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Report to the Chairman, Subcommittee on Transportation and Infrastructure, Committee on Environment and Public Works, U.S. Senate

March 2014

NUCLEAR SAFETY

Countries' Regulatory Bodies Have Made Changes in Response to the Fukushima Daiichi Accident

GAO-14-109

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GAO Highlights

Highlights of GAO-14-109, a report to the Chairman, Subcommittee on Transportation and Infrastructure, Committee on Environment and Public Works, U.S. Senate

Why GAO Did This Study

The March 2011 accident at Japan's Fukushima Daiichi nuclear power plant led to a worldwide review of nuclear power programs. NRC licenses and oversees civilian nuclear reactors. The State Department coordinates policy matters with international organizations and treaties, including those dealing with nuclear safety.

GAO was asked to examine (1) the actions nuclear regulatory bodies from selected countries have taken to strengthen nuclear safety; (2) the extent to which these countries have established automated systems to collect and transmit accident data; and (3) steps international organizations have taken to support nuclear regulatory bodies and promote nuclear safety worldwide since the accident. The countries GAO selected represent a cross section of established and emerging nuclear power countries. GAO also reviewed relevant documents and interviewed or obtained information from U.S. federal agencies, 15 foreign nuclear regulatory bodies, and international organizations.

What GAO Recommends

GAO recommends (1) that State and NRC work with and encourage IAEA to systematically track the status of recommendations made by IAEA peer review missions and (2) NRC consider expediting its decision on whether or how to upgrade its automated system for transmitting key reactor data. NRC neither agreed nor disagreed with the recommendations. State partially concurred with the first recommendation and had no comment on the second. GAO believes that fully implementing these recommendations would enhance nuclear safety.

View GAO-14-109. For more information, contact David C.Trimble at (202) 512-3841 or trimbled@gao.gov.

What GAO Found

All the nuclear regulatory bodies in the 16 selected countries in GAO's review—13 of which currently operate nuclear power reactors and 3 of which are developing or considering developing civilian nuclear power programs—have taken steps to strengthen nuclear safety in response to the Fukushima Daiichi accident in Japan. Japan in particular has fundamentally restructured its nuclear regulatory framework, and 3 other countries—China, Sweden, and Vietnam—are providing additional resources to their nuclear regulatory bodies. Countries are taking steps to improve safety with a focus on considering previously unimagined accident scenarios. Specifically, regulatory bodies in several countries (e.g., Belgium, Canada, Russia, and the United States) are now planning for accident scenarios that could involve multiple reactors at a single power plant. In addition, new requirements for emergency equipment, such as backup electric generators, in case of the loss of off-site power, as occurred at the Fukushima Daiichi nuclear power plant, are an area of focus among the regulatory bodies in GAO's review.

Officials from 6 of the 13 countries with operating nuclear power reactors in GAO's review said they have automated systems for collecting and transmitting critical nuclear power plant data to the nuclear regulatory body or designated technical experts who work with the regulatory body during an accident, and officials from a seventh country said that it has plans to build such a system. Officials from 3 of the countries with automated systems, including the United States, told GAO they are considering steps to ensure their systems can operate in certain emergency conditions, such as during the loss of off-site power, but none has a specific timetable for doing so. For example, the U.S. Nuclear Regulatory Commission (NRC) is first completing higher priority nuclear safety enhancements before deciding whether or how to upgrade its automated system because how enhancements are done may affect how upgrades to an automated system would be implemented. By delaying its decision on upgrades to enable the system to function under emergency conditions, the system may not function when needed most—during a severe accident.

Three key international organizations—the International Atomic Energy Agency (IAEA), the World Association of Nuclear Operators, and the European Union—along with the Convention on Nuclear Safety, have taken steps to support nuclear regulatory bodies and help them identify the most important lessons of the Fukushima Daiichi accident and promote regulatory changes to enhance nuclear safety worldwide. For example, one key way IAEA helps countries improve nuclear safety and regulatory effectiveness is through peer review missions, which evaluate, among other things, a country's nuclear safety regulatory framework based on IAEA Safety Standards and good regulatory practices. However, according to IAEA officials, the agency does not systematically track whether the recommendations of the peer review missions are implemented by the host countries. Without this information, IAEA cannot fully determine the impact and effectiveness of the peer review missions.

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Abbreviations

Action Plan	Action Plan on Nuclear Safety
ASN	Autorité de Sûreté Nucléaire
CNSC	Canadian Nuclear Safety Commission
Convention	Convention on Nuclear Safety
DOE	Department of Energy
ENS	Emergency Notification System
ENSREG	European Nuclear Safety Regulators Group
ERDS	Emergency Response Data System
EU	European Union
EURATOM	European Atomic Energy Community
IAEA	International Atomic Energy Agency
IRRS	Integrated Regulatory Review Service
IRRT	International Regulatory Review Team
NEA	Nuclear Energy Agency
NEPC	Nuclear Emergency Preparedness Commission
NISA	Nuclear and Industrial Safety Agency
NRA	Nuclear Regulation Authority
NRC	U.S. Nuclear Regulatory Commission
NSSC	Nuclear Safety and Security Commission
OECD	Organization for Economic Cooperation and Development
ONR	Office for Nuclear Regulation
OSART	Operational Safety Review Team
SSM	Swedish Radiation Safety Authority
TEPCO	Tokyo Electric Power Company
UN	United Nations
VPN	Virtual Private Network
WANO	World Association of Nuclear Operators
WENRA	West European Nuclear Regulators' Association

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March 6, 2014

The Honorable Thomas R. Carper
Chairman
Subcommittee on Transportation and Infrastructure
Committee on Environment and Public Works
United States Senate

Dear Mr. Chairman:

The March 2011 accident at Japan's Fukushima Daiichi nuclear power plant destroyed three nuclear reactors and resulted in the most extensive release of radioactive material at a nuclear power plant since the 1986 Chernobyl disaster.[1] The accident, which led to the evacuation of over one hundred thousand residents from the area around the plant and is expected to cost Japan tens of billions of dollars, has led to a review of civilian nuclear power programs worldwide. For example, Germany accelerated the shutdown of its nuclear power reactors, and Jordan reassessed plans to establish a civilian nuclear power program.[2] Nuclear regulators and industry officials question whether public acceptance of civilian nuclear power could survive another severe accident. The Secretary General of the United Nations (UN) noted at a September 2011 UN high-level summit on nuclear safety and security that "the effects of nuclear accidents respect no borders."

[1]On April 26, 1986, the worst accident in the history of civilian nuclear power occurred at the Chernobyl nuclear power plant in Ukraine, where an explosion destroyed the core of a reactor containing approximately 200 tons of nuclear fuel. The explosion also destroyed much of the reactor building, severed the reactor's cooling pipes, and spewed hot fragments of reactor fuel from the core. The explosion dispersed radioactive material over 60,000 square miles of land primarily in Ukraine, Belarus, and Russia. A separate fund was established to help stabilize the damaged reactor at Chernobyl by constructing a new containment structure. We reported in 2007 that the estimated cost of this effort was $1.2 billion, of which the United States pledged $203 million. See GAO, *Nuclear Safety: Construction of the Protective Shelter for the Chernobyl Nuclear Reactor Faces Schedule Delays, Potential Cost Increases, and Technical Uncertainties*, GAO-07-923 (Washington, D.C.: July 19, 2007).

[2] In 2010, Germany amended its Atomic Energy Act to align with an "energy concept" where nuclear power would serve a "bridging function" until an infrastructure for renewable fuel sources was reliably in place, without setting a timeline for phasing out nuclear power. On June 30, 2011, after the Fukushima Daiichi accident, the German parliament voted to fully shut down its nuclear power plants by the end of 2022. This vote followed the suspension of operations of 8 of Germany's 17 nuclear power plants.

Any event that compromises a nuclear power plant's power supplies can create the conditions for a nuclear accident. The Fukushima Daiichi accident resulted from a prolonged loss of electrical power when a powerful earthquake triggered a tsunami wave that exceeded the plant's seawall and flooded the site. The loss of power also largely disabled Japan's automated system for collecting and transmitting data during emergencies. Various stakeholders, including Tokyo Electric Power Company (TEPCO), which operated the Fukushima Daiichi power plant, acknowledged that design and operational shortcomings contributed to the accident sequence. Furthermore, numerous studies have concluded that failures in regulation contributed to those shortcomings. For example, according to the Kurokawa Commission[3]—an investigation commissioned by Japan's parliament—Japan's nuclear regulatory body at the time of the accident, the Nuclear and Industrial Safety Agency (NISA), and TEPCO were aware of the risks of a station blackout and reactor core damage from the loss of seawater pumps from a tsunami. According to the investigation, NISA knew that TEPCO had not taken actions to mitigate those risks but did not require any corrective measures. The Kurokawa Commission attributed NISA's reluctance to require greater preparedness of TEPCO to a flawed safety culture and to the fact that NISA was part of the government ministry responsible for promoting nuclear power, finding that NISA was not independent of the nuclear industry that it was charged with regulating or of the government agency responsible for promoting that industry.[4] NISA's lack of independence is believed by the Kurokawa Commission to have contributed to NISA's lax oversight of the nuclear industry. Nuclear industry representatives have said that their industry needs effective nuclear safety regulation and that the regulatory body must be independent from both operators and politics. The international cooperative and assistance programs of the U.S. Nuclear Regulatory Commission (NRC)—the nuclear regulatory body of the United States—

[3]The National Diet of Japan—the Japanese parliament—commissioned an investigation of the Fukushima Daiichi accident, chaired by Kiyoshi Kurokawa, known formally as The National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission. The commission issued its findings on June 9, 2012.

[4]Safety culture implies individual and organizational awareness of and commitment to the importance of safety. It also refers to the personal dedication and accountability of all individuals engaged in any activity that has a bearing on the safety of nuclear power plants. We reported in 2010 that development of a positive safety culture often involves a shift in how workers view and address safety-related events. See GAO, *Biological Laboratories: Design and Implementation Considerations for Safety Reporting Systems*, GAO-10-850 (Washington, D.C.: Sept. 10, 2010).

over the past 20 years have focused on promoting the independence and effectiveness of such bodies.

Nuclear power reactors generated about 11.3 percent of the world's electricity in 2012. As of November 2013, there are 435 civilian nuclear power reactors operating in 30 countries and 71 more under construction, primarily in China and Russia. In addition, as we reported in November 2010, countries such as Vietnam and Jordan, which do not yet have operating civilian nuclear power reactors, are building the necessary regulatory infrastructure for nuclear programs.[5] In April 2013, international regulators from 49 countries gathered in Ottawa, Canada, for a conference organized by the International Atomic Energy Agency (IAEA) devoted to improving nuclear regulatory systems following the Fukushima Daiichi accident.[6] The conference concluded that nuclear regulatory bodies have learned many lessons from the Fukushima Daiichi accident and that implementing these lessons will take time and commitment.

In light of the Fukushima Daiichi accident, you asked us to examine worldwide nuclear regulation and safety.[7] This report examines: (1) the actions regulatory bodies from selected countries with existing or planned civilian nuclear power reactors have taken to strengthen nuclear safety; (2) the extent to which these countries have established automated systems for collecting and transmitting data to the nuclear regulatory body and taken steps to enable such systems to withstand emergency conditions; and (3) steps key international organizations have taken to support nuclear regulatory bodies and promote nuclear safety worldwide

[5]GAO, *Nuclear Commerce: Governmentwide Strategy Could Help Increase Commercial Benefits from U.S. Nuclear Cooperation Agreements with Other Countries*, GAO-11-36 (Washington: D.C.: Nov. 4, 2010).

[6]IAEA is an autonomous international organization affiliated with the United Nations, established in Vienna, Austria, in 1957. The agency has the dual role of promoting the peaceful uses of nuclear energy by transferring nuclear science and technology through its nuclear science and applications and technical cooperation programs, and verifying, through its safeguards program, that nuclear material subject to safeguards is not diverted to nuclear weapons or other proscribed purposes. The IAEA also develops (nonbinding) international standards for nuclear safety, as well as criteria for nuclear regulatory independence.

[7]When we originally accepted this request, Senator Carper was Chairman of the Subcommittee on Clean Air and Nuclear Safety, Committee on Environment and Public Works. In February 2014, Senator Carper became Chairman of the Subcommittee on Transportation and Infrastructure. As a result, we are addressing this report to him in his current capacity.

since the Fukushima Daiichi accident and the impact of some of these steps.

