THE FUTURE OF NUCLEAR ENERGY TO 2030 AND ITS IMPLICATIONS FOR SAFETY, SECURITY AND NONPROLIFERATION

Part 2 – Nuclear Safety

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CIGI
The Centre for International Governance Innovation
Centre pour l'innovation dans la gouvernance internationale

Addressing International Governance Challenges

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CIGI's Nuclear Energy Futures Project is conducted in partnership with the Canadian Centre for Treaty Compliance (CCTC) at the Norman Paterson School of International Affairs, Carleton University, Ottawa. The project is chaired by CIGI Distinguished Fellow Louise Fréchette and directed by CIGI Senior Fellow Trevor Findlay, director of CCTC. CIGI gratefully acknowledges the Government of Ontario's contribution to this project.

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Technical Glossary

Units

BTU	British thermal unit
g	gram
kWh	kilowatt hour – a unit of electrical energy equal to the work done by one kilowatt acting for one hour
SWU	separative work unit – a measure of work done by a machine or plant in separating uranium into higher or lower fractions of U-235
t	tonne
We	watt (electric)
Wth	watt (thermal)

Elements and Compounds

C	carbon
CO2	carbon dioxide
Pu	plutonium
U	uranium
UF6	uranium hexafluoride

Metric Prefixes

k	kilo	10^3
M	mega	10^6
G	giga	10^9
T	tera	10^{12}

All dollar values in this report, unless otherwise noted, are in US dollars.

Foreword

By Louise Fréchette

2010 will be a pivotal year for nuclear issues. In April, President Obama will host a special summit on nuclear security. In May, parties to the Nuclear Non-proliferation Treaty will gather in New York for a review conference and in June, at the G8 Summit hosted by Canada, nuclear proliferation issues will occupy a prominent place on the agenda. New challenges to the nuclear nonproliferation regime by countries such as North Korea and Iran and growing concerns about the possible appropriation of nuclear material by terrorist groups arise at a time when there is much talk about a major increase in the use of nuclear energy for civilian purposes.

This so-called "nuclear renaissance" was the starting point of the Nuclear Energy Futures project which was initiated in May 2006. The purpose of this project was three-fold:

- to investigate the likely size, shape and nature of the purported nuclear energy revival to 2030 – not to make a judgement on the merits of nuclear energy, but rather to predict its future;
- to consider the implications for global governance in the areas of nuclear safety, security and nonproliferation; and
- to make recommendations to policy makers in Canada and abroad on ways to strengthen global governance in these areas.

The project commissioned more than a dozen research papers, most of which have been published in CIGI's *Nuclear Energy Futures Papers* series; held several workshops, consultations and interviews with key Canadian and foreign stakeholders, including industry, government, academia and non-governmental organizations; convened two international conferences, one in Sydney, Australia, and one in Waterloo, Ontario; and participated in conferences and workshops held by others. The project has assembled what is probably the most comprehensive and up-to-date information on possible additions to the list of countries that have nuclear power plants for civilian purposes. Along with this Survey of Emerging Nuclear Energy States (SENES), the project has produced a compendium of all the nuclear global governance instruments in existence today which will, I believe, prove to be a valuable reference tool for researchers and practioners alike.

The project was generously funded and supported by The Centre for International Governance Innovation and was carried out in partnership with the Canadian Centre for Treaty Compliance (CCTC) at Carleton University, Ottawa. I was very fortunate to have found in Dr. Trevor Findlay, director of the CCTC, the perfect person to oversee this ambitious project. I am very grateful to him and his small team of masters students at the Norman Paterson School of International Affairs, especially Justin Alger, Derek de Jong, Ray Froklage and Scott Lofquist-Morgan, for their hard work and dedication.

Nuclear issues are quintessential global issues. Their effective management requires the collaboration of a broad range of actors. Canada, with its special expertise in nuclear technology and its long history of engagement in the construction of effective global governance in this area, is particularly well placed to help deal with the new challenges on the horizon. My colleagues and I hope that the findings and recommendations of the Nuclear Energy Futures Project will be of use to policy makers as they prepare for the important meetings which will be held later this year.

Louise Fréchette
Chair of the Nuclear Energy Futures Project
Distinguished Fellow,
The Centre for International Governance Innovation

Preface to the Final Report of the Nuclear Energy Futures Project: Parts 1 to 4

This report culminates three-and-a-half years' work on the Nuclear Energy Futures (NEF) project. The project was funded and supported by The Centre for International Governance Innovation (CIGI) and carried out in partnership with the Canadian Centre for Treaty Compliance (CCTC) at Carleton University, Ottawa.

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- to make recommendations to policy makers in Canada and abroad on ways to strengthen global governance in these areas.

Numerous outputs have been generated over the course of the study, including the Survey of Emerging Nuclear Energy States (SENES) online document, the GNEP Watch newsletter and the Nuclear Energy Futures papers series. The final installment from the project comprises six outputs: the Overview, an Action Plan, and a four-part main report. A description of how the project was conducted is included in the Acknowledgements section at the front of the Overview.

Part 1, The Future of Nuclear Energy to 2030, provides a detailed look at the renewed interest in global nuclear energy for civilian purposes. Growing concerns about energy security and climate change, coupled with increasing demand for electricity worldwide, have prompted many countries to explore the viability of nuclear energy. Existing nuclear states are already building nuclear reactors while some non-nuclear states are actively studying the possibility of joining the nuclear grid. While key drivers are spurring existing and aspiring nuclear states to develop nuclear energy, economic and other constraints are likely to limit a "revival." Part 1 discusses the drivers and challenges in detail.

Parts 2 through 4 of the main report consider, respectively, issues of nuclear safety, security and non-proliferation arising from civilian nuclear energy growth and the global governance implications.

Introduction To Parts 2 To 4: Implications of the Nuclear Revival

The implications for global nuclear governance of the less-than-dramatic nuclear revival projected by this report are not as alarming as they would be if a full-bore nuclear renaissance were on the horizon. Nonetheless, they are sufficiently serious to warrant attention now, especially as many aspects of the nuclear regime are today ineffective or under serious threat. Indeed, the slow pace of nuclear energy expansion gives the international community breathing space to put in place the necessary reform of global governance arrangements.

Parts 2 to 4 of the report will consider the implications of the nuclear revival — in the form predicted in Part one — for global governance in the key areas, respectively, of safety, security and weapons nonproliferation. Each section will:

1. Assess the current status of each issue area, including the existing global governance arrangements and their strengths and weaknesses;
2. Characterize the impact of the revival on the existing arrangements; and
3. Make recommendations for adapting the system so that it effectively and efficiently manages such change.

For the purposes of this report, "global nuclear governance" refers to the web of international treaties, agreements, regulatory regimes, organizations and agencies, monitoring and verification mechanisms and supplementary arrangements at the international, regional, sub-regional and bilateral levels that help determine the way that nuclear energy, in both its peaceful and military applications, is governed. Governance at these levels is in turn dependent on national implementation arrangements which ensure that each country fulfills its obligations in the nuclear field. Such a broad conceptualization of governance is intended to emphasize that a holistic approach is necessary when contemplating the implications of a civilian nuclear energy revival. Global governance will axiomatically be a collaborative enterprise involving many players. It will also be perpetually a work in progress. The NEF project has published a *Guide to Global Nuclear Governance: Safety, Security and Nonproliferation* which provides background to all of the governance elements considered here (Alger, 2008).

Although for the purposes of clarity this report treats nuclear safety, nuclear security and nuclear nonproliferation separately, there is a strong relationship among them that is not always reflected in the ad hoc evolution of the global governance regime pertaining to each. Nor is it often reflected in policy or academic analysis. In particular the nonproliferation community on the one hand, and the safety and security communities on the other, tend to ignore each other. Helping overcome this intellectual "stove-piping" is one of the secondary goals of this project.

The extent of the overlap between safety, security and nonproliferation is, however, increasingly recognized. Common principles, for instance, are seen to apply to safety and security, such as the philosophy of "defence in depth." As Richard Meserve points out with respect to nuclear power reactors, "The massive structures of reinforced concrete and steel … serve both safety and security objectives" (Meserve, 2009: 107). A major breach of physical security, such as sabotage of a nuclear power plant, could pose serious safety risks. Meserve also notes that occasionally plant features and operational practices driven by safety considerations conflict with those that serve security purposes: "Access controls imposed for security reasons can inhibit safety, limiting access for emergency response or egress in the event of a fire or explosion" (Meserve, 2009: 107). Furthermore, safety and security measures designed to prevent unauthorized access to nuclear material can help prevent the acquisition of nuclear weapons by terrorists and other unauthorized entities. Again, nonproliferation measures, such as each country's State System of Accounting and Control (SSAC), designed to help verify non-diversion of nuclear material to weapons purposes, also serve to deter unauthorized activities such as illicit trafficking and help the state account for and thus protect its nuclear assets.

Fortunately there is growing official recognition of the close relationship among these three areas and a recognition that they have to be considered holistically if the global governance of all three is to be strengthened. The "3-Ss" concept — safeguards, safety and security — was adopted by the 2008 Independent Commission of Eminent Persons convened to make recommendations on the role of the IAEA to 2020 and beyond (IAEA, 2008d). It was later endorsed by the Group of 8 (G8) Summit in Hokkaido in 2008 as a means of raising awareness of the importance of integrating the three fields and strengthening "3-S" infrastructure through international cooperation and assistance (G8, 2008).

PART 2: Nuclear Safety

Nuclear safety has always been among the paramount concerns of those who oppose or are skeptical about the use of nuclear energy for electricity generation. It also should be a paramount concern of states that host nuclear power plants, the civilian nuclear industry that operates them and, not least, the "new entrant" countries that are seeking nuclear energy — since a single major accident could kill the nuclear revival. In this sense a nuclear accident anywhere is a nuclear accident everywhere. World Association of Nuclear Operators (WANO) Chairman William Cavanaugh III warned the organization's biennial meeting in Chicago in September 2007 that "Another Chernobyl or another Three Mile Island … would be enough to halt the nuclear renaissance, with all the imaginable negative consequences to our world's economies and to the environment" (Weil, 2007), not to mention the nuclear industry itself.

This part of the report on nuclear safety will focus mainly, although not entirely, on the safety of nuclear reactors since these are central to the nuclear revival and are an important concern for the public. Fuel cycle facilities will only be considered incidentally. This report will not consider the safety of uranium mining and milling, research reactors or radioactive sources, although serious accidents and safety breaches in these areas have implications for the reputation of the civilian nuclear industry generally.[1]

It is impossible to treat nuclear safety (and security) as a global governance issue in isolation from other levels of governance. In principle and ideally, there should be a seamless web between industry, national government oversight and international governance of nuclear safety, and all should share responsibility. The following analysis, while emphasizing the role of the international community in nuclear safety, will necessarily also deal with national and industrial responsibilities.

The nuclear safety community — regulators, operators and owners — generally tends not to favour the concept of global governance with respect to their enterprise. Their philosophy is that the principal responsibility for nuclear safety lies with the operator of the nuclear facility. National governments set the policy framework and establish legislation and regulation within which the operators are obliged to act. The role of the global regime is generally perceived as providing an international legal framework, broadly agreed safety principles, standards, guidance and support to help states implement them. Intrusive multilateral monitoring and verification is viewed as unwarranted; instead, peer review is seen as the best approach to achieving continuous improvements in nuclear safety. Such a philosophy clearly informs national policies at the international level when the negotiation of new multilateral instruments is proposed and when consideration is given to enhancing the role of the IAEA in global nuclear safety.

This report defines nuclear safety as the protection of people and the environment, present and future, from unacceptable risks of exposure to the harmful effects of ionizing radiation, otherwise known simply as radiation.[2] Such exposure may result from a discrete event, for instance an accident at a nuclear power plant or during transport of nuclear materials, or over the longer term as a result of poor containment or disposition of nuclear materials, such as nuclear spent fuel or waste. Nuclear safety is relevant to the entire civilian nuclear fuel cycle, including uranium mining and milling, uranium conversion and enrichment facilities, fabrication plants and reprocessing facilities. It also applies to nuclear transport and nuclear waste storage facilities, both temporary and permanent. The issue of nuclear safety is also pertinent to the entire life cycle of nuclear facilities, including their design, construction, operation, startup, shutdown, maintenance, decommissioning, dismantlement, site cleanup and disposition of contaminated materials (Ramsey and Modarres, 1998: xxv).

Notwithstanding the multiplicity of activities where nuclear safety should be a concern, the emphasis of international governance tends to be on complex nuclear facilities with large inventories of fissionable material that have the potential for being involved in major accidents (IAEA, 2003a). These comprise nuclear power reactors as well as large fuel cycle facilities, notably enrichment and reprocessing plants. Among these, nuclear reactors are considered most at risk of a serious accident because they are designed to operate in a state of controlled criticality (Nuttall, 2005: 37) and because a severe accident may release radioactivity not just locally but via atmospheric transport across a wide area, including over national borders. Moreover, because nuclear fission produces radioactive products that can last from fractions of a second to billions of years, the decision to develop a nuclear power program "carries with it a responsibility to protect human health and the overall biota for more than thousands of years through safe and secure management of radioactive waste" (Ferguson and Reed, 2009: 54).

The safety of conversion, enrichment[3] and reprocessing plants, while important, is of less concern than nuclear power plants since the chances of a catastrophic accident are lower, and also because there will always be fewer such facilities compared with the number of nuclear reactors. While accidents at uranium conversion or enrichment plants can be more severe than those at large oil refineries or liquid natural gas facilities,[4] accidents at reprocessing facilities are potentially as severe as those associated with some types of reactor accidents.

The Requirements of Nuclear Safety

Nuclear reactors and other nuclear facilities must meet two broad safety requirements:

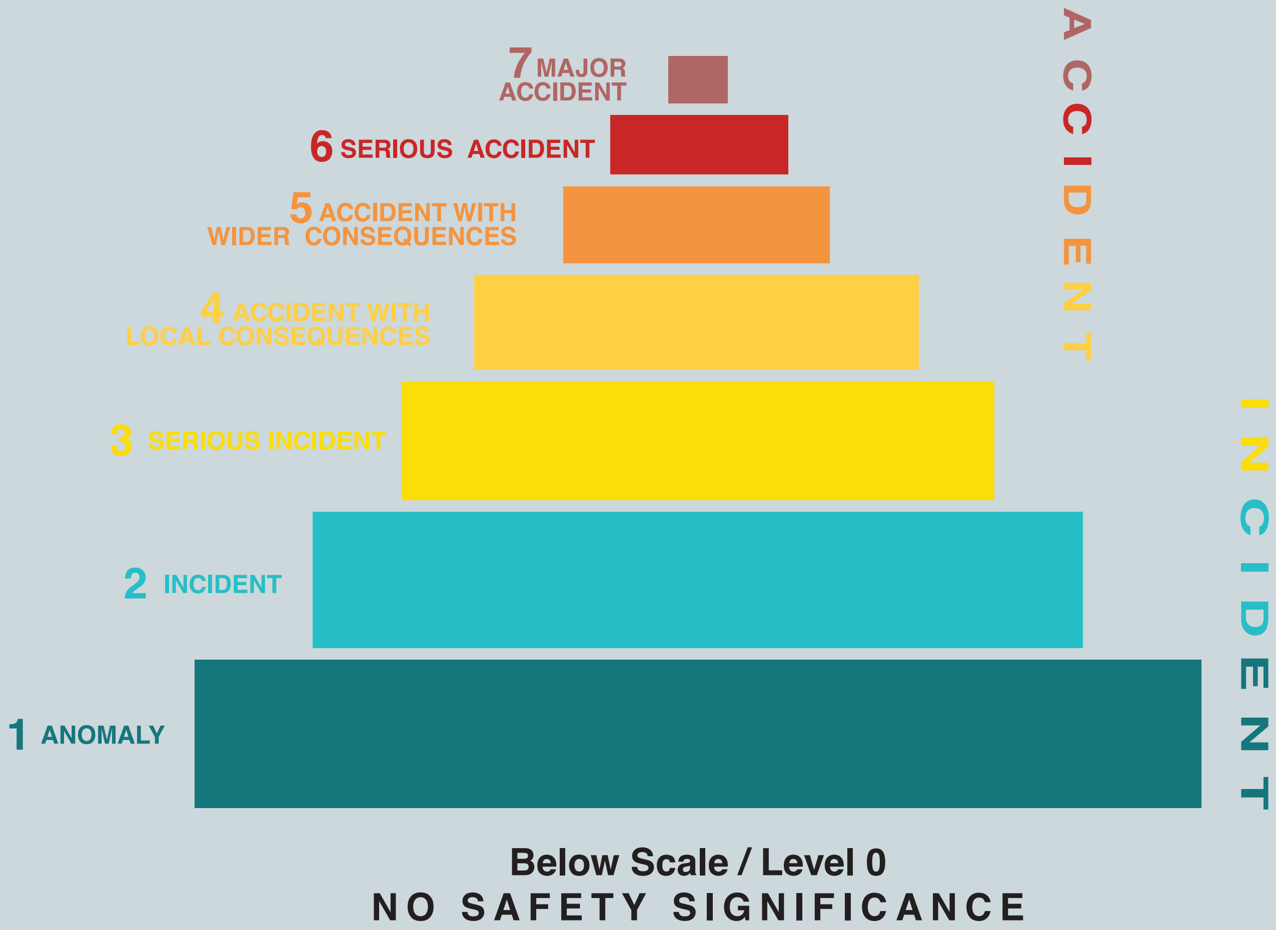
- A nuclear safety requirement that the facilities be safe to operate with a very small probability of accidents; and
- A radiation safety requirement that the radiation exposures in normal operation be below certain limits for both personnel and for members of the public (IAEA, 2003a: 65).

According to the IAEA's *Handbook on Nuclear Law*, it is the operating organization that has prime responsibility for the safety of a nuclear facility during its entire life cycle — siting, design, manufacturing, construction and commissioning, operation and decommissioning (IAEA, 2003a: 69). The operator must take technical safety measures and comply with the binding provisions of the licence granted by the national regulator. In particular it must apply "defence in depth": this requires several physical barriers and several levels of protection to ensure that an unintended release of radioactivity into the environment cannot result from a single failure, but would require less likely multiple failures. For the management of safety to be effective, the operating organization must have, in addition to policies and procedures (including for emergencies), a sufficient number of competent and fully trained staff. It is increasingly recognized that

> For the management of safety to be effective the operating organization must have a very high level of commitment to safety, best expressed by a highly developed safety culture. (IAEA, 2003a: 69)

International Nuclear and Radiological Event Scale

The way that nuclear and radiological events are publicly rated is through the International Nuclear and Radiological Event Scale (INES), originally designed in 1989 by the IAEA and the NEA (IAEA, 2009p). Its purpose is to communicate to the public and media the severity of events reported at nuclear facilities, using a seven-level scale, ranging from an "anomaly" to a "major accident." Chernobyl was ranked at INES Level 7, and is the only such event in history (IAEA, 2001a). INES has recently been extended and adapted to events associated with the transport, storage and use of radioactive material and radiation sources.



Source: Adapted from IAEA (2008f)

The safety of nuclear reactors in theory

The problem that the nuclear power industry faces is that while there may be a low risk of a severe nuclear accident, such an accident would have significant consequences. There are three ways of estimating the safety risk of nuclear power plants: historical experience; Probabilistic Risk Assessment (PRA); and deterministic safety analysis. Each has its imperfections, but taken together they provide some reassurance about the safety of nuclear facilities.

The first comprehensive study of reactor safety was the NRC's Reactor Safety Study (WASH-1400) of October 1975, commonly known as the Rasmussen Report. It used PRA to estimate that the probability of a serious accident was roughly one chance in two million years of reactor operation (Keeny, 1977: 231). It was widely criticized at the time for consistently underestimating uncertainties. The historical approach, on the other hand, is illustrated by the report of an eminent group of scientists in 1977, the Nuclear Energy Policy Group (Keeny, 1977: 229). In noting that the 200 "reactor years" of US commercial light water reactor operations had had no demonstrable adverse effects on public health, they concluded that thus far the safety record had been excellent. Luckily they also concluded that the Rasmussen Report was "of only limited value" in predicting the likelihood of accidents to the year 2000, when US commercial nuclear plants might have collectively operated for some 5,000 "reactor years."

Two years later in Pennsylvania, on March 28, 1979, the Three Mile Island accident occurred, which, despite the absence of major radiation release, essentially destroyed the reactor. The report of the subsequent President's Commission of enquiry, subtitled "The need for change," concluded that "The accident was initiated by mechanical malfunctions in the plant and made much worse by a combination of human errors in responding to it" (Keeny, 1977: 213).

Quantitative estimates of the impact of a worst case nuclear accident — involving the breach of a nuclear reactor — are complicated. They are subject to numerous uncertainties due to the large number of variables involved, including the amount of radioactivity released, the timing of the failure of the containment structure, the prevailing meteorological conditions, and the population in the surrounding area and their level of radiation protection (Smith, 2006: 188). Typically, quantitative estimates have been found to underestimate uncertainty, since they cannot predict unknowables that have not been incorporated into the calculations. They also tend to downplay the role of human error. The same can be said of deterministic safety analysis and for any safety analysis or hazard analysis of a major industrial facility.

A 1981 report by Sandia National Laboratories released in 1982, sought to identify the ten US reactors with the likely largest peak early fatalities and cancer deaths resulting from a worst case nuclear reactor accident, defined as a maximum "credible" accident during the worst possible meteorological conditions (NRC, 1981). The estimated early fatalities resulting from radiation exposure at an accident at one of these plants ranged between 31,000 and 100,000, while the long-term cancer deaths ranged from 23,000 to 40,000. Additional impacts included long-term contamination of surrounding areas, economic costs of the cleanup and loss of productivity, and social and psychological effects. Of course, the possibility of such a catastrophic accident occurring at any particular nuclear plant is remote given the safety measures in place and the low probability that the worst weather would occur simultaneously with an accident, but these are the types of estimates that must be made in order to calculate risk and thereby reassure the public. Paradoxically, however, because of the complexities involved, such studies usually have the opposite effect on the public, heightening concerns about the dangers of nuclear energy, which is why this study was only released under pressure from a non-governmental group, the Council for a Liveable World.

In May 2009 the US Nuclear Regulatory Commission (NRC) presented preliminary findings from its new State-of-the-Art Reactor Consequences Analysis (SOARCA) to the Regulatory Information Conference 2009 indicating, based on a pilot study of just two reactors, that the probability of accidents was "dramatically smaller" than predicted in the 1982 Sandia study (Tinkler, 2009). Even if no mitigation measures were taken, the report said, there would likely be no large releases of radioactivity due to the relatively slow progress of the accidents envisaged and the small probability of containment failure. The methodology used in the study and its conclusions have been criticized by the Advisory Committee on Reactor Safeguards.[5] It is also unclear whether they can be extrapolated internationally. But they illustrate that risk assessments of nuclear power are complex and evolving, in turn reinforcing the political and technical importance of nuclear safety both nationally and internationally.

The safety of nuclear reactors in practice

Since the first accident at a nuclear facility, at Chalk River in Canada in 1952, there have been seven nuclear reactor incidents resulting in damage to the reactor and release of radioactivity, including that at Three Mile Island.[6] Only one has resulted in a major release of radioactivity and significant environmental consequences — the 1986 Chernobyl accident in the Ukraine. In addition, there have been several other known accidents (called "precursor events" in the US) in which nuclear reactor systems malfunctioned, but there was no release of radioactivity. These include the Unit 1 fire at the Brown's Ferry reactor in Alabama in 1975.[7] In 2002 there was a "near miss" incident at the Besse-Davis plant in Ohio, in which boric acid leaking from inside the core ate a pineapple-size hole through the carbon steel top of the reactor vessel (Nuclear Power Joint Fact-Finding Report, 2007: 174-175). Other countries are not immune to nuclear incidents. In 2003 there was a serious fuel damage incident at Hungary's Paks nuclear plant, although it occurred during cleaning of a vessel outside the reactor and the reactor was not operating at the time (Hungarian Atomic Energy Authority, 2003).

One difficulty in assessing the safety of the global nuclear industry in its entirety is that it is unclear whether all such events at all nuclear power plants in all countries are publicized. The former Soviet Union was notoriously opaque about its sprawling nuclear establishment, including its civil sector, and until recently Russia has not been much better. Japan has a history of attempts at covering up the occurrence or severity of nuclear accidents.[8] India has a known poor safety record (Ramana, 2009: 12-18).

The nuclear power industry, to its chagrin, often feels itself held to higher safety standards than other energy-producing industries, especially coal.[9] If true, this is undoubtedly due to public fears, both rational and irrational, of the dangers of radioactivity; the industry's history, until relatively recently, of secrecy and avoidance of "stakeholder engagement;"[10] and the high level of publicity surrounding the spate of accidents that have occurred (the industry would say these were "over publicized") compared with those in other energy industries. The collapse of a coal tailings dam in December 2008 in Harriman, Tennessee, that wreaked havoc on thousands of acres of land was barely noticed internationally or even within the US.[11] Paradoxically it is not far from the Watts Bar nuclear power plant.

Nuclear Safety in the Nuclear Weapons Sector

A difficulty for the civilian nuclear industry is that the public tends not to distinguish between civilian nuclear facilities and defence-related facilities. Nuclear safety practices at the latter have often been worse than in the civilian sector, especially during the early scramble by the nuclear weapon states to acquire their initial arsenals. This resulted in several severe accidents in the former Soviet Union, including the worst nuclear disaster ever, at the Chelyabinsk plutonium production plant in 1957, and significant environmental contamination, in the US case at the Hanford weapons materials production complex in Washington State (NRC, 2009c; GAO, 2009). The UK's only significant nuclear reactor accident occurred at a military plutonium production facility at Windscale in 1957. There have also been accidental (and deliberate) discharges into the North Sea from the UK's Sellafield reprocessing plant which services both the civilian and weapons sectors (MIT, 2003: 51).

The US nuclear weapons complex has increasingly adopted safety standards matching those of the US civilian nuclear industry, while Russia and the former Soviet republics have been the beneficiaries of massive US and other international assistance, such as the US Cooperative Threat Reduction Programs and the Global Partnership Program (GPP), to deal with the Soviet nuclear legacy (Global Partnership Program, 2007). This has led to significant improvements in both safety and security. The situation at other states' nuclear weapons complexes is uncertain due to secrecy and a lack of national accountability. In past decades serious events in the nuclear weapons complex were kept secret when they occurred, but details have only been revealed with the passage of time. Given the current state of monitoring of nuclear releases worldwide, including by the Preparatory Commission for the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) and the IAEA, it will be more difficult to conceal such incidents (along with those at civilian plants).

