Supplely regulating nuclear risks: The origins of a French exception (1960-1985)

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France has a historical tradition of codifying rules and regulations into an elaborate corpus of public law applied by a powerful administration. However the nuclear industry seems to have long been spared this tradition. This analysis of the development and operation of the French system for regulating nuclear risks between 1960 and 1985 brings to light a suppleness of the first rules, standards and orientations for risk-management. This French exception has two explanations: the structure of the network of the institutions involved in regulations; and the political, industrial and social context in which the "small world" of nuclear safety evolved. This analysis stimulates thought about how the French risk-regulation regime is evolving in the current context.

A French model for regulating nuclear risks?

France has a long tradition of codifying rules and regulations, and it has an extremely developed corpus of public law implemented by a powerful administration.[1] However the nuclear industry seems to have been spared, for a long time, this tradition, as others have noticed: "*Everything, or nearly everything, has to be written in the law; the Conseil d'État sees to the application of a very developed corpus of public law, and civil servants draft and apply many regulations. [But] this cliché does not hold for nuclear safety*" (LÉVÊQUE 2013a, 2013b). Members of the organizations of the safety and security of nuclear energy share this viewpoint, as a commissioner of the ASN explained in 2007, "*There is a large enough number of documents, called 'guides' or 'fundamental rules of safety' with an uncertain legal status*".[2] How to explain this phenomenon? Not only does it seem specific to the French nuclear industry but it also sets France apart from the other major "atomic" countries? Answering this question can help us inquire into the origins of a regime of risk regulation, its determinants and evolution.

To understand the origins of the French model for regulating nuclear risks, we have chosen to concentrate on the period from 1960 to 1985, which corresponds to the emergence of nuclear safety as a technical discipline and its gradual institutionalization by the countries with a nuclear industry. During this period in France, instruments for regulating nuclear risks were designed that combined political orientations, technical specifications and regulatory "obligations". These instruments took the form of ministerial directives, guides

[1] This article has been translated from French by Noal Mellott (Omaha Beach, France). The translation into English has, with the editor's approval, completed a few bibliographical references.

[2] Quotation from the ASN's *Revue Contrôle*, 178, January 2007. The ASN (Autorité de Sûreté Nucléaire) defined nuclear safety as the set of arrangements for ensuring the normal operation of a nuclear power plant, warning about accidents or malevolent actions, and limiting their effects on workers, the public and the environment. The ASN was set up in 2006 as an independent administrative authority. However this control function existed since 1973 in other legal forms and under other denominations.

of good conduct, rules of design and safety reports. By seeing how these instruments were designed, we have produced new evidence for understanding the French model of safety regulations for the nuclear industry during this period. This look back on history will help us clarify the current situation with its different sociopolitical and economic context.

Analyzing "risk-regulation regimes" through their instruments

What is risk regulation? We take the public regulation of risks to be "*the set of institutions, rules and norms that contribute to supervising activities with a potential or proven danger for the population's health or well-being*" (BORRAZ 2015, p. 258). Gabrielle Hecht's (2014) work has shown how France, through nuclear energy, has designed "technopolitical" systems that have shaped a "national identity" and formed a technological exception on the planet. His recounting of the history of the French nuclear industry has shed light on the persistence over time of a French specificity in nuclear energy. He has defined a technopolitical system to be "*a set of individuals, engineering and industrial practices, technical objects and institutional ideologies*" that encompasses, in particular, the activities for regulating risks, the topic of ths article.

Others authors (HOOD *et al*. 2001) have tried to describe "*risk-regulation regimes*" by focusing on cases as varied as air pollution, the use of pesticides or even road safety in the United Kingdom. They have described the diverse elements — the institutional organization, rules, regulations, practices and ideas associated with the regulation of specific risks — in these regimes and tried to detect correlations between them. With the help of studies such as these (DETSYK 2010), even though they have not always served as references in this discipline, we have sought to bring to light, without any normative intent, the characteristics of the French risk-regulation regime and to explain the changes in it.

Nonetheless, most researchers agree that there is a variety of risk-regulation regimes, which differ with regard to several variables and, in particular, the type of risk or the country (GALLAND 2011). For instance, a series of studies in the 1980s pointed to major differences in regulating risks between Europe and the United States (VOGEL 1986). In the United States, risk regulation is considered to be an open system involving conflict where stakeholders play a leading role whereas, in Europe, a closed system induces "*a confrontation between the experts who know the best solution […]. In a closed system with a monopoly over knowledge, there is very little room for alternative sources of expertise*" (BONNEUIL & JOLY 2013).

These remarks seem relevant to studies on nuclear safety in France, whose authors (FOASSO 2012, LÉVÊQUE 2013b, ROLINA 2009) have pointed to a French exceptionalism in regulating nuclear risks as compared with the United States. Historically, the systems of nuclear safety in these two countries were grounded on a notable difference in philosophy: for the United States, the use of regulatory instruments, and for France, a "technical dialog", which has been called "French cooking". This phrase draws attention to the intellectual and cultural proximity between the persons in charge of nuclear safety, and to the direct, close relations between experts, safety authorities and plant operators. Accordingly, the French model's conception of nuclear safety based on a dialog is correlated with a weak (or even absent) regulatory framework whereas control characterizes the US model of regulation based on a major body of legislative and regulatory instruments (acts of law, regulations, standards and codes). These studies have emphasized the existence of two contrasting ideal types of risk regulation in the nuclear industry.