To examine the actions that national regulatory bodies have taken to strengthen nuclear safety in the aftermath of the Fukushima Daiichi accident, we selected a nonprobability sample of 16 countries for case studies to represent a cross section of established and emerging civilian nuclear power countries in terms of program size,[8] the country's dependence on nuclear power, and the country's nuclear regulatory framework.[9] Of these 16 countries, the 13 countries with established nuclear power programs operate 78 percent of the world's nuclear power reactors; the other 3 countries do not currently operate nuclear power reactors but have emerging civilian nuclear power programs or have stated an interest in developing such programs.[10] Appendix II contains a complete list of these countries and information on their civilian nuclear power programs. For the 16 countries selected, we reviewed reports they prepared to document the lessons learned from the Fukushima Daiichi accident, including reports prepared for various international meetings on nuclear safety, and/or presentations in which they summarized those lessons.[11] We interviewed one or more officials from each selected regulatory body and/or technical support organization and/or received written responses to our questions. For some countries, we interviewed nuclear power plant operators and/or other nuclear energy industry officials. We also interviewed NRC and U.S. nuclear industry officials, as well as two former NRC chairmen. To examine the extent to which other countries have established or are considering establishing automated systems for collecting and transmitting data to the nuclear regulatory body during emergencies, we interviewed officials or received written answers

[8]The 16 countries we selected are Argentina, Armenia, Belgium, Canada, China, France, Indonesia, Japan, Pakistan, Russia, South Korea, Sweden, United Arab Emirates, United Kingdom, United States, and Vietnam.

[9]Because this is a nonprobability sample, information from these countries is not representative of the entire population of established and emerging civilian nuclear power countries and cannot be generalized. However, this information can provide illustrative examples of these countries' nuclear regulatory framework.

[10]We included countries with emerging or potential nuclear programs in our sample because the implications of the Fukushima Daiichi accident extend to such countries.

[11]These meetings include the April 2011 Convention on Nuclear Safety review meeting; the August 2012 Convention Second Extraordinary Meeting; and the International Atomic Energy Agency's April 2013 International Conference on Effective Nuclear Regulatory Systems.

to our questions from the respective nuclear regulatory bodies and some power plant operators. Because some country officials were more responsive than others, the amount of corroborating evidence we were able to obtain varies by country. For more information, see appendix I. To examine the steps key international organizations have taken to support nuclear regulatory bodies and promote nuclear safety worldwide since the Fukushima Daiichi accident, we first identified such organizations through interviews with officials from the U.S. State Department, Department of Energy (DOE), and NRC officials. Based on these discussions, we identified IAEA, the Organization for Economic Cooperation and Development's (OECD)[12] Nuclear Energy Agency (NEA),[13] the World Association of Nuclear Operators (WANO),[14] and the European Union (EU). We then reviewed, as applicable, the reports or action plans of these organizations and interviewed or exchanged written questions with relevant officials from them.

We conducted this performance audit from May 2012 to March 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. Appendix I contains more detailed information on our scope and methodology.

[12]The OECD is an organization of 34 countries that work together to address the economic, social, and environmental challenges of globalization. The organization provides a setting where governments can, among other things, compare policy experiences, seek answers to common problems, and seek to coordinate domestic and international policies.

[13]NEA is a specialized agency within OECD, an intergovernmental organization of industrialized countries based in Paris, France. In September 2013, OECD's NEA issued a report on the actions taken and lessons learned by NEA member countries and standing technical committees in response to the Fukushima Daiichi accident.

[14]After the Chernobyl disaster, nuclear power plant operators worldwide were determined to work together to ensure such a disaster could never happen again. From this, WANO emerged and formally came into being on May 15, 1989, during an inaugural meeting in Moscow. The WANO Charter is signed by 144 power companies, committing them to work in support of the WANO mission to maximize the safety and reliability of nuclear power plants worldwide by working together to assess, benchmark, and improve performance through mutual support, exchange of information, and emulation of best practice.

Background

This section describes (1) the Fukushima Daiichi nuclear accident, (2) nuclear energy and its regulation, (3) automated data transmission systems used by some nuclear regulatory bodies, and (4) international organizations and a treaty involved in promoting nuclear safety.

The Fukushima Daiichi Nuclear Accident

The March 11, 2011, tsunami wave that flooded the Fukushima Daiichi nuclear station destroyed the station's power supplies and emergency equipment, which, in turn prevented the plant's operators from cooling the reactors. The tsunami wave, at 13.1 meters, or nearly 43 feet was beyond the Fukushima Daiichi plant's "design basis"—that is, it exceeded the size of the tsunami that the site was designed and built to withstand, which was 3.1 meters, or slightly more than 10 feet above sea level. The station's emergency power supplies, including diesel generators and batteries, were below ground and not in waterproof containers. The station's three operating reactors had shut down during the earthquake that preceded the tsunami,[15] but the radioactive fuel continued to decay and produce heat. The tsunami destroyed the Fukushima Daiichi power station's emergency power supplies, with the exception of one diesel generator for the sixth reactor.[16] The electric wiring system for the three operating reactors, as well as seawater pumps, which were used to remove heat from the plant and cool diesel generators, were also destroyed. Without power to cool the reactors, the water in the reactor vessels boiled away and exposed the fuel, which melted. The steam from the boiling water increased pressure inside the primary containment vessel, allowing steam and other gases to move into the reactor building.[17] The steam reacted with melting fuel, generating hydrogen gas that built up in at least two of the reactor buildings before eventually exploding. In the wake of the accident, the Japanese government has directed that all but 2 of Japan's 50 civilian nuclear power reactors be

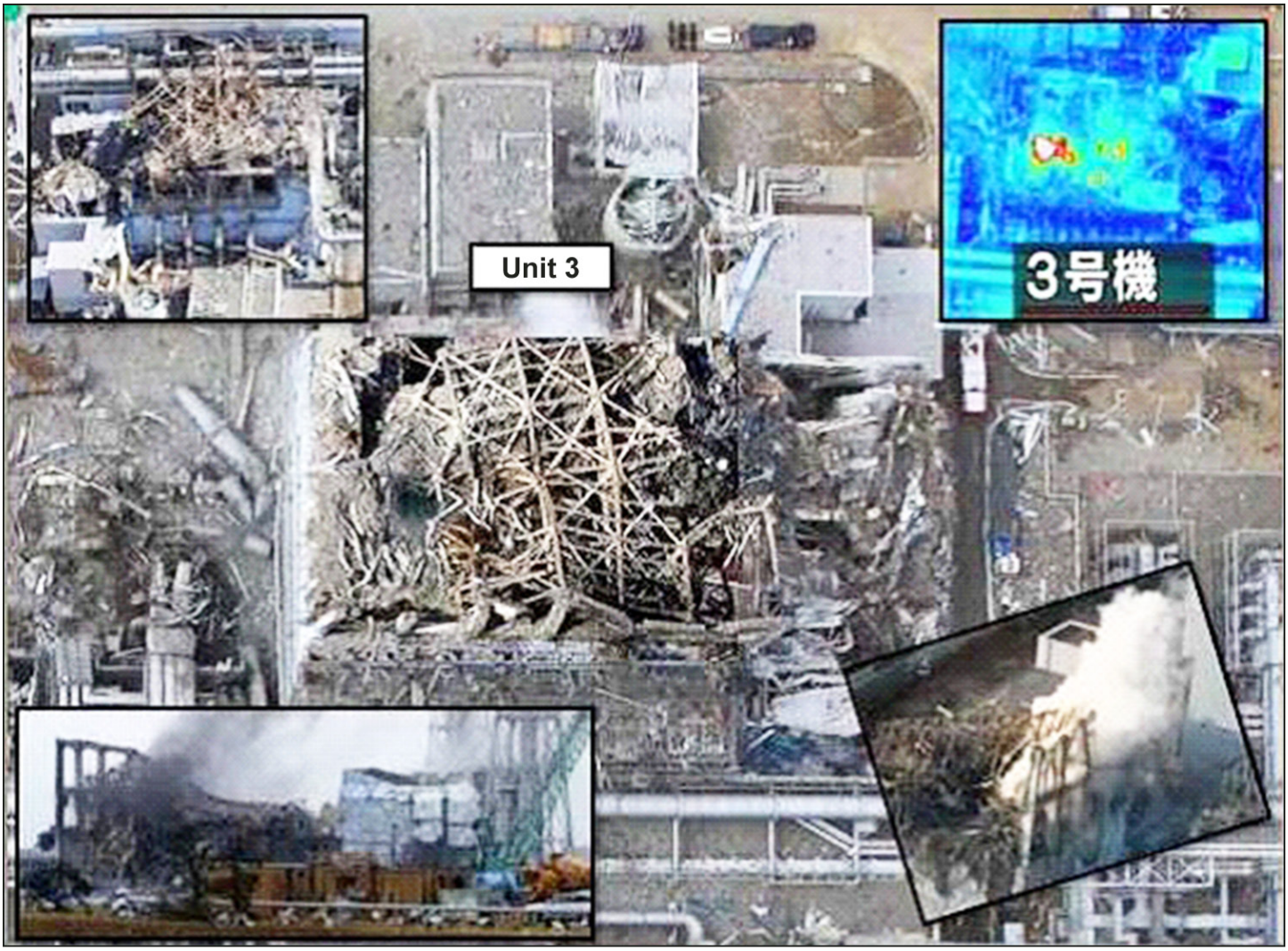
[15] Reactors 1, 2, and 3 were operating at the time of the accident. Reactors 4, 5, and 6 were off-line for scheduled outages.

[16] The tsunami caused by the earthquake flooded and totally destroyed all but one of the emergency diesel generators, the seawater cooling pumps, the electric wiring system, and the direct current power supply for reactors 1, 2, and 4, resulting in loss of all power except for an external supply to reactor 6 from an air-cooled emergency diesel generator. In short, reactors 1, 2, 4, and 5 lost all power. Reactor 3 first partially lost power and later lost all power.

[17] "Containment" refers to the structure and associated systems that enclose the nuclear reactor and are the final barrier to the radioactive materials that may otherwise be released into the environment in the case of an accident. Such enclosures are usually dome-shaped and made of steel-reinforced concrete.

shut down pending a complete safety review and, as of this writing, all reactors have been shut down. It is uncertain when these reactors will be brought back online. Figure 1 shows Unit 3 of the Fukushima Daiichi nuclear power station following the March 11, 2011, earthquake and tsunami.

Figure 1: Unit 3 of the Fukushima Daiichi Nuclear Power Plant Following the March 11, 2011, Earthquake and Tsunami



Source: NRC

Nuclear Energy and Its Regulation

The safe operation of nuclear power reactors worldwide has been a long-standing concern of the international community. According to IAEA, it is a fundamental safety principle that nuclear power plant operators have primary responsibility for nuclear safety during the life of the plant. However, nuclear regulatory bodies play a key role in ensuring nuclear safety. In the United States, NRC, an independent federal agency composed of five commissioners, licenses civilian nuclear power reactors and regulates and oversees their safe operation and security.

According to IAEA documents, effective nuclear regulatory bodies are characterized by independence, as well as other key factors, such as transparency and commitment to safety culture. NRC, for example, defines regulatory independence as independence from

- economic interests regarding the use of any nuclear materials or technology,
- policy interests, and
- political interests.

To that end, according to NRC, it does not (1) make decisions based on financial costs to nuclear plant operators when considering matters of safety significance or (2) consider the impact of its actions on the future of nuclear energy or any particular technology. Furthermore, NRC does not report to a cabinet agency or to the White House.

Automated Data Transmission Systems

Automated systems for collecting and transmitting data enable operators to provide data on selected nuclear power plant parameters—such as the status of reactor coolant and containment systems, radiation monitoring and containment, and weather—directly to regulators. According to NRC officials, receiving automated, accurate, real-time data directly from automated sources at the site reduces the burden placed on operators to manually transmit information during an emergency and gives confidence to government authorities involved in responding to the event and the public that the plant operator is not withholding information.

International Organizations and Treaty Involved in Promoting Nuclear Safety

IAEA, WANO, and the EU play an important role in promoting nuclear safety worldwide. Specifically:

- IAEA develops (nonbinding) international standards for nuclear safety, as well as criteria for nuclear regulatory independence. IAEA also

offers technical cooperation and peer review missions to its member states. These peer review missions evaluate, among other things, a country's nuclear safety regulatory framework based on the IAEA Safety Standards and conduct in-depth reviews of operational safety performance at nuclear power plants. A Secretariat, headed by the Director General, is responsible for implementing the agency's policies and programs. The U.S. State Department is the lead agency on U.S. policy regarding the IAEA, including the promotion of effective functioning in the agency and management reform. In addition, the department coordinates U.S. policy matters with international organizations and treaties, including those dealing with nuclear safety. NRC participates regularly in a variety of IAEA activities related to, among other things, nuclear safety. For example, NRC serves as the U.S. government's representative to the IAEA Commission on Safety Standards, as well as other technical committees.

- WANO, established in 1989, 3 years after the Chernobyl accident, promotes the safe and reliable operations of all of the world's civilian nuclear power plants. WANO works to achieve its goals through confidential peer reviews, shared access to members' operating experience, technical support and exchange activities, and professional and technical development sessions. These peer reviews help members compare their operational performance against standards of excellence through an in-depth, objective, and confidential review of their operations conducted by nuclear experts drawn from other WANO members' plants. To permit the free and open exchange of information among WANO members, plant specific information, such as that gathered in the course of a peer review, may not be released outside WANO without the approval of the originating member. Since 1992, WANO has conducted more than 500 peer reviews of operating nuclear power plants in 31 countries or regions—including at least one at every WANO member plant. Membership is voluntary, but every nuclear operator in the world is currently a member, and participation in these activities is mandatory for members. WANO members are committed to take timely action to correct performance issues identified during peer reviews.

