THE RADIANCE OF FRANCE

NUCLEAR POWER AND NATIONAL IDENTITY AFTER WORLD WAR II

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FOREWORD BY MICHEL CALLON AND A NEW AFTERWORD BY THE AUTHOR

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Warring Systems

In November 1969, hundreds of CEA employees around the country went on strike to protest the demise of the gas-graphite program and the imminent purchase of an American license for the construction of light-water reactors. Workers, technicians, scientists, and engineers marched through the streets of Paris and staged sit-down strikes at Marcoule and Saclay. "We are in the process of losing our national independence," they cried. "We are on the path to underdevelopment and colonization."[1] They also feared that they would lose their jobs: rumor had it that the government would soon announce several thousand layoffs. The French public followed the strikes in newspapers, on radio, and on television.[2] In southern France, the Bagnolais suddenly became alarmed that the Marcoulins might have to move away, leaving them stuck with the large debts they had incurred for their new public facilities. Gas-graphite engineers and workers at EDF also became angry, but they had more immediate worries which prevented them from staging anything more extensive than a few protests: the day after the termination of the gas-graphite program, the new reactor at Saint-Laurent underwent a partial meltdown. EDF employees thus had to contend simultaneously with the demise of their program and the cleanup of the most serious accident they had ever faced.

Dramatic though these events were, they quickly faded from the official history of the nuclear program. Men who had participated in the strikes or the accident cleanup remembered well, but those who hadn't soon forgot. Some remembered if I jogged their memories, others did not: one former CEA scientist was not only surprised but also skeptical when I assured him that the demise of gas-graphite had loomed large in the 1969 strikes—all he remembered were protests over the layoffs of cleaning ladies at Saclay.

Such lapses in memory, I believe, stem partly from the fact that the narrative of the *guerre des filières*—the war of the systems—has been transformed over the years from the story of the demise of the gas-graphite program to that of the birth of the pressurized-water program. The standard version of the story which circulates in French industrial circles goes something like this: In the beginning, there were two nuclear systems: one centered around gas-graphite reactors, the other around light-water reactors. In the late 1960s France had to choose between these two systems. A battle ensued. The nationalist CEA wanted to pursue the gas-graphite system for irrational political reasons, while the eternally reasonable EDF wanted to switch to the light-water system for rational economic reasons. Rivalry among engineers aggravated the quarrel. De Gaulle supported the CEA because he trusted it better, and because top CEA officials had his ear and could plead their case directly. De Gaulle thus became mistakenly and unfortunately convinced that only the gas-graphite system was compatible with national independence. Once de Gaulle stepped down, his better-informed successor, Georges Pompidou, could make the obviously correct choice. France could finally abandon the inferior gas-graphite system and build the superior light-water reactors under license. EDF's current nuclear program was born. Later, the light-water system became *francisé* (Frenchified), thereby providing the ever-coveted national energy independence as well as a source of national pride.

Like many origin stories, this one has served to erase events and circumstances crucial to understanding the process, the outcome, and the meaning of the *guerre des filières*. Some scholars have begun to unravel this history, showing that the positions for and against the gas-graphite system did not divide so neatly along institutional lines.[3] The light-water system had serious supporters in the upper echelons of the CEA, while many middle-ranking EDF engineers defended the gas-graphite system. But other aspects of the process remain unclear. How were the comparisons between the two systems carried out? How did the light-water system emerge as the rational, "apolitical" solution? How, indeed, did a nominally apolitical solution even become desirable? And what did the *guerre des filières* mean to gas-graphite engineers, workers, and technicians? Ironically, this is both the most studied episode in the history of the gas-graphite program, and the least well understood.

The *guerre des filières* weaves together the diverse thematic threads which I have teased out so far. Most of the historical actors we have encountered make an appearance: technologists, engineers, labor militants, technicians, workers, journalists, politicians, and Gardois (only Tourangeaux are absent). One of the central questions debated during this episode concerned French radiance: could the nation not only preserve its autonomy but also export reactors if it abandoned the gas-graphite system? In the roughly three years over which this war extended (1966–1969), engineers, managers, and union leaders proposed different technological scenarios and corresponding conceptions of France and its future. In advocating the light-water system, EDF's economist-managers (whom we last encountered in chapter 3) sought to reformulate the utility's technopolitical regime. Their reformulation efforts made the relationship between technology and politics a central arena of struggle in the battle. Ensuing debates were not only about the features of each system but also about the appropriate selection criteria. Should the choice be based on economics or politics? To what extent could these be intertwined? In an attempt to define selection criteria and defend the gas-graphite system, labor militants at both the CEA and EDF presented their own economic and political analyses. CEA employees further responded to the threat to gas-graphite by staging a series of strikes. These called attention to the specter of layoffs at Marcoule, which prompted a reconciliation of sorts between Bagnolais de Souche and Marcoulins. Finally, EDF employees had to contend with the Saint-Laurent accident. The cleanup provided them with a means of responding not only to the technical threat posed by the accident, but also to the cultural and political threat posed by the termination of the gas-graphite program. The *guerre des filières* thus provides an appropriate finale for my story.

Preliminaries to the War: Public Relations and Technological Mishaps

The idea that France might pursue other reactor technologies did not appear out of the blue. The research and military branches of the CEA had been investigating alternative designs for some time. These included a small light-water submarine reactor as well as heavy-water, high-temperature, and breeder prototypes. EDF helped the CEA with some of these prototype efforts—especially for the heavy-water and breeder reactors. EDF's nuclear division also sought reactor projects not tied to the CEA. In the late 1950s the United States concluded an agreement with Euratom that favored the importation of American reactor designs into Europe; reluctantly, the French government allowed EDF to cooperate with Belgium in the construction of the first such reactor in 1960.[4] These efforts notwithstanding, support for the gas-graphite system held fast in both technopolitical regimes through the mid 1960s.[5]

What happened in 1966 to shake this consensus? Most scholars agree that the trigger for the *guerre des filières* came from outside. In 1965, American reactor manufacturers embarked on an aggressive marketing campaign based on extremely optimistic capital cost estimates. (Recall that the capital cost of a reactor is the amount of money required to build it.) Persuaded by these attractive numbers, American utilities jumped on the nuclear bandwagon, ordering 49 reactors—destined to produce nearly 40,000 megawatts of electricity—in 1966 and 1967. Not until the mid 1970s did utilities discover that actual costs were more than twice the original estimates.[6] In 1966, however, the American estimates presented a serious temptation to French program leaders.

Of course, these figures did not, by themselves, mandate a change in policy. Had harmony reigned in the nuclear program, the *guerre des filières* may not have taken place at all. As we have seen, however, relations between the technopolitical regimes of the CEA and EDF had worsened as their collaboration deepened. Conflicts had also emerged within each regime. The possibilities raised by the American capital-cost estimates deepened and rearranged existing fault lines.

The first official intimation that EDF leaders were seriously considering abandoning the gas-graphite system came in March 1966 in a letter from André Decelle, EDF's director-general, to Robert Hirsch, the CEA's administrator-general.[7] Affirming that gas-graphite reactors were competitive with conventional power plants, Decelle stated that they were nonetheless "significantly more expensive" than light-water reactors.[8] A system based on natural uranium did promote French autarky, Decelle observed, but in the long term this advantage might not be worth the price difference. Noncommittally, Hirsch agreed that the matter required further study. In May the two leaders created a committee to study the various reactor systems operating in Europe and America. The committee was jointly headed by Jules Horowitz of the CEA and Jean Cabanius of EDF.[9]

Much as Decelle and Hirsch may have wanted these investigations to maintain a low profile, this quickly proved impossible. The press learned about the committee, and a wave of articles asserted that the current nuclear program would soon be terminated. These articles flustered regime leaders and worried labor militants. CGT representative Claude Tourgeron demanded an explanation at the May 1966 meeting of EDF's board of directors. Was EDF indeed abandoning the gas-graphite system? Decelle insisted that this was not the case, and that the media had, as usual, gone overboard. EDF and the CEA had simply decided to study both breeder and light-water reactors. Hirsch (who represented the CEA to the board) backed Decelle, declaring firmly: "This information . . . is more spectacular than it is well-founded, since of course the question of abandoning the natural uranium, gas-graphite system has never been raised anywhere."[10]

Clearly the directors hoped that the publicity problem would simply disappear. However, a series of technical mishaps at EDF3 not only aggravated the utility's public relations problem but also intensified ongoing debates within the establishment over industrial contracting and EDF's relationship with private companies.

EDF engineers and managers had nourished high hopes that EDF3, the latest Chinon reactor, could compete economically with conventional power plants. Construction delays had dampened these hopes, but in late 1966 all appeared ready. As engineers began to power up the reactor, however, more difficulties arose. Two of these were serious: the heat exchangers developed numerous leaks, giving engineers reason to doubt the integrity of the entire exchanger ensemble, and the system intended to detect rupturing of fuel rods failed to function adequately.[11]

Nicholas Vichney at *Le Monde* and staff writers at *Le Canard Enchaîné* quickly publicized these difficulties. Vichney blamed both the private builders and EDF. French technology could not meet the high standards demanded by nuclear plants, he wrote, and furthermore EDF had flawed industrial contracting practices.[12] The utility had tried to build something too complicated too fast, and the technical abilities of its personnel could not rise to the occasion. The CEA, Vichney continued, should stop distancing itself from EDF's difficulties and make more serious efforts to help. Predictably, *Le Canard* interpreted events more bluntly: "In short, our home-grown nuclear equipment doesn't hold up." *Le Canard* also gleefully noted de Gaulle's displeasure at the incidents: "Heads will roll, citizens!"[13]

These accusations of incompetence disturbed EDF's board. Hirsch tried to console board members and mitigate these harsh judgments by praising EDF design teams for their dynamism.[14] EDF's management noted indignantly that the press had neglected to mention the complexity of the reactor, the difficult trial periods undergone by all new technologies, and the troubles experienced by foreign reactors.[15] Union militants joined management in expressing outrage at the accusations leveled against EDF's technical know-how. Tourgeron insisted that the personnel was experiencing a deep "malaise," which he attributed to the "harm done to the prestige of [our] Establishment."[16] The personnel urgently needed reassurance, he said; the board had to counterattack.[17] But CEA and EDF management declined to engage in an active battle with the press, instead issuing a brief statement that simply averred the intimate collaboration between the two institutions.[18]

As time went on, media attacks on the nuclear program—particularly from these two newspapers—continued to escalate. Relations between Vichney and the CEA became openly hostile. Suggestions that French nuclear engineers lacked technical expertise angered both union and non-union employees at the CEA.[19] In April 1968, Hirsch accused *Le Monde*'s editor of lacking patriotism.[20] The paper's recent report of an EDF2 incident lacked objectivity, he said (thereby associating disinterestedness with nationalism), and demonstrated Vichney's "customary lack of good will in the face of the difficulties inherent in the development of nuclear energy." Hirsch continued: "Such publicity over an incident that even the article characterized as minor can only complicate the task of French industry, currently in charge of constructing the same kind of reactor abroad." In a subtle insult, he contrasted the unhelpful attitude of *Le Monde* with the discretion of the German press during similar incidents in Germany's power plants. Vichney retorted that he was the one acting in the public interest. He called the recent technical incidents "'serious' to the extent that they cast doubt both on the competence of French industry and on the competence of engineers in the different institutions called on to build these different plants."[21] "*It is therefore a matter of national interest,*" he concluded. By evoking journalism's claim to speak in the public interest, Vichney challenged the CEA's claim that it acted inherently in the national interest.

On the surface, such media attacks led the two regimes to close ranks, both internally and with respect to each other. EDF's unions defended the utility as an institution, and EDF and the CEA affirmed their solidarity. Officially, technical difficulties were just a normal part of technological innovation. Internally, however, the technical difficulties—transformed by the media into a failure of French technology—triggered renewed battles over the EDF's technopolitical regime. As in the past, the debates centered on the role of private industry in nuclear development. Repairing EDF3, for example, would be costly and time consuming. Who should bear the responsibility? There seemed to be two options. In the first, EDF's Direction de l'Equipement could accept the contractors' suggestion simply to repair the existing leaks and restart the reactor to find out whether the problems were systemic. But if that turned out to be the case, the plant would suffer frequent shutdowns, which would entail heavy "psychological" consequences.[22] The threat of more negative press, in other words, militated against this course. The second solution involved having contractors rebuild all the potentially problematic components from scratch. But the builders would undoubtedly object, leading to "a lawsuit whose outcome could only be uncertain and far away."[23] This too, then, entailed technopolitical costs.

EDF's management proposed a third solution, which it hoped would minimize technopolitical costs. This scheme called for the complete replacement of EDF3's heat exchangers. The contractors would pay for the faulty exchanger components. (This cost was estimated at 13 million francs.) EDF would pay for the rest of the new exchangers, and would also pay the cost of dismantling, rebuilding, and improving the exchangers (estimated at 29 million francs). This solution would allow EDF3 to restart more rapidly with better equipment and would avoid a long and difficult quarrel with the manufacturers. But several board members objected that this solution was too easy on private industry. Tourgeron protested that the builders had had plenty of opportunities to test the exchanger prototypes and that the problem stemmed quite simply from manufacturing defects. Management's solution would "reward mediocrity."[24]

Though most of the board members would have liked contractors to take greater financial responsibility, they ended up voting for management's solution. The government's representative to the board, Charles Chevrier, took the opportunity to make a little speech:

> [EDF's] policy of rapidly increasing reactor power . . . enabled [us] to reach competitiveness with four reactors, while our English friends have not attained this with 16 reactors, even though for the moment they have a higher capacity factor [i.e., proportion of time that the reactor is actually on line and producing electricity] than we do.
>
> The EDF3 incidents . . . do not throw this competitiveness into question. Indeed, what they will cost does not represent a very considerable percentage of the expenses initially foreseen.
>
> Now we need to increase the capacity factor of the equipment, and for this it is necessary to make a big effort to improve the technology. This above all is the lesson to learn from this unfortunate affair.
>
> In the future . . . we must find a way to link the manufacturers to [reactor downtime], not in order to make them pay for all the expenses, but . . . to develop their solidarity and their conscience with respect to the equipment they build.[25]

EDF3's difficulties thus had heterogeneous origins (including media scrutiny) and demanded a hybrid solution. This was not simply a matter of fixing a few leaks. Instead, a host of heterogeneous issues clamored for attention: the reactor's capacity factor, the relationship between EDF and private industry, institutional prestige, the components of the heat exchangers, France's competition with Britain, and the public image of the nuclear program.

Tensions over EDF3's leaky heat exchangers were also tensions over the changes that EDF's new managers wanted to make in the institution's technopolitical regime. Management's willingness to foot most of the bill was not just about saving time and repairing EDF's public image. Managers also sought to redefine the meaning of "public service" for EDF. For these new economist-managers, the utility could serve the public not only by making electricity but also by creating a climate congenial to the development of private industry. This outlook worried labor militants, who wanted to preserve a regime in which EDF would *control* industrial development. For example, the Confédération Française Démocratique du Travail worried that private industry would gradually take over making programmatic decisions about nuclear development at the expense of EDF employees. It also worried about management's internal changes, claiming that rank-and-file employees had recently lost a great deal of decision-making responsibility. EDF's original mission as the model for a new society was being betrayed. "EDF's ambiguous and weak attitude toward the Manufacturers in applying contracts" exemplified these complaints.[26] The CFDT did not oppose management's desire to help industry ready itself for international competition. But these efforts could not come at the expense of salaried employees or of "nationalized firms, which represent a social and economic achievement which we all value."[27]

EDF3's leaky heat exchangers thus became technopolitical tools in a growing struggle over the utility's regime. Would nationalization continue to mean the contractual and technological subordination of private industry? Or would it acquire a new, more ambiguous meaning in which EDF would make national energy policy by supporting rather than dominating private industry? As we shall see, the *guerre des filières* would provide ample terrain for this struggle. All the issues raised in the course of negotiating the repair of EDF3—industrial relations, reactor capacity factors, public relations, EDF's technopolitical regime, France's international position—would be played out in the debates over the future of the nuclear program and its relationship to the future of France.

The War Starts in Earnest: The Horowitz-Cabanius Report

In late January 1967, the Horowitz-Cabanius committee, charged with comparing available nuclear systems, presented its results. It immediately became obvious that the effort to smooth over quarrels had failed. Though Horowitz and Cabanius agreed on some basic numbers (including the capital costs for various reactors), they strongly differed on the technopolitical meanings of those numbers—so much so that they produced separate reports, each written as though the other did not exist. The points of contention formed a dense weave composed of

- the responsibility of private industry in guaranteeing reactor reliability,
- the meaning of public service for the two regimes, particularly with respect to their role in fostering the growth of private industry,
- the proper criteria for evaluating the performance of the gas-graphite system,
- the development status of gas-graphite reactors (were they fully functioning industrial systems, or mere prototypes?),
- the relevance of the French context to the final choice, and the nature of that "context,"
- uncertainty in the data, and how to handle it, and
- the "political" dimensions of the comparison, and who had the right or responsibility to analyze these dimensions.

In some respects, the last point is the most important. While the CEA's report maintained the tight links between technology and politics that had characterized both regimes during the first two decades of the nuclear program, EDF's report separated technology and politics. Horowitz maintained these links in order to justify the gas-graphite system. Only by severing these links, however, could Cabanius advocate the switch to light-water.

Cabanius, the director of EDF's Direction de l'Equipement (which designed reactors, coordinated industrial contracting, and supervised construction), stated that his goal was simply to compare the cost of the kilowatt-hour produced by different reactor systems. Politics was not his affair: "Political considerations, in particular those relating to the acquisition or manufacturing . . . of enriched uranium are up to the public authorities and will not be raised in this study. The rapporteur has strictly limited himself to the industrial, technical, and economic side [of the comparison]."[28] In contrast, Horowitz, the director of the CEA's Direction des Piles Atomiques (which engaged in research and development related to experimental and industrial reactors), stated that his goals were to "reveal the lessons to be learned from the current program," to "appraise once more the possibilities of the gas-graphite system," and to examine the future orientation of the French program.[29] While Cabanius sought to distance himself from the "politics" of system choice, Horowitz aimed to address "political" issues directly.

Cabanius began by briefly summarizing the state of French industry. This summary alone clearly reflected the desire of EDF's management to change its technopolitical regime by redefining public service. EDF, wrote Cabanius, played the dual role of customer and supplier to French industry. As a supplier, it had to offer manufacturers cheap electricity in order to help them compete with foreign companies. As a customer, it had to help companies reorganize themselves into large consortia capable of taking on the massive investments required by reactor manufacturing. Encouraging these consortia to work under a foreign license would further help French industry because the dynamism and success of the licensers would provide important financial and technical support for the licensees.[30] Ostensibly, then, EDF's first priority should be to strengthen French industry.