Starting from the hypothesis of a specificity of the French model of regulation, we have chosen to explore this model's instruments, which are a key component in the sense of Hood *et al*. (2001), for whom regulations and standards are the components of risk-regulation regimes. Such instruments are methodologically easy to grasp. For political scientists who have studied public interventions, an instrument is a "*technical arrangement with a generic vocation that bears a concrete conception of the relation between politics and society, and relies on a conception of regulation*" (LASCOUMES 2004, ¶14). Such instruments are, therefore, a litmus test of relations between the rulers and the ruled. They are efficient indicators of the conception of, and changes in, a regulation regime. Among these different forms of instruments for action by public authorities, we have focused on apparently "*depoliticized*" (BORRAZ 2005) technical instruments, all of them intended to help control dangerous activities — what we shall call "instruments of risk regulation". We shall inquire into the factors that have led to choosing such and such a risk-regulation instrument (LASCOUMES & SIMARD 2011).

Two levels of analysis seemed relevant for explaining the types of risk-regulation instruments adopted. The first level is the structure of the network of institutionally implicated stakeholders (BRESSERS & O'TOOLE 1998). We have shed light on the characteristics of this network, which operates like a "small world" of nuclear safety. On a "macro" level, we have examined the effects of the political, industrial and social contexts in which this small world moves and evolves. These two types of variables[3] seem to have provided the keys to understanding the choice of instruments and, through them, the origins of the risk-regulation regime for the nuclear industry. This will lead us to formulate hypotheses about recent trends.

Methodology and choice of period

Adopting a sociohistorical approach (BAUDOT 2014, NOIRIEL 2006), we have chosen to study the period from 1960 to 1985: from 1960 when the first organization for controlling nuclear safety was set up in France till 1985 (on the eve of the Chernobyl catastrophe) at a

[3] These two variables can be seen in relation to the analytical grid proposed by Hood *et al*. (2001), who have differentiated between a regulation regime's variables of "contents" (the institutional characteristics of regulation) and its variables of "context" (in particular, stakeholders' interests).

time when 56 out of the 58 nuclear reactors that EDF (Électricité de France, the French national electricity utility) was operating in France in 2016 were being built or were already under operation and when the institutional system for regulating risks seemed stable.

This research has mainly relied on archives for this period. Among our sources of information were approximately 300 documents that recount the designing and drafting of risk-reduction instruments. These sources encompass the gray literature available on questions of nuclear safety: technical assessments, minutes of meetings, reports of inspection or from trips abroad, communications to conferences, regulatory and quasi regulatory texts, and documents of public communications. Most of these sources were found in the public archives of the Institut de Radioprotection et de Sûreté Nucléaire (IRSN), EDF, the IAEA (International Atomic Energy Agency) and Framatome.[4] We also obtained newspaper clippings from records in these archives and from *Sud-Ouest* and *Le Monde*. In addition, we used available social science studies (sociology, history, managerial sciences, etc.) on nuclear safety.

The analysis of these sources in the archives was completed with a few interviews conducted with persons in charge of nuclear safety at the end of the 1970s and during the 1980s.

After describing the history of the management of nuclear safety and risk-reduction instruments in France from 1960 to 1985, we shall turn to two major categories of factors that account for the choice of the instruments retained herein: the key role of the small world of institutional actors; and the political, economic and social context at the time. The third part of this article will use this analysis to propose thoughts about the current state of the French regime for reducing nuclear risks and the trends in it.

The formation of a nuclear safety regime and its instruments, 1960-1985: A brief history

Although the dangers related to radioactivity were known since the mid-1920s, researchers and engineers addressed, little by little, the question of these risks only after the nuclear industry (initially for military and then for civilian purposes) started developing. Between 1945 and 1955, the principal activity in this sector was research under the auspices of a single institution: the Commissariat à l'Énergie Atomique (CEA). The use of atomic energy was "*not concurrent with any specific safety rules save for those that researchers, engineers and technicians voluntarily set for themselves*" (FOASSO 2003).

EDF's entry into the field of civilian nuclear energy in 1955 marked the start of industrialization in this sector. This process called for safety procedures, which would be adopted through a formal dialog between the CEA and EDF based on a single document: the safety report. This system had been set up for EDF's first nuclear power station in Chinon in 1962. In the United States (already since the 1950s), the operators of nuclear installations had to present to supervisory authorities, during each phase (design, construction, operation), a written report describing the state of the installation along with a study of the worst possible accidents. This report had to show that the accidents mentioned were the most serious ones and that the protective measures taken were capable of avoiding disturbances outside the plant. In contrast, the French safety report assessed the risks and protective measures related to the installation but with the goal of obtaining from public authorities permits to build and then operate the installation. In the early 1960s, this report, the key to assessments of an installation's safety, served as the grounds for a dialog between several organizations. Specific arrangements organized this dialog.

