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The European Nuclear Power Industry: Restructuring for Combined Strength and Worldwide Leadership

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ACRONYMS AND ABBREVIATIONS

ABB	Asea Brown Boveri
ABWR	Advanced boiling-water reactor
A-E	Architect-engineer
AECL	Atomic Energy of Canada, Ltd.
ANS	American Nuclear Society
APW	Advanced pressurized-water reactor
ASME	American Society of Mechanical Engineers
BBC	Brown Boveri Company
BMU	German Federal Ministry of Environment and Nuclear Safety
BOP	Balance of plant
B&W	Babcock and Wilcox
B&WNT	Babcock and Wilcox Nuclear Technology
BWNS	Babcock and Wilcox Nuclear Services
BWR	Boiling-water reactor
CASA	Spanish Aircraft Corporation (government owned)
CE	Combustion Engineering
CEA	Commissariat a L'Energie Atomique
CER	Cooperative European Regulators
CGE	Compagnie Generale d'Electricite
CNNC	China National Nuclear Corporation
DAE	Department of Atomic Energy (India)
DFD	Deutsch–Frazõslacker Direktionsausschub
DKB	Dai-ichi Kanayo Bank (Japan)
DSIN	Direction de la Sûreté des Installations Nucléaires
EdF	Electricite de France
EEC	European Economic Community
ENEL	National Electric Energy Agency
EPR	European Pressurized Water Reactor
EPRI	Electric Power Research Institute
EUR	European Utility Requirements Document
EVU	Private Utility Association (Germany)
FBFC	Franco Belge De Fabrication De Combustibles
FFR	French frames
FRAMA	Framatome
FSU	former Soviet Union
GE	General Electric
GKN	Gemeinschaftskernkraftwerk Neckar (Germany)
GmbH	Incorporated (Germany)
GRS	Gesellschaft für Anlagenund Reactorsicherheit (German equivalent of NRC)
IBM	International Business Machines
IPSN	Institute for Nuclear Protection and Safety (French equivalent of NRC)
JPC	Japan Power Company
KEPCO	Korea Electric Power Company
KWU	Kraftwerke Unñon (Power Generation Group)
LOCA	Loss of coolant accident
LWR	Light-water reactor
MITGR	Mitsubishi Group (Japan)
MITSU	Mitsubishi Taiyo Kabe (Japan)
MOU	memorandum of understanding

MOX	mixed oxide fuel
MTU	metric ton of uranium
NE	Nuclear Electric (United Kingdom)
NN	CU.K. National Nuclear Corporation
NPI	Nuclear Power International
NRC	U. S. Nuclear Regulatory Commission
NSSS	Nuclear steam supply system
PRIME	Passive Resilient Inherent Malevolence Extended
PWR	Pressurized-water reactor
RSK	German Reactor Safety Commission
SA	Societé Anonyme (French equivalent of Incorporated)
SGN	Société Générale Pour Les Techniques Nouvelles
SNPC	Siemens Nuclear Power Corporation
SKODA	Skoda-Energo
TEPCO	Tokyo Electric Power Company
TUV	German standards organization
UNESA	Unidad Electrica SA (Spanish Utilities Federation)
URD	EPRI Utilities Requirement Document
Ussi	Ussi Ingénierie
VDEW	Vereinigung Deutscher Elektrizitätwerke (German Utilities Producers Federation)

EXECUTIVE SUMMARY

The European Nuclear Power Industry: Restructuring for Combined Strength and Worldwide Leadership

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The European nuclear power industry is being restructured along pan-European lines in response to changes in market and political conditions since the mid-to-late 1980s. Demand for new nuclear power plants has declined—in part because of antinuclear political pressures and in part because much expensive oil-burning capacity has already been replaced—creating, conversely, excess capacity within the nuclear power supply industry. At the same time, traditional reliance on national nuclear vendors has fallen out of step with European Common Market trends, and common market mechanisms have enabled increased contact among European nuclear regulatory authorities. Furthermore, the accident at Chernobyl in 1986 emphasized the impact that the actions of any one utility could have on other utilities.

The shift toward a Europe-wide industry is reflected in three key efforts currently under way, all of which are expected to be completed in the next six or seven years:

- Formation of Nuclear Power International (NPI)—a joint venture of the French national reactor vendor Framatome and its private counterpart in Germany, Siemens—to design and build the next generation of European light-water reactors (LWRs) for domestic and foreign sales. This undertaking in many ways is the driving force behind the other two efforts at "harmonization."

- Creation of a European Utility Requirements (EUR) document, in which many European utilities will agree on what they want in future nuclear plants, and other utility cooperative efforts. The EUR is a mechanism for resolution of issues between utilities and regulators in multiple European countries.

- Development of a consensus among European nuclear regulators on a common regulatory base.

If successful, these combined activities could have several implications for the United States and other non-European countries. First, these European efforts could result in acceptance of a single European reactor design, which would, in turn, shift the lead for reactor design and regulation decisively to Europe. Historically, U.S. standards have been the basis for design and regulation of most of the world's reactors; European influence has been diluted by the existence of multiple national standards. Should more up-to-date, pan-European rules and standards help Europe redefine de facto world standards, this presumably would aid European vendors by reflecting their capabilities and skills. Moreover, the application of a single reactor design across Europe would produce economies of scale that would be advantageous to European vendors. Thus, Europe's lead in design and regulatory matters would, in effect, improve European competitiveness in the nuclear power sector compared to U.S. and other non-European vendors.

Development of uniform, widely-accepted European standards and regulations could also significantly improve reactor safety in the former East bloc over the mid-to-long term. Once agreement on engineering codes and standards is reached by a significant fraction of the international engineering community, it tends to become a very strong force for compliance. From individual designers to political leaders, it becomes easier to adopt such rules than to explain exceptions and rewrite or design to local rules. Thus, we would expect that new reactors in Eastern Europe and much of the former

Soviet Union would be designed to the new European rules and that those rules also would influence backfitting of existing reactors. The desire to trade with or join the European Economic Community further reinforces these trends.

Last, the architects of European standards and regulations hope the shift toward a pan-European nuclear rules will improve the political profile of nuclear power. Countries with poor nuclear safety records and nonconforming nuclear plants can be more easily distinguished from European plants that are in compliance, and debate over safety differences between European countries will be reduced.

This transformation is not yet complete, however. The history of the Airbus joint venture—a successful case of restructuring a high-tech European industry on pan-European lines—demonstrated that this type of reconfiguration is evolutionary, drawn out, and often involves changing partners.

Moreover, despite the strength of the trend toward consolidation, it remains to be seen how other European vendors—in particular, the Swiss-Swedish Asea Brown Boveri (ABB)—will respond to the NPI challenge. Nor do all European utilities favor a single European vendor, given the loss of competition it implies. Should some vendors decide to remain aloof from French-German "harmonization," they could choose to join forces to form a second European joint venture, perhaps led by ABB with its advanced reactor designs, or to ally themselves with American or Japanese vendors.

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ABSTRACT

The European nuclear power industry is being restructured from an industry drawn along national lines to a European-wide industry. This, in part, reflects growth of the European Economic Community, but it also reflects changes in the international nuclear power industry. The objectives of the participants, beyond better integration of the nuclear power industry in Western Europe, are to (1) obtain European leadership of the worldwide commercial nuclear power industry, (2) improve medium- and long-term safety of Eastern Europe and the former Soviet Union (FSU) power reactors, and (3) reduce domestic concerns about nuclear power. The activities to achieve these goals include (1) formation of Nuclear Power International (a joint venture of the German and French nuclear power plant vendors for design and construction of nuclear power plants), (2) formation of a utility group to forge agreement throughout Europe on what the requirements are for the next generation of nuclear power plants, and (3) agreement by regulators in multiple European countries to harmonize regulations. This is to be achieved before the end of the decade. These changes would allow a single design of nuclear power plant to be built anywhere in Europe. The creation of European-wide rules (utility requirements, engineering standards, and national regulations) would create strong economic and political forces for other European countries (Eastern Europe and FSU) to meet these standards.

1. INTRODUCTION AND SCOPE

1.1 REPORT OBJECTIVES

The objectives of this report are to describe the changing structure of the European nuclear power supply industry and how those changes may affect international competitiveness, nuclear power safety, and acceptance of nuclear power in Europe.

This report is a snapshot in time. The European restructuring is partly completed, but major unknowns remain. It is in a period of transition.

1.2 HISTORY

The late 1950s and 1960s saw early development of nuclear power in Europe along national lines with each major country having its own national vendor, national standards, and national regulatory authority. Cooperation between and among countries was primarily limited to research with competition in the commercial application of nuclear power. National governments were heavily involved because nuclear power was viewed as a future source of energy.

In 1973, dramatic changes in nuclear power occurred as an aftermath of the Arab oil embargo and rising oil prices. In Europe, most electricity was produced by oil. The increased oil prices caused by the embargo made oil-generated electricity very expensive and made nuclear power the low-cost option for production of electricity. A dramatic growth occurred in the use of nuclear power and in the size of the European nuclear power supply industry. In the United States the oil embargo had exactly the opposite effects. Higher oil prices slowed the economy and the growth in electrical demand. Structural changes in the economy further slowed electric growth. Because most of the electricity was generated by burning coal that did not increase in price, there was little incentive to build nuclear power plants. Overbuilding of U.S. electric power plants and low electric growth rates collapsed the market for new nuclear power stations and radically reduced the U.S. supply industry.

By the mid-to-late 1980s conditions in Europe began to change in a way that created the driving forces for the restructuring of the nuclear power industry in Europe:

- Demand for additional nuclear power plants decreased—partly because in many countries most of the expensive oil-burning electric plants had been replaced and partly because of increased controversy over nuclear power.
- The nuclear supply industry had excess capacity.
- The common market was making the concept of a national nuclear power vendor obsolete. National regulatory authorities were in increased contact throughout the European Economic Community (EEC).
- The Chernobyl nuclear power accident raised serious doubts about the assumption that each country could act independently in the area of nuclear power. Utilities recognized that the health of their own operations depended on what other utilities did or did not do.

1.3 REPORT ORGANIZATION

This report describes the ongoing transformation of the European nuclear power industry from one organized strictly along national lines to European transnational enterprises with characteristics of both a true European-wide industry and a strict set of national enterprises. The next three sections describe the internal (Western Europe) changes that are occurring as separate and distinct activities. Section 2 discusses the joint venture among the French and German vendors to design and build new reactors. Section 3 discusses efforts by utilities across Europe to define what type of European-wide nuclear power plant they desire. Section 4 discusses regulatory efforts to make a nuclear power plant design that is acceptable in one country to be acceptable in multiple countries. Section 5 discusses synergistic effects and how these activities together may radically improve the worldwide competitiveness of European reactor vendors while improving Eastern European and former Soviet Union (FSU) reactor safety. Section 6 discusses general conclusions.

About half of the report is appendixes that give more detailed information on Framatome (Appendix A), Siemens (Appendix B), Airbus (Appendix C), and the European utilities (Appendix D). Appendix C provides a history of Airbus; this history is noteworthy because of the historical similarities between Airbus and Nuclear Power International (NPI).

1.4 CAVEATS

Several caveats apply to this report.

- The characteristics of this industrial transformation are changing with time as the goals of the participants change. The initiating event was the decision of the French and German reactor vendors to create a joint venture to sell their products overseas and develop new reactors for the overseas market. This evolved into development of a common design for the next generation of nuclear power reactors in France and Germany. A common design required agreement of French and German regulators and utilities. The French-German utility discussions soon included other European utilities to discuss the broader issues of what the utilities wanted. The development of the European utilities requirements (EUR) will address the proposed French-German reactor but also the advanced designs from other vendors. The regulatory discussions similarly expanded beyond discussions of the French-German reactor design.

- The formation of the French-German vendor consortium still left several other vendors in Europe. It is likely these vendors will alter their activities to compete. Whether they will join to form a second European reactor joint venture, join with American or Japanese organizations, or pursue some other strategy is as yet unclear.

- Europe has had some major success in restructuring high-tech industries. The best example is Airbus—the European joint venture that manufactures commercial aircraft. The history of Airbus shows such restructuring takes time, often involves changing partners, and evolves with time. Restructuring of the European nuclear power industry may follow a similar course.

2. CONSOLIDATION OF THE EUROPEAN NUCLEAR POWER INDUSTRY: NPI

2.1 WHAT IS NPI?

NPI is the recently formed joint venture between the French government-controlled reactor vendor Framatome and the private German reactor vendor Siemens. The stated purpose of NPI is to develop, sell, and build a new generation of reactors—the European pressurized-water reactor (EPR)—for use worldwide. More importantly, NPI almost certainly intends to dominate European reactor sales in the future. Through its parent organizations, NPI represents the largest reactor vendor group in the world, has more experience in designing and building reactors [more than 100,000 MW(e) built], and has more reactor years (900) of operating experience [NPI 1992] than any other company in the world. Table 1 provides a perspective of the size of NPI partners relative to other reactor vendors by listing the world's vendors and their respective sales [Forsberg 1992a]. Sales include reactors sold before and after 1980. Sales since 1980 give a perspective on current vendor capabilities, while total sales provide some perspective on available market for spare parts for a particular vendor. NPI was established in the fall of 1989 following the signing of a cooperative agreement in early 1989. Each company owns 50% of NPI.

2.2 INCENTIVES BY GERMAN AND FRENCH ORGANIZATIONS TO CREATE NPI

The formation of NPI is a response to long- and short-term trends in both the world economy and the nuclear power industry. Those trends made it attractive for the German and French vendors to create NPI.

2.2.1 General Economic Factors Favoring Formation of NPI

Economic incentives exist for reactor vendors to form joint ventures. Joint ventures are prevalent in industries in which there is a need to pool capital and spread risk such as advanced technology industries. Comparing the steel and commercial aircraft industries will (1) highlight the differences between high-technology industries and those industries that are seeing slow technological advances and (2) illustrate the incentives for joint ventures.

Steel production costs depend on the costs of capital, labor, energy, and materials. Because steel-making is a mature industry, R&D requirements are minor. Because economies of scale are reached in plants with fairly small capacities, a steel company horizontally integrated over multiple countries may have only a small economic advantage over a single-plant company.