Horowitz focused his definition of public service on the gas-graphite system. He proudly noted that the system had already exceeded expectations in several ways: the price of natural uranium fuel had dropped faster than anticipated, the fuel rods had proved technically reliable, and the reactor cores had performed well. He argued that the system costs would have been much lower without the many difficulties that plagued the construction and startup of Chinon's reactors. He blamed EDF's technical incompetence and inconsistent attitude toward private contractors for this poor performance, rather than the system itself. Marcoule, after all, had proved that French reactors could maintain a high capacity factor.[31]

Cabanius blamed the mishaps not on EDF but on the technology. The complexity of the gas-graphite system, he observed, posed particularly delicate construction problems. Yes, Marcoule had performed well, but its reactors were smaller and less complex than EDF's, and the difficulties of building gas-graphite reactors increased dramatically with the scale of the reactor. "The natural uranium-gas-graphite system," wrote Cabanius, "therefore contains a source of incidents which could have serious consequences not so much for the safety of people as for the length and frequency of stoppages and therefore for the capacity factor of a series of plants which are integrated into an energy system."[32] Thus the gas-graphite system was inherently flawed. The light-water system, however, was not. Cabanius described this system with considerable enthusiasm. The capital costs were low. With many reactors on order, manufacturing could be standardized (leading to even lower costs and greater reliability than the gas-graphite system). Best of all, General Electric would price reactor fuel as a function of its energy production, thereby guaranteeing a performance standard for the fuel rods. "This formula," Cabanius asserted, "leaves a powerful manufacturer [GE] with the costs of technological uncertainties. Surely its acceptance is based on tremendous confidence in the technological quality of the supplies. This trend will probably be irreversible."[33] General Electric's confidence justified France's confidence. Cabanius portrayed the spread of light-water reactors as inexorable. He thus planted the seeds of technological determinism among EDF's economist-managers, simultaneously seeking to separate technology and politics.

Horowitz admitted no such determinism. Yes, American utilities had ordered a remarkable number of light-water megawatts in the last two years. Even more amazing, he noted snidely, this enthusiasm was based on the actual performance of just two 200-MW reactors! The performance data, therefore, were hardly statistically significant. True, the American program would probably succeed, thanks to its technical rigor and the vast resources of its manufacturers. *But this did not mean that the same program would succeed in France.* National context mattered deeply. Insufficient data made good predictions nearly impossible: "The catalogue [listings] for 'nuclear boilers' . . . do not give a breakdown of the price per [boiler] component; they do not, therefore, enable one to make a detailed techno-economic analysis. And in any event, as the promoters themselves admit, these prices do not correspond to the cost of a few isolated plants; it is only by anticipating the effect of [building] a whole series [of reactors] that nuclear power has been able to penetrate the market in the United States."[34] While Cabanius treated the American figures as reasonably accurate characteristics of the *technology*, Horowitz treated them as rough estimates based on the *context*. In Cabanius's analysis, the technology, abstracted from its context, was the most important variable. In Horowitz's analysis, the functioning and cost of technologies could not be separated from their contexts. What worked for the United States would not necessarily work for France.

Handling Uncertainty

Despite his skepticism about the American numbers, Horowitz used them in his calculations; they were, after all, the only ones available. Therefore, like Cabanius, he estimated the cost of a conventional kilowatt-hour to be between 3.95 and 3.35 centimes (depending on the plant's capacity

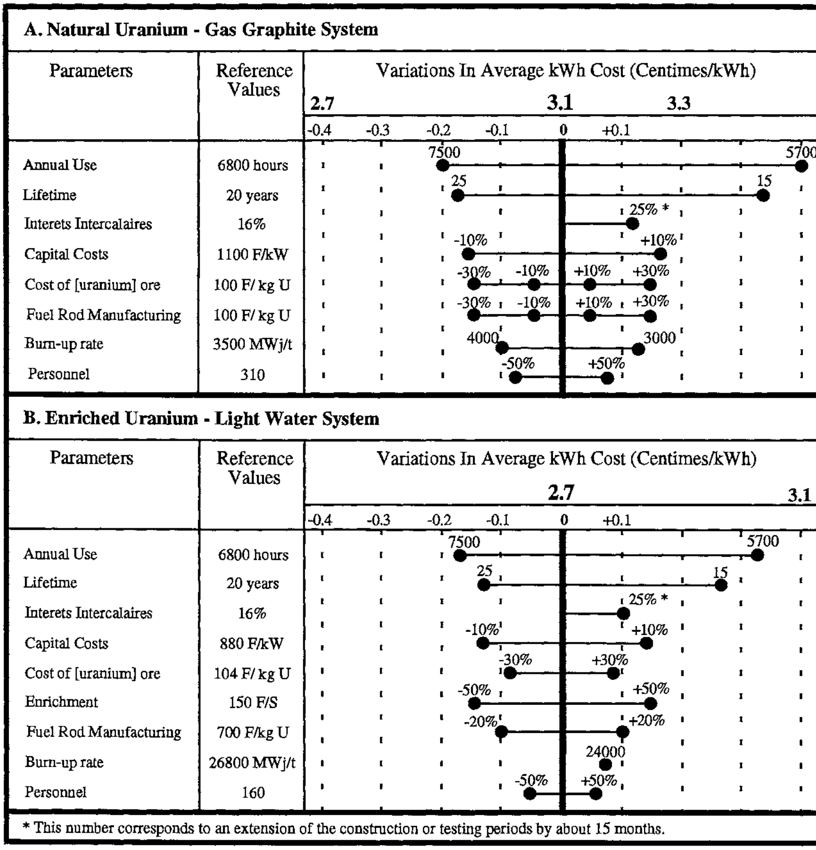


Figure 8.1
Variation in cost of a kilowatt-hour with variations in base parameters. This diagram (shown here as reconstructed by Carlos Martín) originally appeared in Cabanius's "Rapport du Groupe de Travail."

factor) and that of a kilowatt-hour produced by a pressurized-water reactor at 2.67 centimes.[35] The two men differed only on the cost of a gas-graphite kilowatt-hour: Cabanius priced it at 3.14 centimes, while Horowitz priced it at 3.04 centimes. Horowitz hoped, on the basis of experimental data, that the CEA's new fuel rods would reduce the cost, whereas Cabanius refused to rely on the experimental data. Horowitz thus emphasized the paucity of data on actual operating light-water reactors while expressing great confidence in the CEA's equally unconfirmed estimates. Cabanius took the opposite approach, expressing confidence in the American estimates and skepticism toward the CEA's.[36]

The two men also handled the uncertainty in the data differently. Cabanius, admitting that the parameters used to calculate costs were subject to change, constructed a table describing the "sensitivity of the cost of the kilowatt-hour" (figure 8.1). This table showed how the costs of the two nuclear kilowatt-hours would change with variations in parameters such as fuel burnup rate, capacity factor, and capital costs. Plotting uncertainty offered a sense of control, suggesting that because uncertainty was quantifiable it was manageable. Naming and describing uncertainty, in other words, eliminated the need for qualitative assessment.

For Horowitz, however, uncertainty *required* qualitative judgment. In the absence of hard "facts," political acumen had to guide the choices. This conviction came through most clearly in Horowitz's discussion of enriched uranium supplies. Cabanius had dismissed the topic in a single short paragraph, suggesting that, although light-water plants would initially rely on foreign supplies, eventually France or Euratom would build enrichment plants. He relegated any further discussion to the realm of "politics," which defined as beyond his mandate. Horowitz too saw this as a political matter, but he understood it to fall well *within* his mandate. Where Cabanius had written of foreign "supplies," Horowitz wrote of foreign "dependence." "Political reasons" (which he left unspecified) would make a European enrichment plant impossible, and France could never afford one on its own. Furthermore, the enriched uranium produced in France or Europe would cost considerably more than American uranium, thereby negating the cost advantage of the light-water system.

And Horowitz found other reasons not to plunge headfirst into the light-water system. Foremost among these was the need to capitalize on the time, money, and knowledge already invested in France's existing technologies. In addition, France's plutonium needs would increase as its breeder-reactor program took off. Buying plutonium abroad would increase France's dependence on foreign sources—a compelling reason to continue with plutonium-producing gas-graphite reactors.

Nonetheless, Horowitz concluded that France should probably acquire some experience with light-water reactors. But France could not afford to pursue both types of light-water reactors (pressurized-water and boiling-water), and the choice between them had to take political considerations into account. "General technological and economic arguments do not provide enough information to choose between pressurized and boiling water reactors; this [choice] must therefore follow from considerations proper to the French context, and in particular from the consequences in either case of the recourse to American licenses. We must ensure that, pending a decision, French industry does not get involved in . . . costly relationships that may later prove useless or premature."[37] Further, whatever the choice, it should not come at the expense of the gas-graphite program, which was a major source not only of France's political security but also of its financial security.[38]

Cabanius conceded some of the advantages of the gas-graphite system and agreed that the plans to build two gas-graphite reactors at Fessenheim should proceed. But he concentrated his efforts on subverting the connection between gas-graphite reactors and national glory by transferring France's national interest onto the light-water system. This system, he wrote, would "allow our manufacturers, grouped into consortia, to assert their technological value, acquire references that will carry great weight both for export purposes and for agreements with other European manufacturers, and participate in the great industrial confrontation of the next decade."[39] Thus light-water reactors, even though they were not made in France, would still contribute to one aspect of France's radiance: they would enhance the nation's ability to export technology. That the light-water system was operated under an American license was relevant only because it meant that the French would get American technical support for their endeavors. What mattered in terms of national interest was that French companies would be manufacturing parts for the world's leading nuclear system.

Independence or Interdependence?

Thus, both Cabanius and Horowitz constructed their arguments in terms of France's national interest. Horowitz's argument conformed to the familiar CEA association of the gas-graphite system with French independence. Cabanius, rather than deny this notion, sidestepped it. His arguments became part of a larger effort to reform EDF's regime. The national interest remained foremost, but its definition revolved around a vision of France in a set of interdependent international relations. He centered French national interest on the economy, which in turn depended on the growth and competitiveness of private industry, which in turn were measured in international terms. The corollary conception of EDF's regime reflected a subtle but significant shift: EDF no longer commanded private industry; instead, it helped to reshape industrial structures so that France could compete in world markets. In this regime, pursuing light-water technologies under a foreign license made national sense. Horowitz did not repudiate the goal of helping French companies compete internationally; indeed, as we saw in chapters 2 and 3, this had been a goal of the CEA's "policy of champions." However, for the CEA industrial "champions" had always meant French companies building French technology. Abandoning this pursuit now, Horowitz asserted, was folly. In arguing for different systems, the two men promoted two different versions of France. Choosing a system was also about shaping the nation's future. Technology and context were thus inseparably entwined for both men, even if only one of them admitted it.

The differences in the two reports signaled divisions that would sharpen over time. Gas-graphite technology had succeeded as a technopolitical system. Its developers, having consistently invested its technical features with political meaning, promoted the resulting hybrid as the best choice for the nation. The success of this practice (particularly with de Gaulle) had made it difficult to argue against the gas-graphite system, for to do so could appear unpatriotic. Promoting the use of a foreign license, therefore, required a different strategy—one that involved rhetorically separating technology from politics. Cabanius claimed repeatedly that his responsibilities did not include political analysis. For him, politics included anything that had to do with fuel supply. He construed resituating EDF with respect to private industry not as politics but as economic good sense. This position necessarily involved a reconstruction of EDF's role in such a way that the utility would move from the political to the economic epicenter of the nation. EDF's initial technopolitical regime had deliberately conflated politics, economics, and technology. In advocating a new regime, management sought a rhetorical separation of the first element from the latter two. From the viewpoint of this book, of course, rhetorical separation did not mean actual separation; this strategy itself constituted a political quest to change not only the identity of EDF but also that of France.[40]

Although EDF's economist-managers sought to exclude politics from their analysis, they could not exclude politics from their world. Indeed, their arguments in favor of economic criteria held little sway with de Gaulle, who ultimately had the final say on this matter. De Gaulle held fast in his commitment to French independence and glory, and his close advisors assured him that these were synonymous with the gas-graphite system. The historical record becomes murky here, especially because appropriate documentation remains inaccessible. In retrospect, the light-water victors argue that had de Gaulle truly understood the technological and economic aspects he might not have supported gas graphite technology so fervently. But de Gaulle (an enduring icon who even today remains above serious criticism from all but the most ardent leftists) was "ill-advised." One man usually emerges as the nefarious advisor: Maurice Schumann, the minister of scientific research and atomic questions in 1967–68. Proponents of the light-water system claim that Schumann maneuvered de Gaulle into an intransigent position in favor of gas-graphite. One commented disparagingly: "Schumann wasn't an economist, but a typical *homo politicus*. . . . [He] did not reason in terms of international industry. He did not recognize the international situation."[41]

Of course, Schumann's version of the story differs somewhat. In a 1981 interview, he proudly admitted that he had defended the gas-graphite system. But, speaking twelve years after the launch of France's light-water program, he claimed more nuanced reasons for this defense. "After studying the file very attentively, I gave absolute priority to the breeder."[42] Breeder reactors would ensure French independence in the future; in the meantime, "the simple and pure abandonment of the French system was not justified; certainly not before the *francisation* of the light-water systems."[43] He portrayed his position not as a simple knee-jerk reaction against light-water technology but as a reasoned argument that prioritized French independence and that saw in gas-graphite reactors the technological bridge to a future of breeders. He had to ensure that de Gaulle understood the implications of each option. Proponents of the light-water system, he noted, "had advocates—I was about to say 'accomplices'—inside the CEA, who invoked the dangers inherent in the French system as arguments against it," but "the studies that I commissioned showed that foreign systems had at least as many accidents and delays."[44] Had de Gaulle remained president, Schumann concluded, the gas-graphite program would have continued.

Whatever the case, all agree that Charles de Gaulle had a formidable will. André Decelle, EDF's director-general, passionately desired a solution to the frustrating impasse. He had tried to persuade various ministers to change de Gaulle's mind. But, he said in a later interview, Pierre Massé (then EDF's president) would not back him—not because he disagreed with Decelle's position, but because he disagreed with his strategy.[45] Depressed and discouraged, Decelle resigned in September 1967, citing health and personal reasons.[46] Apparently, he and Massé had agreed not to mention Decelle's advocacy of the light-water system in the resignation statement because doing so would only make it more difficult to pursue that American system later on.

This precaution failed completely. The very day that Decelle announced his resignation to the board, *Le Figaro* proclaimed: "André Decelle, director-general of EDF, resigns. Partisan of the enriched uranium system, he disagreed with the government."[47] Pierre Massé, backed by Robert Hirsch, denounced the headlines as "serious counter-truths."[48] They objected to claims that Decelle and others had blindly "championed" particular technologies. Like others, they said, Decelle had simply aimed at "determining, with maximum objectivity and in the spirit of science, where the interest of the country lies in this matter." Hirsch was "particularly shocked to see this effort transformed for public opinion into some kind of passionate conflict."

Regardless of such disclaimers, Decelle's resignation did not signal the end of the debate; quite the contrary. As Marcel Boiteux replaced him at the end of 1967, it became increasingly clear that positions with regard to various reactor systems did not fall neatly along institutional lines. The advocates of light-water included EDF's top management, private manufacturers, and a handful of CEA top officials (including Robert Hirsch). Some CEA employees adopted a middle position, arguing that, should it become necessary or expedient to build light-water reactors, France should develop these itself on the basis of the CEA's submarine prototype. According to this middle position, reactors built in France should remain French, regardless of type.[49] The advocates of gas-graphite included labor unions and rank-and-file employees in both EDF and the CEA who had devoted their careers to that technology. All attempts at negotiation having failed, the impasse was referred to the PEON commission.

PEON: Defining the Context for Technological Development

The Commission pour la Production d'Electricité d'Origine Nucléaire (PEON), founded in 1955, was a government-appointed commission composed of top EDF and CEA leaders, ministerial officials, and a few industrialists. Its ostensible purpose was to advise the government on matters nuclear. It was not a decision-making body. At least until the late 1960s, programmatic decisions were negotiated within and between the CEA and EDF. PEON did little more than discuss and bless such agreements.[50]

The PEON commission's role grew more subtle and complex during the *guerre des filières*. In the contentious climate fueled by technopolitical uncertainty, meetings of this commission provided a place for constructing notions of objective arbitration. The commission's discussions and reports provided a stage on which members could play a hybrid role: although they were there to represent specific institutions, their membership in PEON symbolically separated them from their institution and gave them a larger constituency—the nation. This hybridity conflated the self-proclaimed disinterestedness of state technologists with that of the nation. At least in principle, any PEON conclusion or document represented an arbitrated negotiation for the greater good of the nation among otherwise competing interests. When reporting back to their home institutions, PEON's members carefully nurtured the commission's status as objective arbiter. The same policy conclusion would carry more weight all around if reached by PEON.[51]

PEON inherited the Horowitz-Cabanius mission: to investigate the ramifications of each reactor system and provide a rational, objective basis for short-term and medium-term programmatic choices. Accordingly, in late 1967 its members produced reports on a variety of issues[52]:

- the current technological state of each system
- national and international fuel sources and their costs
- the comparative costs of various energy systems (not only gas-graphite and light-water reactors but also advanced gas-cooled and heavy-water reactors and conventional—i.e., non-nuclear—power systems)
- industrial organizations and contracting
- licensing agreements.

The criteria for comparing different reactor types were heterogeneous:

- the reliability and longevity of reactors
- capital, fuel, and operational costs
- construction times
- dependence on foreign countries
- export potential
- existing industrial infrastructures
- the shape of foreign licensing agreements.[53]

On the surface, these reports appeared to meet expectations for an objective and consensual conclusion, particularly in the domain of cost calculations. PEON's cost calculations favored the light-water system, though its numbers differed somewhat from those of Horowitz and Cabanius.[54] Further (and this conclusion appeared especially objective, since PEON was supposed to be fundamentally pro-nuclear), the commission did *not* find nuclear power competitive with conventional sources—largely, it seemed, because the price of conventional fuels had dropped significantly.[55]

Once again, however, numbers did not tell the whole story. To begin with, many numbers were missing, uncertain, or incalculable. Comparing system costs raised the same problems for PEON as for the Horowitz-Cabanius commission: the data corresponded to very different economic contexts, and the prices offered by American and German companies did not necessarily reflect the real building costs. Commenting on the PEON discussions, Jules Horowitz noted bitterly that "the variation in American prices, the sacrifices that AEG and Siemens admit having made recently in order to obtain their first large orders, and the difficulties encountered by Belgian industry in the Doël and Tihange affairs all illustrate well the distinction that must be made between the real cost of an undertaking and the price that must be conceded in order to succeed in certain markets."[56] Another CEA commentator reached similar conclusions:

After reading [the PEON reports] one can see, as indeed is well known:

1. that the differences between the systems are the same order of magnitude as the uncertainties.

