United States and France: A Regulatory Perspective

by

Matthew D. Aichele

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Signature of Author...
Department of Nuclear Engineering
May 7, 2004

Certified by...
Andrew C. Kadak
Professor of the Practice
Thesis Supervisor

Accepted by...
Andrew C. Kadak
Chairman, Undergraduate Thesis Committee

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ABSTRACT

Nuclear materials and their uses are regulated differently in countries around the world. In the United States, the Nuclear Regulatory Commission regulates the different commercial and academic uses of nuclear technology, including nuclear power plants. In France, the Direction Générale de la Sûreté Nucléaire et de la Radioprotection (DGSNR) and the Electricité de France (EDF) control the nuclear industry, with the DGSNR controlling most of the regulation and the EDF presiding over the construction.

In this thesis, the two systems of regulation will be reviewed and compared for efficiency and efficacy. Furthermore, those efficiencies will be examined for implications in the technical, social, and economic regimes.

This thesis will review the histories and present-day structures of two different regulatory agencies, propose reasons for the difference, and argue the benefits and shortcomings of each. At first glance, the American regulatory system appears to be in the hands of the lawmakers and founded on a legal basis. The French system, however, emphasizes the scientists and engineers as the regulatory experts and is thus founded more on a scientific and technical foundation.

Thesis Supervisor: Andrew C. Kadak

Title: Professor of the Practice

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In loving memory of my grandparents,

George Aichele

Helen Bernice Aichele

Willis Howard Henry

Merle Althea Henry

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GLOSSARY OF TERMS

Boiling water reactor (BWR) - Nuclear reactor in which water, used as both coolant and moderator, boils in the reactor core. The steam from the boiling water is used to turn the turbine-generator.

Coolant/moderator - Substance used to cool the reactor and to slow neutrons. In most nuclear power plants, water is used for cooling to keep the reactor from getting too hot and to slow down neutrons so they are more likely to cause uranium-235 to fission.

Fossil fuel - Natural, burnable, carbon based substance resulting from millions of years of biological decay of ancient plant and animal matter. Coal, oil, and natural gas are common examples.

Graphite - Pure form of carbon used as a moderator in some nuclear reactors.

Heavy water - Water in which the hydrogen atoms contain one neutron in their nucleus in addition to the characteristic proton.

Kilowatt-hour (kwh) - Energy unit defined as 1,000 watts of electricity for one hour (equivalent to 3,413 Btu).

NRC - Nuclear Regulatory Commission, U.S. agency chartered to develop and administer rules for regulating commercial nuclear applications (including nuclear power plants, medical and industrial uses).

Operating license - Permission given by law to operate something, e.g. a nuclear power plant.

Plutonium - Radioactive element used to produce nuclear energy. It has an atomic number of 94, an atomic weight of 244, and is thus a relatively heavy element. Plutonium is formed by neutron absorption in uranium-238, and like uranium, has two principal isotopes that are fissile. Its symbol is Pu.

Pressurized water reactor (PWR) - Nuclear reactor in which water is kept under pressure in a vessel to prevent boiling. Steam is made in a second vessel.

Regulation - Maintenance of standards of performance through rules.

Uranium - The heaviest element normally found in nature. The fissile isotope uranium-235 is the principal nuclear fuel material used in today's nuclear power reactors. Uranium is a hard, shiny, metallic radioactive element. Its atomic number is 92, its atomic weight is 238, and its symbol is U.

1. History of French System

1.1 Regulatory

France has always celebrated a tradition of involvement regarding nuclear science. First was Becquerel, who discovered natural radioactivity and was awarded the prestigious Nobel Prize in 1903. [1] Later came the research of the Curies, who were the first to isolate the radioactive element radium. Also prominent in French nuclear history and development was the communist physicist, Frédéric Joliot-Curie. During World War II, Joliot-Curie was a key member of the French Resistance charged with the often-dangerous task of hiding all their nuclear secrets from the Germans and organizing the smuggling of sensitive nuclear materials out of France. [2]

After the war ended, Joliot-Curie was instrumental in the founding of the Commissariat á l'Energie Atomique [CEA]. Joliot-Curie was joined by Raoul Dautry, who had served France as the minister of armaments prior to the German invasion. The two men easily convinced Charles de Gaulle that a national agency needed to be created for the advancement of nuclear science. De Gaulle then made the recommendation to the National Assembly who quickly approved the creation of the CEA in 1945. At the creation, the mission of the agency was to "pursue scientific and technical research in the view of using atomic energy in the various domains of science, industry, and national defense." [3] Since this agency was created by the scientists and for the scientists, Joliot-

Curie argued that the agency should be protected from the "whims of ministerial politics." [3] Thus, the CEA was under the responsibilities of the prime minister, and made to be financially independent from other state institutions.

This independence of the nuclear energy program is due largely in part to the respect the French society gives to its scientists and innovators. [4] The French appreciation of the sciences can be witnessed in the way they chose to structure the CEA. The agency was headed equally by two positions. The first position was that of High Commissioner and was filled by a top scientist. The other position was the Administrator General and was filled by a professional administrator. At the inception of the CEA, Joliot-Curie and Dautry were appointed to these two positions, respectively. [3] Thus, the scientist and politician shared responsibility for the development of the French nuclear program.

This equality of leadership in the CEA between the politicians and scientists only lasted the better part of a year. Following de Gaulle's departure from the head of the French government in 1946, French politics experienced a dynamic period. After experiencing over eighteen different prime ministers over the course a decade, [3] the CEA quickly fell out of the public's eye, and perhaps even temporarily out of the minds of the French Parliament. As a result, the scientific minds at the CEA were essentially free to chose their own research and still receive full funding from the French government, due to the financial independence the CEA was granted at its creation.

According to Gabrielle Hecht, "they concentrated on conducting fundamental research in nuclear physics and chemistry, developing large-scale experimental equipment such as reactors and accelerators and prospecting and mining uranium." [3] These areas of research are essential for any country hoping to create a competitive nuclear system. The CEA continued to advance the French nuclear program on its own, due to the intense secrecy with which both the United States and the United Kingdom both guarded their own nuclear research. In fact, the United States protested the placement of Joliot-Curie, a known communist sympathizer, at the head of the CEA. At the rather firm request of United States, Joliot-Curie was removed from his office and replaced by a less controversial Francis Perrin. [3]

Simultaneous with the leadership change at the CEA, the French scientists and engineers began to see the need to initiate development of a large-scale reactor program. This urgency was very much due to the current competitive edge over Germany, both academic and industrial, and an intense drive to keep that edge. Thus, the next action in implementing the large-scale reactor program was choosing the reactor.

1.2 Design Choices

The procedure in standardizing the components for use in the national reactor program and the existence of the French national reactor program itself is indicative of the French inclination toward science-based regulations, as contrasted by the American system of regulation-based science.

The scientists first had to choose the fuel with which they would base their reactor design. The two options available at the time were natural uranium based fuels, or enriched uranium based fuels. The French had access to plenty of natural uranium, due to its colonial territories in Africa. [5] Enriched uranium, however, was not widely available. In fact, in 1950 when this choice was being considered, enriched uranium was not available anywhere. This required the French to build their own uranium enrichment facility, which was an undesirable use of land, funds, and most importantly, time. At the time, there were those among the scientific community who were concerned about the primary reactor's ability to produce both electricity and plutonium. Plutonium was known primarily as bomb fuel, and while it was believed possible to fuel secondary reactors with plutonium, no such reactor had been built and tested. The steering committee in charge of the final decision decided to proceed with the natural uranium based fuels, and curiously, specified a production goal equal to "fifteen kilograms of plutonium within five years". [3]

With the decision to utilize and focus on natural uranium reactors already made, the next logical step was to choose a moderator for the new French reactors. The two options at the time were heavy water and graphite. The French had experimented with heavy water reactors, but due to the difficulty in obtaining heavy water as compared to graphite, the committee decided to use graphite as the moderator. Gabrielle Hecht suggests in her research another possible, more political motive for the graphite choice. "Many of those who had worked on the experimental heavy water reactors were communists," [3] Hecht observed. Since the committee had already expressed a curious interest in producing plutonium, it was expected they would eventually proceed with a French nuclear bomb. Not wanting communist sympathizers involved in such sensitive future projects, it was best to choose the tools in which they had the least experience. Thus a graphite-based moderator was chosen not only for its availability compared to deuterium, but also it's unfamiliarity to the communist sympathizers the French were so intent on keeping out of the project.

Critical design choices out of the way, the CEA decided to begin construction on a prototype reactor in Marcoule and, simultaneously, a plutonium extraction factory. Though the CEA committee had been adamant about these being crucial steps toward a nuclear energy program, it was only after the first prototype reactor, named G1, that the extraction of electricity from the facility was even discussed. This was entirely the work of Pierre Ailleret, the head of a research division at France's new national utility company, Electricité de France (EDF). [3] During these early years of reactor technology, regulatory control was very lax, with the CEA regulating the reactors it was helping to create, with period reports to the appropriate ministers.

Electricité de France was created shortly following World War II. It was, and still is, a state-owned utility company responsible for producing and distributing electricity all across France. As such, the possibility of a new method of generating electricity was of great interest. Thus, it became the EDF who was in charge of the non-nuclear, electricity generating components and the CEA remained in charge of the nuclear-related engineering tasks, such as the fuel rods and the core housing. This dual control worked well for both groups, and the experience the CEA gained from regulating the nuclear aspects of the reactors formed the foundation for the forthcoming national regulatory legislature.

