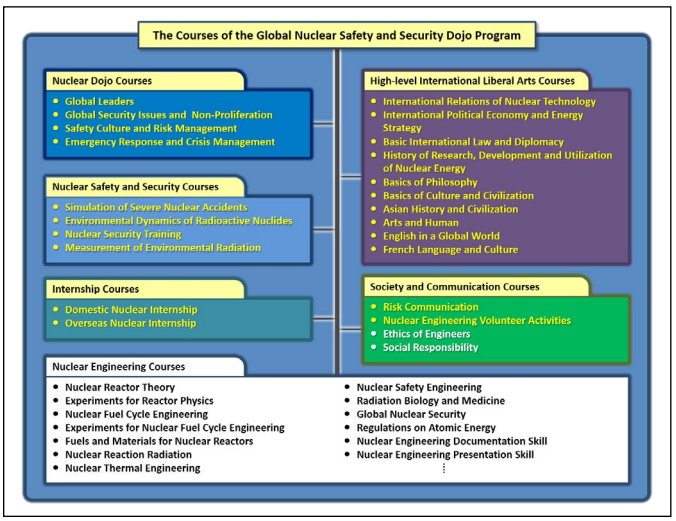

Figure 2. Courses in the Dojo Program

The Society and Communication courses deal with risk communication and volunteer activities in addition to engineers' ethics and social responsibility, which have also been covered in Nuclear Engineering courses. Dojo students are required to volunteer in response to society's needs, such as the Fukushima recovery.

The high-level International Liberal Arts courses cover a broad variety of liberal arts areas, such as international politics, international law, economics, history, culture, philosophy, arts, and languages, to cultivate a high level of global awareness and understanding.

The Internship courses were designed to enhance the students' academic and personal development in preparation for their careers. Dojo students are required to perform domestic (three to six months) and overseas (six months to one year) internships in their research field, receiving financial support from the academy. This experience will enable students to expand their academic studies during these internship periods related to their career path.

The following sections give a brief description of the Nuclear Safety and Security courses, which cover simulations of severe nuclear accidents, environmental dynamics of radioactive nuclide dispersion, nuclear security training, and measurement of environmental radiation.

Simulation of Severe Nuclear Accidents

This course is a simulation exercise course developed in cooperation with the Tsuruga General Education Center of the Japan Atomic Power Company (JAPC), to have students practice simulation of transient events, design-basis accidents, and severe accidents of a boiling water reactor (BWR) using a plant simulator. The simulation familiarizes students with the major systems related to the safety of nuclear power plants (NPPs) so they can experience and understand the accident response.

The simulation exercises are an intense immersive experience that includes topics such as operation of control rods (normal operation and emergency shutdown), reactor power control (control rods and recirculation flow control), turbine system and reactor pressure control, turbine trip and reactor scram, plant start-up and shutdown, validation of severe accident management, and similar accidents as occurred at Fukushima (station blackout and reactor water injection failure).

Students learn about the main structures and safety equipment of NPPs, typical severe accident sequences, and the

progression of the accident at the Fukushima Daiichi NPP (FNPP1) unit 3 using a severe accident analysis code called the *Modular Accident Analysis Program*. The students then perform practical simulations of transient events, design-basis accidents, and severe accidents by using the plant simulator at the Tsuruga General Education Center. After the simulation exercise, the students visit JAPC's BWR and pressurized water reactor facilities.

Environmental Dynamics of Radioactive Nuclide Dispersion

This course is another simulation exercise course, developed in cooperation with the Research Group for Environmental Science of the Japan Atomic Energy Agency (JAEA), that helps students develop the ability to predict the environmental dispersion of radionuclides released from nuclear accidents by numerical simulation and the ability to evaluate the radiological consequence of the accidents. For the simulation exercise, Tokyo Tech installed the Worldwide Version II of the System for Prediction of Environmental Emergency Dose Information (WSPEEDI-II) system in early 2014. It is the first and only installation of this system in academia. WSPEEDI-II combines two models: the nonhydrostatic atmospheric dynamic model and the Lagrangian particle dispersion model.

This course is also an intense immersive experience for students. It is composed of classes on nuclear accidents and radionuclide release, biological effects of radionuclides, atmospheric dispersion models, water environmental dynamics, consequence analysis, WSPEEDI-II input and use, WSPEEDI-II simulation exercises, presentation and discussion, and reports. Students are required to understand nuclear accident source terms, radiation environmental dispersion, the biological effects of radiation, and the structure of the WSPEEDI-II system for prediction of environmental dose information. They must then perform numerical simulations of the environmental dispersion of radionuclides by virtual nuclear accidents and evaluation of the public exposure.

Assuming a hypothetical nuclear accident at FNPP1, different weather conditions are assigned to each student, who performs two simulations of a reference and his or her own scenarios and compares both simulation results in dispersion, deposition, and exposure. The reference scenario is based on the weather conditions at the time of the FNPP1 accident in 2011, and the course provides students with a case that has different weather conditions than were present at FNPP1 in 2011. This case is based on wind fields and rainfall events, because atmospheric dispersion of radioactive nuclides strongly depends on wind fields, and rainfall events considerably influence their depositions on the surface. The students' scenarios include typhoons passing through Japan and the rainy season of Japan with a typical weather pattern that would lead to different features of dispersion and deposition. In the last day of the course, students discuss the nuclear emergency response based on their simulation results, comparing the evacuation routes at the FNPP1 accident.

Nuclear Security Training

This course covers the fundamentals of nuclear security, physics, nuclear security culture, international regulatory frameworks, nuclear and radioactive materials, physical protection (PP) system design, and structural material resistance against shock wave (hydrodynamics simulation). Students perform practical exercises in three ways: (1) numerical simulations of the hydrodynamics of structural materials and nuclear material criticality in the classroom, (2) experiments of uranium enrichment verification using nondestructive assay, and (3) PP training at the JAEA.

In the numerical simulations of hydrodynamics, students learn the important physical mechanism of structural material damage by using an explicit dynamics code, ANSYS Autodyn, covering impact, high pressure, or explosions. Various case studies are assigned for students to simulate the effects of shock waves on structural materials, for example, steel projectiles colliding with a target, polycarbonate projectiles colliding with a target, and an explosive's shock wave against a target. Physical properties such as kinetic and explosive energy are discussed to understand their physical mechanism. Students recognize the importance of the impact pressure in the spallation fracture mechanism, either from collision or explosion, in the design of structural material.

In the experiments of uranium enrichment verification, students measure gamma-ray spectra from uranium oxide samples of different uranium enrichment using digital handheld gamma spectrometers called identiFINDERs. They determine the uranium enrichment of the samples by analyzing the relation between gamma-ray count rate and uranium enrichment obtained for each measurement, including measurement of known standard samples.

In the latter part of the course, the students visit the PP training field of the Integrated Support Center for Nuclear Nonproliferation and Nuclear Security (ISCN) and the Tokai Reprocessing Plant run by the JAEA. The students can achieve practical knowledge of nuclear security through training and discussion with the security operators and facility visits.

Measurement of Environmental Radiation

This course is a field exercise of radiation measurement in the Fukushima area that allows students to acquire hands-on experience measuring environmental radiation contamination caused by the FNPP1 accident with multiple types of radiation detectors. Three types of survey meters (ionization chamber, Geiger-Mueller tube, and sodium iodide scintillator) and gamma spectrometers (identiFINDERs) are used for the radiation measurement.

This course is an intense immersive experience, too. Students learn how to operate the survey meters and gamma-ray spectrometers to measure the environmental radiation contamination while driving around Fukushima Prefecture and to collect environmental samples (soil, plants, etc.) that are brought back to the university to be analyzed for isotope identification and spatial distribution. The students discuss the cause of radiation hot spots they found and the expected impact on the residents and environment of Fukushima.

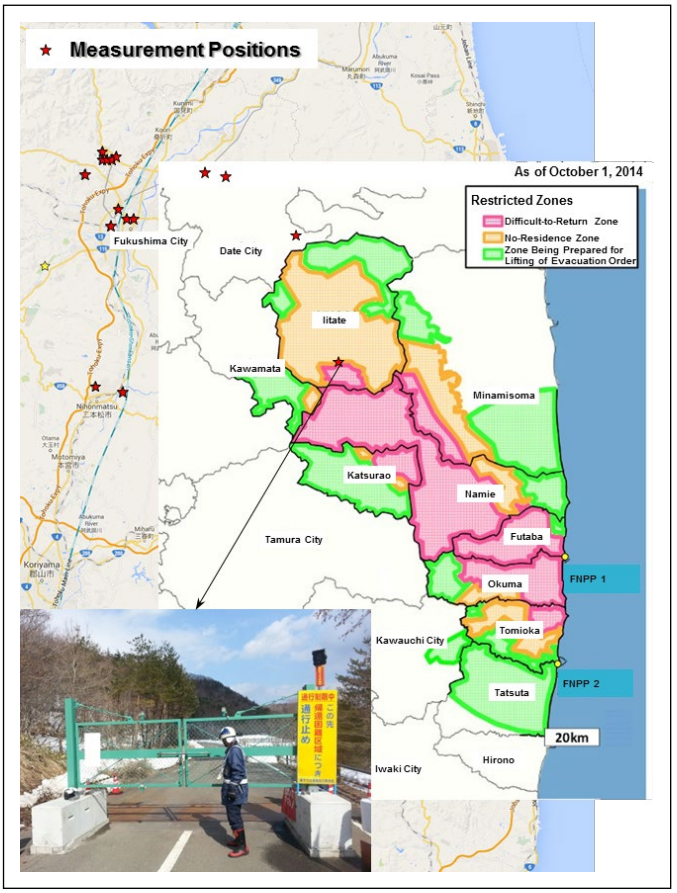

Figure 3. Radiation measurement positions in Fukushima (redrawn from the Ministry of Education, Culture, Sports, Science and Technology [MEXT] and Google Maps)

During the radiation measurement, students are divided into several groups, each advised by faculty in charge who drive them and guide where to make the measurements. Figure 3 indicates the radiation measurement positions with the radiation contamination level map by MEXT as of October 1, 2014. The environmental radiation contamination is measured first in Fukushima city at about 70 km away from the FNPP1, moving south and east, and finally in front of the barricade for the "difficult-to-return zone" inside the village of Iitate at about 35 km from FNPP1. Students also visit the environmental radioactivity monitoring center in Fukushima Prefecture and the JAEA Sasakino Analysis Office in the city of Fukushima to observe the system for measuring trace amounts of radioactive nuclides in food and environmental samples.