2. that light-water is being "pushed" and gas-graphite is being "jinxed" on the following economic bases: what is gained on the investment front will very certainly be lost on the fuel front, and the only parameter that tips the balance is a lower operational cost for light-water (21.7 F/kW-year, which is to say 0.3 c/kW-h instead of 33.9 F/kW-year or 0.5 c/kW-h).

One could ask oneself whether the real decision-making point is not simply a big difference in the reliability of the two systems (what comes from abroad always seems more attractive to French minds, but watch out for painful awakenings).[57]

EDF members of PEON were just as aware of the uncertainty in the numbers. Later, Pierre Massé acknowledged that the cost difference between the two systems was less than the margin of error in the data used to calculate that difference.[58]

The numbers were uncertain, and calculations indicated that conventional power might prove a wiser course. But PEON did not recommend abandoning the entire nuclear endeavor. Instead, PEON members attempted to define and describe, and therefore shape, not the artifacts directly, but the *context* in which they would operate. For industrial leaders, this context was the Common Market—a context that demanded the pursuit of nuclear technology regardless of the current price of fuel. Offering familiar arguments about competitiveness, the structure of French industry, and the increasing worldwide dominance of this technology, one industrialist added slyly: "Just imagine the position of French industry in a Common Market in which, nuclear power having succeeded, German industry dominated this sector."[59] Since light-water reactors dominated the world markets, he continued, the light-water system was the only plausible choice for this context. Industrialists added weight to their argument in favor of light-water by stipulating that they would offer warranties for that technology, but not for gas-graphite technology.[60] The mere act of offering warranties transformed the light-water system into a more reliable technology than the gas-graphite system, without doing any technological work per se.

CEA representatives to the PEON commission sought to limit the context to France (rather than Europe). Here they met with stubborn resistance from the industrialists, who apparently refused to discuss matters in these terms:

> It has been practically impossible to get [PEON] to concretely consider the national context, technological continuity, the dangers of dispersion and oversupply in a market that will remain fairly narrow for a long time—in short, the real cost for the country, not to mention the concern to create a truly major French nuclear industry that could negotiate on equal terms with the largest European companies. I tried several times to provoke a discussion about these important industrial problems; the Industry representatives to the Commission remain prudently reserved.[61]

When the question of French economic independence arose separately from that of the Common Market, said another CEA member, "opposition came both from the industrialists, who refused to provide the smallest piece of data, and from the Planning Commission, which as always preferred multiple abstract schemes."[62]

In April 1968 these disagreements were glossed over by PEON's formal report. The report concentrated on two elements: the outcome of the cost calculations once the uncertainties were factored out, and the need to base decisions on "objective" economic criteria rather than on political considerations. This second item reflected efforts to redefine the French context: "It is pointless to hope for total independence. . . . The potential for economic independence can be defined as the capacity to maintain economic competitiveness over the long term and on the international front. . . ."[63] The numbers and the context, in turn, pointed to a clear set of recommendations:

- France should immediately build an American-style reactor.
- Pending a reevaluation in 1970, no new gas-graphite reactors should be ordered in the next two years.
- The Canadian heavy-water design might deserve further consideration.[64]

One industry periodical joyfully proclaimed these conclusions the result of a "profound unanimity." And where did this unanimity come from? Quite simply, from the separation of technology from politics:

> The essential reason for this unanimity comes, we believe, from the fact that men in good faith, from the most diverse origins, were eventually bound to agree over the analysis of such a complex question from the moment that this [question] was entirely depoliticized and subjected to the objective analysis of the real problems involved.[65]

The important point was that politics had not dominated the debate. This, in turn, provided the government with a clear basis for action.

The main achievement of PEON's 1968 report was, therefore, to legitimate two key strategies of light-water's supporters: the separation of technology from politics and the redefinition of the context of nuclear development as Common Market economics.

Breeder Reactors: Flexibility and Consensus

Nonetheless, turmoil continued to lurk beneath PEON's facade of consensus. De Gaulle continued to favor the French system. Within both EDF and the CEA, employees remained split. Not everyone agreed that technology and politics should be separated, or that the context for the nuclear program should be primarily economic.

A different source of consensus emerged in discussions outside PEON: the breeder reactor. As a technology that still existed primarily on paper (only one prototype existed: the CEA's Rapsodie), the breeder was still flexible enough to fulfill a broad spectrum of technopolitical scenarios. As we saw in the cases of Jules Horowitz and Robert Schumann, gas-graphite enthusiasts had already begun to endow breeders with the power to carry France's technological glory. In the wake of the PEON report, proponents of gas-graphite reactors focused increasingly on a future of breeders. Light-water's proponents, meanwhile, used that future to build a stronger constituency for the American solution.

Some engineers and labor militants at EDF maintained that the breeder future demanded further pursuit of the gas-graphite system. In July 1968, for example, Claude Bienvenu, the leading project engineer for Saint-Laurent 1, lambasted recent decisions that jeopardized the gas-graphite program. He was angry because an impasse over industrial contracting methods had stalled the construction of a gas-graphite unit at Fessenheim. Worse, the companies in charge of construction were trying to reinvent the pressure vessel, the heat exchangers, the command and control systems, and nearly everything else. "Saint Laurent will have been useless!" exclaimed Bienvenu. "The gas-graphite system, which had been ready to derive maximum profit from the experience accumulated and perhaps even to battle with some chance of success against the American system, will find itself blown away like a straw in the wind."[66] Breeders could return France to a more rational path. They also provided the best reason for maintaining the gas-graphite system, which could supply both the plutonium and the experience required by breeder development. Such a course would ultimately allow France to surpass the United States, which had no breeder experience.[67]

The CGT militant Claude Tourgeron also saw a future of breeder reactors. His, however, was a socialist future. Tourgeron juxtaposed his argument for breeders with an argument for the "formation of nationalized companies that would free this industry from the joint pressure of large capitalist monopolies and military management."[68] These nationalized companies would provide the basis for a true socialist democracy, which could only lead to national economic growth. Breeder technology would take some time to mature, though, so France had to pursue an intermediate system in order to maintain its nuclear knowledge. Only a system based on natural uranium would allow France both to escape the clutches of American imperialism and to produce plutonium for the breeder future. Cost calculations that disadvantaged the gas-graphite system resulted from nefarious capitalist practices. The Fessenheim estimates, for example, had been inflated by capitalist monopolies in their thirst for profit and their desire to tip the balance in favor of the American design. Thus, successful gas-graphite reactors, breeders, and a socialist order were mutually dependent.[69] The technopolitical circle was complete.

Though their visions differed, Bienvenu, Tourgeron, Horowitz, and Schumann all saw a future of breeders. This consensus was remarkable, since aside from their enthusiasm for gas-graphite and breeder reactors the four men had little in common. Proponents of the American system seized on this consensus to propose a different path to that future. For example, in February 1969 EDF's top management sent a memo to the prime minister arguing that France should make every effort to research and develop breeders ("the system of the future"). But it contended that the main road to that future went through the American system. Using an American license would allow France to recover from the disappointment of the gas-graphite experience and to "catch its breath while waiting for a new breakthrough—that of the breeders—to which it will devote all its research and development efforts."[70] Not even the CEA's experience in designing a light-water reactor for submarines would go to waste. Instead, this experience would help French teams "mix French intelligence with American experience to build a Frenchified reactor."[71] Thus they too transferred the burden of French grandeur to the breeders. Further, the nebulous "Frenchifying" of American reactors would preserve French nuclear know-how (and, presumably, pride). In April 1969, Marcel Boiteux and Robert Hirsch proposed a "plan of action" that essentially reframed the proposals and arguments of the PEON report to suit the logic of a breeder future.[72]

In presenting this "plan of action" to EDF's board, Hirsch and Boiteux emphasized that the plan prudently kept the natural-uranium option open. They stressed that "the realization of the first light-water reactor will take place in the framework of a general license in order to draw from the Americans a maximum of amount of knowledge about the chosen system."[73] The French would derive maximum benefit out of the partnership while leaving the Americans responsibility for the technical warranties. Paul Delouvrier, Pierre Massé's successor as president of EDF, waxed enthusiastic about the plan. Although light-water reactors were more expensive than oil-fired plants, he affirmed that this was the price that France had to pay to keep up to date on matters nuclear. "It is not without some sadness," he said, "that one sees AEG and Siemens put a plant in Holland, given that the nuclear industry got a much later start in Germany than in France. It is definitely time for the country to get hold of itself in order not to be surpassed and dominated."[74] Once again, then, light-water appeared to provide the path to French radiance. Delouvrier gave the plan of action his blessing. With Tourgeron absent from the board meeting, no one raised any objections. PEON approved the plan in May 1969. Meanwhile, EDF's managers had already begun to prepare for the first light-water reactor.[75]

In the mid 1950s, the CEA capitalized on the ambiguity of the gas-graphite design to advance the French bomb program. In 1969, light-water advocates capitalized on a variety of ambiguities to move forward with plans to buy an American license. Each successive report tightened the case for the light-water system, using a combination of three techno-political strategies:

- managing technological and economic uncertainty, either by quantifying and plotting potential data fluctuations or by pronouncing on the relevance and function of different uncertainties

• defining the context in which future nuclear development would occur, notably by renegotiating the meaning of "national independence"

• constructing a new logic for light-water development in which that development would contribute to French radiance.

Embedded in successive reports, these strategies created a narrative teleology of nuclear development. As Philippe Simmonot argues in *Les nucléocrates*,[76] each report further instantiated a logic of technological determinism. With each successive refinement, American light-water reactors became more and more necessary for the future of France.

Unions Strike Back

As 1969 wore on, opposition to light-water became increasingly difficult to orchestrate. Advocates of the American system had developed their plans incrementally, carefully reframing ambiguities that could have argued for either system in their favor. Their stated goals—to give France cheap energy and to make breeder reactors the new symbols of French technological glory and independence—were irreproachable. Further, they had not actually proposed terminating the gas-graphite program yet. Finally, these advocates occupied the top administrative positions in the CEA, in EDF, and in private industry.

The case was not closed—the government had not yet made a decision on the choice of system. But things looked bad for gas-graphite. Clearly EDF's management, private industry, and top CEA officials were poised to buy American. Equally clearly, buying American would come at the expense of the French system. Furthermore, by then the man seen as a guarantee against the purchase of a foreign license—Charles de Gaulle—had resigned the presidency and had been replaced by Georges Pompidou, who had distinct sympathy for the American system.[77]

In an effort to obstruct the growing forces in favor of light-water, labor militants began to contest the economic analyses constructed by program leaders. Unions offered alternative figures, calculations, and interpretations. These efforts began when CGT representative Claude Tourgeron registered an official protest at EDF's June 1969 board meeting.

Focusing on the uncertainty in the light-water data, Tourgeron's protest contested the notion of light-water's worldwide dominance, resurrected the issue of national independence, and challenged the push for "purely" economic selection criteria. He noted that in the United States orders for light-water reactors had dropped dramatically between 1967 and 1969. Tourgeron attributed this dropoff to an increase in the capital costs of these reactors (now up to 1000–1100 francs per kilowatt, in the same range as the gas-graphite reactor Saint-Laurent 2). He also argued that American utilities had lowered their predictions for the capacity factor of light-water reactors and were even building "rustic" thermal plants to take over when reactors had to go off line. He reiterated familiar arguments about the threat that reliance on enriched uranium would pose to France's independence. He also added a new twist: American enriched uranium was inexpensive primarily because isotope separation plants "had been financed a long time ago [presumably during World War II] by taxpayers."[78] Neither France nor Europe could ever hope to approach American prices. Finally, he argued that economic criteria alone did not suffice for making decisions about the future of the French program: prices fluctuated too much to provide a reliable foundation for decision making. Both technical and political considerations militated in favor of more gas-graphite reactors to link the present with the breeder future.

Several board members countered Tourgeron's claims. Robert Hirsch attributed the decline in American reactor orders to market cycles. Others denied the validity of Tourgeron's calculations by simply reiterating PEON's economic estimates. Marcel Boiteux closed the discussion by insisting that consensus existed on two matters. First, the future belonged to breeders, and France should do everything to preserve its lead in this domain. Second, the country had to engage in some kind of intermediate program to ensure that French industry would maintain its mastery over nuclear technology. The only two truly viable candidates for this intermediate program, Boiteux continued smoothly, were the gas-graphite system and the light-water system. Boiteux then completely ignored Tourgeron's estimates by asserting: "All the numbers cited in this discussion—which are based on experimental results, developments, and recent requests for bids—proved that the light-water system was the most economically viable and the least capital intensive. This is the reason it was chosen."[79] Had a choice been made? Was this last statement a slip of the tongue, or a reference to American decisions? It was not clear. Nor were there any significant new data about the economics of light-water reactors. Boiteux elided these points and hastened to add that, for the moment, the natural-uranium option had not been closed. He postponed that decision for another twelve or eighteen months, pending further data. Other board members murmured their assent, and the matter was temporarily tabled.

Meanwhile, CEA union leaders had begun objecting to the emerging plan, which they felt threatened both their jobs and the future of the French nation. Initially, they protested that these plans had been drawn up not by the government—the ultimate representative of the people, however objectionable it might be—but by institutional leaders. They added that, contrary to allegations in the news media, political rather than technical weakness had caused the current problems. A CFDT publication asserted that "the difficulties faced by the [CEA] today do not come from technical failures, but from the government's lack of research policy and industrial policy."[80] The CEA's scientific and technical potential was being ignored. The government needed to establish a coherent research program addressing "technological areas in which France is especially and dangerously underdeveloped."[81] The CFDT advocated a new institution similar to that proposed by Claude Tourgeron: a state-run financial institution that could create new companies or regroup existing companies. The state could thus manage private industry and give rational direction to the nation's research and industrial development. This would also prevent Westinghouse from taking over France's electromechanical industry.[82] Finally, the CFDT—echoing the *autogestion* (self-management) demands of the May 1968 strikes, during which many CEA employees had become radicalized—asked that CEA workers (white-collar and blue-collar) be given more say in program management and in decision making.[83]

By October 1969, rumors had begun to circulate that the CEA's programs would be cut back and that layoffs would ensue. The CEA's five main unions joined forces to protest the layoffs, the introduction of American light-water reactors, the implied slurs on their technical competence, and the incoherence of French nuclear research policy. On October 10, some 800 employees staged a demonstration at Marcoule. Meanwhile, at the Saclay research center, unions avidly defended the performance of the French nuclear program, which, according to one flyer, had been "submitted to systematic . . . unfounded criticism by the press, encouraged by the eloquent silence of CEA and EDF top management."[84] The real problem, this flyer suggested, "contrary to what is written daily in the press, has nothing to do with the high price of French nuclear plants, but instead [is due to] on the one hand, the dumping prices practiced by oil companies . . . and on the other hand the current structure of the French electromechanical industry in general and the nuclear industry in particular."[85] The price of a gas-graphite kilowatt-hour was already 30 to 40 percent lower than the most optimistic estimates of the Plan several years earlier. On that basis, the Plan—which, however imperfectly, still represented popular will better than EDF and CEA leaders—had called for 2500 megawatts' worth of new reactors. Only 1300 megawatts' worth had been built.

The unions demanded a coherent nuclear program whose main criteria of success would be continuity, independence, and the development of a national electromechanical industry. This policy "must first and foremost be translated into the development of the gas-graphite system."[86] It would be "stupid" to abandon this and other national technologies. In a separate statement, the CGT called for the publication of reports that would "reestablish the truth which is indispensable to the defense of French atomic energy. . . . The CGT's engineering and white-collar worker section will not hold back in its efforts to ensure that France remains independent in the energy sector."[87] Others used even stronger language to denounce the intrusion of Westinghouse into French industry:

> What some are calling the "*guerre des filières*" is a booby trap! It's really a war between international trusts orchestrated by one of them: Westinghouse. What could Westinghouse's intrusion into the closed world of bourgeois businessmen and technocrats which governs us mean, other than the brutal manifestation of American imperialism in our midst. Elsewhere, it kills by war; here, it seeks to reduce us to the state of an economic colony. Let us not be dupes: *the French government is not neutral in this affair. It's an accomplice. It's the enemy of the workers.*[88]

The government could not be counted on to produce a reasonable solution. It was colluding with private industry to orchestrate an American takeover of France.

Boiteux Declares the End of the Gas-Graphite Program

The situation finally exploded in mid October at Saint-Laurent 1, the pride and joy of the gas-graphite program. The reactor had been operating for several months and had already produced a respectable amount of electricity. On October 16, Marcel Boiteux, accompanied by Robert Hirsch and Francis Perrin, went to the site for the official inauguration of the reactor. During his press conference, Boiteux congratulated the site's teams on their success, declaring that Saint-Laurent was the best of EDF's reactors. Unfortunately, he added, the gas-graphite system was not commercially viable. From then on, he said, EDF would be building light-water reactors under an American license.[89] This announcement sent a shock wave throughout the nuclear program, the government, and the press. Everyone knew that this was the direction in

Figure 8.2
Marcel Boiteux gives a press conference at Saint-Laurent on October 16, 1969. EDF's official caption for this picture is "Inauguration of the plant at Saint-Laurent-des-Eaux." Gas-graphite supporters would have titled this picture "Boiteux announces the termination of the French system." Photograph by Michel Brigaud. Source: EDF Photothèque.

which the program was headed, but no one realized that a decision had been reached.

Reactions in the press were mixed. Nicholas Vichney of *Le Monde* was jubilant. Acknowledging the technical success of Saint-Laurent, he followed Boiteux in emphasizing its economic drawbacks; then he added several comments about the CEA's unreasonable attitude.[90] But Pierre Juin, writing in the Communist daily *L'Humanité*, was scandalized. His front-page article featured a photograph of Saint-Laurent with a caption describing the site as a "prestigious French achievement."[91] Saint-Laurent's technical success, Juin wrote, might lead one to expect that "the top brass of EDF and the CEA who piloted specialized journalists through the vast construction site of Saint-Laurent on Thursday would be overjoyed. Well no." He went on to impute the decision, not just to EDF, but to the government more generally:

In his press conference last Monday, Mr. Ortoli, minister of industrial and scientific development, had declared that France's nuclear policy would be fixed at the end of the year. . . . Mr. Boiteux, however, could not hide that the case had already been heard. . . . During a lightning interview, which only allowed for a half-dozen questions, Mr. Boiteux affirmed that all countries were now oriented toward light-water reactors and that, as a result, it would be tasteless to obstinately pursue our own technology in the restricted space of the French hexagon.