An accident at a nuclear weapons facility resulting in a similar global impact to that of Chernobyl, for instance, would sour the atmosphere for a revival as much as, or even more than, an incident at a civilian plant. It is in the interests of the civilian nuclear industry therefore to encourage the adoption of global safety and security standards in all aspects of the nuclear enterprise, rather than their traditional approach of pretending that the nuclear weapons complex is a completely separate undertaking.

Nuclear safety today

Nuclear safety has improved in many states and in many areas since the Chernobyl disaster. All of the Chernobyl-style Soviet reactors have either been shut down or, if economic to do so, have been upgraded to improve their safety. Since many of the former Soviet states found themselves at independence with very little supportive infrastructure for their inherited nuclear reactors, the US, along with the European Union, the UK, Sweden and the IAEA established programs to help them improve the safety of their plants and strengthen regulatory oversight (Trossman, 2009: 65). Independent international safety reviews have identified significant progress in Eastern European countries to improve the safety of their nuclear power plants since the early 1990s (Trossman, 2009: 65).

Beyond these types of reactors, nuclear safety has also improved worldwide. According to the World Association of Nuclear Operators (WANO), the most important plant-based Performance Indicators of improved safety are: the rate of unplanned "automatic trips" (when the reactor is automatically shut down by safety systems rather than plant operators); radiation exposure of workers; and discharges to the environment (WANO, 2009). WANO data indicates that all three have "drastically decreased" compared with 40 years ago when civilian nuclear programs began (OECD/NEA, 2008: 224). On average, according to the NEA, worker exposures at operating nuclear power plants halved between 1992 and 2006 and such gains were relatively uniform across all types of reactors (OECD/NEA, 2008: 219).

In the US, in March 2009, on the thirtieth anniversary of Three Mile Island, the NRC reported that the number of significant reactor events — those with serious safety implications such as a degraded fuel rod — have dropped to nearly zero over the past 20 years (NRC, 2009c). The average number of times that safety systems have had to be activated is about one-tenth what it was 22 years ago. Radiation exposure of plant workers has steadily decreased to about one-sixth of 1985 levels, well below federal government limits. The average number of unplanned annual reactor shutdowns decreased nearly ten-fold (there were about 52 shutdowns in 2007 compared with 530 in 1985). Improvements in other aspects of nuclear safety, especially ephemerals such as safety culture (a major factor in the Besse-Davis incident (Lochbaum, 2006: 38)) are less easily measured and hence more contestable.

Noting that one of the principle lessons of Three Mile Island was the need for industry-wide, systematic evaluation of operating experience by both the nuclear industry and its regulators, the NEA claims that one of the major reasons for improved safety performance has been the extensive use of lessons learned from operating experience (OECD/NEA, 2008: 226). This has resulted in the retro-fitting of safety systems, improved operator training and emergency procedures and a focus on human factors, safety culture and quality management systems. The philosophy of continuous safety improvement has, according to the NEA, been adopted by many in the nuclear industry. But there are limits, says the NEA, as embodied in the industry's "as low as reasonably achievable" (ALARA) principle (OECD/NEA, 2008: 212). It notes that as in any mature industry there is an "asymptotic" limit to future major improvements given the cost-benefit analysis that necessarily is a factor in considering the search for safety perfection.

Then NRC Chairman Dale Klein told a US Senate committee in March 2009 that improved safety in the US nuclear industry since Three Mile Island has come from revisions to emergency preparedness planning, modifications to plant control room equipment, better operator training and changes to his Agency's enforcement authority (Nuclear News Flashes, 2009a). Regulatory improvements include deploying two resident inspectors at each nuclear power plant (rotating them every seven years), centralized NRC incident command and response centres, more stringent requirements for and tighter controls on operators, more inspector and operator training and a performance-based, "risk-informed" regulatory approach rather than focusing on compliance with "lots of rules and regulations," many of which were administrative rather than safety-oriented (Dalrymple, 2009: 29).[12] Critic Ed Lyman of the Union of Concerned Scientists accuses the NRC of wanting to "wave a magic wand of probalistic risk assessment and make a lot of the requirements go away" (Ward, 2009). He says analysts cannot always anticipate the full range of risks at a given plant; he recommends "defence in depth" instead.

As International Safety Advisory Group (INSAG) Chair Richard Meserve notes, "noteworthy safety lapses continue to occur at nuclear power plants around the globe, including at reactors in countries with extensive operational experience and strong regulatory capabilities" (Meserve, 2009: 102). A Union of Concerned Scientists study has revealed that in the 27 years since Three Mile Island, 38 US nuclear power reactors have had to be shut down for at least one year while safety margins were restored to minimally acceptable levels (Lochbaum, 2006). Seven of the reactors experienced two-year outages. A majority of the extended outages, it says, were caused not by broken parts but by a "general degrading of components to the point that safe operation of the plant required a shutdown for broad, system-wide maintenance" (Lochbaum, 2006).

In July 2008 the US Government Accountability Office (GAO), after studying just ten US reactors, reported that some of the country's nuclear power plants have yet to comply with some of the government's fire safety regulations issued after the 1975 Browns Ferry fire that had been caused when a worker using a candle to check for air leaks ignited electrical cables (World Nuclear News, 2008; GAO, 2008). Long-standing unresolved issues include continuing reliance on manual actions by plant workers to ensure fire safety (for example, a worker turning a valve to operate a water pump), rather than "passive" measures (such as fire barriers and automatic fire detection and suppression). In addition, workers use "interim compensatory measures" (primarily fire watches) for extended periods, rather than making repairs. As for the NRC itself, it has no centralized database on the status of compliance. The GAO noted that while the recommended fire standards were being adopted for half of the US reactor fleet, the operators doing so faced significant "human capital, cost and methodological challenges," including a "lack of people with fire modeling, risk assessment and plant-specific expertise" (World Nuclear News, 2008; GAO, 2008).

Such difficulties are not confined to the US. France's Nuclear Safety Authority (ASN) wrote to Areva CEO Anne Lauvergeon in August 2009 to ask the company to undertake a "broad review of safety management" across all divisions and subsidiaries, after several incidents at its fuel cycle facilities (MacLachlan, 2008a: 3). Reportedly, Areva's Groupe Permanent, an advisory body devoted to safety management, had never met and there had apparently never been a thorough review of safety management across the group.

Nuclear safety is thus, necessarily, a work-in-progress, particularly in terms of the human dimension that is difficult to "engineer" out of the system. Paradoxically, even a strong performance record can lead to deep-rooted internal problems due to complacency. Then NRC Chair Dale Klein told his Agency's 21st Annual Regulatory Conference in March 2009 that "We have continued to see incidents over the last few years … that indicate that safety culture was not a priority through all the staff at all the plants" (Weil, 2009: 1).

The international nuclear safety regime

A brief history

The first glimmers of a future international nuclear safety regime emerged in the 1950s during negotiations on the creation of the IAEA (Gonzáles, 2002: 273). Early discussions appeared to have tacitly assumed that the IAEA would be mandated to impose safety standards on the civilian nuclear industry worldwide (Fischer, 1997: 461). The Preparatory Commission for the Agency even foresaw the recruitment of safety inspectors and the development of "Safety Standards" (IAEA, 2008e: 1). Ultimately, however, as in many other areas, state prerogatives and the views of industry prevailed over innovations in international governance. The IAEA Statute thus makes clear that the Agency is authorized to impose mandatory safety requirements only on projects for which it provides assistance and not on member states.[13] Its role in nuclear safety is, in consultation with other UN bodies, to adopt and promulgate safety standards, but these are adhered to by states only voluntarily.[14]

Although there were numerous proposals in the 1960s to negotiate a legally binding international convention to govern the safety of civilian nuclear power facilities, the states with major programs were disinclined at that stage to proceed, insisting that nuclear safety was primarily a national responsibility (despite the fact that national governments insist that the owners or operators of nuclear power plants have prime responsibility for nuclear safety). There was also continuing resistance to any extension of the IAEA's role in nuclear safety, with a clear preference for restricting it to the promulgation of non-binding safety standards (OECD/NEAa or b, 2006: 13). Instead, states turned their attention to creating nuclear accident liability regimes, specifically the Vienna and Paris conventions (see the liability section below for further details), making them the first multilateral treaties governing any aspect of nuclear power generation (IAEA, 2003a: Part IV). These were an early recognition that serious nuclear accidents might have transboundary effects and that the nuclear industry itself was unable and unwilling to shoulder all of the financial risks involved.

The 1986 Chernobyl disaster was a "wake up call" to the nuclear industry, national governments and the international community in demonstrating the cost of such trans-boundary effects and the truism that global nuclear safety requires a global, not purely national, approach (Savchenko, 1995). It led, in record time, to the negotiation of two legally binding conventions — the 1986 Convention on Early Notification of a Nuclear Accident and the 1987 Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency. These were intended to fill obvious shortcomings in international response mechanisms for a major nuclear accident. Chernobyl also provided the impetus for two conventions designed to help prevent nuclear accidents in the first place — the 1994 Convention on Nuclear Safety and the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. In addition, the competing nuclear liability regimes were strengthened and linked (IAEA, 2003a: 108). Numerous other initiatives were taken by industry, government and international bodies to strengthen global governance of nuclear safety to the point where it may now be described as truly an international nuclear and radiation safety regime. How effective the regime is remains a critical question that will be considered below.

Elements of the current international nuclear safety regime

The current nuclear safety regime is sprawling and loosely integrated, reflecting its episodic and largely uncoordinated evolution. It comprises legally binding international conventions; non-binding international safety standards; programs to facilitate the implementation of those standards by international organizations and multinational networks; the international nuclear industry itself; and the national nuclear infrastructure of each state, including vendors, operators and regulators. An additional group of players is the media, non-governmental organizations, academia and the general public. Programs for promoting nuclear safety include information exchanges, research and development, technical assistance for developing states, education and training, safety appraisal services, including evaluation of accidents, and peer review. The International Nuclear Safety Group (INSAG) has pictorialized the regime in the following chart.

Main Elements of the Global Nuclear Safety Regime

Source: Adopted from IAEA (2006b: 5)

The Convention on Nuclear Safety

The 1994 Convention on Nuclear Safety (CNS) is a marked advance on the previous absence of a legally binding nuclear safety regime. The CNS was adopted in June 1994, opened for signature in September 1994 and entered into force in October 1996. As of August 2009 there were 65 signatories and 66 contracting parties (IAEA, 2009b), including all states that currently have operating nuclear power plants or are building them — with the significant exception of Iran.

Negotiation of the Convention

Despite the impetus provided by Chernobyl, negotiation of the treaty was "extremely difficult" (Gonzáles, 2002: 278). One immediate issue was scope. At the outset a majority argued for a convention that would cover the entire fuel cycle, plus research reactors, transportation and the use of radioisotopes. A significant minority of states, many of which had extensive fuel cycle activity (although there were exceptions), argued for a narrow scope limited to the activity of greatest international concern: nuclear power plants. The staunchest opposition to a limited convention came from those, including the Scandinavians, who argued strongly for waste management to be included. Ultimately waste management was not included as there were at that time no internationally agreed safety principles applicable to such material. The treaty instead would contain preambular language committing the state parties to begin work on a waste management convention as soon as there was broad international agreement on such standards.

A second key issue over which states were divided was the degree of technical specificity that should be included in the treaty and thus whether there should be legally binding safety regulations as opposed to broad commitments to implement safety principles. Proposals were made to include technical annexes which would be based on the five Codes of Practice published in the IAEA's Nuclear Safety Standards (NUSS). It was argued that this degree of detail would facilitate judgements about whether or not a country was complying with the convention.

Most states without nuclear power plants wanted binding standards and a strong role for the IAEA. Sweden and a few states with nuclear power agreed. The minister of the environment for the newly reunited Germany, who chaired the 1991 IAEA International Conference on the Safety of Nuclear Power: Strategy for the Future which led to the treaty's negotiation, was particularly keen on forcing the closure of old Chernobyl-type Soviet reactors in Eastern Europe through the imposition of mandatory safety standards. Struggling to emerge economically from the collapse of their communist systems, the Eastern Europeans were reluctant to lose the workhorses of their baseload power generation capacities. But both Russia and the Ukraine were puzzlingly silent on the issue of binding legal standards and the Eastern Europeans as a group were not the principal objectors (Russian policy makers were apparently too divided to settle on a position).

Rather it was the UK and the US which were adamantly opposed, even rejecting a proposal that the IAEA Secretariat prepare a draft of what might be included in the convention for discussion by legal and technical experts. Consensus on the need for technical details could not be achieved and there was agreement to proceed with fundamental principles only, although all also agreed that the Nuclear Safety Standards documents could and would be used as valuable input when the parties met to review compliance. The result was a compromise text described as "relatively mild" (Gonzáles, 2002: 278). On the other hand, from the outset there had been a realization that for any safety convention to be effective, it needed to have the support of all states with nuclear power.

Provisions of the Convention

The treaty applies only to land-based civilian nuclear power reactors, including existing, decommissioned and (importantly in terms of a nuclear revival) future plants. It also covers the generation of radioactive waste resulting from the operation of a nuclear installation and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation (IAEA, 1999b: Art. 19). This is significant in that most countries store radioactive waste or spent fuel at the site of nuclear power plants pending the opening of long-term geological or other disposal sites.[15] Also significantly, the CNS excludes other facilities that are part of the nuclear fuel cycle — those for fuel fabrication, uranium conversion and enrichment, and reprocessing. While states may apply the CNS to such facilities, this is not required. This represents a significant lacuna in the nuclear safety regime.

The CNS acknowledges in its preamble that "responsibility for nuclear safety rests with the State." The treaty thus sets out an international safety "framework" within which states should operate. The preamble also declares that the treaty only commits parties to the application of "fundamental safety principles" rather than "detailed safety standards." As the negotiating history shows, these principles derive "to a large extent" from the IAEA's 1993 Safety Fundamentals document "The Safety of Nuclear Installations" (IAEA, 1993).[16] While Articles 7-19 of the Convention are literal versions of the safety fundamentals language modified only to fit treaty format, others were weakened (for example, while the fundamentals require the establishment of policies that give safety the highest priority, Article 10 requires only "due priority").

With no further reference to "standards," the CNS notes that there are "internationally formulated safety guidelines which are updated from time to time and so *can* [emphasis added] provide guidance on contemporary means of achieving a high level of safety." Thus, not only does the CNS fail to require that states follow legally binding safety standards, it even refrains from recommending that states in all cases follow the "guidelines." Nor does it mention that it is the IAEA's guidelines that are the most likely to be considered "internationally formulated." This is presumably because there were, in addition to the IAEA standards, two others of note: one was the Russian regime for VVER and RBMK reactors and the US Nuclear Regulatory Commission's regime. Since US companies Westinghouse and General Electric exported reactors worldwide it is no surprise that several countries would follow US safety guidelines and recommendations.

It is, however, the IAEA's safety standards and guidelines that have the greatest global credibility and legitimacy and are thus considered by states to be the international benchmark against which they should measure their compliance with the CNS. Three years after the treaty entered into force (June 1999) revised safety standards were promulgated by the IAEA (IAEA, 1999a), while revised "safety fundamentals" were released in 2006 (IAEA, 2006a). As the treaty foretold, there is likely to be continuing evolution in IAEA standards to which all states will be expected to aspire.

Essentially, though, the CNS is as much about activities and measures as it is about safety principles. It requires each state party to:

- Immediately assess the safety of existing reactors, and if necessary, affect improvements or shut them down;
- Take the necessary legislative, regulatory and administrative steps to implement their obligations under the convention, including: national safety regulations; a licensing system for nuclear installations, an inspection and assessment system; and sanctions in the event of breaches;
- Establish domestic legal provisions that at a minimum mirror those found in the treaty;
- Establish a regulatory body with the necessary authority, competence and resources;
- Conduct a comprehensive and systematic safety assessment prior to a nuclear plant being allowed to operate and repeat this exercise periodically throughout its lifetime;
- Undertake verification activities to ensure the safe operation of all installations using analysis, surveillance, testing or inspection;
- Put in place emergency plans, both on-site and off-site, to mitigate the consequences of any radiation release;
- Ensure that installation design and construction provide for "defence in depth" against the release of radioactive materials;
- Ensure that relevant levels of maintenance, inspection and testing are conducted by plant operators and that procedures exist to respond to operational incidents and accidents; and
- Ensure that safety-related engineering and technical support is available and that all significant safety incidents are reported.

An "Incentive" Instrument: The Role of Peer Review

In contrast to the nuclear weapons proliferation conventions, the CNS has no monitoring, verification or compliance system and no penalties for non-compliance. The negotiators of the convention agreed that no supranational regulatory body should be created. They also rejected proposals to give the IAEA a role in verification as it has in respect of nuclear safeguards. The Convention's preamble vaguely describes it as an "incentive instrument," although it is not clear how this differs from other treaties, most of which contain incentives of some type.

Instead of verification, the parties committed themselves to peer review — at the time a significant innovation in nuclear governance. The peer review language was among the most carefully worded in the Convention, an indication of the seriousness with which it was treated. Peer review entails each party providing all others with a detailed periodic report on the measures it takes to implement the convention. Review meetings are convened every three years to review such reports, with states usually represented by their national regulators. The texts are submitted six months in advance and circulated to all contracting parties for written exchanges of questions, answers and comments. Unusually in international agreements, attendance at such meetings is mandatory. Instead of being attached to the Convention itself, a non-binding Annex was attached to the Final Act of the diplomatic conference to clarify procedural and financial arrangements, the expected form and content of national reports and the conduct of review meetings (IAEA, 1994).

Role of the IAEA in Implementation

The lukewarmth of the CNS text about the nuclear safety role of the IAEA, the premier international nuclear governance body, may seem surprising given the global impact of the Chernobyl accident to which the treaty is a response. Countries with no nuclear power programs, or small ones, and therefore with less national technical expertise, generally wished to give the IAEA a significant technical role — in conducting reviews, summarizing available information, organizing ad hoc technical meetings, giving advice on technical matters and generally contributing to effective review of the convention's implementation. In contrast, countries with large nuclear programs generally wished the IAEA role to be limited to that of a secretariat, with essentially administrative and organizational functions. The latter group carried the day. The Agency's formal duties in implementing the treaty are thus restricted to two: its Director General is designated the treaty's depositary and its secretariat acts as secretariat for the meetings of the parties (Fischer, 1997: 461). (A much more active IAEA role is envisaged in the other three post-Chernobyl nuclear safety-related treaties.)

In practice, however, the Agency has a significant degree of influence on the treaty's operation, one that has increased over time, simply by virtue of its role in organizing the review meetings and peer review system and in general promoting nuclear safety and assisting states in achieving it. During the peer review process, for instance, states often turn to the Agency for guidance on technical, legal and other issues.[17] In addition, the Agency issues guidance "established by the Contracting Parties" and "intended to be read in conjunction with the text of the Convention," on how to interpret compliance and how to report on it (IAEA, 1999c).

Implementation of the CNS

Given the concern of Western European states about the safety of Soviet-type nuclear reactors after Chernobyl, it was Article 6 of the CNS on "Existing nuclear installations" that was of greatest concern in terms of the treaty's immediate implementation. Article 6 requires the parties to "take the appropriate steps to ensure that the safety of existing nuclear installations is reviewed as soon as possible" and that "all reasonably practicable improvements are made as a matter of urgency to upgrade the safety" of such installations. If this was not possible they were to be shut down "as soon as practically possible." In effect this was done, in large part due to pressure from the then Group of 7 (G7)[18] and the incentive of accession to the European Union (EU).

All first generation Soviet reactors, the VVER 440-230 and the RBMK designs, none of which could be economically upgraded to an acceptable safety standard, were closed in the former East Germany, Bulgaria, Lithuania and Slovakia. Second-generation Soviet plants that could be economically upgraded to meet international safety standards were given upgrades. It is not clear, however, whether it could be claimed that the CNS was responsible for the closure of nuclear plants elsewhere. After a lackluster report to the first review meeting for the convention, Russia was pressured by the parties to provide to the second review meeting a more convincing account of the measures taken to install safety retrofits to its own Soviet-era reactors. It reportedly did this, to the satisfaction of its treaty partners. According to INSAG, with this first round of closures and basic safety improvements achieved, "the first stage of implementing the CNS is now over" (INSAG, 2006b).

The attention of the review meetings subsequently turned to ensuring that all other articles of the convention are fully implemented by all parties. The most recent review meeting (the fourth) was held in April 2008. The discussions, over five and a half days, were judged by the 55 parties in attendance to be "constructive" (IAEA, 2008e). Prior to the meeting they were organized into six "Country Groups," each including states with nuclear power programs of different sizes, as well as those with no program. Fifty-seven of the 61 parties (93 percent) submitted national reports for consideration. In 2005, by comparison, 52 of 55 parties (94 percent) submitted reports, 47 of 53 (88 percent) in 2002, and 47 of 50 (94 percent) in 1999 (IAEA, 1994). Compliance with the reporting requirements is therefore excellent. The four parties that did not submit a national report in 2008 were Kuwait, Mali, Nigeria and Sri Lanka. Six states — Bangladesh, Kuwait, Mali, Moldova, Sri Lanka and Uruguay — did not attend the meeting despite their legal obligation to do so. None of these non-compliant states have nuclear power plants, although at least three, Bangladesh, Kuwait and Nigeria, have declared their interest in acquiring them. In any case, whether they have their own plants or not, all contracting parties are obliged by the CNS to take steps to prepare for nuclear accidents outside their territory that may affect them. While some parties submitted reports too late to allow for the preparation of written questions by others, it is not possible to determine from the public record whether any of these were countries with nuclear power programs.

The substance of reporting is also improving. In 2002 Canada became the first to present a comprehensive national report that goes beyond measures taken to comply with the CNS and involves industry and the regulator in its compilation. In 2008 the US delegation set a precedent by including a presentation by a representative of its nuclear industry, John Ellis, president of the Institute of Nuclear Power Operations (INPO).

The summary report of the 2008 meeting agreed by the contracting parties concluded that the national reports submitted were in many cases of high quality and provided ample information (IAEA, 2008e: 15-16). A "high degree of compliance" was reported (IAEA, 2008e: para. 3). The discussion of national reports apparently "resulted in identification of good practices, challenges and planned measures to improve safety." In general, the report claimed, "the overall safety and radiation protection performance" at nuclear power plants "appear to remain satisfactory." But it also cautioned that "the worldwide nuclear industry and regulators must avoid complacency" (IAEA, 2008e: para. 3).

The parties continue to seek to improve the CNS process by convening open-ended working groups to consider ideas. The 2008 meeting agreed on steps to improve inter-sessional communication and to make the review process more efficient, following the failure of previous efforts at the 2005 meeting (MacLachlan, 2008d: 10). One potentially valuable reform is the holding of joint meetings between the parties to the CNS and the parties to the Joint Conventions on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management to discuss issues of concern (these apparently have not yet eventuated).

Compliance with the CNS

The parties themselves conceded in their summary report that in making judgements about compliance with the CNS they are forced to "rely on the accuracy and completeness of the information provided by each contracting party and in its answers to the questions asked of it" (IAEA, 2008e: para. 22). In fact, drawing conclusions about the reality of compliance with the CNS — or more pertinently the reality of nuclear reactor safety in each country — based solely on this peer review system, is problematic. Indeed, the reports are not meant to be an assessment of the level of nuclear safety per se, but rather an account of the measures that each country has put in place to help implement the convention. To what extent such measures are effective or whether, in the worst case, they are mere window-dressing is open to question. On the issue of safety culture, increasingly recognized as one of the lynchpins of nuclear safety but difficult to measure, the summary report noted that it is now "in place" in only some state parties, implying that it is not yet mature or commonplace (IAEA, 2008e: para. 25).

Yet the peer review process is clearly effective in exposing the parties to critical scrutiny. The national reports are examined carefully, detailed questions are asked in advance, and during the question and answer sessions there is reportedly polite but pointed, and at times persistent, probing. Only security-related issues are off-limits. Representatives are pressured not just to provide assurances that problems will be fixed, but are expected at the subsequent meeting to provide information on the steps actually taken.

The intense peer review can make representatives of some countries uneasy, especially those in Asia, where losing face is culturally taboo, or countries like Russia with a tradition of pervasive state secrecy. Yet all of these countries have submitted comprehensive reports and submitted themselves to intense questioning about their compliance with the CNS. As familiarity with each country's situation has improved, the process has become increasingly focused on particular issues of concern. As in all peer review processes, those doing the reviewing appear to gain as much as those being reviewed. Of interest

Canada and the Convention on Nuclear Safety

At the Third Review Meeting of the CNS Canada accepted, as a result of suggestions by other state parties, to take the following actions to improve safety at Canadian facilities (CNSC, 2007: 3):

1. Develop its regulatory approach for refurbishment and life extension of nuclear power plants;
2. Modernize its regulatory framework for licensing new reactor projects;
3. Maintain safety competence in the nuclear industry and its regulatory body;
4. Complete the quality management program implementation in its regulatory body;
5. Improve the rating system used to evaluate licensee performance;
6. Finalize its Power Reactor Regulation Improvement Program;
7. Evaluate its use of periodic safety review in Canada;
8. Enhance a risk-informed performance-based regulatory approach;
9. Continue its program to improve safety margin for large loss of coolant accidents;
10. Continue its project on safe operating envelope; and
11. Host an Integrated Regulatory Review Services mission.

As good practice, Canada elected to prepare a report summarizing the progress on each "action" in the first year after the Third Review Meeting, and reported in full to the Fourth meeting.

An example of the changes implemented by Canada is the adoption since May 2006 of "risk-informed decision-making" for the safety regulation of nuclear power plants (CNSC, 2008). The Canadian Nuclear Safety Commission (CNSC) has used the process to identify approximately 75 CANDU safety issues and rank the 21 most significant ones according to risk. These were reportedly identified through "extensive national and international research as well as interaction with numerous specialists." Findings were communicated to the industry in 2007 and as a result several of the issues have been dealt with.

in respect of the nuclear revival, two states seeking nuclear energy for the first time, the UAE and the Philippines, have indicated that they wish to present national reports at the next review meeting, even though they do not yet have operating reactors, presumably in order to set out their plans for meeting their CNS obligations in advance.

