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JNMM Journal of Nuclear Materials Management

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INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

The Importance of Japan

By Scott Vance
INMM President

The final impact to the global nuclear industry from the earthquake and subsequent tsunami that occurred off the coast of Japan on March 11 are not clear. Realistically, the *final* impact probably won't be known for years. What is known, however, and unfortunately almost always ignored in media reports regarding the tragedy, is that thousands of lives were lost as a result of the devastating natural phenomena. Yes, the eventual impacts to the global nuclear industry may be significant. Yes, the monetary devastation was unfathomable. However, we should never lose sight of the loss that is truly significant by allowing the *potential* for nuclear ramifications to overshadow the *actual* human suffering caused by the initiating events. As I have personally expressed to INMM's Japanese colleagues, our hearts are deeply saddened by the tremendous loss of life as a result of these events.

Some of you may not know the significance of the Japanese Chapter to the Institute. Since its founding in 1958, INMM has had the goal of advancing nuclear materials management in all aspects. INMM works to ensure that the collective experience of nuclear materials managers around the globe is available to all professionals in the field and to encourage the adoption of best practices that continually improve the safety and security of nuclear materials. But setting a goal is different than achieving it. This is where the Japan Chapter becomes integral to the success of INMM.

The Japan Chapter was INMM's first regional chapter. Before its formation, all activities were accomplished through the international organization, which was centered in the United States. Recognizing that this geographic limitation significantly restricted the ability of some members in non-U.S. countries to contribute to the organization, individuals with foresight began to contemplate how different geographic areas could be involved more effectively. Eventually, the concept of chapters was born, wherein locally based groups of individuals could participate in advancing the goals of INMM without having to participate in the larger organization. And so, in September 1976, the Japan Chapter was formed.

The Japan Chapter never looked back. Often on the cutting edge of developing innovative ways to encourage involvement by the nuclear materials community, the Japan Chapter has continued to grow and proper over the last thirty-five years. The Institute simply would not be the organization that it is without the contributions of the Japan Chapter and its members.

But will all of the efforts of the Japan Chapter be for naught? Will the term "Fukushima" now become synonymous with "Three Mile Island" and "Chernobyl?" Time will tell, but the categorization of the event as a "Level 7" incident indicates that it will become a rallying cry for those opposed to the use of nuclear energy. At the same time, early reports indicate that there may be some very positive lessons learned. Many of the safety features were apparently pushed well beyond the design limit, and nonetheless were able to protect the general public from immediate harm from the event.

As I considered the potential impacts of this event on the Japan Chapter and INMM in general, I considered INMM's overall role in the international nuclear community. The Institute was established more than fifty years ago to promote the best practices in what is now known as materials control and accounting. However, the Institute has grown tremendously since then, and while MC&A professionals are still an important part of our membership, we now also promote best practices in facility operations, international safeguards, nonproliferation and arms control, nuclear security and physical protection, and packaging, transportation and disposition. Without question, there will be lessons learned from this event that can be applied to each of these areas. A very preliminary look at these events is included in this *Journal*, but look for much more information in the coming months. Several members suggested that we should have a special session at this Annual Meeting, but after considering this option, the Technical Program Committee determined that there was no benefit to rehashing the aspects of the situation that dominated the nightly news programs for months afterward. The value to INMM members will be to step back and consider the lessons learned from a broader perspective. Not only will the Institute work to develop that perspective and corresponding best practices, but I have every confidence that our Japan Chapter will be right there beside us, diligently and effectively working to improve industry practices based on what we learn.

I would be remiss if I failed to address many of you who are reading this because you received your copy of the *Journal of Nuclear Materials Management* at the Annual Meeting. Based on the past several years, many of you are reading the *Journal* for the first time. Welcome, both to the Annual Meeting and to the premier publication dedicated to the appropriate management of nuclear materials. I am confident that you will find both the Annual Meeting and the *Journal* to be more than you expected and pertinent to your professional life. Regardless of whether you are new to the field or have been actively managing nuclear materials for several years, I know that you will find INMM to be an organization that will be useful to you throughout your career. INMM, like the nuclear industry, is here for the long term.

Looking at Japan, WINS, and ITV

By Dennis Mangan
INMM Technical Editor

This issue of the *Journal* has three articles on three distinctive topics. The first, *The Great East Japan Earthquake and Its Nuclear Consequences,* is a thoughtful article detailing the nuclear event at the Fukushima Nuclear Power complex in Japan, that compares and contrasts it to the events at Three Mile Island and Chernobyl. This article, co-authored by Markku Koskelo (*JNMM* Assistant Editor and Senior Scientist at Mele Aquila Technologies in Albuquerque, New Mexico, USA) and Lake Barrett (of Lake Barrett Consulting in Rockville, Maryland, USA, and former acting director of the U.S. Department of Energy's Office of Civilian Radioactive Waste Management and former NRC site director at Three Mile Island), examines the circumstances that led to these three events and discusses some of the health effects that they have had or may have on residents near these sites and other surrounding areas and/or countries. It is definitely interesting reading and well done. The article's genesis is interesting. Koskelo and I attended an ANS International High-Level Radioactive Waste Management Conference in Albuquerque in April. Barrett was a speaker and provided an interesting comparison of the three events. Koskelo and I approached Barrett after the presentation to inquire about the possibility of getting a timely article in the *Journal*. Barrett didn't have time to actually write the article, but offered his slides and promised to review what Koskelo and I wrote. Koskelo and I made plans to meet on a Monday to begin the effort. During the preceding weekend, Koskelo wrote a first draft of the complete paper, which was exceeding well done. As it turned out, Barrett and I only made some minor changes and editorial comments. Although the plan was to publish this article in this issue of the *Journal*, a decision was made to likewise post it on the INMM Web site for INMM members to allow them to read the article early.

The second article is an interesting piece on the status of the World Institute for Nuclear Security (WINS) by Roger Howsley, its executive director. As you may recall, in a plenary speech to the INMM 46th Annual Meeting in 2005, the president of the Nuclear Threat Initiative, Charles Curtis, challenged us to create an organization to promote best practices in nuclear security. Within about three months, a subcommittee of a few Fellows created a blueprint for such an organization, including its name. Subsequently, a coordinating committee of members from NTI, INMM, DOE's National Nuclear Security Administration, and the International Atomic Energy Agency (IAEA) was formed to ensure WINS would have broad international support. WINS opened for business in January 2009. As Howsley notes in this article, *Promoting Best Practices in Nuclear Security through the World Institute for Nuclear Security,* much progress has been made and an aggressive schedule for the future has been formulated. INMM remains a supporter of WINS and our immediate past president serves on the WINS board of directors.

The final article, *Summary of International Target Values 2010 for Measurement Uncertainties in Safeguarding Nuclear Materials,* is authored by Charles Pietri, INMM's Annual Meeting Technical Program Committee chair and chair of our ANSI Analytical Chemistry Laboratory Measurements Control Committee. Pietri is a member of the international committee convened as by the IAEA to update the International Target Values (ITV) based on improvements in technology and schemes. Pietri's report reflects the introduction of the ITV 2010 report. The complete report is on the INMM Web site (www.inmm.org).

Finally, Jack Jekowski's Industry News article, *Taking the Long View in a Time of Great Uncertainty* focuses on the nuclear crisis in Japan and provides some key insights and questions. Jekowski's articles are definitely worth reading.

In closing, I'd like to make an observation. On May 19, 2011, I attended the Annual Technical Meeting of the INMM Southwest Chapter in Taos, New Mexico, USA. There were several members from the student chapters of Texas A&M University and the University of New Mexico as well as intern students from Los Alamos National Laboratory. For this meeting, the Southwest Chapter encourages attendees to practice presenting papers that will be presented at the 2011 Annual Meeting. The students seem to take enthusiastically advantage of this opportunity and actively participate in a spirit of helping each other. Here are the topics of the student papers:

- Safeguarding India's Advanced Heavy Water Reactor
- How to Strengthen International Safeguards: Moving Forward with the Additional Protocol
- Room Temperature Semiconductors Radiation Detectors
- Analysis of the Effects of Precipitation on Radiation Portal Monitors
- Nuclear Warhead Verification Using Nuclear Florescence
- Development and Evaluation of a Safeguards System Concept for a Pebble –Fueled HTGR
- Bent-Crystal Spectrometer Analyzing Plutonium K X-Rays for Applications in Nuclear Forensics

Impressive!

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The Great East Japan Earthquake and Its Nuclear Consequences

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Disclaimer: The interpretation of the events at the Fukushima Nuclear Power Plant is preliminary and based on public information that was available approximately one month after the earthquake. Opinions expressed in this paper are those of the authors alone.

Introduction

On March 11, 2011, at 2:46 p.m. local time a 9.0 magnitude earthquake struck off the coast of Japan at a depth of 32 km (19.9 miles) approximately 129 km (80 miles) east of Sendai, 177 km (109 miles) east northeast of Fukushima, and 373 km (231 miles) northeast of Tokyo.[1] This magnitude places the earthquake as the fourth largest in the world since 1900 and the largest in Japan since modern instrumental recordings began 130 years ago. The impacts of the earthquake and the resulting tsunami up and down the northeast coast of Japan is currently estimated to result in a tragic loss of more than 20,000 lives,[2] extensive damage, and destruction of the infrastructure (including water, electricity, gas, buildings, and roads).

Within seconds after the earthquake started, the nuclear reactors 1, 2, and 3 of the Fukushima Nuclear Power Plant went into a controlled, orderly, automatic shut down with the insertion of the control rods into the cores at each reactor and the nuclear chain reaction at each reactor stopped. As designed, the cooling system at each nuclear power plant remained in operation to carry away the residual heat, which is about 7 percent of the full power heat load. Reactors 4, 5, and 6 at Fukushima were undergoing routine maintenance and were not operating at the time of the earthquake.

Unfortunately, the earthquake had the additional effect of causing the power plant to be cut off from the Japanese electricity grid, which caused a rapid loss of power for the cooling system. Nuclear reactors have backup systems for such events and backup diesel generators kicked in to continue cooling the reactor cores.

For the first hour or so after the earthquake hit the plant, the backup generators continued to operate as planned providing core cooling. However, when the tsunami arrived, it flooded the diesel generators causing them to fail. It should be noted that the tsunami was much larger than ever anticipated. The best estimates based on physical evidence, such as discoloration in the walls at the reactor buildings puts the height of the tsunami wave at more than 14 meters (46 feet).[3] Based on historical data, the design basis for the Fukushima plant was a 5.7 meters (18.7 feet) tsunami.[4] For added safety margin, the reactors and diesel generators were placed at 10-13 meters (33-43 feet) above sea level, which clearly was not enough for an historical event like this.

When the diesel generators failed after the tsunami, the operators switched to yet another core cooling backup system, a battery controlled passive isolation condenser for Unit 1 and steam-turbine-powered injection pumps for the newer Units 2 and 3. These cooling systems appeared to provide core cooling for approximately eight hours, until the batteries ran out. Once these systems failed, there was no plant system available to cool the cores. The loss of reactor cooling finally led to the overheating of the cores and the subsequent chain of other events that has caused all the news and the concerns. That is also when the inevitable comparisons to Three Mile Island and Chernobyl began. In the following, a view on what happened at Fukushima based on publicly available sources about one month after the earthquake is presented. New information will undoubtedly be available by the time this makes it to print. In particular, differences between Fukushima and Three Mile Island and to a lesser extent between Fukushima and Chernobyl will be highlighted. This is not intended to be a detailed timeline of the events as they happened but rather an overview and a comparison of how similar the world's reaction seems to be to these events. For a detailed analysis of the timeline see, for example, http://www.iaea.org or http://en.wikipedia.org.