In 1968, to put an end to standoffs between the CEA and EDF, an enlarged group of experts was formed of representatives from the CEA, EDF and the Ministry of Industry. Its assignment, which had been the CEA's alone, was to analyze the contents of safety reports. This group, institutionalized by a ministerial order in 1972, was called the Permanent Group (of Experts). It became a key element in the risk-regulation regime of France's nuclear industry. In the mid-1970s, the Permanent Group (made up of representatives of the supervisory authority and of the ministries concerned, and of public experts and industrialists) could be consulted on problems related to the various phases during an installation's life cycle, the drafting of regulations or any other topic having to do with nuclear safety.

In the year following the first oil shock in 1973, the Messmer Plan (Messmer being the name of the minister of Industry) formulated the country's choices with regard to nuclear energy. It also signaled the institutionalization of the organizations in charge of nuclear safety. A supervisory authority was set up in 1973 (SCSIN: Service Central de Sûreté des Installations Nucléaires) and then, in 1976, the Institut de Protection et de Sûreté Nucléaire (IPSN), within the CEA. These organizations, as well as EDF, were then placed under the Ministry of Industry. The supervisory authority formed along with experts and with EDF (the only operator of power stations in France) a "*tripod of safety*" (FOASSO 2003), the Permanent Group serving as its keystone.

Till the mid-1970s, documents (studies, notes, reports, etc. — without any legal status) from these organizations served as the grounds for the work of safety experts. Apart from a decree in 1963,[5] there was no legislative or regulatory text on nuclear safety. Following the adoption of the technology for pressurized water reactors (henceforth PWRs), the pressurized components in nuclear installations had to be regulated

[4] In 2006, Framatome was renamed AREVA NP. Its archives were consulted at the François Bourdon Academoy in Creusot.

[5] Decree n°63-1228 of 11 December 1963 on nuclear installations created the status "base nuclear installations" (INB).

by a decree in 1973[6] that placed them under the oversight of the Mining Administration, which, since the 19th century, had the assignment of controlling pressurized installations. This administration's role in nuclear safety would be reinforced.

At the end of the 1970s, technical regulations were drafted in a limited number of documents. These documents mostly took the form of ministerial "notes of orientation" or "orders".[7] In addition, there were the "documents on doctrine" drafted by EDF. Meanwhile, the SCSIN was, on "*subjects of interest*" (as a former head of a supervisory authority said during an interview), drafting a set of fundamental safety rules (RFS: *règles fondamentales de surêté*), which stipulated what was deemed good practices for nuclear power station operators. All of this formed a *de facto* list of regulatory specifications but without creating an actual legal framework — unlike elsewhere, as in the United States or Germany, which were building a more conventional regulatory hierarchy based on acts of law. In France, a regulatory model of this sort would not be adopted till much later, after the turn of the century, as we shall see in the last part of this article.

The "small world" of nuclear safety

The "tripod" formed by the organizations in charge of safety already had a long history of collaboration when it was institutionalized in the mid-1970s. These organizations and the persons representing them had been working together for several years, even decades, before the government launched the Messmer Plan. The experts, who knew each other well and shared views, would be at the origin of a risk-regulation regime based primarily on a dialog and consensus.

The isolationism and discretion of expertise and decision-making circles

Till the middle of the 1970s, the CEA was the only organization for expertise on nuclear risks. Its relation with the military and its initial orientation toward developing nuclear weapons probably explain, in part, the closed, discreet operation of the persons in charge of regulating nuclear risks: "*We observe in France a sort of organizational internalization of risks, in other words, the process of managing risks is maintained within the organizations implicated in the nuclear industry*" (VALLET 1984). Discussions between experts took place inside a closed circle, whose members thought they had the best knowledge about the very technical questions of safety. Although experts from the CEA and EDF sometimes did not agree on technical issues, reaching a consensus through a dialog among peers was the preferred solution.

In 1973, newcomers were introduced in this system: the SCSIN, a regulatory authority, and the IPSN, a source of expertise. However this did not modify the operational principle of a dialog between experts who knew each other very well.

The endogamy of these circles

As of 1960, experts from the CEA and EDF were led to work together on plans for nuclear reactors. They had been educated in the same schools and shared a common outlook. Since 1955, engineers at EDF had been learning the CEA's techniques, in particular through the INSTN (Institut National des Sciences et Techniques Nucléaires), the CEA's training institute, which offered several technical courses on nuclear safety. These experts had it easy talking together since "*the men from the CEA (scientists, engineers), the people from EDF in charge of nuclear reactors or, later, officials from the ministries, all of them were engineers, physicists, who had a scientific or technical education and who shared the same confidence in 'technical rationality', which could be the only truly objective judge*" (FOASSO 2012).

The circulation of engineers and experts between these various organizations augmented this endogamy. Several experts were involved in the safety both of the CEA's installations for producing plutonium for military purposes and of EDF's first reactors for generating electricity. This closeness was even geographical since, at its creation, the SCSIN's offices were located in Saclay — on the same site as the CEA (FOASSO 2003). Furthermore, these persons were all, since the end of the 1960s, officially under, in one sense or another, the Ministry of Industry.