Notwithstanding the achievements of the CNS process, any peer review system "poses an inherent danger of under-enforcement" (Handl, 2003: 19). First, participants may be influenced either by mutual reluctance to criticize their peers, or by political pressure unrelated to the issue at hand. The CNS's sub-group structure, with its mix of states with nuclear reactors and those without them, is designed to help alleviate this danger. Another safeguard is the random electronic reshuffling of country group membership for each meeting to attenuate potential "group think." A second challenge in achieving comprehensive and thorough peer review is information overload. The amount of information in each national report is likely to tax the resources of all but the most competent and diligent of peers. In practice only the major nuclear energy powers will have the time or personnel to analyze each report in detail.

A third obstacle in achieving effective peer review is a lack of openness and transparency. The CNA itself protects the confidentiality of information identified in national reports as well as, unusually, "the content of the debates" during the review meetings (IAEA, 1994: Articles 27.1, 27.2). The latter is designed to promote open and candid discussion among delegations.

The drawback is that interested non-governmental organizations (NGOs) or other members of the public are not permitted to attend or intervene in the proceedings, making it impossible for outsiders to truly assess the system's effectiveness. Parties are encouraged to make their own reports public, but as of October 2009 only 23 were posted on the IAEA website, six less than are available from the 2005 meeting.[19] The reports that are accessible are impressively detailed. Five states — Canada, Luxembourg, Slovenia, Switzerland and the UK — also included their detailed responses to questions from other parties. An open-ended working group at the 2008 meeting proposed that the first and final plenary sessions of the next meeting, in 2011, should be open to the media (MacLachlan, 2008d: 17). France supported each state having the option of opening its conference presentations to the public, but there was no support for opening up the question-and-answer sessions.

Current CNS practice runs counter to a major trend in international law towards greater inclusiveness (Vierucci and Dupuy, 2008; Ripinsky and Van Den Bossche, 2007). CNS practice may not only "diminish the overall effectiveness of the review process," but "shape negatively public perceptions of its legitimacy" (Handl, 2003: 21) and, ultimately, of the safety of nuclear installations. There is a natural tension and trade-off between confidentiality and transparency, but governments, at least in many Western democracies, have policies and mechanisms that seek to achieve the right balance.[20] Such practices could be emulated by the CNS review meetings. The difficulty will be achieving agreement from states that domestically are unused to such openness.

Role of the International Atomic Energy Agency

Nuclear safety is one of the three pillars of IAEA activities — in addition to the promotion of nuclear energy and the non-proliferation of nuclear weapons. The Agency's role as the global "hub" of nuclear safety has been steadily enhanced and become paramount since the Chernobyl disaster. In addition to becoming the secretariat for all of the new safety-related conventions, its key activities in nuclear safety are the setting and promotion of safety standards, safety advisory missions and management of peer review processes.

Safety Standards: Setting, Promoting and Assisting

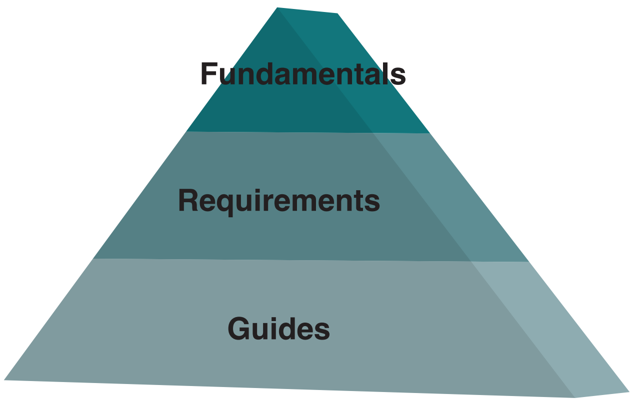
The IAEA has created comprehensive, detailed sets of safety standards covering a wide array of subjects covering all aspects of the peaceful uses of nuclear energy: radiation safety, radioactive materials transport safety, radioactive waste safety and nuclear safety. In respect of civilian nuclear energy, they cover the establishment of an adequate legislative and regulatory infrastructure, radiation protection, reactor site evaluation, and the design, safe operation and safe decommissioning of nuclear power plants.

The types of IAEA safety documents, which the Agency ranked hierarchically in 1989 following the major, post-Chernobyl expansion of its nuclear safety activities (Gonzáles, 2002: 280-281, 295-297), are:

- Safety Fundamentals, which set out basic objectives, concepts and principles;
- Safety Requirements, which establish basic requirements that "shall" be fulfilled in the case of particular activities or applications; and
- Safety Guides, which contain recommendations, based on international experience that "should" be followed in fulfilling the Safety Requirements.

The Agency also establishes guidelines and codes of conduct, such as its 1998 Guidelines for the Management of Plutonium and its 2004 Code of Conduct on the Safety of Research Reactors.

IAEA Safety Standards Series



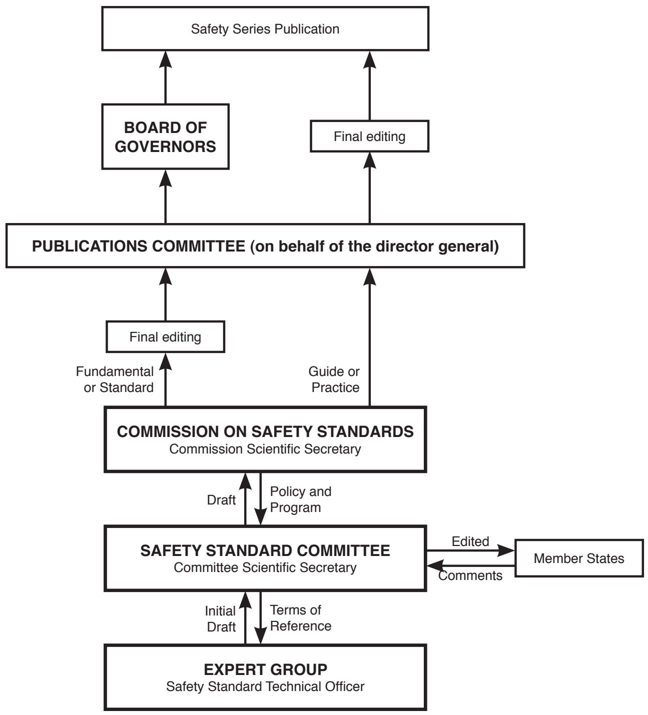
Source: Adapted from Akira (2009: 214)

IAEA Fundamental Safety Principles

1.	Responsibility for safety	The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.
2.	Role of government	An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.
3.	Leadership and management for safety	Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.
4.	Justification of facilities and activities	Facilities and activities that give rise to radiation risks must yield an overall benefit.
5.	Optimization of protection	Protection must be optimized to provide the highest level of safety that can reasonably be achieved.
6.	Limitation of risks to individuals	Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.
7.	Protection of present and future generations	People and the environment, present and future, must be protected against radiation risks.
8.	Prevention of accidents	All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.
9.	Emergency preparedness and response	Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.
10.	Protective actions to reduce existing or unregulated radiation risks	Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

Source: IAEA (2006a: 5-16)

Preparation and Review Process for Safety Standards



Source: Gonzáles (2002: 294)

Negotiations in each safety area have tended to follow a pattern — the negotiation of a fundamental set of standards, supported by a number of documents containing more detailed guidance (Gonzáles, 2002: 280). The Commission on Safety Standards (CSS) and its various safety committees, on which member states are widely represented, oversee the development of IAEA safety standards. In addition, in order to ensure the broadest possible consensus, safety standards are submitted for approval to the IAEA Board of Governors (for Safety Fundamentals and Safety Requirements) or, on behalf of the Director General, to the IAEA Publications Committee (for Safety Guides) (ElBaradei, 2003: v).

More than 200 safety standards have been negotiated under the auspices of the IAEA, focusing on four main areas (Gonzáles, 2002: 281):

1. Basic Safety Standards (BSS) and supporting documents (radiation safety/protection);
2. Nuclear Safety Standards (NUSS) program, relating to nuclear facilities including reactors;
3. Radioactive Waste Safety Standards (RADWASS) program; and
4. Transport Regulations and supporting documents.

Commission on Safety Standards

The Commission on Safety Standards (CSS) is a standing body of senior government officials with national responsibilities for establishing standards and other regulatory documents relevant to nuclear, radiation, transport and waste safety (IAEA, 2009l). Its functions are:

- To provide guidance on the approach and strategy for establishing the Agency's safety standards, particularly in order to ensure coherence and consistency between standards;
- To resolve outstanding issues referred to it by its standards advisory committees on nuclear safety, radiation safety, transport safety and waste safety;
- To endorse, in accordance with that process, the texts of the Safety Fundamentals and Safety Requirements to be submitted to the Board of Governors for approval and to determine the suitability of Safety Guides to be issued under the authority of the Director General; and
- To provide general advice and guidance on safety standards issues, relevant regulatory issues and the Agency's safety standards activities and related programs, including those for promoting the worldwide application of the standards.

Nuclear Safety Standards for Nuclear Reactors

Since nuclear reactors are at the heart of the nuclear energy revival, the IAEA's Nuclear Safety Standards (NUSS) program is particularly germane to this report. This "ambitious" program began in 1974 with the objective of negotiating internationally agreed safety standards for land-based stationary thermal nuclear power plants.[21] In September 1974 a Senior Advisory Group (SAG) composed of regulators from 13 IAEA member states was set up to negotiate the NUSS program, supervising, reviewing and advising on it at all stages and approving draft documents for the IAEA Director General. Five areas were considered: governmental organization, siting, design, operation and quality assurance. Each area was to be covered by a specific standard called a code. A Technical Review Committee (TRC), composed of experts from IAEA member states, was created for each of the five areas. On average each document took more than three years to complete. As Abel Gonzáles, senior advisor to the Argentinian Nuclear Regulatory Authority, notes, "NUSS documents are not expected to tell designers how to design plants or operators how to operate their plants … They serve as advisory documents for designers, operators, and regulators, allowing them to check their relevant activities against what is internationally considered to be good practice" (Gonzáles, 2002: 286).

In 1979 the NUSS program documents were renegotiated by SAG and the TRCs on the basis of the investigation into the Three Mile Island accident. It was concluded that the accident did not invalidate any NUSS document and that the IAEA "had shown foresight in setting up the NUSS program, providing a good basis for the safety of nuclear power plants" (Gonzáles, 2002: 285).

In 1985 the SAG and TRCs were disbanded, replaced in 1988 by a Nuclear Safety Standards Advisory Group (NUSSAG), composed of 16 senior regulators, whose first task was to negotiate a document to encompass the full program of nuclear safety standards. This 1993 document, called "the Safety of Nuclear Installations," inaugurated the category of Safety Fundamentals in the IAEA Safety Series and eventually became the basis for drafting the Convention on Nuclear Safety.

The Legal Status of IAEA Safety Standards

IAEA safety standards are legally binding on the IAEA itself in its own operations and on states in relation to operations assisted by the IAEA. While otherwise not legally binding on IAEA member states or on parties to any treaty, the degree to which national safety requirements are expected to be in compliance with the IAEA Safety Standards depends, according to INSAG, "on the level of the publication in the hierarchy" (INSAG, 2006b: 11). Safety Fundamentals (see box above) "should not be amenable to significant changes over time, and they are expected to be met without exception." Safety Requirements "should be met by new facilities and related new facilities, and are a target that should be met over a period of time that is reasonable for existing facilities and practices." Safety Guides "are practical guidance on achieving state-of-the-art nuclear safety;" meeting them is "recommended unless alternative means can be taken to provide the same level of safety."

The Agency's view of its safety standards is more expansive. Then Director General Mohamed ElBaradei, in the foreword to the Agency's guide *Periodic Safety Review of Nuclear Power Plants* says:

> The attention of States is drawn to the fact that the safety standards of the IAEA, while not legally binding, are developed with the aim of ensuring that the peaceful uses of nuclear energy and of radioactive materials are undertaken in a manner that enables States to meet their obligations under generally accepted principles of international law and rules such as those relating to environmental protection. According to one such general principle, the territory of a

> State must not be used in such a way as to cause damage in another State. States thus have an obligation of diligence and standard of care.
>
> Civil nuclear activities conducted within the jurisdiction of States are, as any other activities, subject to obligations to which States may subscribe under international conventions, in addition to generally accepted principles of international law. States are expected to adopt within their national legal systems such legislation (including regulations) and other standards and measures as may be necessary to fulfill all of their international obligations effectively (ElBaradei, 2003: vi).

In his last speech to the United Nations General Assembly before his retirement in December 2009 ElBaradei went so far as to call for IAEA safety standards to be "accepted by all countries and, ideally, made binding" (ElBaradei, 2009b), although whether binding in international law or national legislation he did not make clear.

Compliance with IAEA Safety Standards

There is no monitoring and verification system, as there is in the case of IAEA safeguards, to determine compliance with IAEA safety standards. At least in respect of new reactor designs some insights can be gleaned from the Multinational Design Evaluation Program (MDEP) (see below for details) (OECD/NEA, 2009a: 4). Its pilot expert group on severe accidents concluded that all of the MDEP participating countries (Canada, China, Finland, France, Japan, South Korea, Russia, South Africa, the UK and the US) perform regulatory review processes to ensure that reactor design requirements have been met "to various extents" and that a "significant degree of similarity" exists in their processes. In doing so many (although apparently not all) follow the basic objectives of the IAEA Safety Guide *Review and Assessment of Nuclear Facilities by the Regulatory Body* (IAEA, 2002). In general, design requirements are also reportedly in line with IAEA Safety Requirements.

The reason why states have been resistant to making IAEA safety standards legally binding is partly due to their differing reactor technologies and regulatory systems, but also partly due to two competing philosophies about nuclear regulation. One school of thought favours the IAEA's "prescriptive approach," setting standards and making compliance with them compulsory. The US NRC has traditionally adopted this approach. The second approach is a performance-based one favoured by Canada and the UK. Such an approach sets basic standards and expectations, but is flexible about how these are achieved as long as safety is maintained. The NRC has recently indicated that it would move to a more performance-based approach, with more emphasis on higher-level safety principles and fundamentals.

Harmonization of nuclear safety standards, much less making them legally binding, is difficult. Then NRC Chairman Dale Klein noted that although reactor design reviews might be harmonized, it would be harder to internationally harmonize the regulatory oversight and safety culture for operating reactors because of "differences in the ways countries approach those issues" (MacLachlan, 2009a: 3). He cites the NRC's resident inspector program, which is claimed to be effective in the US context, but may be unnecessary in a smaller country where every reactor site can be reached within hours from the regulatory

Agency's central office. Both French regulator Andre-Claude Lacoste, MDEP chairman, and Michael Micklinghoff, chairman of the WNA's Working Group on Cooperation in Reactor Design Evaluation and Licensing (CORDEL), agree, noting that national regulators will always have oversight over siting, commissioning and operational aspects of reactors (MacLachlan, 2009b: 6). Lacoste has suggested that the most practical approach is for regulators to harmonize their routine practices from the "bottom-up," which he predicted would lead them in time to harmonize their regulatory philosophies (MacLachlan, 2009b: 6).

Despite differences in philosophical approaches to nuclear safety most countries appear to support the IAEA role in setting international standards and in providing guidance, advice and assistance in implementing them. The US has recently been more favourably inclined towards this than in the past. The IAEA provides significant advice and assistance to states on safety matters through a staggering array of activities, publications and other information.[22]

In addition to its own safety experts employed by the IAEA Secretariat, the Agency relies on experts from member states, industry and academia. Experts may be convened by the IAEA itself or by intergovernmental or other UN system bodies. Formal bodies include INSAG, those convened by the OECD's NEA or the European Atomic Energy Community (Euratom), the European Nuclear Energy Forum and the G8 Nuclear Safety and Security Group (NSSG).[23]

International Nuclear Safety Group (INSAG)

INSAG is a group of experts, appointed by the IAEA Director General, with high-level professional competence in the field of safety who work in regulatory organizations, research and academic institutions and the nuclear industry. It was originally constituted as the International Nuclear Safety Advisory Group in 1985 to provide advice to the IAEA Director General on the safety of nuclear power plants. It has been a forum for exchange of information and views and has sought to formulate, where appropriate, common safety concepts. For instance, it provided initial suggestions on the peer review process for the CNS.

In 2003 INSAG's name was changed from International Nuclear Safety Advisory Group to its current one to emphasize that it would now address issues that not only affect the IAEA, but could serve the international community as a whole, including nuclear design organizations, nuclear power plant operators, national regulatory authorities, vendors and other stakeholders, notably members of the public interested in nuclear issues and the environment in general (INSAG, 2006a: 3). Its objective remains to provide authoritative advice and guidance on nuclear safety approaches, policies and principles. Its reports are published as IAEA documents (INSAG, 2009).

In 2006 it sought for the first time to define the global nuclear safety regime and make recommendations for strengthening it (INSAG, 2006b). It proposed action in the following areas:

- Enhanced use of the peer review meetings of the CNS as a vehicle for open and critical peer review and a source of learning about the best safety practices of others;
- Enhanced utilization of IAEA Safety Standards for the harmonization of national safety regulations, to the extent feasible;
- Enhanced exchange of operating experience for improving operating and regulatory practices; and
- Multinational cooperation in the safety review of new nuclear power plant designs.

Radiological Safety and Protection

While nuclear safety is concerned with ensuring the safe operation of nuclear facilities and other activities, radiological standards and protection are designed to shield the public, workers and the environment from the harmful effects of radiation. In seeking to enhance nuclear safety the IAEA draws on the work of two key bodies.

The International Commission on Radiological Protection

The International Commission on Radiological Protection (ICRP) is a professional organization founded in 1928 by the International Society of Radiology. At any one time about 100 eminent scientists, mostly biologists, medical doctors and physicists, are members. Since its foundation, and in the absence of any other international authority, the ICRP has issued radiological protection recommendations. These are non-binding, but due to the Commission's reputation have been "broadly adopted by all national regulatory authorities and international bodies dealing with radiological protection as a key basis for approaches to protection" (OECD/NEA, 2008: 218). According to the NEA, although the evolution of ICRP standards is "more or less continuous," based on scientific studies and data gained from experience, the release of new standards, and the resulting legislative and regulatory responses, tends to be episodic. Significant changes, for example, occurred after the Chernobyl accident. The most recent ICRP recommendations, released in 2007, are currently being assessed by national regulatory authorities.

United Nations Scientific Committee on the Effects of Atomic Radiation

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was established by the UN General Assembly in 1955 to assess and report levels and effects of exposure to ionizing radiation, which at that time was a result of atmospheric nuclear weapon tests. Its scientific estimates provide the basis for many states' evaluation of radiation risk and their implementation of protective measures. It was intended to be a strictly scientific body, but its 21 members are nominated by UN member states and due to the sensitivity of the issues involved its conclusions must often be negotiated (González, 2002: 273). The ICRP bases its work on current radiological science as "summarised" by UNSCEAR. There has been considerable overlap in the membership of the ICRP and UNSCEAR.

IAEA Technical Assistance in Ensuring Nuclear Safety

The IAEA has several mechanisms for assisting states in improving nuclear safety, including:

- Provision of safety-related assistance;
- Fostering of safety-related information exchange;
- Promoting safety-related education and training;
- Coordinating safety-related research and development; and
- Rendering of safety-related services.

The most important programs in regard to the safety of nuclear reactors are considered next.

Safety-Related Assistance

The IAEA provides significant technical assistance to member states to improve their safety performance across a broad range of nuclear and radiological areas, mostly under its Technical Cooperation (TC) program. For 2009 the TC program included 178 projects on nuclear safety, for which the IAEA had allocated €25,649,900 (IAEA, 2009n). Of particular relevance to the nuclear energy revival is the "Integrated Strategy for Assisting Member States in Establishing/Strengthening Their Nuclear Safety Infrastructure" (IAEA, 1997b: 3-4). This involves a joint review by the IAEA and the state, including identification of areas where the safety situation falls short of the reference situation and thus where assistance could be most effectively applied.

Safety-Related Services

The provision of nuclear-safety and radiological services to states, at their request, has become a major part of the IAEA's nuclear safety agenda. They include:

- Operational Safety Review Teams (OSART)
- Peer Review of Operational Safety Performance Experience (PROSPER)
- Integrated Regulatory Review Service (IRRS)
- Periodic Safety Review (PRS)
- Safety Culture Assessment Review Teams (SCART)
- International Regulatory Review Teams (IRRT)
- Engineering Safety Review Service (ENSARS)
- International Probabilistic Safety Assessment Review Teams (IPSAER)
- Review of Accident Management Programmes (RAMP)
- Transport Safety Appraisal Service (TransSAS)
- Various radioactive waste management services.

The most important of these for nuclear reactor safety are considered in detail below.

Operational Safety Review Teams

The Operational Safety Review Teams (OSART) program, established in 1982, is designed to aid IAEA member states in improving the operational safety of their nuclear power plants. At the request of a member state, teams of international experts will conduct three-week intensive reviews of a nuclear facility. Ultimately, the regulator of the member state is meant to bear the costs of the mission through agreement with the IAEA; however, many are alternatively funded by the IAEA's Technical Cooperation program (IAEA, 2007b).

The scope of these reviews is wide, covering management goals and practices, organization and administration, training and qualifications of personnel, operations, maintenance, technical support, operational experience feedback, radiation protection, chemistry and emergency planning and preparedness. The OSART program allows nuclear experts and power plant operators from one country to assist power plant operators in another through the sharing of information and international best practice. Not all of OSART's work is remedial; an important aspect is to identify strengths that can be shared with other states and fed back into the Agency's work to improve safety standards.

OSART missions arrive at a plant site already familiar with its main features, operating characteristics, history, regulatory provisions, technical specifications, procedures, organization and key personnel as a consequence of an Advance Information Package (AIP) prepared by the IAEA Secretariat in consultation with the receiving state's authorities (IAEA, 2005). After the initial visit a follow-up review is conducted one year to 18 months after the initial mission took place. An IAEA database indexes the results of all missions and follow-up missions, noting recommendations, suggestions and strengths and weaknesses. The first OSART mission was to the Ko-Ri nuclear power plant in South Korea in August 1983. Since then there have been more than 132 missions, carried out at 87 nuclear power plants in 31 countries (IAEA, 2005: 2).

While OSART teams purportedly "do not attempt to assess a plant's adherence to regulatory requirements or a plant's overall safety," on the assumption that the plant meets the safety requirements of the host country (IAEA, 2005: 6), they are in effect doing that by identifying areas for improvement in conformity with IAEA safety standards and proven international performance and practices. OSART missions are therefore a useful lens through which to view the safety performance of the nuclear industry.

The outcome of OSART missions is typically good, with most operators scoring high grades for their safety performance. A mission usually yields between 20 and 30 recommendations. Nuclear operators have thus far received OSART recommendations well; between 40 and 50 percent of issues are resolved by the operator within a year, with satisfactory progress eventually being made for 96 to 97 percent.[24] Confidentiality restrictions on OSART reports are removed 90 days after their official distribution to the host country, unless otherwise requested. Many host countries and host plants post the OSART reports on their websites to enhance transparency (IAEA, 2005: 9).

Only three countries with operational power reactors — Armenia, India and Taiwan — have not hosted an OSART mission so far. Each of these has, however, permitted its nuclear experts to participate in OSART missions in other countries. Armenia, which was left with a nuclear reactor after the collapse of the Soviet Union but with little indigenous infrastructure to support it, would appear to be in need of OSART services (Sevikyan et al., 2009). India's unwillingness to host an OSART mission, despite having one of the largest civilian nuclear power industries, is a blight on the global nuclear safety regime. It is undoubtedly due to India's relatively poor safety record, which it partly blames on sanctions imposed on nuclear trade with the country after it tested nuclear devices in 1974 and 1998. This isolation cannot be the only reason, however, as Pakistan has faced similar sanctions but has continued participating in the OSART process after its 1998 nuclear tests and has hosted five missions. Although Indian scientists and regulators often cite safety as their number one priority, that claim is undermined by the numerous accidents at Indian nuclear facilities and the poor emergency responses to them.[25] Whether India will begin to receive missions now that it has been readmitted to the international nuclear community remains to be seen. Taiwan's absence, perhaps due to its contested political status and inability to readily join international regimes, is troubling, as it has six operating reactors and ambitious plans for more.

Although the OSART program seems generally sound and useful, the IAEA has only a modest role in it (IAEA, 2008d: footnote 14). The Agency oversees the program, but its own personnel do not participate in the on-site visits. This could be remedied easily and would provide the Agency with greater insight into nuclear safety in its member states. Another flaw in the system is that states are not required to include OSART outcomes in their national reports under the CNS, although some do. The system could be further enhanced by collaboration with WANO in its industry-led peer review process. Consideration should be given to joint IAEA/WANO processes, including site visits, in order to avoid duplication of effort and to enhance the synergistic effect of their respective lessons-learned mechanisms. WANO already on occasion takes into account whether particular power plants have recently received an OSART visit in planning its own visits.[26] Due precautions would need to be taken in ensuring confidentiality of proprietary information during joint visits, but the IAEA has long had effective systems in place to achieve this.

Given the potential increase in the number of reactors worldwide as part of nuclear revival, the Agency should be given more resources for such an expanded OSART program. Considering the time-consuming nature of the OSART process and future increased demand, one could envisage the IAEA establishing a dedicated cadre of experts in the various reactor types and technologies, including new generations, to permit Agency participation in all visits.

Peer Review of the Effectiveness of the Operational Safety Performance Experience Review

Peer Review of the Effectiveness of the Operational Safety Performance Experience Review (PROSPER), launched in 2000, helps actualize the vague requirement of the CNS for its contracting parties to report reactor operating experience and how they use that and experience from other operators to improve their own performance. PROSPER provides advice and assistance to member states with nuclear power plants in developing and managing their operational experience feedback process. A PROSPER mission visits a reactor operator and considers the existence of effective management practices, sound policies and procedures, the comprehensiveness of available instructions, the existence of adequate resources, and the overall capability and reliability of plant personnel (IAEA, 2003c). If the feedback process does not meet with internationally accepted best practice, improvements are suggested. The findings and corresponding corrective actions are reported to the national regulatory body. Additionally, a follow-up mission, at the request of the state, is conducted within 18 months to assess whether and how the PROSPER recommendations have been implemented. No details are publicly available on which states have availed themselves of the PROSPER service.