In industries whose product or process development costs are a major fraction of total costs, powerful incentives exist for international cooperation that spreads development costs and risks over expanded markets. Commercial aircraft is such an industry. The development and licensing costs for new commercial aircraft are measured in billions of dollars. Product development costs are extremely high. If the aircraft manufacturer doubles production of a new aircraft, additional facilities may cost a few hundred million dollars plus direct manufacturing costs; however, the cost per aircraft drops dramatically because development and licensing costs are a significant fraction of total costs and are independent of the number of aircraft produced. If partnerships or joint ventures with other companies can increase sales, the joint effort drastically reduces unit costs, reduces risks, and increases profits for all partners. The Boeing-Japan partnership and the Airbus consortium (French, German, Spanish, and British companies) are designed to ensure wider markets for expensive-to-develop aircraft. The electronic integrated circuit industry is also similar, except that the industry's major costs involve developing the production technology. The recent joint venture of IBM (United States), Toshiba (Japan), and Siemens (Germany) to develop the next generation of computer memory chips is a mechanism to spread the process development

Table 1. Power reactor vendors worldwide

Organization or group Country	Major subsidiaries **Vendors,** Subsidiaries, or Corporations	Number of reactors[a] *Construction started* *currently operating*	Ownership	Products	Comments
Asea Brown Boveri (ABB) Sweden and Switzerland		Pre-1980 *34/25* post-1980 *6/1*	Private 50% Asea 50% Brown Boveri	Large industrial plants and equipment	ABB incorporated in 1988—formerly fierce competitors in heavy-electrical and power-generation fields, Sweden's Asea & Switzerland's Brown Boveri joined forces.
	Asea (ABB-Atom)	Pre-1980 *12/10* post-1980 *1/1*	Private Traded on Sweden's stock exchange	Reactors and Industrial and electrical equipment	ASEA designed the PIUS reactor.
	Brown Boveri Company (BBC)	Pre-1980 *2/0* post-1980 *0/0*	Private Traded on Swiss stock exchange	Industrial and electrical equipment	
	Combustion Engineering (ABB-CE)	Pre-1980 *20/15* post-1980 *5/0*	Private ABB bought control of CE for $\$1.6{\times}10^9$	Reactors, nuclear components, industrial equipment, and nuclear service	Designer and builder of numerous reactor plants in the United States and foreign countries. CE design chosen as basis of Korean standard reactor design
Minatom Russia		Pre-1980 *54/41* post-1980 *51/15*	Russian Government	Nuclear power plants	Future structure and size of Russian nuclear program and vendor unclear due to Chernobyl nuclear power accident and breakup of the Soviet Union.
Atomic Energy of Canada, Ltd. (AECL) Canada		Pre-1980 *23/21* post-1980 *5/3*	Owned by the Canadian Government	Nuclear plants, equipment, and services	AECL has built all Canadian reactors. AECL is building two reactors for Korea and is negotiating for a third.

Table 1. Power reactor vendors worldwide (continued)

Organization or group Country	Major subsidiaries **Vendors,** Subsidiaries, or Corporations	Number of reactors[a] <u>*Construction started*</u> *currently operating*	Ownership	Products	Comments
China National Nuclear Corp. (CNNC) Peoples Republic of China		Pre-1980 *0/0* post-1980 *3/2*	China	Nuclear power plants	China started its first plant December 15, 1991, and contracted to build another for Pakistan on December 31, 1991—16 days later. Two unit plant bought from France included in totals.
Framatome France			French government controlled		
	Commissariat a l'Energie Atomique (CEA)	Pre-1980 *13/5* post-1980 *0/0*	French Government Agency	Nuclear energy	CEA is responsible for France's nuclear research activities. CEA partly owns Framatome with close connections with vendor.
	Framatome	Pre-1980 *46/45* post-1980 *24/13*	40% CGE 35% CEA 10% EdF 15% other	Reactors, nuclear equipment, and service	Initially Framatome built PWRs with Westinghouse Company's licensing agreements.
	Babcock & Wilcox Nuclear Technology (B&WNT)	Pre-1980 *12/8* post-1980 *0/0*	Owned by Framatome	Reactors, nuclear equipment and service	B&WNT is now owned by Framatome. Formerly U.S. vendor controlled by B&W (U.S.)
	Nuclear Power International (NPI)	Pre-1980 *NA* post-1980 *0/0*	Joint venture of Framatome and Siemens	LWR power plants	NPI is a Framatome/Siemens effort to design and build a nuclear plant aimed at the European and world market.

Table 1. Power reactor vendors worldwide (continued)

Organization or group Country	Major subsidiaries **Vendors,** Subsidiaries, or Corporations	Number of reactors[a] *Construction started* *currently operating*	Ownership	Products	Comments
Dai - Ichi Kangyo Bank DKB Japan	688 Subsidiaries		A Keirestu group not a company	A broad base of products and banking	The Zaibatsu (family) organizations were disbanded after World War II. They remained dormant for many years but have emerged as industrial groups. The Dai-ichi Kanayo Bank (DKB) is the group that includes Hitachi.
	Hitachi Ltd.	Pre-1980 *6/6* post-1980 *5/3*	Private and part of DKB group	Power systems, electronics, industrial cable, and chemicals	Hitachi is part of a joint venture with GE and Toshiba building two ABWRs for TEPCO. Power systems is 15% of Hitachi sales.
Department of Atomic Energy (DAE) India		Pre-1980 *8/8* post-1980 *8/0*	Indian government agency	Atomic energy	India built small reactors with the help of many other nations (two with the United States, one with France, one with Great Britain, and two with Canada). Has developed indigious capacity.
General Electric (GE) United States			Private	Power systems, electrical equipment, electronics, and plastics	GE is building its next generation of nuclear plants (ABWR) for TEPCO as part of a joint venture with Hitachi and Toshiba.
	Power Systems Division	Pre-1980 *66/53* post-1980 *2/0*	Division of GE	Nuclear plants and services	Power Systems contributed 12% to GE sales in 1987.
Korean Electric Power Corporation (KEPCO) South Korea			Government (49% of stock to be sold to public)	Electric company power plants	Prior to 1980, Korea bought reactors from Westinghouse and Framatome. Since 1980, Korea has used ABB-CE and AECL. There is a clear national policy to develop a nuclear power vendor capability with greater Korean involvement with each subsequent reactor project.

Table 1. Power reactor vendors worldwide (continued)

Organization or group Country	Major subsidiaries **Vendors,** Subsidiaries, or Corporations	Number of reactors[a] <u>*Construction started*</u> *currently operating*	Ownership	Products	Comments
Mitsubishi Group (MITGR) Japan	190 companies 459 subsidiaries		A Keirestu group not a corporation	A broad base of products and banking	When the Mitsubishi Zaibatsu was broken in the 1940s, about a dozen companies maintained contact and developed into the Mitsubishi Group (banking, chemicals, shipbuilding, power plants, aircraft, industrial and consumer products).
	Mitsubishi Heavy Industry	Pre-1980 *9/9* post-1980 *11/6*	Private, part of the Mitsubishi Group	Ship building, power plants, aerospace, and heavy machinery	Japan's largest comprehensive heavy machinery maker. The leader in nuclear power in Japan.
	Mitsubishi Electric Corporation		Private, part of the Mitsubishi Group		The corporation is third among comprehensive electric machine makers. It is top in defense electronics and has agreements with Westinghouse in nuclear power.
Mitsui Taiyo Kobe MITSUI Japan	513 subsidiaries		A Keirestu group, not a company	A broad base of products and banking	MITSUI is the Keirestu that has regrouped since World War II and includes Toshiba.
	Toshiba	Pre-1980 *8/8* post-1980 *5/3*	Private, part of the Mitsui Group		Japan's second all-around electric machinery maker. Toshiba cooperates with GE and Hitachi in nuclear power generation.
National Nuclear Corp. (NNC) United Kingdom		Pre-1980 *39/34* post-1980 *5/4*	Government		NNC currently has the reactor vendor strength of Great Britain. However, Rolls Royce was in a joint venture with CE when ABB acquired CE.

Table 1. Power reactor vendors worldwide (continued)

Organization or group Country	Major subsidiaries **Vendors,** Subsidiaries, or Corporations	Number of reactors[a] *Construction started* *currently operating*	Ownership	Products	Comments
Siemens Germany	418 subsidiaries		Private	Large industrial plants, electrical equipment, medical equipment, chemicals, and automation	Siemens is engaged in the entire field of electrical engineering & electronics.
	Power Generation Group [Kraft Works Union (KWU)]	Pre-1980 *25/18* post-1980 *8/5*	Owned by Siemens	Power plants and processing plants	KWU contributed 12% of Siemens' sales in 1987.
	Nuclear Power International (NPI)	N/A	Joint venture of Framatome and Siemens	LWR power plants	NPI is a Framatome/Siemens effort to design and build a nuclear plant aimed at the European market.
	Skoda (of Czechoslovakia) (SKODA)	Pre-1980 *9/8* post-1980 *8/0*	Siemens plans to purchase 67% of SKODA group for production of power equipment		SKODA has 1937 employees involved in nuclear divisions (out of 37,000 employees). Framatome is expected to acquire 10% from Siemens, leaving them with 57%.

Table 1. Power reactor vendors worldwide (continued)

Organization or group Country	Major subsidiaries **Vendors,** Subsidiaries, or Corporations	Number of reactors[a] *Construction started* *currently operating*	Ownership	Products	Comments
Westinghouse United States	26 nuclear associates in nine countries		Private	Electric equipment, power equipment, waste systems, fuel cells, and solar power	First builder of AC equipment, naval reactors, and commercial nuclear power plants.
	Nuclear Energy Systems Division	Pre-1980 *94/86* post-1980 *3/2*	Divisions of Westinghouse		Designer of the AP600 PWR. Historically, designer and builder of the largest number of nuclear plants. Westinghouse APWR 1300 was developed with the aid of funding from Japanese utilities. It will be Japan's next PWR project.

[a]The number of power reactors built is divided into two time periods. The more reactors built, the stronger the vendor's market for spare parts. Recent sales give a perspective on current capabilities to build power reactors.

costs over products sold in North America, Japan, and Europe (Wallace 1992).

The industrial structure of the commercial nuclear power plant industry is closer to that of the commercial aviation industry than the steel industry. National governments may prefer domestic suppliers, but unlike the steel industry, the economies push for either international companies or domestic companies as part of larger international consortia to spread development costs and minimize risks.

Joining together increases total sales over those of individual partners by strengthening financial and political resources to assist sales. A single nuclear power plant is a multibillion dollar investment. The sale of such facilities depends not only on costs, but also on availability of financing. Furthermore, the large economic impact of foreign sales in terms of domestic employment pressures national governments to support their local industries by encouraging exports. Support of multiple national governments improves the prospects of foreign sales.

Last, for Europe the experience of Airbus (Appendix C) provided an example in which a multinational joint venture accomplished goals that no individual manufacturer or country was able to achieve. Through the 1970s, the United States dominated the manufacture of commercial aircraft. A succession of countries and companies in Europe attempted unsuccessfully to enter the market. After a series of false starts, the European joint venture Airbus was created to manufacture and sell commercial aircraft worldwide. Today, Airbus and the U.S. manufacturer Boeing dominate the world market. The combining of European technical, financial, and political forces made Airbus successful. Airbus provided a belief that a nuclear power equivalent could be successful.

2.2.2 Specific Factors Encouraging French and German Vendors to Form NPI

A key economic development in western Europe over the past decade has been creation of the EEC, which moves European economies toward unification. A single European economy provides increasing incentives for the formation of joint ventures among European companies. The German and French vendors are the largest nuclear power vendors in Europe and, hence, are the natural partners.

The legal status of European reactor licensing agreements also has changed to allow the formation of large European joint ventures. In the 1960s and 1970s, U.S. companies licensed the technology to European organizations. By the mid-to-late 1980s, these licensing agreements began to expire. This removed a significant legal barrier for joint ventures in Europe, but not elsewhere in the world where licensing agreements were signed later in time and have not expired.

The formation of NPI reduces some of the political controversy over nuclear power. In the past, comparisons were often made of the relative safety of German and French power reactors. Moreover, various nuclear power decisions in one country have had adverse impacts on nuclear power in the other. The formation of NPI, development of a single French-German power reactor design, and closer coordination of industrial nuclear power activities can eliminate some of these issues.

Last, shrinking numbers of orders for European nuclear power plants provide a strong incentive to reduce costs and increase foreign sales through a European joint venture. When sales are growing, most companies will not consider joint ventures in hope of emerging as the dominant world supplier. In a shrinking market, organizations will consider more radical structural change. Germany is not currently building additional nuclear power plants because of reduced electric growth rate and political controversy over nuclear power. Nuclear power plant construction has slowed down in France because of market saturation. Over 75% of French electric power is currently produced by nuclear reactors. Worldwide, only a limited number of partners exist. In the far east, there is large-scale construction of nuclear power plants—thus, vendors are not interested in joint activities. The U.S. vendors have a limited presence in Europe with an uncertain home market. The other large European vendor is Asea Brown Boveri (ABB), but it has a major presence in the United States and large-scale programs with the South Koreans which may have reduced its incentives to join NPI.

2.3 OWNERSHIP AND ORGANIZATION

As discussed in Sect. 2.2, Framatome and Siemens each own 50% of NPI. This appears straightforward, but the details of ownership and operation are somewhat more complex (Fig. 1). First, Siemens, which is the parent company, is under private ownership and is involved through its Power Generation Group, which is the former Kraftwerk Union (KWU). This group is designated by Siemens as the Power Generation Group, but it will be called KWU in this report. This group is both a reactor designer and power plant constructor and, as such, is responsible in Germany for the entire scope of a power reactor project.

Framatome, on the other hand, is directly or indirectly controlled by the French government. Because Framatome itself is owned primarily by several government-owned companies, it does not make independent business decisions as a private company like Siemens does. Alcatel-Alsthorn, [formerly Compagnie Generale d'Electricite (CGE)], Commissariat a L'Energie Atomique (CEA), Electricite de France (EdF), and Dumez own 40%, 35%, 10%, and 12% of Framatome respectively. The remaining 3% ownership is held by company employees. Commissariat a L'Energie Atomique is the French government Atomic Energy Agency, while EdF is the French government-owned national electric utility.