The decree which first formed the regulatory authority and detailed the way in which reactors should be regulated was issued in 1963. This decree created an Interministerial Commission for Basic Nuclear Installations which seized the role of regulator from the CEA. However, given the CEA's fifteen years of experience in regulating and monitoring the research reactors in France, they acted as the technical advisor to the young Interministerial Commission. The Commission, in turn, reports directly to the Ministers of Environment and Industry to assist the Ministers, the executive authority, with informed opinions on the regulations and operation of the basic nuclear installations. [6]

Later, in 1976, the departments of the CEA experienced in nuclear safety and radiation protection were assembled into one central organization, the Institute for Nuclear Safety and Protection (IPSN). Though still associated with the CEA, this new advisory organization assisted and supported the safety authority in regulation and safety matters. [6]

Another organization created by the government, autonomous of any existing agency, was the Office for Protection against Ionizing Radiation (OPRI). This office was exclusively charged with all tasks ensuring public safety and the safety of radiation workers. The OPRI is in charge of controlling and inspecting all radiation protection programs designed with minimizing exposure to the public and verifying compliance with all regulations specific to radiation protection. [6]

Standardization of the French power reactor program is also a product of the national electric utility EDF. In the United States, multiple utilities working independently to design power reactors resulted in differing reactor design choices. Conversely, the singularity of the EDF as France's only electric utility resulted in the standardized reactor design, where all power reactors in France are constructed from the same design. This uniformity throughout all the reactors allows the French to appreciate some unique advantages over the non-standardized American system. [7]

First, the initial safety investigations and safety related matters can be more thoroughly explored when multiple identical reactors exist. Safety and design tests that might otherwise conflict with each other if performed at the same facility can be performed simultaneously at different identical facilities throughout France. Another advantage is that the experiences gained from the design, construction, and operation of one reactor can subsequently be applied to later units. The third advantage that standardization offers is the ability of regulators to concentrate on aspects unique to each specific site, such as the reactor administration, training programs, and ability to safely operate the reactor. If the reactor design has already been shown to be safely operable at numerous other sites, then a deviation from safe operation is more likely to be attributed to operator error rather than a design error.

Standardization is not without its faults, however. Since all units are built to similar specifications and with similar components, a problem at any unit suggests a likely problem at all other units of the same series. This phenomenon will be discussed later with respect to vessel head degradation. Another fault that arises through standardization is the dispute between design constancy and technological innovation. In the event a new reactor technology becomes available, the cost of implementing the necessary design changes to standardize the new technology through all the reactors should not outweigh the advantages in safety or efficiency gained from the technology. [7]

1.3 Economical

For the better part of the decade, the CEA and EDF operated and collected data from the new gas-cooled graphite-moderated reactors at Marcoule and Chinon. It became apparent during this time that the small power density of the natural uranium reactors would greatly increase the capital cost per installed kilowatt, which significantly decreased its economic competitiveness. [3] Simultaneously, an American company Westinghouse was working on the first pressure water reactor (PWR). The prototype was originally intended for submarine propulsion but the potential as a high power density reactor for electricity production was quickly realized. Westinghouse quickly started spreading its new PWR technology throughout Europe, increasing the belief that the original French gas-cooled reactors could never compete, economically, with the fossil-fueled plants. [8]

In 1973, the world faced an oil shock due to warring countries in the Middle East. France, at the time, was up to 76% reliant on foreign oil and drastically wished to reduce that dependence. Nuclear power produced only 2% of the national electricity at that time, but the operation of the plants had proceeded so smoothly that France dedicated itself to expanding the nuclear program and reducing its energy dependence. [9,2] With the PWR technology as the new economic choice for the French fleet of reactors, the CEA and EDF looked to finally implement a large-scale reactor program.

One of the first characteristics that the EDF and CEA both agreed on was standardization, which was discussed in the previous section. If all national reactors are PWR, maintenance and regulations will be focused only on issues pertinent to PWR. Thus, in March 1974, a contract for sixteen PWR units was signed by EDF and Framatome, the new merger of Westinghouse and the French Schneider group. [2] This was the beginning of the modern day French nuclear industry, which separates the construction responsibilities from the fuel management. EDF was selected as the contractor in charge of construction and power delivery, while newly formed CEA-subsidiary Cogema was placed in charge of all fuel management.

1.4 Social Norms

The national acceptance of nuclear energy in France is unlike any other country. One researcher even noted, "In France, unlike in America, nuclear energy is accepted, even popular." [4] What makes the French so accepting and proud of their nuclear energy? It is believed by some that the French people tend to view themselves as independent and thus despised the feeling of depending upon others for their energy needs. Also, the French people tend to support large scientific endeavors, such as the Concorde supersonic jet and the super-fast TGV train. [2]

French government and French science have always been much intertwined. In fact, many top officials and civil servants in France are educated as engineers and scientists at the elite Ecole Polytechnique, a prestigious engineering and science institution run by the state. This national pride in scientists and engineers as natural leaders emerged shortly after the first World War, when many of the state engineers were proclaimed "heroes". [3] Jon Palfreman quotes Claude Mandil, the General Director for Energy and Raw Materials at the Ministry of Industry as saying, "For a long time, in families, the good thing for a child to become was an engineer or a scientist, not a lawyer. We like our engineers and our scientists and we are confident in them." [4] This appreciation of the engineer in French society will later be compared with the ideal of the political American lawyer.

2. History of the US Regulatory System

2.1 Regulatory

The United States' nuclear energy program was born from the use of nuclear weapons in World War II. Shortly after the bombing of Hiroshima and Nagasaki, influential Americans began asking the government to find peaceful applications of this incredible new science. In 1945, the United States Senate commissioned a Special Committee on Atomic Energy to investigate all possible uses of the nuclear technology. To do so, the committee began interviewing prominent scientists knowledgeable in the field as well as energy consultants to question the economic feasibilities of a new type of power production. Alvin M. Weinberg, a nuclear physicist, told the committee "atomic power can cure as well as kill. It can fertilize and enrich a region as well as devastate it. It can widen man's horizons as well as force him back into the cave." [10] Nuclear science was still a very young technology, but many optimistic Americans, both scientists and non-scientists, felt it had wonderful potential, in applications ranging from the practical to the absurd.

Racing to stay ahead of the Soviet Union, the government passed the Atomic Energy Act of 1946. While acknowledging the potential of civilian nuclear research and power generation, this legislation did not allow private commercialization of atomic energy. In fact, this enactment essentially formed a government monopoly. To direct the new atomic energy initiatives around the country, the law also called for the formation of the Atomic Energy Commission (AEC), a committee of five-members. [10]

Seven years later, in 1953, little had been accomplished to advance nuclear energy for civilian purposes. This was starting to change, however, as the nuclear arms race intensified between the United States and the Soviet Union. In fact, the push for swift civilian nuclear progress was not spurred by a current energy need, or even for estimated energy demand. The United States feared that falling behind the Soviet Union in the race to develop nuclear power would be a "severe blow to its international prestige and world scientific dominance." [10] In a speech to the United Nations that same year, President Dwight D. Eisenhower delivered his "Atoms for Peace" agenda, and emphasized that "this greatest of all destructive forces can be developed into a great boon, for the benefit of all mankind." [10] Soon after, Congress passed new legislature called the 1954 Atomic Energy Act. This terminated the government-held monopoly over nuclear energy research and encouraged the growth of a private commercial nuclear industry. The Act was also responsible for the beginning of a regulatory system designed to protect the public from radiation and safety hazards created by nuclear energy facilities and research. Lastly, it called upon the AEC to continue the advancement of the nuclear weapons program.

The AEC believed that the newly encouraged private nuclear energy industry would best be advanced by private companies building and operating their own reactors. In fact, private companies were even encouraged to experiment with various reactor types, and government incentives were provided to make this more feasible for the companies. These incentives included using government labs for power reactor research, and a deferred-cost loan program to make nuclear materials easier to procure and more available.

To handle the new private applications for nuclear reactors, the AEC specified a small staff in charge of creating regulations and designing a licensing procedure complete enough to guarantee maximum safety but flexible so as to allow for the ever-changing technology. The final license design was twofold. The first part consisted of a conditional permit, which companies could obtain by showing with "reasonable assurance" that construction and testing of their reactor would not pose a public risk. The second part of the licensing procedure proceeded simultaneously with the construction, and consisted of a thorough safety analysis assessment for the plant. This two-step procedure was helpful in allowing quick development of nuclear facilities, while still allowing the AEC ample time for safety reviews. [10]

The 1954 Atomic Energy Act instructed the AEC "to encourage widespread participation in the development and utilization of atomic energy for peaceful purposes". [10] Additionally, it charged the AEC with regulating the new industry to protect the public from radiation and health hazards. Thus the responsibility of regulating nuclear power and the duty of promoting its advancement were assigned to the same agency. In a following chapter, these two contrasting responsibilities will prove to be too incompatible for one agency to handle effectively and credibly.

2.2 Obstacles and Opportunities

The next obstacle in the way of private nuclear companies was obtaining sufficient insurance. At the time, private insurance companies realized the risk of a major disaster would never fall to zero yet still offered to insure the companies for a tremendous $60 million per reactor. Though this was substantially more than was currently available to any other industry, company executives still did not feel secure. To help alleviate their fears and encourage industry growth, the government suggested it could provide additional insurance. This idea was realized with the Price-Anderson Act of 1957, which enabled the government to provide an additional $500 million of coverage per reactor.

Following the Price-Anderson Act, the late 1950's and early 1960's did not experience much growth in the nuclear sector. Companies were still contemplating the economic feasibility of construction and operation. One development in 1963 greatly increased the economic potential for power companies. At the time, two major companies were selling nuclear plants, Westinghouse and General Electric. To win a bid with the Jersey Central Power and Light Company, General Electric offered a "turnkey" contract. This implied that General Electric would pay for the construction of the entire plant, and the utility company would merely have to "turn a key" to begin operation of the new facility. Though this actually resulted in GE losing money, they believed it would help stimulate the market and increase their sales. [10]

Shortly after the Jersey Central contract, Westinghouse began also offering "turnkey" contracts to compete with General Electric. This stiff competition resulted in losses for both companies in the hundreds of millions of dollars by the time they stopped offering their "turnkey" contracts. However, it also triggered the beginning of competition in the American nuclear energy market.

This competition peaked in 1967. The following table shows the increase in units ordered for the four-year period 1965-1968.

Table 1. Annual Units Ordered

	Units Ordered	Percentage of total electricity capacity
1965	4	17
1966	20	36
1967	31	49
1968	17	47

In 1967 and 1968, one out of every two kilowatts of capacity ordered by the utilities was from a nuclear reactor. This rapid increase from just two years before placed a heavy burden on the AEC's small regulatory staff. The resulting long delays for licensing approval caused the utilities to lose money while waiting for construction permits. One utility executive criticized the slow licensing procedure for being carried out by "AEC engineers, scientists, and consultants who have no serious economic discipline." [11]

2.3 Safety

As more nuclear facilities were built around the country, and closer to residential areas, the public began asking questions about the safety of the reactors and safeguards against disasters. Since the US had encouraged companies to experiment with different reactor designs, each plant also had different engineering safeguards. This made a standardized assessment of engineered safeguards difficult. The basic functions of these safety systems, however, were congruent. Each reactor had a system to remove decay heat from the fuel under normal operating conditions. Also, each reactor built in the United States was required to be enclosed within a containment building, which was usually a thick-walled steel or concrete dome structure that separated the reactor facilities from the environment. [10]

As each reactor built was modified for the utility company operating it, discussing all the differences and similarities among the US reactors would be a formidable task. It is sufficient for this paper to acknowledge that all reactors, regardless of type or geography, was required to adhere to certain AEC restrictions, which will be discussed in greater detail in the next chapter.