Integrated Regulatory Review Service

The IAEA's Integrated Regulatory Review Service (IRRS) aims to provide advice and assistance to member states to enhance the effectiveness of their regulatory infrastructure. Importantly, it requires the state to first provide a self-assessment of how, in regulatory terms, it is complying with the CNS and the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. These reports are subject to extensive peer review, providing the opportunity for "open and frank discussions on trends, challenges and best practices" (IAEA, 2009h). The requesting state decides on the scope, which may range from a discrete regulatory issue to consideration of an entire regulatory enterprise. The process includes site visits, interviews and documentation review. Canada hosted an IRRS mission in 2009 in response to an "action" requested of it by other countries at the third CNS review meeting (CNSC, 2007: 3). The exercise was reportedly intense, thorough and essentially a clause-by-clause audit of Canada's regulatory system matched to IAEA principles and guidelines. Vietnam, a potential new entrant in the nuclear power business, also hosted an IRRS in 2009 even though it currently does not have an operating nuclear power reactor.

Periodic Safety Reviews

In many countries Periodic Safety Reviews (PSR) are conducted by nuclear power plant operators, which are in turn reviewed by the national regulator. The IAEA may be invited to review the conduct of a PSR. PSRs are seen as additional to routine reviews of nuclear power plant operation and special reviews following major events of safety significance (IAEA, 2003b: 1). PSRs aim to assess the cumulative effects of plant ageing and plant modifications, operating experience, technical developments and siting aspects. The reviews include an assessment of plant design and operation against current safety standards and practices and have the objective of ensuring a high level of safety throughout the plant's operating lifetime. The Agency recommends that PSRs be conducted every 10 years. PSRs are already part of the mandatory regulatory system in some states, but some states prefer alternative arrangements such as a systematic safety assessment program or a safety review that deals with specific safety issues, significant events and changes in safety standards and practices as they arise (IAEA, 2003b: 3-4). While the IAEA does not discourage these, it suggests that any alternative should demonstrate that it can satisfy the objective of a PSR. The IAEA guide to PSRs is currently undergoing revision.[27] In addition, the Agency has established a web-based platform to support member states with advanced reactor safety assessment training methods, including training simulators.

Other IAEA Activities

IAEA/NEA Incident Reporting System

The IAEA/NEA Incident Reporting System (IRS) was started by the NEA for its membership in 1996 and extended to encompass IAEA members in 1983. Currently, all 31 countries that operate nuclear reactors, plus Italy, are participants. The IRS collects information from participating states' national regulators on unusual events in nuclear power plants that may have safety or accident prevention implications. The information is assessed, analysed and fed back to operators to prevent similar occurrences at other plants. The IRS is also concerned with identifying "precursors," events of apparently low safety significance, which, if not properly attended to, have the potential to escalate into more serious incidents. Through its study of such events, IRS helps to accelerate identification of event precursors.

The value of IRS is enhanced through studies on topical problems, annual meetings of national coordinators and a joint annual IAEA/NEA meeting to exchange information on unusual events. While some countries are active in reporting to the IRS, some never report. In 2006 the IRS received just 80 reports, compared to 1,000 for the WANO reporting system (for further details see below). The Chairman of INSAG, Richard Meserve, told the INSAG Forum in Vienna in September 2007 that regulators are not reporting enough incidents to the IRS, nor are they providing enough information on how they have used others' operating experience (Maclachlan, 2007a: 10). He warned that the international nuclear community needs to do much more to collect, analyze and disseminate feedback from plant operating experience, lest failure to learn from past experience "serves to derail" the "promise of nuclear power." In fact, the failure of states to report and share experience could be regarded as non-compliance with the CNS, which requires parties to "take the appropriate steps to ensure that … existing mechanisms are used to share important experience with international bodies and with other operating organizations and regulatory bodies" (IAEA, 1994: article 19(vii)).

International Seismic Safety Centre

The International Seismic Safety Centre (ISSC) was inaugurated in 2008 to serve as a focal point on seismic safety for nuclear installations worldwide (IAEA, 2009h: 14). The ISSC will assist member states in assessing seismic hazards faced by nuclear facilities in order to mitigate the consequences of strong earthquakes. The IAEA has begun re-evaluating the integrity of existing nuclear installations, taking into account the increased magnitudes observed in recent severe earthquakes, such as those in Japan, which led to plant shutdowns,

The Ukraine – A Special Case

Significant progress has been made in a major extra-budgetary project involving the IAEA, the European Commission (EC) and Ukraine in assessing comprehensively the compliance of all 15 Ukrainian nuclear power plants with the Agency's safety standards (IAEA, 2009h: 14). As part of the project an IRRS mission was conducted in June 2008 and the results provided to the Ukrainian regulatory authority. The first pilot design review mission was conducted at the Khmelnitski nuclear power plant in October 2008 and an OSART mission took place at Rovno units three and four in November-December 2008. A program for implementing recommendations for improving safety at Ukraine's reactors is proceeding. The project is scheduled to be completed by February 2010.

and other extreme natural events (IAEA, 2009h: 9). A number of states listed in the Nuclear Energy Futures Project's Survey of Emerging Nuclear Energy States (SENES) face potential earthquake hazards to their proposed nuclear power plants, including Turkey and, most notably, Indonesia, which is located in both a highly active earthquake zone and a tsunami zone.

Other international bodies involved in nuclear safety

There are several other bodies besides the IAEA, both governmental and non-governmental, involved in nuclear safety, with some degree of cooperation and collaboration between them. Most notable is the collaboration between the Organisation for Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) and the IAEA. The NEA, for instance, participated in the negotiations on the CNS, along with the International Labor Organization (ILO) and the then Commission of the European Communities (CEC). The NEA works closely with the Agency on several projects, such as the Multinational Design Evaluation Program. The non-governmental bodies, on the other hand, tend to keep a diplomatic distance from the IAEA and each other.

World Association of Nuclear Operators

The World Association of Nuclear Operators was established at a meeting in Moscow in 1989, in direct response to the Chernobyl disaster, to enhance the safety of nuclear plants worldwide. It does so by facilitating "communication, comparison and emulation" among its members in order to maximize safety and reliability. Headquartered in London, it has four semi-autonomous branches in Atlanta, Paris, Moscow and Tokyo. It sees itself as complementary to national and international regulators and does not advocate nuclear power or particular nuclear policies (Crawford, 2009). Membership of WANO is open to all companies that operate electricity-producing nuclear power plants and organizations representing nuclear operators.

While WANO claims that "Every single organization in the world that operates a nuclear electricity generating power plant has chosen to be a member of WANO," in fact its membership of more than 30 is a mix of individual operating companies and national organizations that represent operators. Thus the US is represented not by electricity utilities but by the Institute of Nuclear Power Operations (INPO). Nonetheless, impressively, all operators of nuclear power plants are directly or indirectly represented. It is also impressive that the monopoly nuclear operators in Iran (which does not yet have a functioning power reactor), India and Pakistan are represented — namely the Atomic Energy Organisation of Iran, the Nuclear Power Corporation of India Ltd. and the Pakistan Atomic Energy Commission. In 2006 the British Nuclear Group Sellafield became the first operator of a reprocessing facility to join WANO.

Members sign the WANO Charter which commits them to strive to improve the safety of their own operations and that of others by exchanging information and sharing operating experience. This is not as impressive as it seems, since, as noted, not all individual nuclear reactor operators are members. Members also sign a confidentiality statement, undertaking to respect the confidentiality of each others' information, which limits its value to outsiders seeking to assess WANO's effectiveness and that of its "member" nuclear reactors.

WANO Peer Review

WANO, like the IAEA, runs a peer review system that has become a major feature of its activities. In 2008 it conducted reviews at 29 nuclear power plants, bringing its total to 387 since the program began in 1992 (IAEA, 2009h: 40). As of 2009 all operating reactors worldwide have had at least one peer review and 70 percent of WANO member "stations" (120) have hosted two or more peer reviews since the program began (WANO uses the term "station" to include sites with one or more reactor, depending on how their regional centres handle each review).[28] The 2007 WANO Review (its planning document) establishes a long-term goal of having at least one peer review every six years at each reactor, either as a multi-unit review or as an individual review. It acknowledges that more frequent reviews may be necessary.

WANO Chairman William Cavanaugh III warned WANO members in 2007 that many of them are not assimilating the recommendations from peer reviews. Analysis by WANO staff showed that

> the most common and significant weaknesses in plant performance are similar to those already identified in previous years …The success of the peer review program is being tainted by issues only being resolved at the symptom level. (Nucleonics Week, 2007: 14)

There is currently no systematic peer review of the safety of the rest of the civilian nuclear fuel cycle, but Sellafield's membership of WANO and acceptance of a peer review may help lead to this in future. However, like those of the IAEA, the results of WANO's peer reviews are confidential (not even shared with the IAEA) and do not carry the same weight for outsiders as those conducted under an authoritative international body like the IAEA.

In addition to peer reviews, WANO conducts over 200 technical support missions each year, where a group of highly qualified peers visits a plant to solve a specific issue. It also promotes professional and technical development through workshops, seminars, expert meetings and training courses. WANO conducts approximately 20 such courses and workshops each year.

WANO Operating Experience Reports

WANO oversees two types of operational reporting: Operating Experience Reports (OER) and Significant Operating Experience Reports (SOER). Although the NEA claims that "all utilities around the world" measure the principal safety and other indicators and routinely report them to WANO (OECD/NEA, 2008: 224-225), this is incorrect. While the number of events reported to WANO has risen sharply from 321 in 2004 to 936 in 2006, the aggregate numbers belie the great disparity among members, with some members reporting many events and some next to none (Weil, 2007: 1, 14). Moreover, the jump in reported events is somewhat artificial, since WANO now includes events with low safety significance.

As noted above, the IAEA runs an incident reporting system, the IRS, which receives reports from regulators rather than plant operators, has different reporting criteria and records far fewer incidents than WANO's. The two systems operate independently and their data is treated as confidential and not shared with each other or non-member organizations or entities, including national regulatory authorities (INSAG, 2006b: 14). The latter are excluded due to the risk that they will be forced to reveal the information under national freedom-of-information or other transparency measures (INSAG, 2006b: 14). WANO only notifies the IAEA of "trends." INSAG Chairman Richard Meserve says there is a "serious disconnect" between the two systems and a "need to make data available to international regulators" (MacLachlan, 2007a: 10).

WANO officials confirm that operators are not reporting all incidents and, as in the case of the IAEA system, are not using others' operating experience to avoid making the same mistakes through its "lessons-learned" process (Weil, 2007: 1, 14). For example, despite many reports of circulating water intake blockage, the frequency of such events worldwide has not lessened. Moreover, the frequency of events concerned with rigging, lifting and material handling has worsened over the six years to 2007. WANO had warned operators not to use foreign materials in order to prevent failures in fuel turbines and generators, but such events continue to occur. Control room culture issues and valve misalignments continue to "proliferate" and many operators ignore or learn to live with longstanding equipment problems (Nucleonics Week, 2007: 14).

As part of its effort to promote the exchange of operating experience, WANO compiles performance indicators for safety system performance that are available publicly (WANO, 2009). Many of the owner groups for different nuclear plant types have developed experience-sharing networks, but their insights are often limited to the technically unique issues they encounter and they operate under proprietary confidentiality rules (INSAG, 2006b: 15). Despite all of the measures put in place by the IAEA, WANO and others, INSAG concludes that:

> The OEF [international operating experience feedback] systems available today are not adequate to meet the needs of the ever-increasing number of nuclear stakeholders. There is an acute need to improve the mechanisms that are in place for sharing operating experience, as well as to develop newer, simpler processes to expand on these overtaxed mechanisms. Both the positive (good practices) and the negative (root causes) aspects of OEF must be shared if they are to be effective at reducing and eliminating risks. (INSAG, 2006b: 15)

WANO is attempting to prepare members for a nuclear revival, including organizing the first ever plant managers conferences. One of the challenges identified by WANO is the increasingly common recruitment of senior utility executives who have no nuclear experience. Face-to-face meetings with some of them had been "eye-opening," revealing that they "were not aware of the weaknesses" of their plant operations. Worryingly, there have been reports that WANO has had trouble engaging with senior executives of large companies, like Electricité de France and some of the German companies, which did not see much need for interacting with it.

WANO Chairman William Cavanaugh III told WANO's Biannual Conference in 2007 that record levels of nuclear safety cooperation are being achieved among the world's nuclear operators, but that the task was never-ending and would be made more challenging by the nuclear revival:

> Meeting the unprecedented demands of the nuclear renaissance will require operators not only to take on their individual responsibility to guarantee the safety of their own fleet, but also to assume a collective responsibility to work together to continually upgrade the safety of operating nuclear power stations worldwide. The public demands no less from us. We have not gathered here to pat one another on the back. The test of public confidence is like a rigorous exam on the subject of safety that all of us in the nuclear field must take every day. There will never be a time when we no longer have to take the test. (WANO, 2007)

Fuel Cycle Facilities

The fact that the CNS ignores fuel cycle facilities (and research reactors) is of concern. As the IAEA points out, "Fuel cycle facilities face unique nuclear safety challenges such as criticality control, chemical hazards and susceptibility to fires and explosions" (IAEA, 2009h: 16). In March 2006, for instance, there was a near criticality accident involving highly enriched uranyl nitrate at a facility involved in downblending highly enriched uranium (HEU) to low enriched uraniums (LEU) in Erwin, Tennessee, US. The plant, owned by Nuclear Fuel Services, has reportedly had a history of "regulatory challenges" and "ineffective solutions" (Horner, 2008: 8). In France there were incidents at two of Areva's fuel cycle facilities in July 2008, the uranium waste treatment plant at Tricastin and the Cerca research reactor fuel fabrication facility in Romans (MacLachlan, 2008a: 3-4).

Former NRC Chairman Dale Klein suggested that national nuclear programs would benefit from "more formal mechanisms" for cooperating in "overseeing the nuclear fuel cycle." Regulators would need to be knowledgeable about safety at reprocessing plants, fast reactors and developments in fast reactor fuel (Nuclear News Flashes, 2007a; Klein, 2007). Many fuel cycle facilities rely heavily on operator intervention and administrative controls to ensure nuclear safety, rather than the gamut of approaches applied to nuclear power plants.

There has recently been increasing openness among operators of fuel cycle facilities to share safety information and more use is being made of the Fuel Incident Notification and Analysis System (FINAS) developed by the Agency and the OECD/NEA (IAEA, 2009h: 16). The Agency offers a Safety Evaluation During Operation of Fuel Cycle Facilities (SEDO) service to assist member states, at their request, in enhancing safety at their fuel cycle facilities. It is a peer review process that bases its performance evaluation on IAEA safety standards and the expertise of its team. Its objective is to promote the continuous development of operational safety and the dissemination of information on good safety practices as fuel cycle facilities. However, it does not systematically evaluate and enhance nuclear safety measures. The Agency says it is continuing its efforts to establish a complete set of safety standards to cover all types of fuel cycle facilities (IAEA, 2009h: 16). As in the case of nuclear weapons-related facilities, accidents at commercial fuel cycle facilities can taint the prospects for the revival of nuclear energy.

Nuclear Energy Agency

The Nuclear Energy Agency (NEA), founded in 1958, is a semi-independent body attached to the Paris-based Organisation for Economic Co-operation and Development (OECD), whose membership comprises the most economically developed states.[29] Its mission is to "assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for the safe, environmentally friendly and economical use of nuclear energy for peaceful purposes" (OECD/NEA, 2009b). To achieve this, the NEA focuses on selected areas and produces authoritative assessments that reflect, or seek to develop, common understandings among member states. The NEA has seven main international standing technical committees dealing with the nuclear sciences, safety, regulation, waste management, technical and economic studies, nuclear law and radiation protection. In contrast to the IAEA, the NEA focuses on research and on providing and exchanging information.

Euratom and the European Commission

The 1957 Euratom Treaty does not specifically mandate the European Atomic Energy Community (Euratom) to regulate nuclear installation safety. As a result, the regulation of nuclear safety in EU member states has developed at the national level. Nevertheless, Euratom promotes the highest level of safety in the operation of nuclear facilities and the best accident prevention and mitigation strategies through the cultivation of common views on nuclear safety issues and by identifying best practice. The European Nuclear Safety Regulators Group (ENSREG), established in 2007, is the focal point of cooperation between European regulators and is intended to lead to continuous improvement in nuclear safety requirements, especially with respect to new reactors (IAEA, 2009i: 4).

In July 2007 the European Commission (EC) also established a European High-Level Group on Nuclear Safety and Waste Management to pursue "common understandings" and "reinforce common approaches" in the fields of nuclear safety and waste management, with a view to creating common European rules (Froggatt, 2009: 26-27). It was envisaged that this would lead to binding European nuclear safety standards, including verification of compliance. This approach failed due to the disparate views among member states about the future of nuclear energy and the need for a common European approach (Ferguson and Reed, 2009: 58). Only 15 of the 27 EU member states currently operate nuclear power reactors, although nuclear power provides one-third of the EU's total electricity. Several states — Belgium, Germany, Italy, Spain and, until recently, Italy and Sweden — have nuclear phase-out programs or bans on new reactors. Others, mainly Austria, Ireland and Luxembourg, oppose nuclear energy.

The EC directive, adopted in June 2009, although legally binding, establishes a "framework" to "maintain and promote the continuous improvement of nuclear safety and its regulation," but has no provisions for EC verification or EC-wide regulators. Essentially it only requires compliance with the CNS, to which all EU states are already party (Froggat, 2009). EU member states are required to report on implementation of the directive for the first time by July 2014 (which seems rather distant given the importance of the issue) and every three years thereafter, in order to take "advantage of the review and reporting cycles under the Convention on Nuclear Safety."

The only novel element in the EU directive is the requirement that at least every ten years member states arrange for periodic self-assessments of their national framework and competent regulatory authorities and invite an "international peer review" of "relevant segments" which must be reported to member states and the European Commission. France and the UK, strong supporters of common standards, reportedly threatened to set up their own nuclear "club" in response to this disappointing outcome (MacLachlan, 2008b: 1).

Regional Networks, Industry Organizations and Training Institutes

There are two regional networked databases maintained with support from the IAEA to facilitate regional knowledge-sharing and capacity-building in nuclear safety: the Asian Nuclear Safety Network (ANSN) and the Ibero-American Nuclear and Radiation Safety Network. The ANSN was established in 2002 under the Agency's Programme on the Safety of Nuclear Installations in South East Asia, Pacific and Far East Countries (Asian Nuclear Safety Network, 2009). It includes full participant and partner states, and its activities are supported by the IAEA and individual states.[30] The Ibero-American Forum of Nuclear and Radiological Regulators established the Ibero-American Nuclear and Radiation Safety Network. The database contains "technical knowledge of regulatory interest in areas such as radiological protection of patients, safety of radioactive sources, national and Agency safety standards, national legislation and education and training" and provides a working environment for technical cooperation projects (IAEA, 2008c: 45). The forum itself is composed of participating national nuclear regulators, it has an office hosted by Argentina and is supported by the IAEA; infrastructure for the network is hosted by Brazil.[31]

Apart from WANO, industry-based bodies include the World Nuclear Association (WNA), the World Nuclear Transport Institute (WNTI) and the Institute of Nuclear Materials Management (INMM). Nuclear safety is one of the concerns of the World Nuclear University (WNU) and the US-based Institute for Nuclear Power Operations (INPO). INPO, established in 1979, nine months after Three Mile Island, has reportedly helped the US industry "strive for excellence" in plant operations rather than just meet minimum regulatory requirements (Nuclear News Flashes, 2009a). According to Ferguson and Reed, INPO, over the past 30 years has used "peer pressure, confidential safety assessments, safety inspections, and a principle-based and results-oriented management approach to achieve a high standard of safety while maintaining reliable operations" (Ferguson and Reed, 2009: 54). Funded by the US nuclear industry, it sets performance standards and conducts WIPO-like plant evaluations that it shares among its members.[32] In 2008 South Korea opened the International Nuclear Safety School (IAEA, 2009i: 6).

Safety of Advanced Reactor Designs

Whether they are constructed in existing nuclear energy states or in newcomer states, the industry claims that Generation III and Generation III+ reactors will be inherently safer. They promise safety features "built in" to their designs rather than added on as in previous generations. According to the NEA some of the most common features envisaged for new generation reactors are:

- Explicit consideration of severe accidents as part of the design basis;
    - Effective elimination of some severe accident sequences by the use of inherent safety features;
    - Significant reduction or elimination of the potential for a large radioactive release, even if a severe accident were to occur;

- Improved efficiency and effectiveness of operation and maintenance through the extensive use of digital technology; and
- Reduction in system complexity and avoidance of the potential for human error (OECD/NEA, 2008: 232).

The NEA notes that if all of these features are successfully implemented they "could result in the reduction of on-site and off-site protective measures, such as evacuation plans for the public" (OECD/NEA, 2008: 232). It is not clear that the public will be reassured by this.

Since only a handful of these reactors are operating and most designs have not yet even been built, it is too early to assess these claims based on operational experience. However, the international safety regime is able to offer some reassurances. For instance the IAEA will conduct, on request, reviews of new reactors' conceptual design safety features. The IAEA in July 2009 completed such a review of the Areva-Mitsubishi Heavy Industries 1,100 MW Atmea 1 pressurized water reactor (Nuclear News Flashes, 2009b; Atmea, 2009).

The contention of the nuclear industry that small reactors will be ideal for widespread use in developing countries is based on claims that they will be safe and secure. These designs should also be subject to international scrutiny. IAEA safety regulations may need to be reviewed and where necessary amended to take into account the range of new designs on offer.

Harmonization of regulatory approaches to new reactor designs

One reassuring feature of reactor licensing is that all national regulators insist on reviewing reactor designs before approving construction and/or operation in their country, even when design approval (the term used in the UK) or design review (the term used in Canada) has been obtained in the vendor's country of origin or in other buyer countries. "Certification" of a reactor design by the US NRC is regarded by many countries as useful, but all of them still insist on their own review prior to issuing a licence for construction and/or operation.

The difficulty for the vendor is that it may have to go through virtually an entirely new process in each country in which it seeks to build a reactor. Several initiatives attempt to deal with this problem by seeking to harmonize regulatory requirements to ensure that new reactor designs are as safe as advertised and to facilitate the regulatory process across countries (WNA, 2008). Collaborative studies are being conducted to consider the possibility of harmonization of codes and standards, joint inspections of manufacturers and cooperation among regulators to converge on regulatory practices for new build (MacLachlan, 2009b: 6). Industry also favours this approach. As the WNA explains it:

> For potential investors … global expansion of nuclear power continues to be viewed primarily through a financial and economic prism that focuses particularly on nuclear power's competitiveness vis-à-vis other sources of base-load power such as coal and gas. A major factor in this equation is the potential for economies of scale. Currently, national variations in safety regulations present an obstacle to internationally standardized nuclear reactor designs, which would foster these economies. (WNA, 2008: 1)

One approach is being pursued through the Western European Nuclear Regulators Association (WENRA), whose members are senior regulators from all of the EU states with nuclear power sectors, plus Switzerland and Italy. In January 2007 the group published "safety reference levels" covering existing reactors and is about to commence work on requirements for new designs.[33]

Additional groups considering the issue include: the NEA Committee on Nuclear Regulatory Activities (CNRA)'s Working Group on Regulation of New Reactors (WGRNR); the Generation IV International Forum Risk and Safety Working Group; and the WNA's Working Group on Cooperation in Reactor Design Evaluation and Licensing (CORDEL). The NRC is working extensively with Chinese regulators to explain the design certification for the AP1000 "so they understand the process, not just the outcome" (MacLachlan, 2009a: 3). Ultimately, countries can draw on each others' experience and seek harmonization, but they invariably insist on their sovereign right to make their own decisions in these matters.

Multinational Design Evaluation Program

The most impressive harmonization efforts are apparently being carried out by the Multinational Design Evaluation Program (MDEP). Initiated in 2005, MDEP's mandate is to develop "innovative approaches to leverage the resources and knowledge of mature, experienced national regulatory authorities who are, or will shortly be, undertaking the review of new reactor plant designs" (OECD/NEA, 2009a: 4). The main objective is to establish "reference" regulatory practices and regulations that could ultimately lead to a "multinational vendor inspection program" (OECD/NEA, 2008: 232-233). Currently the national regulators of ten countries participate — Canada, China, Finland, France, Japan, Russia, South Africa, South Korea, the UK and the US. These states have three-quarters of the operating reactors and most new reactors under review. The IAEA also participates, but secretariat services are provided by the OECD/NEA. MDEP "interfaces" with all of the groups mentioned above. Although the group is starting with Generation III and Generation III+ reactors, it is hoped that it will ultimately consider Generation IV reactor designs. All of the MDEP members except Finland are also members of the Generation IV International Forum (GIF).

A pilot project was launched in 2006, focusing on Areva's European Pressurized Water Reactor (EPR), the first of which is being built in Finland. The aim was to assess the feasibility of enhancing multilateral cooperation and convergence of codes, standards, and safety goals within existing regulatory frameworks. A good dialogue reportedly ensued between the national regulators of Finland, France, the US and the UK. With the success of the pilot project, MDEP has established working groups on the EPR and the AP1000. The EPR working group has reportedly already been successful in identifying issues that were addressed by one country but not fully considered in others (OECD/NEA, 2009a: 4). This is undoubtedly a reference to the allegedly unnecessarily complicated digital control system for the EPR which has caused some controversy. The UK's Nuclear Installations Inspectorate has expressed concerns about the safety system "architecture" of the EPR, one of the contenders for UK new build (Stellfox, 2007: 7).

In addition to working groups on two of the new reactor types, MDEP has also established groups on Vendor Inspection Cooperation; Digital Instrumentation and Controls; Codes and Standards; and Component Manufacturing Oversight. An innovative system of parallel vendor inspections is envisaged, in which two or more regulators conduct inspections of a nuclear component manufacturer simultaneously and compare results. Currently manufacture of the highest safety class components is subject to multiple inspections and audits conducted by different organizations in different countries. The aim would be to rationalize this system. The first parallel vendor inspection was held in May 2008, in which both the Korean Regulator (KINS) and the US Nuclear Regulatory Commission conducted independent, simultaneous inspections of Doosan Heavy Industries. Insights from both groups were shared each day and subsequently with all MDEP members. Expected difficulties over potential loss of proprietary information do not seem to have eventuated. In 2009 MDEP plans trial multinational vendor inspections.

The primary goal of MDEP's Codes and Standards Working Group is to achieve convergence of regulatory requirements in the area of component design. The initial effort involves Canada, France, Japan, South Korea and the US, but Russia has initiated a code comparison effort and China may join in at a later date.