The picture is further complicated by the central role of EdF on the French side of NPI. In France, Framatome designs the nuclear steam supply system (NSSS), while the utility, EdF, designs the rest of the plant and has overall project responsibility. EdF is indirectly a major NPI partner. First, it owns a significant fraction of Framatome and, hence, part of NPI. Second, it is the major customer of Framatome and the likely major customer of NPI. Third, EdF will design the nonnuclear systems of any NPI reactor on the French side of the NPI consortium for Framatome. EdF has a major role of supplier, owner, and customer for NPI. The general structure and scope of NPI is shown in Fig. 1. NPI has three basic areas of work:

- Marketing for export of the existing French and German PWR designs, including fuel services.
- Coordinating the development of their generic future PWR design.
- Providing leadership for the consortium of companies performing NPI work for manufacture, integration, and delivery of products.

NPI, as a joint venture, coordinates work, but the detailed engineering and other activities are done by components of the parent organizations. As shall be seen in the following sections, providing leadership in the latter two areas may be very challenging because of the number and type of companies involved.

2.4 CHARTER AND GOALS

NPI represents a cooperative venture between two companies, one based in France and one in Germany, both with a significant reputation worldwide in the construction and operation of nuclear power plants. This high reputation has been achieved through application of high safety standards and standardization and has resulted in high levels of on-line reactor availability. Based on their experience, the NPI parent companies have demonstrated capability for high quality and achievement.

The charter of NPI is to develop and market the next generation of nuclear power plants that are to be licensed and built in France and Germany. The goals of NPI are as follows:

- Stated—to market PWR units for export based on the existing technology of the parent companies.

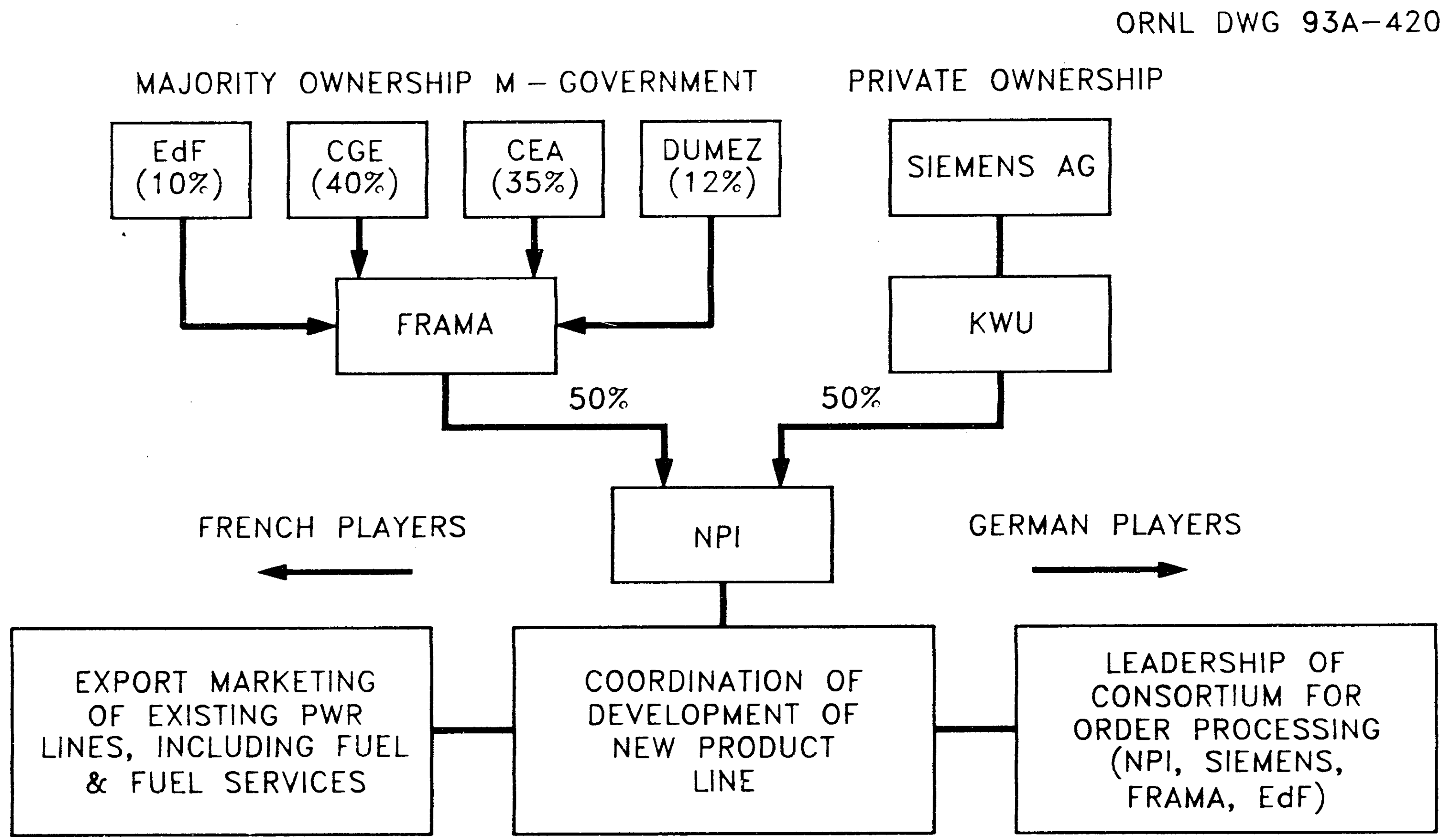

Fig. 1. Structure of NPI showing the major players and NPI's role.

- Stated—to build demonstration plants of a common design for the next generation PWR, one each in Germany and France.

- Stated—to develop and market for export of the design.

- Unstated--to improve the marketability of their design, with minimum changes, in at least the rest of Europe and possibly the world.

Achievement of these goals requires cooperation in three major areas: industry (Sect. 2), utilities (Sect. 3) and licensing authorities (Sect. 4). Only industrial activities are under the direct control of NPI. This type of cooperative effort has never been achieved before on this scale between countries.

Cooperation between Europe's two top reactor vendors has also initiated close cooperation among European utilities in the nuclear sector. At the same time as NPI was formed, two utility efforts—one each in France and Germany—were directed at developing a future reactor for each country with potential for sale elsewhere in Europe after modification for local regulations. In France, this program, under EdF sponsorship, was called "REP 2000/N4+." In Germany, a parallel program, under sponsorship of several utilities (through Siemens), was based on an advanced "Konvoi" technology [NPI 1992]. In May 1990, EdF and several German utilities established a cooperative agreement that provided for developing joint reactor-requirement specifications, making joint contacts with NPI, and cooperating on promoting joint licensing requirements in both countries. The concept of a future PWR unit, which was worked out by NPI, Framatome, and Siemens, was developed as a part of this agreement; as a result, work was halted on the previously mentioned separate efforts. Instead, the results were merged, and the ultimate objective then became joint development of the new product line, the EPR, in both countries. This decision encompassed the ideas stated above from the NPI charter [Baumgartle 1992].

Furthermore, the basis for cooperation between the French and German licensing authorities also was laid in a joint declaration of June 6, 1989. In this declaration, the French Ministry of Industry and the German Federal Ministry of Environment and Nuclear Safety (BMU) stated that they intended to set up an ad-hoc working group of safety authorities of each country. The role of this group is to verify the joint NPI design with regard to its licensability [NPI 1992] in both countries.

2.5 SPLIT OF RESPONSIBILITY AMONG NPI, FRAMATOME, EdF, AND SIEMENS FOR THE EPR DESIGN EFFORT

As noted previously, the structures of the German and French nuclear power supply industries are significantly different; thus, there is not a one-to-one correlation between French and German organizations involved with NPI. The split of responsibility is as shown below.

NPI	- Participate in and coordinate all design efforts of the design team of Framatome/ Siemens/ EdF.
	- Coordination of utility input into the design.
Framatome	- Develop the nuclear system design in cooperation with NPI and Siemens, and EdF.
Siemens	- Develop the nuclear system design in cooperation with NPI and Framatome, and EdF.
	- Develop the balance of plant (BOP) design for and act as the overall A/E at the German demonstration site.
EdF	- Develop the nuclear system design in the areas of containment design and control room layout in cooperation with NPI, Framatome, and KWU.

- Develop the BOP design and act as the overall A-E for the French demonstration site.

These relationships are shown in Fig. 2. EdF involvement on the French side reflects the organization of the French nuclear industry. In France, the utility designs the power plant around the Framatome nuclear system. This is in contrast to Germany, where the entire power plant is designed by Siemens.

2.6 DESIGN PHILOSOPHY AND TIMING OF EPR DESIGN EFFORT

The proposed EPR is a large [1450 MW(e), 4250 MW(th)] pressurized-water reactor similar in design, with several noteworthy exceptions, to recently built nuclear power plants in western Europe. The plant includes the expected improvements in the technology that occur with time that improve plant reliability and reduce the risk of an accident. The large power plant size reflects the French and German perspective that large plants are the most economical.

There are several changes in the proposed reactor safety systems of the EPR vs current power reactors (Krugmann 1992). The largest change is a significant improvement in the performance of the reactor containment system compared to all existing reactors and compared to other proposed future commercial designs. The reactor containment building and associated support systems are designed to protect the reactor against external threats (storms, terrorist attack, etc.) and contain the radioactivity in the event of a severe reactor core-melt accident. This includes almost all possible internally generated accidents. The objective of this improved system is to greatly reduce or eliminate the possibility of land contamination or population evacuation after a severe reactor accident. This reflects a European perspective that long-term land contamination from a reactor accident is unacceptable. This strong emphasis is in part a response to the Chernobyl nuclear power plant accident.

The second direction to improve nuclear power safety is the use of passive and inherent safety systems without moving parts or dependence on operators (Forsberg 1991). Current reactors use "evolutionary" safety systems with active safety systems that contain pumps, motors, and diesel generators to stop progression of an accident. Proposed "evolutionary technology" power reactors such as the Westinghouse AP-600 reactor and the General Electric simplified boiling-water reactor will use semipassive safety systems. These systems must be activated (valve opened etc.) to start up after an accident begins, but they do not require operator actions or power for continued safety system operation. The EPR preliminary design is a combination of evolutionary and evolutionary technology safety systems. Semipassive evolutionary technology systems, such as a safety condenser, are proposed. These systems ensure reactor core cooling during many types of incidents and the most probable types of accidents that may be expected during the life of a power plant. The EPR is expected to become commercial before the Westinghouse or General Electric evolutionary technology power plants.

The plan for the development of the EPR includes the following:

- Establishment of the joint technical (conceptual) design by the end of 1992.
- Establishment of a "basic design" by the end of 1994. All documents produced up to this point will be site independent. This design is equivalent to what is considered a conceptual design in the United States.
- Selection of both demonstration sites (one in France and one in Germany) at the end of the basic design phase (i.e., the end of 1994).
- Completion of the detailed design phase between 1995 and 1998. These documents will be site specific. At the same time as this phase, the site-specific safety analysis licensing report will be prepared.

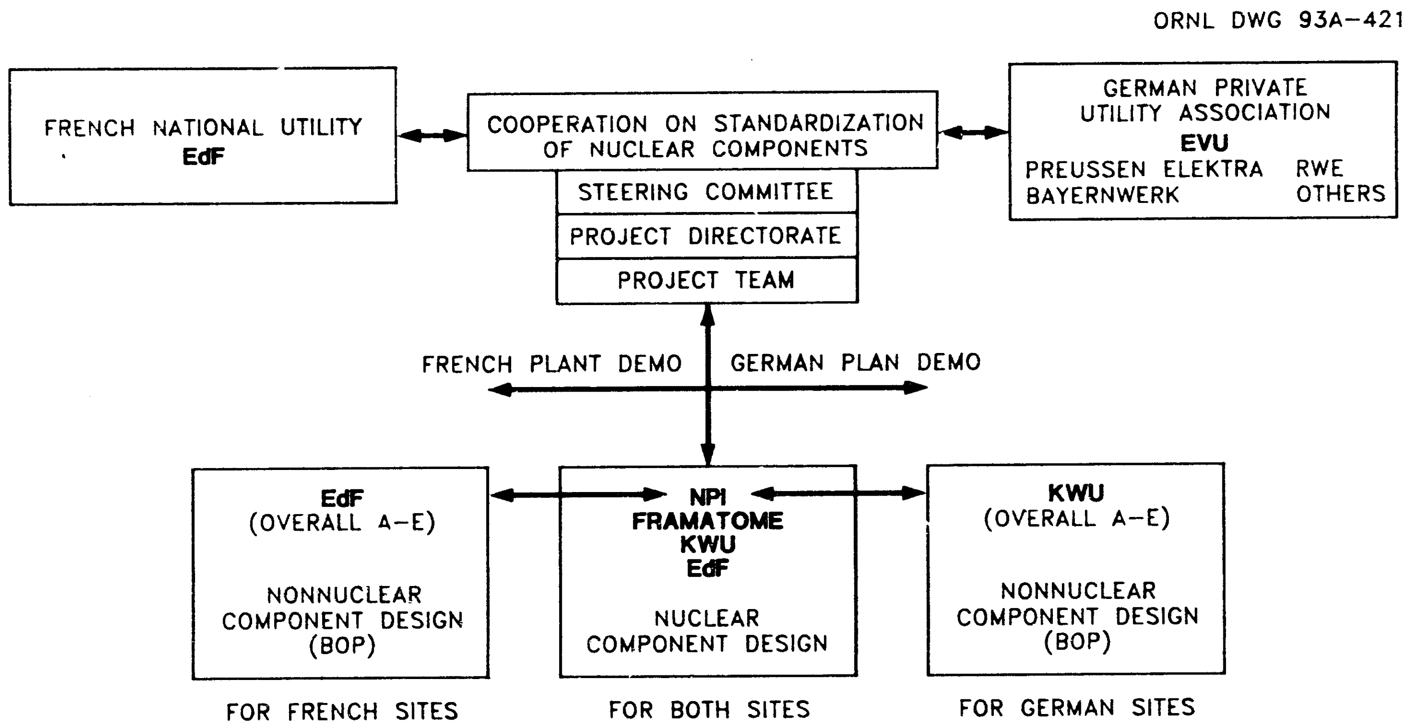

Fig. 2. Organization and working contacts for basic-design phase of NPI effort.