Three Mile Island Unit 2

The Three Mile Island (TMI) nuclear power plant in the United States had a cooling malfunction at 4 a.m. local time on March 28, 1979, which caused part of the core to melt in the number 2 reactor (TMI-2). The TMI-2 was a pressurized light water reactor (PWR) with the typical multilayer containment design of its era. Virtually all releases were basically contained within the reactor containment building. Some radioactive gas was released during the accident, but not significant amounts. There were no injuries or adverse health effects from the Three Mile Island accident. Inadequate operator response to deficient control room instrumentation proved to be root causes of the accident.[5]

The accident was initiated by a relatively minor malfunction in the secondary cooling circuit. This caused a relatively routine automatic reactor shutdown. However, a relief valve on the pressurizer failed to close, but instrumentation did not reveal this failure. This made the operators unable to diagnose or respond properly to the loss of coolant from the stuck open valve. Because they did not know the valve was stuck open, they believed the system was nearly full of water because the pressurizer water level indication remained high. Thus, they prevented the addition of cooling water believing there was too much water, when in fact there was not enough. Instead, the reactor coolant water boiled away, the reactor's fuel core was uncovered, and fuel rods overheated, and were severely damaged, with some melting and releasing most of the core's highly radioactive material into the cooling water. The residual decay heat boiled away much of the primary coolant resulting in a partial meltdown of the fuels rods. These events are illustrated in Figure 1. Finally, the situation was diagnosed correctly and cooling to the core was restored at 7:50 p.m. on the same day.

While the fuel rods were exposed during the morning of March 28, a high-temperature chemical reaction between water and the zircaloy cladding of the fuel rods created hydrogen gas. In the afternoon of March 28, the control room instruments indicated a hydrogen burn had occurred (see Figure 2).

The "hydrogen burn" at 1 p.m. in the containment was a deflagration of the hydrogen gas released from the overheated core, but the strong (~four-foot thick reinforced concrete) containment building contained the pressure spike.

Core cooling was restored by operating the large main coolant pumps with heat being rejected through the steam generators. The operation of the main coolant pumps required some highly contaminated primary coolant to be circulated into the Auxiliary Building. This highly contaminated water in the main coolant loop caused contamination and radioactive gases to be released in the Auxiliary Building ventilation system. This led to uncertainty in releases from the plant and on Friday morning produced a reading of 12 mSv (1,200 mrem) directly above the stack of the auxiliary building. Unfortunately, this led to misunderstandings and officials concluded that the 12 mSv (1,200 mrem) reading was an off-site reading and a misunderstanding that another hydrogen explosion was possible. That caused an evacuation order around the plant. The resulting exodus from the area was based on what officials and the media imagined might happen, not what was actually happening.

In actuality, hundreds of environmental samples were taken around TMI during the accident period and thereafter and there were no unusually high readings, except for noble gases, and virtually no iodine. All readings were far below health limits. Without significant off-site releases, the TMI Unit 2 accident is classified as a level 5 event according to the international nuclear and radiological event scale (INES).[6] Nevertheless, it caused concerns about the possibility of radiation-induced health effects,

Figure 1. Three Mile Island Unit 2 during the accident on March 28, 1979

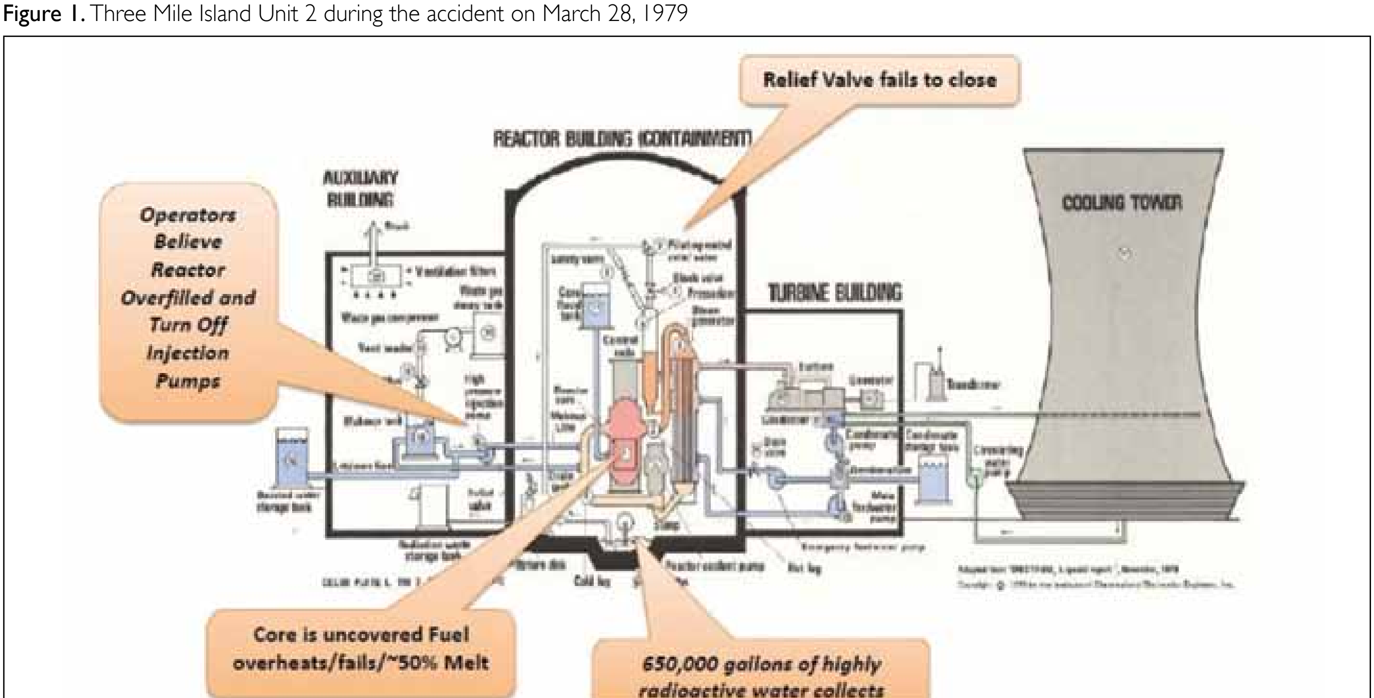


Figure 2. TMI Unit-2 hydrogen burn

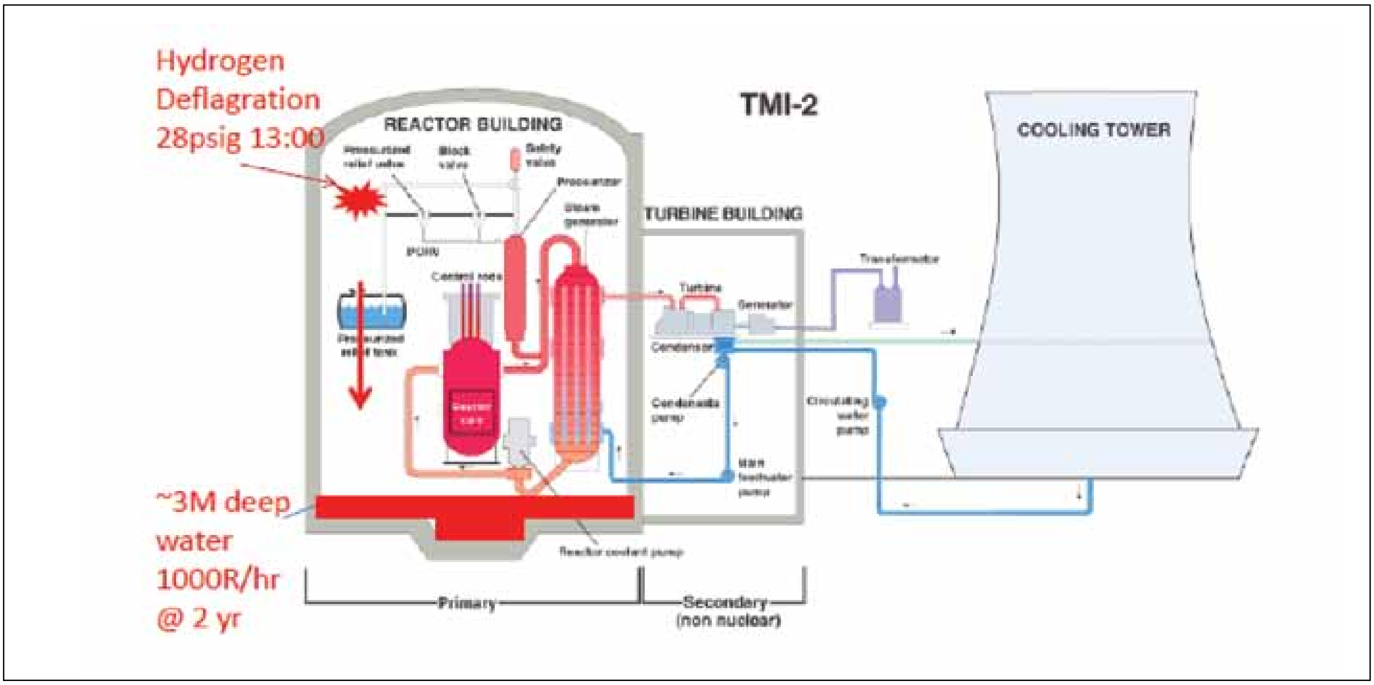
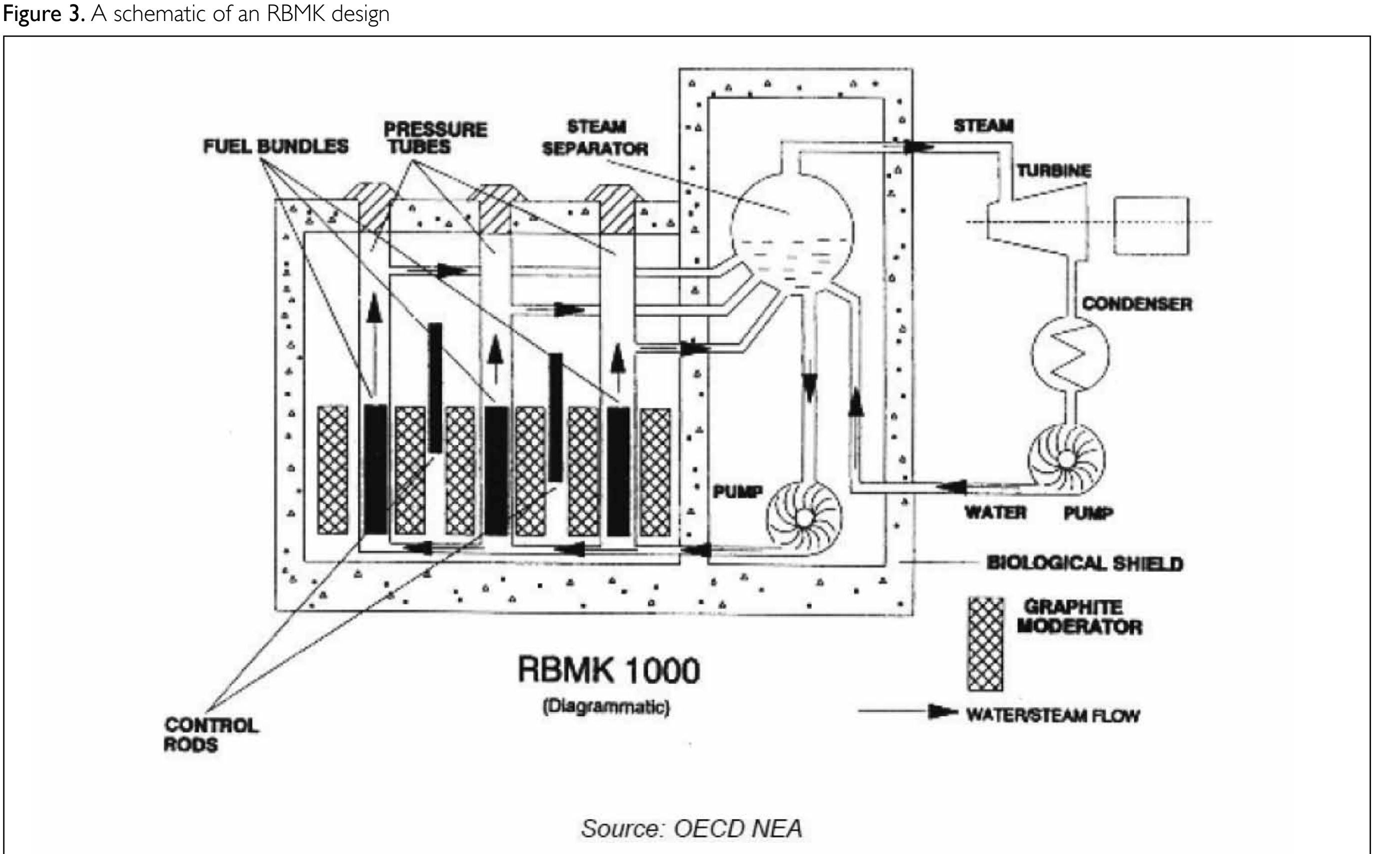


Figure 3. A schematic of an RBMK design



principally cancer, in the area surrounding the plant. Because of those concerns, the Pennsylvania Department of Health for eighteen years maintained a registry of more than 30,000 people who lived within five miles of Three Mile Island at the time of the accident. The program was discontinued in 1997, without any evidence of unusual health trends in the area.