These programs are an indication that key regulators are taking the challenge of safety requirements for new reactor designs seriously. The key will be to involve not just the most competent and professional regulatory bodies, but those which are inexperienced, under-resourced or subject to extraneous political and commercial pressures to quickly approve "new build" and ensure that regulations do not hamper their operations and commercial success. Michael Micklinghoff, chairman of the Cordel group, has noted that following discussions on this issue at the NEA and IAEA in September 2009 he sees the possibility that some countries considering new reactors — especially newcomers like Italy or the UAE or those with small regulatory bodies — could endorse and use a joint design review process within a relatively short time (MacLachlan, 2009b, 6).

Safety of Nuclear Spent Fuel and Radioactive Waste

This section outlines the international regime governing both spent fuel and radioactive waste.[34] Spent fuel is nuclear fuel that has been irradiated in a reactor core. It may be reprocessed to produce uranium and plutonium which may be recycled as reactor fuel. Radioactive waste is defined as radioactive material in gaseous, liquid or solid form for which there is no foreseen further use and which has been declared as radioactive waste. The international regime is meant to ensure states and operators of facilities handle spent fuel and radioactive waste safely whether it is in process, being transported, stored or disposed of. The main international agreement is the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, while the most important international Agency involved is, again, the IAEA.

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

The objectives of the Joint Convention are:

- To achieve and maintain a high level of safety worldwide in spent fuel and radioactive waste management, through the enhancement of national measures and international cooperation, including where appropriate, safety-related technical cooperation;
- To ensure that during all stages of spent fuel and radioactive waste management there are effective defences against potential hazards so that individuals, society and the environment are protected from harmful effects of ionizing radiation, now and in the future, in such a way that the needs and aspirations of the present generation are met without compromising the ability of future generations to meet their needs and aspirations; and
- To prevent accidents with radiological consequences and to mitigate their consequences should they occur during any stage of spent fuel or radioactive waste management (IAEA, 1997: Article 1).

The Joint Convention was adopted and opened for signature in September 1997 and entered into force in June 2001. As of October 2009 there were only 52 state parties plus Euratom and 42 signatories, far fewer than for the CNS. All states with civilian nuclear reactors, with the significant exceptions of India, Mexico and Pakistan, have ratified the Joint Convention. A couple with significant programs — China and South Africa — have only recently acceded. Two African states with nuclear power ambitions, Nigeria and Senegal have also recently joined, but many SENES countries have not, including Bangladesh, Egypt, Indonesia, Jordan, Turkey, Venezuela and Vietnam.

One of the compromises necessary for achieving consensus on the adoption of the Convention on Nuclear Safety in 1994 had been the removal of the safety of spent fuel and radioactive waste from its purview. The CNS thus contains only a passing reference to nuclear waste. Once the CNS was adopted, however, countries dissatisfied with this outcome, notably some of the Nordic countries, exerted political and diplomatic pressure for the negotiation of an additional international convention on the safety of radioactive waste (Gonzáles, 2002: 278). The treaty thus follows the CNS model closely in terms of periodic review meetings, national reports and peer review.

The Joint Convention is the first legal instrument to directly address the major challenges arising from spent fuel and radioactive waste on a global level. The first challenge is that radioactive waste will need to be managed safely well beyond the present generation on a time scale that is "evolutionary." The second difficulty is that what one state regards as radioactive waste to be disposed of, another may see as an energy resource to be reprocessed for recycling. Hence the "Joint Convention" dealing with both. Many states, implicitly or explicitly, consider that radioactive waste should be disposed of in the state in which it was generated (IAEA, 2003a: 97). Most states also consider that whoever was responsible for the generation of waste within the state should be responsible for its safe disposal.

Under the Joint Convention ultimate responsibility for ensuring the safety of spent fuel and radioactive waste management rests with the holder of the relevant licence issued by the state regulatory authorities (IAEA, 2003a: 97). Where there is no such holder, responsibility devolves to the state. The treaty covers spent fuel not just from nuclear power plants, but from research reactors, as well as radioactive waste from the nuclear industry and medical, research and industrial applications. In addition, it applies not only to spent fuel management facilities built after the convention's entry into force, but existing facilities. Moreover, it applies to planned and controlled releases into the environment of liquid or gaseous radioactive materials from spent fuel and radioactive waste facilities and the decommissioning of nuclear facilities. It also contains requirements related to the transboundary transport of spent fuel and radioactive waste unless declared as spent fuel or radioactive waste for the purpose of the convention by the contracting party. The convention does not apply to military or defence-related waste or spent fuel. Nor does it apply to spent fuel held at a reprocessing facility unless a party declares it to be applicable (IAEA, 2003a: 280). As implied by its title, the convention is divided into provisions relating to spent fuel and those relating to radioactive waste management but with some joint provisions applicable to both.

Provisions Relating to Spent Fuel Management

A contracting party is obligated to take the appropriate steps to ensure that all stakeholders in spent fuel management — individuals, society and the environment — are adequately protected against radiological hazards. Among the issues that a contracting party must adequately address are: residual heat generated during spent fuel management; ensuring that the amount of spent fuel waste generated is kept to a practical minimum; applying national protective methods approved by a national regulatory body; and taking into account all hazards associated with spent fuel management.

When determining where to build a new spent fuel management facility, the treaty requires a party "to evaluate all relevant site-related factors likely to affect the safety of such a facility during its operating lifetime." In addition, the state party must make information on the safety of such a facility available to the public. A party must also consult other state parties in the vicinity of such a facility, insofar as they are likely to be affected by that spent fuel management facility. During the design and construction of a spent fuel management facility each party must ensure that its design and construction limits possible radiological impacts from discharges or uncontrolled releases. These facilities must incorporate only proven technologies in their design and construction. A systematic safety assessment and an environmental assessment must be completed prior to the construction of a spent fuel management facility and an updated assessment prepared before it becomes operational.

During the operational life of a spent fuel management facility a state party must ensure that any licence granted to operate it meets safety and environmental assessment criteria. Operational limits of the facility must be revised as necessary and the "operation, maintenance, monitoring, inspection and testing" of the facility should be carried out using recognized procedures. Safety-related engineering and technical support must be put in place to ensure that significant incidents are reported promptly to the regulatory body. Finally, a state party must also make regularly reviewed plans for decommissioning spent fuel management facilities.

Provisions Relating to Radioactive Waste Management

The provisions regarding radioactive waste management mirror many of those for spent fuel. Waste management obligations include upgrades to existing waste management facilities, siting of proposed facilities, design and construction, safety and environmental assessment and the operation of facilities. As in the case of spent fuel, obligations are imposed on a contracting party after the closure of a waste disposal facility.

One of the peculiarities of nuclear energy is that is produces waste that can last more than 10,000 years. The safety of disposal sites for high-level waste across this time span must be independent of institutional control since no human institutions have ever been known to have lasted that long. Each contracting party must ensure that records regarding the location, design and inventory of the closed facility are preserved and that either active or passive institutional controls remain in place if required. The safety of the disposal site should not rely on such measures (IAEA, 2003a: 100).

Obligations Covering Both Radioactive Waste and Spent Fuel Management

State parties are required to incorporate the obligations set out in the convention into their domestic law, having at a minimum, domestic legal provisions that mirror those found in the Joint Convention. Each party is thus required to put in place a legislative and regulatory framework to govern the safety of spent fuel and radioactive waste management that must establish national safety regulations, create a system of licensing for spent fuel and radioactive waste and prohibit operating without a licence. The legislation must also provide for a system of institutional control, regulatory inspection, documentation and reporting. There must also be provisions for the enforcement of the national regulations and terms of licence. A regulatory body must be created that has the authority, competence, and financial and human resources to oversee the safety of waste management and spent fuel management facilities. Likewise, a state party must also ensure the presence of adequately qualified staff and adequate financial resources to ensure the safety of these facilities.

The Joint Convention also contains a set of obligations governing the international movement of radioactive waste and spent fuel. These include a requirement to ship only with the notification and consent of the state of destination and in accordance with relevant international legal obligations governing radioactive transboundary movement, notably the 1980 Convention on the Physical Protection of Nuclear Material (CCPNM) (see Part 2 of this report). Moreover, the receiving state may only take delivery of radioactive waste or spent fuel if its administrative, regulatory and technical infrastructure meet the broader requirements of the Joint Convention.

As in the case of the CNS, the Joint Convention requires that parties attend periodic review meetings to consider mandatory national reports submitted by the each party detailing the measures that it has taken to implement its obligations under the convention. These reports should detail what each state party has done in terms of spent fuel and waste management policy and practices, and its classification system. Each report must also provide a list of the spent fuel management facilities and radioactive waste facilities, their location and essential features, and an inventory of spent fuel and radioactive waste.

Implementation and Compliance

The review meetings for the Joint Convention operate and have evolved in similar fashion to those for the CNS. As in the case of the CNS, the first two review meetings helped evolve the process of conducting the meetings, submitting and presenting national reports and subjecting them to questioning by other parties. Also as in the CNS case, the IAEA has produced guidance for states based on the outcome of these initial discussions (IAEA, 1997). In particular, the two meetings led to the conclusion that there needs to be a "holistic" approach to nuclear waste management which "encompasses all types of radioactive waste from their generation to their reuse, recycling, clearance or disposal" (MacLachlan, 2007b: 10). The Third Review Meeting was held from May 11 to 20, 2009. Forty-five parties participated, including five new parties, China, Nigeria, Senegal, South Africa and Tajikistan. Three parties — Kyrgyzstan, Uruguay and Uzbekistan — failed to attend despite their obligation to do so (although Uruguay did submit a national report). Senegal, Kyrgyzstan and Uzbekistan did not submit a national report as required. None of these states have significant nuclear industries that produce spent fuel or radioactive waste, although Senegal has expressed interest in a nuclear power program.

In summarizing the results of the Third Review Meeting the contracting parties recognized that the safety of spent fuel and radioactive waste management "is a crucial and difficult topic" and that there remained "considerable areas for improvement" (IAEA, 2009r: 9). But they also noted that the review process was maturing and that "more constructive exchanges and more knowledge sharing took place than at previous Review Meetings" (IAEA, 2009r: 9). The conclusions of the meeting most relevant to the nuclear revival included the recommendation that the safety of spent fuel and radioactive waste management "be taken into account from the very beginning of such considerations." This is to avoid repeating the mistakes of the original nuclear energy states which, according to the World Energy Council, still have not yet decided how to manage the "back end" of the nuclear fuel cycle — where they must deal with their spent fuel and nuclear waste (Marshall, 2007: 17). Hence the need to bring new entrants to nuclear power into the convention as soon as possible. Areas where parties were enjoined to make more progress included:

- Implementation of national policies for the long-term management of spent fuel, including disposal of high level waste and/or spent fuel;
- Siting, construction and operation of spent fuel and radioactive waste disposal facilities;
- Management of "legacy" wastes from old programs;
- Knowledge management and human resources; and
- Financial resources for liabilities.

Parties were asked in their reports for the Fourth Review Meeting in 2012 to include or expand their coverage of the following issues (IAEA, 2009r: 7): development of a comprehensive legal framework; the effective independence of the regulatory body;[35] implementation of strategies with visible milestones; funding to secure waste management; education and recruitment of competent staff and employees; and geological repositories for high level waste.

While the subject of regional repositories was raised by several parties with small nuclear programs (a number likely to increase in any nuclear revival), the report declared bluntly that "no real practical progress has been achieved up to now" and suggested further cooperation between the parties on this issue (IAEA, 2009r: 5). Of further relevance to new entrants, the parties stressed that building competence in the management of spent fuel and radioactive waste was "crucial" for such states. Moreover, the parties stressed the "utmost importance" of involving "stakeholders and affected communities, from the beginning," in the process of developing facilities for spent fuel and waste management. This lesson has been sorely learned by the existing nuclear energy states, as exemplified in the Yucca Mountain fiasco. While it is encouraging that new entrants are being counselled to avoid such mistakes, it is of concern that so many of the likely new entrants, for instance Egypt, Iran and Morocco, do not have societies that encourage "stakeholder" participation in any question, much less one as sensitive as nuclear waste disposition.

One difficulty not faced by the CNS national reports is the difficulty of determining exactly what kind of radioactive waste is being referred to in national reports on the Joint Convention. Phil Metcalf, head of the IAEA's Disposable Waste Unit, has noted that diverse terminologies in different countries and even among different facilities in the same country, make communication difficult, especially in the context of the Joint Convention (MacLachlan, 2007b: 11). For example, what the Russians call intermediate-level waste, which in Russia has been disposed of in deep boreholes, might qualify in another country as high-level waste that must be packaged and emplaced in a deep geologic repository. After working on new classification guidelines since 1994, the IAEA finally published them in November 2008. The Commission on Safety Standards approved them for publication in September 2008 (IAEA, 2008a). Australia, meanwhile, has reported that it has no high-level waste, as the material from its research reactors at Lucas Heights, south of Sydney, is classified as intermediate-level. If the new IAEA guidelines oblige Australia to reclassify some of that waste as high-level there may be political difficulties — an indication that waste classification is not just a technical but a political issue.

In summary, the review meeting process for the Joint Convention appears to operate effectively, in the same manner as those for the CNS, in exposing state parties to probing questions by their peers about their policies and plans in fulfillment of their international obligations. Many delegations are comprised of the same individuals who attend the CNS meetings, effectively making the review process part of a holistic international regime for all aspects of nuclear and radiological safety — as had been advocated by those states which had wanted the CNS to be comprehensive. In a sense these countries ultimately achieved their objective, although at the expense of some duplication of organization and process. Given the similarity between the Joint Convention and CNS processes there could be an argument for combining them. This would encourage states themselves to adopt a more holistic approach to nuclear and radiological safety and help avoid past experience where states established nuclear power programs without giving much, if any thought, to long-term management of the spent fuel and nuclear waste that they were producing or to the long-term costs associated with it.

IAEA Safety Standards, Advisory Services and Missions

The IAEA became involved in establishing safety standards for radioactive waste soon after its creation in 1957 (Gonzáles, 2002: 288). The standards have since then been a work-in-progress as public attitudes evolved and experience was gained in handling such materials. Initially it was envisaged that the radioactive wastes would be disposed at sea and the Agency dutifully drew up regulations to manage this process. However, by the 1970s international opinion had shifted to favouring long-term disposition on land in underground repositories and in 1977 the IAEA initiated a program to produce guidelines on the subject. By the 1980s the growing political salience of the nuclear waste issue induced the IAEA to produce, in 1988, a "high-profile family of safety standards" (Gonzáles, 2002: 289), the Radioactive Waste Safety Standards (RADWASS). In 1995, after being subject to peer review, RADWASS was broadened to include a new emphasis on discharges and environmental restoration, and to rationalize the complex set of Agency documents on the subject.

Today the Agency has a detailed set of safety standards that address radioactive waste and a draft set addressing spent fuel management (IAEA, 2009k; IAEA, 2009m). The regime continues to evolve, especially in the areas of geological disposal and environmental restoration, "where little or no experience has yet been gained" (Gonzáles, 2002: 290). A Working Group on Principles and Criteria for Radioactive Waste Disposal is currently drafting a technical document, *Common Framework for the Disposal of Radioactive Waste* and a safety report, *Model Regulations on Safety of Radioactive Waste Management* (IAEA, 2009d).

The Agency's Disposable Waste Unit, which develops the standards that deal with radioactive waste, also assists states in their application. One means is by undertaking a Peer Review, by a team of international experts, who visit to assess and make recommendations regarding the applicable safety standards of the requesting state. Subsequently the IAEA may offer technical assistance to facilitate implementation. Among the 52 states involved in a 1999-2001 pilot project (called various combinations of pilot/model and project/program) on "Upgrading of radiation protection infrastructure," several identified in this project's SENES database were included, notably Nigeria, Senegal, Bangladesh, Kazakhstan, Qatar, UAE, Vietnam, Belarus and the Baltic states (Gonzáles, 2002: 299-300). While it was originally envisaged that five to six member states would benefit from the program each year, by the end of September 2001 the Secretariat had received requests from 29 states in addition to the 52 states that had participated in the pilot project (IAEA, 2001b). Many of these are SENES states: Egypt, Indonesia, Iran, Kenya, Kuwait, Libya, Malaysia, Morocco, Philippines, Thailand, Tunisia, and Venezuela. As a result of the overwhelming demand, an integrated management approach has been adopted with the aim of achieving "adequate" national radiation and waste safety infrastructures in the participating countries and by appointing four Regional Managers for Africa, East and West Asia, Latin America and Europe.

In 2008 an International High-Level Waste Management Conference took place in Las Vegas that was well attended by representatives from around the world (IAEA, 2009i: 26). However, the dearth of operational experience to inform global governance in this area, despite half a century of civil nuclear electricity generation, was illustrated by the fact that the regulatory process for deep geologic deposition is only just beginning in the first two countries to attempt it, Sweden and Finland, and that the host country, the US, had just cancelled the Yucca Mountain project after decades of scientific and technical study and controversy.

Guidelines for the Management of Plutonium

One of the little known and remarkable agreements in the area of spent fuel and waste management is the innocuous-sounding Guidelines for the Management of Plutonium (IAEA, 2004). In 1992, the IAEA initiated a series of meetings involving countries with the largest plutonium holdings in order to determine the necessity of international methods of managing the fissile material.[36] The countries involved were the nuclear weapon states recognized by the 1968 Nuclear Non-Proliferation Treaty (NPT) (China, France, Russia, the UK and the US), as well as Belgium, Germany, Japan and Switzerland. These countries were concerned about the increasing amounts of civil separated plutonium, as well as the large quantities of fissile material expected to result from the dismantling of nuclear weapons. The proposal thus has its origins in concerns about nonproliferation, safety and security.

In 1993 the IAEA convened an unofficial study of ways to manage plutonium. Participants decided, however, that they preferred to agree in confidence among themselves on such methods, partly to avoid the complications of a large official negotiation process.[37] Director General Hans Blix felt that since openness and transparency were a hallmark of the Agency's operations he could not chair closed meetings. It was also felt that the countries themselves should be responsible for the information they produce and therefore there was no role for the IAEA in that respect. However, the IAEA Secretariat was kept informed throughout. The guidelines were agreed in late 1997 and communicated to the IAEA in the form of identical letters from the participants. The guidelines were published as an IAEA document in March 1998, along with subsequent relevant declarations.

In principle the guidelines cover all plutonium in all peaceful nuclear activities, but in fact they focus on the material that poses the greatest proliferation concern: separated plutonium in storage, in unirradiated fuel elements, in other unirraidated fabricated forms and in the course of manufacture or fabrication into these items. Although plutonium in spent fuel is not subject to the guidelines, each country has agreed to publish annual estimates of the amount of plutonium in its spent fuel. (The guidelines also cover plutonium declared excess to military nuclear programs.) The guidelines do not cover plutonium that is more than 80 percent plutonium 238, plutonium used in gram quantities or plutonium on which IAEA safeguards have been terminated or exempted. Nor do they apply to the management of HEU, but they do recognize the need to manage HEU with the same vigilance as separated plutonium.

The guidelines express agreement that civil plutonium should be handled in accordance with the major international agreements on nonproliferation, safety, physical protection, material accountancy and control and safeguards and the rules on international transfers of civil plutonium. The participants also agreed to formulate national strategies on plutonium management that consider the risks of proliferation, especially during storage before irradiation or permanent disposal; the need to protect the environment, workers and the public; and the resource value of the material. Such strategies should also take into account the importance of "balancing supply and demand" in order to minimize the amount of separated or unirradiated plutonium as soon as is practical.

The most amazing aspect of the guidelines, however, is agreement on increasing transparency by publishing:

- Occasional brief statements explaining the national strategy for nuclear power and spent fuel, and general plans for managing plutonium holdings;
- An annual statement of holdings of all plutonium, subject to the guidelines; and
- An annual statement of the estimate of the plutonium contained in holdings of spent civil reactor fuel.

Such reporting is of course voluntary since the guidelines are not a legally binding agreement, even though based on agreement between the original drafters. It is significant however that compliance has, overall, been good and, according to the Institute for Science and International Security (ISIS) in Washington DC the declaration system is "now a mature program (ISIS: 2005)." The submissions are available on the IAEA website, and are an unprecedented level of public transparency in this field.

There are some differences between states' willingness to declare certain aspects of their plutonium holdings. However, it is encouraging that France, Germany and the UK regularly disclose their holdings of civil HEU.

Regrettably several states with civil separated plutonium have not yet chosen to participate, including India, Italy, the Netherlands, Spain and Sweden.

Safety of Nuclear Transport

International nuclear transport, via air, sea or land, requires by its very nature an international governance regime in a way that no other aspect of nuclear energy generation does.[38] As early as 1959 the United Nations Economic and Social Council charged the IAEA with establishing recommendations on the transport of radioactive material. These were established in 1961 as Safety Series 6. These were to cover category 7 of the hazardous substance identification and classification system established by the United Nations Committee of Experts on the Transport of Dangerous Goods (IAEA, 2003a: 90). This has led to continuing cooperation between the Committee and the IAEA. As a result the IAEA Transport Regulations are both a stand-alone document and a part of the UN Committee's Model Regulations.

In 1977, in recognition of the rapid scientific and technological developments in the field of nuclear transport, the IAEA established a Standing Advisory Group on the Safe Transport of Radioactive Materials (SAGSTRAM). It reviewed the existing guidelines; established a system for future such reviews; developed general guidelines and methods for establishing international coordinated research programs and identifying the effects of these on the comprehensive revision of the regulations; designed an information collection and retrieval system for the worldwide volume of nuclear traffic; and considered recommendations for the further development of the transport regulations. As predicted, the regulations underwent further revisions in 1967, 1973, 1985 and 1996. Together the IAEA's transport regulations and supporting Safety Guides serve as the basis for the regulation of nuclear transport involving all international organizations and states with significant nuclear transport activities.

The IAEA Transport Regulations address all categories of radioactive material, from very low activity material such as ore and ore concentrates, to very high activity material such as spent fuel and high level waste. They apply to transport by all modes — land, sea and air. Beginning in 2000 they are being revised in a two-year cycle. In 2008 the IAEA Board of Governors approved revisions to the 2005 edition of the Transport Regulations and the updating of the suite of transport safety standards was being completed (IAEA, 2009i: 24).

Unlike other aspects of the international governance of nuclear energy, the transport domain does not have its own international treaty.[39] (The 1979 Convention on the Physical Protection of Nuclear Material is concerned more with nuclear security, although it is still relevant to nuclear safety since it is intended to prevent unauthorized access to nuclear material).[40] Rather, the UN Model Regulations and therefore the IAEA's Transport Regulations are implemented through incorporation into various related international instruments. For air transport these have become mandatory through International Civil Aviation Organization (ICAO) Technical Instructions annexed to the 1944 Convention on International Civil Aviation (the Chicago Convention). In addition the International Air Transport Association (IATA) has made the Model Regulations a prerequisite for the transport of dangerous goods by air. For sea transport the 1974 International Maritime Dangerous Goods Code has been made mandatory through incorporation into the International Convention for the Safety of Life at Sea (the SOLAS Convention). For instance, in 1997 the International Maritime Organization (IMO) incorporated the Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes In Flasks on Board Ships (INF Code) into the SOLAS Convention (Goldblat, 2002: 113). For land transport, while there is no single international agreement which includes the UN Model Regulations, they are incorporated into such agreements as the Model Regulations of the United Nations Economic Commission for Europe and the Regulations Concerning the International Carriage of Dangerous Goods by Rail. Even states that are not party to these agreements may decide and are encouraged to use the regulations as a basis for national legislation.

For decades nuclear shipments have taken place worldwide largely without serious incident and unnoticed by the general public. With reference to the US, which has the largest and most dispersed civilian nuclear power program, "The government and the nuclear industry have been transporting nuclear materials, including a modest amount of commercial spent fuel, for decades, without incident" (Smith, 2006: 274). There are two exceptions to this low profile. One is plutonium shipments from France to Japan which pass through Southeast Asia, including pirate-infested waters such as the Malacca Straits, and which require military escort. Greenpeace and others have protested these shipments in part because they oppose a plutonium-based fuel cycle but also because of safety and security concerns. A second issue, arising from opposition to nuclear power but also due to safety and security concerns, has been the movement of nuclear material within Europe, particularly in the UK and Germany. In the US there has been continuing controversy over the robustness of transportation casks for spent fuel and high level nuclear waste (Smith, 2006: 274-275). In Australia there used to be protests against uranium shipments, but these were due principally to nonproliferation concerns, not just (or even) safety, and have in any event abated.

The nuclear revival is likely to pose challenges to the governance of nuclear transport. Already difficulties are being experienced due to heightened concerns about nuclear terrorism since 9/11. Shipping companies and ports have faced tighter regulations which they fear will inhibit a nuclear revival. Bernard Monot, a vice president in Areva's logistics department states that "The shippers complain about the port authorities, who in turn hold the shipping lines responsible and everybody accuses heavy regulations" (Stablum, 2008). The World Nuclear Transport Institute (WNTI), a group of 42 firms that claim to be "committed to ensuring safe nuclear transport,"[41] notes that a revival will mean an increase in the volume of nuclear material transported internationally as demand grows. Some firms are leaving the business altogether due to the difficulties of shipment and trans-shipment. Moeller Maersk, the world's largest container shipping line (measured in vessel capacity), adopted a policy of not shipping radioactive materials in April 2007 (Stablum, 2008). The IAEA has set up a committee on Denial of Shipments to try to solve bottlenecks in the industry. Most of these concerns, however, focus on small shipments, especially of radioactive sources which have short half-lives and need to get to customers quickly.

A revival in nuclear electricity generation will inevitably lead to greater amounts of bulk material being transported both domestically and globally. This is likely to include uranium, LEU, fuel assemblies, spent fuel, plutonium, MOX fuel and nuclear waste. Initially spent fuel and nuclear waste is likely to continue to be stored at nuclear power plant sites. However, ultimately this material will have to be transported for reprocessing or, more likely, long-term storage. For states with smaller nuclear energy programs the cheapest and most appealing solution for their nuclear waste would be to ship it to regional centres. From a nonproliferation standpoint Russia's offer to take back spent fuel from reactors that use Russian LEU, as in the case of its sales to Iran, is also eminently sensible. However both of these arrangements would increase the amount of material that needs to be safely transported long distances. The US already faces this prospect internally as it considers alternative sites to Yucca Mountain. Coastal and shipping nations are taking some initiatives in this regard. In 2008 a group of them, with Agency participation, held a fourth round of informal discussions in Vienna with a view to maintaining dialogue and consultation aimed at improving "mutual understanding, confidence building and communication in relation to safe maritime transport of radioactive material" (IAEA, 2009i: 24). While it is reassuring that meetings are being held, the agenda suggests that these areas currently need sustained attention.