- Licensing applications to licensing bodies in each country will be made simultaneously in France and Germany in early 1995.

- Construction license approval is scheduled for mid-1998 with construction to start immediately in each country.

This information is shown in Fig. 3.

2.7 FUTURE EVOLUTION OF NPI

NPI may expand to include additional partners. B. J. Baumgartle, the Chief Executive Officer of NPI has stated that discussions are under way with Spanish organizations to join NPI (Forsberg 1992b). Similarly, NPI executives have had discussions with Russian manufacturers. From the perspective of NPI, additional partners make good economic sense if those partners have access to markets in which NPI would not be expected to make a commercial sale.

In this context, the development of NPI has many parallels to the formation of Airbus—the successful European manufacturer of commercial aircraft. The original Airbus partners were from France, Germany, and Great Britain, countries which have dominated European aircraft manufacturing. Other organizations were added that could provide added markets, technology, and financing to the Airbus consortium. The history of Airbus (Appendix C) suggests that similar economic forces will likely result in additional partners for NPI.

2.8 ASEA BROWN BOVERI (ABB) AND OTHER EUROPEAN VENDORS

Despite the strength of the consolidation movement led by France and Germany, there are forces that are likely to counter this economic concentration. There are a number of other suppliers in Europe, the most important of which is Asea Brown Boveri (ABB), which is a Swedish-Swiss company. ABB is the largest manufacturer of industrial equipment in the world and owner of the reactor vendor ABB-Atom in Sweden and ABB-Combustion in the United States. It is heavily involved in the South Korean nuclear program. ABB is developing several advanced reactors hence, the very real potential of further consolidation of other European suppliers with ABB as the lead organization. ABB is working with other European organizations on designs of PRIME reactors [Forsberg 1991] with totally passive safety systems to eliminate almost all dependence on reactor operators for safety. PRIME is an acronym for passive safety, resilience against operator error, inherent safety, malevolence resistance, and extended time safety. Such designs are for the generation beyond the NPI European Pressurized Water Reactor. There is also a British vendor, NNC, plus several other large nuclear power supply organizations in Italy, Belgium, and Spain.

Nor do all of the utilities in Europe want a single vendor. Competition is desired by many utilities to balance NPI. The old philosophy that each country should have its own vendor is clearly dead in Europe, but that does not imply that Europe itself will have a single vendor.

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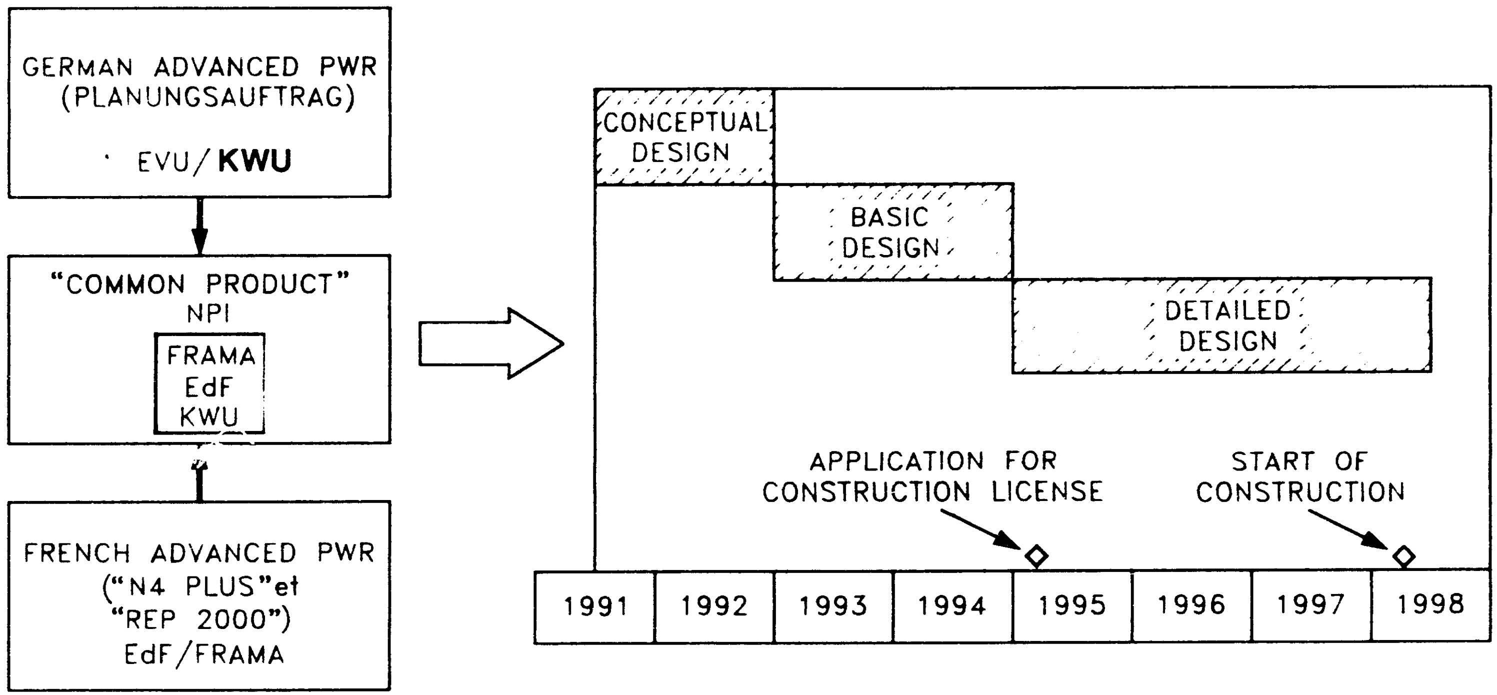

Fig. 3. Joint development of EPR by FRAMA EdF, KWU, EVU, and NPI.

3. CURRENT DIRECTION OF EUROPEAN UTILITIES

Standardization of nuclear power plant designs is often cited as necessary to minimize cost and licensing difficulties. However, standardization requires that the customers (the utilities) agree to a common set of requirements for the reactors they are going to buy. This knowledge has led to utility standardization efforts in several areas including both development of an EUR and separately but connected cooperation between French and German utilities in support of the new NPI reactor design. This section describes the current effort directed toward nuclear power plant standardization in Europe and briefly discusses the utility commitments to NPI.

3.1 EUR PROGRAM

The European utility requirements program is a joint effort by utilities in France, Germany, Belgium, Great Britain, and Spain to define a common set of utility requirements for future European nuclear power plants. It grew out of a program launched by EdF in the late 1980s [Baumgartle 1992] to define what was wanted in future power reactors by EdF, a similar effort by the Electric Power Research Institute (EPRI) in the United States, and several other related activities. In 1990, the utilities decided to work together and to draft what has become known as the EUR document [Bacher 1992]. The effort developed in this direction most likely because of the formation and development of NPI in 1989. The initial utilities in this effort were: EdF (France), Nuclear Electric (NE) (U.K.), UNESA (Spanish utilities federation), Tractebel (Belgium), and Vereinigung Deutscher Elektrizitätwerke [VDEW (an organization of German utilities)]. Italy is expected to join the EUR program, and other utilities may follow. Initially, the EUR will address only pressurized-water reactors (PWRs).

As this work evolved, it was decided that the EUR would be a three-tiered document [Bacher 1992]. The first tier will give the general requirements (similar in scope to the first tier of the EPRI requirements document developed by U.S. utilities—see below). The second tier will give the specific requirements for a particular reactor type [i.e., pressurized-water reactors (PWRs)]. The first two tiers of the EUR will minimize the differences between the EUR and the EPRI requirements [Bacher 1992]. This is being done to contribute to international harmonization of the requirements. The third tier will give the requirements specific to a particular design, which will require several volumes, one for each potential design. The first design for tier 3 will be the EPR design being developed by NPI and its partners.

One of the most important issues is that of the design and construction codes and standards. The EUR has taken a position that these will be specific, not generic. This decision reflects the policy of these European utilities not to restrict NPI's product to the European market through technical barriers and is indicative of plans for world-wide marketing. Some differences will exist however, because of differences in licensing philosophy between the Europe and the United States [Bacher 1992].

The importance of the standardization of utility requirements and of the engineering and licensing codes (see Sect. 4) cannot be overemphasized as critical to the success of the entire effort that has been launched by the NPI. Additional utilities have been invited to join in this effort. As more utilities join, the probability for success increases.

3.2 WHY AN EUR?

Multiple incentives exist for the development of an EUR. The factors important for one utility or country to support an EUR are not necessarily those of another utility or country.

- Development of an EUR provides a mechanism for utilities to work together to define what features they want in future plants to maximize plant reliability and simplify operations. This, in turn, minimizes cost. In the last several decades, many nuclear power plants have been built with many different features. Some design features have worked well; there have been operating problems with other features. Combining utility experience helps define future requirements for better operating plants. In a country such as Germany, which has 26 nuclear power plants owned by 15 different utilities (Appendix D), strong incentives exist for a cooperative effort because no single utility has sufficient experience or staff to evaluate all aspects of power plant design. This incentive is smaller for a large utility such as EdF, which has 55 operating plants and very large in-house resources.

- An EUR minimizes costs by allowing a manufacturer to develop a single product for utilities throughout Europe. Reduced product development costs, in turn, lower final product cost. From the utility's perspective, it allows the utilities to share spare parts, and inventories to reduce both capital and operating costs. For example, all utilities buy spare parts to repair their facilities when equipment fails. When multiple utilities buy the same equipment and work together, they can reduce the number of spare parts each must have on hand in the event of equipment failure. Equally important, they can afford to buy expensive replacement parts, such as turbines and large pumps. This type of equipment only occasionally fails, but the costs are sufficiently high such that spare parts cannot be justified for a single plant. This sharing of inventory is done now among utilities worldwide, but it is limited by the differences in plant designs.

- The EUR is designed to provide a mechanism for harmonization of regulations, codes, and standards in Europe. Historically, each country in Europe has had its own regulatory structure and rules. With the formation of the EEC have come strong desires to have common regulatory standards. The political controversy associated with nuclear power also creates strong forces to develop consistent regulations across Europe. The EUR is the vehicle for discussions between utilities that own the nuclear power plants and the regulators on what would be acceptable design requirements for safety for future plants across Europe.

- The EUR is a mechanism to increase the competitiveness of European suppliers worldwide. Many European utilities have long-term relationships with their suppliers and believe it is in their long-term interests that their suppliers remain competitive and prosper. Some European utilities, such as EdF, own part of their suppliers and, thus, have a direct financial interest (Appendix A). Many are partly owned by national or state governments with an interest in encouraging local industry. Historically, European suppliers have been at a disadvantage in international sales because the rules (codes and standards) were primarily written in the United States and reflected U.S. strengths. No single European country had sufficient economic power to make its codes and standards the world's codes and standards. A common set of European requirements may create a single market and a set of suppliers so large as to potentially dominate the world's nuclear power industry.

3.3 UTILITY COMMITMENTS TO NPI VS EUR DOCUMENT

Since May 1990, EdF (representing French utility interest) and EVU (a group of German utilities) have had a cooperative agreement concerning future light-water reactor (LWR) units [Baumgartle 1992] with NPI. This agreement includes reaching joint requirement specifications and promoting the harmonizing of licensing requirements in both countries and joint contracts with NPI and its parent companies as has been discussed in Sect. 2. This agreement forms the basis for the commitment of the French-German utilities to NPI. These vendor-utility activities are "separate" from EUR, focusing exclusively on what is only the third tier (NPI's EPR design) in the EUR, but the two effects are closely related because many but not all of the participants are common to both.

3.4 U.S. EPRI REQUIREMENTS DOCUMENT AND ITS RELATIONSHIP TO THE EUR

EPRI is an organization created by U.S. utilities to conduct research and other activities that jointly benefit many utilities but that no single utility could justify by itself. The EPRI, working with and for the U.S. utilities, has been creating a U.S. utility requirements document with the assistance of the major reactor vendors—as was requested by their customers, the utilities. The EPRI requirements document was started several years earlier than the EUR document and is nearing completion. The reasons for creation of the EPRI requirements document are similar to those for the EUR: (1) to combine utility experience to define requirements for future reactors, (2) to facilitate standardization of reactors for lower costs, and (3) to foster agreement between the utility industry and the U.S. regulatory organizations to what is required for future reactors.

Because EPRI is a **utility** consortium, many of its programs are cooperative efforts with foreign utilities who share costs. The EPRI requirements document program includes many foreign utility participants including National Electric Energy Agency (ENEL) of Italy, Gemeinschaftskernkraftwerk Neckar (GKN) of the Netherlands, JPC of Japan, EdF of France, UNESA of Spain, NE of the United Kingdom, Tractebel of Belgium, VDEW of Germany, and Korean Electric Power Company (KEPCO) of South Korea. It is noteworthy that all of the EUR participants are also involved in the EPRI requirements document. This has several implications:

- The EUR and the EPRI requirements documents will have much in common. In particular, all the utilities want some generally agreed-upon minimum requirements for safety for all nuclear power reactors. The utilities as a group recognize that nuclear power plant safety problems anywhere in the world can hurt their own operations.

- The joint participation provides a mechanism for utilities to discuss among themselves their long-term goals.

There are clear reasons for European utilities to support their own separate EUR although both documents will have much in common.

- European utilities wish to use European codes and standards rather than those of the United States for their reactors. This is a mechanism to integrate the European nuclear power industry.

- European utilities need to work with European nuclear power regulators in producing a requirements baseline.

- European utility goals include support of European vendors, and a U.S. document is a competitive advantage for U.S. vendors. The EPRI requirements document, for example, is being used by some small foreign utilities (Taiwan) to prepare their request for bids for new power plants.

- There have been philosophical differences in utility preferences between U.S. and European utilities.

    — European utilities have usually preferred larger power stations than have most U.S. utilities. European industry and population are more concentrated than those in the United States; thus, Europe requires a stronger, higher-capacity electrical grid. This type of electrical structure can make more efficient use of large power stations and better handle the loss of a large power plant when shut down for maintenance by transporting electricity from neighboring power plants. Similarly, the financial structure of European utilities allows easier financing of very large plants. With these conditions, larger plants are usually more economical.