Finally, the smallness of this world of nuclear safety also fostered "endogamy". This small world included a few organizations and, more importantly, a single nuclear power station operator: EDF. This situation was unique in the world. There were, in 1980, a dozen operators in the United States and five in Germany.

Resisting American pressure

The shift at the end of the 1960s from the CEA's national technology based on graphite-gas to the American technology based on PWRs (licensed from Westinghouse) opened a new era, since everyone in nuclear safety had to update their education. At the start, this shift forced the CEA and EDF to "copy" American technology in order to be able to build as fast as possible the first PWRs in Fessenheim and Bugey in the early 1970s.

The concept of using another nuclear power station as a benchmark originated in this experience. For Fessenheim, the benchmark was Beaver Valley in Pennsylvania (built in 1976). This concept served to reduce both costs and delays and to gradually train personnel from EDF, Framatome, the SCSIN and CEA by presenting the experiences of nuclear safety authorities in the United States and of American engineering firms. For these two power stations, "*EDF and safety authorities agreed to apply in France the regulations*

[6] This entailed an abandonment of the CEA's graphite-moderated reactors in favor of EDF's pressurized water reactors designed by Framatome, under a licence with Westinghouse since 1958. This shift in technology meant that existing texts on pressurized components were no longer applicable as such.

[7] Order (*arrêté*) of 26 February 1974 on the construction of the pressure vessel's principal primary circuit. SIN letter (n°1076/77 of 11 July 1977 from the minister in charge of Industry to the general manager of EDF) on major safety options with regard to PWRs.

of the US Nuclear Regulatory Commission."[8] When examining safety reports from the power stations in Fessenheim and Bugey, the experts of the Permanent Group backed their opinion with American regulations.

This pragmatic mimicry, seen as a necessary step, would, in the 1970s, be counterbalanced by the very the strong determination to develop French know-how about nuclear safety. This can be related to the determination of certain stakeholders to take up a technological challenge (following the events related to atomic bombs) and save a "*national identity*" (HECHT 2014). As of the middle of the 1970s, considerable effort was put into making the reactors and technical rules "French"; and a start was made at drafting French regulations (rules, codes, standards, orientations).

These forms of resistance also occurred when drafting a "doctrine". An international consensus soon formed around the so-called "deterministic" approach to a "deep defense", adopted by the United States in the 1960s and figuring in IAEA's documents. This approach foresaw several layers of protection from the initial phase (designing an installation) onwards. These "lines of defense" were intended to reduce to a very low level the risk that an accident might have serious consequences outside the power plant. This would, however, be completed with a so-called "probabilistic" approach, which publications in English were making well known.[9] This probabilistic approach tries to identify cascades of defects that might lead to a major accident; it seeks, in particular, to state the probabilities of the occurrences of these events and of chains of such events.

To analyze nuclear safety in France, experts preferred the deterministic approach even though the IPSN and SCSIN tried to take into account the probabilistic approach. Nevertheless, the latter would never occupy the place it gradually acquired in the United States and United Kingdom. In effect, France would not follow the probabilistic approach's orientation for using statistics to set an acceptable level of risk. The tendency to use statistics in this way was frequent in US documents on "safety goals",[10] which set the level of acceptability in terms of the number of deaths or cases of cancers linked to a nuclear installation. For many French experts, basing a risk assessment on statistics alone

[8] P. TANGUY, "Philosophie de la sûreté en France", *Revue Nuclear Safety*, July 1983.

[9] In particular the report by Norman RASMUSSEN, "Reactor safety study: An assessment of accident risks in US commercial nuclear power plants, Executive Summary", WASH-1400 (NUREG-75/014). Rockville, MD, USA: US Nuclear Regulatory Commission, October 1975. Available via https://www.osti.gov/servlets/purl/7134131.

[10] NRC, 10 CFR Part 50, "Safety goals for the operation of nuclear power plants: Policy statement", republication 1986.

The SCSIN's letters of orientation: Discreet technical and policy instruments

The SCSIN's "letters of orientation" illustrate what we have called "risk-regulation instruments" and provide a glimpse of the characteristics of the French risk-regulation regime during the 1970s and 1980s. They present, in general terms, the principal safety options to be retained for nuclear power plants on the drawing board or under construction. Each letter has an introduction and then technical appendixes with details about the safety options retained (size of installations, containment buildings, accidents, etc.). The five letters of orientation between 1977 and 1984 were signed by the minister of Industry and sent to EDF's general manager. They came out of the joint work of the IPSN, SCSIN and EDF.

These letters were supple regulatory instruments since they did not formulate obligations. Moreover, they were not published in the *Journal Officiel* and were not visible to the public.

By analyzing the first two letters (1977 and 1978), we could detect the "negotiations" under way between the controlling authority and the operator about the type of nuclear safety options to adopt for building the next nuclear power stations.