As in other areas of nuclear safety, it will be critical to urge and assist new entrants in the nuclear energy business to make plans for nuclear transport as early as possible. With their focus on buying, financing, siting and building reactors they are unlikely to have even begun to consider such issues as part of their regulatory and infrastructure planning. As Jérôme Sermage, chair of the Uranium Concentrates Industry Task Force puts it, "It is understandable that since this is both a narrow field of interest and one that is at the very beginning of the fuel cycle, that many other participants in the nuclear fuel cycle would have given little thought" to the transport issue (Sermage, 2009). Given the absence of a single treaty under the auspices of which parties can be peer reviewed or enjoined to comply with their obligations, the IAEA needs to take on the role of ensuring that future nuclear energy states join the relevant international agreements and adopt and implement the Agency's Nuclear Transport Regulations. The Agency's Technical Cooperation program needs to be boosted to provide the required advice and assistance.

National role in nuclear safety oversight and regulation

While the plant operator and those involved in handling nuclear material may be held ultimately responsible for nuclear safety, governments are also critically involved, not only because nuclear accidents can have international repercussions but also because domestic public opinion invariably demands that the industry operate in a regulatory framework that ensures compliance with the highest standards. The NEA says that the overall objective for nuclear facilities — a very high level of safety performance — is achieved through two complementary approaches: giving the operator prime responsibility for safety; and setting the right environment for compliance and supervision by the regulator (OECD/NEA, 2008: 225).

The principles of good regulatory governance seem to be universally agreed, if not practiced. After its last meeting, in Washington DC, in April 2008, INRA issued a statement, forwarded to the IAEA identifying the following four commitments that countries should consider in order to achieve and maintain high levels of nuclear safety (NRC, 2008a):

- To have a legislative and regulatory framework to govern the safety of nuclear materials and installations that meets the requirements of the international Convention on Nuclear Safety, relevant fundamental safety principles, and appropriate standards;
- To establish an independent nuclear safety regulatory body with authority, competence, and financial and human resources to fulfill its responsibilities to secure a high level of safety;
- To ensure that such an independent regulatory body is able to come to its regulatory judgments or decisions on nuclear safety issues based on expert nuclear safety technical understanding unfettered by outside interest or pressure, and that this is underpinned by an appropriate legal framework, custom and practice and through other measures established by governments and parliaments; and
- To anchor an effective system of nuclear safety regulation and control on a strong national commitment to develop cultures in all relevant organizations and bodies that emphasize nuclear safety as the priority.

Global governance in helping achieve these goals in the regulatory area is relatively rudimentary and novel, but growing. Senior regulators meet annually at the IAEA's annual General Conference and the issue is considered in other venues, including at CNS review meetings. But the General Conference meetings, while well attended, last only a day and involve a general discussion on just two themes. There are several regional and reactor-type networks of regulators to supplement the international regime. They include: the International Nuclear Regulators Association (INRA); the Network of Regulators of Countries with Small Nuclear Programs (NERS); the CANDU[42] Senior Regulators; the Cooperation Forum of State Nuclear Safety Authorities of Countries which operate WWER[43] Reactors; the Western European Regulators Association (WENRA); the Ibero-American Forum of Nuclear Regulators;[44] the NEA Committee on Nuclear Regulatory Activities (CNRA); and the European Nuclear Safety Regulators Group (ENSREG) (IAEA, 2009i: 4).[45] Both the IAEA and INSAG provide advice to IAEA member states on regulatory issues (INSAG, 2003a).

The only international body devoted to regulation that sounds like it is intended to be universal is the International Nuclear Regulators Association (INRA). Established in 1997, it is a small self-nominated "club" of like-minded senior regulators from Canada, France, Japan, Spain, South Korea, Sweden, the UK and the US. It operates independently of other international bodies and provides members with a periodic forum to discuss nuclear safety, notably their collective strategy for multilateral meetings (CNSC, 2008: 38). Clearly a problem here is that it only includes eight of the 31 national nuclear power plant regulators. There is therefore a need to create a universal international nuclear regulators organization.

Regulatory independence

A prominent issue at the 2008 CNS Review Conference, prompted by the Canadian government's sacking in January 2008 of the President of the Canadian Nuclear Safety Commission, Linda Keen (see box), was the independence of national regulators. Delegates called the event troubling because of Canada's status as a "leading nuclear country" and because of the threat that if politicians can interfere in the regulatory process in Canada, the same could happen anywhere.

The CNS requires state parties to "establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework … and provided with adequate authority, competence and financial and human resources" (IAEA, 1994: article 8). Each state party is also obliged to "take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy." CNS Review Conference Chairman Maurice Magugumela of South Africa noted that this was not the same as "independence," although there was a strong link between the two (MacLachlan, 2008d: 17). However, the IAEA's Fundamental Safety Principles, on which the CNS is supposedly based, require that "An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained." Some state parties reportedly would like to amend the CNS to require independence, although others were opposed. Several states also came under the spotlight at the 2008 conference because their regulatory bodies were considered too close to organizations that promote nuclear energy, including those of Brazil, India and South Africa. The meeting agreed to "further discussion" of the issues of regulatory independence and separation from promotional bodies.

Nuclear Emergency Preparedness and Response

This section considers the regime that applies to emergency preparedness and response to a nuclear accident. Although triggered only after an aspect of nuclear safety has failed, emergency preparedness and response systems are vital in convincing the public that a nuclear revival should be permitted to proceed. Emergency and preparedness response systems should be designed to reduce the risk of emergencies and to mitigate their consequences. Organizing emergency response at the international level requires cooperation with the competent bodies of other states and with a wide range of international organizations. The two key multilateral conventions described below, both negotiated in the immediate aftermath of the Chernobyl accident, are

Independence of the Nuclear Regulator – The Canadian Case

Canada's National Research Universal (NRU) reactor — which used to supply roughly half of the world's medical isotopes — was temporarily shut down for routine maintenance in November 2007 (CTV News, 2007). During the shutdown the Canadian Nuclear Safety Commission (CNSC), Canada's national nuclear regulator, discovered that emergency backup power was not connected to two pumps that are intended to prevent fuel melting. CNSC President Linda Keen insisted that the backup power be connected before restarting the reactor, causing a month-long shutdown that disrupted the global supply of medical isotopes that quickly became a political issue in Canada. Federal Natural Resources Minister Gary Lunn insisted in a private letter to Keen that was leaked to the public that the reactor be restarted immediately (CBC, 2008). Keen refused on the grounds that she had legitimate safety concerns about the NRU validated by the Commission, a quasi-judicial tribunal (CBC, 2008). Keen's refusal ultimately led to her firing as president of the CNSC in January 2008, although she remained a CNSC Commissioner. Canadian Prime Minister Stephen Harper politicized the issue by asking, "Since when does the Liberal party [the official opposition in Canada in 2008] have a right, from the grave through one of its previous appointees, to block the production of necessary medical products in the country?" (Times Colonist, 2008). Subsequently the Canadian parliament unanimously voted in favour of restarting the reactor despite the potential nuclear safety risks (Toronto Star, 2009b). The firing of Linda Keen raised concerns nationally and internationally about the independence of nuclear regulators and the injection of partisan politics into the regulation of nuclear safety. The NRU was shut down again in May 2009 when it was discovered that it could no longer operate safely due to a heavy water leak, and is not expected to come back online until late winter 2010 at the earliest (Toronto Star, 2009a). No crippling shortage of radioisotopes has ensued.

The Federal Court of Canada ruled in April 2009 against Keen's appeal against unlawful dismissal as President, noting that the Executive branch of government, the Parliament of Canada, had acted within its powers. The Court also noted that Keen's dismissal as President did not silence her "voice" and indeed may have enhanced it, since as President she could only cast a deciding vote, while as an ordinary Commissioner she could vote on all issues before the Commission (OECD/NEA, 2009d: 90-91). While this legal ruling affirms that regulatory "independence" is always bounded by the constitutional requirements of each state, as it should be, the case nonetheless damaged the public perception of the Canadian regulator's independence. Similarly, the court ruling did not gainsay the accusation that the Canadian government failed to maintain separation between the regulator and political interference as required by the Convention on Nuclear Safety.

designed to help the international community prepare for and facilitate this process in the event of an emergency. In addition, both the CNS and the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management require their state parties to ensure that they have in place, nationally, on-site and off-site emergency plans.

Convention on Early Notification of a Nuclear Accident

The Convention on Early Notification of a Nuclear Accident (CENNA) was adopted by a special session of the IAEA General Conference in September 1986 and entered into force in October 1986. As of October 2009 there were 106 contracting parties and 70 signatories (IAEA, 2009b). Among the contracting parties are the World Health Organization (WHO), the World Meteorological Organization (WMO), the Food and Agriculture Organization (FAO) and Euratom.

The Convention applies when an accident has the potential to, or results in, the release of radioactive material that has transboundary effects with consequences for the safety of another state. Unlike the CNS, it covers nuclear reactors, nuclear fuel cycle facilities, radioactive waste management facilities, nuclear fuels or radioactive waste in transport or storage and radioisotopes. In the event of a nuclear accident on its territory, a state party must provide full details to the IAEA and any state which is or may be physically affected. The IAEA is mandated in turn to inform all state parties, IAEA member states, relevant international intergovernmental organizations, or any other states which are or may be physically affected. Additionally, the IAEA will provide full information relevant to any state which might eventually be affected by the accident.

In order to facilitate this process, each state party is obliged to ensure that the IAEA and other state parties are aware of the competent national authorities and a point of contact responsible for issuing and receiving a notification and information in the event of an accident. The IAEA is obliged to maintain an up-to-date list of such national authorities as well as points of contact for relevant international organizations.

Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency

The Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (CACNARE) was adopted, also by the special session of the IAEA General Conference in September 1986 and entered into force in October 1986. As of October 2009 there were 104 contracting parties and 68 signatories (IAEA, 2009a). Among the contracting parties are the WHO, the WMO, FAO and Euratom.

Under the Convention, in the event of a nuclear accident a state party may call on any other state party or international intergovernmental organization for assistance. The recipient of such a request is obliged to promptly notify the requesting party whether or not it is in a position to render such assistance. The assisting party must notify the IAEA of its capacity to assist and lay out the terms under which such assets will be made available. Under the Convention the IAEA is given a central international role in the prevention and mitigation of nuclear accidents. If a request for assistance is made, the IAEA will make appropriate resources available, liaise with states with the necessary resources, and, if requested, coordinate assistance at the international level. In the longer term the IAEA is tasked with collecting information regarding experts, equipment and materials that are available to assist in nuclear emergencies, in addition to communicating methodologies, techniques and the latest research in response techniques. The Agency will also, when requested, assist states to prepare emergency plans, develop training programs, transmit requests for assistance, put in place radiation monitoring programs, and conduct feasibility studies regarding radiation monitoring systems. Finally, the IAEA acts as an international hub by maintaining liaison with international organizations which deal in some way with nuclear emergencies.

Biennial meetings of "competent" authorities

According to both CENNA and CACNARE, state parties are obliged to designate competent authorities to deal with the various obligations under the two conventions. In order to facilitate international cooperation and communication, the IAEA has convened biennial meetings of these authorities. These generate reports strengthening nuclear safety and improving emergency preparedness and international assistance in the event of a crisis. In addition to the biennial meetings, at the second meeting of competent authorities in June 2003, a National Competent Authorities' Co-ordinating Group (NCACG) was established. The NCACG, consisting of a Chair and six members representing Africa, Asia and Australasia, Eastern Europe, South and Central America and the Caribbean, North America and Western Europe, manages the tasks assigned to the competent authorities and coordinates their contributions.

According to the NEA, the international emergency and response systems established by the two treaties are becoming outdated and need revision, as evidenced by a resolution by the IAEA General Conference in 2006 that "welcomed" the preparation of a Code of Conduct on International Emergency Management (IAEA, 2006b). In December 2006 a technical meeting to discuss a draft Code provoked mixed views, with some states expressing concern as to whether such a Code was "the appropriate instrument to achieve the desired objectives" (IAEA, 2007c). References to work on a Code since then have been absent, suggesting that the initiative is either languishing or has vanished, an example of the difficulties facing the attempt to strengthen global governance in some areas of nuclear safety.

Incident and Emergency Centre

The Incident and Emergency Centre (IEC), established in 2005, coordinates the provision of assistance and allows for the effective sharing of information between states, their competent authorities, international organizations and technical experts. The Emergency Notification and Assistance Technical Operations Manual (ENATOM) clarifies the expectations of the Secretariat and the roles of the IAEA, member states, and international organizations in the event of a nuclear emergency. The Emergency Response Network Manual (ERNM) and the Response Assistance Network (RANET) are further attempts to strengthen international response by improving coordination of assistance and promoting emergency preparedness in member states. Unfortunately, by the end of 2008 only 14 member states had registered expert capabilities with RANET, which is insufficient if it is to become a global repository of information on national assistance offerings (IAEA, 2009i: 10). The IAEA Response Plan for Incidents and Emergencies (REPLIE) details how the Agency staff will organize themselves in response to an emergency. At the request of the IAEA General Conference, the IAEA Secretariat is currently developing a unified system that will replace the current Early Notification and Assistance Conventions (ENAC) website and the Nuclear Events Web-based System (NEWS) (IAEA, 2009i: 11).

Inter-Agency Committee on Response to Nuclear Accidents (IACRNA)

The Inter-Agency Committee is designed to coordinate the response of all relevant international organizations in the event of a nuclear accident.[46] To facilitate this the Committee has developed the Joint Radiation Emergency Management Plan of the International Organizations (JREMPIO). The JREMPIO describes the roles and responsibilities of the different international organizations, lays out the interfaces among them and with states, and establishes a framework for emergency preparedness.

IACRNA and IAEA Emergency Response Exercises

The IACRNA, in partnership with the IAEA Secretariat, coordinates international emergency response exercises to increase preparedness for a nuclear accident. A recent example is the ConvEx-3 (2008) exercise at the Laguna Verde reactor in Mexico. Seventy-five countries and nine international organizations participated (IAEA, 2009i: 11). Such exercises allow the international community to identify weaknesses in its response capacities and mitigation strategies.

IAEA Advisory Services and Missions

The IAEA has safety standards dealing with emergency preparedness and response. It also dispatches Emergency Preparedness Review Teams (EPREV) at a state's request, to evaluate emergency preparedness and make recommendations to improve it.

Overall, the global governance of emergency preparedness and response has moved rapidly since the Chernobyl disaster from non-existence to a complex web of treaties, arrangements and measures. It is difficult to fully assess its adequacy until it is tested during an actual disaster. On the face of it, however, the requisite international structures are in place as never before. Yet the IAEA's Nuclear Safety Review for 2008 notes bluntly that while member states with nuclear installations tend, in general, to have adequate emergency preparedness and response capabilities to deal with local incidents and emergencies, only a few have adequate capabilities to respond to a major nuclear emergency (IAEA, 2009i: 7). If and when increasing numbers of states acquire nuclear power plants they will need to be drawn tightly into this system, beginning with ratification of the two major Conventions and fully complying with their obligations.

The International Nuclear Accident Liability Regime

The international legal regime governing nuclear liability is the oldest, least understood and most fragmented aspect of global nuclear energy governance. It also has the lowest levels of state participation.

The regime emerged in the early 1960s, which makes the original liability conventions the first multilateral treaties governing any aspect of nuclear power generation. They were seen at the time as vital in enticing power companies to invest in an unfamiliar, potentially dangerous form of electricity generation. It has been a continuous work-in-progress ever since. The regime operates on the following principles (IAEA, 2007e: 2):

- The operator of a nuclear installation is exclusively liable for nuclear damage, including during the shipment of nuclear material; this helps avoid complicated legal actions to determine who is legally liable and obviates the need for those associated with construction of the reactor to take out prohibitively expensive insurance and thus allows a concentration of insurance capacity.
- Strict no fault liability is imposed on the operator owing to the "special dangers" and the difficulty of

establishing negligence in particular cases; liability results from risk, irrespective of fault.

- Exclusive jurisdiction is granted to the courts of one state, to the exclusion of others, usually the state in which the accident occurs, to avoid insoluble conflicts between national legal jurisdictions.
- Liability is limited in amount and time, a compromise between the interests of those suffering damage and the interests of operators.

The liability regime is an important part of global nuclear safety since it is the only dedicated legal mechanism by which an operator can be held internationally accountable for a nuclear accident that causes transboundary deaths, injuries and damage. It aims to sustain public confidence in nuclear energy by ensuring that those harmed by a nuclear accident are adequately compensated no matter where the accident occurs or whose fault it is. By imposing responsibility on operators the regime in theory reinforces the incentives for them to run their nuclear reactors safely. In limiting the liability of the operator, with the state and the international community guaranteeing to fund damages above the limited amount, the liability regime also reinforces the interest of the state in properly regulating the nuclear industry. Morover, it encourages financiers and utilities to invest in nuclear energy, encourages insurance companies to insure operators for limited liability and lowers operators' insurance premiums. Finally, it provides stronger legal protection against unlimited liability for vendors that operate outside their own countries (MacLachlan, 2008e: 6).

But the regime has paradoxical, less welcome aspects. First, it creates moral hazard for the nuclear industry and violates the "polluter pays" principle. Despite the mantra that the operator is ultimately responsible for the safety of its nuclear reactor, the nuclear liability regime attenuates this principle by limiting liability and thereby reducing the industry's incentives for relentlessly pursuing nuclear safety. This is particularly of concern when cost pressures in a deregulated market push in the direction of cutting expenses. Knowing that the government will foot the bill for a catastrophic accident (and will assume part of the blame due to the perceived failings of the regulator), the industry may be less driven in pursuing safety than it might otherwise be.

A second problematic aspect of the regime is that it represents a hidden subsidy to the nuclear industry.[47] It renders nuclear energy cheaper than it would be if the full costs of private liability insurance were internalized in the price of nuclear electricity and thereby privileges it over other forms of energy generation.[48]

A third difficulty of the regime is its sheer complexity and fragmentation. Even IAEA Director General Mohamed El Baradei once remarked that, "the provisions of the liability conventions, and the relationships between them, are not simple to understand" (ElBaradei, 2007).

Two Legal Frameworks: Paris/Brussels vs Vienna

The main element of complexity comes from the fact that the regime is based on two separate international legal frameworks that the international community has constantly tampered with and attempted to cobble together. Each framework encompasses more than one international treaty and several amendments and additions that add further rights and obligations. The oldest by a few years is the Paris/Brussels framework, established under the auspices of the OECD/NEA, and covering most OECD member states. The second, established under the auspices of the IAEA, was designed to be "worldwide in character" (OECD/NEA, 2009c).

The Paris/Brussels regime comprises the following legal instruments:

- The 1960 Paris Convention on Third Party Liability in the Field of Nuclear Energy, amended by protocols adopted in 1964, 1982 and 2004 (the 2004 protocol has not yet entered into force); and
- The 1963 Brussels Convention Supplementary to the Paris Convention amended by protocols adopted in 1964 and 2004 (again the 2004 protocol has not yet entered into force).

The IAEA regime comprises:

- The 1963 Vienna Convention on Civil Liability for Nuclear Damage and its 1997 Protocol;
- The 1988 Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention; and
- The 1997 Convention on Supplementary Compensation for Nuclear Damage (not yet in force).

The original Paris and Vienna Conventions establish comprehensive and almost identical regimes for civil liability for nuclear damage (IAEA, 2003a: 108). The Brussels Convention provides for additional compensation from national and international public funds in cases where the Paris Convention's compensation is insufficient. The Convention on Supplementary Compensation for Nuclear Damage also provides additional compensation from international public funds but in respect of shortfalls under either the Paris or Vienna Conventions or under national legislation. The Joint Protocol, an initiative of the US, links the Vienna and Paris Conventions for the purpose of ensuring that the benefits of one are extended to the parties of the other. In addition to supplementary compensation, reform attempts have produced larger amounts of mandatory liability minimums, broader categories of damage and wider geographical application. Admirably, the 1997 Protocol mandates access to compensation by residents of non-parties.

According to the IAEA the modernization of the regime through the 1997 Protocol to Amend the Vienna Convention and the 1997 Convention on Supplementary Compensation for Nuclear Damage was a "major milestone" (IAEA, 2007f: 1). The latter, in particular, purportedly "provides the framework for establishing a global regime with widespread adherence by nuclear and non-nuclear States."

Despite their complexity, the main principles and essential content of the nuclear liability conventions are today internationally accepted as appropriate legal means for dealing with nuclear risks. They form the international yardstick for assessing whether national nuclear liability legislation is adequate. The IAEA enjoins states to become parties to the treaty regime and for legislators to consider the advantages of aligning their domestic legislation with the conventions (IAEA, 2003a: 108). In addition to the Paris and Vienna regimes there is also a specific treaty dealing with maritime nuclear accidents: the 1971 Convention Relating to Civil Liability in the Field of Maritime Carriage of Nuclear Material. It entered into force in 1975 and its depositary is the International Maritime Organization (IMO). It limits the liability of nuclear operators that transport nuclear material. As of November 2009 it had only 17 state parties.

Sparse Adherence

Unlike most other areas of nuclear global governance, states have proved remarkably reluctant to become parties to the liability conventions and protocols that they have negotiated. Fewer than half the world's nuclear power plants are currently covered by the regime (MacLachlan, 2008e: 6). Tellingly, states with the largest civil nuclear programs have not joined, which is "clearly a disincentive for other states to join" (Rautenbach et al., 2006: 34).

The Paris Convention, as of June 2009, had 18 signatories and only 16 parties, while the Brussels Convention at the same time had 15 signatories and 12 parties. Neither the treaty's 2004 protocol is in force yet and there is a risk that they will be overtaken by a 2004 EU Environmental Liability Directive. This exempts nuclear damage, which was assumed would be covered by the international conventions, but provides for a review in 2014 "to see if it is still justified." Unlike the nuclear conventions, the EU directive does not channel liability to operators or provide for a single court to have jurisdiction, both of which the industry says are central to nuclear liability schemes (MacLachlan, 2008e: 7).

The Vienna framework in some respects fares even worse, considering it is meant to be universally applicable. As of December 2008, there were 14 signatories and only 36 parties to the Vienna Convention. Only 15 of these had signed the 1997 Protocol, while only five had ratified (Argentina, Belarus, Latvia, Morocco and Romania); none have significant nuclear energy capacity. No state has ratified since 2003. The Joint Protocol, as of July 2009, had 22 signatories and 26 ratifications.

The 1997 Convention on Supplementary Compensation for Nuclear Damage has drawn such little support that is has not yet entered into force either. By May 2008 there were 13 signatories and only four parties — Argentina, Morocco, Romania and the US. American ratification in May 2008 was a major fillip for the treaty. It had been primarily promoted by the US, and other states were waiting to see if the Americans would actually ratify it (MacLachlan, 2008e: 6). So far even this has not induced other states, notably nuclear energy producers, to sign and ratify. The Convention enters into force only when at least five states with 400,000 thermal MW of installed nuclear capacity ratify it. US ratification brings the total to 305,000 MWth (MacLachlan, 2008e: 6).

These financial complications and the low levels of participation by states are highly problematic for the international nuclear liability regime since it needs adherence by as many countries as possible to create a sizeable compensation fund. In particular it needs all of the major nuclear power countries contributing, as the size of each national contribution depends on how many reactors a country has. The Supplementary Convention provides that 90 percent of contributions to the international fund will come from states with nuclear power, while the non-nuclear energy states will contribute on the basis of normal UN assessment rates. Moreover, half of the international fund is reserved for transboundary damages. Small states therefore stand to gain disproportionately from the availability of international compensation funds. The convention, which is modeled on the US Price-Anderson Act,[49] also for the first time requires that suppliers of reactors, not just operators, contribute to the international funds (a move away from the principle that the operator should bear all the risk but one that better internalizes costs across the nuclear industry) (MacLachlan, 2008e: 7).

One of the reasons given for the lack of adherence is dissatisfaction with various provisions of the conventions. Many states view the minimum liability provisions as too high. Others find the broadened definition of nuclear damage to include environmental damage, or the extended geographical scope, to be unpalatable (Schwartz, 2006: 49). Still others see the preferential treatment given to extra-territorial victims as discriminatory (Schwartz, 2006: 52). Differences between the Vienna Convention and the Brussels Supplementary Convention have led to claims by some states that that it would be "hard to envision signing two complementary conventions with different mechanisms, allocation rules and beneficiaries" (Dussart, 2005: 24). Some national practices differ wildly from the model reflected in the international regime. Germany for instance insists on unlimited operator liability and requires €2.5 billion ($3.4 billion) security for each plant (MacLachlan, 2008e: 7).

A further difficulty is that even the maximum amounts foreseen in the revised Paris and Brussels Conventions totalling €1.5 billion, much more than currently provided by the international conventions, would not come close to covering the costs of a catastrophic accident. Many billions of dollars in compensation have been paid out in the former Soviet Union and some Western European states for damage associated with the Chernobyl accident and the payments continue because land is still contaminated and long-term health effects are being claimed. According to Ann MacLauchlan, "A threat hanging over all the liability regimes is that as the coverage has been broadened, in the light of experience from Chernobyl, to include more types of damage, longer claim periods, and higher compensation, the insurance industry has baulked at providing the coverage operators must legally contract under national liability legislation" (MacLachlan, 2008e: 7).[50] Such insurance is achieved most commonly in the form of private insurance, but it can also be provided by state bank guarantees, an operator pooling system (Pelzer, 2007), government re-insurance (as in Canada) (MacLachlan, 2008e: 7) or even self-insurance (Schwartz, 2006: 41). But since the terrorist attacks of September 11, 2001 the insurance industry has looked much more critically at its exposure to the risk of unlikely but high consequence events.

A worrying recent development is that the EU is contemplating steps that may fragment the regime even further. INLEX has expressed concern that the EC is proposing that all European states join the Paris/Brussels framework in preference to the Vienna one and that Euratom adopt a separate directive (legally binding under EU law) on nuclear liability (IAEA, 2009i: 12).