2.4 Social Influence

Prior to World War II, radiation protection was applicable to only a very small amount of scientists dealing with radioactive substances on a routine basis. As such, it was not heavily studied and there was not a lot of data at the time. This all changed however, with the bombing of Hiroshima and Nagasaki, both

Japan towns, by the United States. The use of the atomic bomb instigated two new elements into radiation protection. The first was the scientific fact that the nuclear reaction itself created a plethora of never-before seen radioisotopes that did not exist in nature. As a result, health physicists had to deal with additional types of radiation beyond the x-rays they were already somewhat familiar with. The second factor was the number of humans affected by the bomb, which was magnitudes larger than had ever been affected by man-made radiation before. [10]

The first sign that the American public was starting to form a negative opinion about all things nuclear was the reaction to the fallout controversy. Since the beginning of nuclear testing, scientists had disagreed on the affect on the general population from the fallout. Since this was such a hotly debated topic, it started to leak out of scientific debates and into news magazines, radio shows, and political campaigns. [10] This brought the public's attention to the potential hazards even small doses of radiation could inflict on a large population. Even though scientists were still learning much about the effects, that fact that they acknowledged low doses could still harm humans was enough to cast a significant doubt in the public's eye.

The awareness of the public to AEC's regulatory program increased after the fallout debate was brought to the forefront. For example, citizens began to protest the dumping of low-level waste into the oceans, a practice that had been allowed for over a decade, yet was only criticized after the public was introduced to the idea of low-level radiation hazards by the fallout controversy. As a direct result of increased public scrutiny, the AEC increased its safety requirements for reactors, requiring multiple redundant systems, all fully capable of safety securing a runaway core excursion. [10]

The greatest safety concern to the AEC was the behavior of a core meltdown, most likely caused by a loss-of-coolant accident. For smaller reactors, it was believed that the containment shell and the emergency core cooling system (ECCS) would be sufficient to contain the molten core. As reactors grew in size, however, engineers started to realize that the safety measures in place for the small reactors might not provide sufficient emergency cooling and containment for the new, larger breeds of reactors. The worse case scenario was labeled the "China syndrome", because the large molten core would be melting through the earth, presumably toward China. To find a solution to this uncertainty, the AEC established a task force whose sole purpose was to investigate core melting. Unfortunately, the findings of the task force were grim; the current ECCS in light-water reactors across the country might not work as intended. [10] The AEC came under criticism for allowing the reactors to be built and operated without first obtaining the data they now had on the ECCS.

Another controversial weakness of the nuclear plants was the contribution to thermal pollution. Though all types of utilities contributed to this pollution, nuclear reactors were the worst contributors due to lower plant efficiencies. Under pressure from environmental groups and the news media, Congress asked the AEC to start regulating thermal pollution levels. Defiantly, the AEC claimed it did not have the jurisdiction under the 1954 Atomic Energy Act. Even though the Department of Justice upheld this claim, the AEC's perceived inability to monitor all aspects of its own plants greatly reduced public and federal confidence in the AEC.

The final issue that damaged the reputation of the weakening AEC was the topic of high-level radioactive waste disposal. As the industry continued growing, the need for a permanent storage location for spent fuel rods and other high-level waste was increasing. The AEC announced it would build a facility in Lyons, Kansas to store the waste. The state geologist of Kansas questioned the suitability of the site and a dispute commenced between the AEC and the Kansas officials. When it was later proved [10] that the geologist's assumptions and qualms about the site were justified, it caused great embarrassment to the AEC and was the final wound in the ailing commission.

3. Comparison of Present Day Structures

This chapter begins the comparison of the regulatory systems. First, the differences between the historical and the current day regulatory structures will be discussed for each country. Once each present day system has been presented, they will be analyzed independently for safety, efficiency, and economic advantages. Finally, they will be juxtaposed to observe the similarities and differences between the two. From that comparison, a conclusion will be drawn discussing the advantages of each system over the other, as well as possible areas of improvement for both.

3.1 Present Day US Regulatory System

In 1973, the energy crisis that had spurred the growth of the French nuclear industry also started impacting American nuclear policy. [10] The crisis, combined with the recent shortfalls and criticisms of the Atomic Energy Commission, caused the government to consider creating two new agencies to replace the AEC. Most important in the decision to reorganize the regulatory system and the agencies involved was the conflicting interests problem the AEC had with dual promotion. Since it was the mission of the AEC to promote the promulgation of the nuclear energy industry as well as to regulate the operation and safety of that industry, critics argued that the agency could not adequately perform both duties without bias. Thus, the Energy Reorganization Act of 1974 divided the AEC into the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA). [10] The ERDA reserved the role of research, development, and promotion of nuclear energy and technology while the NRC inherited the licensing and rulemaking functions from the now defunct AEC. Unlike the AEC, however, the NRC's primary focus was on ensuring safety throughout the nuclear industry without the added responsibility of industry promotion. The NRC's rulings on safety were less vulnerable to being superceded by a utility attempting to rush the application review process. Since the purpose of this paper is to compare regulatory systems, we will be concerned mostly with the functions of the Nuclear Regulatory Commission.

Like the AEC before it, the NRC is headed by a five-member commission. Each of the five Commissioners is appointed to a five-year term by the President and then confirmed by the Senate. The President designates one of the Commissioners as the Chairman. Under the guidance of the commission, the NRC serves the United States by providing three distinct functions. This paper will consider all three of these functions; the establishment of standards and regulations, the issuing of all licenses to nuclear facilities and the persons who wish to use any nuclear material for any purpose, and the enforcement of all regulations and policies through facility and user inspections.

Formerly, the NRC required two separate licenses for each prospective power plant. A construction permit was required for the actual erecting and assembling of the facility and an operating license was required for normal operation once the site was completed. However, to improve the efficiency of the regulatory process, there now exist alternative licensing processes, such as a Combined License (COL) or an Early Site Permit (ESP). The processes for obtaining these licenses will be the focus of the following section.

In addition to granting facility licenses to the nuclear facilities, the NRC is also responsible for issuing licenses to the individuals who are responsible for operating the controls of the reactor. These reactor operators must complete a very thorough training program designed to enable them to properly and safely manipulate the reactor controls. Training periods often include up to two years of full-time studying and training on a simulated reactor. Following this training period, the operator is required to pass an examination proctored by NRC examiners. Once licensed, the individual continues to receive periodic training and successfully complete periodic re-qualification exams. [10]

3.1.1 The Regulation of an American Nuclear Power Plant

From an idea to its first criticality, a nuclear power plant in America must pass through several stages of licenses, regulations, and hearings. The first step in obtaining the necessary construction license from the NRC is the submission of a preliminary Safety Analysis Report (SAR). All application materials for a license are first filed with the Director of Nuclear Reactor Regulation.

A preliminary SAR must include all information requested by section 34 of part 50 of Title 10 of the *Code of Federal Regulations*. These criteria include:

- Intended use of the reactor facility including maximum planned power level
- Projected inventory and nature of all contained radioactive materials
- Environmental impact of facility
- Accident analyses, assuming full power operation and simultaneous multiple system failures
- Environmental impact of accident scenarios, including a fission product release into containment and a loss-of-coolant accident (LOCA)
- Organizational structure – administrative, training of personnel, standard operating procedures
- A preliminary design of the facility, including planned components and dimensions, and reasonable assurance that ultimate design will correspond within margin for safety. Also, this design will include safety features of the plant designed to prevent accident or, if they should occur, mitigate their effects
- Plans for coping with emergencies

Once this application is received by the NRC, the next step is for the staff to review the application for completeness. This generally entails reviewing all information received and verifying it satisfies their requirements for a detailed review. It is important to note that at this point in the process, the technical details and design plans themselves are not reviewed, rather their existence is verified to allow for approval at a later date. This application review normally takes thirty days. If, however, the Commission wishes to accept the application based on technical adequateness as well as completeness, it may do so. If so desired, a technical hearing will be scheduled as soon as possible to demonstrate the technical adequacy. After the Commission is satisfied, the application will be accepted. This auxiliary process takes an average of sixty days. [12]

Following the tendering of the initial application, the applicant is required to notify the "chief executive of the municipality in which the facility is to be located". [12] A description of the proposed facility and its environmental impact will be included in the notification. In addition to local officials, the applicant must distribute copies of the application to Federal and State officials as well. Once notification is completed, the applicant is required to file an affidavit with the NRC indicated that all required notifications were carried out and should include the name and address of each person or office notified. When the Director of Nuclear Reactor Operations receives all the application materials and the affidavit of appropriate distribution to the required agencies, the application will be formally docketed.[20] Once complete, the Director of Nuclear Reactor Regulation is required under the Atomic Energy Act to transmit a copy of the docketed application to the Attorney General for review. [12]

After the application is accepted by the NRC, a public hearing is held near the proposed site. A notice of this hearing must be published in the Federal Register at least thirty days prior to the date of the hearing, and should be published as soon as possible after the application has been formally docketed by the NRC. Such notice provides ample time for concerned and interested parties to make appropriate arrangements for attendance and possible testimony. In addition, the notice of hearing must include the applicable rules and regulations that the applicant has proffered as evidence of compliance, as well as the qualifications of the applicant to even apply for the appropriate license. [12]

The purpose of this hearing is to inform the public of the proposed facility, explain the potential environmental and safety aspects of the facility, and the regulatory structure during the process. In addition, these hearings inform the public of the various ways in which they can be involved in the licensing process. This is the first of many potential public hearings in the process. Following this meeting, all application materials and related documents are placed online and in the NRC Public Document Room. Finally, the NRC issues a press release to announce the initiation of the application process.

Now, the NRC staff once again reviews the application materials. This time, however, the staff takes all the information into careful consideration, and begins preparing a Safety Evaluation Report (SER) based on the data provided. This report is a very comprehensive report which takes into consideration the plant design, possible accidents and their consequences, benefits of such a plant, emergency planning, and qualifications of the applicant to run such a plant. Also considered is the effect on the surrounding population, both human and natural, as well as potential natural influences including seismology of the area, meteorology of the region, and geology of the site.