- The EU was active in the aftermath of the Fukushima accident, exploring and implementing options for using its authorities to advance nuclear safety in Europe, particularly among the 14 EU member states with operating nuclear power plants. The requirements in the EU nuclear safety directive and nuclear waste directive are legally binding in all EU member states.

The Convention on Nuclear Safety (the Convention) is a multilateral treaty that, among other things, seeks to strengthen the safety of civilian nuclear power reactors. In the mid-1990s, representatives of over 50 nations, including the United States, participated in the development of the Convention in the aftermath of the Chernobyl accident. Today, 75 countries, including the United States, and one international organization, the European Atomic Energy Community (EURATOM), are contracting parties to the Convention.[18] The Convention calls on parties to establish and maintain a legislative and regulatory framework and a regulatory body with adequate authority, competence, and financial and human resources to govern the safety of nuclear installations, among other things. Specifically, parties to the Convention are obligated to take steps to ensure an effective separation between the regulatory body and any other body or organization concerned with the promotion or utilization of nuclear energy. Under the terms of the Convention, each contracting party—regardless of whether it operates nuclear power plants—is obligated to submit a national report, months in advance of the review meeting, which identifies the measures taken to implement each of the relevant nuclear safety obligations contained in the Convention. Obligations cover such points as siting, design, construction, and operation of civilian nuclear power installations. Parties that do not operate nuclear power plants submit reports focusing on, among other things, the steps they have taken to prepare and test emergency plans to deal with an accident in a neighboring country that operates nuclear power plants. Countries considering establishing nuclear power programs are expected to provide information in their national reports about the steps they are taking to meet the Convention's obligations including, for example, reactor design and siting requirements. The parties to the Convention have also established detailed guidance to help parties prepare their national reports. The purpose of the guidance is to encourage parties to describe the steps they are taking to meet the Convention's obligations and to facilitate other parties' review of the national reports of other countries. The countries meet every 3 years in Vienna, Austria, for review meetings to present their national report, address questions that may arise about the report, and assess and ask questions about the reports of other parties. This is considered a

[18] EURATOM acts in several areas connected with atomic energy, including research, safety standards, and the peaceful uses of nuclear energy. One of the fundamental objectives of the EURATOM Treaty that established EURATOM is to ensure that all users in the EU enjoy a regular and equitable supply of ores and nuclear fuels.

peer review process. Parties may also submit written questions in advance of the review meeting on other parties' national reports and receive written responses to these questions.

Nuclear Regulatory Bodies Have Taken Steps to Strengthen Safety

The nuclear regulatory bodies in the selected 16 countries in our review have taken steps to strengthen nuclear safety. Countries are taking steps with an increased focus on considering previously unimagined accident scenarios, such as those affecting multiple reactors within a given power plant. In addition, most countries with operating reactors in our review are considering or have issued new requirements in common categories: emergency equipment, hydrogen control, and filtered venting. Japan has fundamentally restructured its regulatory framework, and 3 other countries—China, Sweden, and Vietnam—are providing their nuclear regulatory bodies with additional resources. Four countries—France, South Korea, Sweden, and the United Kingdom—have also reformed their regulatory framework but not specifically in response to the Fukushima Daiichi accident.

Countries Are Strengthening Regulatory Effectiveness and Considering Previously Unimagined Events and Accident Scenarios

All 16 selected countries in our review have taken regulatory action in response to the Fukushima Daiichi accident. For example, in the United States, NRC formed the Near-Term Task Force in March 2011 to conduct a comprehensive assessment of NRC's processes and regulations in light of the accident to determine whether the agency should make additional improvements to its regulatory system or reactor safety in the United States. This task force issued a report in July 2011 with its findings and 12 recommendations, which were prioritized in an October 2011 report into three tiers. The commission then approved the NRC staff's three-tier prioritization in December 2011. Tier 1 recommendations were those that NRC staff determined should be started without unnecessary delay and for which resources are sufficient. Tier 2 comprises recommendations requiring further technical assessment or that depended on Tier 1 issues or availability of resources. Tier 3 recommendations require further study, depend on a shorter-term action to be completed to inform the longer-term action, or depend on the availability of resources or on the resolution of Task Force Recommendation 1, which deals with clarification of the regulatory framework. All of the items identified for long-term evaluation fall into Tier 3.

Each of the other selected countries in our review, with the exception of Vietnam, which does not have operating power reactors—undertook

safety inspections, including comprehensive risk safety assessments, more commonly known as stress tests.[19] The findings from the stress tests were used to consider further action to improve nuclear safety. Stress tests examine what are known as "beyond design-basis events"—those where conditions exceed what the facility or site was designed to withstand. For example, one of the beyond design-basis scenarios considered by the Belgian Doel nuclear power plant operator was a severe storm combined with an unfavorable wind direction—which together could breach the embankment protecting the plant from a flood.[20] For this scenario, the plant's operator analyzed the consequences of such a breach, estimating flooding levels and potential consequences, including weak points—such as buildings not designed to be watertight—as well as ways in which the plant was adequately prepared, such as emergency equipment that remains protected.

The results of the stress tests served as a basis for corrective measures. For example, the proposed corrective measure for the scenario described at the Doel plant is to reinforce the top of the embankment with concrete tiles. In Sweden, regulators are considering a revision of the country's emergency planning zones after stress tests revealed that the existing emergency planning zones were insufficient for a radioactive release similar to that of the Fukushima Daiichi accident.[21] In the United Arab Emirates, which does not have operating power reactors, the regulatory body commissioned a task force to study the implications of the Fukushima Daiichi accident from the standpoint of facilities with pending license applications, where operators were asked to supplement their license applications in consideration of external event contingencies, according to regulatory officials we interviewed. In the United States, NRC did not require plant operators to conduct stress tests. Instead, nuclear power plant operators were required to complete detailed inspections and engineering assessments of their plants, known as "walk-

[19]These assessments examined how nuclear installations can withstand the consequences of various extreme external events and, in certain cases, security threats and incidents due to malevolent or terrorist acts. The topics of the tests included natural initiating events (earthquake, tsunami, and extreme climatic conditions), loss of the facility's safety systems, and severe accident management.

[20]The Doel power plant is located along the Scheldt River and has four reactors with a combined output of 2,912 megawatts.

[21]NRC defines emergency planning zones as areas for which planning is recommended to assure that prompt and effective actions can be taken to protect the public in the event of a radiological incident at a nuclear power plant.

downs," to check that all safety features were in operating condition and to submit reports to NRC for review. Any issues identified in the walk-downs were to be addressed by plants' corrective action programs.[22] For example, the flooding walk-down at the Vermont Yankee power plant identified a discrepancy in the procedure for sandbag barricades. The procedure has since been enhanced to provide specific, detailed guidance on the placement of sandbag barriers, and an exercise in accordance with the new procedure was successfully completed.

According to a 2013 IAEA nuclear safety review, nuclear regulatory bodies are now focusing more on a wider range of possible events as a result of the Fukushima Daiichi accident. According to this review, nuclear regulatory bodies have not historically required nuclear operators to include multireactor accidents in their design basis. Canadian Nuclear Safety Commission (CNSC) officials also told us that a significant shift in regulatory focus in Canada pertains to the management of multiple reactors. They said that prior to the Fukushima Daiichi accident, which destroyed four reactors, CNSC's guidelines did not consider the possibility of an event that could impact multiple reactors. These officials told us that certain safety features are more complicated for multireactor plants because some systems and equipment are shared among reactors, allowing for common-cause failures during an accident. CNSC officials told us that, in response to the Fukushima Daiichi accident, they are incorporating multireactor specifications into their regulations. Similarly, a Belgian nuclear regulatory official said that the Fukushima Daiichi accident has led regulatory bodies to "think outside the box" in considering scenarios that could threaten nuclear power plants. For example, one of the items in a national action plan that the Belgian nuclear regulatory body developed after the accident pertains to an internal emergency plan in case of an event that impacts multiple reactors. A Russian regulatory official also told us that regulators need to consider previously unimagined events, including the impact on nuclear power plants from a meteor, such as the one that struck Russia in February 2013.[23] In March 2012, in keeping with the shift toward considering events that may impact multiple reactors, Russia's nuclear regulatory body approved a corrective action plan that includes special

[22]A corrective action program is an operator's process for tracking, evaluating, and resolving deficiencies.

[23] On February 15, 2013, a meteor exploded over Chelyabinsk in Russia. The Mayak nuclear facility, which is near the explosion, was not affected.

consideration for plants with multiple reactors.[24] In the United States, NRC is revisiting its beyond design-basis requirements to better integrate them into its overall regulatory procedures. For example, NRC's Near-Term Task Force report contains a section that focuses on operators' capabilities to respond to a prolonged station blackout—that is, a loss of power—and events that impact multiple reactors. This report explains that the accident at Fukushima Daiichi has shown that such events are realities that must be addressed as part of emergency planning because, although they are of low probability, they have the potential for severe consequences.[25] In that vein, an NRC commissioner said, in June 2013, that the accident has blurred the distinction between design-basis and beyond design-basis.

Most Countries in Our Review Are Considering Common Categories of New Regulatory Requirements—Emergency Equipment, Hydrogen Control, and Filtered Venting Systems

To improve nuclear safety based on the lessons learned from the Fukushima Daiichi accident, the regulatory bodies in our review are considering or have issued new requirements with regard to the following common categories: emergency equipment, hydrogen control, and filtered venting systems. In the course of the Fukushima Daiichi accident, the loss of emergency equipment—including backup power supplies, such as batteries and diesel generators, as well as water supplies, such as pumps—prevented operators from cooling the reactors. Consequently, as the water in the reactors boiled and the fuel melted, hydrogen built up and exploded, destroying three reactor containment structures and releasing radioactivity into the environment. New regulatory requirements worldwide in response to these events include the following:

- *Emergency equipment.* New requirements for emergency equipment—for example, the number of diesel generators on-site and their placement—are an area of focus among the regulatory bodies in our sample. Examples are as follows:
    - South Korea's regulatory body issued a list of 50 action items, which included securing the availability of a portable electric

[24]"Updated Measures to Mitigate Consequences of Beyond-Design Basis Accidents at Nuclear Power Plants."

[25]In the United States, an August 23, 2011, magnitude-5.8 earthquake in Mineral, Virginia, which had its epicenter approximately 11 miles from the North Anna Power Station was a beyond design-basis event. The ground motion at the site during the earthquake exceeded levels for which the plant was originally designed and licensed. Nevertheless, the plant did not experience significant damage to its structures or safety systems.

power generator vehicle and batteries and installing paths for the injection of emergency cooling water.

- The Canadian Nuclear Safety Commission has issued new requirements for emergency equipment and resources, such as requirements for backup power at emergency facilities; on-site storage of emergency equipment, such as portable generators; and the availability of portable backup power and emergency response equipment.

- NRC has issued an order to address operators' capabilities to move water to maintain or restore reactor core cooling, among other things. A senior NRC official said that, because the order requires these capabilities to be maintained even if power is lost, the order includes implicit requirements for emergency power supplies or suitable alternative methods to continue reactor core cooling indefinitely.

- *Hydrogen control.* All but one of the 13 nuclear regulatory bodies in our review with operating nuclear power reactors in their countries have issued additional requirements for hydrogen control systems or are studying alternative options for hydrogen removal. In some cases, countries that already have some hydrogen control systems are looking to test existing systems and further strengthen hydrogen safety. For example, Russia's regulatory body required complete implementation of hydrogen monitoring and removal systems in reactors where they were not part of the original design and also required an analysis of the adequacy of existing hydrogen monitoring and removal systems to prevent the formation of explosive gas mixtures in the most unfavorable scenarios in severe accidents. Similarly, France's regulatory body has required that one type of hydrogen control system be qualified for external hazards beyond the level currently considered,[26] and has issued requirements for the detection of hydrogen in places not planned for in the design.

- *Filtered venting systems.* Eleven of the 13 regulatory bodies in our review with operating reactors have issued new requirements or are studying options for filtered venting systems to minimize the release of radioactive materials into the environment in the event of an accident.

[26]This type of hydrogen control system refers to catalytic recombiners, which oxidize the hydrogen (or "recombine" it with oxygen to make water or steam).