TMI Unit 2 had only operated for a few months before the accident. Therefore, there was no spent fuel in the spent fuel pool. A water cleanup system was eventually installed in the spent fuel pool to process all the contaminated water that had accumulated in the basement of the unit. Unit 2 at the TMI site was cleaned up in the subsequent decade at a cost of approximately $1 billion and has never operated as a nuclear power plant after the 1979 accident. The sister plant, which has the same design, Unit 1, continues to operate today and has one of the highest capacity factors of all the U.S. nuclear power plants.

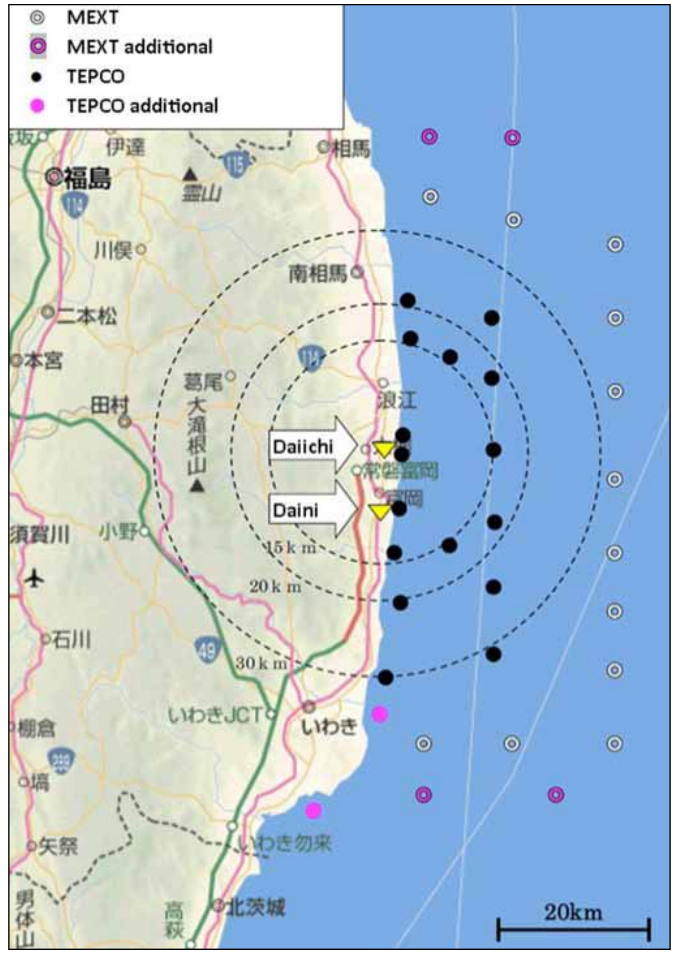
Chernobyl Unit 4

On April 26, 1986, an accident occurred at Unit 4 of the Chernobyl nuclear power plant in the former Ukrainian Republic of the Soviet Union. A summary of the events based on the *Chernobyl Forum 2003-2005* report[7] is presented here. The explosions ruptured the reactor vessel and the reactor building roof. The subsequent fire, which continued for ten days, resulted in large amounts of radioactive materials being released into the environment. The release spread radionuclides over much of Europe. Cs-137 remains measurable in soils and some foods in many parts of Europe even today. The greatest deposits of radionuclides occurred over large areas of the Soviet Union in what are now the countries of Belarus, the Russian Federation, and Ukraine.

The Chernobyl reactor was a Russian RBMK design. Such a reactor uses natural uranium for fuel, water as a coolant, and graphite as a moderator. If an RBMK reactor loses its coolant its nuclear reaction proceeds faster producing explosive quantities of energy rather than shutting itself down as light water moderated reactors like Three Mile Island and Fukushima do. An RMBK design (see Figure 3) also does not have the type of multi-layer containment like the light water reactors used in most countries. The flawed Soviet reactor design, coupled with serious mistakes made by the plant operators, Cold War isolation, and the resulting lack of any safety culture were determined to be the root causes of the accident.[8]

Lack of the multi-layer containment structures and the high temperature of the fire allowed for a large release of both fission products and spent fuel fragments. The high temperature of the fire caused the lighter particles to be lofted high into the atmosphere, which allowed the contamination to spread to a very large geographical area. Approximately 5 percent of the reactor core has been estimated to have been released downwind. With the significant off-site releases, the Chernobyl Unit 4 accident is classified as a level 7 (the highest level) event on the international nuclear and radiological event scale.

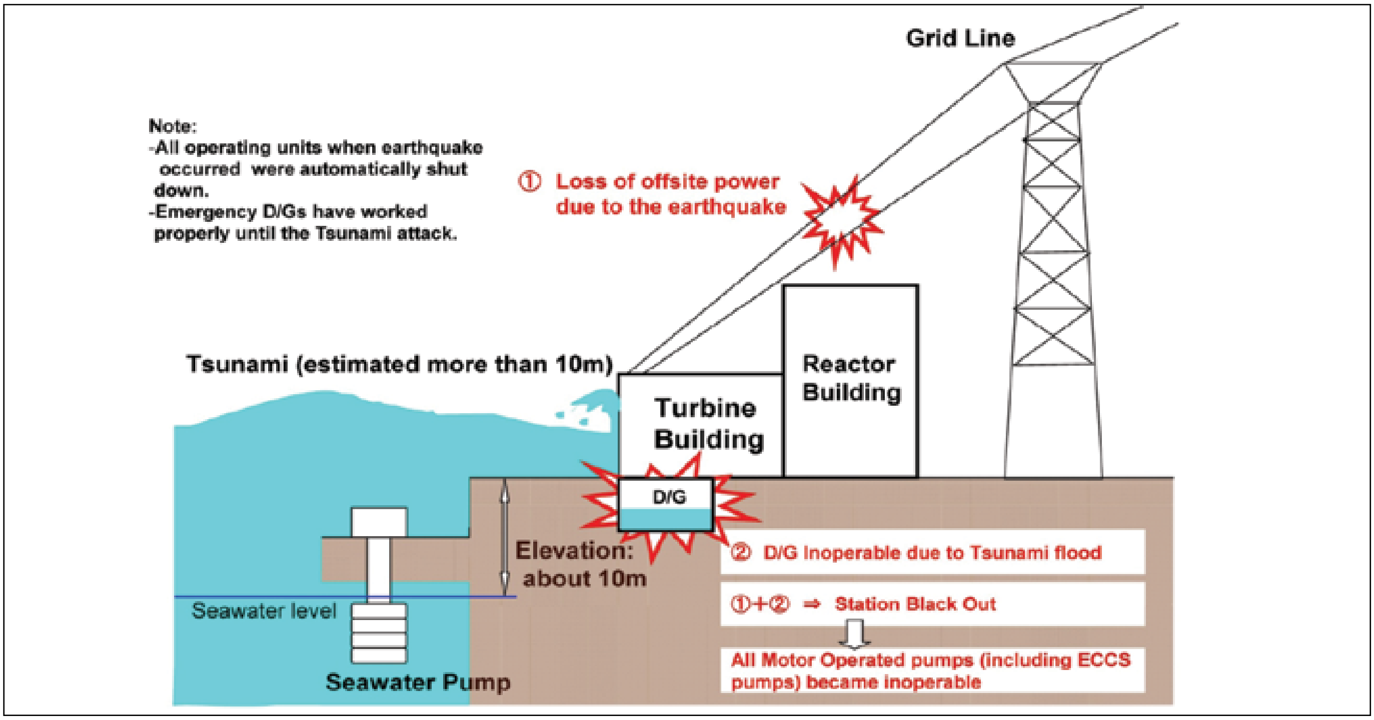
Figure 4. Location of the Great East Japan earthquake



Two plant workers died on the night of the accident, and twenty-eight more people, who were part of the emergency response crew, died within a few weeks as a result of acute radiation poisoning. This was a direct result of the complete breach of the innermost reactor core. Anecdotally, there are stories of the emergency workers shoveling pieces of spent fuel into barrels without wearing any protective clothing. Unfortunately for the public, reliable information about the accident and the resulting dispersion of radioactive material was initially unavailable to the affected people in what was then the Soviet Union and remained inadequate for years following the accident. This failure and delay led to widespread distrust of official information and the mistaken attribution of many ill health conditions to radiation exposure.

With the exception of the on-site reactor personnel and the emergency workers who were present near the destroyed reactor during the time of the accident and shortly afterwards, most recovery workers and people living in the contaminated territories received relatively low whole-body radiation doses. Their doses were comparable to background radiation levels accumulated over the twenty year period since the accident. In fact, the United

Figure 5. Illustration of the tsunami impact



Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) says that apart from increased thyroid cancers in the immediate vicinity of the plant, there is no evidence of a major public health impact attributable to radiation exposure twenty years after the accident.[9] The UNSCEAR Report goes on to say:

"The accident at the Chernobyl nuclear power plant in 1986 was a tragic event for its victims, and those most affected suffered major hardship. Some of the people who dealt with the emergency lost their lives. Although those exposed as children and the emergency and recovery workers are at increased risk of radiation-induced effects, the vast majority of the population need not live in fear of serious health consequences due to the radiation from the Chernobyl accident. For the most part, they were exposed to radiation levels comparable to or a few times higher than annual levels of natural background, and future exposures continue to slowly diminish as the radionuclides decay."

Fukushima Units 1-3

On March 11, 2011, about 2:46 p.m. local time, a 9.0 magnitude earthquake struck off the east coast of Japan (see Figure 4). The Fukushima Nuclear Power Plant went into an orderly shutdown and all plant safety systems reportedly functioned satisfactorily. Units 1, 2, and 3 went through a scram and Unit 4 has a one hundred-day-old core offloaded into its spent fuel pool. All units at Fukushima, including units 5 and 6 are boiling water reactors (BWR). Since the plant was disconnected from the power grid due to disruptions caused by the earthquake the backup diesel generators, which are part of the safety systems, started automatically to provide cooling for the cores. At about 3:45 p.m. local time, a 14-meter (46 foot) high tsunami inundated the plant site. See Figure 5. The tsunami covered the backup diesel generators causing a loss of all AC power. In the following hours, engineers managed to provide some limited core cooling with battery controlled systems for Units 1, 2, and 3. No elevated radiation measurements are shown outside the plant boundaries at this point in time. Nevertheless, as a precaution, an evacuation order is issued by the Japanese government to persons within a 3 km (1.9 miles) radius of the Fukushima stations.[10]

After about eight hours, the batteries were exhausted and with no cooling, the cores slowly became partially uncovered. The cores began to overheat. At approximately 900°C, the fuel cladding burst. At approximately1,200°C, the zircaloy cladding began to oxidize causing creation of hydrogen gas. At temperatures between 1,800°C and 2,700°C the fuel went through a partial meltdown.