In the first of these two letters, the Ministry of Industry, via the SCSIN, recommended EDF to use probabilistic goals to study safety, and it even set a number that, deemed to be the threshold between acceptable and unacceptable levels of risk, conditioned the scaling of protective measures for nuclear power stations: "*The global probability that a unit can be at the origin of unacceptable consequences should not be more than 10^{-6}/year.*"[a] Though unable to reconstitute the full process of these negotiations, we think that EDF had a difference of opinion about the recommendation on using probabilities. It felt that this recommendation was "*not well founded [and was] in any case, premature*".[b] The debate would be closed by the Ministry, which choose to not impose its views: "*The figures on probability in my letter SIN n°1076/77 ultimately ought to be considered to be orders of magnitude*".[c] So, there was no longer any question about releasing limits of acceptability, and the probabilistic goals were to serve only as a guide for a technical risk assessment. This deterministic approach, combined with a dialog among experts, was the grounds for evaluating safety.

[a] SIN letter n°1076/77 of 11 July 1977 (from the minister of Industry and EDF's managing director) on the major safety options of PWR units.
[b] EDF's reply of 5 October 1977 to the aforementioned SIN letter.
[c] SIN letter n°576/78 of 16 March 1978 (from the minister of Industry to EDF's managing director) on the major safety options of PWR units.

would mean abandoning their "technical dialog", which was the grounds for assessing safety (LÉVÊQUE, 2013b). At the time, these experts were convinced that the acceptance of nuclear energy by society had to be based on a strong, discreet technical expertise grounded on the judgment of engineers rather than on tables of statistics.

A fine illustration of how this small world worked together comes from the ministerial "letters of orientation" (cf. Insert 1), which provide information about the process for drawing up, within a closed group of experts, a "doctrine" and the instruments (supple instead of coercive) implied by it. As much can be said for the various policy instruments created in the late 1970s. This process falls in line with the analysis made by Bressers and O'Toole (1998), who found in the operation of persons in a coherent, interconnected network the explanation of why policy instruments were chosen that were not very normative and were co-constructed with the "targeted public" (in this case, nuclear power plant operators).

This process allowed for freedom of choice when applying these instruments. The latter were, it is worth pointing out, paradoxically part of a process that seemed to be highly standardized, "routine" (involving meetings of the Permanent Group and the examination of safety reports).

This making of risk-reduction instruments in "*discreet*" places (CHANTON *et al*. 2016, GARRAUD 1990, GILBERT & HENRY 2012) has implications for the form chosen for most of these instruments, namely: "reglulations or quasi regulations". In effect, the French Parliament did not have a word to say about the organization of the nuclear industry before the turn of the century. This "institutional architecture" was very cohesive, all of it under the Ministry of Industry. What characterizes the risk-reduction instruments produced in these discreet circles, by this small world of nuclear safety, is their regulatory suppleness. The 1980s would bolster this French risk-regulation regime, which experts and decision-makers in France called a "technical dialog", but which international observers have called "French cooking". The context reinforced this process.

The impact of the political, industrial and social context on risk-reduction instruments

In the 1970s, choices about the safety regime were tightly coupled with the development of a nuclear program and the efforts to boost exports. Meanwhile, tensions were growing with society, in particular with antinuclear activists, who were trying to block, physically or legally, construction sites for nuclear installations. This context would affect the choice of risk-reduction instruments.

Supple rules to avoid hampering construction

While not hiding their interest in the American regulatory model, which served as a reference mark, French experts wanted to stymie the growth of regulations. An official at the SCSIN had this to say about American regulations: "*Public authorities are very directive, and this is not unrelated to the diversity of the producers of electric energy in the country. The complex set [of regulations], of which we have difficulty seeing the coherence, […] is, nonetheless, currently a very useful reference for drawing up technical regulations in other countries.*"[11] French experts extended this criticism to the time needed to obtain permits for operating nuclear power plants: "*A request for a permit can take two years of procedures. We can, therefore, conclude that the AEC has probably gone too far, too fast*"[12] (QUENIART 1974). In effect, the average length of time for building a nuclear power station in France was six years compared with ten years in the United States (KITSCHELT 1986).

According to a note from EDF's Direction of Equipment, the drafting of a regulation should make it possible "*to limit demands for supplementary studies, to not have to deal with new challenges when examining safety for each new program filed by the prime contractor.*"[13] In line with this point of view and with the ministry in charge, which was trying to speed up work at construction sites, industrialists introduced the preoccupation with efficiency in their communications. Meanwhile, the first difficulties were cropping up technically (overshot deadlines) as well as socially and politically (the increasing virulence of opponents at worksites).[14] For EDF, the role of regulation "*is not just to coerce but also to help the operator by providing him with arguments that are legitimate since they are based on science and the law*".[13]

Exporting reactors and French standards

In France, stakeholders in the nuclear industry wanted a system of simple, stable rules; but the determination to export industrial techniques forced the constructor (Framatome) and the operator (EDF) to draft rules for designing and building nuclear power stations. As top executives at Framatome explained, "*Exportation, maybe even more than the nation's program for generating electricity from nuclear power, leads to French technical regulations being rapidly drafted and established*" (COUDRAY & PERRAIS 1974). The United States and Germany developed important systems of standards that linked the design and construction of power stations to nuclear safety. In France, this was not yet the case at the end of the 1970s, a situation that "*can be a handicap on exportation, while others constructors are cleverly stating that they have 'systems of standardization' more developed than in France and more or less in line with safety regulations*".[15]

[11] Course on the establishment and execution of projects for producing electricity from nuclear power, IAEA, 1976.