For example, filtered venting systems are included in Japan's new safety regulations under "measures for preventing core damage/containment failure." Canada's Action Plan in response to the Fukushima Daiichi accident includes requirements for "Emergency Filtered Containment Venting." Countries that already have filtered venting systems, such as Sweden, are studying potential updates and improvements to their systems—for example, to ensure that they function in prolonged accident scenarios. France's regulatory body has required the operator to submit a detailed study of possible improvements to its venting-filtration system, taking into account the possibility of needing filtration in two or more reactors simultaneously. In the United States, NRC announced that it is in the process of a technical evaluation to support rulemaking on filtering, with the deadline for the final rule set for 2017. NRC staff recommended that the commission order the installation of filtered venting systems at boiling water reactors with Mark I and II containments—those similar to the ones at Fukushima Daiichi.[27] However, the commission voted against issuing an immediate order to require installation of filtered venting systems and instead gave NRC staff a year to produce a

[27]There are three major types of containment designs for boiling water reactors: Mark I, Mark II, and Mark III. The Fukushima Daiichi reactor Units 1-5 had Mark I containments, and reactor Unit 6 had a Mark II containment. According to a commissioner vote, Mark I and II containment structures' relatively small volume presents "long-recognized vulnerabilities" in their ability to contain radioactive materials during a severe accident. A 1975 NRC study (NUREG-75/014) found that the risk of containment failure during severe accidents is higher at boiling water reactors with Mark I containments because the containment volume of Mark I containment designs was significantly less than that of the other containment designs, approximately one-sixth the volume of large dry pressurized water reactor containments. In boiling water reactors with a Mark II containment design, the containment volume could be approximately 25 percent larger than the volume of Mark I containments. According to NRC's Near-Term Task Force, it can reasonably be concluded that under circumstances similar to those of the Fukushima-Daiichi accident, a Mark II would have suffered similar consequences because its containment design is only slightly larger in volume than Mark I containment designs.

technical evaluation to support rulemaking on filtering,[28] thus deciding to address filtered venting through its regular process rather than as an emergency issue. The commission directed the staff to consider both the use of a filter to be placed on the vent, as well as a more performance-based approach using existing systems to achieve a similar reduction in radioactive release during an accident.

Japan Restructured Its Nuclear Regulatory Framework, and China, Sweden, and Vietnam Devoted Additional Resources to Nuclear Safety

Japan was the only country in our review that fundamentally restructured its nuclear regulatory framework in response to the Fukushima Daiichi accident. Specifically, in June 2012, Japan's parliament passed the Establishment of the Nuclear Regulation Authority Act, which, effective in September 2012, established the new Nuclear Regulation Authority (NRA) as an independent commission in charge of all of the nation's nuclear regulatory functions. NRA replaced the organizations previously responsible for nuclear safety regulation, including NISA. This restructuring separated the government's nuclear regulatory function from that of nuclear power promotion. The reform also established a Nuclear Emergency Preparedness Commission (NEPC) under Japan's cabinet and required the new regulatory body to incorporate the latest scientific and technical knowledge into the nation's nuclear regulatory basis, in keeping with the Kurokawa Commission finding that NISA had a negative attitude toward new advances in knowledge and technology from outside Japan. An NRA commissioner told us that Japan's restructuring of its nuclear regulatory system is necessary to address the issue of "regulatory capture"—the collusion between NISA and the nuclear industry—that compromised the nation's nuclear safety prior to the accident and to regain the public trust, which the commissioner told us was NRA's biggest challenge. NRA's mission statement lists among the agency's core values

[28]Generally, federal regulations, including those of NRC, can only be changed through the rulemaking process. An order—which is issued immediately—bypasses NRC's rulemaking process, which could take years and seeks comments from stakeholders, such as industry and the public. NRC's "backfit rule" requires, in order to impose new requirements on existing licensees, that NRC determine that the new requirements would result in a substantial increase in the overall protection of public health and safety or common defense and security and that this increased protection justifies the cost of implementation, unless the new requirement fits within one of the exceptions to the backfit rule in 10 C.F.R. § 50.109(a)(4)(i)-(iii). Backfitting is defined by NRC as the modification of or addition to systems, structures, components, or design of a facility; or the design approval or manufacturing license for a facility; or the procedures or organization required to design, construct, or operate a facility; any of which may result from a new or amended provision in NRC's regulations or the imposition of a regulatory staff position interpreting NRC's regulations that is either new or different from a previously applicable staff position, relative to specific dates, such as issuance of licenses.

and principles the fostering of a genuine safety culture, where public safety is the highest priority.

According to the commissioner, NRA's structure is largely modeled on NRC's, and, to a lesser extent, on that of France's nuclear regulatory body. For example, NRA will have a five-commissioner voting system like the U.S. and French nuclear regulatory bodies. However, the Japanese government has not determined how to reconcile NRA's independence from the Japanese bureaucracy with its status as a government agency within that bureaucracy. According to the commissioner, the fragmentation under the previous system—with multiple agencies responsible for various aspects of nuclear safety— was problematic, and the need for integration "obvious" and that integrating all nuclear oversight agencies into one is an international trend. He said, however, that merging the staff and budgets of previously separate agencies will take time, as NRA is an amalgam of these disparate agencies. The commissioner said that NRA currently has no budget autonomy, as its budget, as that of any other Japanese government agency, is allocated by the government. However, the issue of NRA funding has not been finally settled, and fees from nuclear operators are still under consideration as a funding source. The commissioner said that funding the agency independently of the government will be difficult but that not having budgetary independence could limit organizational and personnel independence, which are essential.

The NRA completed new regulations for civilian nuclear power plants in Japan in July 2013. All of Japan's nuclear power plants with operators that wish to restart their reactors must meet criteria established by the new regulations. In addition, reactors built in the 1970s and 1980s will be reexamined in light of the latest science on earthquakes and geology. Once the safety of each reactor is assessed based on the new regulations—a process that is expected to take 2 to 3 years—the Japanese government is to determine whether each reactor can restart. The operator of each reactor must also obtain the support of the public; the governor of the prefecture where the reactor is located and, in some cases, the governors of nearby prefectures; and the national government of Japan. NRA will only be involved in the technical deliberations and will not have a role in other aspects of the governmental decisions to restart reactors.

Three other countries in our review—China, Vietnam, and Sweden—did not change their regulatory structures in response to the Fukushima Daiichi accident, but senior nuclear regulatory officials we interviewed from those countries said that the accident reinforced to their governments the importance of a strong regulatory body. As a result, the

officials said that their governments provided additional human and financial resources to their nuclear regulatory bodies. According to the respective regulatory officials, the governments of China and Vietnam paused or slowed their nuclear programs after the Fukushima Daiichi accident to strengthen their regulatory authorities. The Chinese government suspended the licensing of new reactors in 2011—there were 14 operating reactors and additional ones under construction at that time—until a National Nuclear Safety Plan was developed and safety inspections were completed, according to a senior regulatory official. The Chinese government also agreed to nearly double the regulatory body's staff to 1,100 and increased its budget. In Vietnam, the government plans to begin construction on its first nuclear power plant in 2014 and to begin operation in 2020. However, since the Fukushima Daiichi accident, the nuclear regulatory body sees this timeline as overly ambitious as the country needs time to develop a nuclear safety infrastructure that meets IAEA standards. To that end, Vietnam's Atomic Energy Law will be reevaluated in the aftermath of Fukushima with regard to regulatory independence, among other things. According to the Department of Energy, Vietnam announced in January 2014 that the start of construction on its first nuclear power plant may be delayed until the 2017-2018 timeframe. In Sweden, senior regulatory officials told us that the government had previously hesitated to fund the regulatory body with the amount it had requested but, after the accident, it provided a larger budget allocation than requested, allowing the regulatory body to hire more staff.[29]

Four Countries' Regulatory Changes Were Not Made in Response to the Fukushima Daiichi Accident

Four countries in our sample—France, Sweden, South Korea, and the United Kingdom—have recently made changes to their regulatory structures that were not directly in response to the Fukushima Daiichi accident. Two of the countries, France and Sweden, made changes to their structures before the accident occurred. The other two countries (South Korea and the United Kingdom) made changes after the accident but, according to regulatory officials from those countries, these changes were planned prior to the accident. In all four countries, the regulatory changes were consistent with the lessons learned from the Fukushima Daiichi accident.

[29]According to Swedish nuclear regulatory officials, Sweden's nuclear regulatory body's nuclear safety work is funded primarily by user fees. The increased allocation since the Fukushima Daiichi accident reflects an increase in the amount of the budget funded by the government.

Specifically, France did not change its regulatory structure in response to Fukushima but overhauled its nuclear regulatory system in 2006 with a law on "Transparency and Security in the Nuclear Field," which established the Autorité de Sûreté Nucléaire (ASN) as an independent commission.[30] ASN has responsibility for nuclear safety, but not physical security, which is the responsibility of a separate authority. French regulatory officials told us that they would prefer that security also fall under the nuclear regulatory body—that integration of these functions would give the regulatory body more expertise and lead to more thoughtful and comprehensive regulation. According to French officials, regulatory and others, the Fukushima Daiichi accident did not drive more nuclear regulatory changes within France because France had already implemented many nuclear safety improvements in response to vulnerabilities exposed in 1999, when strong winds raised the tide, and water breached the seawalls of the Blayais nuclear power plant near Bordeaux and flooded it, including its safety-significant equipment. The plant shut down without incident but, in response, the regulatory body and the plant operator launched a 10-year program to create a more systematic approach to flooding hazards, including raising seawalls and making underground facilities watertight. Studies on flood preparedness at French nuclear power plants were commissioned, and new flood scenarios were considered and modifications made, such as raised seawalls.

Sweden also made changes to its nuclear regulatory structure independently of the Fukushima Daiichi accident. The Swedish Radiation Safety Authority (SSM), established in July 2008 to consolidate various agencies previously involved in nuclear regulation, oversees nuclear safety and security, among other things. In 2010, the Swedish government assigned SSM to review the nation's regulatory framework and strategy. Sweden, like France, had also already implemented many nuclear safety improvements in response to events prior to Fukushima. For example, the Swedish Parliament decided to require filtered venting equipment to protect against large-scale ground contamination following the Three-Mile Island accident in 1979 in the United States. Sweden also

[30]Even before the 2006 law that established ASN as an independent commission, the French agencies responsible for nuclear regulation became more independent over time. The first nuclear regulatory body was within the French Atomic Energy Commission, which also operated the reactors.

established a Severe Accident Management Program in response to the Three-Mile Island accident.[31]

In 2011, the South Korean government established a new stand-alone regulatory body, the Nuclear Safety and Security Commission (NSSC), which comprises a panel of commissioners that reports directly to the President of South Korea. The establishment of NSSC separated nuclear promotional functions from regulatory ones by removing regulatory decision making from South Korea's Ministry of Education, Science and Technology, which previously oversaw nuclear regulation, as well as nuclear policy and research and development support. South Korean nuclear regulatory officials said that plans for this restructuring were in place before the Fukushima Daiichi accident. According to these officials, NSSC responded to recent nuclear safety incidents, such as the falsification of documents for reactor components at the Yeonggwang nuclear power plant in November 2012, with 20 measures to address such issues, including a program to improve safety culture.[32]

The United Kingdom also created a new regulatory body in April 2011—the Office for Nuclear Regulation (ONR)—to replace the Nuclear Installations Inspectorate, a quasi-autonomous nongovernmental organization.[33] According to the memorandum announcing the body's creation, this change was unrelated to the United Kingdom's response to the Fukushima Daiichi accident. However, the memorandum stated that the events at Fukushima further confirmed the need for a modern, independent and flexible nuclear regulatory body. According to a senior ONR official, the change was prompted by recruitment and retention challenges the nuclear regulatory body was facing in competing with the

[31]A Severe Accident Management Program is a program to prevent and mitigate the consequences of beyond design-basis accidents, including severe accidents. According to IAEA, accident management means taking actions during a beyond design-basis accident to prevent it from escalating into a severe accident, mitigate any consequences, and achieve a long-term safe stable state.

[32]NSSC found 215 cases of quality-record falsification among 20 suppliers of reactor components for the Yeonggwang nuclear power plant. Another incident of concern to NSSC was a safety failure at the Kori nuclear power plant that was not reported to NSSC until a month after the incident. According to Korean nuclear regulatory officials, both incidents had an impact on public perceptions of nuclear safety.

[33]Under the quasi-autonomous nongovernmental organization construct, an agency can perform functions of the government and be entirely funded by the government but not controlled directly by the central government.

nuclear industry. According to this official, recruiting from the nuclear industry was a challenge because the pay and conditions within the government, restrained by a public pay policy, were not competitive with those in the industry. An independent study recommended taking the nuclear regulatory body out of the civil service where it would not be subject to the same pay policy. The body remains under the umbrella of the Health and Safety Executive but is not subordinate to it; rather, it is a separate agency. The additional flexibility of this change has allowed ONR to retain staff and to better recruit staff from the industry, which helps meet the needs for new licensing applications. ONR manages the conflicts of interest that could arise from recruiting inspectors directly from industry by starting recruits out in its lower rungs, in technical assessment posts, where inspectors have no contact with operators, with particular care to avoid contact with the operators that had employed them.

Nearly Half of Countries with Nuclear Power Reactors in Our Review Have Automated Data Transmission Systems

Six of the 13 countries that have operating nuclear power reactors in our review have established automated system for collecting and transmitting critical data to the nuclear regulatory body or designated technical experts who work with the regulatory body during an accident, and a seventh country has plans to build such a system. However, officials from some of these countries, including the United States, told us that their automated data transmission systems are not currently designed to operate under severe emergency conditions, such as loss of off-site power and lines of communication as occurred at the Fukushima Daiichi nuclear power plant.[34] Officials from 5 of the other countries with operating nuclear power reactors told us they either had no plans to establish such a system or they might consider establishing such a system in the future. We were unable to determine whether a sixth country has or plans to establish such a system.