As required by the National Environmental Policy Act (NEPA), a separate environmental review is conducted by the staff of the NRC. This longer, more detailed review evaluates all the potential environmental issues, both beneficial and harmful. Upon completion, the staff issues a Draft Environmental Impact Statement which is then forwarded to all affected federal, state, and local agencies. These agencies, as well as the public, have an opportunity to read the report and comment where necessary. After reviewing all appropriate comments, the staff of the NRC issues a Final Environmental Impact Statement (FEIS) to address all concerns and comments. [12]

According to section 34 of part 50 of title 10 of the Code of Federal Regulations (10 CFR Part 50), each applicant must also provide the NRC with a Safeguards Contingency Plan. Part of this plan is the proposed physical security plan. This includes methods for securing the boundary area to ensure no unauthorized people are allowed in or out of the facility. Also, a guard qualification and training program is required to ensure competent and efficient use of human security guards to further secure the site from threats, thefts, and radiological sabotage. Upon reviewing this information, the Advisory Committee on Reactor Safeguards (ACRS), which is independent from the NRC, creates a report detailing its findings and submits this report to the Chairman of the NRC.

Also pursuant to section 34, the application for a construction permit must contain the basic design criteria for the proposed facility. These criteria cover the design, fabrication, construction, testing, and performance of the reactor systems. These systems include any component necessary for safe reactor operation and to ensure the safety and health of the public. The NRC has provided applicants with the "General Design Criteria for Nuclear Power Plants" in appendix A of 10 CFR Part 50.

These General Design Criteria set the minimum required design criteria for an application for a water-cooled power reactor. They are generally applicable to other types of reactors as well, and are intended as guidance for the establishment of the specific design criteria for those other types of units.

The General Design Criteria contains sixty-four criteria the utility must address in the principal construction permit application. Six different sections of the criteria (Overall Requirements, Protection by Multiple Fission Product Barriers, Protection and Reactivity Control Systems, Fluid Systems, Reactor Containment, and Fuel and Radioactivity Control) address various issues of reactor operation. Each section contains a number of specific criteria pertaining to the system concerned. For example, the fourth section, "Fluid Systems", contains the criteria for the Emergency Core Cooling System (ECCS). This criterion states "*Emergency core cooling*. A system to provide abundant emergency core cooling shall be provided. The system safety function shall be to transfer heat from the reactor core following any loss of reactor coolant at a rate such that (1) fuel and clad damage that could interfere with continued effective core cooling is prevented and (2) clad metal-water reaction is limited to negligible amounts." [13] This is an example of how the NRC's General Design Criteria establish for the utility the various safety system capabilities and redundancies required to ensure the reactor facility can be operated in a safe manner.

Before a construction permit can be approved based on the following application reviews, the law requires that there exist an opportunity for a public hearing to be held. Any member of the public can request a hearing to intervene with the issuance of the construction permit based on technical factors. [14] This hearing is conducted by an Atomic Safety and Licensing Board. This three-member board consists of one lawyer and two persons qualified to discuss the technical aspects of the proposed facility. At the public hearing, members of the public are allowed and encouraged to voice comments and concerns. Also, members of the public are allowed to submit written statements for consideration. Both oral and written statements are entered into the final record of the hearing.

Finally, after the preliminary SAR, the FEIS, and the public hearing, the NRC may with to offer the applicant a construction license to begin construction of the facility. The only exception in which an applicant can begin any type of work on the site prior the issuance of the construction permit is a Limited Work Authorization (LWA). This provisional authorization may be granted after the licensing committee has reviewed all the reports and the NEPA findings and concluded that the proposed site and facility is safe and practical. All work performed under this authorization, however, is at the risk of the applicant because the public hearing or another factor may cause a delay or ultimately, a denial of the construction permit.

Assuming the construction permit is issued and the facility is near completion, the applicant must now submit a Final Safety Analysis Report (FSAR) which should complement the preliminary SAR. The FSAR will describe the final design as built and address the operational and emergency procedures specific to the plant type and location. From this final report, the NRC will prepare a Final Safety Evaluation Report (FSER) and the Advisory Committee on Reactor Safeguards makes its own independent evaluation. Both reports are submitted to the Commission for final approval. [12]

3.1.2 Public Involvement

The preceding pages outline the required procedure an applicant must follow to properly build, license, and operate a nuclear power facility in the United State of America. Those procedures outline the applicant's responsibilities to the NRC, the NRC's responsibility to the applicant, and the joint responsibility to the public. However, part 2 of title 10 of the Code of Federal Regulations also includes the procedures and opportunities in which a concerned individual or party of the public can involve themselves in many aspects of the licensing process. Those will now be discussed.

While the application is still being considered by the Commission for completeness, the utility is required to submit information to assist the Attorney General's office with an antitrust review. Once this information is submitted, receipt of said information will be published in the Federal Register. Any person who wishes their views to be heard on the information submitted for the purposes of the antitrust review can submit such views within sixty days of publication. After receipt of the antitrust information and any information submitted by the public, the Director of Nuclear Reactor Regulation must then publish in both the

Federal Register and appropriate trade journals a "Notice of Receipt of Initial Operating License Antitrust Information." The notice shall invite persons to offer, within thirty days after publication of the notice, comments or information concerning the antitrust portions of the application to assist the Director in determining whether significant changes in the licensee's activities or proposed activities have occurred since the close of the previous antitrust review in correlation with the construction permit. [12] Once the Director has reviewed all submitted comments on the antitrust matters and concludes no significant changes have been made, the finding of "no change" must be published in the Federal Register. As before, anyone who questions the validity of the finding or can present new information that might change the outcome of the evaluation must submit said information to the Director within thirty days of publication. After this final thirty day period has passed, the finding will be considered the Commission's final decision on the matter.

Following the acceptance of the initial application, the Commission is required to hold a public meeting. This first hearing is primarily informational, and not particularly open for public debate. However, it is at this meeting that the application is presented to the public near the proposed site, and instructions are given detailing the opportunities for public involvement in the rest of the licensing process. Notice of this meeting must be published at least thirty days in advance of the meeting date, and should be issued as soon as practically possible after the docketing. If the notice does not include the proper information such as specifying the time and place of the hearing, another notice will be published to include that information, with the hearing taking place no sooner than thirty days from publication of this second, revised notice. [12]

Once the application has been thoroughly reviewed and considered, the Commission will publish a notice of proposed action in the Federal Register. This notice announces that the Commission plans to issue a construction permit and an operating license in the near future, and allows any person or concerned parties to request a hearing on the proposed action. Thus, if the Commission decides it will grant a construction permit to a utility, a member of the general public can request a formal hearing to delay the issuance of said permit until the presiding officer at the hearing has ruled on the request or petition.

If a formal request for a public hearing is requested, the Nuclear Regulatory Commission assembles an Atomic Safety and Licensing Board consisting of three members – a lawyer, an engineer and an environmental scientist. Their job is to determine whether the contentions raised by the "intervenors" are legitimate and should be considered in a formal adjudicatory proceeding in which testimony is presented and witnesses are heard on each of the admitted contentions. This process can take many months or years to resolve depending on the contentions raised. The license application can not be acted upon until the Atomic Safety and Licensing Board finally acts in resolving the contentions. This may require changes to the plant design that the NRC will also have to review. The NRC staff and the utility staff are parties to these hearings since by this time the NRC staff will have issued a preliminary safety evaluation report.

It is also possible for any concerned person to file a request with the NRC to initiate a hearing in regards to a facility license. This petition is granted through section 206 of part 2, and is thus referred to as a 2.206 petition. This section reads, "Any person may file a request to institute a proceeding... to modify, suspend, or revoke a license, or for any other action as may be proper... The request must specify the action requested and set forth the facts that constitute the basis for the request." [12]

This 2.206 request allows any person with a valid safety or technical concern regarding any aspect of a nuclear facility to petition directly to the Director of the appropriate NRC division, and have their argument heard. If the Director, after reviewing the claim, accepts the concerns or questions valid, a proceeding will be initiated by that Director to investigate the concerned utility.

This individual initiated request is unique to the American system. This is important to note since it is within the scope of this thesis to identify the differences in the regulatory systems and illustrate the disparity they create. This adjudicatory nature of the NRC is very well served by the opportunity for any concerned person to file a request for an investigation. Since the NRC is a legal-based scientific agency, it allows equal opportunity to petition under the law until the 2.206 request is either validated or rejected by an NRC director. This is in stark contrast to the more science-based DGSNR, as will be explained in the following chapter.

3.1.3 Compliance

Once the utility is granted the proper licenses and begins operation, the NRC continues to stay intimately involved with every aspect of the facility. Each power reactor is assigned at least two resident inspectors. [15] These resident inspectors observe all aspects of operation and maintenance of the reactor and its system. If a potential problem is observed or suspected, the inspector focuses on the problem area in more detail.

The NRC also has inspection specialists, based out of their regional offices. These specialize in specific areas of facility operation, such as security, radiation protection, environmental monitoring, fire protection, and other specific areas. Each facility undergoes almost twenty of these specialized inspections each year. [15] All inspector findings, both resident and specialized, are documented and filed in inspection reports.

When the inspectors find violations at a facility, the NRC has a variety of enforcement options. The simplest is to issue a notice of violation. This notice requires the facility to immediately remedy the violation and take measures to prevent a repeat of the violation. The preventative actions must be documented and approved by the NRC before the notice of violation can be considered appropriately answered.

For more severe or repetitive violations, the NRC can fine the utilities up to $120,000 a day or even request that all licensed activities be immediately halted pending investigation. [15] In the most extreme violations, the NRC may choose to revoke an individual or facility license.

The facility licenses initially granted to nuclear reactors allow the reactors to operate for up to forty years. Once the initial license term is expired, the facility must apply for a license renewal if they wish to continue operation. Should the utility desire to continue operation, the facility license renewal process proceeds along two separate paths, a safety review and an environmental review. [13] The safety review is designed to prove that continued operation of the plant will maintain the appropriate levels of safety required under the original license.