International Symposium and Seminar

The academy hosts the International Symposium and Seminar on Global Nuclear Human Resource Development for Safety, Security and Safeguards for two weeks each year in Tokyo. The Symposium and Seminar provides Dojo students with a customized forum for discussions with leading experts and other distinguished students or young professionals from Japan and abroad. Such discussions build up their global mindset with international competitiveness as well as professional competence.

The Symposium and Seminar alternates topics every year, focusing on nuclear safety one year and nuclear security and safeguards the next. These events are conducted in cooperation with the International Atomic Energy Agency (IAEA), the European Nuclear Education Network, the JAEA, the Institute of Nuclear Materials Management Japan chapter, and the Nuclear Security Science and Policy Institute (NSSPI). Students and young professionals from outside are invited based on a recommendation by their university, institute, or industry. Approximately 10 students from Japan and 20 from other countries in Asia, Europe, North America, and Russia attend each year.

Under the guidance of mentors, Dojo students are trained to lead a small group discussion on emerging issues and challenges addressed by international lecturers and to present solutions and conclusions they derived through internal discussions and debates. The group discussion and presentation aim to be very participatory, interactive, and collaborative. All participants are also given an opportunity to visit Hiroshima or Fukushima and gain firsthand experience and education on the history of both places. The following sections give a brief description of the main components of the Symposium and Seminar.

Nuclear Safety

The topic of nuclear safety begins with a discussion about the Fukushima nuclear accident. The discussion covers what happened, why it was unexpected, why the plant was severely damaged, and what was correct about the plant's reaction to the crisis. Problems and challenges with a perception of the Fukushima nuclear accident then are discussed for nuclear safety in the post-Fukushima era, including environmental consequences, lessons and changes, safety culture, risk management, safety improvements for future reactors, resilience management, and crisis leadership post-Fukushima.

Leading experts in nuclear safety from Japan and abroad are invited as guest lecturers and/or mentors for the participants during the period, including executive officers from the Tokyo Electric Power Company, deputy directors general and department heads from the IAEA, commissioners from the Nuclear Regulation Authority of Japan, directors from Japanese ministries and agencies, and specialists from industries, universities, institutes, and foreign government agencies.

Nuclear Security and Safeguards

The topic of nuclear security and safeguards deals with relevant issues and challenges in the aftermath of the Fukushima nuclear accident, with a diverse perspective that covers nuclear security culture and education, nuclear security threats, nuclear security technologies and risk analysis, nuclear security in transportation and at borders and ports, nonproliferation issues and nuclear governance, nuclear forensics and law enforcement, and protected plutonium and fuel cycle in the future.

Experts in various fields from professional institutes, universities, companies, and especially international organizations and institutes, including the IAEA, the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), the World Institute for Nuclear Security, and the ISCN participate in this topical area. Special speakers, such as ambassadors from France and the United States, attend and deliver an address covering international nuclear security and nonproliferation.

Global Leadership

The Symposium and Seminar is designed to allow adequate time for participants to discuss and interact with each other, sharing experiences and knowledge. Participants, comprising men and women of different academic and cultural backgrounds, are divided into small groups of six or seven members, balanced by region and gender so everyone can contribute actively and equally (see Figure 4).

Figure 4. A group discussion in the International Symposium and Seminar

The group members attend lectures together and then discuss one of the assigned challenging issues facing nuclear energy, receiving guidance from mentors composed jointly of the academy faculty and international guest lecturers. They will reach a consensus view in the group for their assigned issue and present it to the seminar. One or two Dojo students in each group have to navigate the process of conversing, collecting information, drawing conclusions, preparing a presentation, and team building, as well as creating a global balance and understanding.

Another leadership training experience is to learn communication skills and conflict resolution in a short breakout session. The participants are temporarily rearranged into different small groups based on their backgrounds and interests to discuss a specific topic in nuclear safety, security, and safeguards within a limited time. They have to quickly accommodate themselves to a new situation and come to a consensus agreement on the topic with their new group members.

Field Experience and Education

Field education is another vital aspect of the Symposium and Seminar. Participants measure environmental radiation in both Fukushima and Tokyo by using several types of survey meters and confirm by themselves the radiation dose levels. They discuss the difference in radiation levels between both places, the cause of the radiation hot spots they found, and the expected impact on the residents and environment of Fukushima. Moreover, since 2015, a site visit to the Fukushima NPPs is conducted to allow more real field experience at the front line to understand

difficulties. The participants visit the emergency-response room of the seismic-isolated building where the headquarter personnel conducted the crisis response at the moment of the accident. They talk to field executives of the Fukushima NPPs and observe the restoration site and workers while getting to measure a higher level of radiation than possible elsewhere.

In some cases, the participants travel to Hiroshima to visit the Hiroshima Peace Memorial Museum, the Atomic Bomb Dome, and the Radiation Effects Research Foundation. The trip is intended as a poignant reminder to the next generation of global leaders of the importance of preventing the use of atomic weapons such as occurred at Hiroshima and Nagasaki from ever happening again. Students have the opportunity to listen to the testimony of a survivor of the Hiroshima atomic bombing, who presents his or her firsthand account of the destruction and sorrow in the aftermath of the atomic bombing.

Other educational experiences include visits to the Onagawa NPP and the Monju fast breeder reactor. The Onagawa NPP is located about 120 km north of the Fukushima NPP, but it was the closest one to the earthquake epicenter on March 11, 2011. The plants underwent very high levels of ground motion, with the strongest shaking that any NPP has ever experienced from an earthquake, but they shut down safely without severe damage. The participants learn the different outcomes at Onagawa and Fukushima caused by the effects of having different safety cultures and emergency responses. In the Monju reactor visit, participants learn about the safety challenges of operating a sodium-cooled reactor and avoiding accidents such as the liquid sodium leak in 1995. They also explore the safeguards system implemented at the Monju fast breeder reactor for safeguarding the use of mixed oxide fuels containing both uranium and plutonium in a reactor designed to breed plutonium, including a dual containment and surveillance system.

Overseas Educational Training Tours

The academy expands the opportunities for Dojo students to enhance their learning experiences in a wider variety of out-of-class settings through the overseas educational and training tour program, in which academic and cultural exchange activities with overseas students are combined with realistic training, practical experiences, and facility visits. They can visit universities, national laboratories, institutes, international organizations, and nuclear facilities in the United States, Europe, Russia, and Asia. A brief description of the tour program is given in the following sections.

Academic and Cultural Exchange

The academic and cultural exchange activities are process-centered. Dojo students participating in the overseas tour program collaborate first by email or online with associated students of the university that they will visit. For example, they prepare their own academic exchange meeting under the guidance of advisors from both universities, including introduction of research, discussions on issues of common concern, and exchange of information on key issues. They collaboratively determine the goals, contents, and intended outcomes of their meeting and jointly organize the entire program during the meeting. The academic exchange meetings are held in cooperation with universities that have a special program in nuclear security and safeguards, such as the NSSPI at Texas A&M University; the Nuclear Science and Security Consortium at the University of California, Berkeley; and the Nuclear Nonproliferation Education and Research Center at the Korea Advanced Institute of Science and Technology.

Students also plan various cultural exchange programs to expose themselves to each other's different cultural, linguistic, and religious backgrounds, and in so doing, provide the opportunity for them to develop an understanding of diversity and international friendship as well.

Radiological Emergency-Response Exercise

Radiological accidents involving commonly used radioactive sources are more frequent than nuclear reactor accidents. Dojo students can take part in a radiological emergency-response exercise at the Disaster City facility of the Texas A&M Engineering Extension Service. This exercise aims to provide students with an opportunity for emergency-response training in a realistic situation and to increase their understanding of the importance of the coordinated preparedness needed to adequately respond to nuclear emergencies, including radiological emergencies.

The exercise consists of one-day field and tabletop exercises with a radiological accident scenario that involves destruction of an industrial park caused by a large earthquake. A building in the park contains radioactive materials, but there is no information on what kinds of materials or where to find them. First responders are not allowed to enter the area until the radioactive materials are accounted for. As radiological responders, the Dojo students must locate, identify, and retrieve the radioactive materials in a pile of concrete and rebar containing a series of interior tunnels that is part of the Disaster City training compound.

The emergency-response activities include identifying the

Figure 5. A radiological emergency-response exercise at the Disaster City training compound

structure that contains the radioactive materials by using a radiation detection system in a vehicle, mapping out radiation levels around the accident scene using different radiation detectors, and determining the best entry point into the pile and the safest tunnels to use in the pile. Several different types of radiation sources, such as Co-60, Na-22, Eu-152, and Cs-137, are used for the exercise.