The creation of the hydrogen gas caused the primary coolant system to over- pressurize. The pressure opened the relief valves and vented the hydrogen from the primary coolant loop into the primary containment. Besides hydrogen, this release contained steam and fission products such as Xe, Kr, I, and Cs. Without cooling in the primary containment, it over-pressurized and vented the mixture of hydrogen and the fission products into the secondary containment. On March 12, Tokyo Electric Power Company (TEPCO) confirmed that it had vented small amounts of vapor to the outside air to relieve the pressure in units 1 and 2. This release contained small amounts of radioactive materials.

Normally there would have been fans and filters in this vent path, but with the loss of all offsite power and all emergency diesel electric power, these gases collected within the secondary containment reactor building.

At some point on March 12, the day after the shutdown of the reactors, a spark inside the secondary containment caused the hydrogen gas to explode at Unit 1. Four TEPCO employees were injured at the explosion in Unit 1.[11] The evacuation zone is extended to 20 km (12.4 miles). With no power to the cooling pumps and with obvious overheating of the reactor cores, and with the possibility of further hydrogen explosions, a decision was made to use diesel-powered fire engine pumps to inject sea water mixed with boron first into Unit 1 and then to the other units to provide core cooling to relieve the pressure inside the units.[12] The decision was not made lightly since the use of sea water meant that the reactors where it was used would not be reparable.

On March 14, despite the best efforts of the emergency crew on site, a hydrogen explosion occurs at Unit 3.[13] Eleven employees are injured in the explosion at Unit 3.[14]

On March 15, an explosion and a fire were reported both in Unit 2 and in Unit 4. The Unit 4 fire appears to have been an explosion that appears to have occurred at the spent fuel pool given the location of the damage at the upper levels. Despite the explosion in the basement of Unit 2, the outer containment of Unit 2 seems to be intact.

By March 22, temporary off-site power was brought to all six units. Making sure that the power was available at all the necessary locations was challenging to say the least. But, work has progressed steadily, and the situation at all plants has become far more stable than during the first few weeks of the event.

The Japanese officials had initially classified the Fukushima situations as a level 5 incident on the international nuclear and radiological event scale. On April 12, it was re-classified as an INES level 7 event, the same level as the Chernobyl accident. However, Japan's Nuclear and Industrial Safety Agency (NISA), noted that unlike at Chernobyl there have been no explosions of reactor cores, which are more serious than hydrogen explosions external to the cores. All reactors still apparently have intact reactor vessels that contain their nuclear cores. Although all the primary containments are being vented for pressure control, Units 1 and 3 primary containments appear to be intact. The Unit 2 primary containment may likely have been damaged by an internal hydrogen explosion and may not be intact. NISA officials said they raised the incident level because of the cumulative amount of radioactive particles released into the atmosphere. Other factors included damage to the plant's buildings and accumulated radiation levels for its workers.[15]

It should be noted that at Chernobyl, operator actions led to explosions that destroyed the reactor while it was under power, releasing a cloud of radiation that contaminated large areas of Europe. The reactors at Fukushima were damaged by a monster tsunami that followed a huge earthquake. At the time the tsunami hit, the reactors had already achieved shut down.

According to the IAEA,[16]

"Overall, the situation at the Fukushima Dai-ichi nuclear power plant remains very serious, but there are early signs of recovery in some functions, such as electrical power and instrumentation."

Nitrogen gas is being injected to the primary containments to reduce the possibility of further hydrogen explosions. The pressure at Unit 1 has stabilized. The pressure vessels and drywells at Units 2 and 3 remain at atmospheric pressure (no over pressure).

A lot of work remains even though the situation has been stabilized. The plant workers need to continue efforts to control the energy output and residual heat dissipation from all affected units. This may occasionally call for release of gases, which will need to be filtered and monitored to stay within international and Japanese guidelines. The same thing is true of the liquids now at the plant. There are millions of gallons of highly radioactive water in basements of all the units. This water needs to be purified and disposed of in an appropriate manner. The Japanese are already receiving technical assistance from both the United States and the IAEA. In addition, they have requested help from the Russian Federation for whom Japan recently financed a radioactive water treatment system built into a ship. Eventually, solid debris will need to be evaluated, contained and properly disposed as well.

Radiation Exposures

The news reports have been full of a variety of alarming stories regarding the amount of radiation released and the workers at the plant having been exposed. For example, on March 24, three workers installing electrical cables in the Unit 3 turbine building were reported to have been exposed to high levels of radiation and contamination. Two workers were sent to the hospital and were suspected to have received skin overexposures from high-level beta radiation. Three workers were exposed to radiation doses between 170 mSv (17 rem) and 180 mSv (18 rem). TEPCO reported that 17 workers had received a dose of 100 mSv (10 rem) or more.[17]

As of April 14, among approximately 300 radiation workers at the Fukushima Dai-ichi plant, twenty-eight have received accumulated doses exceeding 100 mSv (10 rem) in the period related to this emergency. No worker has received a dose above Japan's guidance value of 250 mSv (25 rem) for exposure of emergency workers.[18] In contrast, thirty people had died of acute radiation sickness within a few weeks of the Chernobyl accident.

On March 19, there were reports of radiation having been detected in many areas of Japan, including Tokyo. At the same time, the Japanese Ministry of Health, Labor, and Welfare announced that radiation levels that exceeded legal limits had been detected in milk produced in the Fukushima area and in certain vegetables in Ibaraki.[19] (Not everyone noticed that except for the radiation levels near the Fukushima Dai-ichi plant, all other readings were well below allowable levels, and that the measurements in Tokyo, for example were barely traces of iodine.)

Locally, near the plant, tap water in Fukushima was found to have higher than allowed levels of radioactive iodine. On March 22, sea water downstream of the Units 1, 2, 3, and 4 discharge canal was found to have levels of I-131 and Cs-134 and Cs-137 that exceeded regulatory limits. On March 28, plutonium was detected in the soil of the Fukushima Dai-ichi site, however these levels were quite low. These low on site detected levels pose no threat to public health.

The core cooling water injection is causing highly radioactive water to flood the lower levels of the reactor buildings. This radioactive water can flow through various pipe and electrical tunnels into the lower turbine buildings. Thus, water found in the turbine buildings of units 1, 2, and 3 contains radioactive substances and at some points, especially in Unit 2, the level of radiation on the surface of water puddles is very high. High levels of radiation have also been reported in water in a trench outside the turbine building near Unit 2 where some of the water was flowing into the sea through cracks. These leak paths were sealed with a sodium silicate solution.

On April 4, TEPCO announced the decision to discharge approximately 11,500 tons of water with low levels of radioactivity into the sea.[20] This discharge was necessary to allow for the storage and treatment of the more highly contaminated water being collected in other locations at the plant. The estimated dose to the public from this discharge is about 0.6 mSv (60 mrem) per year for residents eating fish and seaweed from the adjacent area. At this point, this dose is about a quarter of the annual dose received by the public from natural sources in the area.

According to the United Nations organizations that are closely monitoring the situation at Fukushima and Japan in general,[21] as of April 1, 2011, radioactive material from the damaged Fukushima Dai-ichi plant is gradually spreading outside Japan into the global atmosphere but at extremely low concentrations that do not present health or transportation safety hazards. There will be no health consequences for people farther away from the plant, such as the United States or Europe, or even mainland Asia.[22] Japanese authorities confirm that all airports in the country, with the exception of Sendai, which was affected by the tsunami of March 11, continue to operate normally for both international and domestic operations. Continuous monitoring around these airports confirms that radiation levels are well within safe limits from a health perspective. Japanese authorities also confirm that all international seaports not damaged by the earthquake and tsunami are operating normally and that no health risk has been detected around the ports, based on the results of measurements of radiation levels by local governments. Screening for radiation of passengers arriving from Japan is currently considered unnecessary at airports or seaports around the world.

Conclusion

The *accident* at the Fukushima Dai-ichi nuclear power plant is not, and is not likely to become, a public health catastrophe. The human toll is and will continue to be inconsequential compared to impacts of the earthquake and the tsunami in other areas of human activity. The U.S. decision to evacuate all U.S. personnel within a fifty-mile radius early in the process now appears to have been based on very incomplete information.

The accident at Fukushima can be ranked as an industrial and economic catastrophe. From a human toll perspective, it will be much, much smaller than for example the Bhopal accident in India, December 2–3, 1984. The cost of cleaning up a single unit at TMI was approximately $1 billion over about twelve years. Units 1-4 at Fukushima are expected to be a complete loss. Units 5 and 6 are technically recoverable. But, the cleanup will be long and expensive, much more expensive than TMI.

The handling of the energy dissipation at the stricken reactors is getting better but remains challenging. There is still a concern of possible explosions if oxygen gets into the hydrogen rich primary containments before the hydrogen gas can be removed. The reactors need to be brought to a state where no further venting is required. Once the reactors have been brought to a cold shutdown and the cleanup begins, there will be a large challenge not only do it safely, but also to ensure the containment, nuclear security and safeguards for materials that are on site.

The monitoring of releases at the plant and in the surrounding area for air, water, and food is now a growing challenge. There will be significant social challenges no matter how insignificant the radioactive material levels are measured to be. Japan does have the knowledge base, the personnel, and the economic wherewithal to handle this going forward. They can be expected to do it in a meticulous, careful, measured way to make sure that everything is done correctly without any undue harm to the public or personnel working at the site. For example, it has been reported that as a consequence of the Fukushima situation, the European Union (EU) recently modified their acceptable limits of certain radioactive elements in food imported from Japan.[23] What should be noted is that the EU limits were lowered to match those of the Japanese official limits. The European allowable limits were actually higher.

The difficult lessons of the TMI Unit 2 accident have significantly improved the safety and productivity of U.S. nuclear power plants. One can only hope that the eventual lessons from Fukushima will teach us all additional lessons about the safe, effective use of nuclear power. Removing the nuclear option as a means of generating power as a result of this could mean very dire economic and climate consequences for the entire world, given that the only other energy sources that could replace nuclear on the scale needed are all based on fossil fuels.

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Promoting Best Practices in Nuclear Security through the World Institute for Nuclear Security

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World Institute of Nuclear Security, Vienna, Austria

At the INMM 46th Annual Meeting in 2005, NTI President Charles Curtis challenged INMM to create an organization to promote best practices in nuclear security and help put those best practices in place in nuclear facilities throughout the world. A team of experts responded and agreed to create the World Institute for Nuclear Security (WINS). WINS was launched at the 2008 IAEA General Conference and established in Vienna as an Austrian Association. It opened for business in January 2009. Since then, WINS has been officially recognized as an international NGO and made important progress to establish its operating model and vision of nuclear security and has convinced major international nuclear security stakeholders of its political credibility and independence. This article reviews the progress made by WINS to date.

From Concept...

WINS was created to fill a gap between international and national commitments and initiatives to implement or strengthen nuclear security, and those with the responsibility to implement those measures — the people with the practical day-to-day responsibility. As its mission, WINS would provide a forum to bring together experts, operators, industry, governments, and other state entities to exchange information about on-the-ground experiences and lessons learned. By facilitating the global sharing of best practices, WINS could help security practitioners worldwide implement more effective and efficient security programs. The WINS concept was intended to be new, innovative, and put WINS in a unique position to disseminate best practices widely and flexibly in response to new threats, using innovative tools and techniques. WINS would offer workshops and training programs, publications, seminars, and topical meetings with the goal of improving the implementation of nuclear security measures on the ground. Other potential areas might eventually include on-site support for nuclear security, support of peer-review missions, and assistance with self-assessment of nuclear security culture, management, and governance.