[12] The Atomic Energy Commission (AEC) was the organization in the United States in charge of promoting and controlling nuclear energy till 1974, when it was replaced with the Nuclear Regulatory Commission (NRC), a move that separated "promotion" from "control".

[13] EDF, "Intérêt d'une réglementation française en matière de sûreté", February 1977.

[14] At the peak of opposition in 1977, demonstrations on the worksite of the Creys-Malville fast-breeder reactor resulted in a demonstrator's death during confrontations with law enforcement.

[15] Minutes of the meeting "Codes et normes utilisés dans l'industrie électronucléaire", Ministry of Industry and Research, 1976.

Since it wanted to export PWRs, France needed to create its own system of standards. A start would be made at doing this in 1978: a set of rules of design and construction (RCC: *règles de conception et de construction*) was intended to be exhaustive, exportable and modifiable over time (*cf.* Insert 2). These documents "*should be capable of being published right away and of being amended, if need be, without excessive effort*" (COUDRAY & PERRAIS 1974).

Avoiding legal battles with antinuclear activists

The strong antinuclear movement in the mid-1970s also probably had an indirect effect on the form of policy instruments. The period between 1975 and 1980 was tense owing to strong local protests, approximately a hundred violent attacks: bombs on construction sites, acts of arson or sabotage (of materials or operating systems), and attempts on the lives of persons linked to atomic energy. On the initiative of a group of scientists (Groupement de Scientifiques pour l'Information sur l'Énergie Nucléaire, GSIEN), a scientific campaign of counter-information was organized.

Meanwhile, protest was moving into the courts, as environmentalist associations and locally elected officials filed lawsuits in administrative tribunals for the purpose of nullifying building permits (GARRAUD 1979). These suits cited several grounds: irregularities in public hearings, incomplete administrative documents, problems with expropriation procedures, etc. Although these legal actions came to naught when the Conseil d'État dismissed them,[16] the "*construction of nuclear power plants has been delayed by two years on the average*" according to EDF's chairman of the board.[17]

One effect of this protest was to complicate and tighten technical and administrative procedures. This was the context for the passage of the act of 1978 on the protection of nature, which "*forces EDF to make, on each site, an impact study that assesses the initial state and the impact on the environment of constructing a power station*" (GARRAUD 1979). It is likely that, to avoid more conflicts with environmentalist organizations and local officials, one political strategy was to see to it that regulatory instruments on technical questions were not legally binding, the intent being to avoid public hearings and controversies with opponents.

The combination of this context (social, political and industrial) with the collaboration among stakeholders in the nuclear industry explains why the risk-reduction

[16] *Le Monde*, February 1978.

[17] *Le Monde*, 13 October 1978.

Two sets of rules, the RCC and RFS: Endorse French practices and export them

In 1974, an invitation to bid was made by ESKOM, a South African power station operator. Three consortiums (respectively, American, German and French, the last led by Framatome) tendered bids for the two reactors to be built at Koeberg. The safety of nuclear installations was an extremely important issue, in particular for importing countries, like South Africa, that were venturing into nuclear energy.

ESKOM criticized the French offer, mainly from a technical viewpoint, as being based on weak national regulations. Nevertheless, the American consortium, though the frontrunner, would lose this market for political reasons, since Dutch MPs (the Netherlands being part of the consortium) did not want a deal with South Africa. In addition, the German consortium's financial package fell short compared with the French offer.[a] Following this major success, EDF and Framatome realized that a set of French safety rules had to be drafted if they were to win other foreign markets.

EDF and Framatome started codifying practices for design and construction. This would lead to the adoption in 1978 of a set of rules, the RCC (*règles de conception et de construction*), which would serve as the reference for designing and building future nuclear power plants in France and elsewhere. The RCC, though optional, dealt with all subjects related to the design and construction of nuclear reactors, even topics not directly related to questions of safety and security. The SCSIN would tranpose the rules directly related to safety issues into the RFS (*règles fondamentales de surêté*). According to a former member of the Permanent Group, Framatome thus wanted a sort of "free rein from the French safety authority" for exporting its power plants.

The CEA (along with its arm of expertise, the IPSN) and EDF (the single operator of PWRs in France) drafted the RFS. The SCSIN — with, at the time, little technical competence and a small staff — managed to put on the agenda the validation of the proposals made by the two organizations and the objective of drafting a new RFS. French experts chose to design safety rules for handling issues of current importance and to address fewer issues than in the United States. In the middle of the 1980s, the RFS contained approximately thirty rules (This number has remained nearly constant, even today), whereas the US Nuclear Regulatory Commission had already published nearly a hundred guidebooks by the end of the 1970s. The RFS deals with broad topics ranging from natural risks (floods, earthquakes, etc.) to waste storage and even including civil engineering.

Given the lack of an exhaustive regulatory framework, the RCC and RFS have been the major risk-regulation instruments for the safety of the nuclear power stations built not just in France but also abroad.

[a] Appendixes of "Le contrôle de la sûreté et de la sécurité des installations nucléaires", report n°278 by Claude Birraux, MP, in the name of the Office Parlementaire d'Évaluation des Choix Scientifiques et Technologiques, 12 May 1996.

instruments drafted in these discreet circles took a form that was not binding in the eyes of the law and not visible to the public — in contrast with other fields of public action. By preferring negotiations among experts and supple regulations, the organizations concerned with safety designed, with the consent of political officials, a peculiar risk-regulation regime.