A major element of the exercise is teamwork. The students enter the tunnel in teams of two, as shown in Figure 5, and explore within a limited time frame. Once they exit the tunnel, they must map where they have been and the dose rates they recorded and pass this information to a new team who will continue the mission. The students have to share information until the threat situation is identified and characterized.

Practical Experience of Nuclear Security and Safeguards Facilities

Another hands-on component to enrich the overseas educational and training tour program is to give students firsthand experience of international nuclear security and safeguards facilities. Dojo students can have practical experiences with various nondestructive assay methods and instruments at the Idaho National Laboratory (INL), which has standardized the IAEA safeguards equipment and deployed that equipment in field configuration to perform spent fuel measurement, gamma-ray spectrometry, and neutron counting. INL also has an IAEA training course designed for training candidates who desire to be safeguards inspectors.

The practical experiences of the equipment involve spent fuel measurements using a digital Cherenkov viewing device, isotopic measurements of plutonium using handheld radiation detectors and a miniature gamma-ray and neutron detector system, and design information verification activities of safeguard-relevant facilities using a 3D laser range finder (3DLR). The students can also participate in a computerized surveying experience of nuclear facilities by a virtual reality system, the Computer Assisted Virtual Environment at the Center for Advanced Energy Studies, which is a research and education consortium between INL and local universities. This system is expected to be combined with nuclear security systems, where the 3DLR can be used for computerized mapping of nuclear facilities.

Technical Visit to International Organizations and Nuclear Facilities

The overseas educational training tour program also includes technical visits to international organizations and nuclear facilities abroad, which aim to expose students to the international arena and give them relevant knowledge about global issues, challenges, and goals. Dojo students have the opportunity to visit the IAEA, the CTBTO, the United Nations (UN), and the World Bank and to tour nuclear facilities related to reprocessing, interim storage, and disposal in France, Sweden, Switzerland, and South Korea.

The visit to IAEA headquarters enables students to gain a better understanding of the IAEA's mission and work, especially that of the Departments of Nuclear Safety and Security and Safeguards, through briefings by and conversation with IAEA specialists. It also provides an opportunity for students to meet with some IAEA deputy directors general and department heads and receive their professional advice as global leaders. At the CTBTO, students visit the International Data Centre and learn about the ongoing buildup of the verification regime of the Comprehensive Nuclear-Test-Ban Treaty (CTBT), which is designed to detect any nuclear explosion conducted on Earth that occurs underground, underwater, or in the atmosphere. They will realize the importance of the need of the entry into force of the CTBT and the many difficulties that need to be overcome in implementing this regime.

The visit to UN headquarters is a combination of a visitor tour to facilitate a general understanding of the UN's mission and work and a technical visit to the UN Office for Disarmament Affairs (UNODA), where the students can receive briefings on disarmament matters from UNODA officials and discuss the Treaty on the Non-Proliferation of Nuclear Weapons. At the World Bank, students will exchange opinions with officials on why the World Bank Group, which consists of five institutions, does not currently

engage in providing support for nuclear power while it continues to support and finance renewable energy.

During the visit to international organizations, female students realize that the international organizations are trying to increase the number of women staff in the professional fields and to produce friendly working environments for women. They are encouraged to think about their own future role as women professionals and be inspired to take leadership roles in their fields.

The technical tour of the AREVA La Hague reprocessing plants in France involves visits to the spent fuel unloading facility, spent fuel storage pool, vitrification facility for fission products and other discarded waste, main control room, and decommissioning facility. They also have the experience of handling the remote manipulators and glove box equipment. The students will learn and converse about safety, environmental impact, and social acceptance of the reprocessing facilities as well as the reprocessing technologies and handling of waste from the process.

In Sweden, students visit the spent fuel handling facilities of the Swedish Nuclear Fuel and Waste Management Company (SKB) at Oskarshamn, including the Clab (the central interim storage facility for spent nuclear fuel), the *Äspö* Hard Rock Laboratory (see Figure 6), and the Canister Laboratory. Students will understand the history and the way in which the SKB has been developing a method to enable the handling and management of spent fuel safely for long periods of time, and how they selected the process of encapsulating spent fuel in copper canisters surrounded by bentonite clay about 500 m underground in Swedish bedrock. This is a good chance for students to realize that public trust in the process is essential, and the process of building that trust is long term.

In South Korea, students visit the low- and intermediate-level radioactive waste disposal facility at Gyeongju, of which the first phase was completed in 2014 and the second phase will be completed by 2019. They learn that it took almost 20 years until the site selection was secured for use with the process, starting in 1986, and they recognize again that it is vital to achieve a public acceptance encompassing local government and residents.

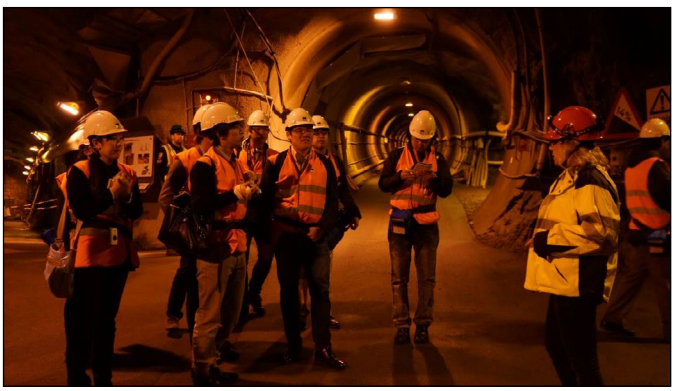

Figure 6. A visit to the underground facility at the *Äspö* Hard Rock Laboratory

Military Border Experience

An opportunity to experience the most heavily militarized border in the world is provided during the overseas educational and training tour in South Korea. The Korean Demilitarized Zone (DMZ) is an approximately 250 km long and 4 km wide truce line bisecting the Korean Peninsula into South and North Korea. It has been a mandatory military-free zone since the 1953 armistice, serving as a buffer zone between both countries.

Students visit the South Korean troops standing on the outlook at the DMZ and observe North Korea across a barbed-wire fence nearest the southern limit line, experiencing this virtual infiltration through a wire fence nearby the DMZ. They also visit the Third Tunnel of Aggression, which is one of four known tunnels located beneath the DMZ and the one closest to reaching Seoul. It was built by North Korea to send soldiers through it secretly to attack South Korea.

Conclusion

The Academy for Global Nuclear Safety and Security Agent has initiated a new nuclear safety and security education program to develop the next generation of global nuclear leaders with communication skills and social literacy as well as technical specializations in key areas of safety, safeguards, and security. The academy seeks to accomplish its mission by creating learning environments in which students are encouraged to think about their own future roles as professionals and are inspired to take leadership roles in their fields. The program prepares students to play leading roles internationally in academics, industry, and government, providing them with a special living option of a nuclear-safety-and-security interest house, an incentive scholarship, and a well-balanced curriculum of academic study and field experience.

Since 2012, the academy has accepted 30 students in five classes, among which the students of the first through third classes are currently in the doctoral program, and new students of the fifth class entered the Dojo Program in 2016. The academy will have the first graduates of the Dojo Program in 2017. Mentoring programs also provide students with professional preparation for entry into fields of work. The hope for this program is to

create balanced technical and policy leaders for building a strong nuclear safety, safeguards, and security establishment for the 21st century.

Keywords

Nuclear safety, nuclear security, safeguards, safety and security education

Plutonium Management of Japan

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Abstract

In promoting a comprehensive nuclear fuel-cycle policy, stringent management of plutonium is an absolute requirement. Japan firmly maintains the principle of not possessing excessive inventories of plutonium. This commitment has been reaffirmed at the IAEA, the Security Summits, and other meetings. Japan is evolving its plutonium management scheme (PMS) in three layers. The first layer is full-scope IAEA safeguards with all strengthening measures applied. Japan has worked closely with the IAEA, and the broader conclusion (BC) has been granted to Japan by the IAEA since 2003. Reaffirmation of the BC guarantees that all nuclear material, including plutonium, has remained in peaceful activities, and that there are no indications of undeclared activities in Japan. As the second layer, based on internationally agreed-upon guidelines, the Cabinet Office (CAO) annually publishes for enhanced transparency a "Status Report of Plutonium Management" that contains detailed information. The third layer consists of Japan's original and voluntary efforts, such as the management of reprocessing through the Nuclear Reprocessing Organization (NuRO), which is supervised by the Ministry of Economy, Trade and Industry (METI). NuRO's midterm implementation plan (MIP) specifies the amount of plutonium to be separated and utilized, which needs to be approved by METI; before granting its approval, METI must seek the views of the Atomic Energy Commission (AEC), which is one of the committees in the CAO. The AEC is the independent custodian of the PMS, and it may request corrective actions as necessary. The effectiveness of the PMS depends on the credibility of its supervision and how realistic the plutonium utilization plan is. If the utilization plan is not realistic, complementary arrangements should be added to the PMS. This paper reviews the political aspects of atomic energy policy in Japan, reflecting on the sensitivity of plutonium use and its management, and the State's responsibility in this undertaking. It evaluates the effectiveness of the PMS, taking into account the unexpected changes after the Fukushima Daiichi accident. Finally, a possible complementary arrangement is proposed for maintaining confidence of the international community even as the predictability of Japan's nuclear future remains uncertain.