The decision, said Juin bitterly, had been the result of pressure by foreign monopolies and would seriously endanger French independence.[92] In a similar vein, the caption of one *Canard Enchaîné* cartoon read "US Go Ohm!"[93] *Le Canard* did note, however, that the decision had not emanated from the government. "Pompidou is slowly rushing to decide nothing," sneered the weekly. "For the moment, he is still in training. After all, the French system is the General's gadget. Got to treat that carefully. The dear old gentleman might take offense."[94]

Indeed, Boiteux's announcement apparently surprised Georges Pompidou, who had taken no official decision, and some of EDF's board members, who had thought that matters were still up for debate. Boiteux himself emphatically denied that he had announced any sort of decision. He had merely stated that, because the economic success of Saint-Laurent was less certain than its technical success, the future of the gas-graphite system remained uncertain. It was, he said, "regrettable that his words were given the political meaning that they were."[95] Journalists had misinterpreted his responses to their questions. He had said that "there was no reason to regret what had been done in this domain, [since] the effort poured into the 'gas-graphite' system fit into the logic of the nation's history, but that today the fact nonetheless remained that nuclear plants were too costly, and it was only right to question whether an Establishment like EDF should continue to build them."[96] He had merely indicated that EDF had a *preference* for the light-water system. The press had not mentioned that he had referred all final decisions to the government. Paul Delouvrier expressed his support for Boiteux. Claude Tourgeron and other labor union representatives reiterated their objections.

Disclaimers notwithstanding, Boiteux's statement was widely understood to signal the end of the gas-graphite program. For CEA employees, the first of the rumored layoffs confirmed this signal: the same day that Boiteux held his notorious press conference, 98 cleaning ladies subcontracted to the Saclay research center were let go. The next few days saw several more layoffs, all branded by the unions as violations of the labor agreements drawn after the 1968 protests. On October 23, Saclay's director returned from a trip to find the site's union personnel up in arms. He refused to revoke the layoffs. Four days later, 700 Saclay employees launched a series of strikes that would last for more than a month.

The CEA Strikes

In order to understand these strikes, we must briefly go back in time to 1968. During the nationwide protests that year, numerous CEA engineers and technicians had joined unions.[97] Like demonstrations elsewhere in the country, the 1968 sit-ins at the CEA focused on democratizing the workplace and loosening the institution's decision-making hierarchies. From the perspective of the protesters, the results had been somewhat mixed. They had obtained new administrative bodies that, at least in theory, made room for broader participation in managing daily workplace affairs. However, as the October 1969 layoffs indicated, not all of the CEA's directors had taken well to these new structures. Further, as the termination of the gas-graphite program showed all too clearly, the CEA's administration had no intention of including the personnel in programmatic planning, not even in the cursory style to which EDF's board of directors had devolved.

Still, the 1968 sit-ins had provided a brief opportunity for many CEA employees to experiment with solidarity among engineers, technicians, scientists, and workers. (Recall from chapter 4 that the national confederations had advocated this solidarity in their discussions about recruiting the technical elite.) The most extensive of these sit-ins had occurred at Saclay, where the working population consisted primarily of engineers, scientists, and technicians.[98] At Marcoule, 1968 apparently did little to change the relationship between workers and engineer-managers described in chapter 5. But the fact that protests occurred at many CEA sites suggested that workers there might share sentiments with engineers and technicians around the country. In 1969, this shaky alliance across multiple CEA sites resulted in protests that combined the practices and goals of labor unions with those of engineers. The ensuing strikes combined demands to halt the layoffs with calls for greater employee participation in management and challenges to the termination of the gas-graphite program. The 1969 CEA strikes, in other words, fused questions of national technological policy with concerns about social relations.

The first group of protesters at Saclay included five hunger strikers. These men demanded the revocation of all layoffs. Echoing the tones of 1968, they presented their case as a moral issue, a matter of basic social equity:

> We refuse to play the game of dividing the personnel between CEA employees (the nobility) and subcontracted employees (the pariahs) which the administra-

tion wants to impose on us and which does tempt some of the personnel. Workers, not matter who they are, have a right to a decent life. . . .

We refuse to be complicit in a hypocritical and cowardly society that always makes those pay who can defend themselves the least.

We refuse to be complicit in a repressive society that uses all means, even those that run counter to its own legal framework, to manipulate and intimidate those who in the end are the source of all wealth: the workers.[99]

On that note, the five men installed themselves in Saclay's labor union offices on the afternoon of October 29, only to be evicted a few hours later when 240 policemen stormed the site. For the next two and a half weeks, the strikers would continue their fast in a nearby church.[100]

On October 31, news leaked that the CEA's administration planned to announce another 2000 layoffs. The unions responded by broadening their demands and intensifying their strike actions. Though they continued to express outrage on behalf of the cleaning ladies and other subcontracted workers, protests now focused primarily on nuclear policy. The strikes spread to all of the CEA's research and production centers and continued through the end of November.[101]

Echoing earlier arguments, strikers denounced the termination of the gas-graphite program and the threat of an American industrial takeover.[102] They contested the assertion that gas-graphite reactors were not competitive and argued that "profitability [was] not the only important criterion."[103] National independence had to count too—especially independence from the United States. Never had the threat posed by American capitalism loomed larger. "We are," one tract warned, "in the process of losing our national independence; we are on the path to underdevelopment and colonization."[104] French plants, the protesters asserted, were equivalent in quality and cost to American ones. Nuclear research had been a source of French pride for decades. Even the British were said to have admitted that the French had a "natural flair" for nuclear technology and science.[105]

The problem, said the unions, lay in the fact that the government had not handled either industrial or research policy properly. "Such an important decision . . . should be preceded by consultations with employee representatives, not announced on the fly by a bureaucrat, no matter how highly placed he might be."[106] Only the unions had the nation's welfare firmly in sight: "Our goals are clear. We are in favor . . . of funding research which will ensure the intellectual, economic, and social future of an entire people and guarantee its independence."[107] Although nuclear weapons were not a significant subject of discussion in the strikes,

Pour faire face à la technologie américaine, le COMMISSARIAT A L'ÉNERGIE ATOMIQUE peut et doit devenir dans l'intérêt national un groupe puissant et diversifié où les agents seront associés à la marche de l'entreprise et la garantie de l'emploi assurée.

En raison de la crise énergétique actuelle, le Commissariat, qui est à l'origine du développement nucléaire en France, doit recevoir, dans le domaine de l'électro-nucléaire, des responsabilités accrues, des crédits suffisants et le personnel nécessaire.

Une nouvelle politique du personnel doit être définie impliquant la reprise des recrutements.

REJOIGNEZ LA C.G.C. !

Figure 8.3
A flyer issued during the 1969 strikes by the Confédération Général des Cadres, the white-collar workers' union. Note the alterations made to the front of the bill (all in English): "What is good for Westinghouse is good for France," "In EDF we trust," "Business is business," "MB" (for Marcel Boiteux), and "PWR" (for pressurized-water reactor). The following explanation was printed on the back of the flyer: "To confront American technology, the COMMISSARIAT A L'ENERGIE ATOMIQUE can and must—in the national interest—become a powerful and diversified group in which employees are involved in managing the firm and in which employment is guaranteed. Because of the current energy crisis, the Commissariat, which is at the origin of nuclear development in France, must acquire greater responsibilities in the nuclear arena, as well as a sufficient budget and the necessary personnel. A new personnel policy must be defined, one which involves the resumption of recruitment." Flyer courtesy of Jean-Claude Zerbib.

three of the unions could not resist a jab at the military program: "Strangely, military applications, which constitute the least important part of nuclear research, are not in the least affected by restricted funding. The government talks of national independence when atomic bombs are involved; at the same time, it is liquidating our national industry, which is the measure of true independence and the source of progress and well-being."[108]

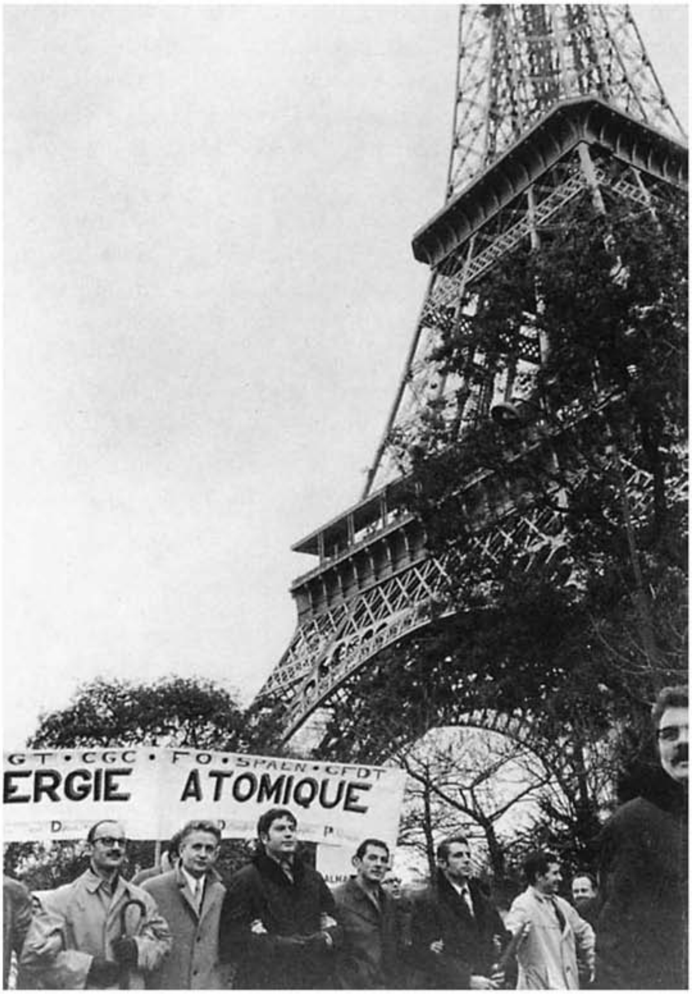


Figure 8.4
CEA protesters march past the Eiffel Tower, a historic symbol of French technological glory. Photograph by Philippe Mousseau, Lumifilms. Courtesy of CFDT archives.

On November 14 the CEA's administration reinstated the cleaning ladies and the hunger strikers stopped their protest. If the administration hoped that this concession would end the strikes, however, it hoped in vain. That same day, President Pompidou formally announced the termination of the gas-graphite program for the foreseeable future. Although the "foreseeable future" clause was intended to leave open the possibility (at least rhetorically) that the gas-graphite system might find favor again some day, no one paid it much attention. The CEA strikes continued to intensify. On November 17, between 4000 and 6000 protesters descended on the Place des Invalides in Paris and marched past the Eiffel Tower. Strikes continued in the provinces too. According to CGT statistics, 90 percent of Marcoule's personnel were on strike between November 14 and 18.[109]

These strikes combined typical employment matters and issues of national industrial and research policy in a seamless web. The heterogeneity of the issues raised during the strike doubtless was due in part to the heterogeneity of the strikers, who ranged from the blue-collar workers at Marcoule to research scientists and engineers at Saclay. No doubt realizing that purely political tactics would have little effect in a debate whose terms were defined by its dominant participants as economic and apolitical, a group of union engineers, scientists, and technicians prepared a counter-report on the relative merits of the competing nuclear systems.

Economic Comparisons, Union-Style

One major difference between the union report and those written by Cabanius and by PEON lay in how the reports posited the relationship between technology and politics. As we have seen, advocates of the American light-water system sought to remove what they derisively called "political" considerations from the decision-making process. Union advocates of the French system, on the contrary, sought to retain such considerations. Paralleling but also extending the points Horowitz had made, the union document attributed the importance of political considerations in nuclear energy policy to the fundamental uncertainty of the data on nuclear power.

A major source of this uncertainty, according to the union report, were differences in the financial and technological conditions under which power plants operated in the United States and France. These differences gave the American system an artificial advantage in at least four ways. First, the amortization period for reactors in France was twenty years, whereas in the United States it was typically thirty. Since a shorter amortization period penalized plants with higher capital costs, this difference unnecessarily disadvantaged gas-graphite reactors. Second, the capacity factor used in the calculations differed in the two nations: 6800 hours per year in France versus 7500 in the United States. This too penalized French reactors, and there was little empirical evidence to suggest that American reactors really spent that much more time on line. Third, price comparisons between nuclear and conventional power in the two countries operated under different principles. In the United States, for example, the price of conventional fuel included the cost of transportation to the power plant. French pricing included freight costs only to the port of entry. Taking port-to-plant transportation into account would raise the price of French conventional fuel by 0.37 centime per kilowatt-hour and therefore make the gas-graphite system more attractive. Finally, were France to engage in the "draconian" precautions taken in the United States to reduce pollutant emissions, the price of conventional fuel would increase even further, perhaps by as much as an additional 0.85 c/kWh. None of these factors, said the unions, had been included in the EDF's calculations.

Indeed, the report maintained, "the capital costs announced by EDF are incomprehensible and incoherent."[110] For example, the figures used to represent the capital costs of light-water reactors did not include the fact that two such reactors in the United States had gone, respectively, 30 percent and 90 percent over budget. Combine this with the spectacular reduction in the gas-graphite costs achieved at Saint-Laurent 2 and the two reactor types had equivalent capital costs. According to calculations presented in the report's appendix, electricity from an American light-water reactor would cost between 2.93 and 3.08 c/kWh, whereas the electricity from the second Fessenheim gas-graphite reactor would have cost 2.91 c/kWh.

Still, the union report argued, such numbers had limited value: "All the plants on which current economic comparisons, and therefore decisions, are based are 'theoretical' plants."[111] Reliable numbers for fuel cost, use rate, operational costs, and amortization would come only with more extensive operational experience. Further, it was impossible to tell how the numbers used by EDF and PEON had been derived, since the actual calculations remained hidden. And finally, current economic studies were based only on the direct cost of the reactors, without taking into account the investments that either nation had already made in the technological system that supported each reactor type. (This system included fuel manufacturing plants, treatment plants for spent fuel, research infrastructure, the military functions of reactors, and more.) "The unannounced but implicit abandonment of this system, into which the CEA and EDF have poured considerable investments, is therefore completely incomprehensible."[112] The unions thus demonstrated that the decision had followed the logic of politics, not that of abstract economic rationality.

How did the unions view the politics of the situation? For them, the decision to terminate the gas-graphite program represented a capitulation to capitalism—American capitalism in particular. "Everyone is aware of the concerted offensive launched by American industrial consortia to get hold of the French electromechanical [industry]," said the union report. Pompidou's announcement merely confirmed the "Americanization of the French electronuclear [program]."[113] But the report did not argue that politics should have been left out of the decision. Instead, it argued, the *wrong* politics had guided policy makers. When the uncertainty of the economic data was taken fully into account, the resulting estimates were "sufficiently close for other criteria of choice (currency flow, capitalizing on existing investments, national independence, full employment) to be considered on the same plane."[114] Rather than base a decision purely on the politics of capitalist development, in other words, the government should have also taken the politics of social relations into account. And it should have weighted other political elements (such as national independence) differently. In conclusion, the report called for the creation of a new commission—composed of ministerial officials, EDF and CEA management, and labor unions—to reexamine the case.

On the evening of November 20, a delegation of union representatives brought this report to a meeting with Prime Minister Jacques Chaban-Delmas. He refused to revoke the layoffs, and he did not offer much hope on the programmatic front. He did not refuse outright to consider the unions' proposals, but he made it clear that he would probably turn them down. Discouraged, the CFDT, the CGT, and Force Ouvrière called for more strikes the following Monday. Those would be the last of the strikes: as it became increasingly clear that the programmatic decisions would hold, the unions lost heart.

Back to Bagnols

Although the strikes had no practical effect on national nuclear policy, they did have an important consequence at the local level. In the Gard, the strikes served to reassert a sense of common destiny among regional elected officials and Marcoulins—a sense that, as we saw in chapter 7, had begun to weaken by the end of the 1960s.

In mid 1969, as rumors about CEA layoffs began to circulate in Bagnols, members of the municipal council and shopkeepers who catered to the Marcoulins began to worry. True, the newcomers had caused unwelcome upheavals in local life, but in fifteen years they had also become tightly integrated into the region's new economic life. The departure of large numbers of Marcoulins would mean a significant loss of tax income for the municipality; without that income, the town would have an extremely difficult time paying the debts it had incurred while building its new facilities. "The state provided the town of Bagnols with large subsidies," the council fretted, and "it would be disastrous if such expenditures were approved without measures taken to ensure that they become profitable."[115] Similarly, Chusclan, Codolet, and other villages had only just begun to reap benefits from the presence of the site. Not only could the region ill afford to lose jobs; with a birth rate of 600 per year, it would soon need new sources of employment. Two hundred job cuts had been announced for Marcoule, with rumors of more to come.[116] Anxieties ran high.

Marcoule's labor militants and Bagnols's municipal council wrote a joint petition to department and state authorities explaining the gravity of the situation and demanding that "initiatives be taken in high circles in order to calm the emotions and dissipate the unease that currently weigh on the people that [we] have the honor to represent and the duty to defend."[117] Their suggestions included measures to encourage further industrial development in the region, creating new jobs, and averting the threat of job loss. Not content with writing plaintive letters, Mayor Pierre Boulot marched over to Marcoule to meet with Michel Molbert, the site's new director. Molbert, no happier than his employees about the looming unemployment, calmed Boulot's worst fears, assuring him that, in the end, not more than fifty people would be asked to leave the site. Through the prefect of the Gard, Boulot also obtained an appointment with the CEA's upper management in Paris in order to air his concerns personally.[118]

Meanwhile, unionized Marcoule workers had gone on strike to protest the demise of the gas-graphite program.[119] With the help of Mayor Boulot, a departmental official, and several social scientists from regional institutions, they prepared a document, titled *Marcoule et sa vocation dans le Languedoc-Rhodanien*[120] and more than 450 pages long, that described the site's functioning and organization and its importance for the region and for the French nation. In essence, this document rehearsed the narrative of local modernization explored in chapter 6—with one important difference: it also confronted the disillusion and difficulties that had characterized the actual experience of modernization.