Could this French exception last? Applying the analytical grid used to understand the origin of the country's risk-regulation regime, we shall now conjecture a few points for answering this question.

The end of French "exceptionalism"?

Risk-reduction regimes evolve, especially under outside pressure, as pointed out by Hood *et al*. (2001). During the 1990s, there were movements for more transparency and accountability. Although this trend was not limited to the nuclear industry, it is worthwhile recalling its role in France and dwelling on its effects on the current state of the French regime for regulating nuclear risks.

Routinizing the risk-reduction regime

The changes undergone by the risk-reduction regime at the end of the 1990s were not so important as those in the middle of the 1980s. This regime was stabilized around one source of expertise (the IPSN), one controller (the DSIN: Direction de la Sûreté des Installations Nucléaires, which replaced the SCSIN in 1992) and the original players (EDF, the CEA and Framatome). Whereas the accident at Three Mile Island in 1979 did not spawn technical innovations, the Chernobyl catastrophe in 1986, along with the shortcomings in the Soviet risk-regulation regime, would stimulate a long current of thought about the French system.

In the 1990s, a series of incidents occurred at nuclear power stations in France. At the start of this decade, cracks were discovered in the cover of several reactor pressure vessels. In the middle of the decade, several incidents at Superphénix spurred a debate in the media and in political circles before the definitive shutdown of this fast breeder reactor in 1997. In 1998 and 1999, two incidents received wide coverage by the mass media: a crack in pipes at the Civaux plant and a tank overflow at Blayais. Meanwhile, affairs in the field of health (*e.g.* mad cow disease, asbestos, the "contaminated" blood supply) were receiving international coverage. What also marked this period was the gradual assertion of authority by the Autorité de Sûreté Nucléaire (ASN). Its director from 1993 to 2012, André-Claude Lacoste, used the media as a means; he did not hesitate, at times, to go public with problems in order to bring pressure to bear on EDF (SAINT RAYMOND 2012).

This was the context for the report by the MP Jean-Yves Le Déaut (1998) to the Prime Minister. It proposed several major institutional changes in the regulation of nuclear risks, in particular the creation both of an institute of expertise on nuclear safety and radioactivity independent from the CEA and of a safety authority independent of the ministries, all of this to be included in an act of law on nuclear safety. The report stated: "*The French will not have confidence in nuclear energy unless they acquire the deep conviction that they are being told the truth. Transparency is the* sine qua non *of confidence […] A foundational law on nuclear energy that states the major principles, updates the decree of 1963 and creates an independent authority must be debated in parliament in order to reinforce transparency […] Nuclear activities must be socially acceptable*" (LE DÉAUT 1998). This report's conclusions were not without effect. The IPSN and OPRI (Office de Protection contre les Rayonnements Ionisants) were replaced in 2002 with an institute that, independent of the CEA, was not placed under a ministry: the Radioprotection and Nuclear Safety Institute (IRSN: Institut de Radioprotection and de Sûreté Nucléaire). Furthermore, the act on transparency and nuclear security, which would not be adopted till 2006, set up the ASN, an independent administrative authority.

Nuclear power station operators thought that independence and transparency would provide leverage for making nuclear energy more acceptable to public opinion and, thereby, foster this industry's economic development. The act of 2006 and the creation of the ASN were deemed positive for the nuclear industry's image, as Pierre Gadonneix, general manager and chairman of the board at EDF, stated in 2007: "*Through its action on the standardization of safety rules at the European and world levels, the ASN is helping to create conditions for stimulating the growth of nuclear energy worldwide.*"[18]

As for risk regulation, the ASN started, in 2008, "*completely reworking regulations*"[19] so as to gradually replace the RFS with "*guides*", which had the same status as codes of conduct but were, under the act of 2006, part of a hierarchy of regulations that did not exist in the 1970s or 1980s. Already at the turn of the century, there was a system of regulatory decisions and formal notifications, which the public could now consult, not to mention the advisory opinions of the IRSN. This system strengthened the new model and made visible (part of its) operations, which used to be cloaked

Meanwhile, the awareness of threats to the environment beyond national borders was growing: the claim that the "cloud from Chernobyl" had stopped at the border with Germany had spurred many a comment. There was a gradual determination to harmonize, or standardize, regulations at the international and European levels, through, in particular, regulatory instruments such as the Safety Reference Levels designed by the Western European Nuclear Regulators Association (WENRA), which, created in 1999 on the initiative of André-Claude Lacoste, grouped nuclear safety authorities from European countries.

[18] ASN's *Revue Contrôle*, 178, January 2007.

[19] ASN's *Revue Contrôle*, 197, March 2014.