History: The Plutonium Management Scheme before 2011

International Scheme

Table 1. Major historical events related to the plutonium management scheme (PMS)

1957	International Atomic Energy Agency (IAEA) Statute Article XII A.5 (excess plutonium to be deposited to the IAEA).
1970	Treaty on the Non-Proliferation of Nuclear Weapons became effective.
1972	Model Comprehensive Safeguards Agreement (CSA, INFCIRC/153) was released.
1977	Comprehensive Safeguards Agreement between Japan and IAEA.
1977–1980	International Nuclear Fuel Cycle Evaluation was conducted. The International Plutonium Storage (IPS) for Article XII A.5 of IAEA Statute was discussed.
1982	Report on the IPS was completed; related activities were concluded in 1984.
1993	Informal Meeting of Experts on International Plutonium Management took place under IAEA auspices.
1997	Guidelines for the Management of Plutonium were agreed to and published.
1997	IAEA published a model Additional Protocol (AP) in INFCIRC/540 aimed at strengthening the ability of the IAEA to detect undeclared nuclear material and activities.
1999	Japan's AP entered into force.
2003	Basic Guideline for Utilization of Plutonium (Japan Atomic Energy Commission).

Historically, plutonium management has been a cornerstone of the nuclear nonproliferation regime. Science and technology have developed dramatically over the 72 years since the Trinity test. The technology gap between separated plutonium and nuclear weapons has become narrower, and as of today, nine states possess nuclear weapons, all using plutonium and/or highly enriched uranium (HEU).[1] Therefore, naturally, the possessor of plutonium should be required to be strictly accountable for the peaceful use of plutonium. PMS was mentioned for the first

time in Article XII A.5 of the International Atomic Energy Agency (IAEA) Statute (1957), which authorizes the IAEA, in the context of Agency safeguards, to require deposit with the IAEA of any excess of special fissionable material. In 1970, the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) came into force, and in 1972, the framework for the IAEA's Comprehensive Safeguards Agreements (CSA, INFCIRC/153(Corr.)) was approved by the Board of Governors, as an agreement that specifies safeguards on all nuclear material in all nuclear activities in a state.[2] Because the INFCIRC/153 does not address Article XII A.5, PMS was not required. Several efforts to articulate PMS implementation measures have been made since then. For example, from 1977 to 1980, the International Nuclear Fuel Cycle Evaluation was conducted, and International Plutonium Storage was discussed as a measure under Article XII A.5 of the IAEA Statute, and a report was adopted on the subject in 1982.[3] This report was discussed at the IAEA's Board of Governors until 1984, when related activities were frozen. However, due to growing interest by the international community, an informal meeting of experts on International Plutonium Management took place in November 1993. Discussion focused on the need for additional confidence-building measures (CBMs) with regard to plutonium and HEU, and the Guidelines for the Management of Plutonium (hereinafter referred to as "International Pu Guidelines") were formally agreed to in 1997 by nine countries, including Japan, NPT Nuclear Weapon States (China, France, Russia, the UK, and the United States), Belgium, Germany, and Switzerland. There have been other PMS activities voluntarily implemented by possessors of plutonium. The activities in Japan and their effectiveness are the main topic of this paper.

Table 2. Projection of Japanese Plutonium balance (as of August 1995) from a white paper on atomic energy (1998)[4] "(Unit: tons Puf (Pu239+Pu241))

Balance of Plutonium storage in Japan		
1994–1999		
Annual Plutonium Balance		
Demand: Approx. 0.6 JOYO, Monju, FUGEN, etc.	Supply: Approx. 0.4 Tokai Reprocessing Plant (TRP)	Difference: Approx. –0.2
Cumulative Demand and Supply		
Cumulative Demand: Approx. 4 JOYO, Monju, FUGEN, etc.	Cumulative Supply: Approx. 4 TRP and repatriated plutonium	Difference: Approx. 0 tons Puf
2000–2010		
Annual Plutonium Balance		
Demand: Approx. 5 Monju, etc. 0.6 FBR Demonstration 0.7 Full-MOX-ABWR 1.1 MOX LWR 2.6	Supply: Approx. 5 RRP 4.8 TRP 0.2	Difference: Approx. 0
Cumulative Demand and Supply		
Cumulated Demand Approx. 35–45 Monju, etc., and FBR demonstration 10–15 Full-MOX-ABWR and MOX LWR 25–30	Cumulated Supply: Approx. 35–45 TRP and RRP	Difference: Approx. 0
Plutonium to be separated in France and the UK		
By about 2010		
Demand: Not specified. To be repatriated in the form of MOX fuel assemblies for LWR and Full-MOX-ABWR.	Cumulated separated plutonium: Approx. 30	Difference: Cannot be specified

Japanese scheme

First layer: Safeguards

Full-scope safeguards, the first layer of the PMS, have been implemented since 1977[5] by the IAEA in collaboration with the Japan Safeguards Office (JSGO) under the Nuclear Regulatory Authority (NRA), and since 1999, with an Additional Protocol (AP).[5]

The IAEA has, since 2003, concluded annually that all nuclear material, including plutonium, has remained in peaceful activities and that there are no indications on undeclared activities in Japan. According to all the information available to the author of this paper, there is no particular unresolved issue in Japan from the nuclear proliferation point of view. Nevertheless, there are still technical challenges for continuously attaining safeguards verification goals for the most complex nuclear fuel cycle (NFC) as a Non-Nuclear-Weapon State under the NPT safeguards. The provisions in the CSA/AP are generally reflected in the "Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (Act No. 166 of June 10, 1957)."[6] However, the issue of excess plutonium is not specified in any laws, since the CSA/AP does not reflect those provisions of Article XII A.5 of the IAEA Statute. Because of this, no governmental body is legally responsible for this matter at present. From a logical point of view, the JSGO is "the national system" (Article 3 of INFCIRC/255) for implementing safeguards in Japan, and the JSGO should

be accountable for overall matters of safeguards, including the matter of excess plutonium.

Second layer: Internationally agreed-upon guidelines

As the second layer of the PMS, the CAO has been publishing the Status Report of Plutonium Management in Japan (hereinafter referred to as the Pu management report[7]). The report is based on the Act for Establishment of the Cabinet Office, which specifies the CAO's role in coordinating nuclear-related issues. The report follows the International Pu Guidelines at the most detailed level. The report is usually published mid-year and contains data on plutonium as of the end of the previous year, both in Japanese and in English.[7] Simplified information, in accordance with international guidelines, is forwarded to the IAEA through diplomatic channels.[8]

Third layer: Japan's original and voluntary efforts

In addition to these internationally coordinated efforts, Japan has initiated several efforts on its own, including the 2003 CAO/AEC publication on "Basic Guidelines for Utilization of Plutonium"[9] (hereinafter referred to as "CAO/AEC's Pu Guidelines"). On the basis of these guidelines, the CAO/AEC has been evaluating the appropriateness of the Plans for the Utilization of Plutonium to be Recovered at the Rokkasho Reprocessing Plant (RRP)—hereinafter referred to as the Pu-Utilization Plan—that is submitted to CAO/AEC by Japan's electric power utilities and the Japan Atomic Energy Agency (JAEA).

In this way, Japanese plutonium has been under effective PMS, starting with the implementation of IAEA safeguards and adherence to the International Pu Guidelines, and proactive and voluntary activities for evaluating the appropriateness of utilities' plans for plutonium utilization. Until March 2011, when the great earthquake and tsunami hit Fukushima Daiichi, the consumption of plutonium at the mixed oxide (MOX) reactors was progressing steadily; the fast breeder reactor (FBR) Monju project was still intact, although it was experiencing occasional difficulties and the delay of the commissioning of the RRP; the amount of predicted consumption and the amount of separated of plutonium were generally in balance, as projected in Table 2, although at the point of the late 2000s, the delay of development of Monju and FBR demonstration was evident. After the accident, many things changed, and the predictability of future plutonium consumption has become blurred. The following sections review recent developments in Japan's NFC and the history of enhancements to Japan's PMS.

Table 3. Recent events related to PMS

09/2010	Latest plan for utilization of plutonium
03/2011	Fukushima Daiichi accident
09/2013	Ooi-4 halted operation (all LWRs halted)
08/2015	Sendai-1 restarted
01/2016	Takahama-3 (MOX) restarted
03/2016	Takahama-4 (MOX) restarted and halted. Takahama-3 (MOX) halted. The FEPC announced that the Plan for Plutonium Utilization will be unchanged, with a modified timeframe, and that modified plan would be published in near future.
07/2016	The Cabinet Office publishes the Status Report of Plutonium Management in Japan (2015). The plutonium reserves on 31 December 2015 were 47.9 ton Pu.
08/2016	Ikata-3 (MOX) restarted
12/2016	Decision to discontinue Monju project and continue development of fast reactors through utilization of JOYO and international collaboration
05/2017	Takahama-4 (MOX) restarted
06/2017	Takahama-3 (MOX) restarted

Developments after 2011

Overall development

During the past 60 years since Japan's first reactor, the JRR-1 (Japan Research Reactor-1), was commissioned in 1957, Japan has been acquiring all important technologies for closing the NFC, including enrichment, nuclear fuel fabrication, reactor technologies (including thermal and fast neutron reactors), reprocessing, and waste handling and disposal technologies. In these activities, plutonium has always been considered a precious resource for energy. As of the end of 2015, the amount of separated plutonium reached 47.9 tons Pu. While Japan continues to pursue a NFC that includes plutonium use, the magnitude of the impact caused by the Fukushima Daiichi accident has prompted a fundamental review of the future direction of Japanese nuclear activities. Japan, sooner or later, will have to revisit its nuclear policy to reflect today's situation and future prospects. Because of the uncertainties associated with the future of Japan's NFC and the utilization of plutonium, Japan needs to enhance the effectiveness of the PMS to mitigate both domestic and foreign concerns[10] that emerged after Fukushima Daiichi accident.