3.2 French Regulatory System

The primary participant in the French Regulatory System besides the applicant is the recently created Direction Générale de la Sûreté Nucléaire et de la Radioprotection (DGSNR). The DGSNR, also called the Safety Authority, replaced the DSIN in 2002, but this was mostly a political change, as the responsibilities with regards to regulatory processes stayed the same. [16] The DGSNR is the French equivalent of the American NRC, except the DGSNR is not the final regulatory authority. The final regulatory authority lies with the Prime Minister and the Ministers of Environment and Industry. In the United States, the NRC can itself license the applicant after thoroughly reviewing the application. Thus, it holds both the responsibility of regulation and the authority to grant and enforce its licenses. The DGSNR, however, carries out the various application process and safety reviews, and then passes on its recommendation to the

Prime Minister through the Ministries of Environment and Industry. It is the Prime Minister who holds the executive authority and possesses the final say on the issuance of the various facility licenses. [16]

The DGSNR was created in an effort to hasten the regulatory procedures. Another merger of agencies intended to streamline the relevant processes was the merger of the Institute for Nuclear Safety and Protection and the Office for Protection against Ionizing Radiation into the Institute for Radiation Protection and Nuclear Safety (IRSN). The IRSN was established to continue the research of the two combined organizations into nuclear safety methodology. Also, they are the organization primarily in charge of protecting the public from ionizing radiation and educating the public about their specific role in that capacity. It is important to note that the IRSN does not have any regulatory authority. They are a valuable consulting resource for the DGSNR, but make no regulation decisions on their own. The authority for regulating the nuclear industry lies with the Ministry of Industry which makes its rulings based on the on the consulting input from the DGSNR and the IRSN.

Much like its American counterpart, the French licensing system progresses in defined steps. Each step requires a different license, which enables the utility to begin construction once the construction permit has been issued but before the authorization for testing with nuclear materials has been granted.

The initial step towards the creation of a new nuclear facility is a local public inquiry involving the local Chief Administrator, which is defined as the local governmental administrative authority. [16] In this meeting, the facility operator provides a general description of the reactor design. This information should include the processes used in the reactor, the safety features, and the estimated impact to the environment.

In addition to the meeting, the operator must create and publish a Preliminary Report (PR). This report, though similar in name, differs broadly from the NRC's Preliminary Safety Analysis Report. The French Preliminary Report is developed to contain only the preliminary or conceptual design choices as well as the safety goals and the rules the operator has in place to meet those goals.

The DGSNR also provides the utility with twenty-three Basic Safety Rules (RFS) governing the design and operation of nuclear power plants. These rules, akin to the NRC's General Design Criteria, give safety goals and principles for external hazards, process systems, safeguard systems, radiation protection, and operation-related functions. [17] Unlike the General Design Criteria, the RFS are recommendations given by the DGSNR to the utility. Strictly, they have neither an official regulatory nor legal status. As such, the operator is able to break certain safety rules, as long as it can be demonstrated that the eventual safety objective will be obtained via a different path. This places a significant level of responsibility in the technical abilities of the utility. This opportunity to reach safety objectives by evaluating differing paths is much less prominent in NRC regulation.

Based on the information presented in the meeting and contained within the Preliminary Report, the Chief Administrator reports a recommendation to the

Ministries of Industry and Environment, which in turn review the application and offer a recommendation to the Prime Minister. Also providing the Prime Minister with recommendations are the Standing Group of experts and the DGSNR. If satisfied with the information, the Prime Minister will then approve the decree of creation of the nuclear facility. This is the first of four regulatory steps required for a facility to begin power production.

During construction of the facility, the safety analyses of various reactor components (confinement, criticality, shielding, heat removal, natural phenomena, etc.) are carried out and then submitted to the DGSNR for review. Also, the DGSNR and other radiation protection groups tour the facility to conduct surveys and certify compliance between the design proposal and safety analyses. Also, any feature or reactor section that will be inaccessible once criticality is attained is thoroughly surveyed and tested now, to ensure proper operation.

The second licensing phase is the submission of a Provisional Safety Report along with the General Operation Rules (RGE) and the Emergency Plans (PUI). The PSR demonstrates the ability of the facility's design and construction to ensure the already established safety goals and rules from the Preliminary Report are completely satisfied. The General Operation Rules describe the routine operation and maintenance procedures for the facility and illustrates how the safety goals discussed in the PSR are attained during operation. Also contained is the method for quality control and testing, as well as rules for operation and maintenance in non-routine conditions. The Emergency Plan covers the management of beyond design basis accidents, which would have a potential for on-site radioactive consequences. Also, strategies for accidents with potential off-site hazards are connected to the appropriate local or national emergency plans already in place to protect the public and the environment. [18]

The third step of the licensing process, the environmental release limits, is conducted concurrently to the second phase. The Ministry of the Environment issues limits on the allowed gaseous and liquid releases from the facility, based on the expected environmental impact. Once these reports are received and construction is completed on the facility, the license for operation with radioactive materials is granted. The Safety Authority closely monitors facility operation and performance through inspections, walkthroughs, radiological surveys, and interviews. During this time, the DSGNR also provides a specific set of safety limits which are even more conservative than required by the safety envelope for normal operation.

This testing phase is the fourth step in the licensing process, requiring four separate licenses of it own. The first license of this phase allows the utility to load the fissile fuel in the core, to prepare for the subsequent licensing steps. The second license authorized permits the pre-critical hot testing, which allows all process systems and pumps to be operated, thus fully pressuring the vessel and simulating operating conditions without actually attaining criticality. Following successful pre-critical testing, the third license granted allows the facility to attain its first criticality and power increase up to ninety percent of the nominal power level. Lastly, the fourth license is granted which allows power build up to full operating power.

In this testing status, a facility may operate for years before the Final Safety Analysis Report is released. The FSAR incorporates all the information gathered from the active testing period. This includes a final updated copy of the operating procedures, variations from the original design, the safety effects, if any, of these variations, and an updated version of the facility emergency plan. This Final Safety Report is created by the operating company for use in ensuring the safety of the facility and the capacity to operate within the safety envelope. The safety authority then uses the FSAR to develop inspection and assessment procedures. [16]

Finally, after the four phases are successfully completed, the Prime Minister authorizes the nuclear facility to commence normal operations and power production. Unlike the NRC's licenses which carry a 40-year term, the French authorizations to operate do not contain any term-limiting expirations. However, the Ministries of Industry and Environment can request an in-depth safety reassessment of any facility at anytime. Current practice includes these periodic safety reassessments approximately once every twenty years, though not required.

3.2.1 Public Involvement

Though public involvement in the French regulator process is not as prevalent as in the American system, opportunities do however exist for interested parties. It is also important to note that public perception of nuclear power differs greatly between France and the United States. Unlike the United States, nuclear power in France is accepted by the public, and even popular to many. [4] The broader public acceptance of nuclear power in France is often attributed to the popularity of engineers and scientists in French society and government. Where lawyers hold the majority of high ranking civil service and government positions in the US, Frenchmen often elect science-educated officials to high ranking offices. Also very important in explaining the French public's affinity for nuclear power is the government's efforts, through television advertising campaigns and public tours of the reactors, to educate communities of the benefits. [2]

Once an application for an authorization decree has been sent to the appropriate Ministries, a public inquiry is required. All territories within a five kilometer radius of the proposed site are included in the process. All available documentation from the operator is collected and the information must include the identity and credentials of the applicant, the purpose of the inquiry, a hazard analysis, an environmental impact study, and the basic characteristics of the proposed facility. The purpose for the public inquiry is to both inform the public and in turn allow their opinions to be heard. Suggestions and counter-proposals are also submitted at this time to the Inquiry Commissioner. [16]

The Inquiry Commissioner is appointed by the administrative court in France and is in charge of maintaining all relevant documents, allowing interested parties to view those documents, visiting and touring the proposed site, meeting people who wish to express their views and opinions, and also to arrange public meetings to discuss the proposed decree.

Once the inquiry is finished, the Commissioner collects all observations and suggestions and creates his report, which is then forwarded to the appropriate Prefect, who is the highest ranking administrative official in the concerned region. This official then reviews all the information, finally passing his recommendation on to the Ministries of Industry and Environment who are authorized by the Prime Minister to rule on the validity of any concern. If a valid concern is discovered, it is then presented to the Prime Minister who has the final authority to further the investigation or rule against it.

3.2.2 Compliance

Once a reactor facility is operating, it is responsible for reporting any deviations from a safe state or incidents. These incidents are analyzed to determine their exact cause and relevance to similar reactors since the industry is standardized. Also, the consequences of each deviation along with the causes are used to improve safety techniques and provide lessons-learned to the operators.

To ensure that all appropriate safety systems and auxiliary systems function properly when needed, surveillance tests and calibrations are performed with regular frequencies. The operator schedules all applicable surveillance tests and includes the conditions in which the tests are to carried out and the acceptable parameters and tolerances. These are all submitted to the DGSNR for review and approval.

An anomaly is reportable if it meets one of ten criteria specified by the safety authority. These criteria are automatic reactor shutdowns, actuation of safeguards systems, violation of Technical Operating Specifications, external event likely to affect safety, malevolent act or attempt likely to affect safety, uncontrolled radioactive release, incident resulting in elevated exposure to ionizing radiation, incident resulting in human fatality or severe injury, a design failure, or any other anomaly deemed significant but not covered in the previous nine conditions. [17]

4. Nuclear Safety and Emergency Response

This section will examine the regulations and established procedures each country employs to deal with any deviation from the intended, safe operational state of a reactor.

In 1991 the International Atomic Energy Agency (IAEA) created the International Nuclear Event Scale, or INES. This scale classifies any deviation from safe normal operation, either in a nuclear facility or involved in the transport of radioactive materials. Eight possible classifications (0 to 7) are assigned to each event. An event unrelated to safety is classified as a Level Zero and referred to as a "deviation". An "incident" refers to events from Level One to Level Three and any event greater than or equal to a Level Four is termed an "accident". [19]

The French safety authority utilizes the INES to help the public and media understand the safety significance of an particular nuclear event, and compare it to previous events. Each safety event is fully investigated an classified as one of the previously mentioned levels. In doing so, the application of the INES scale to events at French nuclear facilities is based on three different criteria. First, offsite consequences are evaluated. If there are no offsite effects, the event will be a Level Two or below. Otherwise, the degree to which radiation was released and the public exposed determines the classification given.

Next, the extent to which the event harmed the physical condition of the reactor, its systems, and the workers of the plant is evaluated. These onsite consequences can range from severe damage to reactor core and radiological barriers, which would be a Level Five, to a significant spread of contamination or acute overexposure to a worker, which would be classified at least a Level Two incident. Lastly, impact of the event on the facilities "defense in depth" redundancy systems is investigated. This evaluated the procedures and systems in place to prevent accidents from happening, and determining which failed and which performed as expected. [16]

Though the NRC primarily uses different classes of emergency events (Notification of Unusual Event, Alert, Site Area Emergency, and General Emergency), discussion of that classification system and a juxtaposition with the French use of the INES would be speculation at best. However, since 1993, the NRC has participated, in a limited fashion, in the INES. Under this partial participation, the NRC rated all events at reactor facilities which resulted in the declaration of an Alert or higher emergency classification, thus enabling a comparison of the two agencies to be completed.