[34]Normally, alternating current power, which is essential for safe operation and accident recovery at commercial (civilian) nuclear power plants, is supplied by off-site sources via the electrical grid. Loss of this off-site power can have a major negative impact on a power plant's ability to achieve and maintain safe shutdown conditions.

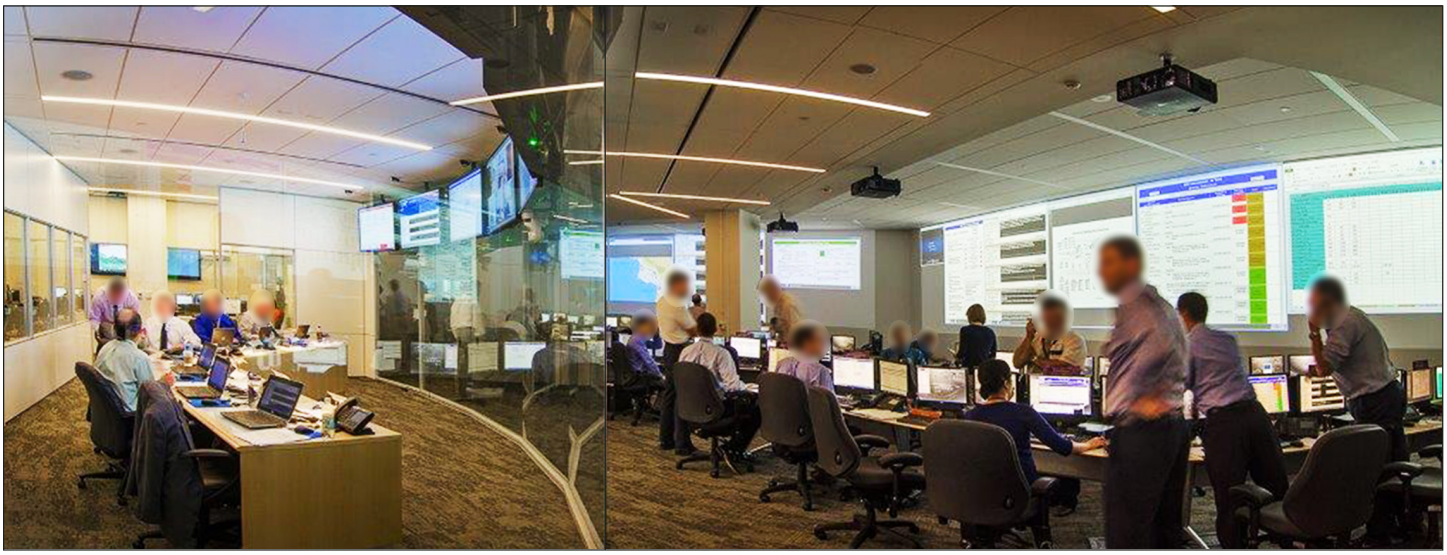
Six Countries Have Automated Systems, and Some Are Considering Steps to Ensure They Can Operate in Emergency Conditions

Officials from 6 of the 13 countries in our review with operating nuclear power reactors—Japan, the United States, France, South Korea, China, and Argentina—told us that they have automated data transmission systems, and officials in a seventh country, Sweden, told us they are working to install such a system. However, none of these officials told us that their automated data transmission system is currently designed to operate under severe emergency conditions, such as loss of off-site power and lines of communication as occurred at the Fukushima Daiichi nuclear power plant. Although nuclear regulatory officials from 3 countries (Japan, the United States, and France) told us they are considering upgrading their automated data transmission systems to operate under emergency conditions—to a satellite-based system, for example—only Japan, according to a senior Japanese official, has made a final decision to upgrade its system to a more durable and reliable satellite-based communications system. None of these countries' officials told us they have a specific timeline for upgrading their system.

We obtained the most information regarding automated data systems from the United States and France.

United States. NRC established an automated data transmission system in the aftermath of the 1979 Three-Mile Island accident due to a high error rate from plant operators in data transmission during the accident. At that time, NRC relied on telephone calls with its resident inspectors and plant operators to verbally communicate technical data to NRC. In order to substantially improve access to key plant and reactor data, NRC began developing what became the Emergency Response Data System (ERDS) in 1985, and the system became operational in 1993. At present, when activated, ERDS data flow directly to NRC's Operations Center at its Maryland headquarters and are also available, as needed, at NRC regional offices in Pennsylvania, Georgia, Illinois, and Texas. According to NRC officials, approximately 39 of the 62 U.S. nuclear power plants have opted to transmit ERDS data continuously at all times; the remainder has the capability to do so in the event of an incident or emergency. Figure 2 shows NRC's new Headquarters Operations Center.

Figure 2: NRC's Headquarters Operations Center



Source: NRC.

However, according to NRC officials, ERDS' capacity to collect and transmit information would be compromised under certain emergency conditions, such as the loss of off-site power and lines of communication, as occurred at the Fukushima Daiichi nuclear power plant. Although NRC has not required that ERDS be upgraded to function under these conditions, NRC had taken steps before the Fukushima Daiichi accident to upgrade ERDS— to move the system from an analog based platform to a digital one and to address cybersecurity concerns. In particular, NRC officials told us that, prior to 2009, ERDS used a process requiring the use of a modem to transmit data. Over time, modems have become obsolete, making it difficult to maintain the system. Modems also inherently introduce cybersecurity vulnerabilities. ERDS has been upgraded to use a Virtual Private Network (VPN) to create a secure point-to-point data pathway from each operator site to NRC headquarters.[35] VPN technology, according to NRC, is the current, stable, and reliable information technology industry standard.

[35]A VPN is a private network that is maintained across a shared or public network, such as the Internet, by means of specialized security procedures. VPNs are intended to provide secure connections between remote clients, such as branch offices or traveling personnel and a central office.

NRC is considering additional upgrades to ERDS so that it would function more reliably during severe emergency conditions but has not yet acted because ERDS is not considered a "safety related" system, as it does not directly ensure the safety of a facility or play a direct or essential role in emergency response. These officials added that they thought ERDS was "a nice supplement" to voice communications but that it was not essential because NRC can communicate directly by telephone with its resident inspectors and the operator. They added that telephone communications have been upgraded since the 1979 Three-Mile Island accident. Specifically, NRC funded the establishment of the Emergency Notification System (ENS), which bypasses the local telephone switching network. Plant operators are now required to establish multiple, continuously-staffed ENS telephone lines early in any accident scenario. NRC and licensees have also developed response plans using ENS and conduct frequent exercises to validate these plans.

NRC officials acknowledge that data transmission via ERDS improves the efficiency of information sharing between the licensee and the NRC Headquarters Operations Center but said that the practices and procedures used to obtain the data using ENS would enable NRC to evaluate the severity of the reactor accident without ERDS if necessary. Accordingly, these officials told us that NRC is first completing higher priority post-Fukushima nuclear safety enhancements before deciding whether or how to upgrade ERDS because how these enhancements are resolved could affect how any ERDS upgrade might be implemented. They also noted that both the Three-Mile Island and Fukushima Daiichi accidents were managed without the benefit of functioning automated data transmission systems. However, an IAEA fact-finding mission to Japan in the aftermath of Fukushima stated that greater consideration should be given in the future to providing hardened systems, communications, and sources of monitoring equipment for providing essential information for on-site and off-site responses, especially for severe accidents. Moreover, without upgrades to enable ERDS to function under emergency conditions, it may not be available when the need for it is greatest, such as during a severe accident.

France. French officials told us, during our tour of one of their national crisis centers—the French government's emergency response center for dealing with events with possible radiological implications—that France also does not consider its automated data transmission system a "safety system." These officials told us that there are accident scenarios under which emergency diesel generators would power their automated data transmission system, but whether the system would function would depend on the severity of the accident and level of damage to the plant's

electrical system. In particular, if power were lost during a severe accident as it was during the Fukushima Daiichi accident, the automated system would not function. French officials also told us that they maintain close telephone contact with plant operators during an accident. Regardless of whether its automated data transmission system functions, France requires that "quarter-hour messages" be sent from the nuclear power plant control room to technical experts at its national crisis centers. According to French officials, these messages convey data on the most important nuclear power reactor parameters, a subset of data collected by the automated transmission system. These data are read by plant operator technicians from the control room instruments, copied by hand to a paper form, and then faxed to its national crisis centers every 15 minutes. Nonetheless, France is also considering upgrading its automated data transmission system to reliably function without off-site power; according to French officials, studies are in progress, but no decisions have been made.

Nuclear regulatory officials we spoke with from 5 of the 6 remaining countries with operating reactors—Armenia, Belgium, Canada, Russia, and the United Kingdom—told us they do not currently have automated data transmission systems, and officials from 3 of these countries said their countries may consider establishing such systems in the future. We were unable to determine whether a sixth country, Pakistan, has or plans to establish such a system.

For the 3 countries with emerging or potential nuclear power programs, regulatory officials in Vietnam told us that they plan to develop an automated data transmission system; officials in the United Arab Emirates told us they have not yet decided whether to do so and, in the case of Indonesia, which has not yet decided whether to pursue a civilian nuclear power program, we were unable to obtain information.

International Efforts Taken to Support Nuclear Regulatory Bodies and Promote Nuclear Safety

Three key international organizations—IAEA, WANO, and the EU—along with the Convention on Nuclear Safety have taken steps to support nuclear regulatory bodies and promote nuclear safety worldwide since the Fukushima Daiichi accident—including playing a significant role in helping nuclear regulatory bodies identify the most important lessons from the accident and supporting the associated regulatory changes to enhance nuclear safety.

IAEA

IAEA adopted an Action Plan on Nuclear Safety (Action Plan) in September 2011, 6 months after the Fukushima Daiichi accident. The plan's purpose is to define a program of work to strengthen global nuclear safety by taking into account lessons learned from the accident. The Action Plan focuses on, among other things, safety assessments of nuclear power plants in light of their vulnerabilities to extreme natural hazards, peer reviews of nuclear regulatory bodies and nuclear power plants, provisions for emergency preparedness and response, and the adequacy of existing IAEA safety standards. The success of the Action Plan, according to IAEA, depends on its implementation through the full participation and cooperation of the member states, with the involvement of relevant stakeholders such as international organizations, nuclear industry associations, and research organizations. The plan is divided into 12 actions, each of which is divided into subactions and activities. The status of each action is tracked at the activity level and posted on IAEA's publicly available website. According to IAEA officials, the agency does not track the efforts of member states under the Action Plan but encourages member states to share information on progress in the implementation of the Action Plan through international conferences and international experts' meetings on nuclear safety-related topics.

One of the key ways in which IAEA helps countries improve nuclear safety and regulatory effectiveness is through peer review missions. The most prominent peer review missions are the Integrated Regulatory Review Service (IRRS) and Operational Safety Review Team (OSART) missions. These missions evaluate the operations of a member state's nuclear regulatory system and civilian nuclear power plant operational safety, respectively, and make recommendations and suggestions for improvement. According to IAEA officials, countries and plant operators hosting peer review missions are also encouraged and expected by IAEA to host follow-up missions, typically 2 to 4 years after the initial review in the case of IRRS missions and 18 to 24 months in the case of OSART missions. According to these officials, follow-up missions have been a part of IRRS and OSART peer reviews since 2006 and 1989, respectively.

IRRS missions, which are voluntary to all but EU member states, assess the safety practices of the requesting country through an examination of its regulatory framework and organization and compare the country's

practices with IAEA Safety Standards and good regulatory practices.[36] IRRS mission teams include experts drawn largely from IAEA member countries' nuclear regulatory bodies, including NRC. The requesting country is typically provided with recommendations and suggestions for improvement at the conclusion of the mission. According to IAEA officials, recommendations are proposed to host countries where aspects of their regulatory system relative to the IAEA Safety Requirements are missing, incomplete, or inadequately implemented. These recommendations, according to IAEA officials, should be specific, realistic, and designed to result in tangible improvements to regulatory effectiveness. When IAEA peer reviewers identify opportunities for improvement not directly related to inadequate conformance with IAEA Safety Requirements, but that may contribute to improvements in national regulatory arrangements, they make IRRS suggestions. According to IAEA, suggestions are primarily intended to make the regulatory body's performance more effective or efficient, and to point out potential improvements to current regulatory activities.

IAEA conducted 75 IRRS missions to 45 countries from 1992 through the end of June 2013.[37] In addition, according to IAEA officials, a special module focused on the regulatory implications of the Fukushima Daiichi accident was incorporated into the scope of IRRS missions immediately after the accident for countries having nuclear power plants. Table 1 lists the number of IRRS missions, including follow-up missions, which member states have hosted through June 30, 2013.