Three major factors of change

Table 4. Projection of Japanese Plutonium balance as of today (Unit: tons Puf (Pu239+Pu241))

Balance of plutonium storage in Japan		
Annual Plutonium Balance		
Demand: Approx. 5.5 to 6.5 MOX-LWR (16 to 18 reactors) Additionally, JOYO and etc.	Supply: Approx. 4 to 5 From the RRP	Difference: Approx. –2.5 to about –0.5
Plutonium separated and stored in France and the UK		
Demand: Not specified To be repatriated in the form of MOX fuel assemblies for LWRs, depending on the situation of restarting the LWRs and the RRP	Cumulated separated plutonium: 37.1	Difference: Cannot be specified

Among the factors that raise concerns, the most important element is the status of operation of light water reactors (LWRs) and the delay in their restart caused by substantially enhanced new regulatory requirements and the unexpectedly issued injunction against operation of LWRs. The delays in reactor restart make the latest Pu-Utilization Plan (September 2010) by the Federation of Electric Power Companies of Japan (FEPC) outdated. In March 2016, the FEPC formally admitted the delay in preparing the new plan at the AEC meeting.[11] Nevertheless, as of June 2017, five reactors, including MOX-reactors, have restarted operations: Sendai-1, Sendai-2, Takahama-3, Takahama-4 (MOX), and Ikata-3(MOX). Genkai-3 (MOX) will start operations toward the end of this year. If the reaffirmed commitment of the FEPC is actually realized, potentially more than 2 tons of fissile plutonium will be in short, and in such a case, plutonium stored in France and the UK will be repatriated in the form of MOX fuel assemblies (see Table 4). Either way, the revised Pu-Utilization Plan will be published before the commissioning of the RRP, which is expected in mid-2018 at the earliest. Given these uncertainties, it is very important that the plan for plutonium utilization is credible and realistic, particularly the expected amount of plutonium to be burned in the MOX reactors.

The second important factor is the changing strategy for developing fast reactors (FRs), discontinuing the FBR Monju project while preserving the NFC policy. Although the planned consumption of plutonium by Monju was relatively small, approximately 0.6 tons Puf (Fissile Pu: Pu239+Pu241) per year, including plutonium for JOYO and FUGEN,[4] and the impact to the plutonium balance was relatively minor, the increased unpredictability of the future use of plutonium for FR development necessitates a clearer and more logical explanation of the utilization plan. The JAEA, under the auspices of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), has to be duly accountable for this matter, and appropriately detailed plans for utilizing plutonium should be prepared.

The third important factor is the accumulated amount of separated plutonium (the "plutonium level"). As of December 31, 2015, the total amount of separated plutonium owned by Japan is 47.9 tons Pu (including 37.1 tons Pu deposited in France and the UK and 10.8 tons Pu in Japan). A slight decrease in the reserve is expected in the amount of plutonium (as of December 31, 2016). This decrease is caused by the repatriation of unspent plutonium fuel for Japan's Fast Critical Assembly (FCA), which is no longer necessary; newly burned fresh MOX fuel at the Takahama-3 and Takahama-4; and other minor reasons.

These factors need to be reassessed—namely, the unpredictability of plutonium consumption at the MOX reactors; the change in strategy for developing fast reactors; and the plutonium level, which may increase after the RRP is commissioned. Actions will need to be taken to maintain confidence by the Japanese public and the international community. In the following sections, recent PMS enhancements are described and evaluated.

Enhancement of PMS (after 2011): Overview

Japan has been adhering to the international guidelines for enhancing the transparency of the utilization of plutonium. Reported information has been improving annually, with Japan's report being the most comprehensive and detailed. In addition, in accordance with the CAO/AEC's Pu Guidelines, the FEPC submits the Pu-Utilization Plan, which is evaluated by the AEC. The obsoleteness of the current plan (which was revised in 2010) was critically pointed out in March 2016, and the AEC requested a timely revision. To mitigate the international community's concerns, Japan has been demonstrating its strong commitment not to possess excess plutonium reserves without specific purposes. This has been reiterated at every possible occasion, such as the IAEA General Conferences and the Nuclear Security Summits, at the highest possible level. In May 2016, an amendment bill to the Spent Nuclear Fuel Reprocessing Fund Act was approved by the Diet, and, accordingly, the NuRO, which is responsible for implementing reprocessing at the RRP, was established in October 2016. The Act was approved with supplementary resolutions[12] that request the AEC to assess NuRO's MIP from the viewpoint of the peaceful use of nuclear energy and securing a balance between the supply and demand of plutonium.[13]

Table 5. Enhanced PMS

PMS		Brief description of scheme
International Pu guideline	9/1997	Enhancement of transparency as to plutonium management
CAO/AEC's Pu guideline	8/2003	Verification of appropriateness of Plan for the Utilization of Plutonium by FEPCO
Fukushima Daiichi accident	**3/2011**	
Japan/U.S. joint statement at Nuclear Security Summit in The Hague and in the U.S.	3/2014 and 2016	Japan's commitment for policy of not possessing excess plutonium reserves
Establishment of NuRO and AEC's verification on the appropriateness of Pu balance	5/2016	Verification of balance between separation and utilization of plutonium
Basic Policy for Atomic Energy in Japan (for public comments)	4/2017	AEC's commitment for policy of not possessing excess plutonium reserves
Clarification of role for managing plutonium	4/2017	Clarification of role of the AEC in verifying balance between separation and utilization

Recently, the Japanese nuclear policy paper, "Basic Policy for Atomic Energy," was published by the CAO/AEC for public comments. Such a policy paper for nuclear energy has not been published during the past 12 years. The upcoming policy paper, where the Japanese commitment for appropriate use of plutonium is firmly written down, is the most important development after Fukushima Daiichi accident.

The CAO/AEC believes that this policy document will be officially endorsed by the Cabinet Meeting in summer 2017, at which time this commitment will become fully effective. In this way, Japan is enhancing its PMS. The question remains whether this enhanced scheme is sufficiently effective under the changing environment surrounding Japanese nuclear activities. This paper now reviews the effectiveness of the PMS.

Effectiveness of the PMS

The effectiveness of the PMS should be reassessed in the context of the environment affecting the use of plutonium, particularly after the Fukushima Daiichi accident. It is obvious that the existing scheme is becoming insufficient. The question is how the PMS can be enhanced. Before 2011, the CAO/AEC's evaluation of the Japanese Pu management reports and the Pu-Utilization Plan effectively functioned as transparency measures for plutonium management by broadly comparing the plan and the stockpile. The steady progress of pluthermal (defined as "the use of plutonium in thermal reactors"—that is, LWRs) and FR development activities gives certain confidence to the PMS. However, today's situation, where both plans and stockpiles have decreased their predictability, requires enhanced measures and the development of another set of CBMs in order to increase, or even maintain, the current level of confidence. These include transparency, control and management, verification, and political commitment. These four aspects reflect the report of the Secretary-General of the United Nations' Comprehensive Study on Confidence-Building Measures (1981) and other related studies.

Effectiveness: Safeguards based on CSA/AP

Table 6. Effectiveness of enhanced PMS

Plutonium management elements	CBM aspects*	Effectiveness of CBMs
1. Safeguards based on CSA/AP (1977)	CM/V/T	Basis of all CBMs. BC since 2003.
2. International Pu Guideline (1997) and the annual reports based on the guideline (1994)	PC/T	The most detailed level of information is provided to the IAEA and directly to international community.
3. CAO/AEC's Pu guideline (2003)	T/CM/V	Effectiveness depends on reliability of the Pu- Utilization Plan by the FEPC and JAEA.
4. Japan/U.S. joint statement at the Nuclear Security Summit in The Hague and in the U.S., repatriation of plutonium based on bilateral agreement (2014, 2016)	CM/PC	The strongest level of commitment, and actual actions accompanied.
5. Establishment of NuRO and AEC's evaluation on the appropriateness of Pu balance through recommendation for the MBP (2016)	T/CM/V	Effectiveness largely depends on the reliability of the Pu-Utilization Plan and the quality of the analysis of Pu balance to be conducted by the CAO/AEC.
6. Basic Policy for Atomic Energy in Japan (2017)	T/PC	Formal policy document, since previous one in 2005, and one needs to see how it will be treated by Cabinet meeting.

* CM: control and management; PC: political commitment; T: transparency arrangement, V: verification;

First of all, IAEA safeguards should be considered to be the cornerstone of all efforts for managing all nuclear materials, including plutonium. Safeguards have been essential for the control and management of plutonium and its verification. The results of safeguards implementation are reported to the Board of Governors of the IAEA; this reporting contributes to the transparency of the process. However, IAEA safeguards cannot specify

the destiny of specific separated plutonium in advance, the reactor where it is going to be utilized, or when, for example. In

that sense, IAEA safeguards only satisfy a part of the PMS objective. Nevertheless, Japan has been granted the BC since 2003, and all nuclear material (including plutonium) and related activities are considered to be used exclusively for peaceful purposes. As is well known, since IAEA safeguards are firmly established, there is not much room for enhancing their effectiveness as a CBM. All Japan can do is to maintain the BC, while strategically maintaining the necessary human resources and their skill levels.

Effectiveness: International Pu Guidelines (1997)

The International Pu Guidelines were originally intended to improve the effectiveness of the PMS through enhanced transparency by setting up common rules for information to be reported. Japan has demonstrated its strong political commitments on this issue by submitting comprehensive reports since 1994, even before the Guidelines were formally agreed to in 1997. The quality of the reports has been continuously reviewed and improved, and they will remain one of the most important sources of information on plutonium management by Japan. However, there are still minor fluctuations in the IAEA's definition of "unirradiated, separated plutonium," and fine-tuning corrections are required for improved control and management. The report could be more effectively used through occasional briefings and discussions with international partners whenever possible and appropriate, for further enhancing transparency, as will be discussed later in this paper.