- European utilities and regulators have placed greater emphasis on strong reactor containments. The containment is the building around a reactor designed to contain radioactivity in the event of an accident. This emphasis reflects the European response to the Chernobyl accident and the higher population densities that would make evacuation near a reactor more difficult in the event of an accident.

- European utilities have historically placed a greater emphasis on plant reliability. Plant reliability can be improved by addition of spare equipment and other mechanisms. Typically, this involves trade-offs between capital and operating costs, an area where the United States has historically emphasized minimization of capital costs, while Europe has emphasized minimization of operating costs.

4. REGULATOR STANDARDIZATION OF EUROPEAN ENGINEERING CODES AND NATIONAL NUCLEAR REGULATIONS FOR NPI STANDARD EPR REACTOR

Since the Chernobyl accident there has been a recognition that what happens with one country's reactors impacts the safety of the public and public acceptance in other countries. The public cannot see the reason why safety regulations should vary at different locations in the world. This has created a groundswell of opinion within much of the nuclear industry, particularly in Europe, that nuclear safety ground rules should be standardized with some required level of safety (MacLachlan, 1993). To define common safety rules used in the licensing process, opinion is growing that universal safety objectives and criteria must be developed. The possibility of an international convention to which all nations might adhere to is also being discussed [Bacher 1992]. This section discusses the European effort at standardizing the safety codes and regulations. The goal among some European players is for a cooperative European regulatory (CER) structure, which ensures safety while avoiding unnecessary differences in requirements between different countries.

4.1 REGULATOR-GOVERNMENT INTEGRATION ACTIVITIES

As a result of the standardization effort and, in particular, the NPI EPR design project, licensing authorities in France and Germany have set up a joint ad hoc working group (see Fig. 4) to define basic safety requirements for evaluating the conceptual design and, later on, verify the licensability of the basic design of the EPR. This procedure should facilitate licensing of the EPR design by both the French and German licensing authorities [NPI 1992]. This effort will require very close cooperation between the different licensing groups. Generation of the site-specific licensing information will be accomplished in parallel with the detailed-design phase.

Part of NPI's standardization (the Europeans seem to prefer the term *harmonization*) procedure is to identify each area of difference between the German and French licensing rules, evaluate the differences, and proceed in the conservative direction (i.e., design for the rule that has the most margin of safety in it). In this way NPI hopes to minimize difficulties during the licensing evaluation of the EPR. Licensing activities are focusing on the EPR because it is a concrete, definitive design that can be used to address differences in licensing requirements among European countries. At the same time, the regulators desire uniform safety requirements—if possible—across Europe that are applicable to all designs of nuclear power reactors. In addition to coordination between French and German regulatory authorities, other discussions include Belgium and British regulatory authorities. As in the development of the EUR (Sect. 3), NPI has become the driving force for the standardization of regulations.

4.2 UNRESOLVED REGULATORY ISSUES

When considering standardization of licensing regulations, one is always faced with the questions of what degree of standardization is possible and what degree is necessary? If one uses the approach described in Sect. 4.1, one can arrive at the following list of currently unresolved issues between German and French regulators that must be resolved [Baumgartle 1992] if identical power plants are to be built in Germany and France. However, this is not necessarily a complete list: these are issues for the EPR, but additional issues might be identified if other reactor designs are evaluated. It is noted that neither French nor German regulations are intrinsically more conservative. What does exist is a different emphasis in particular areas of plant safety.

4.2.1 Protection Against Aircraft Crash

In France, the licensing requirements to protect a reactor against an aircraft collision is handled through a probabilistic risk approach and is site specific. Higher levels of protection are

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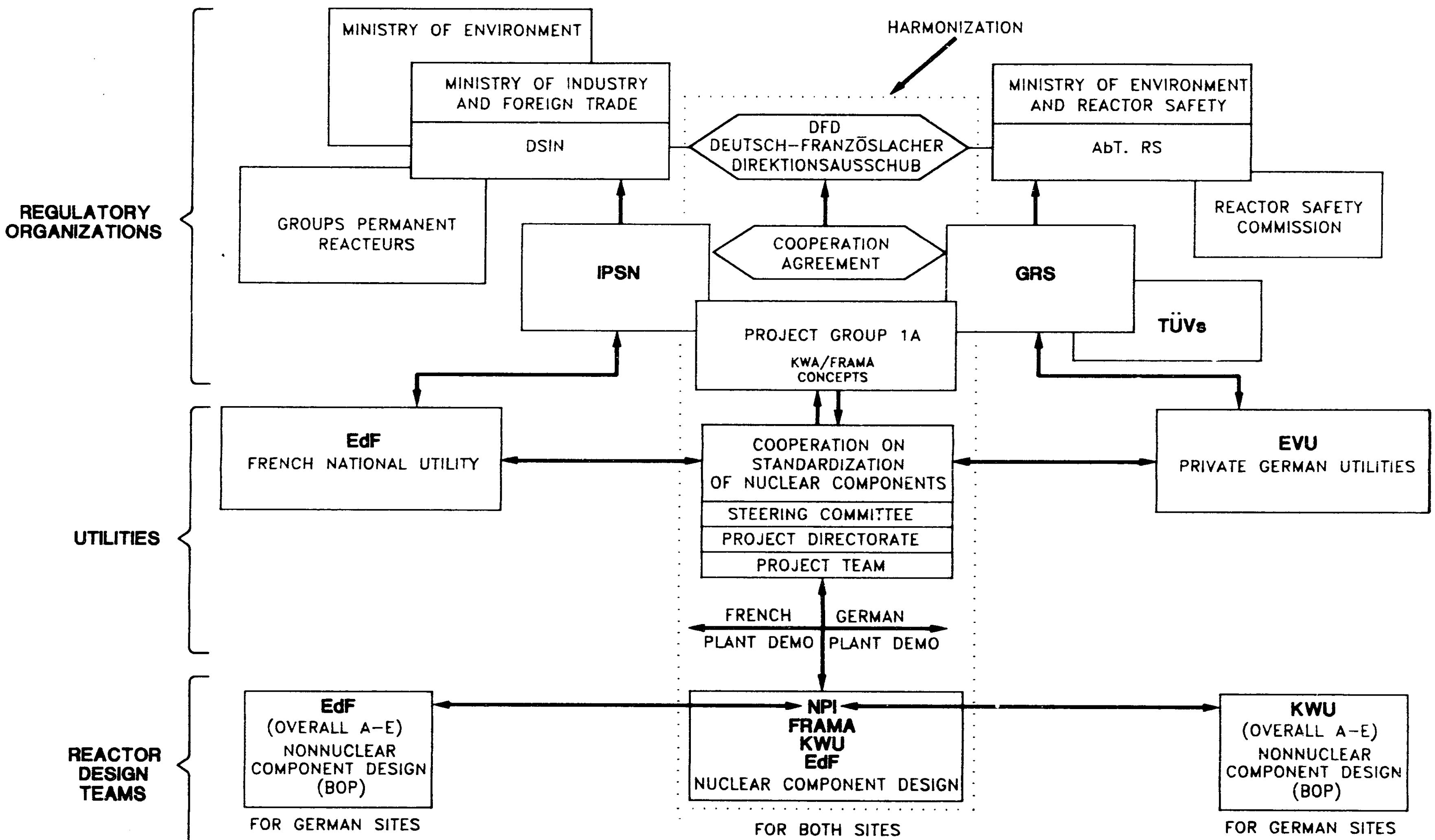

Fig. 4. Relationship of regulatory agencies, utilities, and reactor vendors in NPI standardization effort.

required near airports where the probability of a collision is higher. In Germany, a pure deterministic approach is required. German regulations require that all buildings relevant to reactor safety must be designed for large aircraft collisions no matter how low the probability of a collision. This requires significantly greater concrete and structural materials, thereby impacting the design and cost significantly.

4.2.2 Single Failure Criterion

Nuclear power safety systems are designed to operate even with the failure of some components within the safety systems. The French rule requires that, in the event of an accident, major reactor-core damage be prevented by the safety systems even if one safety system fails (single failure criteria). The German rule requires two additional systems (assumes that one safety system fails while another safety system is off-line for maintenance) beyond that needed to stop an accident. The consequence of these regulations is that safety systems have twice the duplication in Germany as in France.

4.2.3 Radiological Accident Analysis Methodology

The French assume that in a large loss of coolant accident (LOCA) all fuel rod claddings fail and assume activity release is controlled by containment leak rate. The Germans assume that less than 10% of the fuel rod claddings fail and assume activity release is controlled by leakage rate of the inner of two containments.

4.2.4 Leak Before Break Concept

In Germany, the pipe leak-before-break criterion is used as it is in the U.S. and Canada, and it is under consideration in Japan. In France, pipes with pipe-whip restraints are used based on the assumption of rapid pipe failure without leakage before failure can occur.

5. THE WHOLE EXCEEDS THE SUM OF THE PARTS

There are potentially strong synergistic effects from the individual actions by NPI, EUR, and CER that can provide a major competitive advantage, strengthen Eastern European and FSU reactor safety, and reduce domestic nuclear power concerns. If these programs are successful, their consequences could be evident by the turn of the century. These are consequences of the interactions among NPI, EUR, and CER—*not of the individual activities.*

5.1 HE WHO WRITES THE RULES HAS A COMPETITIVE ADVANTAGE

Nuclear power plants and most of the systems are designed according to certain "rules." The rules include the following: engineering standards such as those of the American Society of Mechanical Engineers (ASME) and American Nuclear Society (ANS), requirements by utilities, and regulations. Some of the rules are requirements, but many are voluntary—created by voluntary organizations (usually professional technical societies). Although some rules are voluntary, very powerful economic incentives exist to comply with all such rules:

- Many insurance companies will not insure equipment against normal risks such as fire when such rules are not followed. Others charge large premiums. The high premiums are based on insurance companies experiences that losses are higher for facilities that do not follow such rules.

- Manufacturers who sell in multiple countries build equipment to rules to maximize sales potential.

- Engineers and manufacturers design to standards to avoid the potential for lawsuits. In some areas of plant design, laws require following of standards.

- Developers of computer design codes, textbooks, and design methodologies build into their products the agreed-upon rules. It becomes very difficult and expensive to design on the basis of other rules.

Rules develop slowly, over time—often over a period of decades. Once accepted, they are often more durable than the facilities that are designed according to such rules. Rules are based on experience—particularly failures where experience dictates certain safety factors or approaches to avoid failures.

In the commercial nuclear power business, most of the rules were written in the United States, but these rules have aged. Nuclear power was first developed in the United States in the 1950s through the early 1970s. This, combined with the fact that the Unites States was the dominant economic power in the world, resulted in U.S. rules becoming defacto world rules. The lack of nuclear power plant orders in the United States for over 15 years, the domestic orientation of U.S. government regulatory agencies (MacLachlan 1993), and the smaller relative size of the U.S. economy as a fraction of the world economy have resulted in these rules becoming slowly less applicable. Two examples can clarify how this occurs. The early control systems for nuclear power plants (and all other industrial facilities) used analog control systems. The tremendous developments in digital computer systems have resulted in new industrial facilities using computerized digital control systems. The rules for analog control systems are primarily of interest in maintenance of old facilities. Similarly, improved knowledge of accident phenomena has changed our understanding of what is needed to prevent accidents and contain radioactivity in the event of an accident. U.S. regulatory agencies, where appropriate, have required backfit of safety devices, but rules for backfit of safety devices may not be the optimum rules for new facilities where the design is not constrained by existing equipment.

Writing the rules is a major competitive advantage. To solve any engineering problem, multiple approaches are often available. For example, bridges can be built out of steel or concrete. If it is specified that a concrete bridge is required, those companies with experience in concrete will have a definite advantage. The choice of measurement system (metric or English), testing methods, and numerous other factors also provide competitive advantages.

If Europe can successfully launch NPI, EUR, and CER, European rules will dominate all of Europe and may become the new defacto world rules. The impact of Europe in terms of rules has been historically small to date because there was not a single set of European rules. There were instead French, German, British, Italian, and other rules. A modern, international set of rules would likely be adopted by smaller countries throughout the world that do not have the resources to develop their own rules.

5.2 EUROPEAN-WIDE RULES TO IMPROVE EASTERN EUROPEAN AND FSU REACTOR SAFETY IN THE MID AND LONG TERM

Historically, each country has set its own nuclear power safety standards, but the Three Mile Island and Chernobyl nuclear power plant accidents have raised doubts about this approach. A nuclear power accident anywhere has profound impacts on the worldwide industry. Attempts to influence other countries to adopt particular rules have been slow because there have not been universally accepted rules.

If Europe develops common rules for nuclear power, it will result in very large political, economic, and professional pressures for Eastern Europe and the FSU to adopt these rules.

- As long as each country has its own rules, it is politically difficult to suggest that a second country adopt a particular set of rules. If multiple countries have the same rules, the need for different "national" rules because of local national conditions becomes much harder to justify.
- Some Eastern European and FSU countries desire to be part of the EEC. That will require following European rules.
- With common rules, economic forces strongly encourage countries to follow such rules (see Sect. 5.1). International joint ventures, export sales, and cooperative programs will demand conforming to international rules.
- Professional interactions among the engineering profession encourage such rules via textbooks, international meetings, and international recognition.
- The International Atomic Energy Agency and other international bodies are likely to concur with such rules, given the number of European nations associated with these organizations.

5.3 EUROPEAN-WIDE RULES REDUCE DOMESTIC CONCERNS

If European-wide rules for nuclear power can be agreed to, the agreement may reduce domestic nuclear power concerns by the following mechanisms:

- Improve the safety of Eastern European and FSU nuclear power reactors.
- Develop a mechanism to identify "good"-vs-"poor" nuclear power plants and, hence, a mechanism to "discount" accidents in countries that do not follow such rules.
- Eliminate cross comparisons of who has the best or worst rules.
- Provide visible evidence of addressing public concerns about reactors in neighboring countries.
- Provide a set of European-wide institutional structures which support nuclear power across Europe. Nuclear power in some countries—particularly Germany—is extremely controversial. European-wide institutions can dampen the

wide swings in policies through long-term agreements and interdependencies.