The project to create WINS began with an INMM Fellows' subcommittee formed to address the Curtis challenge. This subcommittee prepared a blueprint of an organization that might meet the challenge, and was named the World Institute for Nuclear Security – WINS – by the subcommittee. This blueprint was presented at the INMM Executive Committee meeting in fall 2005. At that meeting were visitors from the Nuclear Threat Initiative and the U.S. Department of Energy/National Nuclear Security Administration (NNSA). The decision was made at the meeting to form a coordinating committee with members from NTI, the INMM, and NNSA, with the intent to invite the International Atomic Energy Agency (IAEA) to participate. The IAEA accepted. To facilitate their work, and ensure it would have the broadest possible international support base, the Coordinating Committee called together an international "Experts Group" in 2006. This group included participants from seventeen countries and the IAEA. They reached agreement on the need for and value of WINS and the importance of continuing to advance the concept with support from NTI, INMM, and other international partners.

Their vision was timely and relevant. In his "Prague Speech" in April 2009, U.S. President Barack Obama announced an international effort to secure all vulnerable nuclear material around the world in four years, and called for a Global Summit on Nuclear Security. Later that year, a number of world leaders reflected on the importance of giving additional attention to nuclear security.

A joint statement by President Obama and President Dmitry Medvedev stressed that nuclear security requirements need continuous upgrading, and to that end they would jointly initiate practical steps to include conducting worldwide regional nuclear security best practices workshops to facilitate greater international cooperation in implementing this initiative. Within a few days of this joint statement, the G-8 issued a statement that, "We should not wait for an act of nuclear terrorism before working together to collectively improve our nuclear security culture, share our best practices, and raise our standards for nuclear security." In the Road to 2010 Plan, UK Prime Minister Gordon Brown stated that, "all nuclear material must be held securely, to prevent it falling into the hands of terrorist groups or hostile states. The UK believes that nuclear security must become the fourth pillar of the global nuclear framework, alongside civil power, nonproliferation and disarmament. Momentum for greater nuclear security is growing, with President Obama announcing a nuclear security summit in the spring of next year, which the UK will take a full part in."

...To Reality

WINS was launched at the IAEA General Conference in 2008. Those leading the launch included IAEA Director General

Mohammed ElBaradei, former U.S. Senator Sam Nunn, U.S. Secretary of Energy Samuel Bodman, and NTI President Charles Curtis. Dr. Roger Howsley was appointed as WINS' first executive director. The decision was taken to establish offices in Vienna to facilitate communication and cooperation with the IAEA and to provide an opportunity to interact with all of the IAEA member states and the many people that come to Vienna for IAEA and UN security-related events. WINS opened for business in January 2009.

In its short history, WINS has exceeded expectations.

International Best Practice Guides

WINS has published twelve International Best Practice Guides (see Figure 1) on a range of important strategic and operational issues that have a direct bearing on security performance. They are:

1	Nuclear Security Culture
2	Security Equipment Maintenance
3	Managing Internal Threats
4	Threat Assessment
5	Security Governance
6	Legal Accountability and Liability for Nuclear Security
7	An Integrated Approach to Nuclear Safety and Nuclear Security
8	Security by Design
9	Effective Management and Deployment of Armed Guard Forces
10	Nuclear Security Guard Recruitment and Selection
11	Security of Well Logging Radioactive Sources
12	Performance Metrics

International Workshops

In 2010, WINS held nine international workshops, which brought together subject matter experts and lead authors to focus on and discuss best available international guidance on implementing various aspects of nuclear security. WINS established a new style of facilitated workshops to ensure the maximum involvement of participants and to maintain focus and get the most from the events. WINS introduced innovative methods to increase participant interaction at workshops, including theater-based awareness sessions, which use professional actors and playwrights to help enact scenarios and bring issues to life (see Figure 2). As Howsley noted, "How many conferences do you go to where half the participants are not listening, instead doing their e-mail or surfing the Internet? That doesn't happen at WINS events."

More than 450 people from operating organizations, law enforcement, intelligence, and other government agencies, including regulators, have attended the specialist WINS' workshops, which are generally limited to a maximum attendance of thirty-five people. What also makes WINS events different is that nearly all the events are structured and designed to produce an international best practice guide under the guidance of a lead author, who is selected because of their personal experience and contribution to nuclear security.

Figure 1. WINS International Best Practice Guides focus on specific issues that can be problematic for organizations and where clear practical advice and guidance can save time and resources, as well as improving performance and governance. The Guides are sent for technical editing before publication to make them as clear as possible.

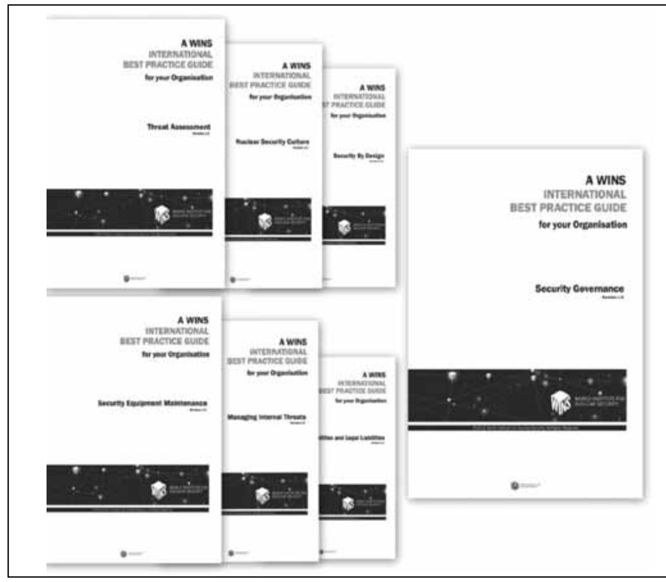


Figure 2. Scenes from the AKT Theater Production "The CEO's Journey;" a four-part play examining the interaction between nuclear safety and security management and the associated cultural issues. The play was produced for the WINS workshop on the "Integration of Nuclear Safety and Security" held in Vienna in October 2010.

Communicating Best Practices

One of the early challenges faced by WINS was a belief amongst some that it was impossible to discuss and communicate security-related information without infringing national rules concerning confidentiality. It is certainly the case that facility-specific security information is subject to confidentiality rules and rightly so, but is it really impossible to discuss best practices for managing security, how boards of directors should exercise effective governance over their security programs, how safety and security personnel should work more closely together? WINS thought not, and discussed with regulators and practitioners how this could be done. Ground rules were established for our workshops to avoid either political statements or the discussion of classified information.

WINS developed a modern and fresh looking Web site (www.wins.org) for its members and published its Guides in seven languages—the UN languages and Japanese. It also publishes topical notes and the presentations made at its workshops and a summary of each workshop so that all the members can learn from the experience. No other organization does this; WINS aims to become the "one stop shop" for security practitioners and related professionals, where they can go and download information that is intended to make their security arrangements more effective.

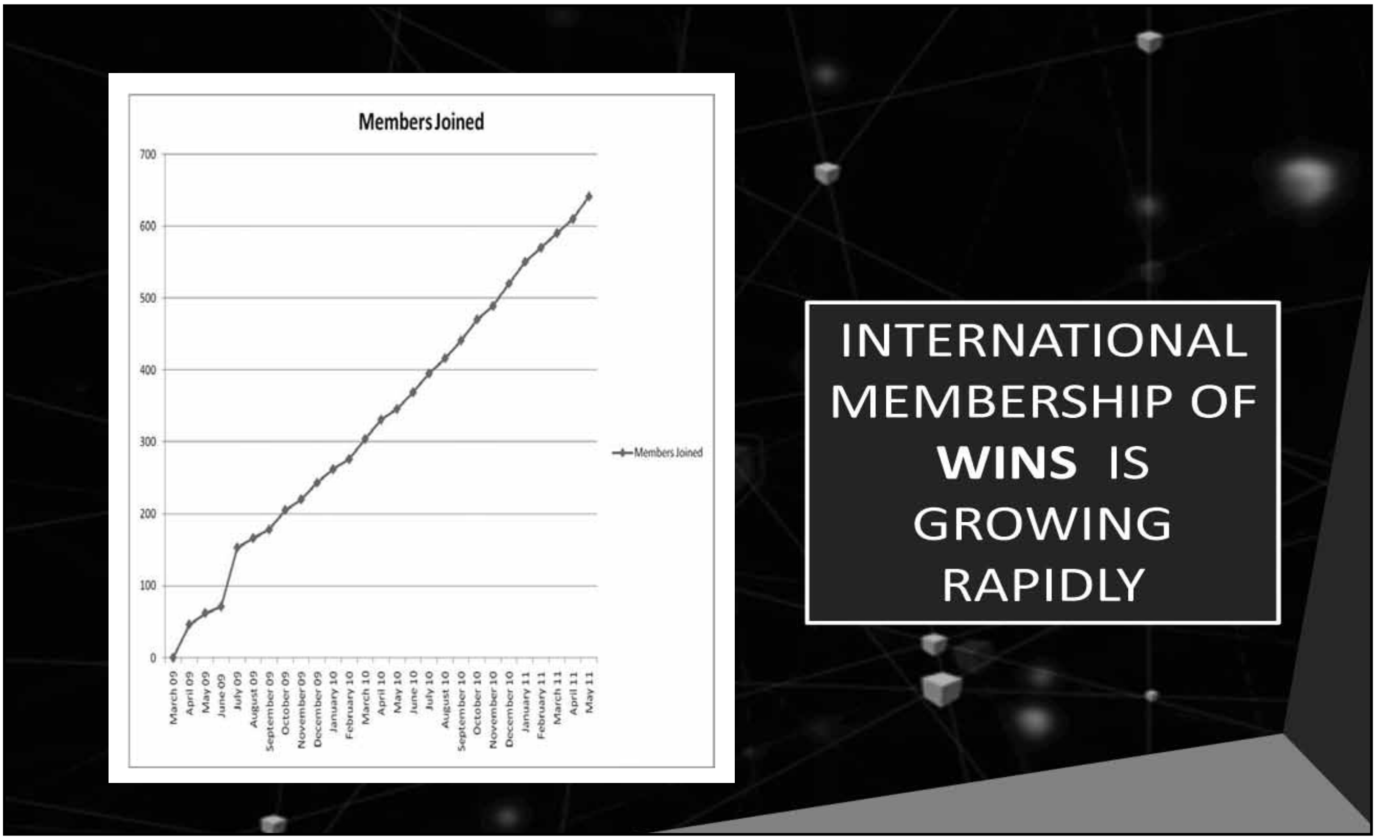
WINS has also had a proactive and energetic outreach program to inform people about our work and the information that is currently available from WINS and our plans for the future—WINS has been invited to speak at more than sixty international conferences and meetings over the past two years. WINS has focused on raising awareness of nuclear security, and management being engaged and taking responsibility. But WINS has also championed the importance of public-private dialogue, that the engagement of operators and the nuclear industry is critical to support the effective implementation of government commitments. WINS has been involved in meetings of a number of major international nuclear security initiatives, including the Global Initiative to Combat Nuclear Terrorism (GICNT) through the Implementation and Assessment Group (IAG); addressed meetings organized with the UNSCR 1540 Committee; and has been involved in the Nuclear Security Summit process.