Effectiveness: CAO/AEC's Pu Guideline (2003)

Following the CAO/AEC's Pu Guideline, the electric utilities need to submit a Pu-Utilization Plan to the CAO/AEC for its review every year before the start of plutonium separation. At the same time, the JAEA submits its plan for utilizing plutonium. Subsequently, the CAO/AEC reviews these plans, including interviews with the operators and the JAEA for clarification concerning the volume, reactors, and timing of consumption of plutonium. This evaluation by the AEC is conducted publicly. Thus, from the CBM point of view—such as transparency, control and management, and verification—this is considered to be effective as long as the plans are timely and reliable. In that sense, the latest utilization plan was published in 2010, before the Fukushima Daiichi accident in 2011, is completely obsolete and unrealistic. The updated plan should be published and reviewed as soon as possible. If not, the trust in the Japanese commitment not to possess excess plutonium will be questioned, and hence the CAO/AEC should request the FEPC to revise the utilization plan immediately, and such a clear message should be spoken out by the AEC. The effectiveness of this scheme is largely dependent on credibility and how realistic the plan is. The major concern of the CAO/AEC is the plan's reliability—namely, the projection of MOX utilization at the LWRs and the JAEA's program for utilizing plutonium that was originally stored for FR development.[14] The JAEA reserves 3.6 tons Pu (2.5 tons Puf) of (unirradiated) separated plutonium in various forms, and the JAEA needs to develop a concrete utilization plan for that plutonium. At the same time, in order to strengthen the control and management aspect of this scheme, the CAO/AEC should more clearly define a "plutonium balance" to enable stakeholders to discuss this matter on common ground.

Effectiveness: Political Statements (2014)

Japan has reiterated its firm political commitment to plutonium balance at every possible occasion. For example, during The Hague Nuclear Security Summit in March 2014, Prime Minister Shinzō Abe stated that, "with regard to plutonium, we will firmly maintain our policy that we should possess no plutonium reserves without specified purposes. In order to effectively carry out this policy, we do pay due consideration to the balance between supply and demand of plutonium. What will continue, also, is our most careful management of the reserves."[15] At the same time, a large amount of plutonium in the form of fresh fuel for the JAEA's FCA has been repatriated to the United States as part of the control and management of the plutonium. Other examples of similar political statements are those made at the IAEA General Conference, as well as the IAEA International Conference on Nuclear Security in December 2016, where representatives at the ministerial level demonstrated strong commitments to the peaceful use of nuclear energy, including plutonium. Political statements are crucial for CBMs, but they are not sufficient unless tangible outcomes, such as reduction of plutonium levels, are continuously demonstrated under a reliable scheme in a transparent manner.

NuRO's Midterm Implementation Plan (2016)

The CAO/AEC's Pu Guideline requires the FEPC to revise the Pu-Utilization Plan before the start of the RRP. Per this plan, the NuRO is to prepare a draft Revised MIP that will include the amount of plutonium to be separated at the RRP as a transparency measure and a control and management measure. The Minister of METI is legally responsible for reviewing and authorizing the plan, which is to specify the balance between consumption and separation of plutonium. In advance of METI's authorization, the AEC is expected to evaluate the appropriateness of the balance between the amounts of plutonium to be used at the MOX

reactors and the planned amount of plutonium to be separated at the RRP.

The effectiveness of this scheme largely depends on the reliability of the plan. The evaluation of the planned amount of plutonium to be separated must be rigorous. Given that its mandated role is not based on the law, but on a supplementary resolution of the Diet, the CAO/AEC needs to develop as solid an institutionalized process for evaluating the MIP as possible. The effectiveness of this CBM depends on the comprehensiveness and concreteness of the modus operandi of the process, which should fully consider the timing of commissioning of the RRP, its operational mode in coming years, the timing of commissioning of JMOX, and the amount of plutonium to be reserved (plutonium input buffer stock[16] or the fabrication input buffer [FIB]) for starting and continuing production of MOX Fuel Assemblies. As the RRP reserves 3.6 ton Pu (2.3 ton Puf) at the end of 2015, it needs to additionally separate the amount of plutonium equivalent to the difference between FIB-JMOX (ton Puf) and 2.3 (ton Puf) in time for commissioning JMOX. The RRP will have to clearly explain this point from the point of view of transparency and control and management.

Basic Policy for Atomic Energy and Clarification of Role of CAO/AEC (2017)

The CAO/AEC has published a draft of the Basic Policy for Atomic Energy for requesting public comments at the end of April 2017. The policy will soon be endorsed by the Cabinet Meeting, requiring all relevant ministries to duly respect the policy. The Basic Policy reemphasizes Japan's commitment to not possessing excess plutonium by striking a strict balance between separation and consumption of plutonium. Hence, it serves as a powerful measure of transparency and political commitment. In this regard, the NRA clarifies the role of the CAO/AEC in evaluating the plutonium balance as the custodian of the process; the response by the CAO/AEC confirmed such responsibility in April 2017. These two events added to the confidence level of Japanese commitment for proper plutonium management and clarified the custodian role of the CAO/AEC. Based on Article 2a.(x)[17] of the AP to the Safeguards agreement between the IAEA and Japan, the Japanese Government will provide information as to the Basic Plan as a part of the declaration. This information will contribute to further transparency as to Japan's policy for the NFC.

Overall Assessment

In reviewing the effectiveness of Japan's PMS from the point of view of specific CBMs as the elements of transparency, control and management, verification, and political commitment, these are generally addressed in the PMS. They were sufficiently effective before 2011. However, today's nuclear situation requires enhance-

Table 7. Additional measures when predictability is low

Phase	Definition of each phase	Predictability	Additional enhancement measures
Transitional phase	The impact of the Fukushima Daiichi accident is still strong enough to cause unexpected delay of plutonium consumption. There could be fluctuations in the balance sheet of plutonium. This phase might last for 5 to 10 years.	Quite low	Introduction of external review process or auditing activities by the IAEA or a bilateral partner might prove effective. Review takes place rather frequently.
Stabilizing phase	At this point, Pu consumption at LWRs steadily increases, surpassing the amount of separation, and total amount of plutonium continuously decreases.	Low	External review mechanism is effective, whereas frequency could be lower compared to the period of transition.
Plateau phase	Finally, at this point, Japan possesses the amount of plutonium necessary for stable fabrication of the MOX fuel assembly and fuel for JOYO, and other research activities under a crystal-clear utilization plan.	High	No particular needs for review mechanism by third party.

ment of the PMS. Emerging issues need to be addressed, such as a clearer definition of "plutonium balance" and "excess plutonium," including treatment of the FIB to be defined for JMOX and shared among stakeholders; the urgent need for a Pu-Utilization Plan with sufficient credibility and appropriate timing; and the timely establishment of an institutionalized mechanism for the CAO/AEC's evaluation of the MIP, including all stakeholders, such as the CAO/AEC, FEPC, and JAEA. However, even if these issues are properly addressed, there is a possibility that the plutonium level will increase. If that is the case, a logical and convincing explanation will be required. The concept of the FIB will become a key element, and contingency measures, such as the possible transfer of ownership of plutonium deposited in Europe or the disposal of plutonium that is no longer practically valuable, might be required.

Further Enhancement of Credibility of the PMS

Phased Approach

As the previous section reviewed, although it is fair to say that Japan's PMS is the most stringent scheme for managing plutonium, the effectiveness of the whole scheme largely depends on its credibility and how realistic the plan is for utilizing plutonium, and the rigorousness of the review by the CAO/AEC. More concretely speaking, the critical and dominant factor is how realistically plu-thermal can be projected by utilities and how convincing is the plan that the JAEA develops. This crucial and difficult challenge derives from the unpredictability of nuclear business in today's transitioning period, which will last for the foreseeable future. The level of opaqueness will be gradually reduced in the long run and, depending on the size of the gap between the clarity of the plan for plutonium utilization and the expectation of the stakeholders, Japan needs to fill the gap to maintain the confidence of the international community.

Possible External Review for Enhancing PMS

The strength of such additional measures can be adjustably implemented depending on the predictability level. For example, the current situation is still in a "transitional phase", from "immediately after accident" to "after accident," where the impact of the Fukushima Daiichi accident is still strong enough to influence the plutonium consumption. After some time, say 5 to 10 years, the "stabilizing phase" will come, when the nuclear environment becomes more stabilized and the consumption of plutonium surpasses its separation, and the total amount of plutonium gradually decreases. Finally, the "plateau phase" will arrive when Japan possesses only the FIB that is necessary for stable fabrication of MOX fuel assemblies for LWRs, JOYO, and other research activities pursuant to a crystal-clear utilization plan.

During the "transitional period", the proposed plan might be rather vague, and the level of credibility might be lower; the scale of plutonium consumption might remain at low levels. During that period, the introduction of an external review process, or auditing activities by the IAEA or a bilateral partner, might be effective for additional confidence building. Such an external review, or auditing activities, could be implemented during bilateral meetings between Japan and the IAEA or the United States, for example. In such an occasion, Japan and its international partner discuss all detailed information and review the appropriateness of the Pu-Utilization Plan and the balance of plutonium. This kind of review could take place frequently, depending on the level of clarity of the plutonium utilization plan. In the same way, even during the "stabilizing period", such a mechanism could be useful, perhaps permitting a lower frequency as compared with the "period of transition". When the "plateau" arrives, at which time the plan will become more reliable and current PMS will effectively function, there may no longer be a particular need for a third-party review mechanism. However, apart from the expected gradual changes in predictability mentioned earlier, one should always consider unexpected risk, such as the injunction preventing operation of nuclear power plants (NPPs), which happened to Takahama-3 and Takahama-4.