Impact of the Revival

The nuclear liability regime is clearly unprepared for the nuclear revival. The international conventions are poorly subscribed to or not yet in force, international funds are far from adequate to cover a serious accident even of the Chernobyl variety and the private insurance industry appears reluctant to insure increasingly expensive nuclear plants and the extended coverage now expected since Chernobyl. It will be difficult to convince new entrants to the nuclear energy business to accede to all of the necessary liability conventions if the existing nuclear energy powers show such reluctance to fully support their own creations. Moreover, if the existing nuclear energy states are struggling to maintain adequate insurance for their existing fleet they will certainly face challenges in adequately insuring their fleets of new reactors. The nuclear revival will compound the insurance problem since "There may not be sufficient market capacity to insure nuclear operators against the increased liability amounts provided for under the new or revised conventions, at least not in all countries" (Schwartz, 2006: 60). While Steve Kidd of the WNA insists that for private insurance companies "Western-designed nuclear installations are sought after businesses because of their high engineering and risk management standards" (Kidd, 2009: 13), others are not so sanguine. According to Julian Schwartz, head of legal affairs at the OECD/NEA, "The private insurance industry has indicated it will not be able to provide coverage for new risks" (MacLachlan, 2008e: 7).

While wealthy new entrants like the UAE will probably be able to self-insure, others like Egypt, Jordan and Vietnam will struggle to find private insurance and will find the international regime inadequate. This situation risks leaving new entrants under-insured, both in terms of national and transboundary coverage, and their governments (the insurers of last resort) facing financial meltdown if an accident occurs. This in turn may make governments reluctant to approve "new build" and act as a further damper on the nuclear energy revival.

Reform is clearly required. First, all of the existing conventions need to attract more parties, be brought into force and have their international funds maximized. The International Expert Group on Nuclear Liability (INLEX) is attempting to increase adherence by holding regional workshops.[51] Second, a more serious attempt needs to be made to rationalize the conflicting requirements of the competing regimes or at the very least to ensure that all states understand the differences and can make wise choices. The European Commission has begun a study aimed at "simplifying" the EU regime which could result in operator liability pooling similar to the US scheme (MacLachlan, 2008e: 7). In 2007 the IAEA published a comprehensive study and authoritative interpretation of the Vienna nuclear liability regime prepared with the assistance of INLEX (IAEA, 2007f). Nonetheless, there remains a need for further work on common understandings and simplification of the overlapping legal frameworks. INLEX is continuing to meet and undertake activities towards this goal. Third, new entrant states will need special assistance, including in the area of national implementation legislation to ensure that their legal framework for nuclear liability is sound. Fourth, creative ways of financing insurance at the national level are required to ensure that states are complying with their legal obligations under the liability conventions. The best solution from the point of view of the polluter pays principle is to ensure that as many costs of the nuclear industry are internalized and for operators and vendors to establish pooling arrangements and mutual insurance schemes. This will work for states with several reactors, but will leave new entrants (those with one or two units) reliant on the insurers of last resort, their governments and the international liability regime.

Adherence to Nuclear Safety Conventions by SENES States

Instrument	Operator's liability (provided by private funds unless otherwise noted)	Details of Nuclear Liability Regimes
Paris Convention	Maximum: EUR 15M/USD 24M with NEA Steering Committee recommendation: EUR 154M/USD 244M Minimum: EUR 5M/USD 8M	N/A
Brussels Supplementary Convention	As per Paris Convention (see above)	Between EUR 5M/USD 8M and EUR 308M/USD 489M
Vienna Convention	Maximum: none Minimum: USD 95M (approximate)	N/A
Vienna Convention Protocol	Maximum: none Minimum: EUR 308M/USD 489M Reduced liability: EUR 5M/USD 8M Operator/State may share liability;	N/A
Paris Convention Protocol	Maximum: none Minimum: EUR 700M/USD 1.1Bn Reduced liability: EUR 70M for small risk facilities EUR 80M for transport	N/A
Brussels Supplementary Convention Protocol	Maximum: EUR 700M	Between EUR 700M/USD 1.1B and EUR 1.1B/USD 1.7B
Convention on Supplementary Compensation	Maximum: none Minimum: EUR 308M/USD 489M Reduced liability: EUR 5M/USD 8M Operator/State may share liability	EUR 308M/USD 489M (approximate, if all major nuclear power generating states join)

Source: "Operator liability and compensation amounts and supplementary state funding" from OECD/NEA (2008: 301).

Implications of the Nuclear Revival for Global Governance of Nuclear Safety

While it is impossible to quantify the impact of a nuclear revival on global nuclear safety because it is unclear how large that revival is likely to be, it is possible to identify some qualitative implications for safety. Some of these arise from power upgrades and life-extensions for existing reactors, while others arise from the construction of new nuclear plants, especially those based on new reactor designs. Still others arise from the type of country that is engaging in nuclear activity — whether experienced old hands or newcomers.

Upgrades and Life Extensions of Existing Plants

Worldwide existing nuclear energy states are upgrading, uprating and granting life extensions of up to 20 years to existing nuclear reactors, some of which are reaching the end of their initially planned 30-40 year life-span. But as Richard Meserve notes, "… aging plants present unique safety challenges because plants and equipment can deteriorate over time through mechanisms that may not yet be fully understood," requiring "heightened attention over time to surveillance, preventive maintenance, and component replacement" (Meserve, 2009: 100-111). Additional concerns about this aspect of the nuclear revival include:

- The management of plant ageing;
- The maintenance of safety margins at upgraded and refurbished facilities (MacLachlan, 2009a: 3);
- Succession planning for retiring staff, technical support organizations and regulatory bodies familiar with old plant types;
- Human factors and operator training; and
- Ultimate decommissioning of such facilities.

There is a danger that the global governance arrangements will be so fixated on "new build" and new entrants that it will fail to pay adequate attention to such challenges and provide the necessary assistance. An elaborate US licence renewal program introduced by the NRC in 1991 was "scathingly criticized" by the commission's in-house safety auditor, the Office of the Inspector General, for lacking proper documentation and failing to independently verify operator-supplied data (Brett, 2009).

In the US, the renewal of the licence for the Indian Point nuclear plant, located 34 miles north of New York City, was contested in 2006 by the Attorney-General of Connecticut, who noted that its operators had "compiled an unacceptable record of abject, repeated, multiyear failure to effectively address vital safety and security issues," a view shared by the regulator's safety auditor in a 2000 report (Brett, 2009). In August 2009 the NRC issued a safety evaluation of the plant as part of the renewal process which showed that of 87 parts of the reactor vessel and related elements examined, all but three showed signs of aging damage, as did 39 out of 44 steam generator components and 57 of 59 structural elements (NRC, 2009b). Still, the NRC concluded that Indian Point met regulatory standards for licence renewal.

There are some in the industry advocating even longer life extensions than 40 years. NRC Chairman Dale Klein warned the Topfuel and Global 2009 conference that margins inherent in the US reactor fleet had "allowed us to make the transition" from 40 to 60 years of operation "fairly easily," but that operating to 80 years or beyond would require "a very important R&D program" (MacLaclan, 2009a: 3). Among the issues that need investigating are ageing of cable insulation, ageing of concrete in high-flux radiation fields and material embrittlement. He also wondered "where are we going to get the people?" Additional challenges include finding spare parts for old reactor types. Former inspector general for Electricité de France, Pierre Wiroth, has claimed that efforts by the company to cut costs by centralizing procurement have lead to a "years-long dearth of spare parts on the ground" (Brett, 2009). Finally, there is the challenge of the obsolescence of analog systems which either need to be replaced by digital ones at the risk of system malfunction, or maintained and used by new generations of operators who are unfamiliar with and uninterested in improving them.

"New build" in existing nuclear energy states

Almost all existing nuclear energy states, including the UK and US, have not built new reactors in decades and will need to update their regulatory requirements and infrastructure. Others, like Argentina and Brazil, have only ever had one or two reactors on which to base their experience. The danger is that in their rush to expand nuclear energy, even experienced states may permit industry to compromise on safety under pressure of cost-overruns and lengthening construction schedules. Former NRC Commissioner Peter Bradford told a US Senate committee in March 2009 that before the Three Mile Island (TMI) accident the NRC had moved too quickly to licence too many reactors in the US. He said that one of the lessons of TMI was that "nuclear power is least safe when complacency and public pressure to expedite are highest" (Nuclear News Flashes, 2009a). A recent example is that of the Westinghouse AP1000 which originally received design certification from the NRC in 2006 (WNN, 2009). The company, which plans to build some 14 reactors in the US (and is already building two in China) submitted revisions to the certified design to "reduce cost and financial risk to buyers, afford extra protection against large aircraft crashes, improve instrumentation and control and finalize details such as pipe layouts." The NRC rejected the application, saying that more work was necessary on the shield building to protect the main nuclear components during events such as severe weather.

In existing producers the issues will include:

- Ensuring quality control and maintenance of high safety standards during rapid, large new build programs where several facilities are being built simultaneously;
- Avoiding shortages of trained and experienced safety personnel, both at nuclear plants themselves and in the nuclear regulatory authority, including at senior management levels;
- Ensuring that increasing consolidation and internationalization of the nuclear industry does not dilute or undervalue nuclear experience at the top levels in the new utility companies and vendor groups (OECD/NEA, 2008: 229); and
- Ensuring harmonization of safety standards in a situation where different brands of nuclear power plants are being built by multinational consortia and supplied by multiple parts suppliers (the shortage of spare parts may tempt counterfeiters to enter the market as they have done in the aircraft spare parts business).

In planning ambitious new programs, existing states may encounter a shortage of regulatory and expert safety personnel, especially as older generations of skilled personnel from the first "wave" of nuclear energy in the 1970s and 1980s are nearing retirement. The British nuclear regulator, the Nuclear Installations Inspectorate (NII), reportedly remains chronically understaffed, according to its umbrella organization, the Health and Safety Executive, and thus is ill-prepared for assessing new reactor designs as part of the UK's planned nuclear energy expansion (Nuclear News Flashes, 2007b). The December 2008 National Regulatory Review (the Stone Report) aimed to address this situation (Stone, 2008). While making up such shortfalls is largely the role of the state concerned, the international regime can help by expanding training programs, further pursuing peer review and lessons-learned processes and ensuring that the IAEA itself is staffed with the necessary expertise in nuclear and radiological safety.

Since companies in the existing nuclear energy states design and export new generation reactors, and build them within their own territory, responsibility rests with them to ensure that their new designs can be operated as safely as possible. Hence Canada, France, Japan, Russia, the US and potentially India, South Africa and South Korea need to engage in continuing efforts, already well underway, to harmonize safety requirements, licensing and other regulatory requirements for new reactor types. These states should also prompt and assist the IAEA in revising its safety standards to take account of the new generation reactors: the current standards were written with existing light water reactors in mind.[52] The new entrants which buy the new reactor types are unlikely to have the capacity or experience to adequately assess the safety of their likely purchases.

"New build" in New Nuclear Energy States

While the global nuclear safety regime may be effective among long-standing nuclear energy states which have had decades to establish and refine their safety systems and processes, it remains unprepared for a major expansion involving states without previous experience of nuclear energy (or of experience with any sophisticated industrial technology as is often the case).

There are yawning gaps in the coverage of the SENES states by the key safety-related international agreements (the CNS, CENNA, CACNARE and the Joint Convention – see chart below). Four SENES states — Bahrain, Kenya, Namibia and Venezuela — are, shockingly, party to none of them. If they are serious about nuclear energy they clearly have a long way to go in preparing for it. While many are party to the two nuclear accident conventions, since they have few obligations and stand to benefit in case of an accident, a surprising number are not party to either the CNS or the Joint Convention. In total 13 of the SENES states have neither signed nor ratified the CNS, while only seven are party to the Joint Convention. Practically none of the SENES states are party to the liability conventions. Clearly a priority is to bring all of these potential new entrant states into the relevant conventions as soon as possible as a prerequisite for seriously moving towards acquiring their first nuclear power reactor. Since achieving an internationally accepted level of safety is not a prerequisite for signing any of the safety-related conventions, and they have no existing nuclear reactors that would have to be shut down under Article 6 of the CNS if they did not comply, new entrants should be encouraged to join all of the conventions immediately.

Almost all of the states identified in SENES, the major exception being Italy which previously had a nuclear energy program, lack the requisite national regulatory laws and regulations, bodies and practices, trained and experienced personnel and appropriate safety culture. Nigeria, for example, where corruption and mismanagement are endemic (Economist, 2009: 30-32), has difficulty running the oil industry in which it has been significantly engaged for decades. Under the CNS states are required to ensure that the "necessary engineering and technical support in all safety related fields is available throughout the lifetime of a nuclear installation" (IAEA, 1994: article 19 (v)). This implies that states which purchase reactors from others will need to make arrangements with vendors for the lifetime of the installation or develop their own national capability after purchase. Some nuclear regulators in vendor countries are beginning to recognize this difficulty. It has been reported that French regulator Andre-Claude Lacoste has suggested to President Nicolas Sarkozy that he be "a little bit more pragmatic" about signing nuclear cooperation agreements with countries now devoid of nuclear safety infrastructure (MacLachlan, 2008c: 10). NRC Chair Dale Klein said that as Sarkozy "goes around the world trying to sell the French reactor, it puts Lacoste in a challenging position" in terms of the time it will take for such countries to develop such infrastructure.

The IAEA, as detailed above, already has an impressive array of programs in place to advise states considering embarking on new build, including with respect to nuclear safety. It is willing to assist states by conducting feasibility studies, as it has done for the member states of the Gulf Cooperation Council and Jordan, into whether states have the requisite infrastructure, including regulatory infrastructure, in place. Such documents as "Considerations to Launch a Nuclear Power Programme" (IAEA, 2007a), "Milestones in the Development of a National Infrastructure for Nuclear Power" (IAEA, 2007d) and "Evaluation of the Status of National Nuclear Infrastructure" (IAEA, 2008b) are thorough and informative in setting out systematically the requirements for a successful nuclear energy program. In addition, the Agency initiated in 2009 an Integrated Nuclear Infrastructure Review (INIR) process to provide a peer review for states seeking nuclear power.[53] In August 2009 Jordan became the first country to receive an INIR mission. The Agency has also developed a variation of its Knowledge Management to Assist Mission to conduct peer review of nuclear education and training systems and offer recommendations. The first such mission, to Malaysia, was completed in July 2009.

There is a danger that the IAEA will be increasingly swamped by requests for assistance. It already says that it has received enquiries from 60 states for advice and assistance. This points to the need for increased resources for the Agency in the area of safety (as well as security). The international regime should help the newly emerging nuclear energy states by expanding training programs, further pursuing peer review and lessons-learned processes and ensuring that the IAEA itself is staffed with the necessary expertise in nuclear and radiological safety. The IAEA should continue to insist that all of the newcomers become party to all of the nuclear safety conventions outlined above as early as possible in the planning stages so that they can begin preparations and avoid the mistakes of others.

Conclusions

The current global governance regime for nuclear safety is complex, sprawling and based on a variety of treaties and implementation mechanisms that have arisen in different eras to meet particular needs. It does, however, seem to have all of the necessary components in place, especially since the Chernobyl accident jolted the international community and the industry to act. Today, in the light of the anticipated increase in the use of nuclear energy, what is needed — rather than wholesale reform or major additions to the regime — is universal adherence to existing treaties, enhancement and in some cases rationalization of existing mechanisms, and increased human and financial resources.

While the IAEA is increasingly (especially since Chernobyl) the paramount international organization in the nuclear safety field, there are numerous other players which either act completely independently or only in partial cooperation with the Agency. This needs attention, especially in regard to nuclear regulators and nuclear accident liability. Differences in safety philosophy should not be permitted to stand in the way of greater international cooperation and such cooperation should be used to increase mutual understanding of different approaches and encourage harmonization.

The international conventions currently set out broad, legally binding undertakings, leaving implementation of agreed international standards and codes of conduct up to each state party. The question arises whether the latter should be made legally binding. In its 2008 report The Group of Eminent Persons suggested that "over time states should enter into binding agreements to adhere to effective safety standards" (IAEA, 2008d: 24). Surprisingly, the OECD/NEA has opined that in the light of the nuclear revival:

> The international community will … be obliged to examine the effectiveness of "incentive" conventions and non-legally binding instruments which provide for little or no recourse in the event of non-compliance. Nuclear materials and technology will continue to spread globally and it is unlikely that political "peer pressure" will prove to be a realizable enforcement measure for responsible use in all cases. While it may be attractive to some, to others it will exacerbate concerns about the safe exploitation of nuclear technology in politically less stable regions. (OECD/NEA, 2008: 305)

While superficially appealing and logical, it is not clear that introducing any more legally binding instruments in the civilian nuclear safety area (beyond those needed to deal with the non-reactor parts of the nuclear fuel cycle and research reactors) or making the entire system legally binding would be effective even if it were politically possible. Richard Meserve states:

> One might imagine a different regime in which an international regulator with sweeping transnational authority ensures the adequacy of licensees' safety performance. Such an approach might be seen as a way both to ensure that all nuclear activities, regardless of location, conform to safety standards as well as to facilitate the harnessing of safety capabilities around the globe in an effective and efficient manner. (Meserve, 2009: 106)

Yet he concludes that this is unlikely to be realizable partly because the local population near a reactor will want reassurance from its local safety authority, not some distant international organization. Moreover, not only will states have the usual concerns about loss of sovereignty, but given the strategic importance of energy supplies they would be reluctant to give an international body the power to shut down, for safety reasons, a vital component of their electricity grid. Finally, the safety regime for any country must fit its national legal, economic and cultural circumstances if it is to be truly effective.

Even making the existing rules mandatory seems unlikely to work. Beyond the IAEA Safety Fundamentals, which are assumed to be incorporated in the CNS, it is difficult to imagine making the IAEA's Safety Standards and Guides legally binding as they are subject to constant revision. They are not applicable in all cases to all types of existing, much less future technology, and they are often open to interpretation (especially the Guides) in terms of how a state might comply with their requirements. The Safety Fundamentals could be made specifically legally binding, but the requirements and guides (that is, the Safety Standards series) below

Adherence to Nuclear Safety Conventions by SENES States

State	Convention on Nuclear Safety	Convention on Early Notification of a Nuclear Accident	Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency	Joint Convention on the Safety of Spent Fuel Management and Radioactive Waste Management	Vienna Convention on Civil Liability for Nuclear Damage*
Albania	Unsigned	In force	In force	Unsigned	Unsigned
Algeria	Signed	In force	In force	Unsigned	Unsigned
Bahrain	Unsigned	Unsigned	Unsigned	Unsigned	Unsigned
Bangladesh	In force	In force	In force	Unsigned	Unsigned
Belarus	In force	In force	In force	In force	In force
Egypt	Signed	In force	In force	Unsigned	In force
Ghana	Signed	Unsigned	Unsigned	Unsigned	Unsigned
Indonesia	In force	In force	In force	Signed	Unsigned
Iran	Unsigned	In force	In force	Unsigned	Unsigned
Italy*	In force	In force	In force	In force	In force
Jordan	In force	In force	In force	Unsigned	Unsigned
Kazakhstan	Signed	Unsigned	Unsigned	Signed	Unsigned
Kenya	Unsigned	Unsigned	Unsigned	Unsigned	Unsigned
Kuwait	In force	In force	In force	Unsigned	Unsigned
Libya	In force	In force	In force	Unsigned	Unsigned
Malaysia	Unsigned	In force	In force	Unsigned	Unsigned
Mongolia	Unsigned	In force	In force	Unsigned	Unsigned
Morocco	Signed	In force	In force	In force	Signed
Namibia	Unsigned	Unsigned	Unsigned	Unsigned	Unsigned
Nigeria	In force	In force	In force	In force	In force
Oman	Unsigned	In force	In force	Unsigned	Unsigned
Philippines	Signed	In force	In force	Signed	In force
Poland	In force	In force	In force	In force	In force
Qatar	Unsigned	In force	In force	Unsigned	Unsigned
Saudi Arabia	Unsigned	In force	In force	Unsigned	Unsigned
Senegal	In force	In force	In force	In force	In force
Syria	Signed	Signed	Signed	Unsigned	Unsigned
Thailand	Unsigned	In force	In force	Unsigned	Unsigned
Tunisia	Signed	In force	In force	Unsigned	Unsigned
Turkey	In force	In force	In force	Unsigned	Unsigned
United Arab Emirates	In force	In force	In force	In force	Unsigned
Venezuela	Unsigned	Unsigned	Unsigned	Unsigned	Unsigned
Vietnam	Unsigned	In force	In force	Unsigned	Unsigned

Legend

Unsigned	(white)
Signed	(grey)
In force	(teal)

* Italy has ratified the *1960 Paris Convention on Nuclear Liability* and the *Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention*, thereby obliging it to be bound by the constraints of the *1963 Vienna Convention*.

Source: IAEA (2009g)

these broad principles would remain non-mandatory. Even if the whole array of IAEA nuclear safety standards was made legally binding it is unlikely that compliance would be any greater without the addition of some enforcement mechanism, which is unlikely to gain the approval of states. Moreover, an egregious safety record is less likely to be due to wilful intent than a lack of government attention to the problem, poor national governance generally, substandard technical or institutional capacity and insufficient funds — which are the critical roadblocks. All of these problems are better solved with international technical assistance than with international enforcement.

Nonetheless, there are certain activities, such as peer reviews and IAEA review services, which could be made legally binding, either through a protocol to the CNS or a separate agreement. One could envisage a system analogous to nuclear safeguards inspections but which would focus on monitoring and assessing the adequacy of the national nuclear regulator. An amendment to the CNS, as suggested by Richard Meserve, could achieve this purpose (Meserve, 2009: 106). Amending the CNS is, however, extraordinarily difficult, as its negotiators intended. An amendment may be adopted by consensus at a review meeting or by two-thirds majority at a specially convened diplomatic conference. Any amendment adopted requires subsequent ratification, acceptance, approval or confirmation by each party for it to be bound by it. A separate, new agreement appears to be a more promising route.

Another option for implementing more rigorous, binding safety and security principles is regional arrangements. None of the existing international treaties prohibit states from cooperating with other states in their region to enforce higher safety standards. The European Union made a failed attempt at such a regional regime, but the failure was in part due to deep divisions among member states about whether nuclear energy should be pursued at all. Such considerations are unlikely to prevail in other regions — such as Asia, Latin America and the Middle East — where nuclear energy is less controversial.

The current system of review meetings for the main treaties appears to work well and attempts are being made to improve them further. There are, however, two separate nuclear plant peer review systems and two separate incident notification systems, run by the IAEA and WANO respectively. The lack of integration creates duplication of effort, unnecessary expense and lost opportunities. Consideration should be given to amalgamating these efforts in order to strengthen nuclear learning overall.

The prospects of a nuclear revival, even one restricted to the existing nuclear energy states, plus a few new entrants, will place strain on global governance of nuclear safety at key points, but mostly will place added responsibilities and burdens on the IAEA. Above all, that Agency and the multitudinous treaties, measures and programs for which it has responsibility, must be given the means to ensure the highest nuclear safety standards and performance worldwide.

In 2010-11 the Agency will spend 13 percent of its total annual budget on nuclear safety (IAEA, 2009o: 19). IAEA Major Program 3 for Nuclear Safety and Security is funded at approximately €90 million. This includes €25.1 million for core safety-related activities out of the regular budget and €29.4 million for Technical Cooperation projects funded by voluntary contributions. By contrast, only €3.2 million is spent on nuclear security in the core budget, while capacity-building projects are covered by €19.9 million from the voluntary Nuclear Security Fund (see Part 3 of this report for details). Currently there are 178 safety-related TC projects underway, the largest number in regulatory infrastructure for radiation and waste safety (50), but with large numbers in the regulatory infrastructure for nuclear safety (34), operational safety (15) and safe predisposal and disposal of radioactive waste (15). There is, however, only one project on fuel cycle facility safety and a mere ten on safety assessment of nuclear facilities (IAEA, 2009n).

The budget for 2010-11 notes that there will be an anticipated three-fold increase in the number of technical cooperation projects in 2009-2011 focused on "aspects related to the introduction of nuclear power," presumably mean assisting new entrants. This will meet increased demands from member states "in a cross-section of Agency activities" for support in such areas as energy planning, nuclear law and regulations, safety culture, site selection, human resources development, knowledge management, plant management, public outreach, waste management and decommissioning (IAEA, 2009o: 1). There is a continuing need for financial support from member states for this vital activity

Recommendations

- **Establish an IAEA program to promote the earliest possible accession by potential new nuclear energy states to all nuclear safety-related international conventions and protocols** (this could be modeled on the campaign mounted for promoting the Additional Protocol which involved targeted regional workshops; in this case West Africa, North Africa and the Middle East should be particular targets).
- **Strengthen the implementation of the Convention on Nuclear Safety** by:
  - Involving the IAEA more directly in the national reporting peer review system as a "peer," including by having it review national reports and participate in the country groups;
  - Making the reporting system more transparent to the public, including by posting national reports on the IAEA website;
  - Broadening the scope of national reports to include — in addition to an account of measures taken to comply with the convention as at present — a national nuclear safety self-assessment and a regulatory self-assessment;[54]
  - Defining the meaning of regulatory independence and crafting precise recommendations on how states should protect it; and
  - Concluding separate legal instruments dealing with the safety of fuel cycle facilities and research reactors.
- **Make peer and IAEA review activities mandatory**, by amending the CNS or other means such as through agreement at a review meeting. Possibilities include:
  - An operational safety peer review of each nuclear power plants every five years, either by OSART or WANO or jointly (WANO's current target is one every six years);
  - Immediate OSART or WANO peer reviews of old nuclear reactors that receive life extensions;
  - A periodic safety review by the national regulator every ten years (the IAEA currently recommends this); and
  - An Integrated Regulatory Review mission by the IAEA every ten years (along with appropriate IAEA resources and personnel to ensure this happens).
- **Fix the currently inadequate international operating feedback/ lessons learned process** by:
  - Establishing a Global Nuclear Safety Network, led by the IAEA, as proposed by the 2008 Report of the Commission of Eminent Persons on the Future of the Agency (IAEA, 2008d: 25), involving reactor vendors, operators, regulators, and all other stakeholders in nuclear safety, to facilitate the freest possible exchange of nuclear safety experience. This should be more than just a web-based network and involve a significant strengthening of the IAEA's role as information hub;[55]
  - Strengthening the IAEA's own capacity to analysis, synthesize and disseminate lessons learned from the international feedback process;
  - Establishing a joint IAEA/WANO peer review processes and missions and including an IAEA expert in each mission, with due protection of commercial proprietary information; and
  - Combining the IAEA/NEA and WANO incident reporting processes and databases as a joint venture, again with due protection of commercial proprietary information.
- **Establish a true international nuclear regulators organization with universal membership** to supplement the current self-appointed "clubs" and replace the relatively brief and informal regulators

meetings during IAEA General Conferences. Such a body will allow nuclear safety regulators to exchange operating experience and best practice systematically and regularly outside the formal treaty processes. This should build on but take further IAEA efforts begun in 2008 to establish an international network of regulators (IAEA, 2009i: 3).