At the April 2010 Summit, the U.S. Statement recognized WINS as an effective forum for sharing best security practices. Japanese Prime Minister Yukio Hatoyama acknowledged that WINS was established for the purpose of promoting the sharing of best security practices, and that Japan highly values the contribution made by WINS. WINS participated in the NGO Summit and the industry side event where U.S. Energy Secretary Steven Chu highlighted the important work WINS is doing to complement that of national governments, and U.S. Vice President Joseph Biden challenged the nuclear industry to develop best practices. Japan and Canada announced the hosting and funding of WINS best practices events. WINS conducted these events later in 2010—between June 14-18 in Canada covering International Best Practices for Nuclear Guard Force Recruitment, Training, Deployment, and Exercises, and on the September 8 in Tokyo, Japan, on Corporate Governance for Security, with the workshop and all materials being in Japanese. WINS also co-sponsored with INVAP and Nuclear Energy Institute an industry side event at the November 2010 Buenos Aires Sherpa meeting, and promoted its Best Practice Guides and workshops at the Vienna Sous Sherpa meeting in March 2011. In addition, WINS is working with a number of national organizations to provide national or regional workshops aimed at engaging operators and practitioners on a full range of nuclear security issues, to raise awareness, promote nuclear security culture, encourage leadership and engagement at all levels to facilitate the implementation of nuclear security programs, examples of which are shown below.

WINS OUTREACH PROGRAM 2010
IAEA Nuclear Security Workshop, Tokyo, Japan, January 19–23
G8 Global Partnership meeting, Ottawa, Canada, January 25–26
Nuclear Security Summit Sherpa meeting, The Hague, The Netherlands, February 10–11
UK Nuclear Security Conference (Kings College, Royal Society, CSSS), London, UK, February 18–19
International Institute for Strategic Studies Workshop, Nuclear Security in India, Delhi, India, March 7–9
League of Arab States Workshop on Improving Security, Safeguards and Safety in Arab Countries, Cairo, Egypt, April 7–9
NGO Summit, Washington, D.C., USA, April 12
NEI Industry Summit, Washington, D.C., USA, April 14
Pacific Northwest International Conference on Global Nuclear Security, Portland, Oregon, USA, April 16
INMM 51st Annual Meeting, Baltimore, Maryland USA, July 11–15
IAEA General Conference, Vienna, Austria, September 20–24
GICNT Implementation and Assessment Group (IAG), Astana, Kazakhstan, September 30
GLOBE Leadership Seminar, Geneva, Switzerland, October 1–2
SIPRI study tour initiative for Chinese industry and government officials to promote nuclear security, Vienna, Austria, October
Partnership for Nuclear Security (US State Department) Conference, Developing a Civil Nuclear Power Workforce, Cairo, Egypt, October 17–20
IAEA Safeguards Symposium, Vienna, Austria, November 1–5
WINS, INVAP and NEI Co-sponsored industry side event at the Nuclear Security Summit Sherpa meeting, Buenos Aires, Argentina, November 3–4
Middle East Energy Security Forum, Doha, Qatar, November 28–30
UNSCR/1540 Committee meeting with international organizations in Vienna, Austria, December
Security Leadership Summit organized by **Central Association of Private Security Industry (CAPSI),** Delhi, India, December 4–5

And of course, the opportunity to speak at INMM events and display WINS' materials has been of great benefit, to help communicate with the extensive number of security practitioners that attend the INMM Annual Meeting and other workshops. We are proud of our association with INMM and seek opportunities to collaborate and promote best security practices.

Figure 3. WINS membership since March 2009



WINS Membership

WINS membership is free of charge, though we require our members to have responsibilities for security and expect them to support the WINS' mission—wanting to help improve nuclear security.

It was decided at an early stage that WINS would not spend its time developing complex rules for membership; our view was that both organizations and individuals should be allowed to join, depending on their preference, and that we would make the same information available to both. Unlike the IAEA, which has states as members, WINS does not. We draw our membership from nuclear operators, police, security practitioners, policy makers, regulators, and research organizations.

In the first two years, WINS membership has grown at a constant and impressive rate, and we now have more than 500 members in more than fifty countries (see Figure 3). These include some of the largest nuclear companies in the world that are corporate supporters of WINS, with a huge influence on security performance and governance.

Measuring Success?

An important question on the minds of those who created WINS was how to measure success—how would we know whether WINS has met its objectives and is making a difference? The WINS Coordinating Committee's answer was that WINS would be judged to have succeeded if its members continue to derive benefits, which would be measured and communicated on a regular basis.

WINS has a modern and effective quality management system that has performance measurement at its heart; it uses a variety of methods to gauge its effectiveness.

First, we seek immediate feedback from workshop participants whilst they are still at the workshop; did they find the workshop useful, was the information relevant, would it lead to a change in implementation? The results are overwhelmingly positive. Figure 4 contains a few of the many representative comments received by WINS.

Secondly, we have introduced electronic voting as a means of capturing participant views on a wide range of issues during the workshops. Participants vote anonymously and the results are displayed instantaneously; this helps the group understand how others feel about particular issues and creates a positive environment for discussion and debate.

And thirdly, we launched our annual questionnaire for members to see if they thought that WINS was adding value. We asked ten questions online and the responses were automatically collated from the votes, ensuring anonymity so that members could express their opinions in an honest and uncon

Figure 4. Comments on WINS

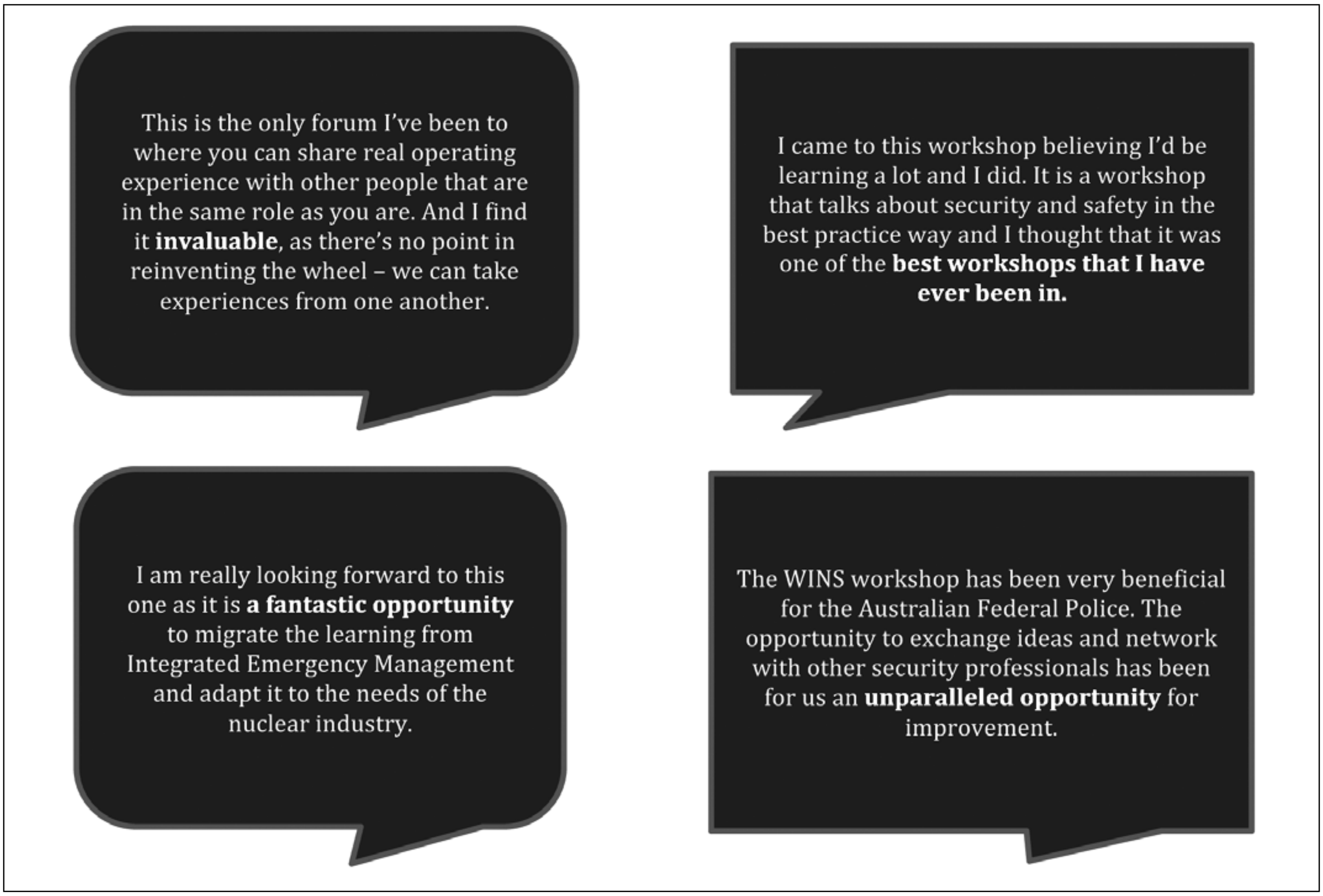


Figure 5. Survey Results

QUESTION	AGREE/ STRONGLY AGREE
DO I BENEFIT FROM WINS MEMBERSHIP?	98.5%
IS WINS A VALUABLE FORUM?	100.0%
ARE THE WINS GUIDES EFFECTIVE FOR SELF ASSESSMENT?	91.5%
DO THE WINS GUIDES COVER RELEVANT TOPICS?	100.0%
IS PUBLISHING THE GUIDES IN DIFFERENT LANGUAGES IMPORTANT?	100.0%
WAS ATTENDING A WINS WORKSHOP TIME WELL SPENT?	97.1%
ARE WINS WORKSHOPS INNOVATIVE?	97.9%
HAVE I MODIFIED APPROACHES TO SECURITY BECAUSE OF WINS?	84.3%
IS THE WINS WEBSITE USEFUL?	98.5%
ARE MY INTERACTIONS WITH WINS DEALT WITH PROFESSIONALLY?	100.0%

Figure 6. A Bruce Power (Canada) hosted workshop was held in June 2010 to share best practices in guard force recruitment, training and deployment. Bruce Power set an international best practice standard for such activities.

strained way. The results of the survey are shown in Figure 5 and summarize the views of those members that expressed a view about the questions.

We will be repeating this survey each year and in the future will make sure that members have the choice of the language in which they wish to respond so that we get as much feedback as possible. If you have any suggestions about how we can further improve our feedback and measure our performance, contact us, because it matters that we make a difference.

Future Plans

WINS continues to strive to identify areas of interest to its members. A new focus this year has been to engage scientists and engineers in nuclear security. This work includes not only those individuals currently working in the nuclear field, which is clearly critical, but also students of science and engineering. WINS is promoting the need to get it right from the start and design in security measures where applicable, rather then add them on after facilities are designed or constructed. WINS' first workshop on this topic was very successful, and attracted interest and requests for additional workshops, which we will schedule later this year and next. WINS is also being asked to organize more workshops aimed at engaging scientists and engineers in the importance of nuclear security, and will continue to explore incentives and ways to encourage greater industry involvement in ensuring effective implementation of security.

Figure 7. A WINS interactive workshop on the engagement of Engineers and Scientists; achieving integration of these different professions with nuclear security is essential."

Keeping abreast of world events, WINS issued a special publication, *"Maintaining Nuclear Security in a Complex Crisis,"* on the security lessons learned from the Fukushima Dai-ichi incident after the earthquake and tsunami earlier this year, and is planning a special discussion group in the months ahead. It is WINS' belief that just as the incident at Chernobyl galvanized the nuclear safety community and 9/11 the security community, the lessons learned from Fukushima will have important consequences for disaster preparedness and response. Further, WINS believes that these three elements are intimately connected and should be viewed as aspects of the same issue; it makes little difference whether the safety of nuclear materials and facilities or radioactive materials is challenged by a natural disaster or the malevolent actions of people. We need to understand the strong links between these disciplines and work to integrate, and review their effectiveness. We have also witnessed the enormous global response to events in Japan and how interconnected the industry is, and we must work to share best practices in all areas of activity as a priority.