Other Issues to Be Addressed

For enhancing the PMS, other issues need to be addressed before the RRP is commissioned. Relevant organizations need to be prepared for some questions to be posed, such as: What will the AEC advise if the expected consumption of plutonium is smaller than planned separation at the RRP (while considering FIB)? Is it possible for the AEC to recommend reduced separation of plutonium at the RRP, lower than capacity, from the point of plutonium balance? Should one consider transferring plutonium originally planned for FR development to JMOX for fabricating the MOX fuel for LWR? The JAEA is said to use this plutonium at JOYO for the next 20 years, but questions remain as to how realistic that is. These are important questions to be properly answered in the coming years, and for that, a clear stance and policy for plutonium levels will need to be defined. Furthermore, one should also consider how to respond to important questions, such as those posed by James Acton[18] in September 2015 about the possible transfer of ownership of the (37 tons) plutonium deposited in Europe to France and the

UK. On this point, one should be reminded that the UK does not currently have MOX fabrication capability, and the one at the MELOX plant in France has a limited capacity. "How can they use the Japanese plutonium?" If one is going to use Japan's plutonium for the ASTRID project, a new MOX fabrication plant needs to be built in France. "Who will pay for that?" If the amount of plutonium in storage remains large for the coming years, Japan should enhance its nuclear security arrangements. Finally, although the PMS is a scheme for managing plutonium for future use, one could also consider contingency measures, such as the possible disposal of plutonium that is technically "dirty" or useless for other reasons. Research and development should be pursued on this possibility.[19]

Conclusion

The 2017 Preparatory Committee for the 2020 Nuclear Non-Proliferation Treaty Review Conference just took place recently. Nonproliferation will be more frequently discussed in the international community. 2020 will be the 60-year anniversary of the NPT. Taking into account the significant changes over the past few years, it is high time for Japan to revisit and verify the effectiveness of existing schemes, such as the PMS. While the author of this paper considers that Japan has been successfully implementing its PMS with continuous improvement, some emerging issues—such as the delay of restarting LWRs after the Fukushima Daiichi accident and the discontinuation of the Monju project—will trigger questions, from the domestic and international communities, as to the effectiveness of the PMS and the level of plutonium available to Japan. Japan needs to be prepared for these questions. Newly added CBMs, such as the evaluation mechanism of the NuRO's MIP, must be properly developed and implemented, continuously reviewed, and improved to maintain confidence in the Japanese commitment not to possess excess plutonium. Repeated public statements of the principle of not possessing excess plutonium are no longer sufficiently convincing. More tangible improvement, such as a clear target for the plutonium level, might become necessary. The CAO/AEC is mandated to evaluate the MIP from the point of view of plutonium balance; they will recommend modification of the MIP, if deemed necessary. In order for the CAO/AEC to perform its role effectively, a credible and concrete plan for the utilization of plutonium is indispensable. However, such a plan will not be available during the transitional phase. During that period, Japan needs to develop supplementary measures for ensuring the effectiveness of existing CBMs. Third-party participation in the PMS process would enhance the effectiveness of the scheme. The IAEA or another bilateral partner, such as the United States, could be a potential participant in that process. One could also establish an International Advisory Group for PMS. The CAO/AEC should act as the custodian of the PMS and the assurer of the peaceful use of atomic energy. Before the commissioning of the RRP, there is more homework to do, such as a clearer definition of the plutonium balance, logical consideration as to FIB, and revision and publication of a Pu-Utilization Plan with sufficient credibility in a timely manner, with a clearly institutionalized process for evaluation by the CAO/AEC. Such an evaluation mechanism should be resilient enough to adapt to changing situations, including unexpected events such as the injunction preventing operation of NPPs. The Basic Policy for Atomic Energy, where the CAO/AEC has firmly committed to assuring the peaceful use of atomic energy, will be finalized and endorsed by the Cabinet Meeting soon. This is the highest level of commitment by Japan to the peaceful use of atomic energy. The Basic Policy must be duly respected by relevant ministries, and the enhancement of the PMS carried out in accordance with the basic policy in an effective and timely manner.

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Book Review

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The Neutron's Long Shadow

Martin Miller

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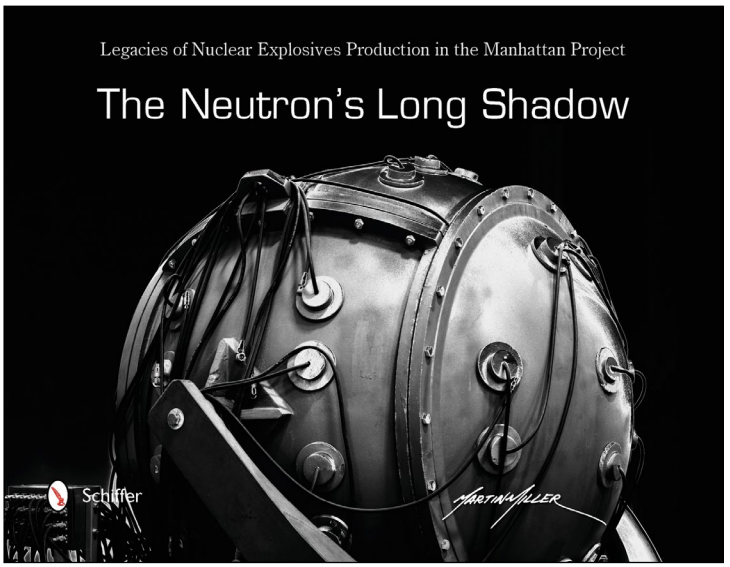

I have always admired books that support the technical material that is learned in the classroom. These are the biographies of the scientists and engineers in our fields, the histories of their great scientific discoveries, and now becoming more numerous are the histories of the technical advances made in the 20th century. Among them, perhaps leading the way in some respects, are the histories of the atomic bomb-making apparatus of the United States. Some have even been reviewed in this column—*Longing for the Bomb: Oak Ridge and Atomic Nostalgia* (University of North Carolina Press, 2015) being one of the better known of this type.

In *The Neutron's Long Shadow*, whose title references the eternal legacy of bomb-making materials granted us by virtue of the efforts at Hanford, Washington, and Oak Ridge, Tennessee, Martin Miller takes readers on a photographic journey of both facilities using U.S. Department of Energy (DoE) archival photos and his own photographic expertise. The result is impressive if not beautiful, striking if not glorious—for how can bolts, steel, and concrete designed to be functional be anything but raw engineering? Ah, but that is not the point.

Industrial photography may be viewed as the poor stepsister of artistic (or all other) photography. But, beauty can indeed be said to be in the eye of the beholder. Photos of factories, laboratories, and otherwise arcane buildings of little architectural value will be admired by those with a special interest in them. And there, quite simply, is the worth of Miller's long, hard work. For those of us who still wonder at the achievements of atomic physics that resulted in the bomb, we can now wander through *The Neutron's Long Shadow* in the comfort of our armchairs without breaking a sweat in the hot Nevada or Tennessee sun, traversing the many miles needed to see the facilities in which humankind isolated the fissile materials that brought a world war to its end.

Having been employed at the DOE for several years back in the late 1980s, I came onto the scene far too late to have fully appreciated this undertaking. My classroom training in health physics and the rather superfluous reading I had done about the building of the bombs left the Nevada test site, Hanford, Oak Ridge, Savannah River, and other historical sites as unfelt, unseen mysteries—unfathomable in their scope of effort, output, and enormity of engineering. Their descriptions only hinted at the greatness of the achievements and the heroism and dedication of the men and women who labored at them. But most importantly, unless one put in some effort to correct their invisibility and mystery, these sites were just names, void of mass, size, or volume. Miller has changed that—at least for two of these temples to the bomb.

While in government service in those days, I could not help notice that the architecture, office furnishings, and laboratory equipment—even the font on the facility signs and letterheads—spoke to the decades that predated my entry on the scene. The place had a tacit sense of heritage. Government scientists protect their equipment: their legacies often remain on daily display, if not still in operation. The wooden chairs that you worked in or the glass-topped conference room tables that you debated at also remained from previous times, subtly reminding you that you are but one link in a long chain of predecessors. You could sense the antiquity of the place by the enameled green paint on the equipment

controls, the exposed nuts and bolts that held a test chamber together, or just the oddly colored linoleum floor that was periodically waxed to a polish that betrayed its age by its imperfect sheen. The place had a feel to it. Miller's photographs—as stark and unbeautiful as they may appear—evoke such memories. He achieved a goal beyond mere visual recording of historic facts.

This book has three main components. The first is a text of some 78 pages written by Miller, explaining the overall atomic bomb effort and in particular the contributions made at Hanford and Oak Ridge. The second component is intertwined with the first. These are the DOE archival photographs that support the text. All of them are high-quality black-and-white images that put reality to the history. Some are quite impressive, particularly the panoramic images of Hanford that show its immense expanse. The final component is a gallery of Miller's more recent photographs—92 high-resolution images comprising about 110 pages of the book. Here, Miller captures the facilities that have been, are being, or will soon be demolished as remediation work progresses at both sites: history literally disappearing before our eyes. His photographs are also black and white, and much like a cinematic experience from before the late 1960s, this choice is deliberate, adding a patina of age to the images and damping the distraction color might bring to them. One can speculate, for example, that the big blue sky out at Hanford might dominate a panoramic of the site and detract from photographer's true aim: to impress upon the viewer the size and emptiness of the reservation.