In spite of this apparent spate offer actions, actual changes occurred incrementally (LINDBLOM 1959) — an evolution rather than a revolution that led to a slow reorientation under outside pressure. At the end of the first decade of the new century, several risk-regulation instruments, such as the RFS and RCC, were still being used to assess nuclear safety in France. The old RFS rules were cautiously replaced with the new "guides": a dozen guides on questions of nuclear safety or on new topics. Likewise, the risk-regulation regime still hinged on the Permanent Group of Experts, the periodical updating of safety reports on installations, decennial visits, and a system of visits by the ASN for supervision and inspection. Till 2010, the safety regulation regime seems to have remained stable in a context favorable to nuclear energy (given the high prices of natural gas and oil, the new "carbon taxes", etc.) and to the opening of new sites for building nuclear power stations around the planet.

The accident at Fukushima in March 2011 would signal a turning point for this risk-regulation regime.

After Fukushima, accelerated changes

As shown, the risk-regulation regime experienced a long period of stability till into the first decade of the new century, when it underwent an evolution without apparently being destabilized.[20] The accident at Fukushima in 2011 was a politicized "*focusing event*" (BIRKLAND 1998) widely covered by the media. This crisis induced a number of changes, still under way, and seems to have signaled a turning point.

The Fukushima Daiichi catastrophe cracked the consensus on public communications among the historical stakeholders in the French risk-regulation regime. Officials at the ASN and IRSN kept their distance from both the government and nuclear power station operators. André-Claude Lacoste declared, "*No one can guarantee there will never be a nuclear accident in France.*"[21] The phrase "gendarme of nuclear energy" would now be used to refer to the ASN, owing, in particular, to its president who was said to be the "*incorruptible of the nuclear industry*".[22]

This shift in the ASN's image coincided with the increasing use, under the act of 2006, of risk-regulation instruments, such as the "regulatory prescriptions" and "decisions" that were now legally binding on plant operators. These instruments, which are made public (as are, too, the IRSN's opinions, the ASN's guides and its followup letters on inspections), suggest a momentum toward a regime that is more open to the public and more rigid at the regulatory level.

Since 2015, the ASN has, relying on recent texts,[23] undertaken various actions with media coverage in relation to suspected anomalies in PWR units or parts of reactors.[24] One episode led, in the autumn of 2016, to stopping 21 reactors (out of 58) for a series of controls — with concern about the effects on the supply of electricity during the winter of 2016-2017.

These events are evidence of a much more coercive use of risk-regulation instruments and, in comparison with the past, of a greater willingness to go public with safety problems. The relation between two different conceptions of nuclear safety is definitely under tension. For some stakeholders, safety is mainly a technical matter for engineers alone to judge; and communications toward society must be controlled so as to have positive effects. For others, whose number is growing, legal rules should prevail; and there must be full transparency toward society. This second viewpoint, which seems to be gradually supplanting the first, could move the French risk-reduction regime into a new phase.

Conclusion

In the 1970s, the organizations in charge of nuclear safety designed supple regulatory instruments that combined safety with industrial efficiency. By analyzing the actions of the small world of nuclear safety as well as the social, political and industrial context at the time, we have shown the coherence between these two factors (the choice of regulatory instruments and context) and the regulatory regime in general. This coherence seems to account for the French exceptionalism discussed at the start of this article, and for its stability over a long period.

Only much later, during the decade 2000-2010, did the risk-regulation regime undergo a major transformation tending, especially since the Fukushima accident, to bring it closer to international standards. The changes under way have broken up the unity of the small world of nuclear safety and introduced a major new player, public opinion, and a new type of intervention, "publicization" in the sense of "making/going public" (a phrase we prefer since we still see very little actual participation by the public in technical discussions on safety problems). Problems that were technical have thus become political and societal, as they move out of the limited circle of this industry's historical stakeholders. This generic process might be relevant to other types of risks, but it seems specific to the nuclear industry in France, given the nature of risks there and, even more, this industry's historical opacity.

But what has changed is the second factor identified by this analysis of the origin of the French regulatory regime. In the changed political and industrial context, France's industrial strategy is no longer rushing to build

[20] This explains why François Lévêque, in his books in 2013 (obviously written well before that date), had a somewhat atemporal opinion of the French regulatory system and did not mention the recent radical change.

[21] *Le Point*, 30 March 2011.

[22] "André-Claude Lacoste, l'incorruptible du nucléaire", *La Croix*, 10 October 2012.

[23] *Arrêté ESPN*, decision of 12 December 2005 on pressurized nuclear equipment.

[24] https://www.asn.fr/Informer/Actualites/Irregularites-detectees-dans-l-usine-d-Areva-de-Creusot-Forge-l-ASN-fait-un-point-d-etape.

a fleet of nuclear reactors but, instead, trying to prolong the life cycles of existing nuclear power plants: only one new reactor is being built (the EPR in Flamanville), and no other program has been announced. Internationally, French industrialists are facing stiff competition from new exporting countries, such as China, in a difficult context since Fukushima.

All of these factors are gradually leading toward an alignment on international standards for regulations and, more broadly, for the regulatory regime.

Little by little, we are apparently observing a shift from a dialog among engineers toward more formal legal rules and higher public visibility. It is, however, too early to talk about the end of French exceptionalism. In practices, we observe the persistence of traits of the regulatory regime that took shape between 1960 and 1985. It would even be possible to describe the current situation as a form of hybridization between two risk-regulation regimes. To make predictions about its stability, we need to better understand this process of hybridization.

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