WINS will complete the suite of twenty-eight Best Practice Guides including an edited compendium of Best Practices for Security Management, that will be available before the April 2012 Security Summit in the Republic of Korea. Details of those planned are shown below. in Figure 8.

WINS also plans to organize ten international workshops in 2011 and further develop the Web site to communicate more effectively with its members. WINS has some exciting new ideas aimed at further engaging operators and other practitioners, and is conducting research to establish online distance learning modules in Security Management Best Practice. Subject to avail-

Figure 5. Planned Best Practice Guides for 2011

PROPOSED BEST PRACTICE GUIDES TO BE PUBLISHED IN 2011			
13	Nuclear Security for Scientists and Engineers	21	Effective Regulations
14	Security of IT & IC Systems at Nuclear Facilities	22	Tracking Transport of Nuclear Material
15	Communicating Nuclear Security Information	23	Working Effectively with External Response Forces
16	Security Exercises	24	Guard Force Training and Motivation
17	Security Competencies	25	The Use of NMAC in Security
18	Advanced Technologies and Simulators for Nuclear Security	26	Security of High Activity Radioactive Sources
19	Learning from Operating Experience	27	Making Security Efficient
20	Human Reliability	28	Nuclear Material Detection and Recovery

ability of funding, WINS will make this online accredited training available to WINS members in 2012. WINS will also work with academic and other institutes to develop educational modules in security management that can contribute to graduate and postgraduate qualifications in nuclear engineering and science, and collaborate with the "Centers of Excellence" that are being established in a number of countries. WINS is keen to continue to support the work on the global nuclear security agenda.

But, inevitably, a key factor for WINS to be able to successfully execute these plans will be to secure sustainable funding. Investment in WINS is small compared with the budgets of government programs to combat nuclear terrorism, and WINS provides good value for the money. WINS' foundation funding—the $3 million grant from the DOE, $3 million from the Nuclear Threat Initiative (NTI), CA$500,000 from the government of Canada, and $100,000 from the government of Norway will be exhausted by the end of this year. WINS hopes these donors will provide additional financial and in kind support, and has also found new partners which include the U.S. State Department, Bureau of International Security and Nonproliferation (ISN), Office of Cooperative Threat Reduction, Partnership for Nuclear Security, U.S. Nuclear Regulatory Commission, and the UK Foreign and Commonwealth Office, but WINS will need more and assured sustainable funding to continue to make a difference.

Conclusion

People of vision were responsible for identifying the gap that existed between the international commitments to improve nuclear security and the need for good practical advice on how to best implement these improvements. WINS has demonstrated that there is a demand for its work and that its work is having a demonstrable impact on the improvement of nuclear security. WINS has overcome obstacles, including the incorrect view that best security practices cannot be discussed without compromising security; a view that is not shared in any other sector.

We wish to thank the INMM for its contribution to the success of WINS and to our funding organizations, board of directors, staff, contractors, and members who all work for a common cause: to promote nuclear security best practices and security leadership around the world.

Many organizations and institutions now look to WINS for assistance and advice.

We hope you will continue to support WINS and its work, participate in WINS events, and continue to help us make the concept of sharing best practices a reality, and join the growing list of fervent supporters. If you haven't yet joined WINS, consider it and apply online at www.wins.org.

Summary of International Target Values 2010 for Measurement Uncertainties in Safeguarding Nuclear Materials

Charles E. Pietri
Chair, ANSI/INMM 5.1 Analytical Chemistry Laboratory Measurement Control Committee

This summary was taken in part from the complete International Target Values (ITVs) ITV 2010 report published by the International Atomic Energy Agency (IAEA), Department of Safeguards, as a Safeguards Technical Report STR-368 (November 2010, Vienna, Austria). This most current issue of the International Target Values (ITV) represents the sixth revision, following the first release of such tables issued in 1979 by the European Safeguards Research and Development Association (ESARDA)/ Working Group on Techniques and Standards for Destructive Analysis (WGDA). **Reader comments on the ITVs are solicited and should be sent to Charles Pietri at cpietri@aol.com for response.**

The ITV are uncertainties to be considered in judging the reliability of analytical techniques applied to industrial nuclear and fissile material, which are subject to safeguards verification. The tabulated values represent estimates of the "state of the practice," which should be achievable under routine measurement conditions. The most recent standard conventions in representing uncertainty have been considered, while maintaining a format that allows comparison with the previous releases of the ITV. The present report explains why target values are needed, how the concept evolved and how they relate to the operator's and inspector's measurement systems. The ITV 2010 are intended to be used by plant operators and safeguards organizations, as a reference of the quality of measurements achievable in nuclear material accountancy, and for planning purposes. The report suggests that the use of ITV can be beneficial for statistical inferences regarding the significance of operator-inspector differences whenever valid performance values are not available.

Safeguarding nuclear material involves a quantitative verification of the accountancy of fissile materials by independent measurements. The effectiveness of these verifications depends to a great extent upon the quality of the accountancy measurements achieved by both the facility operator and the safeguards inspectorate. For this reason a typical safeguards agreement based on INFCIRC/153 stipulates that:

> *The Agreement should provide that the system of measurements on which the records used for the preparation of reports are based shall either conform to the latest international standards or be equivalent in quality to such standards.*

Although the above requirement is directed to the facility operators, it indeed applies equally well to the safeguards inspectorates. IAEA had defined in the 1970s a set of international standards of nuclear material accountancy, which lists the values of measurement uncertainty expected for closing a material balance for five different types of nuclear facilities. In the absence of relevant international standards of measurements, safeguards evaluators, as well as plant measurement specialists, need references regarding the performance capabilities of measurement methods used for the determination of the volume or mass of a material, for its sampling, and for its elemental and isotopic assays. Such information is needed for the various nuclear materials encountered in the nuclear fuel cycle.

The ESARDA WGDA pioneered the way in 1979 by presenting a list of "target values" for the uncertainty components in destructive analytical methods to the safeguards authorities of Euratom and of the IAEA. Revised estimates were prepared in collaboration and published as the 1983 Target Values after four years of extensive discussion and consultation with and within operators' laboratories and safeguards organizations. The international acceptance of the concept grew further with the next review, which involved, besides the ESARDA/WGDA and IAEA, the active participation of the members of two specialized committees of the Institute of Nuclear Materials Management (INMM). The 1987 Target Values, published as a result of this review, defined, as in the previous editions, the values of *random* and *systematic* error parameters to be aimed for in elemental and isotopic analyses of the most significant types of materials using common destructive analytical methods. The same groups took a new step in the 1988 edition when they agreed to define the values of the random error parameter to be met in the elemental assays as a result of sampling.

Following a 1988 recommendation of the IAEA Standing Advisory Group on Safeguards Implementation (SAGSI), the IAEA convened a consultants group meeting in June 1991 to provide expert advice on international standards of measurements applicable to safeguards data. A concept of International Target Values (ITV) was proposed on the model of the 1988 ESARDA Target Values and included estimates of the "random and systematic error" uncertainties originating from the measurements of volumes or masses of nuclear materials. The scope of ITVs was also extended beyond destructive analysis (DA) methods to include nondestructive assay (NDA) methods, which had won acceptance as accountancy verification tools. Specialists from four continents took part in the discussion of the proposed concept. The result was the publication of an IAEA Safeguards Technical Report in March 1993, "1993 International Target Values for Uncertainty Components in Fissile Isotope and Element Accountancy for the Effective Safeguarding of Nuclear Materials." Articles in the *ESARDA Bulletin* and in the *Journal of Nuclear Materials Management* widely publicized the IAEA technical report. The report itself was translated into Japanese. In 2000, international experts reviewed the experience gained with the use of the 1993 ITVs and the progress made in accountancy and safeguards verification measurements. Subsequently, "International Target Values 2000 for Measurement Uncertainties in Safeguarding Nuclear Materials" was published as an IAEA Safeguards Technical Report in April 2001, in the *ESARDA Bulletin,* and by INMM. Each ITV bears a date, reflecting a recognition that the quality of measurements may change and that new methods and instruments may be developed and implemented. The ITV also reflect the current understanding of the structure of the uncertainty components in nuclear material accountancy measurements which may change in the future as this understanding improves or varies. In preparation for the ITV 2010 the IAEA conducted "Verification Measurement Performance Evaluations," using data reported by facility operators and the results of independent measurements performed on the same material by the inspectors. These historical operator inspector paired data, accumulated from more than twenty years, represent the most relevant and complete set of information. Based on these *performance evaluations* and the IAEA's experience from using the ITV 2010, a set of draft ITV 2010 tables were prepared, which included some changes in the target values, the deletion and addition of analytical techniques or methods, and changes in the format of the tables.

As in the earlier formulation and revision of ITVs, the IAEA counted on the expertise available in the Working Groups for DA and NDA of ESARDA, the ANSI/INMM 5.1 Analytical Chemistry Laboratory Measurement Control Committee, the Working Group 1 on Analytical Methodology in the Nuclear Fuel Cycle of the ISO TC85/SC5 Subcommittee, the Japanese ITV 2010 Expert Group, and the inspectorates of Euratom and Argentine-Brazillian Agency for Accounting and Control of Nuclear Materials (ABACC). The above panels and organizations were asked to review the draft document and provide comments. In addition they were asked to report on measurement quality experience, as derived from QC/QA and interlaboratory programs, instrument qualification, or from verification activities.

Representatives of the above organizations participated in a consultants group meeting, convened at the IAEA in March 2010. Their comments and recommendations are reflected in this document. As with the previous lists, the ITV 2010 should be achievable henceforth under the conditions normally encountered in typical industrial laboratories or during actual safeguards inspections. They do not represent the measurement uncertainties, which would only be achieved under exceptional or ideal laboratory conditions, or with most recently developed methods, which have not yet found wide use for daily and routine measurements. It is expected that the ITV 2010 will continue to be a motivating goal for beginner laboratories and be used as an independent reference for experienced laboratories and safeguards evaluators. With the growing acceptance of modern quality assurance concepts it is suggested that the ITV 2010 can also constitute a good reference against which analytical laboratories would validate their measurement systems.

The most recent "Performance Values" are the basis for updating the two columns of random and systematic uncertainty components, u(r) and u(s), in this ITV 2010 document for each measurement method. **New to the ITV 2010 document is a column labelled ITV, which reflects an internationally adopted standard approach to measurement uncertainty evaluation *(Guide to the Expression of Uncertainty in Measurement* – GUM).** This column complements the use of ITVs in the evaluation of operator-inspector data and is provided as a reference for the laboratories. The current *Guide to the Expression of Uncertainty in Measurement* (GUM) was published in 2008 by the Joint Committee for Guides in Metrology (JCGM) in the name of the JCGM member organizations. The goal of the GUM is to provide measurement laboratories with a standardized, methodical approach to determining a quantitative statement of the measurement uncertainty associated with a measurement result. This standardized approach helps to ensure inter-comparability of results between methods and laboratories, ensures transparency (and traceability) in calculation, and by design adds some additional assurance that laboratories are identifying significant contributors to their measurement's uncertainties. This approach has been adopted by many safeguards laboratories and provides important information to laboratory operators and internal and external evaluators. The GUM is not intended to replace quality control systems or other data verification/validation schemes, but to provide laboratory staff, measurement data users, and regulators with useful, comparable information regarding the performance of particular measurement methods on particular sample types.