6. CONCLUSIONS: UNITED WE STAND

Starting about 1990, several European countries, private and government-owned companies, and other organizations began a series of activities to restructure commercial nuclear power in Europe. The success or failure of these efforts will not be known for five or six years, but the potential exists to create European rules that become de facto world rules for nuclear power. This is an evolutionary process. It does not appear that when these efforts were initiated that the participants fully recognized the implications of their actions. This understanding is changing in time as is evident by the changing perspective of key individuals associated with these activities.

Besides country-specific domestic impacts, there are two potential, tightly coupled worldwide impacts: (1) improved competitiveness of European nuclear reactor vendors and (2) improved safety of Eastern Europe and FSU nuclear power plants. For the United States and other countries outside Europe, the dual nature of these activities have advantages (safety) and disadvantages (competitiveness). The key issue for non-European countries is whether they should they become actively involved in developing such rules and, if so, how can rules be developed and accepted that aid safety without strongly biasing international competition? For the United States, these issues will be particularly difficult to address because both industrial groups and government organizations have operated historically in an environment where the United States wrote the rules. For countries outside western Europe and the United States, the changing conditions may create new options that did not previously exist—use of either U.S. or European rules.

Finally, these changes, in many aspects, parallel early developments of Airbus. Airbus (Appendix C) is the successful joint European venture to create a competitive European world-class vendor of aircraft. The existence of Airbus provides strong support of what can be accomplished by multinational, joint public, and private European high-technology programs. The history of Airbus also shows a history of dead ends, false starts, and changing governments and private partners before a stable, successful cooperative enterprise was forged. Similar events are likely in the area of commercial nuclear power. However, there are no guarantees of success.

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Appendix A: PLAYERS ON THE FRENCH SIDE OF THE NPI JOINT VENTURE: FRAMATOME, EDF, CEA, ALCATEL-ALSTHOM, DUMEZ SA, AND PECHINEY

A.1 INTRODUCTION

From a broad perspective, there are four major players in the French nuclear program. The CEA is the French government atomic energy agency and is responsible for all long-term nuclear power research. EdF is the national utility that owns and operates the nuclear power plants. Cogema is the French fuel cycle company responsible for all parts of the nuclear fuel cycle from mining through reprocessing. It is the wholly owned subsidiary of CEA through CEA Industrie and, hence, is indirectly government owned. Framatome is the French reactor vendor that is partly government and partly privately owned, but it is operated as a commercial company.

In addition to the major players, there are many midsize players in the nuclear industry, such as Pechiney, which is typical of these organizations. Pechiney is a large aluminum and specialty-metal company with several midsize subsidiaries that provide special materials, such as fuel element cladding, to the French nuclear program. There are also many specialty companies that are subsidiaries of one or more of the major players. Many of these include both public and private ownership.

The structure of the French side of the NPI ownership is shown in Fig. 1 (Sect. 2). As can be seen, this structure is quite complicated because of several facts. First, Framatome is owned by four companies: EdF (10%); Alcatel-Alsthom, formerly CGE (40%); CEA (35%), and Dumez SA (12%)—with 3% being held by Framatome employees. Second, although EdF has only 10% ownership, it represents the French government as does CEA with its 35% ownership. Third, EdF—the French utility—is the primary French customer for the NPI product. These facts imply that EdF has a great deal more say in the direction of the NPI product line than might normally be expected.

With this information as background, we will look at each of these companies, starting with Framatome. In addition, we will look also at Pechiney, which, although it does not own a portion of Framatome, is the other significant French player.

A.2 FRAMATOME

On reactor projects, Framatome has the scope of a U.S. reactor vendor [i.e., Westinghouse or General Electric Company (GE)]. This involves the design and fabrication of the nuclear steam supply system (NSSS) components including the fuel, core, core support, and reactor pressure vessel. Framatome is not responsible for design and construction of the conventional side of nuclear power plant projects. However, because of the way the nuclear business has developed, Framatome is involved in various nuclear and fuel services just as are its U.S. counterparts. This involvement is shown in Table A.1, which describes the structure of the Framatome nuclear companies. The Framatome group had a 1991 revenue of 14.17 billion French francs (9.35 billion of which was from nuclear enterprises) and total employees of 14,389 (4604 of this assigned nuclear work) (Framatome 1991).

As can be seen in Fig A.1, many French companies are owned jointly by the principal nuclear companies involved. The principal companies on the French side, in addition to Framatome and CEA (through its Cogema subsidiary), are Pechiney (which, in its nuclear efforts, is primarily a distributor of fuels, ores, metals and materials, and a manufacturer of fuel and cladding and uranium hexafluoride feed for uranium enrichment) and the U.S. reactor vendor Babcock and Wilcox (B&W).

Those subsidiaries involved in the Framatome/NPI scope include

- Fbfc (Pechiney, Framatome, and Cogema)—fuel fabrication;
- Fragema (Framatome, Cogema)—fuel marketing and sales;

Table A.1. Framatome SA, nuclear portion—only the players

Company	% ownership by government controlled companies			Comments
	Framatome	Cogema*	EdF	
Framatome	N/A	36%	10%	Other owners: 40% Alcatel-Alsthom (formerly CGE) 12% Dumez SA 3% Employees of Framatome Framatome SA, nuclear portion only Revenue—9.35 billion FFR (66% of total) Employees—4604 (32% of total)
Domestic French companies partially controlled by Framatome				
FBFC	25%	25%		(50% Pechiney) Manufactures light-water reactor (LWR) fuel assemblies; 1991 throughput 1700 metric tons of uranium per year.
Framex SA	100%			Performs nuclear maintenance operations in Belgium, Korea, Sweden, and South Africa.
Zircotube	49%			Jointly owned (Pechiney 51%), manufactures alloy cladding and guide thimbles for reactor fuel assemblies, 4000 km/year throughput.
Fragema	50%	50%		Marketing and sales of reloads manufactured by FBFC
Celtic Maintenance, Training, and Qualification Center	50%	50%		Company provides training and procedure qualification for French nuclear power plants.
Cerca	50%			Designs, markets, and manufacturers research reactor fuel.
Samanu	34%			Jointly owned (unknown 50%), services electromechanical equipment from nuclear plants
Cemo Maintenance Tool and Equipment Upkeep Storage Center				(100% ownership not clear), decontamination, service, and repair materials used in plants.

Table A.1. Framatome SA, nuclear portion—only the players (continued)

Company	% ownership by government controlled companies			Comments
	Framatome	Cogema*	EdF	
Melox Company	50%	50%		MOX fuel production for LWR reloads, currently in construction, 120 MT MOX/year planned throughput.
International companies partly controlled by Framatome				
NPI	50%			Half owned by Siemens Power Generation Group (KWU), to design, market, and build next generation of PWRs (called EPRs) in France, Germany, and perhaps the rest of Europe. See Fig.1 for further details.
B&W Nuclear Service Company (BWNSC)	100%			U.S. Jointly owned (25% B&W), provides nuclear services to U.S. LWR operators including Robotic arm, Cobra.
Framatome U.S.A. Inc.	100%			U.S. Scope of operations unknown.
B&W Nuclear Technologies (B&WNT)	100%			U.S. (Formerly Framatome Services, Inc.) United States owned, provides nuclear technologies to U.S. companies.
CONAM Nuclear Inc.	75%			U.S. 100% BWNSC owned (25% B&W), scope of operations unknown.
Lynchburg Fuels, Inc.	80%			U.S. Jointly owned (20% B&W ownership not clear), scope of operations unknown.
B&W Fuel Company (B&WFC)	30%	30%		U.S. Nuclear fuel supplier (other owners: 25% B&W, 20% Uranium Pechiney)
Virginia Fuels, Inc.	40%	40%		U.S. Jointly owned (20% Pechiney)
Fbfc International SA	100%			Belgium. Assumed scope is fuel fabrication (same as Fbfc in France).

*Owned by CEA industries. CEA Industries is the commercial arm of CEA. CEA Industries owns stock directly in many companies including Framatome. Cogema is the fully owned fuel cycle subsidiary of CEA Industries.

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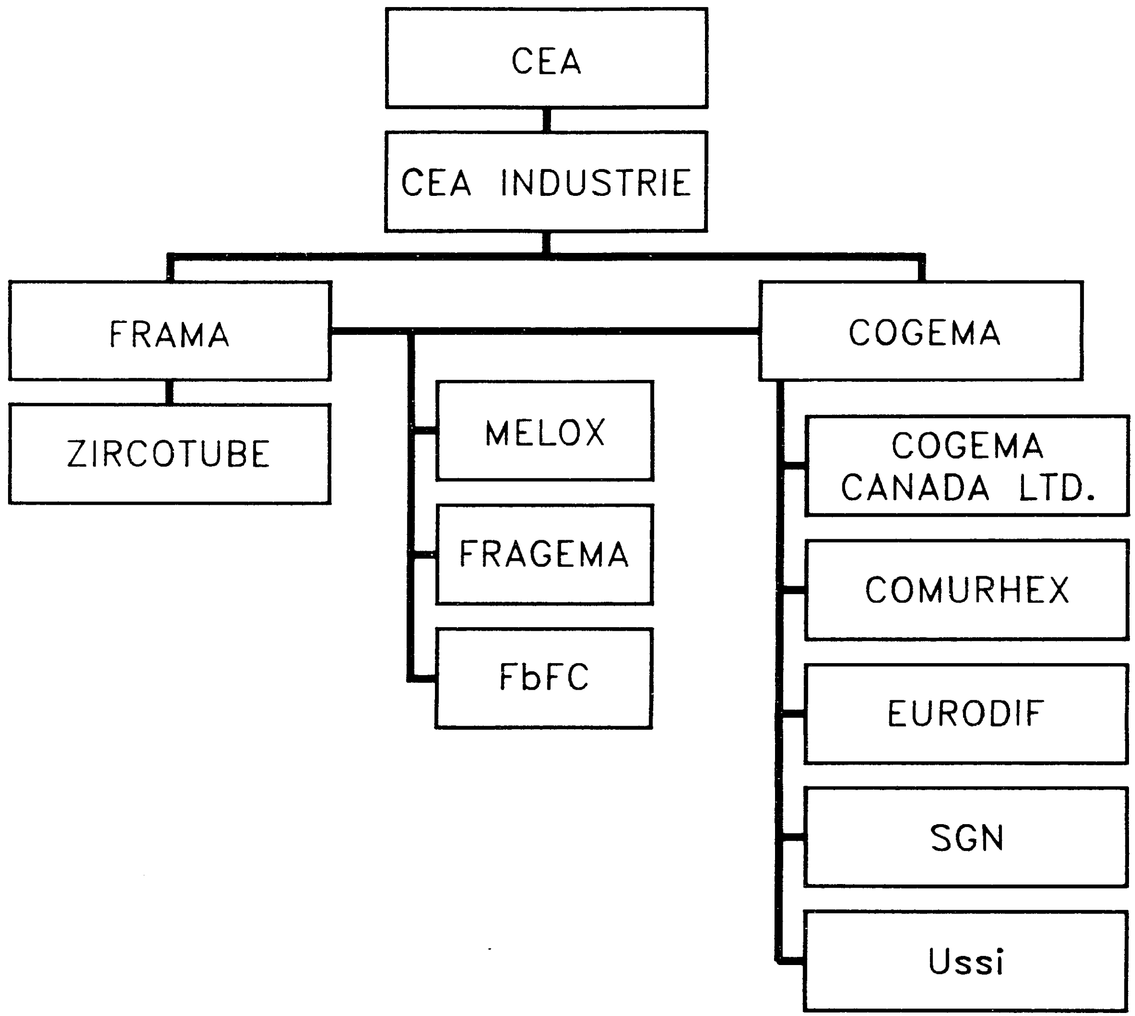

Fig. A.1. CEA Industrie nuclear companies.

- Melox (Framatome, Cogema)—mixed-oxide (MOX) fuel for LWR reloads, currently in construction;
- Zircotube (Framatome, Pechiney)—manufactures alloy cladding;
- The family of B&W companies (mostly jointly owned by Framatome/B&W in both France and the United States);
- Virginia Fuels, Inc. (Framatome, Cogema, Pechiney); and
- Framatome U.S.A. Incorporated, wholly owned by Framatome.

In addition to the previously listed companies, Framatome, through its NPI partnership with Siemens, will have a 10% participation in Skoda-Energo (SKODA), the Czech company, assuming that the currently announced agreement is successfully completed (Framatome 1991). Skoda is the Czech reactor vendor that builds most of the power reactors in Eastern Europe. Siemens plans to buy controlling interest in Skoda.

Framatome has been responsible for the design and construction of NSSS for most of the nuclear power plants built in France and for some built in other countries (e.g., seven units in Belgium, South Africa, and Korea, and two under construction in China). Its experience incudes also maintenance, modernization, and rehabilitation services internationally. Thus, Framatome brings a strong presence to NPI for the NSS scope of the NPI plants.

A.3 EdF

EdF, the national utility of France, generates almost all electricity the for France. It is the operating utility in France from a generation of power standpoint. In 1991 EdF generated 400 billion kWh(t) annually (with 70% being generated from nuclear power) and had a 1991 revenue equivalent to 30 billion U.S. dollars [EdF 1991]. Because of its size and influence, EdF is believed to be the real power behind the French side of the NPI combine.

In addition to this role, EdF has acted as the overall architect-engineer (A-E) for most of the nuclear projects for which it has contracted. In addition, it has developed special areas of expertise in the balance of plant (BOP) design area. EdF has responsibility for these areas at NPI. These include containment design and control room layout.

A.4 CEA

The CEA is the atomic energy agency of France; it is involved in research and development (R&D) through its functional and operational divisions and its research centers. It is also involved in commercial ventures through its industrial arm, CEA Industrie. From a standpoint of the NPI collaboration, it is this arm of the CEA that is of interest. Its Cogema subsidiary is the focus of its nuclear efforts. The French and foreign Cogema companies perform all the activities in the nuclear fuel cycle, from prospecting and mining through ore concentration, uranium conversion, uranium enrichment, the fabrication of fuel elements, and spent fuel reprocessing. In 1991, Cogema had a revenue of 21,700 M francs (CEA 1991).