The document did this by discussing Suzanne Frère's *Bagnols-sur-Cèze: Enquête Sociologique*,[121] which had concluded in 1968 that the region was irredeemably divided between Bagnolais de Souche and Marcoulins. The authors of *Marcoule et sa vocation* argued that Frère's conclusions—initially true—were now, only a year later, outdated. One had to look to "those elements that promote evolution toward the integration of the [two] populations, toward the creation of that future Society"[122]: the new schools, where the children of the two groups mixed everyday; the fact that more and more newcomers had begun to build their own houses, thereby coming into greater contact with the Bagnolais de Souche (they took up the same language); leisure facilities such as the pool or the cultural center, where the two populations increasingly had fun together; and more. Marcoule workers, the 1969 document reported, increasingly felt that Bagnols was their true home. The established population was "conscious of the step forward taken since 1954 and fear[ed] the economic consequences of recession. The first [group] has discovered a town, the second an economy."[123] The two groups now had a common "destiny."[124]

The municipal council of Bagnols supported this conclusion. CEA employees had become emotionally attached to the town; townspeople, the council felt, therefore owed these employees solidarity. Boulot argued that the council had a responsibility to maintain the regional economy. Other councilors elevated their motives to the national level: ultimately, they argued, the strike was about French energy independence, and, just as the CEA employees defended their profession, the municipality had to defend its taxpayers. Some even suggested that the municipal council go on strike if the demands of Marcoule's strikers were not met.[125] For better or worse, the two communities had to face their common destiny together.

In the Gard, therefore, the *guerre des filières* and the strikes that accompanied it brought a reconciliation between the new inhabitants and old-time local leaders. This occurred through a mutual recognition of the problems experienced by both groups. The reconciliation did not mean the end of conflict between the groups, nor did it mean that all local residents now welcomed the Marcoulins into their midst. It did, however, acknowledge that encounters between the two groups had been (and for some, would continue to be) difficult. A collective memory that made room for conflict had been born.

The *guerre des filières* had little effect on the local residents near Chinon. Site employees staged brief demonstrations protesting the termination of the gas-graphite program, but they did not worry about losing their jobs. Their initial difficulties over, the Chinon reactors appeared to have a long life ahead of them, even if they would have no more heirs. In 1973, EDF1 would be decommissioned and transformed into a museum—a fitting end, given that it had been compared to and even served as a tourist destination since its inception. That decision had not been made in 1969, however. At that point, not only did the three existing reactors function well, but it seemed likely that future light-water reactors would be constructed at Chinon. Life in the Touraine continued as usual.

The Cleanup at Saint-Laurent: Healing the Technopolitical Wound[126]

In view of what we know about the two institutions, it may seem ironic that the strikes protesting the termination of the gas-graphite program occurred at the CEA and not at EDF. But the termination of the program did not threaten EDF jobs. The EDF's labor statute guaranteed against technological unemployment—at worst, employees would have to learn new skills. In addition, both union and non-union proponents of the gas-graphite system had already had several opportunities to present counterarguments in reports and at board meetings. Though these arguments had little effect on top management, EDF employees did not feel excluded in the same way as their CEA counterparts. Furthermore, although switching to another technology did hurt the pride of those who had labored on the gas-graphite system, it did not threaten the foundation of EDF as it did that of the CEA. Top management did use the *guerre des filières* to try to reshape EDF's technopolitical regime, but even this did not threaten unionized EDF employees as profoundly as the termination of the gas-graphite system threatened CEA employees. At EDF, unionized employees could continue to oppose the new regime by challenging its contracting practices. CEA employees had no recourse but strikes.

Those who might have protested the loudest—the designers and workers of EDF's gas-graphite reactors—had a more urgent task ahead of them. The day after Marcel Boiteux's announcement, in a strange coincidence, one of the most serious accidents the nuclear industry had yet seen caused a partial meltdown of Saint-Laurent 1. Engineers and workers from Saint-Laurent, and a few men sent over from Chinon, spent a year cleaning up the mess and putting the reactor back on line. It was in this activity, rather than through strikes, that they expressed their reactions to the termination of the program. Instead of contesting the decision by striking, they contested its *meaning* by working to repair their reactor. No discussion of the gas-graphite program's demise can be complete, therefore, without examining the cleanup of Saint-Laurent 1 in 1969–70.

As I have noted elsewhere, even proponents of the light-water system called Saint-Laurent 1 an outstanding technical success in the first few months of its operation. Its designers and workers proudly proclaimed it the most elegant and efficient of all French reactors. They insisted that its exceptionally well-planned and efficiently executed construction showed that nationalized companies should indeed lead France's technological efforts.[127] Even more proudly, they noted that Saint-Laurent 1, at 480 MW, was one of the most powerful reactors in the world. When it went on line in March 1969, it promised to help "defend the colors of gas-graphite"[128] by proving that the French system could compete not only with conventional plants but also with nuclear power in other nations. Workers were prepared to put in long hours to help it succeed. Time, said one man, did not count: he once worked 36 hours in a row without sleeping just to get a job done, and remembered his boss coming by at 2 A.M. to bring his shift "a snack and a pat on the shoulder, and to say how you guys doing?" The work atmosphere was "very friendly, very convivial. We worked hard, but for love, eh?"[129]

Saint-Laurent 1 appeared to hold the technopolitical key to the continuation of the gas-graphite system.[130] As such, the significance of its success for those who designed and operated it was both political and personal: their time, energy, and skill had made it France's most important technological achievement. It is not difficult to understand, therefore, why Saint-Laurent employees experienced Marcel Boiteux's announcement as "a stab in the back."[131]

On October 17, 1969—the day after Boiteux's press conference—loading machine operators began testing a new control tape. As far as they knew, the loading machine contained five uranium fuel rods and was about to load them into an empty channel. In fact, however, the machine contained five slightly thicker rods filled with solid graphite. Everything went smoothly until 6:32 A.M., when the last rod from the loading machine began sliding into place. The operators were puzzled when this rod protruded from the top of the channel. They thought that the difficulty might lie with the automatic control system, which had been acting up a little recently. They decided to override the automatic mechanisms manually, and by 6:58 they had managed to cram the recalcitrant rod all the way into the channel.

At 7:08 A.M. the terrifying siren of the reactor's alarm system blared. Because graphite rods were slightly thicker than uranium fuel rods, the last graphite rod had blocked the flow of cooling gas in the channel, and the uranium rods had begun to overheat. The uranium melted the metal cladding around the rods. The rods then fused together, producing a meltdown (though only in that channel). Fortunately, the operators soon realized that something had gone amiss. By shutting down the reactor quickly, they managed to avoid an accident on the scale of the one that would occur at Chernobyl 17 years later.

Figure 8.5
Saint-Laurent 1's nearly completed core from above. The circles in the floor are the openings into the core's fuel rod channels. The core was made up of nearly 3000 vertical channels, each of which contained fifteen uranium rods. Each rod was encased in a metal shield and surrounded by a graphite shell. The fission reaction took place inside the core, producing a great deal of heat. Carbon dioxide gas flowed through the channels in the core and absorbed this heat. The hot gas then flowed into the heat exchangers, where it converted water into steam; the steam powered the turbines (not shown), producing electricity. The entire reactor was encased in a concrete pressure vessel. On top of that vessel sat the loading machine. Photograph: Jacques, 1967. Source: EDF Photothèque.

Nonetheless, the reactor suffered considerable damage. After the fuel rods fused together, metal shards were blown out of the channel by a sudden burst of pressurized cooling gas. In addition to the damage caused by a melted channel, more than 100 kilograms of contaminated debris littered the structure that supported the reactor core. Furthermore, the pipes that contained the cooling gas had been exposed to radiation. Before Saint-Laurent could go back on line, the contaminated debris had to be cleaned up and the damage repaired.[132]

Figure 8.6
The fuel loading machine at Saint-Laurent 1 in 1974. Reactor operators used this machine in order to remove spent fuel from the core and load new fuel into it. The machine was guided by remote control with the aid of a huge calculator. Operators fed the calculator perforated paper control tapes which contained coded instructions that told the machine which channel to load or unload, and how many fuel rods to load it with. The machine then executed these instructions automatically. Photograph by Michel Brigaud and Marc Morceau. Source: EDF Photothèque.

For Saint-Laurent employees, the accident in their plant enacted the crisis in the gas-graphite program. Repairing the reactor became their way of handling both disasters. Doing so required a complex conflation of technological and cultural work.

Site employees routinely used the word "pollution" to describe the radioactive contamination of their reactor. On the most obvious material level, this pollution threatened the proper functioning of the reactor.[133] The pollution also posed a threat to a fundamental basis upon which Saint-Laurent employees constructed their identities as nuclear

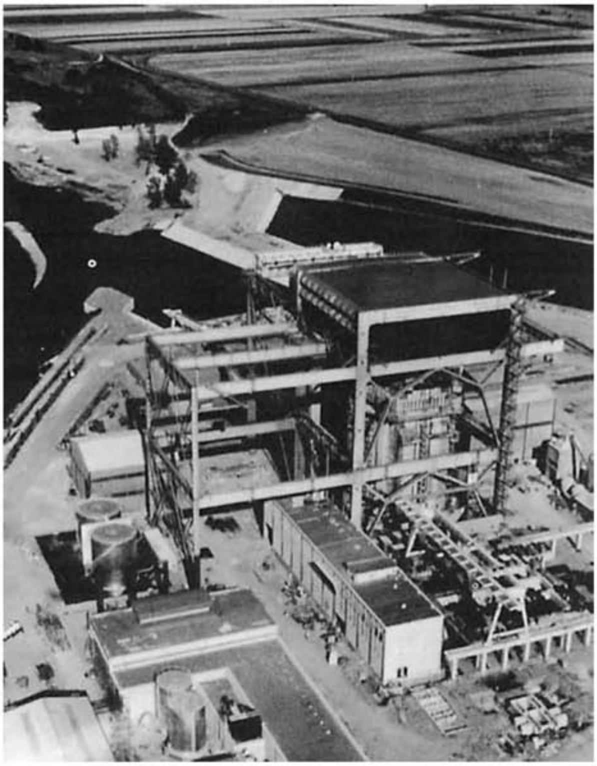


Figure 8.7
A 1966 aerial view of Saint-Laurent 1 under construction. Photograph by Michel Brigaud. Source: EDF Photothèque.

workers, engineers, and managers: it cast doubt on their ability to control the reactor. Meanwhile, the decision to terminate the gas-graphite system threatened their place in the great story of French technological glory. If the gas-graphite program was no longer at the forefront of the French nuclear program, then they were no longer at the forefront of high technology work and therefore no longer pioneers. Finally, the accident seemed to prove that EDF's top managers had been correct to judge the gas-graphite program unsuitable for further development, and thus it seemed to validate Boiteux's decision at the very moment he announced it. The best way for workers and engineers to meet these heterogeneous threats was not to go on strike but to clean up the reactor. The reactor was not only in technical danger; it was also defiled by the implication that it could not perform its electricity-production duties properly. A quick and effective cleanup would restore its functionality and its reputation. On another level, the cleanup would serve a psychological function, providing a means for employees to redeem their skills.

Thus the technological and cultural dimensions of the cleanup were inseparable. If the workers failed to repair the reactor, or did so poorly or with many casualties, then the cleanup would not help them confront threats to their cultural identities. The most challenging cleanup operation in the history of nuclear power would reaffirm their solidarity as nuclear employees, restore their identities as pioneers, and make sense of the decision to build no more gas-graphite reactors.

Even before the cleanup began, site employees attempted to prescribe its meanings. When reporting on Boiteux's speech, the engineer-editor of the site's newsletter did not refer directly to the termination of the gas-graphite system. Instead, he asserted:

> The incident of October 17. . . does not cast doubt on the [operational] principle of our reactors, but it does show that industrial certainty does not exist. There was much talk after the visit of our director-general and the breakdown of the reactor. Terms like design competitiveness, national independence, and foreign offensive were abundantly used. It is normal that each of us should express himself freely about in-house projects or plans, but this should be done without passion, for nothing is certain in technological or economic [matters]. At Saint-Laurent, the time has arrived for repairs, and we will be judged according to the role that we have to play there. The endeavor is sizable, but it will be useful to all regardless of which "nuclear system" is chosen.[134]

Clearly, the writer of this passage was trying to minimize the damage by suggesting that the accident did not threaten the working principles of their reactor and that employees should temper the rage they felt about the discontinuation of their design. Rage served no purpose, and now only their success in repairing the reactor mattered.

Venturing Inside the Reactor

Cleaning the debris under the core posed a particularly thorny problem for the engineers in charge of designing the cleanup operation. There was no passageway to the mezzanine, where much of the debris was located. At first the engineers thought about building a special remote-control device that they could lower down into the mezzanine through the damaged channel.[135] After considerable debate, however, they decided that such a device would cost too much and take too long to build. Instead, they decided to send people directly into the space under the reactor core to clear the debris and the contamination.[136]

The radiation level in the mezzanine was so high that engineers estimated that a single hour there would expose workers to between three and six times as much radiation as they were normally allowed in a year. Engineers decided that no single employee should spend more than 12 minutes in the contaminated zone. This limit, coupled with the extremely dangerous conditions of the work space, meant that every movement would have to be meticulously planned.

Three elements were essential in this planning: dress, motion, and space. Because of the high levels of radioactive contamination, dressing properly involved donning multiple layers of shining white garments, wearing radiation detectors on various parts of the body, and hooking up breathing and communication apparatus.[137] Even wearing all this equipment, however, men could not expect to stay in the work space longer than a few minutes. And much needed to be done while they were there. They had to remove the arm of a remote-control device that had fallen to the bottom of the channel during a previous rescue attempt, clear and scrub the flooring on which the reactor core rested, scrub the cells around the melted channel, and more.[138] Motions therefore had to be carefully choreographed and rehearsed on a replica.[139] Finally, the space in which the "intervention" would occur had to be prepared. A tunnel had to be built, and ventilation, lighting, signals, intercoms, and television cameras had to be installed. Such arrangements notwithstanding, the conditions in this space remained harsh: in addition to high radiation levels, the temperature hovered at around 35–40°C (95–104°F), and the air circulation was very poor.[140]

By April 1970, these preparations were complete and the time to begin the cleanup had arrived. Figure 8.9 shows the space at the entrance to the tunnel where workers prepared to enter the contaminated zone. From the lock chamber, a worker crawled up through the vertical tunnel, using pitons and other equipment. Once at his workplace, he spent roughly 10 minutes performing the motions he had rehearsed so carefully in the replica. These might involve removing a chunk of debris, scrubbing a surface, or any of a number of other small tasks. When his allotted time was up, he then towed whatever debris he had removed back down the tunnel with him, dropped it off in its designated spot, and removed several kilograms of clothes and equipment from his body. Once he left the tunnel, the next worker could enter to perform his tasks. In this fashion, workers succeeded one another in "interventions" which lasted two or three hours each. Each working day consisted of two such interventions. The entire operation took three weeks. Approximately 300 people participated in the operation in some capacity. About 100 actually entered the reactor.[141]

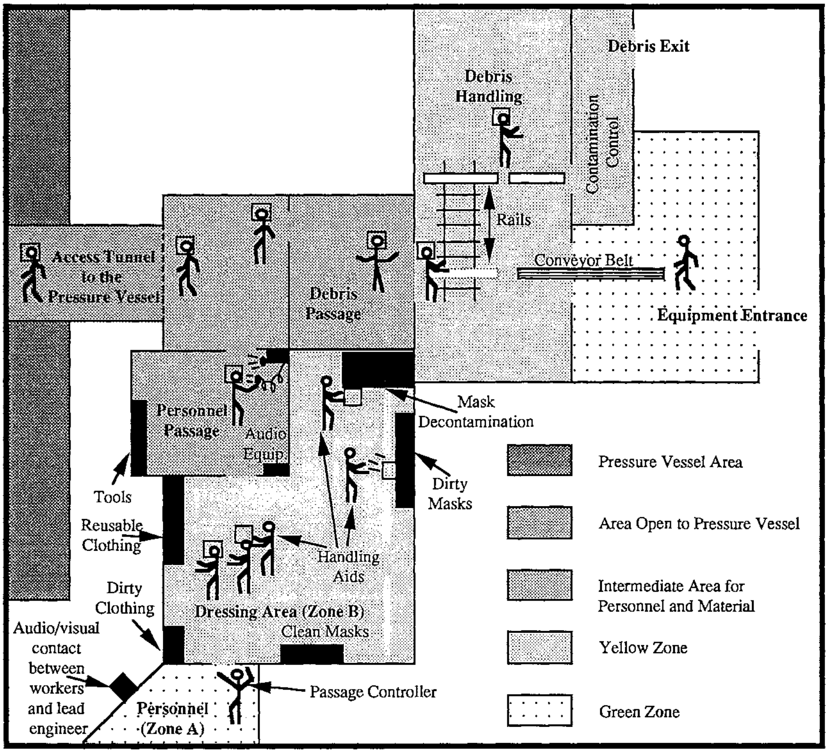


Figure 8.8

The entrance area to the tunnel. In zone A, someone monitored entrances into and exits from the reactor. Workers arrived in their standard work outfits: T-shirt, jacket, pants, socks, and tennis shoes, all made of white cotton. Here they donned additional clothing: two pairs of cotton overshoes, a pair of long-sleeved cotton gloves, a pair of long-sleeved vinyl gloves, and a pair of vinyl leg coverings that came up to the knees. They picked up two kinds of radiation detectors (dosimeters and film badges) and proceeded to zone B. There, each worker received a mask with a filter hooked up to an air supply and equipped with a microphone and a tiny speaker to allow him to communicate with the men watching him on TV monitors. He then put a white cowl over his mask and added a white overcoat with a hood that fitted over the cowl and mask. A team of dressers sealed the seams of his outfit with adhesive tape and stuck radiation detectors all over his body: two on his head, one on his chest, one on his wrist, one at his crotch, and an additional detector somewhere else on his body (which would sound an alarm if it registered a radiation dose over 2.5 rems). Thus equipped, the worker then entered a lock chamber where he got pressurized (the reactor vessel was not at atmospheric pressure). Off to the side of the lock chamber was another set of spaces through which the equipment that the worker needed entered the chamber (and through which the contaminated debris that he removed left the reactor). Sources: M. J. Grand, and M. J. Hurtiger, "Aspect de radioprotection pendant les interventions de Saint-Laurent-des-Eaux," *Bulletin de l'Association Technique pour la production et l'utilisation de l'Energie Nucléaire* 91 (1971): 38–53; Centrale de St. Laurent des Eaux (Electricité de France, GRPT C), "Etat d'avancement des études et travaux, planning au 1er juin '70," Dépannage du réacteur SL1, Rapport 13. Drawing by Carlos Martín.