4.1 France

The French emergency response protocol is comprised of two sets of provisions, local and national. Locally, there are two officials responsible for the handling of any nuclear incident, from a deviation to an incident to an accident. The first and foremost is the operator of the facility. His primary responsibility is to bring the emergency conditions under control, to alleviate the consequences, and to protect the facility workers. These measures are all accounted for in the prepared onsite emergency plan that each operator must prepare prior to licensing. The second local official responsible in the event of an emergency is the local Prefect. His primary concern is the safety of the general population and the immediate property. Keeping the public and authorities informed is also a duty required of this Prefect as defined in the offsite emergency plan prepared by the utility in its initial application. [16]

Nationally, there are four primary departments concerned with nuclear accidents, depending on the severity. The Ministry of the Interior is responsible for the Directorate for Civil Security and Defense and the Nuclear Risk Management Aid Mission which provide the local Prefect with the human reinforcements and supplies needed to ensure the safety of the public and property. The Ministry for Health in coordination with the Office for Protection against Ionizing Radiation ensures the safety of the public with specific regard to ionizing radiation. The Ministry for Industry and the Ministry for Environment work together to keep the public and government informed of the accident details, and work to mitigate its consequences on the national level. Finally, the Secretary General of the Interministerial Commission for Nuclear Safety is responsible for keeping in direct communication with the President and the Prime Minister to keep them informed. It is also the duty of the Secretary General to ensure all other departments listed here are doing their assigned duties and to coordinate with foreign countries if a radiological disaster is substantial enough to possibly affect neighboring countries.

The DGSNR, though the primary participant in the regulatory process, shares its role in an emergency response scenario. It works with the aforementioned departments to inform the media and the general public about the happenings. Furthermore, it collaborates with OPRI and the local operator to keep the Ministers and the Secretary General of the Interministerial Commission for Nuclear Security informed, who in turn inform the President and Prime Minister.

To ensure the emergency coordination capabilities of the DGSNR, unannounced drills are periodically planned and executed. These drills include "nuclear safety" drills which deal with reactor specific problems and require technical decisions to be made in a timely manner to simulate the required decisions in a real accident. Another type of drill conducted is a "civil defense" drill, which is broader in scope because it requires actual measures designed to protect and alert the public based on the drill scenario. These exercises even include simulated media pressure, to test the communication skills of the personalities concerned. [16]

4.1.1 Saint Laurent Nuclear Des Eaux Power Plant

The most significant accident at a French reactor occurred in 1980 at the Saint Laurent power plant. The reactor core was damaged with localized partial melting of some individual fuel rods. [19] The accident involved no off-site consequences and the damaged fuel was removed and replaced. This accident was classified as a Level Four accident on the INES scale.

Though the French regulatory authority offered no official description of the accident, the classification as a Level Four accident offers some clarifying distinctions. Most importantly, while the fuel may have suffered minor damage and radiation levels within the reactor may have reached dangerous levels, there were no environmental hazards released as a result. The accident was fully contained within the safety boundary.

4.2 The United States

The NRC's emergency response begins with the activation of the incident response program at its headquarters, and a similar regional center based at one of four regional offices located throughout the country. [20] It is at these centers that experts evaluate the situation and assist the local and state authorities at the site in mitigating the consequences of the event as well as informing the media and public of the incident and risks it may pose to public health. Meanwhile, the scientists and engineers analyze the event and begin formulating possible recovery strategies and reviewing the actions already taken by the operator and local response teams. Though other federal departments might get involved in the response, the NRC is the Lead Federal Agency for such incidents and coordinates all responses to the situation.

In severe cases, the closest regional office will dispatch a team of experts to the event site. Simultaneously, an Executive Team is assembled at the operations center headquarters and is usually chaired by one of the five NRC Commissioners. Once the team of experts arrives at the site, the authority to coordinate the emergency response is turned over to that team from the utility's response team.

To ensure the staffs at the headquarters and in the regional offices are available to respond to an incident in a timely and efficient manner, emergency response exercise are conducted throughout the year. Five full-scale exercises are selected from a list of Federal Emergency Management Agency graded exercises. These exercises involved the staff at NRC headquarters, regional staff, local and state authorities, and the utilities themselves. [20]

4.2.1 Three Mile Island

The United States' worst nuclear accident occurred in 1979 at the Three Mile Island nuclear power plant. Through a series of equipment malfunctions and operator errors, the pressurized core began losing coolant and overheating. The primary cause was a relief valve that was stuck open and that went unnoticed for hours. Eventually, the zirconium cladding around the fuel ruptured due to the high temperatures and roughly one half of the core melted. Also, a limited release of radioactive gases caused the suggested evacuation of pregnant women and children within a five mile radius. [21]

This event was classified on the INES scale as a Level Five accident due to the severe damage to the core and the limited release of radioactive gases.

Though the off-site health-related consequences were suspected to be minimal, the sociological consequences were more severe. The accident at Three Mile Island greatly increased public fear of nuclear power and scrutiny of the NRC.

5. Comparisons

5.1 Regulatory Controls

As mentioned in an earlier chapter, both regulatory agencies are able to successfully regulate their countries' respective nuclear power industry using both scientific knowledge and legislative means. When the two systems are juxtaposed, it is apparent that each agency tends to favor one type of control over the other. For instance, the United States' NRC emerges as a legislative and government-based scientific agency while France's DGSNR appears to rely more on the scientists, and is thus considered more of a technical and engineer-based regulatory agency. This section will highlight some of the dissimilarities that lead to that conclusion.

The adjudicatory nature of the NRC allows for concerned individuals to petition for a proceeding to investigate a valid safety concern at a plant. This "2.206" petition was explained in more detail in a previous chapter. This petition, instigated by an individual, can call for a license suspension or even revocation. Since the NRC uses a system of adjudication, these petitions are all evaluated and judged by the Commission and considered for valid concerns. Should a petition contain a valid concern, the actions requested by the petitioner may be carried out by the Commission. [12] As such, it is possible and not too implausible for a concerned individual with legitimate evidence to halt the operation of a facility operating in an unsafe manner.

Furthermore, as stated in a previous chapter, the NRC requires that a hearing, or at least an opportunity for a hearing exist before granting a construction or operating license to a utility. Traditionally, this hearing has been conducted as a formal on-the-record adjudication, resembling a judicial trial, with parties, sworn testimony, and cross-examination. Though there exists debate within the NRC on whether all such hearings should be formal, currently hearings related to construction and operation of nuclear power plants are conducted as such. Such a strict hearing "would lead to a more complete resolution of the complex issues affected the public health and safety and would build public confidence in the AEC's decisions and thus in the safety of nuclear power plants licensed by the AEC". [22] Thus, though the NRC may feel like an informal hearing would in principle satisfy the requirement, it prefers the more formal hearings for the final clarity in the decisions it may reach. It allows the American public a sense of more security while providing fewer grounds to appeal rulings. This adjudicatory system of the NRC helps to legitimize the nuclear industry in the public's view by allowing all persons, for or against nuclear power, the ability to be heard.

The situation in France is somewhat different, both legally and culturally. During the licensing phase, the DGSNR allows for a public inquiry. This inquiry is different than the NRC's hearing because it is not a formal proceeding with a judge and formal testimony under oath. Rather, the inquiry allows individuals to submit documents stating their comments or concerns with a prospective site or facility. An Inquiry Commissioner is appointed by the DGSNR for each inquiry instigated. It is the job of the Commissioner to gather all statements and documents, visit the site, and make a report. His report, along with his findings and recommendations, is sent to the Prefect of the region in which the site lays. The Prefect then consults with the various technical authorities (DGSNR, IRSN, CEA) about the site. Finally, the Prefect reports to the ministers in charge of nuclear safety with the inquiry findings, the Inquiry Commissioner's opinion, his own opinion, and the expert technical opinion of the safety DGSNR. The Ministers of Industry and Environment then use all these resources when evaluating the application. [16] Thus, the public involvement in the French system acts in parallel to the scientific consultation and expertise of the regulator. The ministers, with whom the regulatory authority lies, have the ultimate ability to decide the scientific evidence in favor of a site or license is stronger than the public's desire against it. In contrast, in the United States, the public hearing operates in series with the technical evaluations.

Each country's system for responding to public response works within the context of their respective cultures. For instance, in the United States, anti-nuclear groups are more prevalent than in France, and the percentage of citizens who strongly support nuclear power, though rising, is still below the percentage in France. According to psychologists, the French still harbor the same fears and concerns of nuclear power that most Americans possess. The difference lies in their heavy reliance on nuclear energy. They realize life could be much different without the nuclear power plants that provide over 70% of their electricity. Also, national pride plays in a role in trusting the scientists who regulate and operate the industry. While many American anti-nuclear activists point to Three Mile Island and Chernobyl as examples of nuclear technology gone wrong, many French citizens are quick to suggest those countries were not "up to the task. But the French scientists and engineers are." [4]

5.2 Nuclear Safety Analysis

Another important topic of discussion is manner in which the regulatory agencies balance regulatory controls with safety analyses.

5.2.1 NRC Approach

A fundamental reform in nuclear safety analysis was spurred by the difficulty the utilities and the NRC were experiencing in trying to agree on a concept of nuclear safety. Utilities complained of the restraints on operation and the added costs consequent from various aspects of the regulatory process that were debatably justified in terms of nuclear safety.

In recent years, the NRC has begun to implement a “risk informed” approach to safety analysis. [23] This approach utilizes probabilistic methods using large amounts of experience feedback from the previous half century of operation. The purpose of this approach is to update the regulatory system to give greater emphasis to safety concerns that are more likely to arise in a given situation. Also, the risk informed approach seeks to lessen regulatory burden by lessening the amount of strict requirements a reactor must adhere to.

5.2.2 DGSNR Approach

Probabilistic analysis and techniques in French regulatory and nuclear safety analyses is used as another tool in improving nuclear safety, but the entire system is not geared toward it.

It is the belief of the DGSNR that these risk informed methods should be used to increase safety, but never to reduce regulatory constraints, as it does in the United States. If a probabilistic assessment calls into question the validity of a certain requirement or regulation, it is only after a full investigation of the possible regulatory and safety effects of the proposed change that a change will can be considered.

Also, the DGSNR believes that the limitations of probabilistic safety based analyses such as a failure to consider situations not already included in the model and the absence of social concerns prevent it from being the basis of a regulatory system.