[36] The Nuclear Safety Directive of the European Commission requires all EU member states to host an IRRS mission and a follow-up mission once every 10 years.

[37] IAEA has conducted IRRS missions since 1992. The present form of IRRS mission dates to 2006.

Table 1: Number of IAEA Integrated Regulatory Review Service (IRRS) Missions by Country, 1992 through June 30, 2013

Country	Number of IRRS missions
Armenia	2
Australia	2
Botswana	1
Bulgaria	3
Cameroon	1
Canada	2
China	3
Côte d'Ivoire	1
Czech Republic	2
Finland	3
France	2
Gabon	1
Germany	2
Greece	1
Hungary	2
Indonesia	2
Iran	1
Japan	1
Kenya	1
Korea, Republic of	1
Lebanon	1
Lithuania	1
Madagascar	1
Mauritius	1
Mexico	2
Namibia	1
Niger	1
Pakistan	1
Peru	1
Poland	1
Romania	5
Russian Federation	1
Sierra Leone	1
Slovakia	3

Country	Number of IRRS missions
Slovenia	2
Spain	2
Sweden	1
Switzerland	3
Thailand	1
Uganda	1
Ukraine	4
United Arab Emirates	1
United Kingdom	2
United States	1
Vietnam	2
Total	**75**

Source: GAO analysis of IAEA data.

Note: IRRS missions were preceded by a similar program from 1992 to 2004 called International Regulatory Review Team (IRRT) missions. This table combines both types of missions. IAEA does not consider scoping or expert missions to be "full" IRRT or IRRS missions and are thus not included in this table.

OSART missions also include experts drawn largely from IAEA member countries but are more narrowly targeted to review operational safety at specific nuclear power plants. OSART missions also typically make recommendations and suggestions to improve safety. According to IAEA, OSART recommendations provide operators ideas for improving operational safety and should: (1) be based on IAEA Safety Standards or proven, good international practices; (2) address the root causes rather than the symptoms of the identified concern; and (3) be specific, realistic, and designed to result in tangible improvements. An OSART suggestion is primarily intended to, among other things, make good performance more effective. In general, suggestions are designed to stimulate the plant management and supporting staff to continue to consider ways and means for enhancing performance. According to IAEA, the agency has conducted 284 OSART missions in 34 countries from 1983 through the end of June 2013. The Fukushima Daiichi nuclear power station, like most nuclear power plants, has not hosted an OSART mission. Table 2 lists the number of OSART missions, including follow-up missions, that member countries have hosted through June 2013.

Table 2: Number of IAEA Operational Safety Review Team (OSART) Missions by Country, 1983 through June 30, 2013

Country	Number of OSART missions
Argentina	2
Armenia	2
Belgium	4
Brazil	11
Bulgaria	8
Canada	4
China	19
Czech Republic	15
Finland	4
France	44
Germany	9
Hungary	4
India	1
Italy	3
Japan	9
Kazakhstan	1
Korea, Republic of	8
Lithuania	4
Mexico	6
Netherlands	5
Pakistan	6
Philippines	2
Poland	1
Romania	6
Russian Federation	12
Slovakia	10
Slovenia	6
South Africa	6
Spain	9
Sweden	13
Switzerland	9
Ukraine	23
United Kingdom	6
United States	12

Country	Number of OSART missions
Total	**284**

Source: GAO analysis of IAEA data.

According to IAEA officials, the agency is not systematically tracking the status of the recommendations made by the IRRS or OSART peer review missions, and it does not know the extent to which the recommendations or suggestions have been implemented by the host countries and plant operators unless countries and operators have hosted a follow-up mission. Follow-up missions to IRRS and OSART missions are the means for informing IAEA of progress made in implementing the original missions' recommendations and suggestions. IAEA posts on its publicly available website the names of countries and nuclear power plants that have hosted IRRS and OSART missions and follow-up missions and, in some cases, summary or full reports of the main conclusions of a given mission.[38] According to IAEA officials, however, the agency is not authorized by member states to act as a nuclear safety oversight organization and so does not systematically track the status of such recommendations and suggestions. IAEA officials noted that member states are responsible for tracking the status of their mission findings. However, without this information, IAEA cannot determine the impact and effectiveness of the peer review missions. Nuclear regulatory officials from France and Canada stated that greater transparency about the results and follow-up to peer review missions is needed.

The importance of tracking recommendations and improving the impact and effectiveness of IRRS missions was noted at a recent IAEA conference. Specifically, the first action item at the April 2013 IAEA regulators conference in Ottawa, Canada, identified issues that needed to be addressed, implemented, and followed up on, including: (1) countries should develop national action plans to implement recommendations made by IRRS peer review missions, (2) the results of the IRRS missions should be made public, and (3) IRRS missions and follow-up missions should be reported to IAEA's Board of Governors. Because not all of the recommendations and suggestions of IRRS peer review missions are made public, countries may have less incentive to follow up on them.

[38]In the case of IRRS missions, and in accordance with IRRS guidelines, countries are encouraged to make their reports available to the public. IAEA will make a summary report publicly available 90 days after the letter transmitting the report to the host country unless the country specifically requests that it remain restricted.

The experience of the 2011 IAEA-sponsored international expert mission to Japan highlights the current system's limitations. This expert mission, which was established to find facts and identify initial lessons from the Fukushima Daiichi accident, noted, among other things, that despite the technical focus on nuclear safety and radiation protection, the mission also identified more general problems with: the regulatory framework for safety in Japan, the clarity of the roles and responsibilities among government entities and the operator, and the independence of the nuclear regulatory body. The expert mission noted that some of these issues had also been raised by the June 2007 IRRS mission to Japan, and that there had not been a follow-up mission. The IRRS report did not mention "regulatory capture"— a condition that was found by the Kurokawa Commission to have compromised Japan's nuclear safety prior to the accident.[39]

WANO

In the wake of the Fukushima Daiichi accident, WANO is expanding the scope of its operations and activities to do more to help its members achieve its overriding goals to enhance nuclear safety and the operational performance of nuclear power plants. Specifically, according to WANO, the organization is

- *Increasing staff.* WANO is more than doubling the size of its staff over 3 years. It had about 170 employees in 2011 and plans to increase the number to 388 in 2014.
- *Requiring more frequent peer reviews focusing on issues highlighted by the accident.* WANO is moving from 6-year to 4-year intervals for the peer reviews it requires of its members. WANO is also requiring its members to host a WANO peer review team for a follow-up 2 years after its peer reviews so the operator can explain what it has done to address the findings from the previous review. In addition, WANO has now expanded the scope of its peer reviews to include, among other things, issues highlighted by the accident, including emergency preparedness, severe accident prevention, and spent fuel pool management.

[39]The Kurokawa Commission scrutinized the relationship between the plant operators and the regulators and found the relationship lacking in independence, transparency, and safety culture, calling the relationship a "typical example of regulatory capture in which the oversight of the industry by regulators effectively ceases."

- *Increasing coordination with IAEA.* WANO also signed a Memorandum of Understanding with IAEA in September 2012 under which both organizations are to take a more coordinated approach to their activities. For example, under this memorandum, according to both organizations, WANO and IAEA staff are to meet regularly to discuss major safety related activities, share more nuclear power plant operating experience, and better coordinate the timing of their respective peer reviews so that, for example, operators will not have to host a WANO peer review in the same year they host an IAEA OSART mission.

European Union

The EU, acting in concert with national nuclear regulatory bodies and the nuclear industry, among its member states, launched a process in March 2011 to carry out EU-wide comprehensive risk and safety assessments of nuclear power plants. The EU nuclear safety directive and the EU nuclear waste directive grant it the authority to make these assessments legally binding on EU members. Within a few weeks of the Fukushima Daiichi accident, all 14 EU member states that operate civilian nuclear power reactors—as well as two neighboring countries—had agreed, on a voluntary basis, to subject their power plants to targeted, comprehensive safety risk assessments of how well they could withstand the consequences of various extreme external conditions, including those that affected the Fukushima Daiichi plant.[40] These assessments were to focus on the robustness of safety margins of nuclear power plants in three areas: (1) accident-initiating events such as earthquakes, floods, and extreme natural weather; (2) loss of safety systems, including power and ultimate heat sink;[41] and (3) severe accident management capabilities. The methodology of these assessments was determined by EU experts from the European Nuclear Safety Regulators Group (ENSREG) and the West European Nuclear Regulators' Association

[40]In addition to the 14 EU member states with operating nuclear power plants (Belgium, Bulgaria, Czech Republic, Finland, France, Germany, Hungary, Netherlands, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom), and two neighboring states (Switzerland and Ukraine), Lithuania also participated in the comprehensive safety risk assessments even though the two reactors at its Ignalina nuclear power plant are currently being decommissioned.

[41]An ultimate heat sink is a source of water near the nuclear plant—a lake, river, or ocean, or a dedicated water source— to absorb decay heat. An ultimate heat sink is required to provide all of the nuclear power reactor's cooling water needs for the first 30 days of an accident. Two or more pumps are used to take water from the heat sink to the plant.

(WENRA).[42] The comprehensive safety and risk assessments took place from June 2011 through April 2012 and were conducted with a three-step process as follows:

1. Assessment of plants by operators (June to October 2011).
2. Review of these assessments by national nuclear regulatory bodies (by the end of December 2011).
3. European peer reviews of assessments (January to April 2012).

Following the completion of these safety assessments, according to EU officials, the ENSREG action plan was approved on August 1, 2012. The plan is to, among other things, (1) assist in ensuring that the conclusions from the comprehensive safety and risk assessments and their peer review result in improvements in safety across European nuclear power plants and (2) ensure, through further peer review, that the recommendations and suggestions from the peer reviews of comprehensive safety and risk assessments (also known as "stress tests") are addressed by national regulators and ENSREG in a consistent manner.

The EU also undertook a review of the existing legal and regulatory frameworks for the safety of nuclear installations to consider proposing any improvements that may be necessary. Having carried out EU-wide comprehensive risk and safety assessments of nuclear power plants, as well as a review of the existing legal and regulatory frameworks for the safety of nuclear installations, the European Commission concluded that improvements to European nuclear safety were necessary. The commission announced in June 2013 its proposal to update and strengthen its 2009 Nuclear Safety Directive. According to the commission announcement, the proposed new directive substantially strengthens the provisions of the existing directive by

- introducing EU-wide safety objectives;

[42]ENSREG is an independent, authoritative expert body composed of senior officials from national regulatory or nuclear safety authorities from all member states in the EU. WENRA is an organization composed of the chief nuclear regulators of EU countries with nuclear power plants and other interested European countries. WENRA's main objectives are to facilitate the exchange of nuclear safety information and experience among regulators, develop a common approach to nuclear safety, and provide an independent capability to examine nuclear safety in affiliated countries.

- setting up a European system of peer reviews of nuclear installations;
- increasing transparency on nuclear safety matters;
- strengthening the role and independence of national regulatory authorities;
- introducing a requirement of specific safety reviews for older nuclear power plants for which a lifetime extension is considered; and
- enhancing on-site emergency preparedness and response, for example by implementing strict accident management guidelines and by putting in place emergency response centers that must be protected against radioactivity and earthquakes or flooding.

If ultimately adopted by the European Council, this proposed new directive could enter into force as soon as 2014 and be written into binding national legislation by EU member states within the following 18 months.

Convention on Nuclear Safety

The Convention has convened two meetings since the Fukushima Daiichi accident—the regularly scheduled triennial review meeting in April 2011, which was held, coincidentally, about 3 weeks after the accident, and a special meeting approximately 18 months later, in August 2012, to focus specifically on the accident. For the special August 2012 meeting, parties to the Convention (1) prepared a Fukushima Daiichi-related national report describing the safety assessments of their nuclear programs undertaken after the accident and measures taken to address the lessons learned from the accident; (2) reviewed and shared their findings and measures taken with other parties through the peer review process and, to varying extents, the public; (3) reviewed the effectiveness and provisions of the Convention.

One result of these meetings was to make and adopt revisions to the Convention's guidelines on the preparation of the triennial national

reports.[43] The revised post-Fukushima guidelines provide more detailed suggestions for what information parties should include in their triennial national report and how it should be organized. Parties are encouraged to

- refer to IAEA safety standards, such as IAEA Safety Fundamentals and Requirements, in discussing how they are meeting their obligations to the Convention;
- report in more detail about the steps they have taken to follow up on any issues and concerns that may have been raised in earlier review meetings and national reports;
- discuss and address the results of international peer review missions, including IAEA IRRS missions, progress made in implementing recommendations, and suggestions and additional plans for further follow-up; and
- discuss lessons they have learned or actions taken in response to accidents and events, such as the issues highlighted by the Fukushima Daiichi accident.