The physical conditions and motions of the cleanup cannot be understood without also examining the language used to narrate and explain the process. Employees used these narratives to articulate the meanings of their motions and to assert their status in the French technological adventure. The most extensive and coherent of these narratives, titled "Great Spring Cleaning" and published in the site's newsletter, is well worth quoting in full:

> This is truly a rescue [mission], and doubtless this is why those involved in the cleaning of the support structure work with a zeal and courage worthy of admiration.
>
> On one side, there are those who "dress up to go"; on the other, those who stay to help and monitor.
>
> In the dressing room, the latter fuss over the former, turning a clasp that was pointing in the wrong direction, adjusting a wayward buckle on one of many tubes, checking everything scrupulously. It's a moving moment. Through the masks and the cowls, one can detect a certain apprehension, fleeting but nonetheless real and quite understandable.
>
> The operation itself begins. A lapse of time that seems very long goes by before a sound link, then a television link is established.
>
> This is where the essence of the operation lies:
>
> On the one hand, the main actor, looking like an astronaut, who has just played mountain climber to hoist himself onto the support structure and who now crawls as best he can, like a spelunker! On the other hand, those in charge of monitoring, who follow the operation extremely attentively, offering advice and recommendations.
>
> It is difficult to explain what stands out in this spectacle, because it is always difficult to translate how looks, gestures, and words contain sympathy and kindness.
>
> This teamwork, accomplished with so much enthusiasm and great team spirit, can only end in complete success, which everyone hopes will come soon.[142]

The astronaut metaphor evoked the ultimate male pioneer: the man who entered a space not made for men, who crossed a frontier previously thought unattainable, who shone as a symbol for the whole world of what other men could accomplish. Mountain climbers and spelunkers were also respectably male heroes. They too performed difficult physical feats under extreme conditions, and they did so with "courage." Equating the nuclear workers with symbols of heroic masculinity simultaneously reasserted and constructed the pioneering nature of their work.

The event itself was construed as a "spectacle," an enthralling performance that captivated performers and spectators alike. The "main actor" stood at the center of the show. His actions propelled the plot forward, and his predicament generated the emotional tension. The supporting characters fussed over him and sustained him in his trial. The emotion conveyed by the performance was subtle and elusive, contained in "gestures" and "looks," but the message of community and solidarity was clear enough. The participants were bound to one another by "sympathy," "kindness," and "team spirit." They formed a team, and belonging to a community involved in a common project filled them with "enthusiasm" and "zeal." The enormity of their task might cause "fleeting apprehension," but solidarity made them fearless. These images and meanings were repeated in many accounts of the cleanup, both before and after the mezzanine intervention.[143] The solidarity evoked by the process was such that not even the CFDT, the labor union most concerned with workplace health and safety, raised the slightest protest over the methods.[144]

Clearly, cleaning up Saint-Laurent 1 was not a purely technological event. It involved transforming physical motions into culturally and politically meaningful acts. The CEA strikes brought engineers and workers together to construct alternative technological scenarios and to contest the techno-economic practices of light-water's proponents. The Saint-Laurent cleanup brought (a different group of) engineers and workers together to construct alternative meanings for the termination of the gas-graphite program and for their role in the national order.

Twenty years later, the ways in which workers talked about the cleanup show how extraordinary the experience was for them and how deeply it etched some of these meanings in their minds. The associations between the accident and the abandonment of the gas-graphite program remained clear for all of them. As one worker put it succinctly, the accident came at a "politically unfortunate" time.[145] Another man mentioned a rumor, which had circulated right after the accident, that Boiteux's announcement had indirectly caused the accident by making workers too jittery to concentrate properly.[146] In retrospect, the men involved experienced the cleanup as the last hurrah of the gas-graphite program, the last time they felt special. It marked the moment when everything changed.

The Battle Fizzles Out

After the CEA strikes, the *guerre des filières* faded quickly from public view. In January 1970 Marcel Boiteux shared the latest PEON report with EDF's board of directors. This report essentially reiterated the points outlined in the "plan of action" sketched the previous year and specified that the

Fessenheim site would house light-water, not gas-graphite, plants. More as a matter of form than anything else, the union members of the board objected that the termination of the gas-graphite program had not been finalized. Their arguments were futile, however, and soon union members turned their energies to struggles they thought they could win. For the rest of 1970, debates continued to rage on the board over the contracting and organization of the Fessenheim projects. Confrontations over the design itself, however, had ceased.[147] The gas-graphite reactors in service or under construction would continue to function, but no more would be built.

*

I moved to France for the first time in 1975. One of my most vivid memories of the cultural landscape from that period was an advertising slogan that seemed to be everywhere—on suburban billboards, in newspapers and magazines, on the radio, and on television: "En France, on n'a pas de pétrole, mais on a des idées" ("In France, we may not have oil, but we have ideas"). My parents and I found this a wonderful phrase. Repeating it and adapting it to different circumstances became a favorite game. At the time, of course, I neither knew nor cared that the phrase was part of EDF's advertising campaign for its light-water reactor program. The other slogan for this campaign was "Tout éléctrique, tout nucléaire" ("All electric, all nuclear").

Just five years earlier, the *guerre des filières* had ended with a decision to build light-water reactors with an American license. Between 1970 and 1973, EDF broke ground for four Westinghouse-licensed reactors—a "modest" number, as prescribed by the 1970 PEON report. But any impulse to remain modest disappeared during the 1973 oil crisis. In March 1974, Prime Minister Pierre Messmer announced a new energy plan calling for the launch of thirteen 1000-MW light-water reactors within two years. By 1989, when I began my research, France was obtaining more than 70 percent of its electricity from pressurized-water reactors, and engineers were eager to tell me how the light-water system had become *francisé*—Frenchified.[148]

Terminating the gas-graphite program and buying a license from Westinghouse involved a profound rearrangement of industrial and institutional relationships. This had deep repercussions for reactor designers, builders, and workers, whose roles and skills had to change to accommodate the licensing agreements and the new technology. The licensing agreement specified work and safety guidelines that sometimes conflicted with existing practices. The new prescriptions for work practices affected not only those operating the new reactors but also those operating the older gas-graphite reactors.[149] And as the new reactors went up in the 1970s, the first wave of anti-nuclear protesters contested their construction.[150]

The triumph of the light-water design marked the ascendance of the men Robert Frost has called "economist-managers" and James Jasper has called "cost-benefiters": men who measured technological success by purely economic criteria. It also marked the successful reformulation of EDF's technopolitical regime into one that privileged selection criteria defined by economists and took "public service" to mean the support of *private* industry efforts to become profitable on international markets. Light-water reactors were the technopolitics through which these ideologies became policy. Building light-water reactors with an American license meant advocating a France that would evaluate itself in terms of comparative economics—a France measured on a scale whose increments were defined by international institutions and conglomerates.

As we have seen, choosing the light-water system over the gas-graphite system was itself far from a purely economic process. Neither was it purely technological or purely political. It was all these things. The process involved not only competing conceptions of France (independent vs. interdependent) but also complex, ongoing redefinitions of which technological trajectory best embodied those conceptions. The light-water system was either the instrument of American imperialism or the path to French radiance through industrial exports. The gas-graphite system was either the eternal guarantee of national independence or a route to technological and economic obsolescence. The uncertainties inherent in the still experimental breeder system filled it with technopolitical possibility: everybody could agree that it represented France's future, even if they could not agree on what that future should be or how to get there.

In outlining these technological trajectories, the participants in the battle pursued three related strategies. The first involved defining the proper context for technological development and the relationship between context and development. Thus, gas-graphite advocates—including Jules Horowitz, Claude Tourgeron, and CEA labor militants—insisted that the relevant context was the nation. The same technological choice would play out differently in the United States than in France. In the United States, light-water development worked because of contextual conditions that did not apply in France. In the United States, inexpensive enriched uranium, large conglomerates, pollution regulations, pricing structures, and the vastness of the nation made for economies of scale in reactor manufacturing. Meanwhile, France had a need for national independence that—pending the development of breeder reactors—only the gas-graphite system could meet. Advocates of the light-water system ignored these definitions of context and created their own: the international market, a context populated by large conglomerates. To succeed in this domain, France had to develop its own conglomerates, and that would happen only with the jump start provided by the purchase of an American license. French companies could thereby form consortia that would benefit from the experience acquired by American companies without having to incur massive technological and financial risks.

The second strategy involved interpreting the significance of uncertainties in the data used to compare the two technological trajectories. These uncertainties included the lack of significant operational data for light-water reactors, the future performance of the CEA's new fuel rods, fluctuations in the source and price of reactor fuel, the reliability and longevity of reactors (which affected their amortization rates), and potential cost overruns. Advocates of each system claimed that the ambiguity generated by these uncertainties favored their system.

This ambiguity, in turn, prompted the third strategy pursued by both factions: the definition of the appropriate selection criteria. Which combination of possible criteria—technological, economic, or political—should guide the final choice? And how should each type of criteria be weighted?

As we have seen throughout this book, developing and operating the gas-graphite system involved continually associating technology and politics. At the most basic symbolic level, this meant that gas-graphite reactors had come to incarnate the French nation: it was thanks to them that France could fuel its nuclear *force de frappe,* and thanks to them that the country could aspire to energy independence. The gas-graphite system thus enabled a radiant and technological France, the only truly French France. Charles de Gaulle, the nation's biggest hero, stood by these associations.

Clearly, attacking a system that continued to incarnate the French nation would lead nowhere. The only way in which light-water advocates could imagine breaking this powerful association was by rhetorically separating technology from politics. Such a separation undermined the links between gas-graphite technology and the nation. Equally important, excluding politics from technological choice privileged economic selection criteria. Admittedly, the data that constituted these criteria were uncertain. But light-water advocates subjected this uncertainty to quantitative analysis in order to claim control over it. Gas-graphite advocates subjected the uncertainty to qualitative—specifically, political—analysis in order to do the same. As long as de Gaulle remained president, this qualitative reasoning held. Once he stepped down, quantitative reasoning took over. The triumph of light-water meant that it came to be defined as the "economic" system, while gas-graphite became the "political" system.

The effort to separate technology and politics continued in the decade that followed the *guerre des filières*. Consider these retrospective accounts: "The termination of the gas-graphite system was not a political decision but a technological decision; it was a mistake to call it a political decision; a political decision would have consisted of maintaining gas-graphite. The end of gas-graphite was justified by two reasons: its operation was unsatisfactory, and export was very difficult."[151] Separating technology and politics required program leaders to disentangle the gas-graphite system from French identity, an effort which they kept up well after the war's end: "We finally decided in favor of the American system after having lost four years. . . . The explanation [for this waste of time] is purely political. The so-called national system was opposed to the so-called American system. . . . What does that mean? Was it forgotten that in conventional oil-fired plants there are also American licenses?"[152] Questioning the nationality of these systems undermined the legitimacy of the gas-graphite system as a symbol of French glory. Witness the response of a former CEA official to Philippe Simmonot's question about the "French system":

> Oh! It's not as French as all that.
>
> Technologists had convinced politicians of the value of this system, which was in part copied from the English. And these politicians had become even more avid. . . .
>
> The French system has two serious defects. First, it uses metal uranium, which is an unstable material and less safe than enriched uranium, for example in the case of fire. Look at what happened at Windscale (Great Britain). Then, the use of gas poses difficult problems; you have to install a continuous loading system, while with [light-] water reactors you can open the pressure vessel just once a year.[153]

Rather than portray British gas-graphite reactors as *similar* to French ones, this speaker alleged that the French had *copied* elements of the British system—a far less glamorous picture, and one that subverted the technical value (and therefore the symbolic value) of the gas-graphite system. The reference to Windscale made it appear as though the accident had provided a reason to stop gas-graphite's development; it elided the fact that the accident occurred before EDF1 was even completed, and was well known to gas-graphite engineers at the time. The former CEA official also made continuous loading appear to be a requirement rather than an option. The two seemingly pure technical reasons for the failure of the gas-graphite system blurred history. Thus the move to separate technology and politics was closely tied with efforts to disentangle the gas-graphite system from French identity and to create a technologically determinist explanation and outlook.

The move to separate technology and politics succeeded only at one rhetorical level. The very effort to disentangle the gas-graphite system from French identity meant that the discourse of nationalism continued to matter in the nuclear program. During the *guerre des filières*, French identity was not removed from reactors altogether; instead, it was transferred onto breeder reactors. Eventually the discourse of nationalism crept back into the light-water program as builders and developers began discussing the *francisation* of the system. The emphasis had merely shifted from making a French technology to making a technology French.

Meanwhile, the effort to separate technology from politics was by no means uncontested. Unionized CEA employees, Saint-Laurent workers and engineers, EDF labor leaders, and design engineers in both regimes all challenged the exclusion of politics from technological choice. The effort to separate technology and politics was a strategy to gain dominance over programmatic choices. Resisting that dominance involved resisting the separation. It meant, indeed, rehearsing the conflation of technology and politics—through strikes, comparative analyses of the two systems, and the repair of a damaged reactor. The victors tried to invent a technological determinism by defining a context in which there *was* such a thing as a single best technology and by defining new standards for "best." The losers resisted that determinism by asserting the technopolitical nature of their system and by continuing to treat their technologies as hybrid entities through which men wrestled for control over their lives and their nation.

Conclusion

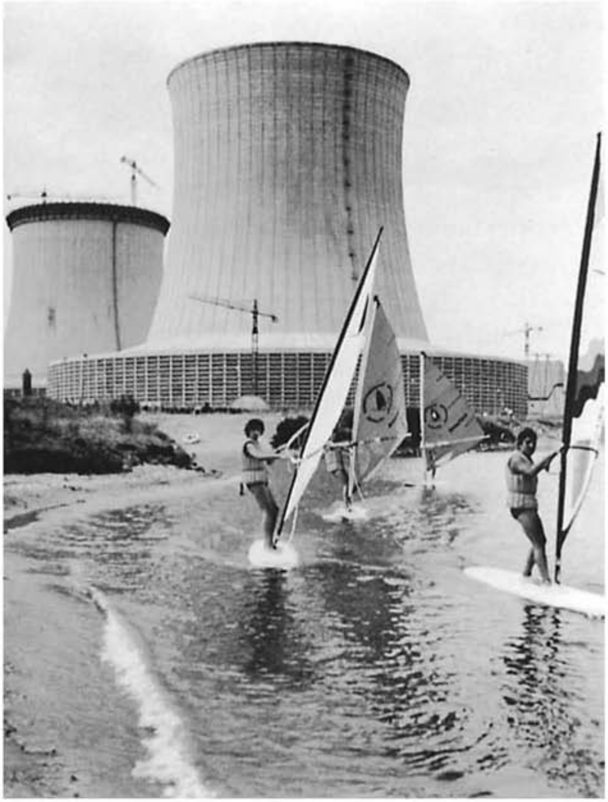
In 1996 I was invited to speak at a three-day conference celebrating the fiftieth anniversary of Electricité de France. The talks took place in the Louis Armand Hall[1] of the Museum of Science and Industry in La Villette. The venue would have appealed to Armand's esthetic sense. Elegant canoe-shaped fluorescent lamps, each lined with emerald green along one edge, graced the walls. The stylish charcoal gray chairs had their own audio hookups, which piped simultaneous translations to the audience. The museum, with its geodesic dome and its light, airy architecture, was exactly the sort of thing the members of the Groupe 1985 had in mind when they said that modern French technology could "engender its own beauty." La Villette's 1996 advertising campaign suggested that the links between technological prowess and national radiance—between technologies of the present and monuments of the past—are maintained as actively now as they had been three decades earlier. All over the subterranean passages of the Paris subways, tourists and commuters saw posters that juxtaposed images of the museum's dome with images of Notre Dame and the Arc de Triomphe.

Technologists of the 1990s continue to link technology and French radiance. In the closing speeches at the commemorative conference, Edmond Alphandéry, EDF's new president, affirmed that the utility's success was "recognized by the French as well as by the rest of the world." Technological prowess, nationalization, the state, and French grandeur: these were all part and parcel of the same thing, embodied in the "world's leading firm in the electricity sector," in "one of France's largest exporters." Minister of Industry Franck Borotra amplified these themes. "France," he declared, "has become the leader of sustainable development. Today, EDF is the symbol of the reconciliation of ecology and growth." Recalling the language Charles de Gaulle had used to talk about the Plan, Borotra maintained that EDF, in its unflagging mission

The Saint-Laurent site in 1974. In this EDF photograph, the two Saint-Laurent gas-graphite reactors appear in the background; in the foreground, we see a man in an old boat, fishing in the Loire in the "traditional" way. This photo was also probably meant to reassure people that fish taken from the Loire were as safe to eat as they had always been. Source: EDF Photothèque.

of public service, had an "ardent obligation" to the nation. He praised France's handling of nuclear waste and reactor decommissioning and averred its commitment to nuclear power. Responding to widespread concern that President Jacques Chirac's enthusiasm for the European Union would lead to the privatization of EDF, he invoked the utility's history: "EDF identified almost perfectly with the spirit of the Liberation and the Reconstruction. . . . Fifty years after its birth, EDF is more than ever the instrument of the nation." Then and now, the utility would "remain public"; "the government's resolve [would] not waver on this matter."[2]

The historians sitting with me groaned, squirmed, and shook their heads throughout these proclamations. They seemed embarrassed by such unabashed displays of national pride. They also appeared puzzled by my behavior. Why was I frantically taking notes and grinning so happily? Indeed, these speeches delighted me. The issues surrounding the



Windsurfers in front of the new cooling towers at the Saint-Laurent site in 1979. Source: EDF Photothèque.

nuclear program had evolved over the intervening decades, but the basic images and interpretive framework remained the same. The heir to the technopolitics whose development I had traced during eight years of research was being staged right before my eyes!

Further evidence of the persistence—and transformation—of this technopolitics could be found upstairs, in the museum itself. The Commissariat à l'Energie Atomique had celebrated its fiftieth anniversary the previous year, and its commemorative exhibit was still on display, arranged along a curved walkway at one end of the museum. At the bottom of the curve, visitors could learn about the CEA's early history. De Gaulle, Joliot-Curie, and Dautry were all there, along with the standard foundational narrative, recounted in the present tense:

> The CEA is born of a political demand: the independence of France in the domain of energy supply. . . . Despite the difficult context—the country must be reconstructed—the CEA receives considerable funds right from the beginning, as well as considerable autonomy of action. Means and skills unite around several great names of nuclear research, leading to a research institution capable of making up for the lag experienced during the war in just a few years.

The G2 reactor also took its place in this official history, accompanied by a now familiar description: "Located at Marcoule in a building large enough to hold three Arcs de Triomphe, G2 goes critical in June 1958. The first reactor hooked up to EDF's network, G2 marks the encounter between nuclear research and industry." Was it simply reflex that made the commentator gloss over G2's plutonium production nearly forty years after France officially embarked on a nuclear weapons program? It certainly could not have been secrecy, since at least a quarter of the exhibit displayed French military nuclear achievements.

In any case, the gas-graphite program received little attention. A single panel told the story of its demise: When EDF and the state embarked on a full-scale nuclear power program, they decided that the French system was not competitive, and it was abandoned. In the 1970s, Framatome, a corporate affiliate of the CEA, began building Westinghouse-licensed reactors. The license contract expired in 1984, "after the builder completely Frenchified the new plants." The rest of the exhibit covered the CEA's recent research and offered ample assurances about the safety of nuclear plants and the benign nature of radioactivity.