The following individuals participated in drafting the ITV 2010:

K. Zhao, IAEA
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Taking the Long View in a Time of Great Uncertainty

A Strategic Inflection Point? – The Nuclear Crisis in Japan

By Jack Jekowski
Industry News Editor

In the last three columns we have discussed strategic drivers ("externalities") that will influence the roles and responsibilities of the INMM in the nuclear future. Some of those discussions have speculated on the global challenges resulting from nuclear technology proliferation; the actions of the Obama Administration to move the world toward Global Zero and the possibility of significant events or *discontinuities*, including what the global response would be to a terrorist nuclear event. In the spring *JNMM* column we also examined *Social Chain Reactions,* and the impact of social media on the political and social upheavals in Egypt and elsewhere in the Middle East, suggesting that this new technology-driven social dynamic could be used by the Institute to facilitate strategic discussions. Since that column went to press, we have seen the social revolution spread to Libya, and escalation in military involvement by the United States and NATO. So influential has that new media become, that the U.S. State Department's Under Secretary for Public Diplomacy and Public Affairs, Judith McHale, made a major policy speech recently on the use of social media and its impact on relationships and communications worldwide.[1]

> *"Ideas are infectious. They always have been. Today, immediate and widespread access to information allows ideas to circulate virally. It empowers people to participate in the political lives of their countries. It equalizes voices.*
>
> *The Internet has made it possible to reach more people in more places. But it has also shifted power and influence to such an extent that it is necessary to engage with more people. This means we can no longer hope to control how and when and through what medium people form their impressions of us…*
>
> *To put it bluntly: The world has changed, and if we do not change the way we interact with people, we risk being marginalized or made obsolete…*
>
> *We are not so naïve as to believe that we can build meaningful relationships with people using nothing but social networking sites. There is no virtual equivalent for face-to-face interactions with Americans.*
>
> *But new media can be the first connection that sparks a curiosity to learn more about one another. Or it can be the second contact that helps cement and build a relationship over time and distance. Each of these interactions leaves a different impression and shows a person he or she is important to you."*

Japan's Nuclear Crisis: A Strategic Inflection Point?

Inherent in these discussions on externalities, but left unstated, was the possibility of a "nuclear event" resulting from an accident or natural phenomenon of such a magnitude that it resulted in global economic, political, or societal discontinuities. Such an event occurred on March 11, 2011, with the tragic earthquake and subsequent tsunami in Japan, and its devastating impact on the Fukishima Daiichi nuclear power plant complex. The complications resulting from that event continue to evolve as this column goes to print, but it is evident that it has all of the characteristics of a *"Strategic Inflection Point"*[2] for the nuclear power industry.

Strategic Inflection Points, or discontinuities in the parlance of the scenario planner, can also be called *"wild cards,"*[3] a term coined by the scenario planning group, GBN,[4] in their journey looking into the future, as discussed in my spring *JNMM* column on Social Chain Reactions. These wild cards can often take an otherwise orderly path to the future and cause it to make a dramatic turn in another direction. Such is the situation unfolding in Japan today.

The world has indelibly etched in their minds Three Mile Island and Chernobyl as examples of technology *endangering* mankind. The fear of the unknown, driven by a general lack of public understanding in basic science, and stoked by an ever-increasing sensationalism-seeking media, can change the landscape of nations and the world. We have seen such change with the stagnation of nuclear power development in this nation as a result of the Three Mile Island accident, and the global reaction continuing to this day from the events at Chernobyl. And now, as we watch the increasing rhetoric from governments and the public questioning the safety of nuclear power as a result of the tragedy in Japan, the challenge is posed to the Institute: "What can the INMM do to better inform the public, assist governments through technology and policy barriers, and help the nations of the world recover from this accident?"

The Nuclear Renaissance?

In this column in the winter 2011 issue of *JNMM*, guest author INMM Vice President Ken Sorenson spoke of the Nuclear Renaissance, describing the complexity of that environment through a discussion on the history of nuclear reactors, enrichment facilities, waste management, and safeguards and security in the light of a renewed global expansion of nuclear power. In that article Sorenson pointed out there are many issues that could impact the strength of the Renaissance, both positively and negatively, with different strategic drivers in the United States versus other regions of the world.

How will the current events in Japan influence that renewal? These events certainly have immediately focused the attention of world governments on the safety envelopes of existing plants, and raised questions about plants under construction or in the planning phase. In the United States, the U.S. Nuclear Regulatory Commission has established a task force to examine Fukishima events as they unfold, as well as the overall safety of plants under its jurisdiction. In Germany, Chancellor Angela Merkel ordered seven of its seventeen reactors that went into operation prior to 1980 be taken off line for three months while that nation reconsiders plans to extend the life of those plants by an average of twelve years, past a previous deadline to shut down all seventeen reactors by 2021. Other reviews of plants under construction or in the planning stage worldwide are being conducted as well, based on the early lessons learned from Fukishima. This includes a decision by the Chinese government on March 16 to order safety inspections of its nuclear facilities and temporarily suspend approval for new nuclear projects pending formulation of new safety rules. How these responses will ultimately drive the Renaissance is yet to be determined, and will be based in part on the successful resolution of the current tragedy,[5] as well as the ability of the scientific community to allay the fears of a largely uniformed public.

Impact on INMM

The fortuitous establishment of the new Facility Operations Technical Division within the INMM this past year provides a venue for further discussion within the Institute to address this new challenge to the nuclear future. Shirley Cox is the new Facility Operations Division Chair, appointed this year by the INMM Executive Committee.[6] The technical and policy expertise that resides within the Institute's membership could contribute to tempering the global response to this situation, and, more importantly, toward the development of safer solutions to nuclear power operations. The gauntlet has been thrown down—it is now up to our membership to pick it up and take a leadership position in this global crisis.

Similarly, the formation of the new Strategic Planning Committee provides yet another mechanism to address the impact of these events on the future of the Institute. The author has been appointed by the Executive Committee to chair the Strategic Planning Committee, and like the other new committees that will be forming this year, the plan is to create a charter and establish initial goals. There will be no lack of tasks ahead to address, as we now add a ninth strategic question to ponder on an uncertain path to the future:[7]

How will the Fukishima Daiichi nuclear plant accident impact the future of the Nuclear Renaissance?

We encourage *JNMM* readers to actively participate in these strategic discussions, and to provide your thoughts and ideas to the Institute's leadership. With your feedback we hope to explore these and other questions in future columns, addressing the critical uncertainties that lie ahead for the world and the possible paths to the future based on those uncertainties.

Jack Jekowski can be contacted at jpjekowski@aol.com.

Endnotes

1. See http://www.state.gov/r/remarks/2011/159355.htm.
2. See http://www.intel.com/pressroom/archive/speeches/ag080998.htm, speech by Andrew Grove, Chairman of the Board, Intel Corporation, to the Academy of Management Annual Meeting, July 9, 1998.
3. See http://www.gbn.com/articles/pdfs/gbn_Plotting%20Scenarios%20new.pdf, "Plotting Your Scenarios," p. 13.
4. See http://www.gbn.com.
5. See http://www.nautilus.org/publications/essays/napsnet/reports/SRJapanReactors.pdf for more information on the *"Short and Medium-term Impacts of the Reactor Damage Caused by the Japan Earthquake and Tsunami,"* Nautilus Institute for Security and Sustainability.
6. See http://www.inmm.org/Technical_Divisions.htm.
7. The previous eight questions that have been posed are:

   How will the world deal with the untenable situations in Iran and DPRK?

   What happens if other nation-states similarly pursue nuclear weapons?

   How are other nations responding to President Barack Obama's global nuclear initiatives – what impact will those responses have on the INMM?

   What will be the worldwide response to the first terrorist nuclear event (either nuclear or dispersal)?

   Can nuclear forensics provide the deterrence needed to prevent terrorist attacks?

   Will unilateral reductions in the U.S. stockpile influence the decision of other Nuclear Weapons States to further reduce their own stockpiles?

   What is the evolving role of the United Nations and IAEA in the new "international order" proposed by President Barack Obama?

   What scientific, technological and policy innovations can INMM promote to make the world a safer place?

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  1. Jones, F.T. and L. K. Chang. 1980. Article Title. *Journal* 47(No. 2): 112–118. 2. Jones, F.T. 1976. *Title of Book*, New York: McMillan Publishing.
- Author(s) biography

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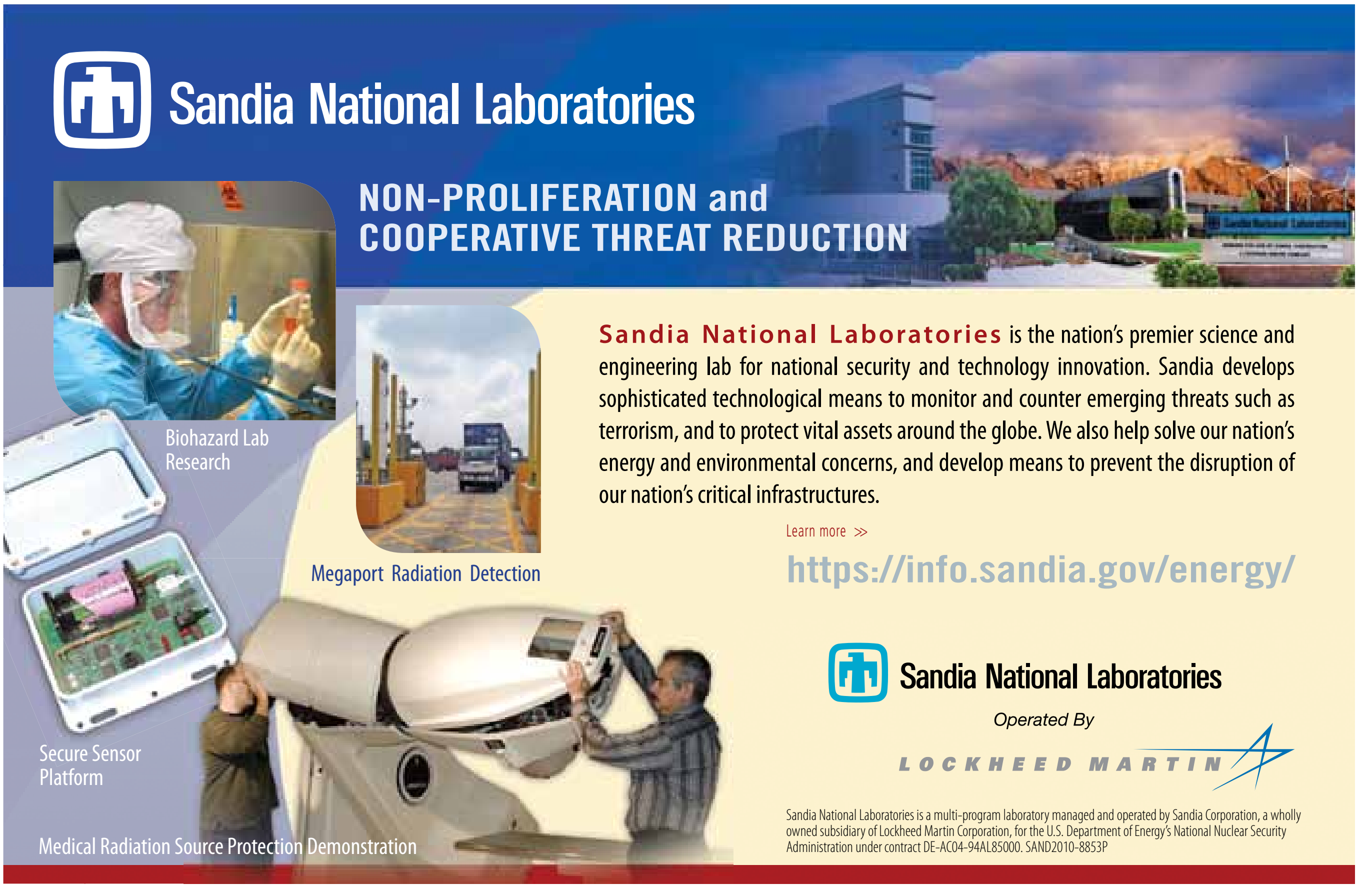
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[1]http://www.ortec-online.com/download.asbx?AttributeFileId=0b1f5761-c46b-4901-91ac-e0b810655b6a

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