The parties also agreed to consider other measures to improve the effectiveness of the Convention at the next review meeting, scheduled for March 2014. In particular, part of the outcome of the August 2012 special meeting was the establishment of an effectiveness and transparency working group open to all interested parties to the Convention, to develop and propose various actions that could be taken to strengthen and amend, where necessary, the Convention. This working group is to consider the various proposals raised during the special meeting to amend the Convention, including proposals already submitted by Switzerland and the Russian Federation. The working group is to present its findings to all parties at the 2014 review meeting. Among the Swiss proposals are several amendments to the Convention, including one that would require each contracting party to have periodic external review of its regulatory body to confirm its competence, independence, and that it is provided with adequate authority and resources. Another Swiss proposal would also require that the regulatory body's findings and decisions on the safety of nuclear installations be made publicly available. The Russian

[43]According to the Convention's national report guidelines, their purpose is to suggest that material that may be useful for parties to include in their reports and to facilitate the most efficient review of implementation by the parties of their obligations under the Convention.

proposals include (1) requiring periodic assessments of nuclear power plant safety and (2) affirming that new construction conforms with IAEA recommendations. NRC officials noted that the U.S. position is that changes to the Convention could be better addressed through guidance documents, rather than through reopening the Convention to amendments.

As we reported in April 2010, IAEA officials told us it was important for parties to make as much information about their civilian nuclear power programs accessible as possible but that it was for each party to determine how much information should be made public and how much should remain confidential.[44] We also recommended in 2010 that the Secretary of State, in coordination with the NRC Chairman, work with other parties to the Convention to, among other things, expand efforts to increase the number of parties' national reports made available to the public by posting them to IAEA's public website, even though there is no requirement to do so. In response to these recommendations, NRC stated that it (1) leads by example by always making the U.S. national report available on the NRC and IAEA publicly available websites and (2) uses its leadership positions in the Convention to work with and encourage leaders of other countries to encourage all contracting parties to make their national reports publicly available. In addition, under U.S. leadership, according to NRC, the Convention on Nuclear Safety Scientific Secretary in 2010 sent out a message to all contracting parties reminding them that "in the spirit of openness and transparency, Contracting Parties are encouraged to notify IAEA when they agree to have their National Reports posted on the IAEA public website." Further, NRC and the State Department stated that they will also raise this issue during meetings of the Convention working group on effectiveness and transparency and continue to encourage contracting parties to make as much information publicly accessible as possible.

Since April 2010, an additional 13 national reports prepared for the four review meetings held from 1999 to 2008 have been made available on IAEA's publicly available website, including 8 additional national reports prepared for the 2008 review meeting. Notwithstanding this overall increase in the number of reports posted, the total number of reports posted on IAEA's publicly available website for the 2011 review meeting

[44]GAO, *Nuclear Safety: Convention on Nuclear Safety Is Viewed by Most Member Countries as Strengthening Safety Worldwide*, GAO-10-489 (Washington, D.C.: Apr. 29, 2010).

declined to 32 reports from 34 reports in 2008 despite the increase in the number of contracting parties to the Convention obligated to submit national reports increasing from 61 to 72 parties. Moreover, according to summary reports prepared by the parties at the end of the August 2012 special meeting called to discuss the Fukushima Daiichi accident, 36 of 61 parties (or 59 percent) that prepared national reports for the meeting did not make them available on IAEA's public website.[45]

Conclusions

The Fukushima Daiichi accident underscored the importance of countries having a strong, competent, and independent regulatory body and the consequences of not having one. Nuclear regulatory bodies worldwide are taking this accident seriously and using it as an opportunity to strengthen regulatory procedures, requirements, and infrastructures, as appropriate. Nuclear regulatory bodies will continue to play key roles in minimizing the chances of a severe accident and ensuring the most effective emergency response possible should an accident occur—factors considered to be fundamental to public safety and to the continued viability of the civilian nuclear power industry worldwide. For example, NRC participates regularly in a variety of IAEA activities related to, among other things, nuclear safety, and the State Department coordinates U.S. policy matters with international organizations and treaties, including those dealing with nuclear safety. Supporting these efforts, IAEA peer review missions provide countries with unique opportunities to strengthen their nuclear regulatory organizations. However, IAEA does not systematically track the status of the recommendations made by the IRRS peer review missions and does not know the extent to which the recommendations have been implemented by the host countries. According to IAEA officials, the agency is not authorized by member states to act as a nuclear safety oversight organization, and member states are responsible for tracking the status of their mission findings. Without this information, IAEA cannot fully determine the impact and effectiveness of these peer review missions as important tools to improve nuclear safety. Furthermore, because not all of the recommendations and suggestions of the IRRS peer review missions are made public, countries may have less incentive to follow up on them.

[45]Of the 75 parties to the Convention, and that were obligated to submit a national report in 2012, 61 prepared such reports.

Although NRC does not consider its automated data transmittal system—ERDS—a safety system, the Fukushima Daiichi accident underscored the usefulness of having such a system fully functioning. NRC has taken steps to upgrade ERDS, but it is still not equipped to collect and transmit information when electrical power and lines of communication are compromised, as occurred at the Fukushima Daiichi nuclear power plant. NRC is delaying its consideration of additional upgrades to ERDS so that it would function more reliably because it is first completing higher priority post-Fukushima nuclear safety enhancements. By delaying its decision on whether or how to upgrade ERDS, a fully functioning system might not be available to regulators when the need is greatest—during a severe accident. Further, NRC may be missing an opportunity to lead by example as it does in other areas to promote nuclear safety worldwide, such as its efforts to encourage parties to the Convention on Nuclear Safety to make their national reports publicly available.

Recommendations for Executive Action

We are making the following two recommendations in this report:

- To further promote the safety of civilian nuclear power programs worldwide by enhancing the effectiveness of nuclear regulatory bodies, we recommend that the Secretary of State, in coordination with the Commission, work with and encourage officials from IAEA to systematically track the status of the recommendations made by the IRRS peer review missions and make this information publicly available to the extent feasible.

- To increase the likelihood of NRC's access to timely, accurate, and comprehensive information during nuclear accidents, we recommend that the NRC Chairman consider expediting NRC's decision on whether or how to upgrade ERDS so that it would remain functional during a severe accident.

Agency Comments and Our Evaluation

We provided a draft of this report to the Department of Energy, the Department of State, and NRC for review and comment. We also provided relevant sections of the draft report to IAEA. State and NRC provided written comments, which are presented in appendixes III and IV. NRC stated that it was in general agreement with the draft report but did not state whether it agreed or disagreed with our two recommendations, including the one recommending that NRC consider expediting its decision on whether or how to upgrade ERDS so that it would remain functional during a severe accident. The Department of Energy provided

technical comments, as did IAEA and NRC, which we incorporated as appropriate.

In its written comments, the Department of State "partially concurred" with our recommendation that it, in coordination with the NRC Chairman, work with officials from IAEA to systematically track the status of the recommendations by the IRRS peer review missions and make this information publicly available to the extent feasible. In its comment letter, the department stated that it would work with NRC and raise the recommendation with appropriate safety officials at IAEA and seek their views to further discuss what possible steps could be taken. However, State raised a number of issues that it believed would need to be considered in discussions with IAEA officials, including: (1) maintaining member states' confidentiality and willingness to participate in IRRS missions if IAEA systematically tracks the status of peer review recommendations and makes those results public, (2) member states' acceptance of such tracking without extensive prior discussions, and (3) IAEA's perspective on whether such tracking would improve the focus of the missions. State also raised questions about the costs associated with such systematic tracking and how they will be paid. We are encouraged that the department plans to work with NRC and raise the recommendation with IAEA and hope that these issues can be addressed in discussions with IAEA officials. NRC echoed issues similar to State's in its technical comments and also noted that its more appropriate role should be to encourage—rather than work with—IAEA to systematically track the status of the recommendations by the IRRS peer review missions. In response to NRC's comment, we have added the word "encourage" to the recommendation so that it now reads, in part, that "the Secretary of State, in coordination with the Commission, work with and encourage officials from IAEA to systematically track the status of the recommendations by the IRRS peer review missions . . ."

We recognize the significance of the issues State and NRC have raised about maintaining confidentiality, member states' acceptance of systematic tracking, how such tracking might affect member states' willingness to participate in future IRRS missions, and the focus of such missions. We agree that these issues need to be factored into discussions with IAEA officials. For this reason, we recommended that the results of these missions be made publicly available to the extent feasible. If discussions among State, NRC, and IAEA officials can lead to greater transparency about the results of IRRS missions and improve prospects for analyzing the impact and effectiveness of these missions, they would be worthwhile. However, as we noted in our report, without

systematic tracking of the results of mission findings, including follow-up, IAEA cannot fully determine the impact and effectiveness of the peer review missions. In addition, our recommendation is consistent with another ongoing international effort—with U.S. participation—to encourage countries to be more open regarding nuclear safety. For example, as we noted in our report, the most recent version of the Convention on Nuclear Safety's guidelines encouraged the contracting parties to discuss and address the results of international peer review missions in their national reports, including IRRS missions; discuss progress made in implementing recommendations; and discuss suggestions and additional plans for further follow-up. Regarding State and NRC's mention of potential added costs associated with any tracking system, we note that neither agency provided any analysis or assessment of the potential added costs of systematic tracking in raising it as an issue.

As agreed with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 15 days from the report date. At that time, we will send copies to the Secretary of Energy, the Secretary of State, the Chairman of the Nuclear Regulatory Commission, the appropriate congressional committees, and other interested parties. The report also will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staff members have any questions about this report, please contact me at (202) 512-3841 or trimbled@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix V.

Sincerely yours,

David C. Trimble
Director, Natural Resources and Environment

Appendix I: Scope and Methodology

In light of the Fukushima Daiichi accident, you asked us to examine worldwide nuclear regulation and safety. This report examines: (1) the actions regulatory agencies with existing or planned civilian nuclear power reactors have taken to strengthen nuclear safety; (2) the extent to which these countries have established automated systems for collecting and transmitting data and taken steps to enable such systems to withstand emergency conditions; and (3) steps key international organizations have taken to support nuclear regulatory bodies and promote nuclear safety worldwide since the Fukushima accident and the impact of some of these steps.

To examine the actions that national regulatory agencies have taken to strengthen nuclear safety in the aftermath of the Fukushima accident, we selected a nonprobability sample of 16 countries to represent a cross section of "emerging" and established civilian nuclear power countries. For countries with emerging civilian nuclear power, we selected the three most often suggested by U.S. agency officials and nuclear experts as available. For established countries, we focused on those where nuclear power represented more than 15 percent of the country's electricity production. From those, we asked agency officials and other interviewees to suggest countries that would provide good examples of actions taken to strengthen nuclear safety. We also considered program size and the nation's nuclear regulatory framework to select 13 countries with established civilian nuclear power.[1] From the sample, we prioritized 5 countries to visit in person. We selected these 5 countries through a combination of suggestions from experts, size of nuclear program, and proximity to one another. We interviewed, at an international nuclear regulators' conference in Ottawa, Canada, regulatory officials from all but 1 of the 11 countries we did not visit in person; Armenia, the country with regulatory officials we did not interview in person, provided written answers to our questions.

The 16 countries are Argentina, Armenia, Belgium, Canada, China, France, Indonesia, Japan, Pakistan, Russia, South Korea, Sweden, United Arab Emirates, United Kingdom, United States, and Vietnam. Thirteen of these 16 countries—those with established nuclear power programs—operated 78 percent of the world's nuclear power reactors as

[1]Regulatory frameworks may differ in that a nuclear regulatory agency could be a cabinet agency or ministry, or an independent commission. We also considered structural changes undertaken by nuclear regulatory agencies from one type to another (e.g., agency to commission).

of September 2013 (the other 3 countries—Indonesia, United Arab Emirates, and Vietnam—do not have operating nuclear power reactors).[2] For the 16 countries selected, we reviewed reports these countries undertook to document the lessons learned from the Fukushima accident, including reports prepared for various international meetings—including the Second Extraordinary Meeting for the Convention on Nuclear Safety—and reports relating to their comprehensive safety risk assessments, and/or presentations in which they summarized lessons learned.[3] We also interviewed officials from each selected regulatory body and/or technical support organization and/or received written responses to our questions. In countries where we conducted in-person site visits—Belgium, Canada, France, Sweden, and the United States—we also visited nuclear power plants and interviewed nuclear power plant operators. In Canada, France, Sweden, and the United States, we interviewed other government officials in agencies or ministries related to civilian nuclear power. In the Canada, the United Kingdom, and the United States, we interviewed nuclear industry association officials. We also interviewed two former chairmen of the Nuclear Regulatory Commission (NRC). GAO did not independently verify statements of foreign law.

We selected six illustrative categories of actions taken in response to Fukushima; our selection was neither an attempt to identify the full range of regulatory responses to the Fukushima Daiichi accident, nor to establish them as best practices or to catalog the extent to which each regulatory body within our sample undertook actions in each category.

To examine the extent to which the 15 selected non-U.S. countries have established automated systems for collecting and transmitting data to the nuclear regulatory body during emergencies, we interviewed officials from the respective nuclear regulatory agencies, technical support organizations, and operators, as applicable, and possible and

[2]This figure includes reactors that are temporarily suspended and thus not "operating," including the 50 reactors in Japan suspended in the aftermath of the Fukushima Daiichi accident. The three "emerging" categories are in varying stages of considering, planning, or licensing their nuclear power programs; for example, the Indonesian government has not yet decided to pursue a nuclear program but had stated an interest in developing one.