5.3 Power Production

The United States and France are the two largest generators of nuclear power in the world. In 2002, France produced 415.5 billion kilowatt hours (bkWh) compared to the United States' 780.1 bkWh. Of course total power produced is an inaccurate indicator given the difference in population of the two countries. A better indicator is the average gross capacity factor. This factor is the "ratio of the gross electricity generated, for the period of time considered, to the energy that could have been generated at continuous full-power operation during the same period". [24]

For the year 2002, the average gross capacity factor for American power plants was eighty-nine percent, compared to the French average gross capacity factor of seventy-five percent. This data shows that the average American plant is operating fourteen percent closer to its maximum output. But it also shows that French reactors have more than twice as many outage days as American reactors do. With an advantage of ninety-one days downtime to the United States' forty, it appears that though the French may lag behind the United States in power production efficiency, but surpass the NRC-regulated American reactors in outage operations. The longer outages may contribute to more thorough and rigorous safety measures by the French.

The capacity factor does not take into account the difference between planned and unplanned outages. Every reactor must schedule outages from time to time to perform maintenance, refueling operations, and general inspections of reactor components. The International Atomic Energy Association defines and calculates an indicator called the unplanned capacity loss factor (UCL). This factor is the ratio of any unplanned energy losses to the reference energy generation. [25] The reference energy generation is the amount of energy that would ideally be produced in a given year, and it takes into account any planned outages. Any power loss or shutdown scheduled four or more weeks in advance by the plant management is considered planned. The unplanned capability loss factors for each country are as follows. [25]

Table 2. Unplanned Capacity Loss Factor

	Lifetime	2000	2001	2002
United States	9.2	4.0	2.6	1.4
France	7.4	5.8	6.3	4.1

Interpreting this data, the United States has the greater lifetime unplanned capability loss factor. This implies that over the lifetime of each countries nuclear industry, the United States has experienced more unplanned outages than France. In each of the past three years, however, the United States' nuclear reactors have functioned more efficiently than the French, with a lower percentage of unplanned capacity loss. While the evidence may suggest that historically, American reactors were more prone to unplanned power outages, recent years have reversed the trend. In the United States, the trend for the past three years is undeniable toward a more efficient operation by decreasing unplanned capability to 1.4%. Meanwhile, the French trend has fluctuated approximately between 4 and 6, with no obvious decreasing or increasing trend.

Quantitatively, the French and United States' nuclear power industries are comparable. While France has fifty-nine units capable of outputting 63,073 MW of electricity, the United States has 104 reactor units capable of producing 98,230 MW of electricity. In other words, using a unit total fifty-seven percent of the United States, France is able to generate sixty-four percent as much electricity. Thus, French reactors, on average are capable of more output than American reactors. [26]

Table 3. Power Capacity

	Reactor Units	Total MW(e)	MW(e) per unit
France	59	63073	1069
United States	104	98230	944

This simply implies that French units tend to be designed with a higher capable operating output. However, this implies little about the safety or efficiency of either program. The next section will examine the financial and personnel welfare of each regulatory agency

5.4 Staffing

Another important factor in the effectiveness of the different regulatory agencies is the use of resources by each agency. Specifically, the number of personnel it must employ to completely and effectively carry out its task.

According to the NEA, the DGSNR of France employs approximately 570 people. This includes 350 technical or professional staff, 100 administrative and 120 inspectors. Meanwhile, the NRC employs 2,801 employees. This employee pool breaks down into 2032 technical or professional staff, 440 administrative staff, and 329 inspectors. According to the NRC's 2003 Performance and Accountability Report, 54% of the staff is responsible for reactor safety, with the rest employed in research and development. [27] For the purposes of comparing the two regulatory agencies, only the portion of the staff dedicated to reactor safety will be considered. The DGSNR staff figures reflect that consideration, since the research and development department is separate from the DGSNR. To better understand how these employees are utilized, a standardized ratio can be constructed. [28]

Table 4. Use of Regulatory Staff

	Reactor Units	Billion Kilowatt Hours (bkWh)	Total Staff	Staff members per reactor	Staff members per bkWh	Inspectors	Inspectors per reactor	Inspectors per bkWh
France	59	415.5	570	9.6	1.4	120	2.0	0.3
United States	104	780.1	1513	14.5	1.9	329	3.2	0.4

Observing the last column first, the DGSNR and the NRC have similar inspector per bkWh ratios and comparable inspector per plant ratios. This means each system utilizes their inspectors in similar fashions, and with similar responsibilities. On average, inspectors in the two countries oversee the generation of similar gross kilowatt-hours. The significant difference in total staff, with the NRC employing 1.9 workers per bkWh versus the French value of 1.4 staff per bkWh, can then be assumed to be non-inspector personnel. The extra employees in the NRC are primarily in administrative and legal positions. This implies that given technically equivalent reactors, the NRC has more employees than the DGSNR to regulate, maintain documentation, and verify regulatory compliance. Thus, the adjudicatory nature of the NRC gives rise to more public hearings and possible court cases, which in turn requires the agency to employ more persons with legal backgrounds to oversee the judicial responsibilities of the regulatory agency. This directly correlates with the proposed thesis that the Nuclear Regulatory Commission functions much more in the legal jurisdiction than does its French counterpart, the DGSNR.

5.5 Average-Based Comparison

An automatic scram of a reactor causes an immediate and unplanned shutdown of the reactor, resulting in outage time in which no power is produced. Automatic scrams are triggered by the alarms that monitor the various reactor systems. When these alarms detect an unusual operating condition that differs from normal operating parameters enough to challenge operating limits, they initiate the automatic scram sequence. These scrams are inconvenient to the utility for a variety of reasons. First, the utility loses money by not producing power. Also, the reactor cannot be restarted until the cause of the scram has been identified and clearly addressed and properly repaired.

Thus, the frequency of automatic scrams at a reactor is a decent indication of facility preparedness, attention to safety, and efficiency. Likewise, the frequency of automatic scrams in reactors under the same regulatory control offer a good indication of that regulator's ability to keep facilities running safely and efficiently. The annual averages of automatic scrams for the French and

American power reactors are as follows [23, 24]

Table 5. Automatic Scrams Per Reactor

	1992	1998	2000	2002
France	2.2	1.02	0.96	1.19
United States	1.52	0.48	0.52	0.44

As can be observed, the NRC-regulated reactors experienced fewer automatic scrams all four of these years. Each system appears to be improving as is seen by the decrease in automatic scrams each country has witnessed in the past ten years. The French reactors have almost cut their average scrams per reactor in half from 2.2 in 1992 to 1.19 2002, while the United States has decreased the occurrence of automatic scrams by almost two thirds from 1.52 in 1992 to 0.44 in 2002. Thus, the United States holds the advantage in preventing automatic scrams.

5.6 Vessel Head Degradation

In September 1991 during an inspection of a PWR vessel head at a French power reactor, cracks were found to be forming near the nozzle penetrations. Before this time, the accepted theory was that such cracks would be initiated by high temperatures under the vessel head and prolonged operating time. However, the cracks were found on a vessel head significantly cooler than then the French thought would be required to initiate the cracks. It was soon evident that a phenomenon labeled primary water stress corrosion cracking was responsible for the cracks. Also, and most important to this discussion, was the determination that the type of steel used to make the vessel heads, Alloy 600, was especially susceptible to primary water stress corrosion cracking. The French were immediately concerned with the possibility of a catastrophic failure of the vessel head penetration nozzles and the inability of the current susceptibility modeling to accurately predict occurrences. The regulator also began to revise the inspection procedures, to include an eddy current analysis of all head penetrations to avoid through-wall cracking before it was even visible. Furthermore, the regulatory agency required pressure vessel head visual inspections with all of the insulation removed during every outage. Soon after the first crack in a vessel head penetration was observed, thorough inspection of all the French reactors soon yielded ten more penetrations with similar cracks. The regulating agency and the utility immediately began to consider vessel head replacement as an economic decision. The increased vigilance required in inspections and the potential for increased outages convinced both regulatory and utility that replacement was the solution in a collaborative decision. Immediately, the EDF began a program to replace every vessel head using the more stress-resistant Alloy 690. As of April 2002, over half of all the heads had been replaced, and each vessel head penetration is inspected visually at every outage.

At the time of the incident, the NRC recommended modifications to enable easier inspection and cleaning of vessel heads in the United States. They also issued a number of communications related to the incident and possibility of future incidents. The first was Generic Letter 88-05 of 1988 which discussed the possibility and observances of "boric acid corrosion of carbon steel reactor pressure boundary components in PWR plants" and suggested visual inspections of vessel head penetrations to detect any visible cracking. In 1997 another communication, Generic Letter 97-01 requested the plant licensees to develop programs to monitor the cracking of vessel head penetrations and their intentions, if any, to perform non-visual inspections. Most recently, the NRC released Bulletin 2001-01 "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles". This Bulletin was issued to

> "request that addressees provide information related to the structural integrity of the reactor pressure vessel head penetration (VHP) nozzles for their respective facilities, including the extent of VHP nozzle leakage and cracking that has been found to date, the inspections and repairs that have been undertaken to satisfy applicable regulatory requirements, and the basis for concluding that their plans for future inspections will ensure compliance with applicable regulatory requirements." [29]

Ten years after the French incident, during an NRC-prompted inspection, the utility found cracks deep enough to allow small amounts of cooling water to leak from the vessel. After workers removed dry deposits of boric acid, corrosion which covered twenty square inches near the center of the head was discovered. At the deepest point, the vessel head had corroded to a mere 3/8-inch thick, just leaving the stainless steel cladding on the underneath of the vessel head. Immediately, the NRC alerted all PWR operators of the incident and recommended more stringent inspection techniques of reactor vessel heads. After reviewing the inspection reports, it was determined not one of the other 68

PWRs exhibited conditions as severe as the ones that led to the David Besse incident. The NRC did not require any operator to upgrade their vessel head to the more stress-resistant Alloy 690. A few utilities planned on their own, however, to replace the vessel heads on their own as a preventative measure in the next decade. [30]

In investigating the incident, it was noted that Davis Besse had an excellent record in regards to economic performance and efficiency. In fact, the French Inspector General for Nuclear Safety and Radiation Protection Pierre Wiroth noted this in his annual safety report and suggested that "the proper balance between productivity and nuclear safety was not achieved, and this situation gradually led to less care to comply with the regulatory constraints and to considering degraded situations to be normal." [23] Also in the report, he suggests "performance and nuclear safety must be the subject of the same attention and professionalism, with priority always being given to nuclear safety". [23]

This vessel head incidents offer a suitable method for comparing the role and response of the two different regulatory agencies. When the EDF in France was first confronted with the evidence that cracks were discovered in vessel head penetrations and at least one head had started corroding from the leaking water and it was possible in any vessel head, it immediately, in agreement with the nuclear authority, began a program to replace all the vessel heads in France. The relationship between the regulatory agency and the utility was a cooperative one which improved communication between the two. Also, the French shared its information and reports with the United States. The utilities in the United States were well aware of the problem in France and believed that the corrosion would first appear in the older reactors first, thus giving the utilities fair warning before the vessel head corrosion could become an obstacle to them. At Davis Besse, these suggested surveillances and programs were not immediately followed. Had the NRC required immediate action from the utilities, the measures might have led to a much earlier discovery of the corrosion damage. [23] These warning signs include streaks of crystallized boric acid outside the reactor vessel, which were dismissed as products of other known leaks. The brown color of the streaks should also have suggested metallic corrosion, but since the streaks were ignored to begin with, this was never considered. Lastly, the containment ventilation filters were clogged with aerosols typically associated with corrosion incidents. Furthermore, though the NRC had instigated a program for all reactors in inspect the vessel head bores, the management at Davis Besse had obtained special permission from the NRC to delay the inspections until the next planned outage, thus postponing the discovery several months. The compilation of these errors and oversights nearly led to a major leak in the vessel head.