EDF also sponsored an anniversary exhibit at La Villette, entitled "An Electric Life." In contrast to the conference, this display elided the institution's history altogether. A few turn-of-the-century electrical appliances occupied one corner of the hall. Otherwise, the exhibit focused on contemporary electricity. Modern appliances were suspended in midair. Captions made statements like "electricity: it brings daily comfort; it changes lives." A map displayed France's entire distribution network, giving visitors a chance to apprehend their nation through electricity. A young man standing in front of a scale model of a light-water plant asked visitors whether they would like him to explain how it worked. Another model represented EDF's latest nuclear plant, N4; its caption made the gas-graphite system disappear altogether, alleging that N4 went beyond the Frenchification of a Westinghouse license, representing "the *first* stage of entirely French design."

The nation's nuclear industry has undergone dramatic transformations since the period covered in this book. Proportionally, France is now the world's largest producer of nuclear energy. It derives 75–80 percent of its electricity from nuclear power, and even exports electricity to neighboring European countries. A reprocessing facility in La Hague treats nuclear waste from France, Japan, Switzerland, Germany, Belgium, and the Netherlands. There can be no question that France has attained the goal articulated by the technologists of the 1950s and the 1960s: it has become the world leader in nuclear power. True, the rest of the world no longer views nuclear power in quite the same light—but one could easily forget this while sitting in a high-speed train powered by nuclear-generated electricity, zooming past the nuclear plants that dot the banks of the Loire and the Rhône.

Ironically, France's nuclear triumph came at the expense of the "French system." Yet, in a sense, this too has been forgotten. Only a few years after establishing the licensing agreement with Westinghouse, French engineers proceeded to "Frenchify" the light-water design. The lure of American technology did not last long; ultimately the French technologists only redoubled their efforts to make their large-scale systems French. This "Frenchification" has entailed the rhetorical erasure of the original French system—so much so that in 1996 an employee of EDF's own archives insisted to me that there had been no nuclear program before 1970!

It may be in part because of this erasure that the engineers and workers who built the gas-graphite program look back on it with such fondness. Nostalgia has preserved, probably even amplified, their memories of the "pioneering spirit" that pervaded much of the program forty years ago. They were on a national mission, the success of which ended up entailing the failure of their program. Perhaps this is why their recollections sometimes conveyed the sense that they had made sacrifices for their country.

In one sense, though, they did not fail. Technological prowess has staked a firm claim as a basic element of French national identity. At least rhetorically, the builders of the high-speed train (the TGV), the Minitel communication system, the Concorde airliner, the Ariane rocket, and numerous other technological systems continue to cultivate the association between technology and French radiance—even when these systems are developed in cooperation with other European nations. Only more research can determine whether and how the design and operation of the systems themselves articulated such associations in a manner analogous to the nuclear program of the 1950s and the 1960s.

Imagining a Technological Nation

Clearly, however, the nuclear program was a site for articulating and negotiating the meaning of a technological France. The image of a radiant and glorious France appeared repeatedly in the discourse of engineers, administrators, labor militants, journalists, and local elected officials. These men actively cultivated the notion that national radiance would emanate from technological prowess.

Linking technological prowess and national identity was a complex, multidirectional process. Technologists, labor militants, and elected officials invoked apparently eternal characteristics of the nation, which at the most general level were qualities they could all agree made France French: radiance, glory, and grandeur. They simultaneously suggested that France had lost these things through wartime defeat, and/or postwar decolonization, and/or general economic and industrial backwardness. This, in turn, implied that France was no longer fully, truly French. In the scenarios these men envisaged, technological development would restore Frenchness to the nation in a way that made them—as men of action, as heroic male workers and militants, as representatives of their regions—central players. At the same time, they repeatedly invoked the nation in efforts to arbitrate disputes and to legitimate their scenarios. Thus the nation (and/or the national interest) justified particular forms of technological development, while technological prowess defined the nation. This circularity bound conceptions of the nation and of technology more tightly together. Furthermore, the fact that these links were so widely articulated gave them strength and flexibility.

Indeed, the general principle of a technological France drew strength from its multiple manifestations. In some respects, these manifestations supported one another. In both the Gard and the Touraine, for example, local elites and technologists *together* represented nuclear development as a glorious spectacle. Each group had different ideas about the meanings of technological France. Local elites focused on how nuclear sites would bind their region to the nation both economically and culturally, whereas nuclear technologists focused on how reactor development would enact French independence and place them in a position of political and/or industrial leadership. Although different, these visions were compatible; they did not undermine or even compete with each other. In the spectacle these men co-produced, regional history, national destiny, and technological development all worked together on several levels. Other images of technological France interacted or intersected in parallel ways—for example, those of CGT and CFTC/CFDT labor militants and EDF engineers (especially up until the mid 1960s), or those of CEA and EDF engineers during the *guerre des filières.*

At the same time, though, the very multiplicity of "technological France" made that notion into contested terrain. Ideas about the nation could divide as well as unite. So, for example, while technologists at the CEA and EDF both cultivated ideologies of public service to a technological nation, from the mid 1950s to the mid 1960s they articulated different ideas about what that nation should be, and how best to serve it. They did work together to establish the nuclear program as an arena for defining France's future and identity. But they had competing definitions of the public interest and of the nation's future, which they translated into two distinct technopolitical regimes. The CEA's *nationalist* regime found form in its Marcoule reactors and its "policy of champions." EDF's *nationalized* regime found form in its Chinon and Saint-Laurent reactors and in its early efforts to control the development of private industry through its contracting practices. Each technopolitical regime developed distinct ideas about nuclear and industrial policy, which were simultaneously distinct prescriptions for the nation's future.

Technologists thus sought to define the nation through the example and action of their regime. At the same time, they invoked the nation in discussing, formulating, and implementing their technopolitical projects. So, for example, the national interest justified manufacturing weapons-grade plutonium before the government had decided to build a bomb. After that decision, the national interest warranted extracting plutonium from EDF reactors. National pride justified using prestressed concrete for reactor pressure vessels, as well as designing EDF3 to run at 500 megawatts. French radiance—especially the notion that France had to export technology in order to maintain its status as a world power—played a major role in conflicts over industrial contracting and the overall structure of private industry.

Labor militancy and reactor work also engendered both conflict and accommodation over conceptions of the technological nation. Conflict appeared in the realm of labor union politics. Militants in the three major unions produced distinct visions of a technological France. The CGT dreamed of the glorious technological France that would follow a socialist revolution. Force Ouvrière situated France's technological future in a non-communist international community. The CFTC/CFDT saw technological change as a potential conduit to a better and more just society. None of these visions stood alone; all were produced in counterpoint with the others and in the context of union rivalries. In this sense, technological France was one of several contested terrains in union politics. Viewed alongside the future France imagined by leading state technologists, however, the three unions' scenarios had at least one point in common: each imagined a sociopolitical order that gave workers a more central and better-recognized role in shaping the nation's future. Yet, from the perspective of the Catholics or the Poujadistes, labor militants of all stripes also shared something with the state technologists: despite the differences they imagined in the sociopolitical order, they all contemplated a technological future for France. And indeed, the fact that all three labor unions sought to enroll the technical elite in their programs indicates that militants did think that their vision of technological France was potentially compatible with that of the technical elite—perhaps not the very top layer (at the level of Pierre Massé or Louis Armand or Marcel Boiteux), but conceivably up to the middle level (such as rank-and-file engineers and scientists at the CEA, like those who went on strike during the *guerre des filières*).

The dialectic of conflict and accommodation found yet another set of manifestations at the nuclear sites of EDF and the CEA. In neither case were the labor unions at odds in a significant way. Instead, the dialectic must be considered not so much across technopolitical regimes as within them. Hence the technological France prescribed by the CEA's regime was a source of conflict for Marcoule workers, who could not find a place for themselves in that vision. The nationalist military hierarchy at Marcoule privileged experts and ignored workers. In contrast, the technological France prescribed by EDF's nationalized regime formally made room for workers, according them a significant ideological and technical role in nuclear development. In the 1960s, most of the utility workers at Chinon accommodated fairly well to this vision of the technological nation. While CEA workers cast themselves in an adversarial role with respect to their regime's prescriptions, EDF workers cast themselves as pioneers on a par with their hierarchical superiors.

In 1969 these roles were replayed under somewhat different circumstances as the dialectic between conflict and accommodation acquired yet another configuration. Toward the end of the *guerre des filières*, unionized Marcoule workers joined engineers, scientists, and technicians throughout the CEA in protesting the termination of the gas-graphite system. Inasmuch as they directed this protest against the regime's top administrators (as well as against EDF and the government), Marcoule workers reenacted their familiar adversarial role. Yet joining with others at the

CEA symbolized an accommodation of sorts: though Marcoule workers felt little loyalty to the technopolitical regime instantiated in the gas-graphite system, they were nonetheless willing to defend that system because this also meant defending their jobs. Meanwhile, EDF workers at Saint-Laurent, who had also cast themselves as pioneers, came to interpret the cleanup of the accident there as a reenactment and an affirmation of those pioneering roles.

The year 1969 also provided an occasion for Gardois leaders and Marcoulins to reconcile and to once again declare a common set of interests. The Gardois had been promised a spectacular technological France, a drama of regional salvation through modernization. Their experiences, however, did not reflect this dramatic new nation. Instead, technological France seemed invasive and suffocating. Even the local leaders who had helped to produce the initial spectacle expressed dismay. But when the termination of the gas-graphite program threatened to remove the Marcoulins from the region, Gardois leaders realized that, for better or worse, their region's infrastructure had become dependent on the CEA. At the same time, they recognized that some cultural cross-fertilization had occurred. Though their place in it remained uncertain and conflicted, the technological nation had definitively arrived in the Gard. The events of 1969 made little difference to the Tourangeaux, whose experience, on the whole, tended to match their expectations. And though they did not yet know it, their region stood on the verge of even greater nuclear development.

Meanwhile, 1969 and the *guerre des filières* reconfigured disputes among nuclear technologists over the meaning of the technological nation. The *guerre des filières* showed just how slippery and malleable the concept of the national interest could be. Technopolitical regimes and visions of technological France were rearranged during that conflict. Top administrators at EDF and the CEA began to define the national interest in terms of economics, corporate development, and international markets. Engineers, technicians, and workers at both institutions continued to frame the national interest in terms of technical distinctiveness and energy independence. Once again, "the nation" legitimated competing technological trajectories, just as those trajectories articulated conceptions of the nation.

In 1969, rearranging the meanings of technological France also meant reconfiguring claims about the relationship between technology and politics. During the nearly two decades of gas-graphite development, enacting scenarios for a technological France had meant the deliberate, conscious interweaving of technology and politics. In the process, the gas-graphite system had become an incarnation of the French nation. The only way to unseat the system was to attack the conflation of technology and politics—at least on a rhetorical level.

Technology and Politics

The relationship between technology and politics has interested scholars for a long time. In the past decade or so, most research has proceeded on two related fronts: (1) examining how politics shape technological design and development in particular historical or sociological contexts and (2) identifying the ontological relationship between technology and politics in those contexts. In this book I have explored these avenues, but I have also pursued two other questions: How do technological artifacts and practices, both in the process of being designed and after the completion of their design, function as forms of politics—as political negotiation, action, iconography, and rhetoric? And how do the actors we study 1conceptualize the relationship between technology and politics?

I have argued that technologists—defined broadly to include engineers as well as top administrators of industrial state enterprises, regardless of technical training—created distinct technopolitical regimes in the pursuit of nuclear development. These regimes consisted of linked sets of people, engineering and industrial practices, technological artifacts, political programs, and institutional ideologies, which acted together to govern technological development and pursue technopolitics. Time and again, a key component of technopolitics was the manipulation of flexibility and uncertainty. Flexibility in the basic principle of gas-graphite reactors meant that they could produce both plutonium and electricity. How well they did one or the other depended on the specific design. But the fact that they could do both made possible the production of weapons-grade plutonium in Marcoule's reactors before the government officially decided to build an atomic bomb. This flexibility also made it possible for the CEA to demand plutonium from EDF's reactors: thus technologies could not only enact political agendas but also make possible new political goals.

The manipulation of uncertainty also played a key role in technopolitics, in instances such as the definition of the competitive nuclear kilowatt-hour. Perhaps the most striking use of uncertainty, though, occurred in the *guerre des filières*. There, uncertainties included the lack of significant operational data for light-water reactors, the future performance of the CEA's new fuel rods, fluctuations in the source and the price of reactor fuel, the reliability and longevity of reactors, and potential cost overruns. Advocates of the light-water system claimed that some of these uncertainties—the most relevant ones, in their opinion—could be quantified. Quantification would remove all ambiguity and would make possible a clear choice (in favor of the light-water system). Gas-graphite advocates did not think that the ambiguity generated by these uncertainties could be so easily erased. They argued that this ambiguity militated in favor of qualitative judgments.

In developing the gas-graphite system, technologists in both regimes deliberately conflated technology and politics. This conflation was itself a strategy, and it operated outside the nuclear program as well as within it. Recall the elaboration of the multi-year nation plans or the discourse of labor militants—both instances in which the conceptual conflation of technology and politics defined a way for planners or unions to shape the nation's future. Within the nuclear program, technologists who effected this conflation gave themselves permission to shape policy not just in the nuclear arena but also in the broader arenas of military and industrial development. This is not to say that technologists were the only policy makers in these arenas—clearly there were others—but rather that conflating technology and politics served technologists as a strategy for acquiring legitimacy as policy makers. In addition, politics and policy making gave the reactor projects significance, both within each regime and in the interactions each regime had with its surroundings. For example, EDF1 was important not because it itself would produce economically viable electricity but rather because it constituted the first step in a nationalized nuclear program that would enact and strengthen the utility's ideology and industrial contracting practices. In this instance as in many others, EDF1's technical characteristics were inseparable from its political dimensions. Had EDF1 failed to function properly, or had engineers and workers been unable to garner adequate operational experience from the reactor, the plant would have failed both technically and politically.

Conflating technology and politics created a major resource for engineers. In the debates over industrial organization, for example, EDF engineers reshaped the political meanings of their contracting policy in order to make it fit the priorities of the Fifth Republic. Under de Gaulle's regime, the conflation of technology and politics ultimately provided the gas-graphite system with its most powerful defense. As long as the identification of the gas-graphite system with national independence and identity held, the French system remained unassailable. In sum, conflating technology and politics delineated an arena of action for gas-graphite technologists and created a defense for the system they produced.

In arguing for quantitative selection criteria, light-water advocates simultaneously sought a rhetorical separation of technology and politics. This separation was every bit as much a strategy as the conflation effected by gas-graphite's developers and advocates. This separation entailed aligning quantitative measurement with technology and economics, and qualitative judgment with politics. It also entailed some redefinitions: the redefinition of "politics" as irrational and backward-looking (which was the sense of "politics" that technologists had used to situate themselves as better qualified to make decisions than politicians) and the redefinition of "public service" as the support of the national economy through the support of private industry. Separating technology and politics made it possible to attack the identification of the gas-graphite system with the nation, and thus made it possible to attack the gas-graphite system. This meant inventing a technological determinism by defining a context in which there *was* such a thing as a single best technology and defining new standards for "best."

In sum, light-water's proponents used the separation of technology and politics in exactly the same way that gas-graphite's developers used their conflation: to delineate an arena of action and defend the system they advocated. In separating technology and politics, light-water advocates adopted what Ken Alder has called a "technocratic pose": a stance that rhetorically places technological activity above and beyond the sphere of politics and the reach of politicians.[3]

This "technocratic pose" is far more common in technological development than the deliberate and proud conflation of technology and politics espoused by gas-graphite advocates. It is particularly common in the United States. For example, Paul Edwards and Donald MacKenzie have observed that Cold Warriors in the United States spent a great deal of energy constructing discursive separations between science and technology (on one side) and politics (on the other). The successful prosecution of the Cold War and the concomitant pursuit of big science and complex technology depended on making this separation appear natural. Cold Warriors located momentum for change within science and technology. Conceptualizing science and technology as apolitical was crucial in justifying the vast resources poured into military and industrial development, as well as in legitimating specific technological choices.[4] Science and technology did take on political meanings, as scholars who have studied the politics of display in Cold War America have shown.[5] But if atomic weapons, nerve gas, the moon landing, or any number of other achievements functioned as credible evidence of American superiority, it was precisely because technology was thought to provide an objective, natural, and *inherently apolitical* measure of strength.

Nonetheless, this separation of technology and politics was itself a political strategy. It worked only at the rhetorical level. As Edwards and MacKenzie have argued, computer and missile-guidance systems were not only shaped by political goals but also used as political tools. They were, in effect, forms of technopolitics. Unlike the developers of gas-graphite, however, American engineers would not— perhaps could not—admit that they engaged in political activity through their technological work.

What made the effacement of politics in American technological development an effective strategy? Part of the reason may lie in the McCarthyite construction of "politics"—in the sense of ideologies that competed with democracy— as un-American. In the black-and-white world of the Cold War, "politics" meant what the communists did. A striking instance appears in post-1947 American commentaries on industrial nationalizations in France. Popular publications such *Business Week* as well as trade journals such as *Electrical World* portrayed nationalized French companies (particularly EDF) as dangerous communist strongholds in which politics tainted the pursuit of technological development.[6]

I made this observation in my talk at EDF's fiftieth-anniversary conference, stressing that French technologists, by and large, did not seem to want or need to separate technology and politics. I meant this point to be provocative—after all, the triumph of light-water at EDF had resulted precisely from a separation of technology and politics. But my attempt at controversy failed. Numerous EDF engineers and administrators (the primary audience for this conference) told me afterward that I had been "absolutely right" in my assessment. Indeed, as efforts to "Frenchify" the light-water design in the 1970s also indicate, the rhetorical separation of technology and politics in the French nuclear program does not appear to have lasted very long.

Of course, this is not to say that everyone in France advocated the conflation of technology and politics. As we saw in chapter 1, in the 1950s and the 1960s many French intellectuals argued strongly for a separation of the two and viewed their conflation as a threat to democracy. This struggle between social scientists and engineers over the proper relationship between technology and politics has a contemporary equivalent, crystallized in attitudes toward the work of Bruno Latour and his colleagues at the Centre de Sociologie de l'Innovation in Paris. Latour has argued that the work involved in keeping nature and culture (and technology and society) separate requires enormous intellectual and social energy, without correspondingly significant returns. It would be better, he believes, to think in hybrid categories.[7] Perhaps in part because it threatens the edifice of their theories, many (though by no means all) French social scientists dismiss this suggestion. Technologists, however, seem to find it eminently congenial. The Centre de Sociologie de l'Innovation (itself housed in the Ecole des Mines) regularly receives contracts from institutions such as the CEA, EDF, and the RATP (Paris's public transportation company) to study their scientific and technological histories, methods, and prospects.