[3]These meetings include the April 2011 Convention on Nuclear Safety review meeting; the August 2012 Convention Second Extraordinary Meeting; and the International Atomic Energy Agency's April 2013 International Conference on Effective Nuclear Regulatory Systems.

corroborated these statements with documents to the extent possible. GAO did not receive documentary or other substantial corroborating information to substantiate the statements of officials from China and Argentina that they have automated data transmission systems, and we have received only limited corroborating information that South Korea has such a system. There is no requirement that officials from these countries provide such information.

To examine the steps key international organizations have taken to support nuclear regulatory bodies and promote nuclear safety worldwide since the Fukushima Daiichi accident, we first identified such organizations through interviews with officials from the State Department, Department of Energy (DOE), and nuclear regulatory officials. Based on these discussions, we identified the International Atomic Energy Agency (IAEA), the Organization for Economic Cooperation and Development's (OECD) Nuclear Energy Agency (NEA), the World Association of Nuclear Operators (WANO), and the European Union (EU). We then reviewed, as applicable, the reports and action plans and other documents from these organizations and interviewed or exchanged responses to written questions with relevant officials from them. We also reviewed NRC documents and responses to written questions from NRC officials, and we reviewed State Department documents. In the case of IAEA, we reviewed IAEA information and details about IRRS and OSART missions, as well as answers to written questions and conference documents. We also reviewed previous GAO work and statements from IAEA officials and other officials from the Ottawa conference.

We conducted this performance audit from May 2012 to March 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Civilian Nuclear Profiles of Selected Countries

Country	Nuclear regulatory agency	Established[a]	Structure	Scope of regulatory authority[b]	Operational nuclear reactor and electricity generation data as of September 2013
Argentina	Argentine Nuclear Regulatory Authority (ARN)	1997	Autonomous entity within the jurisdiction of the General Secretariat of the Presidency (reports to the President of Argentina).	Nuclear safety; nuclear security; nuclear nonproliferation; environment and public health.	2 power reactors (and 1 under construction) generating 5% of the country's electricity
Armenia	Armenian Nuclear Regulatory Authority (ANRA)	1993	The ANRA Chairman is appointed and dismissed by the Prime Minister and reports to the President, government, and Prime Minister, but not to any other ministry.	Nuclear safety; nuclear security; nuclear nonproliferation; environment and public health; nuclear waste.	1 power reactor generating 27% of the country's electricity
Belgium	Federal Agency for Nuclear Control (FANC)	1994	An autonomous public institution that reports to the Minister of Home Affairs.	Nuclear safety; nuclear security; nuclear nonproliferation; environment and public health; nuclear waste.	7 power reactors generating 51% of the country's electricity
Canada	Canadian Nuclear Safety Commission (CNSC)	2000	The Commission Tribunal, CNSC's central decision-making body, is a quasi-judicial administrative tribunal.	Nuclear safety; nuclear security; nuclear nonproliferation; environment and public health; nuclear waste.	19 power reactors generating 15% of the country's electricity
China	National Nuclear Safety Administration (NNSA)	1984	Under the Ministry of Environmental Protection.	Nuclear safety; environment and public health; nuclear waste.	18 power reactors (and 28 under construction) generating 2% of the country's electricity
France	Autorité de Sûreté Nucléaire (ASN)	2006	ASN's 5-person Commission serve for a 6-year, full-time term. ASN reports to the French Parliament.	Nuclear safety; nuclear security; [c] environment and public health; nuclear waste.	58 power reactors (and 1 under construction) generating 75% of the country's electricity
Indonesia	BAPETEN	1997	BAPETEN has the power to establish regulations and to conduct licensing and inspections. BAPETEN is under and directly responsible to the President of Indonesia.	Nuclear safety; nuclear security; nuclear nonproliferation; environment and public health; nuclear waste.	No power reactors (3 research reactors, regulated by BAPETEN)
Japan	Nuclear Regulatory Authority (NRA)	2012	An independent commission (under the Ministry of the Environment).	Nuclear safety; nuclear security; nuclear nonproliferation; environment and public health; nuclear waste.	50 power reactors (and 2 under construction) generating 2% of the country's electricity[d]

Country	Nuclear regulatory agency	Established[a]	Structure	Scope of regulatory authority[b]	Operational nuclear reactor and electricity generation data as of September 2013
Korea, Republic of	Nuclear Safety & Security Commission (NSSC)	2011	The 9-person commission an independent, stand-alone, ministry-level agency and supported by two technical support organizations.	Nuclear safety; nuclear security, nuclear nonproliferation; environment and public health; nuclear waste.	23 power reactors (and 5 under construction) generating 30% of the country's electricity
Pakistan	Pakistan Nuclear Regulatory Authority (PNRA)	2001	PNRA is an independent regulator reporting directly to the Prime Minister. PNRA comprises a chairman and 2 full-time and 7 part-time members. The federal government appoints the chairman and the members.	Nuclear safety; nuclear security; environment and public health; nuclear waste.	3 power reactors (and 2 under construction) generating 5% of the country's electricity
Russian Federation	Rostechnadzor (the Federal Environmental, Industrial and Nuclear Supervision Service)	2004	Rostechnadzor is directly subordinate to the government and not to any ministry.	Nuclear safety; nuclear security; environment and public health; nuclear waste.	33 power reactors (and 10 under construction) generating 18% of the country's electricity
Sweden	The Swedish Radiation Safety Authority (SSM)	2008	SSM reports to the Ministry of the Environment but interprets and executes the law independently of the government.	Nuclear safety; nuclear security; nuclear non-proliferation; environment and public health; nuclear waste.	10 power reactors generating 38% of the country's electricity
United Arab Emirates	Federal Authority for Nuclear Regulation (FANR)	2009	FANR is an independent legal entity with "full legal competence and financial and administrative independence." It is fully separate from the nuclear sector.	Nuclear safety; nuclear security; nuclear nonproliferation nuclear waste.	2 power reactors under construction
United Kingdom	Office for Nuclear Regulation (ONR)	2011	ONR is a stand-alone statutory body, formed as an agency of the Health and Safety Executive but working toward becoming an independent corporation.	Nuclear safety; nuclear security; nuclear nonproliferation.	16 power reactors generating 18% of the country's electricity

Country	Nuclear regulatory agency	Established[a]	Structure	Scope of regulatory authority[b]	Operational nuclear reactor and electricity generation data as of September 2013
United States of America	Nuclear Regulatory Commission (NRC)	1974	Independent federal agency headed by five commissioners (commission is a quasi-judicial body).	Nuclear safety; nuclear security; nuclear nonproliferation; nuclear waste.	100 power reactors (with 3 under construction) generating 19% of the country's electricity
Vietnam	Vietnam Agency for Radiation and Nuclear Safety (VARANS)	2003	VARANS is under the Ministry of Science and Technology.	Nuclear safety; nuclear security; nuclear nonproliferation.	No power reactors (1 research reactor, regulated by VARANS)

Source: GAO analysis of nuclear regulatory body documents; IAEA Power Reactor Information System as of September 4, 2013.

Note: Scope also implies only civilian and commercial nuclear matters; this table does not specify the regulatory agencies that also have oversight over military nuclear matters.

[a]This date represents the establishment of each country's current nuclear regulatory body, which may have replaced an existing nuclear regulatory body.

[b]This column represents each regulatory body's scope of responsibilities as reported by the country and does not convey any GAO analysis of the regulatory body's performance of its responsibilities. Scope of regulatory authority comprises areas addressed by technical support organizations, such as Belgium's Bel-V, France's Institut de Radioprotection et de Sûreté Nucléaire (IRSN), and Korea's KINS; areas not included may be performed by government agencies. For example, the U.S. NRC is not the primary U.S. agency responsible for oversight of environment and public health, but shares in these responsibilities with regard to civilian nuclear power with other federal agencies and state and local governments.

[c]France's ASN is responsible for oversight of nuclear security (for example, security of radioactive materials, including transportation of such materials) but not for oversight of physical protection of nuclear power plants. However, its technical support organization, IRSN, has a role in monitoring physical protection.

[d]Before all but two of Japan's remaining 50 reactors were ordered to suspend operations after the Fukushima-Daiichi accident, nuclear reactors generated 18% of Japan's electricity. As of this writing all reactors have been shutdown.

Appendix III: Comments from the Department of State

United States Department of State
Comptroller
P.O. Box 150008
Charleston, SC 29415-5008

FEB 07 2014

Dr. Loren Yager
Managing Director
International Affairs and Trade
Government Accountability Office
441 G Street, N.W.
Washington, D.C. 20548-0001

Dear Dr. Yager:

We appreciate the opportunity to review your draft report, "NUCLEAR SAFETY: Countries' Regulatory Bodies Have Made Changes in Response to the Fukushima Daiichi Accident" GAO Job Code 361412.

The enclosed Department of State comments are provided for incorporation with this letter as an appendix to the final report.

If you have any questions concerning this response, please contact Patricia Metz, Deputy Director, Bureau of International Security and Nonproliferation at (202) 736-4429.

Sincerely,

James L. Millette

cc: GAO – David Trimble
ISN – Thomas M. Countryman
State/OIG – Norman Brown

Department of State Comments on GAO Draft Report

NUCLEAR SAFETY: Countries' Regulatory Bodies Have Made Changes in Response to the Fukushima Daiichi Accident
(GAO-14-109, GAO Code 361412)

Thank you for the opportunity to comment on your draft report entitled *Nuclear Safety : Countries' Regulatory Bodies Have Made Changes in Response to the Fukushima Daiichi Accident.* The Department of State welcomes this report. Since the accident at Fukushima Daiichi, the United States has continued to work closely with the International Atomic Energy Agency (IAEA) and Contracting Parties to the Convention on Nuclear Safety to strengthen the implementation of the Convention and examine lessons learned from the accident.

Promotion of the safe operation of nuclear reactors worldwide is one of the U.S. government's top foreign policy and national security priorities. The Convention on Nuclear Safety plays a very important role in realization of that objective. However, it must be understood that the Convention is an incentive instrument. It is not designed to ensure fulfillment of obligations through control and sanction, but is based on the common interest of the Contracting Parties to achieve higher levels of safety, which is to be promoted and encouraged through regular meetings of the Parties and peer review missions.

GAO recommends "that the Secretary of State, in coordination with the NRC Chairman, work with officials from IAEA to systematically track the status of the recommendations made by IAEA Integrated Regulatory Review Service (**IRRS**) peer review missions and make this information publicly available to the extent feasible."

State partially concurs. First, as GAO found in its review, although the IAEA promotes peer review missions to improve nuclear safety and regulatory effectiveness, the IAEA does not formally track whether the recommendations of the peer reviews are implemented by the host countries. While we understand the usefulness of gathering this data from the host countries to determine the impact and effectiveness of the peer review missions, we question the acceptance of this action by the Member that will be impacted by this decision, at least without extensive prior discussions. Additional issues that would need to be considered with the IAEA include maintaining Member State confidentiality and the willingness of Member States to participate in IRRS missions if the IAEA will be

examining the status of implementation and making those results public; costing out a tracking system and how will it be paid for; and the IAEA's perspective on whether the tracking system would improve the focus of such missions and whether countries would be more or less likely to go public with the results of peer missions. However, we will raise the recommendation with appropriate safety officials at the IAEA and seek their views.

Again, State thanks the GAO for this constructive report. Please be assured that the Department takes the GAO's findings very seriously and we will work with the Nuclear Regulatory Commission (NRC) and the IAEA to further discuss what possible steps can be taken.

Appendix IV: Comments from the Nuclear Regulatory Commission

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 19, 2014

Mr. Glen Levis
Assistant Director, Natural Resources
and the Environment
U.S. Government Accountability Office
Washington, DC 20548

Dear Mr. Levis:

On behalf of the U.S. Nuclear Regulatory Commission (NRC), I am responding to Mr. David Trimble's letter dated January 16, 2014, requesting NRC's comments on the U.S. Government Accountability Office (GAO) proposed report GA0-14-109, *"Nuclear Safety: Countries' Regulatory Bodies Have Made Changes in Response to the Fukushima Daiichi Accident."* We appreciate the opportunity to provide our comments for your consideration.

As requested, the NRC has reviewed the draft report and is in general agreement with the draft report. The NRC has several technical comments. These comments are detailed in the enclosure.

Sincerely,

for Mark A. Satorius
Executive Director
for Operations

Enclosure:
NRC's Technical Comments on
Draft GAO Report GAO-14-109

Appendix V: GAO Contact and Staff Acknowledgments

GAO Contact

David C. Trimble, (202) 512-3841 or trimbled@gao.gov

Staff Acknowledgments

In addition to the individual named above, Glen Levis, Assistant Director; Alisa Beyninson; Kevin Bray; Antoinette Capaccio; Scott Fletcher; Alison O'Neill; Steven R. Putansu; Kevin Tarmann; and Kiki Theodoropoulos made key contributions to this report.