An important observation from these incidents is the fact that the NRC and its utilities did not show sufficient concern for preventing an incident. While the French decided to replace to vessel heads to avoid even the possibility of a serious vessel head malfunction, the NRC opted to suggest inspections of the PWR vessel heads. At best, these inspections hoped to catch the corrosion after it had begun, but before it breached the entire vessel. Thus the NRC appears to be content on dealing with symptoms as they arise, as opposed to the French approach of preventing the symptoms altogether.

6. Analysis

The previous chapters have outlined the historical foundations for both the Nuclear Regulator Commission of the United States and the Direction Générale de la Sûreté Nucléaire et de la Radioprotection of France. Also presented were the present day organizational structures and the unique licensing and surveillance procedures of each agency. The administrative and regulatory structures are important in understanding the similarities and differences between the two agencies, but by themselves offer no objective comparison between the two countries.

For a stricter, quantitative comparison, the data presented in the previous chapter offer a starting point for juxtaposition. Since the regulatory agencies are similar in their basic function and mission, it is effective to compare the different types of efficiencies evident in the regulatory process as well as in the power production process. For the purpose of an objective comparison, three types of efficiencies will be presented; staff, power, and safety.

Staff efficiency is a ratio of regulatory employees to an output parameter of the agency. In the previous chapter, this ratio is given as staff members per billion kilowatt hours and staff members per plant. Though the NRC encompasses performs both regulatory and research functions, only the 54% of the staff concerned with reactor safety and regulation will be considered for this comparison. In France, the primary research is carried out by the CEA or the EDF, so the DGSNR staff figures are accurate as presented.

For essentially equivalent safety performance, the NRC has 14.5 employees per plant, while the DGSNR has 9.6 employees per plant. When only inspectors are concerned, the NRC has 3.2 inspectors per nuclear reactor facility as compared to 2.0 inspectors per reactor in France. Since the two industries experience similar success in their safety performance, the larger staff per plant of the NRC indicates a larger total regulatory workload per plant in the United States. It is suggested above and here again that the NRC owes its larger staff to the larger judicial responsibilities it holds over its French counterpart. To conclude, in this category of staff efficiency, the French DGSNR holds the advantage over the NRC.

The power efficiency of each agency is a relative measure of regulatory burden and the management of the utilities. This ratio is offered as an indicator of plant performance that affects the overall safety since unplanned outages and safety system trips indicate trouble at a given plant. If an agency requires strict but achievable safety goals, the power plants should be able to produce near their maximum output. If an agency requires safety standards that are barely realistically attainable, the power efficiency will decrease as power plants struggle to comply. Since every reactor requires occasional planned, routine outages, the unplanned capacity loss factor will be used for this comparison. The NRC's unplanned capacity loss factor for 2002 was 0.44 compared to 1.19 for the French DGSNR. In other words, the French nuclear industry experienced nearly twice the capacity loss of the American reactor fleet in 2002. Therefore, based on power production, the American utilities and the NRC surpass the

DGSNR and the French EDF in plant management.

Perhaps most important, however, is the responsibility of the agencies to keep nuclear power safe for the public. This includes protecting the health of the environment, the public, and the workers of the nuclear industry. Safety efficiency is also the hardest to measure quantitively. The frequency of unplanned automatic scrams is offered as one metric of safety efficiency, as is the ratio of regulatory staff to automatic scrams.

The average number of automatic scrams in France is 1.19 scrams per reactor per year compared to 0.44 scrams per reactor per year in the United States. Clearly, the United States has the statistical advantage. While the observed statistical difference in safety performance and efficiency is an important consideration in comparing the two agencies, an analysis of the reasons for these differences is even more important.

As mentioned in previous chapters, the NRC is designed around a legislative based foundation. Problems and concerns are dealt with from a legal standpoint as well as technical. The possibility of a lawsuit being filed against a utility or the NRC is a constant fear for the agency and utility involved. As a result, the resolution of technical problems often involves legal proceedings to adjudicate on the possibility of blame or negligence. The technical issue must be addressed and corrected from an engineering standpoint while the cause and effect must be considered legally. As a result, while the NRC may resolve a technical issue in a similar manner as the French DGSNR, it is forced to do so while also taking legal and administrative measures to appropriately deal with the legal implications of the issue. It is this additional consideration that causes similar regulatory actions and investigations to proceed slower and take longer in the United States.

In contrast, the DGSNR is primarily concerned with the safe and expedient technical resolution of any abnormal condition or incident. When the utility contacts the regulatory agency regarding a problem, the first priority is always the safe resolution of that problem. The utility and the DGSNR work together to correct the incident, evaluate the cause, and prevent a reoccurrence. Since the DGSNR is not obligated to share event reports with the general public, there is often little if any legal concerns resulting from reactor incidents. This is very different from the NRC's position, which must make publicly available many documents concerning reactor incidents and licensee reports. As a result, the DGSNR faces less administrative and legal burden and is thus able to resolve many conflicts using only technical staff and an engineering oriented solution, while the NRC requires a sizable staff of lawyers to handle the additional legislative burden.

A last but very important safety consideration is the frequency of high profile nuclear safety accidents. The prevention of these accidents is critically important to a country's nuclear energy program, because the social and political effect of an event can damage the credibility of the regulatory agency and the trust of the public in that agency.

Fortunately for France, a major nuclear accident has never occurred in the half-century history of its nuclear power program. The worst accident was the fuel damage sustained at the Saint Laurent power plant, a Level Four accident as described in a previous chapter. This accident however was completely contained within the reactor facility and not widely publicized outside of the nuclear community. As a result, the public reaction was minimal.

Unfortunately, the accident at Three Mile Island in the United States was much more detrimental to the nuclear industry and regulatory agency. Though this accident was classified only one level higher than the Saint Laurent accident in France, the difference between Level Five and Level Four is a significant one; Level Five accidents include limited environmental release of radioactive gasses while Level Four accidents do not.

While the Saint Laurent accident was quickly acknowledged and repaired, the accident at Three Mile Island resulted in the shutdown and defueling of the reactor and also served to increase public fear. Combined with the public's misconception of radiation and the reality that nuclear accidents can in fact happen on American soil, the political and regulatory effect of Three Mile Island on the NRC and its method of regulation was significant.

Most important though in the context of comparing the regulatory structures is that the United States has suffered an accident like Three Mile Island while France has not. When correlated to the employment numbers, it appears as if the much larger NRC may be able to keep automatic scrams at a minimum, but unfortunately was unable to prevent the accident at Three Mile Island. This invariably gives an overall safety advantage to the French DGSNR. Because the French have never suffered an accident similar to Three Mile Island, the public and non-nuclear departments of the government are more likely to trust the regulatory agency.

Though many differences of the regulatory agencies have been offered thus far to provide a comparison, it is the comparable safety performance that is most important in judging the regulatory agencies. Due to the highly technical and perceived dangerous nature of nuclear power, it is imperative that each regulatory agency have the confidence of their citizens based on actions to ensure public health and safety. But even more important is the responsibility of the utilities to alleviate the fear of the public by demonstrating the ability to operate safely and preventing any fear to be realized. Though the events of Three Mile Island occurred twenty-five years ago and numerous changes have been made in the United States regulatory process and at the utilities to improve the focus on safety, the perception by the public of the NRC is still tainted by the accident. As such, and for the purposes of this thesis, the failure of the NRC and the utility at Three Mile Island denigrates the efficiency of the regulatory agency, thus giving France the advantage in this most important regulatory consideration.

7. Conclusion

The Nuclear Regulatory Commission of the United States and the Direction Générale de la Sûreté Nucléaire et de la Radioprotection of France share similar missions, and similar successes within those missions. The observations pertinent to this thesis lie in their differences, which have been discussed in the preceding chapters.

The French DGSNR is able to regulate with a similar number of average scrams and a comparable unplanned capacity loss factor while employing far fewer personnel than the NRC. Also, the regulator in France works with the utilities to minimize regulatory burden with continuing efforts to improve safety. This regulatory process in France results in the utilities and the regulatory combining their scientific efforts to reach the common goal of safe, efficient operation.

While the DGSNR and its utilities function as allies or partners in regulation, the NRC's relationship with its utilities is more disciplined, with the regulator acting as a supervisor with whom the utilities must comply. As discussed in previous chapters, the cooperative nature of the French system leads to quicker issue resolution with less of a legal burden.

Furthermore, as discussed, the DGSNR has a better safety record when compared to one data point - the NRC's Three Mile Island accident. This single event drastically changed the public perception of nuclear power in the United States. As a result, the NRC must be constantly aware of public perception and work to restore trust in the nuclear industry. These public relations aspects of the NRC add to its workload without increasing regulatory efficiency. As such, France benefits from the absence of a similar accident by holding a healthier public image and maintaining that image through its unsullied safety record.

In conclusion, the ability of the DGSNR to regulate a similar industry with similar safety histories but with far fewer staff and no major accident to date raises questions about the necessity of the NRC's much larger staff and establishes the DGSNR as the more efficient and effective regulatory agency.

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