And indeed, expansiveness is conveyed. The Hanford and Oak Ridge complexes are sprawling. From the perspective of the 21st century, this is all the more impressive. Without being there to witness it, it is simply incredible to contemplate how buildings such as the K-25 gaseous diffusion plant (Oak Ridge) were conceived and executed. The labor alone, we are told, involved nearly 20,000 workers. Even that number seems to be not enough to construct such a massive building. Miller was not shy in obtaining his photographs. Where he was allowed to shoot (permissions were de rigueur), he did so with pleasure—getting in close or, by stepping back, framing a facility with its associated landscape, thus putting the viewer at the front door or in the neighborhood as was his whim.

Perhaps equally striking, but in terms of the history of technology, are the interior photos (both from the DOE archives and by Miller) of the many buildings, reactors, and support facilities at both complexes. In the close-ups, one can recognize many familiar components that have survived into the digital age, and much more that hasn't. It was totally an analog environment populated by strip charts and galvanometer-type readouts. One can feel the grittiness of the technology: screws and bolts hold together towering metal control panels crowded with mechanical switches and rheostat-like knobs. The government-issued wooden chairs, so out of context with all the metal, toggles, and push-buttons, are common foreground accoutrements.

The book is constructed beautifully—a tribute to both author and publisher. Layout, headers, fonts, and paper weight were well considered, resulting in a look that is befitting of both its industrial subject matter and its historical intent. The text is concise and informative. Facts prevail, with the occasional musing by the author on controversial issues. Miller explains the bomb-making process in four chapters that cover enriched uranium production, plutonium production, overcoming production difficulties, and postwar turmoil over use of the bomb. There are helpful process diagrams, Hanford and Oak Ridge site maps, and photographs of notables such as Lieutenant General Leslie Groves and Robert Oppenheimer, among others. Even the captions convey interesting information—no space was wasted in this telling of atomic bomb history. Endnotes and a chronology of atomic bomb-making events are appended. In perhaps his most poignant statement, Miller reminds us that the creation of the bomb may never be surpassed as an example of humankind's boundless creativity and the terrors that accompany such ingenuity.

In a final assessment of the Manhattan Project, Miller notes that the neutron, the soul of the fission process, does indeed cast a long shadow. In 16,000 years, assuming it is not used, nearly 99.90 percent of the U-235 and about 66 percent of the plutonium produced will still exist. After several hundred years more, there will still be enough plutonium to make another Fat Man bomb. The enriched uranium needed to build a Little Boy bomb will be present for 10 billion years—longer than the estimated habitability of planet Earth. And here we see that atomic-technological history has a bidirectional reach. As we look back in time through Miller's photographs, we must always remember that what they portray—no matter how anachronistic—reaches deeply and ominously into humankind's immeasurable future.

This book review ends a productive association with Patricia Sullivan, managing editor of the Journal of Nuclear Materials Management, who is moving on to other challenging prospects. As every published writer knows, a good editor who works with you is essential. Patricia has indeed been indispensable and is likely to succeed anywhere she goes. This writer wishes her well.

Taking the Long View in a Time of Great Uncertainty

Living in Interesting Times

Jack Jekowski
Industry News Editor and Chair of the Strategic Planning Committee

"May you live in interesting times" is a statement that you may have often heard when individuals reflect on dramatic changes that lie ahead.[1] I have used it myself in conversations, more frequently these days, when it seems that the world around us has become too complex or is being turned on its head.

As this column goes to print, we are seeing an escalating war of words and demonstrations of military might between the United States and North Korea, with President Trump threatening to totally destroy North Korea if the United States were forced to defend itself or its allies,[2] and launching ever-threatening bomber test runs in the Korean Peninsula with fighter escorts from South Korea and Japan.[3] Meanwhile, North Korea is saying it will test a hydrogen bomb in the Pacific Ocean,[4] and that the United States has declared war.[5] There is also growing concern across the international community that President Trump will not certify the Iran Deal compliance, and tensions continue in the Middle East and the South China Sea.

These and many other events in the global community, which have been explored in more detail in recent "Taking the Long View" columns,[6] overwhelm the senses, sometimes even beyond the "interesting times" catchphrase.

Another Successful Annual Meeting

The 58th Annual Meeting in Indian Wells, California, this past summer provided an opportunity for more interesting times in our own world, as the Technical Program Committee, under the leadership of Teressa McKinney, continued to test new formats to provide greater value for participants and to better engage attendees in these important discussions. On Tuesday afternoon, word of an unusual panel session quickly spread via social media in real time, including through a new Annual Meeting app called *Whova*. The session featured two concurrent presentations by Sig Hecker, who spoke about the lab-to-lab initiative he led in the 1990s and the new two-volume history of those events, entitled "Doomed to Cooperate: How Lab-to-Lab Nuclear Cooperation Helped to Avert Post-Cold War Nuclear Dangers."[7] Subsequent, closely linked presentations by Harvard's Matt Bunn and the Nuclear Threat Initiative's Leon Ratz followed through with concepts stimulating the audience on how we now need to view the current world through new glasses. As word spread on the new social media conduits, the large room quickly filled to an overflowing standing-room-only crowd as attendees sat (and stood) transfixed on the expertise relating events at the end of the Cold War to the current-day environment.

As we move into 2018, the EC is continuing to plan to host a Global Security Summit that would engage technical and policy experts, as well as Institute membership, to synthesize current data and information and develop the top priorities for the Institute to address in the future. Many of the challenges the world faces today, which make these interesting times, would be the subject of conversation. These top priorities would then become focus areas for special sessions during the Annual Meetings, serve as a basis to identify potential topics and speakers for plenary sessions, and provide opportunities for special workshops.

Closer to Home

We are also experiencing some interesting times within the Institute with the deployment of the new Strategic Plan[8] and the change in our association management contractor from Kellen to Association Headquarters (AH). AH's new executive director for the INMM management contract, Lacy Lee Baker, spent the week in Indian Wells becoming familiar with the

This column is intended to serve as a forum to present and discuss current strategic issues impacting the Institute of Nuclear Materials Management in the furtherance of its mission. The views expressed by the author are not necessarily endorsed by the Institute, but are intended to stimulate and encourage JNMM readers to actively participate in strategic discussions. Please provide your thoughts and ideas to the Institute's leadership on these and other issues of importance. With your feedback, we hope to create an environment of open dialogue, addressing the critical uncertainties that lie ahead for the world, and to identify the possible paths to the future based on those uncertainties that can be influenced by the Institute. Jack Jekowski can be contacted at jpjekowski@aol.com.

Annual Meeting activities and meeting senior Institute leadership. As we move into the new Institute year, we will all be working with Lacy Lee and the other staff at AH to ensure a smooth transition. We do so recognizing the extraordinary efforts of the Kellen staff over the years, including Patricia Sullivan, whose passion and personal efforts ensured the success of the *JNMM*, and who helped many authors (including myself) provide professionally presented materials.

One objective of the Institute's new Strategic Plan was to improve the Institute's website (to "make the INMM website a more effective tool"), which is now live at inmm.org—check it out and provide feedback to Headquarters or through your local INMM chapters. We can use our website and other new technology media to leverage the collaborations offered by INMM in these interesting times to help solve the myriad of issues we are dealing with in today's complex world.

Endnotes

1. See http://en.wikipedia.org/wiki/May_you_live_in_interesting_times for information on this quote, which became popular in the 20th century but continues today to be attributed to an ancient Chinese curse. Another reference (www.phrases.org.uk/meanings/may-you-live-in-interesting-times.html) states: "No one is sure who introduced the term but the person who did most to bring it to the public's attention was Robert Kennedy. In a speech in Cape Town in June 1966, Kennedy said: 'There is a Chinese curse which says "May he live in interesting times." Like it or not we live in interesting times. They are times of danger and uncertainty; but they are also more open to the creative energy of men than any other time in history.'"
2. Holland, S., & Mason, J. (2017, September 18). If threatened, U.S. will "totally destroy" North Korea, Trump Vows. *Reuters*. Retrieved from www.reuters.com/article/us-un-assembly-trump/if-threatened-u-s-will-totally-destroy-north-korea-trump-vows-idUSKCN1BU0B3
3. US flies stealth jets and bombers over Korean peninsula amid tensions with Pyongyang. (2017, September 18). *Telegraph*. Retrieved from www.telegraph.co.uk/news/2017/09/18/us-flies-stealth-jets-bombers-korean-peninsula-amid-tensions
4. Berlinger, J., & Ullah, Z. (22 September 2017). North Korea could test hydrogen bomb over Pacific Ocean, says foreign minister. *CNN*. Retrieved from www.cnn.com/2017/09/21/politics/kim-jong-un-on-trump-comments
5. This was not the first time that North Korea had declared an incident to be a declaration for war. See Adams, B. (25 September 2017). For perspective: The North Koreans interpret everything as a "declaration of war." *Washington Examiner*. Retrieved from http://www.washingtonexaminer.com/for-perspective-the-north-koreans-interpret-everything-as-a-declaration-of-war/article/2635544 See also Hurlburt, H. (25 September 2017). Wait, are we at war with North Korea now? *New York*. Retrieved from http://nymag.com/daily/intelligencer/2017/09/wait-are-we-at-war-with-north-korea-now.html
6. Jekowski, J. Taking the long view in a time of great uncertainty: All things nuclear. *JNMM, 45*(4), 24–28.
7. See www.youtube.com/watch?v=81ZpFLO4hmE for a short video and www.amazon.com/Doomed-Cooperate-American-Scientists-Post-Cold/dp/0941232441 for the book.
8. See www.inmm.org/Members/Strategic-Plan

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