Of course, the Cold War critics of technocracy were not entirely wrong. Certainly, the elaboration of French nuclear military policy was anything but democratic. Yet surely the road to technologies that better serve society lies along a different path from those that require a rigid and radical split between technology and politics. If for no other reason, such a separation proves impossible in practice, however attractive it may seem in rhetoric or theory. As historians and sociologists have demonstrated time and again, technologies are produced by institutions and people with stakes and interests—political, social, historical, and cultural. This is neither inherently good nor inherently bad; it simply is. Arguing that technology and politics are or should be separate serves only to obscure these interests and the struggles among stakeholders, which are part and parcel of the processes of technological development. It does not serve to produce better or more democratic technologies.

Although the stakeholders in the gas-graphite program rarely if ever resorted to an American-style separation of technology and politics, I am not suggesting that French nuclear development represents some kind of ideal. Clearly, recognizing the links between technology and politics does not *suffice*. But such recognition is a necessary first step to a deeper, broader, and more useful consideration of the social and political dimensions of technological change. There is nothing wrong or shameful about technopolitics. Technopolitics does not necessarily produce bad or inferior technology. But engineers must work within a framework that openly acknowledges the fact of technopolitics. This need not lessen their technical expertise in any way. They will remain, after all, better qualified than anyone else to build technological systems that work, and to judge which solutions can work and which cannot. Obviously, not all engineering choices are meaningfully political; nor are all technologies equally political. But many fundamental technical choices—such as choices about system design and programmatic development—have significant and inseparable political dimensions. Recognizing this is important not just for social scientists and humanists but also for engineers.

Acknowledging the political dimensions of technological change does not imply that anyone and everyone should be able to influence decisions about technological development; this would be neither feasible nor appropriate. It can, however, breathe fresh air into decision making. Acknowledging and (especially) respecting political arguments in the process of technological decision making would, at the bare minimum, create a more honest process. Developing such respect for the full range of stakeholders in technical decisions is incumbent not simply upon engineers but upon all of us, as human beings who live in a technological world.

Afterword

During the sole televised debate of the 2007 French elections, presidential candidate Nicolas Sarkozy asked his Socialist rival, Ségolène Royal, whether she would continue to support nuclear power if elected. She replied with her own question: did he know what proportion of French electricity came from nuclear power? Yes, he answered: around 50 percent. No, she retorted, it was 17 percent. Wrong, he shot back. Right, she insisted. He changed tack: would she confirm the recent decision to build an EPR (European Pressurized Reactor)? No, she said, she would suspend the EPR as soon as she took office. You would suspend new nuclear plants and prolong the life of old ones?, he asked derisively. The EPR isn't a plant, she answered; it's a prototype. Did he even know what generation of nuclear technology it represented? It's a fourth generation reactor, he replied, and it's not a prototype. Wrong again, she snapped, it's a third generation reactor, and it *is* a prototype. Fourth. No, third. You don't know your facts. No, you don't know yours.

The press immediately pointed out that both candidates had their facts wrong. Nuclear power accounts for 75 to 80 percent of French electricity production. Royal's figure of 17 percent corresponded to the share of nuclear power in France's total energy consumption, which includes petrol for transportation. Sarkozy's figure of 50 percent was nothing more than an off-the-cuff approximation. The EPR is indeed a "third generation" reactor, as Royal insisted, but it isn't a prototype. Sarkozy correctly asserted that the first EPR, then under construction in Finland, would be a fully functioning power plant.

These gaffes raised eyebrows because it is scarcely possible to imagine what France might look like today without a nuclear industry. North to south, east to west, nuclear places permeate the French landscape. From reactors lining the Loire, Garonne, and Rhône rivers to uranium mines under the Limousin soil; from the enrichment plant in the Rhône-Alpes to research centers in the Paris suburbs; from reprocessing plants in Normandy and the Languedoc to waste disposal sites in the Manche and the Aube: these sites have transformed France's territory, its rivers, its soil, even its bedrock. Geopolitically too, France has defined itself in nuclear terms: think of its withdrawal from NATO, its prolonged refusal to sign the Nuclear Nonproliferation Treaty, its uranium mines in Africa, or its defiant atomic tests in the Pacific Ocean. Was it precisely because "France" seems so glaringly, self-evidently "nuclear"[1] that neither candidate bothered to bone up on details before the debate? Ultimately, their mistakes remain puzzling.

Whatever the case, in the beginning it was far from obvious that French territory, identity, industry, or diplomacy would become so thoroughly entwined with nuclear technology. These associations were first defined, debated, and defied during the three decades following World War II. *The Radiance of France* probed these origins through a social, political, cultural, and technological history of gas-graphite reactors, the "first generation" of French nuclear power plants.

Reading between the lines of the Royal-Sarkozy debate, we can glimpse how just as reactors have passed through several iterations since the 1950s, so too have the visions and versions of French national identity that nuclear power has reflected, enacted, and performed. At the end of this book, I discussed the so-called *guerre des filières*, a bitter struggle over reactor design that culminated in the choice of pressurized water reactors designed by Westinghouse over gas-graphite reactors designed at the Commissariat à l'Energie Atomique (CEA) and at Electricité de France (EDF). In building this "second generation" of reactors, EDF and its industrial partners insisted that they'd "Frenchified" the design. Increasingly, however, scale—at least as much as design—would come to characterize French nuclear exceptionalism. In the 1980s, France became *more* nuclear than any other place, deriving 75 percent or more of its electricity from this one source. It now has more power than it needs: according to some estimates, France is the world's largest net exporter of electricity, sending billions of kilowatt-hours to Italy and other neighboring countries. It has exported plant design and construction as well, selling its nuclear systems to Belgium, South Africa, South Korea, and elsewhere. In the "second generation," expansive export practices extended France's nuclear technopolitics into an economized, industrial, and increasingly globalized realm.

More recently, the notion of reactor "generations" has offered the nuclear industry a trope with which to claim rupture from past technological practices and disasters. This idiom presents third and fourth generation reactors as "inherently safe," intrinsically unable to succumb to a Chernobyl-like disaster. In EDF's promotional material for the EPR, vestiges remain of the monumental technological spectacles that I describe for the first generation, and the economies of scale and scope touted for the second generation. But its main themes concern safety and environment, in a response to activist objections and an attempt to capitalize on global climate change as a new source of legitimacy for new, large-scale nuclear projects. Simultaneously, the industry has poised itself for a "fourth generation": sodium-cooled, fast-neutron reactors that—according to EDF's promotional material—"reflect France's determination to pursue its strategy of sustainable development."[2]

Compared to these slick advertising campaigns, the technopolitics of national identity in the first period seem particularly raw, arising from an emotional intensity that my narrative may not have captured adequately. Or so implied Claude Bienvenu, the EDF engineer who served as one of my protagonists (and whose help proved indispensable to my research). Shortly after the French edition of my book appeared, he wrote me a long, moving letter that began like this:

> Why must entire spans of our history be written by Americans? The history of Vichy by Robert O. Paxton, and that of the French nuclear program by yourself? The strangest part is that . . . nothing in what you write deforms what I believe to be the truth.

Nevertheless, he felt driven to remark on the state of mind of young scientists and engineers at the beginning of their "nuclear adventure." Most of Bienvenu's own adolescence took place during the war, and while his own father raged against the treason of Vichy, most just accepted it. The letter continued:

> I remember, alas, school friends and professors eliminated because they were Jewish.
>
> I also remember the ignoble attitude of many close relatives toward the demands of the occupation: "My poor François (my father), don't forget that we have been vanquished!"
>
> I remember, finally, the eagerness of our upper classes to satisfy the needs of the Germans and the Italians who, they said, paid in cash and in full.

Such experiences explained why young people felt such intense shame, and why people like Marcel Boiteux and André Decelle (who would become upper management in EDF) fought so valiantly for the Resistance. "In speaking to you like this," Bienvenu concluded, "I relive my motivation at the time: to show that we weren't the decadent defeated, but rather young people filled with drive and hope."

Bienvenu's remarks represented the perspective of a particular generation of technologists whose attachment to matters of national identity came from humiliating lived experience. Vichy still looms large for those of Bienvenu's generation, its history forever entwined with their own. The national transformation they hoped to enact had barely begun by the end of the period I discuss in this book; the long-term outcome of their efforts remained unclear. In 1970, it would have seemed absurd to compare the power of a fledgling nuclear program to that of the Vichy government, whose wartime actions had affected the lives (and deaths) of millions of people on a daily basis.

Over six decades after the end of World War II, however, comparing the power and reach of the French nuclear program to that of a state apparatus (and a state of mind) might seem less far-fetched. In their search for redemption, in their efforts to prove that their nation remained capable of noble endeavors, Bienvenu's generation set in motion processes and projects whose impact and outcome would far exceed—in scale, scope, and duration—that of a four-year political regime.[3] Yet the impact of the nuclear program remains infinitely more difficult to see and experience, as witnessed by the confusion of the 2007 presidential candidates. That is because of the program's *techno*political qualities, the mechanisms that enable technological choices and strategies to carry, shape, and bury social and political ones. Nuclear technologies in France became *naturalized* in both senses: they came to seem a normal, inevitable part of the nation, and they grew inextricably tied to its nature and landscape.[4] In these and other ways, nuclear technopolitics became *infrastructural,* their quotidian impact invisible.[5] Visible and contested within (and between) the regimes that produced them, techno*politics* outside those regimes became, simply, technologies.

Not that there weren't attempts to make visible the power of state technopolitics.[6] In this book I trace a few early efforts. These intensified in 1970s and 1980s, when periodic challenges produced pockets of nuclear counter-expertise, mainly through the CFDT labor union and civil society organizations like the *Groupement des scientifiques pour l'information sur l'énergie nucléaire* (GSIEN) and the *Commission de recherche d'information indépendante sur la radioactivité* (CRIIRAD).[7] These efforts worked best when nuclear infrastructures overflowed, escaping their technopolitical regimes in some way. Black-outs, leaks, contaminations, unburied waste: such material crises have offered opportunities for making visible the power of nuclear technopolitics.[8] Beyond the moment of the "alert,"[9] however, groups like the GSIEN and the CRIIRAD have had trouble getting traction. Nor has the Green Party's ongoing opposition to nuclear power stopped reactor development. As Michael Bess has argued, French environmentalists ultimately gained influence by embracing technological enthusiasm, while other political groups enrolled rather than opposed nuclear energy. Widespread acknowledgment of the inextricability of technology and politics within the nuclear program found its counterpart in more broadly based practices that explicitly hybridized nature and culture.[10]

And so we arrive at the irony that Michel Callon explores in his preface to this edition. Postwar French society may have embraced the hybridities theorized by STS scholarship more openly and self-consciously than anywhere else, but this embrace did not automatically entail a more "democratic" politics of expertise. Broader participation in technopolitical decision making has been at best a difficult, and necessarily partial, achievement. But it is not inherently impossible: recent struggles over radioactive waste management suggest some openings. In the late 1980s, local officials and anti-nuclear groups vigorously contested deep burial of radioactive waste, which experts had sought to enact with no public discussion. To get past the resulting impasse, a 1991 law required another 15 years of research into alternative waste management solutions. Research findings, and their implications, were aired during a four month-long public debate in 2005.[11] The resulting 2006 law required scientists to stick with *reversible* solutions for waste disposal (rather than the irreversible solution of deep geological burial), pending a second public debate in 2012. Only time will tell how broadly—and how durably—this exercise in deliberative democracy will expand nuclear technopolitics.[12]

*

Meanwhile, the first generation of French reactors have become sites of historical memory, objects of nostalgia, monuments that perform identity by perpetually entwining nuclear narratives with the future of the region, the nation, and the planet. In 2007 the Chinon site celebrated its 50th anniversary by publishing a 292-page commemorative book (dutifully printed on recycled paper).[13] The volume's fanciful design goes far beyond standard expressions of nostalgia for halcyon days. It presents two narratives: a straightforward account of technological development, and a fairy tale version. Brimming with groan-inducing, mostly untranslatable puns, the fairy tale takes up 57 pages. It draws upon dozens of regional and national tropes: the protagonist is the electricity fairy, a figure in French cultural discourse for over a century;[14] the narrative style explicitly invokes Rabelais, the region's favorite son; the power of the atom is rendered as the power of round cheeses (*la tomme/l'atome*); nuclear energy production seems akin to winemaking; and on and on.

The authors playfully suggest that their tale offers a truth as profound as the "factual" history that inspired it. And that may well be, though perhaps not quite in the way they meant. I see their story as another in the long line of spectacles.[15] By explicitly rewriting history as legend, the *form* and *fact* of the tale perform a vision of nuclear power as eternally French because of its grounding in regional specificities, because of its inseparable connections to culture. The book's real-life narrative lays a parallel claim to this "truth." The volume opens with a long series of paeans to Chinon by local elected officials, and ends with photographs that juxtapose prime minister Georges Pompidou's 1963 visit to Chinon with Nicolas Sarkozy's 2004 visit as minister of economy and finance. Chinon appears, simultaneously, as the darling of public officials from village mayors on up; the place where ministers go on their way to becoming president; the object of broad social consensus; a personal affair of state; a place for making history, legend, and future on a grand scale.

Today, multiple generations of reactors (and their relics and debris) co-exist, as do the multiple generations of identity discourse and technopolitics that they perform. In 2001, a massive consolidation of the industry resulted in a single, gigantic corporation, Areva, which took over construction and production for the entire nuclear cycle, from uranium mining to reactor building to waste processing (EDF remains in charge of electricity production). Areva's reach extends far beyond that of the industrial "champions" promoted by Gaullists. Scores of affiliates around the world give it a truly global presence, with mines and other facilities in over 40 countries and on 6 continents. CEO Anne Lauvergeon—initially rumored to be a strong candidate for a top ministerial post shortly after Sarkozy's victory—has instead served as the president's partner on state visits. By mid-2008, France had signed nuclear agreements with China, Libya, Morocco, Turkey, and Algeria (among others). Two drum-beats accompanied the Sarkozy-Lauvergeon world tour: nuclear power as *the* solution to the climate change crisis, and the importance of good-faith nuclear cooperation in improving relations between the West and "the Rest" (especially the Islamic "Rest").

Meanwhile, if recent history is any indication, some of these countries may well follow Iran's example in privileging nuclear power as a site for national(ist) technopolitics, domesticating French technology for their own purposes.

This new rendition of the "radiance of France" represents a strategy to conflate foreign policy and nuclear expansion on an unprecedented scale by inseparably linking French technological practices, global political tensions, and planetary environmental crisis. How, then, can the notions of technopolitics and technopolitical regimes—which this book explores in the bounded national register of the metropole—serve to analyze these *trans*national processes? The question that first motivated this book—"what is French about the French nuclear program?"—also takes on new meanings. To my dis-articulation of this question in the book's original introduction, I might now add: How has Frenchness been rendered in nuclear sites around the world? Has French national identity become a brand in the worldwide nuclear industry? How does its valence differ in China, the Middle East, and former French colonies? To what extent can Frenchness serve as a resource for (say) uranium workers in Niger and Gabon who might seek compensation for occupational illness and environmental damage in French courts? This edition of *The Radiance of France* doesn't answer these questions, of course. But I am hopeful that it can provide some historical, theoretical, and methodological clues for how to begin.

Notes

Grateful thanks to Michael Bess, Sara Pritchard, and especially Michel Callon for their comments on this text, and to Margy Avery for her work on this edition.

1. For a discussion of the ambiguities of "nuclear" things, see Gabrielle Hecht, "Nuclear Ontologies," *Constellations* 13, no. 3 (September 2006): 320–331 and Gabrielle Hecht, "Negotiating Global Nuclearities: Apartheid, Decolonization, and the Cold War in the making of the IAEA," in John Krige and Kai-Henrik Barth, eds., *Global Power Knowledge: Science, Technology, and International Affairs*, in *Osiris* 21 (July 2006): 25–48.

2. EDF, available at http://www.edf.fr/35054i/Accueil-fr/Infos-Nucleaire/Le-nucleaire-du-futur/L-EPR.html (accessed 1 June 2007).

3. In saying this, I do not mean to impugn the motives of this generation in any way.

4. Sara B. Pritchard, *Confluence: The Nature of Technology and the Remaking of the Rhône* (Cambridge, Mass.: Harvard University Press, forthcoming).

5. Paul Edwards, "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems," in *Modernity and Technology,* ed. Thomas J. Misa, Philip Brey, and Andrew Feenberg (Cambridge, Mass.: MIT Press, 2002), pp. 185–225; and Paul Edwards, *The World in a Machine* (Cambridge, Mass.: MIT Press, forthcoming).

6. For a recent overview of science, technology, and state power in France see Christophe Bonneuil, "Les transformations des rapports entre sciences et société en France depuis la Seconde Guerre mondiale: un essai de synthèse," in *Sciences, Médias et Société. Actes du colloque, Lyon 15–17 juin 2004,* ed. Joëlle Le Marec and Igor Babou, pp. 15–40 (Lyon: Ecole Normale Superiéure, 2004). Available at http://sciences-medias.ens-lsh.fr/article.php3?id_article=55 (accessed 7 August 2008).

7. Sezin Topçu, "Emergence de nouvelles formes d'expertise dans l'histoire du débat nucléaire en France (1974–1988)," mémoire de DEA, centre Koyré, Ecole des Hautes Etudes en Sciences Sociales.

8. On nuclear waste in France, see Yannick Barthe, *Le pouvoir d'indécision: La mise en politique des déchets nucléaires* (Paris: Economica, 2006).

9. Francis Chateauraynaud and Didier Torny, *Les sombres precurseurs. Une sociologie pragmatique de l'alerte et du risque* (Paris: Editions de l'EHESS, 1999).

10. Michael Bess, *The Light-Green Society: Ecology and Technological Modernity in France, 1960–2000* (Chicago: University of Chicago Press, 2003), along with Pritchard, *Confluence.*

11. For one account of this debate, see F. Laby, "La commission particulière du débat public sur les déchets radioactifs a présenté son compte-rendu," *Actu-Environnement* (8 March 2006). Available at http://www.actu-environnement.com/ae/news/1585.php4 (accessed 18 November 2008).

12. Special thanks to Michel Callon for his contributions to this paragraph.

13. André Laurent, Claude Bougreau, Jean-Pierre Fischer, and Jean-Pierre Le Noc, *La centrale de Chinon, figure de proue du nucléaire civil* (EDF, n.d.).

14. Alain Beltran and Patrice Carré, *La fée et la servante: La société française face à l'électricité, 19e–20e siècle* (1991),

15. See chapters 6 and 7.