The structure of the CEA Industrie nuclear arm is shown in Fig. A.1. Note that near the top of the figure the jointly owned companies of Framatome and Cogema are shown; these include FRAGEMA, FBFC, and Melox. Note also that the partial ownership of Framatome by CEA is depicted and that Zircotube, which is a subsidiary of Framatome and Pechiney, is shown for that reason. In addition, the uranium hexafluoride feed plant (Comurhex) and the uranium enrichment plants (Eurodif) are shown. Finally, near the bottom of the figure are the two French engineering firms, SGN and Ussi, which form the design and construction backbone for the Cogema companies. SGN has been the prime contractor for many of Cogema's jobs, including the U3 reprocessing plant at La Hague. Ussi is currently a prime contractor for the Melox plant.

The companies shown in Fig. A.1 form a complete set of experience and capabilities for reactor projects and their fuel cycle requirements. The Cogema mining companies, number of foreign ventures, have not been shown on this figure.

A.5 ALCATEL-ALSTHOM (FORMERLY CGE)

CGE, a former French government-owned company, became a private corporation in 1987. By January 1991, CGE had consolidated its core businesses and made this known by changing its name to Alcatel-Alsthom, reflecting their increased holdings in the two companies Alcatel and Alsthom. Alcatel-Alsthom is a leading French and European telecommunications company. It also manufactures and supplies electrical equipment to utilities. It is the second largest telecommunications company and the second largest manufacturer of energy generation and transmission equipment in the world with these two divisions sharing over 78% of total corporate sales (ACL 1990). In addition, Alcatel-Alsthom has announced its intent to work with the French government to provide industrial management for Framatome.

A.6 DUMEZ SA

Dumez SA is a varied company. Among other business ventures, it provides wholesale distribution of nuclear energy, construction, and engineering services. It holds 12% of Framatome stock. Its 1991 sales were 5.2 billion dollars. It has 30,000 employees [Dialog 1993].

A.7 PECHINEY

Pechiney, a worldwide company, is involved in five main areas: packaging (mainly aluminum cans), aluminum, engineered products, and related industrial activities. The nuclear portion of its business is contained in the latter area: nuclear fuel fabrication, manufacturing of Zircalloy cladding, and preparation of uranium hexafluoride feed for uranium enrichment. the companies that Pechiney owns jointly that accomplish these tasks are FBFC (Pechiney 50%, Framatome 25%, and Cogema 25%); Zircotube (Pechiney 51%, Framatome 49%); Comurhex (Pechiney 51%, Cogema 49%); and outside France, the B&W Fuel Partnership (Pechiney 15%, Framatome 30%, Cogema 30%, and B&W 25%) [Cogema 1991].

Appendix B: PLAYERS ON THE GERMAN SIDE OF THE NPI JOINT VENTURE: SIEMENS AG AND ITS NUCLEAR SUBSIDIARY POWER GENERATION GROUP (KWU) AND SIEMENS NUCLEAR POWER CORPORATION (SNPC)

B.1 INTRODUCTION

The structure of the German side of the NPI ownership is shown in Fig. B.1 and Table B.1. As can be seen, it is less complicated than that for the French side. The Nuclear Subsidiary Power Generation Group (KWU)—called KWU in this report—is the active partner in NPI for Siemens AG. Its parent corporation is a wholly owned private corporation. This results in Germany having a single owner compared with four owners on the French side. Germany has fewer players than the French (see Fig. A.1 and Table A.1).

B.2 SIEMENS AG

Siemens was established in 1847 as a general partnership under the name of Telegraphen-Báu-Anstalt Siemens and Halske. By 1897 it was converted into a joint stock corporation. In 1903, the power operations were transferred and merged with Elektrizitats AG and became Siemens Schuckert Werke, of which the company became sole shareholder in 1939. In 1966, the company absorbed Siemens Schuckert Werke and another subsidiary, Siemens Reinigerwerke and changed its name to the present name—Siemens AG [Extel 1992].

Siemens AG is a worldwide corporation with annual sales in 1991 of 70 billion DM and 402,000 employees [Siemens 1991]. Sales in Europe represented about three-quarters of this total. The company is involved in many different activities and, consistent with the coming of the single European market, is working on strengthening its presence in Great Britain and France and becoming a presence in Eastern Europe. Through its subsidiaries, Siemens AG provides a complete range of power generating equipment (nuclear, fossil, etc.)

The focus for this appendix is Siemens AG's nuclear business which is accomplished primarily by its subsidiary, KWU, which is made up of the former Kraftwerke Union company. This group had an annual sales of 5-billion DM in 1991, about 7% of the Siemens AG total (Siemens 1991). About two-thirds of KWU's sales volume comes from outside of Germany (Siemens 1991). Other portions of its nuclear business are presented below.

Figure B.1 shows the organizational structure of the nuclear portion of Siemens AG. It is made up of major and minor players. The major players are KWU and SNPC, which is primarily made up of the former Exxon Nuclear Fuel Corporation and serves the U.S. market. The minor players are several companies that have listed nuclear engineering or power equipment in their descriptions. These include Siemens Beteiligungen AG (Switzerland), Siemens SA (France), Siemens SA (Belgium), Siemens S.P.A. (Italy). Very little information was found that described the extent to which these minor players have been involved in Siemens AG nuclear business. It appears that Siemens AG conducts its European nuclear business through KWU. But this was deduced from the information found. No statements were found to this effect. The major players are discussed below.

B.3 KWU

Kraftwerke Union came to Siemens AG from a history of being an old-line German engineering company with a reputation for engineering excellence. It offered both fossil (coal and natural gas) and nuclear power plants as well as other products. It entered the nuclear business in the early days and established a good reputation in this field. Subsequently, several years ago, it was absorbed by Siemens AG and became an integrated part of the parent company (rather than a subsidiary). Its 1991 revenue was 5-billion DM [Siemens 1991].

KWU is expanding in both the fossil and nuclear areas. In the nuclear area, KWU has the combined scope of an NSSS vendor and an architect-engineer in the United States. This

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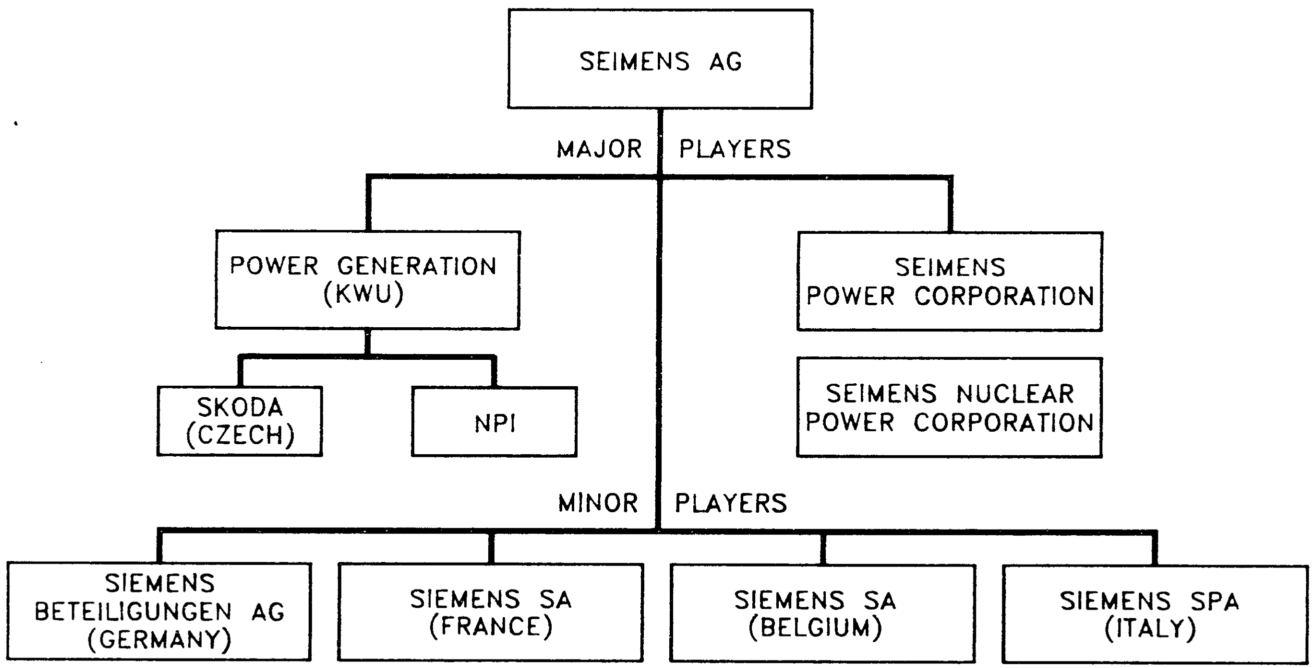

Fig. B.1. Organizational structure of the nuclear portion of Siemens AG.

Table B.1. Siemens AG, nuclear portion only and the European players

Company	Country
Power generation (KWU)	
Currently negotiating joint venture with Skoda (Czech) covering all of power field	
Partner in NPI—developing a reactor for market	
Complete range of power-generating capabilities	
Siemens Power Corporation	
Siemens Nuclear Power Corporation	United States
Siemens Nuclear Power Services	
Siemens Beteiligungen AG	Switzerland
Siemens PLC	U.K.
Siemens Nederland N.V.	
Siemens Elema AB	Sweden
Siemens-Gruppen i Severige	Sweden
Siemens SA	France
Siemens SA	Belgium
Siemens S.P.A.	Italy

means that it designs and constructs both the reactor vessel and internals (including the fuel) and the balance of the plant (BOP).

KWU became a partner in NPI 1989 and is shortly expected to become the majority partner in Skoda, which is the Czech reactor vendor that has manufactured parts for or built most of the nuclear power plants in Eastern Europe. Skoda covers the entire range of power generation. It would appear then that the KWU (and Framatome—also a partner) intends to use Skoda as a way to open the Eastern Europe and Soviet markets to its products.

B.4 SNPC

Siemens Nuclear Power Companies (SNPC) provides initial and reload fuel and reactor services to the U.S. market. This company was formerly the Exxon Nuclear Corporation, a fabricator of nuclear fuel in the United States and Germany. Its reactor services work uses the extensive experience of KWU in reactor and power plant design and services (Sol 1991). SNPC supplies these services to both BWRs and PWRs. SNPC is also involved in R&D to improve fuel performance and reactor services technology (Sol 1991). In 1991 its revenue was 200 million dollars (Sol 1991), and they employed about 1000 people.

Appendix C: AIRBUS INDUSTRIES

Airbus Industrie (AI) is a large European international partnership of aerospace companies and governments with a common objective of designing, constructing, and marketing big commercial passenger jets in a worldwide marketplace (Intyre 1992, Gunston 1988). From its beginnings in the mid 1960s, Airbus has continued to grow and is now recognized as a world leader in the aerospace business with its shares of commercial airliner sales second only to the U.S. firm, Boeing.

The prime shareholders of AI are Aérospatiale of France, Deutsche Airbus of Germany, CASA of Spain, and British Aerospace of the United Kingdom, and about 2000 smaller companies from 39 different countries. Aérospatial and CASA are controlled by the national governments. Deutshe Airbus and British Aerospace are private corporations.

The primary reason for the creation of a European aerospace consortium was a realization of the growing European market for large commercial airliners. In addition, the Europeans recognized that the United States had almost completely dominated the worldwide aviation market for years and would be the only available manufacturer to meet the growing European market. The European governments also recognized that no single country could hope to compete with the well-established U.S. giants—Boeing, McDonnell Douglas, and Lockheed.

To enter this large market and provide some competition in the aerospace marketplace, the French, German, and British governments and their respective aerospace industries began discussions about a partnership to design a European Airbus. Discussions began in the mid-1960s and continued for years before finally arriving at production. After the first 10 years, the new consortium, Airbus Industrie, had sold only a few dozen planes. Its introduction into the marketplace was difficult, costly, and poorly received by many. But as a few customers ventured to try the airbuses, the products sold themselves. The AI airbuses consistently set new world records for quality, reliability, operating economy, and safety. The history of the development of AI is shown chronologically in Table C.1. As the table shows, there were a number of false starts, changing partners, and other problem areas during the earlier years, but the consortium continued to struggle, never losing sight of the ultimate objective of becoming one of the greatest aerospace manufacturers in history. Figure C.1 shows the current structure of AI (Gunston 1988).

This report describes the development of another European consortium, NPI, that is still in the early stages of development. The parallels between NPI and AI are striking. Both ventures started out as a partnership between German and French companies. Both ventures enjoy the support of their respective governments and involve additional support from other European countries. Airbus has been an extremely successful venture that has made the Europeans a major force in the commercial aircraft industry. NPI appears to have the same potential to become a major influential force in the worldwide nuclear industry.

Table C.1. Chronological development of the Airbus consortium

Date	Significant events in Airbus consortium development
May 1965	A Memo of Understanding (MOU) is signed between British and French aerospace industries to build conventional-wing strike fighters/trainers, variable-geometry fighters and to perform a design study of an airbus concept. Companies involved are BAC, Hawker Siddeley, Short Brothers & Har'and (all from the U.K.) and Sud Aviation, and Generale Aeronautique Marcel Dassault (both French).
June 1965	Appearance of the Soviet Antonov An-22 military cargo transport at the Paris Air Show prompts a renewed interest by European airframe manufacturers to produce a civil airbus after Russia discloses the development of a modified An-22 for civil use with a capacity of 700 passengers. This sparks a flurry of Western activity in Europe, Canada, and the United States.
December 1965	Issuance of the 139-page Plowden Report by a British committee studying the British aerospace industry. The industry is described as troubled, but the report also presented six major policy recommendations including a comprehensive European collaboration on future aircraft projects, sustained drive to increase exports, and extensive government financial involvement in airframe companies
October 1966	The British, French, and German governments develop a three-nation economic and technical report on a potential European Airbus Project.
November 1966	Delays in deciding which aircraft design to build and other disagreements cause Britain to announce that it may produce its own BAC 111 design and withdraw from the Airbus project.
May 1967	Continued meetings about Airbus among Britain, France, and Germany yield some progress on a tripartite venture but disagreements about engine manufacturer and other criteria result in project delays. Britain wants to use its engine design while other participants prefer American designs.
July 1967	Tripartite study group submit report to the three-member nations on the prospects for joint development of an airbus. Tentative approval of the consortium is agreed upon in a MOU. The use of British engines is considered likely.
September 1967	United Kingdom, Federal Republic of Germany, and the French Republic sign an intergovernmental agreement on September 26, 1967, to develop and market the Airbus A300B medium-range civil transport aircraft. Prime contractors are Sud Aviation (France) for the airframe, Rolls-Royce (United Kingdom) for the engines, and Hawker Siddeley Aviation (United Kingdom) and Deutsche Airbus (Germany) as supporting firms. Financial interests are 37.5 % French, 37.5% British, and 25% German. This agreement officially launched Airbus International SA as an aircraft manufacturer headquartered in Paris, France.