- **Mandate the IAEA to coordinate international assistance to new nuclear energy states**, including that currently offered by other international bodies, governments and reactor vendors, to help them establish the best possible legislative, regulatory, institutional and infrastructural bases for operating nuclear power reactors.
- **Continue to pursue the harmonization of safety standards for new reactor designs**, especially through the MDEP process.
- **Mount a joint campaign by the IAEA and the OECD/NEA to increase accessions to the various nuclear liability instruments** to enable them to enter into force and trigger the provision of the necessary international funding for nuclear accident compensation; the two organizations should work together to decrease fragmentation of the regime.
- **Increase funding for nuclear safety beyond the current eight percent of the IAEA budget and make it part of the IAEA regular budget** (MacLachlan, 2007a: 11).
- **Link IAEA and other international technical assistance and cooperation in establishing new nuclear energy programs to the recipient's acceptance and implementation of high safety standards and establishment of an appropriate national regulatory system**; nuclear suppliers in particular have the leverage to do this as they can discriminate against uncommitted nations in a way that the IAEA for political reasons cannot. The regime is largely functioning in this way already, so it is really a matter of the connection between assistance and safety being made more explicit.

Appendix

OSART Missions in States with Currently Operating Power Reactors

Country	Operating Reactors	Missions	Year of Mission
Argentina	2	1	97
Armenia	1	0	
Belgium	7	1	07
Brazil	2	5	85, 89, 92, 02, 03
Bulgaria	2	6	90, 90, 91, 91, 95, 99
Canada	18	3	87, 90, 04
China	11	9	89, 90, 91, 93, 96, 97, 01, 04, 05
Czech Republic	6	8	89, 90, 91, 95, 96, 00, 01, 01
Finland	4	3	86, 90, 07
France	59	21	85, 88, 92, 92, 93, 94, 95, 96, 98, 98, 99, 00, 02, 03, 03, 04, 05, 06, 07, 08, 09
Germany	17	6	86, 87, 87, 91, 04, 07
Hungary	4	2	88, 01
India	17	0	
Japan	53	5	88, 92, 95, 04, 09
Korea, Republic of	20	6	83, 86, 89, 94, 97, 07
Lithuania	1	2	95, 06
Mexico	2	4	86, 87, 87, 97
Netherlands	1	3	86, 87, 05
Pakistan	2	5	85, 89, 96, 99, 04
Romania	2	3	90, 93, 05
Russian Federation	31	6	89, 91, 91, 93, 05, 08
Slovakia	4	5	90, 91, 93, 96, 06
Slovenia	1	3	84, 93, 03
South Africa	2	3	89, 89, 91
Spain	8	4	87, 90, 98, 02
Sweden	10	6	86, 88, 89, 91, 08, 09
Switzerland	5	4	94, 95, 99, 00
Taiwan	6	0	
Ukraine	15	13	88, 94, 94, 95, 95, 95, 96, 96, 03, 04, 06, 07, 08
United Kingdom	19	3	89, 92, 94
United States	104	6	87, 89, 92, 00, 05, 08

Source: IAEA (2009e)

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Endnotes

1 The safety regimes for research reactors and radioactive sources are considered in Shull, 2008.

2 Ionizing radiation is that which has enough energy to remove electrons from neutral atoms or molecules that it passes through, creating ions. The chemical changes resulting from ionized molecules can upset the natural chemical reactions that take place in living cells and can cause biological effects (Tammemagi and Jackson, 2009: 39 and 241).

3 The principal hazards at an enrichment plant are chemical hazards result from the handling of compounds of uranium in soluble form, such as UF6 and uranyl fluoride, rather than radiological hazards. Hydrogen fluoride, which can be very dangerous if inhaled, is the principal inhalation hazard at an enrichment plant. These hazards are controlled by plant design and administrative controls to confine soluble uranium compounds. The radiological hazards are relatively low and containers of natural, enriched, and depleted uranium can be handled without additional shielding. Requirements for shipping UF6 are generally equivalent to requirements for shipping non-radioactive corrosive materials (NRC, 2009d).

4 In March 2006 there was a "near-criticality" incident involving HEU, presumably intended for weapons purposes, at an enrichment facility in Erwin, Tennessee (NRC, 2008b).

5 See comments of ACRS member Ed Lyman, senior scientist at the Union of Concerned Scientists (Dolley, 2008: 6).

6 See chart in Smith, 2006: 172.

7 For a brief description of incidents in the civilian nuclear industry to 1998, see Ramsey and Modarres, 1998: 105-136.

8 In 2005 the Tokyo Electric Company was found to have falsified reactor data. As Japanese Nuclear Safety Commissioner Atsuyuki Suzuki has noted, perhaps of "greater moment" than the technical aspects of nuclear accidents is the "procedural aspects of safety such as regulatory frameworks and accountability to society". What has been revealed in the recent nuclear-related events in Japan, he says, "is that this second type of safety issue is a real concern" (Suzuki, 2007: 139).

9 The WNA's Steve Kidd notes that "Nuclear industry people often rest under the illusion that their business is the only one under attack by strong opponents, engendering a feeling of isolation and supreme defensiveness" (Kidd, 2008: 65).

10 As the Nuclear Energy Agency notes, the old policy was one of "decide, announce and defend" (OECD/NEA, 2008: 352). While in most OECD countries this has changed over the last three decades, in Eastern Europe the concept of public stakeholders was non-existent under communism and has taken decades to emerge since. In non-OECD countries like China and India the concept is still emerging. The WNA's Steve Kidd notes that "the early days of the industry were marked by a degree of arrogance in public communications" (Steve Kidd, 2008: 63).

11 On December 22, 2008, a retention pond wall collapsed at Tennessee Valley Authority's (TVA) Kingston plant in Harriman, Tennessee, releasing a combination of water and fly ash that flooded 12 homes, spilled into nearby Watts Bar Lake, contaminated the Emory River, and caused a train wreck. Officials said four to six feet of material escaped from the pond to cover an estimated 400 acres of adjacent land. A train bringing coal to the plant became stuck when it was unable to stop before reaching the flooded tracks. Hundreds of fish were floating dead downstream from the plant. Water tests showed elevated levels of lead and thallium (Sourcewatch, 2009).

12 Risk informed approaches identify and focus remedial attention on the riskiest activities and parts of a plant.

13 Such measures were approved by the IAEA Board of Governors in March 1960.

14 The Statute describes its role as being: "to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the UN and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to lives and property (including such standards for labour conditions), and to provide for the application of these standards to its

own operations as well as to the operations making use of materials, services, equipment, facilities, and information made available by the Agency or at its request or under its control or supervision; and to provide for the application of these standards, at the request of the parties, to operations under any bilateral or multilateral arrangement, or, at the request of a State, to any of that State's activities in the field of atomic energy" (IAEA, 1957: Art. III.A.6). Curiously, the Agency is mandated by its Statute to require the observance of the Agency's health and safety standards in any facility to which it has been asked to apply nuclear safeguards to verify the non-diversion of nuclear material to military purposes (IAEA, 1957: Art. XII.A.1 and 2). Moreover, safeguards inspectors are charged with determining compliance with such standards. This language was devised in an era when safeguards were voluntary. With the advent in 1970 of the NPT, which required that safeguards be accepted by all non-nuclear weapon states parties, these health and safety requirements appear to have become a dead letter. Currently safeguards inspectors are not expected to report on health and safety matters, apart from those that may directly affect them in the performance of their safeguards duties.

15 Currently no states have such sites, although some do remove spent fuel and waste to centralized storage pending final disposition (for further details see nuclear waste section of this report).

16 Another document on which the treaty drew was the "Draft Safety Fundamentals – the Principles of Radioactive Waste Management" prepared at the time under the RADWASS program.

17 For instance the Agency prepares legal advice about changes to the way the CNS is implemented and whether or not a treaty amendment is required. See MacLachlan 2008d: 17.

18 Canada, France, Germany, Italy, Japan, the United Kingdom and the United States.

19 Additional reports may be publically available through various government websites, or may have been previously available and then taken down.

20 France, until recently, was an exception, being relatively non-transparent in terms of its own public where nuclear safety was concerned, but has recently taken steps to improve this record. In December 2007 France's Institute of Radiological Protection and Nuclear Safety (IRSN) for the first time released one of its reports, on the safety of Electricité de France's reactor fleet in 2007, to the public. Director General Jacques Repussard said the publication could help stakeholders and public better understand the "stakes" of nuclear power plant safety (*Nuclear News Flashes*, 2008; IRSN, 2008).

21 The following account draws mostly on Gonzáles, 2002: 284-285.

22 These include a Safety Reports Series, a Safety Series, a Services Series, a Technical Documents Series, a Radiological Assessment Reports Series and the International Nuclear Safety Advisory Group Series. The IAEA also issues the Provisional Safety Standards Series, the Training Course Series, the IAEA Services Series, a Computer Manual Series, Practical Radiation Safety Manuals, Practical Radiation Technical Manuals and Handbook on Nuclear Law.

23 Other bodies less centrally involved include the Food and Agricultural Organization, the International Labor Organization, the Pan-American Health Organization and the World Health Organization.

24 Private meeting with IAEA official, October 2008.

25 For a detailed analysis of India's poor safety standards, see Ramana, 2009.

26 Private communication with WANO, December 2009.

27 Information from Canadian Nuclear Safety Commission, Ottawa, November 2009.

28 Private communication with WANO, December 2009.

29 The OECD has 30 members: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and the United States. The only two OECD members not part of the NEA are New Zealand and Poland.

30 Current participating states are China, Indonesia, Japan, Republic of Korea, Malaysia, the Philippines, Singapore, Thailand and Vietnam; Pakistan and Bangladesh are associated partner states; Australia, France, Germany and the US are supporting states (ANSN, 2009).

31 Participants include Argentina, Brazil, Chile, Cuba, Mexico, Spain and Uruguay.

32 The Kemeny Commission into Three Mile Island had suggested that INPO might be the appropriate body to establish a program that specifies appropriate safety standards including those for management, quality assurance, and operating procedures and practices, and that conducts independent evaluations (Kemeny, 1979: 68). INPO sets performance objectives, criteria, and guidelines industry-wide for nuclear power plant operations, and is intended to promote operational excellence and improve the sharing of operational experience between nuclear power plant operators. INPO is funded entirely by the US nuclear industry. INPO conducts plant evaluations at nuclear sites and identifies both strengths and areas for improvement which are intended to be shared with other nuclear other nuclear operators.. The results of INPO plant evaluations are not shared with the public, and any related information shared within the nuclear industry does not typically include the name of the plant. INPO assigns a score between one and five to each nuclear site following the evaluation, where an "INPO 1" is the most favorable score, and an "INPO 5" is an indicator of a nuclear site with significant operational problems (INPO, 2009).

33 WENRA currently has two working groups; the Reactor Harmonisation Working Group (RHWG) and Working Group on Waste and Decommissioning (WGWD). In 2008 the former began "formulation of safety objectives for new reactors" (WENRA, 2009).

34 Much of the background for this section draws on commissioned research for this project published in Aaron Shull, "The Global Nuclear Safety and Security Regimes," *Nuclear Energy Futures Paper,* No. 2, November 2008 and an unpublished commissioned paper by Aaron Shull and Justin Alger. "The Global Nuclear Safety and Security Regimes: Compliance and Implementation," August 2009.

35 The Parliamentary House of Lords Science and Technology Committee said in a report released on June 3, 2007 that the British government's proposed institutional arrangements for managing the next phase of the country's radioactive waste activity as "incoherent and opaque" and demanded a truly independent body be established rather than an advisory group (House of Lords, 2007).

36 The following is adapted largely from IAEA, 2004.

37 For information on the negotiation history see Friedrich and Finucane, 2001.

38 The following paragraph adapted from Gonzáles, 2004: 290-291.

39 The following paragraph adapted from IAEA, 2003b: 91.

40 See Part 3 of this report for details.

41 One of its activities has been to convene the Uranium Concentrates Industry Taskforce (UCTF) to discuss common means of complying with international transport regulations and guidelines, as well as to take advantage of other joint industry experience (Sermage, 2008).

42 Canada Deuterium Uranium reactor.

43 Water-cooled, water-moderated reactor.

44 It decided in 2007 to expand its scope to include nuclear power programs (Stellfox, 2007).

45 ENSREG was established in 2007 by European Commission Decision 2007/530 which also established the European High Level Group on Nuclear Safety and Waste Management.

46 The members of IACRNA, in addition to the IAEA, include: the European Commission, European Police Office (EUROPOL), Food and Agriculture Organization of the United Nations (FAO), International Civil Aviation Organization (ICAO), International Maritime Organization (IMO), United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), International Criminal Police Organization (INTERPOL), Organisation for Economic Co-operation and Development (OCED)/ Nuclear Energy Agency (NEA), Pan American Health Organization (PAHO), United Nations Environment Programme (UNEP, United Nations Office for the Co-ordination of Humanitarian Affairs (UN/OCHA), United Nations Office for Outer Space Affairs

(UN/OOSA), World Health Organization (WHO) and World Meteorological Organization (WMO).

47 In the case of the US, according to the Congressional Budget Office, the subsidy probably amounts to less than one percent of the levelized cost of new nuclear capacity (cited in Kidd, 2009).

48 While there are other examples of international law relating to transboundary liability, such as the 1969 Civil Convention on Oil Pollution Damage or the 1972 Convention on Damage Caused by Space Objects, nuclear power is unique in the field of energy production in having such an international liability regime. This may change in the future, since state responsibility for transboundary damage is a dynamic area of international law, but at present nuclear is in a league of its own.

49 The 1957 Price-Anderson Act, renewed in 2005 for 20 years, mandates two layers of insurance coverage for all types of US nuclear facilities. The first layer involves purchase by the operator of $300 million liability cover which is provided by two private insurance pools. The second is jointly provided by all reactor operators funded through retrospective payments of up to $112 million per reactor per accident collected in annual installments of $17.5 million (adjusted with inflation). Combined the total insurance comes to over $10 billion. The Department of Energy also provides $10 billion for its own facilities. Beyond this cover, and irrespective of fault the US Congress, as insurer of last resort, must decide how compensation is provided in the event of a major accident (cited in Kidd, 2009).

50 See also Tetley, 2006.

51 The third such Regional Workshop on Liability for Nuclear Damage was held in South Africa in February 2008. The fourth was held early in Abu Dhabi in the UAE in December 2009 for countries that have expressed an interest in launching a nuclear power program (IAEA, 2009f: 12; IAEA, 2009q).

52 For instance the Safety Requirements document explicitly states in its introduction that it applies primarily to water-cooled reactors (Meserve, 2009: 108).

53 Details below from ElBaradei, 2009a.

54 Canada was one of the first to include regulatory matters in its national report.

55 Initiatives like the International Conference on Topical Issues in Nuclear Installations, held in Mumbai, India in November 2008, are useful in having the nuclear safety community focus on current topics of concern and could become an activity of the Global Network.

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Acronyms and Abbreviations

ABACC	Argentine-Brazilian Agency for Accounting and Control
ABWR	Advanced Boiling Water Reactor
ACR	Advanced CANDU Reactor
ADB	Asian Development Bank
AECL	Atomic Energy of Canada Limited
AFCI	Advanced Fuel Cycle Initiative (GNEP)
AFCONE	African Commission on Nuclear Energy
AFNI	L'Agence France Nucléaire International (France)
AIP	Advance Information Package (OSART)
ALARA	as low as reasonably achievable
ANDRA	Agence nationale pour la gestion des déchets radioactifs/ National Agency for the Management of Radioactive Waste (France)
ANWFZ	African Nuclear Weapon-Free Zone Treaty
AP	Additional Protocol (IAEA)
ASE	AtomsTroyExport (Russia)
ASME	American Society of Mechanical Engineers
ASN	Nuclear Safety Authority (France)
AU	African Union
BADEA	Arab Bank for Economic Development in Africa
BMWG	Border Monitoring Working Group (IAEA)
BNFL	British Nuclear Fuels Limited
BOG	Board of Governors (IAEA)
BSS	Basic Safety Standards (IAEA)
BWR	boiling water reactor
CACNARE	Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency
CANDU	Canada Deuterium Uranium reactor
CBO	Congressional Budget Office (US)
CCGT	combined cycle gas turbine
CCPNM	Convention on the Physical Protection of Nuclear Material
CCS	carbon capture and storage
CD	Conference on Disarmament (UN)
CDM	clean development mechanism
CEA	Commissariat à l'Énergie Atomique/ Atomic Energy Commission (France)
CEC	Commission of the European Communities (now EC)
CENNA	Convention on Early Notification of a Nuclear Accident
CFDT	Confédération Français Démocratique du Travail/ French Democratic Confederation of Workers
CHP	combined heat and power
CIA	Central Intelligence Agency (US)
CIRUS	Canada India Research US reactor
CISAC	Committee on International Security and Arms Control
CNRA	Committee on Nuclear Regulatory Activities (OECD/NEA)
CNS	Convention on Nuclear Safety
CNSC	Canadian Nuclear Safety Commission (Canada)
COGEMA	Compagnie Général des Matièrere nucléaire/ General Company for Nuclear Materials (France)
CORDEL	Working Group on Cooperation in Reactor Design Evaluation and Licensing (WNA)
CSA	Comprehensive Safeguards Agreement (IAEA)
CSS	Commission on Safety Standards (IAEA)
CTBT	Comprehensive Nuclear Test Ban Treaty
CTR	Cooperative Threat Reduction
DBT	design basis threat
DOE	Department of Energy (US)
DTI	Department of Trade and Industry (UK)
DUPIC	direct use of spent PWR fuel in CANDU
EC	European Commission
EDF	Electricité de France
EIA	Energy Information Agency (DOE)
ENAC	Early Notification and Assistance Conventions
ENATOM	Emergency Notification and Assistance Technical Operations Manual
ENEN	European Nuclear Education Network
ENSREG	European Nuclear Safety Regulators Group
EPAct	US Energy Policy Act (2005)
EPR	Evolutionary Power Reactor (formerly European Power Reactor)
EPREV	Emergency Preparedness Review Teams (IAEA)
EPRI	Electric Power Research Institute
ERBD	European Bank for Reconstruction and Development (EC)
ERNM	Emergency Response Network Manual
EUP	enriched uranium product
Euratom	European Atomic Energy Community (EC)
FAO	Food and Agricultural Organization of the United Nations
FBR	fast breeder reactor
FMCT	Fissile Material Cut-Off Treaty
FMT	Fissile Material Treaty
FOAK	first-of-a-kind
FP&L	Florida Power and Light
G8	Group of Eight
GAO	Government Accountability Office (US)
GCC	Gulf Cooperation Council
GCR	gas-cooled reactors
GDF	Gaz de France
GDP	gross domestic product
GHG	greenhouse gases
GIF	Generation IV International Forum
GNEP	Global Nuclear Energy Partnership
GPP	Global Partnership Program (G8)
GTCC	gas turbine combined cycle
HEU	highly enriched uranium
IACRNA	Inter-Agency Committee on Response to Nuclear Accidents
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICJ	International Court of Justice
ICNND	International Commission on Nuclear Nonproliferation and Disarmament
ICRP	International Commission on Radiological Protection
ICSANT	International Convention for the Suppression of Acts of Nuclear Terrorism
IDB	Inter-American Development Bank
IEA	International Energy Agency (OECD)
IEC	Incident and Emergency Centre
ILO	International Labor Organization
IMO	International Maritime Organization
INES	International Nuclear and Radiological Event Scale
INF	irradiated nuclear fuel
INFA	International Nuclear Fuel Agency
INIR	Integrated Nuclear Infrastructure Review (IAEA)
INLEX	International Expert Group on Nuclear Liability
INMM	Institute of Nuclear Materials Management
INPO	Institute of Nuclear Power Operations (US)
INPRO	International Project on Innovative Nuclear Reactors and Fuel Cycles
INRA	International Nuclear Regulators Association
INSAG	International Nuclear Safety Group (IAEA)
INSServ	International Nuclear Security Advisory Service (IAEA)
INSSP	Integrated Nuclear Security Support Plan (IAEA)
INTERPOL	International Criminal Police Organization

IPCC	Intergovernmental Panel on Climate Change
IPFM	International Panel on Fissile Materials
IPPAS	International Physical Protection Advisory Service (IAEA)
IRRS	Integrated Regulatory Review Service
IRS	Incident Reporting System (IAEA/NEA)
IsDB	Islamic Development Bank
ISIS	Institute for Science and International Security
ISSAS	International SSAC Advisory Service (IAEA)
ISSC	International Seismic Safety Centre
ITDB	Illicit Trafficking Database (IAEA)
ITE	International Team of Experts (IAEA)
ITER	International Thermonuclear Experimental Reactor
JREMPIO	Joint Radiation Emergency Management Plan of the International Organizations
JSW	Japan Steel Works
KEPCO	Korea Electric Power Corporation
KINS	Korea Institute of Nuclear Safety
LEU	low enriched uranium
LIS	laser-isotope separation
LNG	Liquid Natural Gas
LWGR	light water-cooled graphite-moderated reactor
LWR	light water reactor
MCIF	Major Capital Investment Fund (IAEA)
MDEP	Multinational Design Evaluation Program
MESP	Multilateral Enrichment Sanctuary Project
MIT	Massachusetts Institute of Technology
MOI	Ministry of Industry (Vietnam)
MOST	Ministry of Science and Technology (Vietnam)
MOX	Mixed Oxide Fuel
NAS	National Academy of Sciences (US)
NASA	National Aeronautics and Space Administration (US)
NATO	North Atlantic Treaty Organization
NCACG	National Competent Authorities' Coordinating Group
NEA	Nuclear Energy Agency (OECD)
NEF	Nuclear Energy Futures
NEI	Nuclear Energy Institute
NEPIO	Nuclear Energy Programme Implementing Organization
NERC	North American Electric Reliability Corporation
NERS	Network of Regulators of Countries with Small Nuclear Programmes
NESA	Nuclear Energy System Assessment
NEWS	Nuclear Events Web-based System
NGO	non-governmental organization
NGSI	Next Generation Safeguards Initiative
NIA	Nuclear Industry Association (UK)
NIF	National Ignition Facility (US)
NII	Nuclear Installations Inspectorate (UK)
NJFF	Nuclear Power Joint Fact Finding (Keystone Center)
NNWS	non-nuclear weapon state (NPT)
NPT	Nuclear Nonproliferation Treaty
NRC	Nuclear Regulatory Commission (US)
NRU	National Research Universal reactor (Canada)
NSEL	Nuclear Security Equipment Laboratory (IAEA)
NSF	Nuclear Security Fund (IAEA)
NSG	Nuclear Suppliers Group
NSSG	Nuclear Safety and Security Group (IAEA)
NTI	Nuclear Threat Initiative
NTM	National Technical Means
NUSS	Nuclear Safety Standards (IAEA)
NWFZ	nuclear-weapon-free zone
NWMO	Nuclear Waste Management Organization (Canada)
NWPA	US Nuclear Waste Policy Act (1982)
NWS	nuclear weapon state (NPT)
O&M	operation and maintenance
OECD	Organisation for Economic Co-operation and Development
OEF	operating experience feedback
OER	Operating Experience Reports
OSART	Operational Safety Review Teams (IAEA)
PBMR	Pebble Bed Modular Reactor
PHWR	pressurized heavy water reactor
PIU	Performance and Innovation Unit (UK Cabinet Office)
POC	Point of Contact
PRA	Probabilistic Risk Assessment
PRIS	Power Reactor Information System
PROSPER	Peer Review of the effectiveness of the Operational Safety Performance Experience Review
PSI	Proliferation Security Initiative
PSR	Periodic Safety Review
PUREX	Plutonium Uranium Extraction
PWR	pressurized water reactor
RADWASS	Radioactive Waste Safety Standards (IAEA)
RANET	Response Assistance Network
RBMK	Reaktor Bolshoy Moshchnosti Kanalniy (High Power Channel-Type Reactor)
RDD	radiological dispersal device
REPLIE	Response Plan for Incidents and Emergencies (IAEA)
RWC	Radiological Weapons Convention
SAG	Senior Advisory Group (IAEA)
SAGSI	Standing Advisory Group on Safeguards Implementation (IAEA)
SAGSTRAM	Standing Advisory Group on the Safe Transport of Radioactive Materials (IAEA)
SAL	Safeguards Analytical Laboratory (IAEA)
SEDO	Safety Evaluation During Operation of Fuel Cycle Facilities (IAEA)
SENES	Survey of Emerging Nuclear Energy States
SILEX	separation of isotopes by laser excitation
SMR	small- and medium-sized reactor
SOARCA	State-of-the-Art Reactor Consequences Analysis
SOER	Significant Operating Experience Reports
SOLAS	International Convention for the Safety of Life at Sea
SQP	Small Quantities Protocol (IAEA)
SSAC	State System of Accounting and Control
STUK	Säteilyturvakeskus (Radiation and Nuclear Safety Authority, Finland)
SWU	separative work unit
TCP	Technical Cooperation Programme (IAEA)
TRC	Technical Review Committee (IAEA)
TTA	Nuclear Trade and Technology Analysis unit (IAEA)
TVO	Teollisuuden Voima Oyj (Finland)
UAE	United Arab Emirates
UNFCCC	United Nations Framework Convention on Climate Change
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
URENCO	Uranium Enrichment Company
USSPC	ultra-supercritical pulverized coal
VARANSAC	Vietnam Agency for Radiation Protection and Nuclear Safety Control
VERTIC	Verification Research, Training and Information Centre
VVER	Vodo-Vodyanoi Energetichesky Reactor (Russia)
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association
WGRNR	Working Group on Regulation of New Reactors (CNRA)
WHO	World Health Organization (UN)
WINS	World Institute of Nuclear Security
WMD	weapons of mass destruction
WMO	World Meteorological Organization
WNA	World Nuclear Association
WNTI	World Nuclear Transport Institute
WNU	World Nuclear University (WNA)

About CIGI

The Centre for International Governance Innovation is an independent, nonpartisan think tank that addresses international governance challenges. Led by a group of experienced practitioners and distinguished academics, CIGI supports research, forms networks, advances policy debate, builds capacity, and generates ideas for multilateral governance improvements. Conducting an active agenda of research, events, and publications, CIGI's interdisciplinary work includes collaboration with policy, business and academic communities around the world.

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