Table C.1. Chronological development of the Airbus Consortium (continued)

Date	Significant events in Airbus consortium development
November 1968	France launches an alternate study to construct a smaller airbus design after continued design studies and negotiations result in disagreements among the member countries. France states its commitment to the airbus concept even if the British should pull out. At this point, the project has struggled along for 3.5 years with numerous setbacks and disagreements.
March 1969	Britain formally withdraws from the Airbus Consortium. This is considered by many to be the darkest chapter in the history of Airbus. Many factors contributed to this withdrawal including the slow pace at which customers were coming forward, the failure of Rolls-Royce to produce an engine for Airbus, and the British loss of political prestige because France was considered the project leader (a role that the British wanted to hold).
June 1969	France and Germany sign a $400 million agreement to move ahead quickly with construction of the A300B without British government support. Even so, the British firm Hawker Siddeley is still one of the three major manufacturing companies involved. Others include Sud Aviation and Deutsche Airbus GmbH. The once tripartite arrangement has now turned primarily into a bilateral one between France and Germany.
January 1970	Sud Aviation joins other groups to form the giant called Aérospatiale. Work continued to define the management structure of the Airbus Consortium.
December 1971	A new partner, CASA of Spain, joins Airbus Industrie (AI). AI is the name given to the growing international aerospace consortium.
January 1972	AI expands to 120,000 employees with assets of £752 million. The customer base continues to rise, ever so slowly, over the next 6 years.
Mid-1972	Engine design teams are forced to look to the United States for an engine after Rolls-Royce fails to produce one. The GE CF6-50A is chosen finally with design integration from McDonnell Douglas (both U.S. firms) and two European companies (SNECMA and MTU). Later, the GE CF6-80 will be used on newer Airbus designs.
June 1973	The first three prototype airbuses are flown on June 28, 1973. The tests are successful; few minor or no major problems detected.
March 1974	French and German regulatory agencies award final design certification to AI for its Airbus design on March 15, 1974. U.S. Federal Aviation Administration (FAA) certification followed shortly.
May 1974	At entry to service, the entire AI program is on time and on cost. The first commercial use of an AI Airbus occurs this month with service from Paris to London with 250 passengers.

Table C.1. Chronological development of the Airbus Consortium (continued)

Date	Significant events in Airbus consortium development
January 1979	After a long year of negotiating for partnership, the British government and aerospace industry decide that becoming a member of AI is in the U.K.'s best interest. The agreement (with shareholdings shown) is finalized among Aérospatiale (37.9%), Deutsche Airbus (37.9%), British Aerospace (20.0%), and CASA (4.2%).
1980–1988	Sales of the AI Airbus start to grow rapidly as continued operation of the European Airbus proves its ability to compete with the U.S. giants, Boeing and McDonnell Douglas. By 1986, the accumulated funding for AI from all sources is $2.36 billion.
Mid-1988	AI exceeds McDonnell Douglas in worldwide market share of airliner orders.
1990	AI has over double the market share (36%) of worldwide airliner orders compared to McDonnell Douglas (17%) and has came close to Boeing's share (47%).
Today	AI remains an extremely successful joint European venture among Aérospatiale of France, Deutsche Airbus of Germany, CASA of Spain and British Aerospace of the UK, and about 2000 smaller companies from 39 different countries. A number of innovative Airbus designs have been manufactured since the original A300B. The latest design, the A321, has received 153 firm orders from 11 airlines around the world. All AI Airbus models combined have sold 1800 airbuses as of March 1993.

Sources: *Aviat Week Space Technol.*, dated May 24, 1965 (pg 18), Nov 7, 1966 (pg 47), May 15, 1967 (pg 31), July 31, 1967 (pg 25), April 8, 1968 (pg 34), Nov 8, 1968 (pg 25), and May 2, 1969 (pg 165); *The Engineer* 1965; Davies 1966; *New York Times* May 11, 1967; Giusta 1969; Jeffs 1969; and Davis 1993.

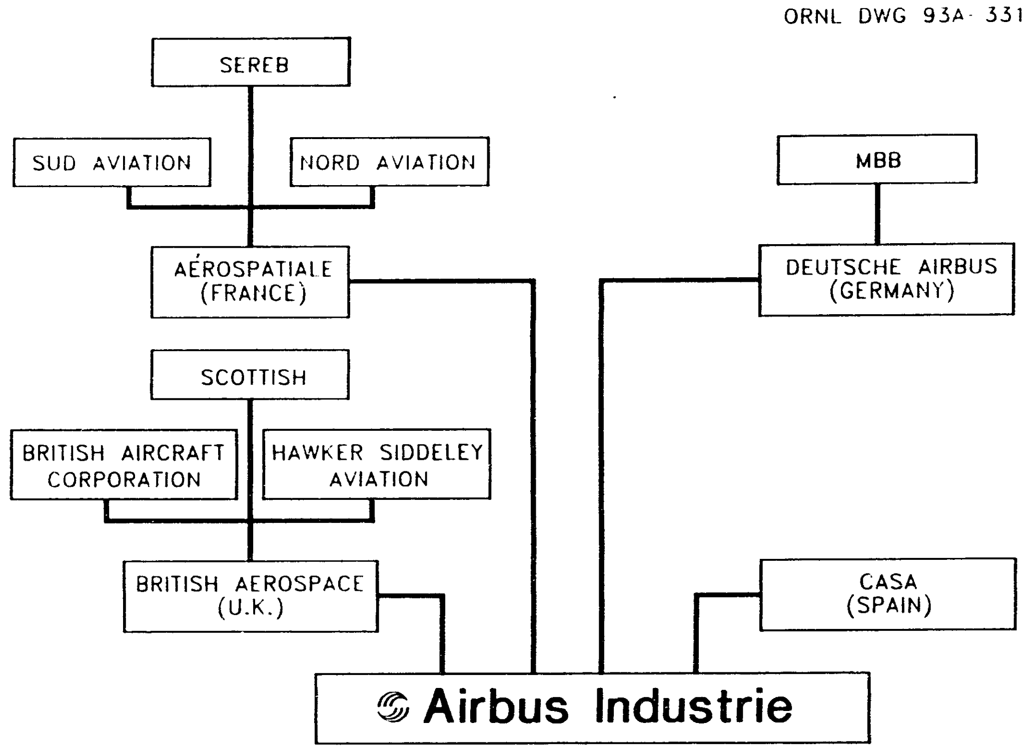

Fig. C.1. The basic organizational structure of Airbus Industrie's main shareholders.

Appendix D:
ELECTRIC UTILITIES IN EUROPE

This appendix briefly describes the western European utility industry. Several observations are noteworthy.

Various European countries have very different combinations of publicly and privately owned utilities. These vary from France with a single national utility to Germany with over 1000 utilities. The different organizational structures imply different institutional arrangements. For example

- In France, the national utility EdF dominates nuclear power decisions by being the only nuclear power reactor customer, part owner of the reactor vendor Framatome, and designer of the overall nuclear power station.

- In Germany, which has multiple utilities, numerous joint utility organizations exist. The reactor vendor dominates technical decisions associated with nuclear power because it designs, builds, and starts up German power plants before they are turned over to an operating utility. The larger role of the reactor vendor reflects the more divided utility structure.

A look at the ownership and method of electric production of various utilities by country is presented in Table D.1.

Table D.1. Electric utilities in Europe

Country	Utility	Ownership type	Total generating capacity (MW)	Nuclear: No. of plants	Nuclear: Amount produced (MW)
Belgium	Societe Reunies d'Energie du Bassin de l'Escaut (Ebes)	Private		*	*
	Societe Intercommunale Belge de Gaz et d'Electricite (Intercom)	Private		*	*
	Unerg	Private		*	*
	Total		13,400	7	5,500
	*Notes: The three companies now come under the control of Tractebel, a holding company, which itself is controlled by Belgium's two largest holding companies: Group Bruxelles Lambert and Societe Generale de Belgique.				
Denmark	Association of Danish Power Stations	Mixed		0	0
	Total		8,700	0	0
	Notes: More than 100 entities of different ownership types comprise the Danish electric power sector. Twelve companies own 18 power stations greater than 25 MW, comprising more than 99% of the country's capacity. These 12 companies formed the Association of Danish Power Stations.				
Finland	Imatran Voima Oy (IVO)	Public		2	990
	Teollisuuden Voima Oy (TVO)	Mixed		2	1,420
	Total		11,000	4	2,410
	Notes: Several different ownership types comprise the Finnish electric power sector, each owning at least one small generating facility.				

Table D.1. Electric utilities in Europe (continued)

Country	Utility	Ownership type	Total generating capacity (MW)	Nuclear: No. of plants	Nuclear: Amount produced (MW)
France	EdF	Public	55	55,545	
	Commissariat a l'Energie Atomique	Public	1	233	
	Total		91,800	56	55,778
Germany	RWE-Energie			3	3,605
	Preussenelektra			1	640
	Kernkraftwerk Unterweser (KKU)			1	1,230
	Kernkraftwerk Stade (KKS)			1	640
	Kernkraftwerk RWE-Bayernwerk (KRB)			2	2,488
	Kernkraftwerk Phillipsburg (KKP)			2	2,132
	Kernkraftwerk Obrigheim (KWO)			1	340
	Kernkraftwerk Lippe-EMS (KKE)			1	1,270
	Kernkraftwerk Kruemmel (KKK)			1	1,260
	Kernkraftwerk Isar (KKI)			2	2,155
	Kernkraftwerk Brunsbuettel (KKB)			1	771
	Hochtemperatur-Kernkraftwerk (HKG)			1	1,307
	Gemeinschaftskernkraftwerk Neckar (GKN)			2	2,010
	Gemeinschaftskernkraftwerk Grohnde (KWG)			1	1,325
	Bayernwerk AG			1	1,235
	Total		99,000	26	24,430

Table D.1. Electric utilities in Europe (continued)

Country	Utility	Ownership type	Total generating capacity (MW)	Nuclear: No. of plants	Nuclear: Amount produced (MW)
	Notes: The electric power sector in Germany is highly decentralized, consisting of more than 1000 utilities. The 8 largest utilities, supplying more than 80% of the nation's power, are affiliated in the German Electrical Power Association, DVG. In August 1990, an electricity contract between the former East Germany and West Germany was signed. The contract gives the three major West German utilities RWE-Energie, Preussenelektra, and Bayenwerk AG--75% of the former East German transmission network and brown coal power stations in return for the three companies' agreement to make enormous capital investments to upgrade the former East German system. The three utilities will set up a separate company for the former East German system.				
Greece	Public Power Corporation (DEI)	Public	8,200	0	0
Italy	National Electric Energy Agency (ENEL)	Public		0	0
	Total		50,000	0	0
	Notes: ENEL generates approximately 80% of Italy's electricity. Legislation enacted in 1962 to create ENEL provided exceptions to ENEL's monopoly on power supply: (1) local municipal systems existing prior to 1962 (approximately 160 municipalities, (2) industrial generators consuming at least 70% of production, and (3) small producers (<15 GWh annually).				

Table D.1. Electric utilities in Europe (continued)

Country	Utility	Ownership type	Total generating capacity (MW)	Nuclear: No. of plants	Nuclear: Amount produced (MW)
Luxembourg	Compagnie Grand-Ducale d'Electricite du Luxembourg (CEGEDEL)	Mixed			
	Total		0	0	0
	Notes: Luxembourg imports more than 90% of its electric power from Belgium and Germany. The remainder is provided by other power purchased by CEGEDEL.				
Netherlands	EPON	Private		0	0
	EPZ	Private		1	452
	UNA	Private		0	0
	EZH	Private		0	0
	Gemeenschappelijke Kernenergiecentrale	Public		1	55
	Total		17,300	2	507
	Notes: In the late 1980s, the Dutch electric power sector was reorganized to include only four electric generating companies, the first four listed. Also, 56 horizontally integrated distribution utilities were created separate from the generating companies.				

Table D.1. Electric utilities in Europe (continued)

Country	Utility	Ownership type	Total generating capacity (MW)	Nuclear: No. of plants	Nuclear: Amount produced (MW)
Norway	Norge Vassdrags-og Elektrisitetsvesen (NVE)	Public		0	0
	Samkjoringen av Kraftverkene i Norge	Public			
	Total		26,700	0	0
Portugal	Electricidade de Portugal (EdP)	Public	6,800	0	0
	Notes: In 1991, legislation was enacted to transform Portugal's power sector from monopoly by EdP to a publicly limited company. EdP will be broken up and private utilities will be allowed to operate.				
Spain	Iberdrola	Private		3	2,758
	Union Fenosa	Public			
	Endesa	Public			
	Total		42,700	9	7,363
	Notes: Two publicly owned utilities, Enher and Endesa, are part of the ENDESA group. Through ownership interests in other utilities, the Group is the largest power supplier in Spain.				

Table D.1. Electric utilities in Europe (continued)

Country	Utility	Ownership type	Total generating capacity (MW)	Nuclear: No. of plants	Nuclear: Amount produced (MW)
Sweden	Statens Vattenfallsverk (SSPB)	Public		7	6,410
	Sydcraft AB (SSPS)	Public		2	1,200
	OKG Aktiebolag			3	2,207
	Total		31,500	12	9,817
United Kingdom	British Nuclear Fuels plc	Public		8	400
	Nuclear Electric plc	Public		25	8,206
	Scottish Nuclear Limited	Public		4	2,650
	AEA Technology	Private		1	250
	Total		71,400	38	11,506

Notes: The break-up of the Central Electric Generating Board was originally to result in three companies: (1) National Power, which was to have taken over all nuclear generating stations and 60% of non-nuclear capacity, (2) Power Generation, the remaining nonnuclear capacity, and (3) National Grid to run the transmission system. Nuclear Electric was created after the decision was made to withdraw the nuclear stations from privatization.

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