

‘Globalization with hardware’: ITER’s fusion of technology, policy, and politics

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This article explores the history of the International Thermonuclear Experimental Reactor (ITER), a fusion energy megaproject currently being built in southern France. It examines three main aspects of the project’s history, focusing largely on the European research community’s perspective. First, it explores how European scientists and science managers constructed a transnational research community around fusion energy after 1960 that was part of Europe’s larger technological integration. This article also expands Gabrielle Hecht’s concept of ‘technopolitics’ to the larger international dimension and explores how the political environment of the late Cold War and the post-9/11 era helped shape ITER’s history, sometimes in ways not entirely within researchers’ control. Finally, this essay considers ITER as a technological project that gradually became globalized. At various stages in the project’s 30-year history, we discover processes whereby national borders became less important while social, economic, legal and technological linkages created a shared social space for fusion research on an expanding scale.

Keywords: International Thermonuclear Experimental Reactor (ITER); fusion energy; transnational; technological integration; globalization; technopolitics

In 1997, when Berkeley physicist T. Kenneth Fowler wrote a popular account of scientists’ 50-year quest to harness nuclear fusion as an energy source, he described the engineering design and political machinations that resulted in plans to build the International Thermonuclear Experimental Reactor (ITER). At the time, the four partners collaborating to build ITER were the European Union (EU), the USA, Japan and Russia. Fowler’s evocative assessment – ‘The sun never sets on ITER’ – became all the more salient after China, India and South Korea joined the effort.¹ By 2005, the megaproject represented over half of the world’s population.

The fusion reactor’s cost, managerial complexity and global scope of its partnership make it an example *par excellence* of what one French newspaper labeled ‘*un investissement pharaonique*,’ i.e. a technological project displaying the scale and perhaps the hubris of the world’s ancient wonders.² ITER – the word is pronounced something close to ‘eater’ and it also means ‘the way’ in Latin – is the global fusion community’s most ambitious project to date and one of the largest and most expensive science projects ever.³ Estimated recently to cost more than US\$20 billion over its 30-year lifespan, it is under construction at Cadarache, a research center for nuclear energy located in southern France near Aix-en-Provence. Although ITER’s completion is still years away, the origins of this megaproject can be traced back to the 1970s. They include the long-term strategy of European scientists to conduct fusion research and build new facilities in an orderly and coordinated fashion and Cold War superpower politics between the Soviet Union and the USA.

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ITER's history prior to 2005, when science managers and national leaders finally resolved a lengthy dispute over where to build the project, offers an opportunity to engage with several thematic questions and issues that have attracted considerable interest from scholars. Taking Fowler's observation as a starting point, this article focuses primarily on the international and transnational dimensions of European fusion research. In doing so, it engages with and contributes to two relatively recent conversations held by historians of technology. These are explorations of transnational history pertaining to the history of technology as well as the role of technology in promoting European integration.⁴

Over the years, scholars have employed the concept of transnationalism in diverse and flexible ways.⁵ Transnational history originally meant the study of international non-governmental organizations as legitimate political and historical actors.⁶ Over time, this term has broadened to include organizations, including those associated with technological projects, which have a role in governance but which are not traditional 'state-centric' actors. A transnational focus may also imply the participation of supranational organizations to which member governments have ceded some power and decision-making ability. Finally, as its prefix suggests, a transnational view toward the study of technology also considers the flow of technological artifacts and technical knowledge across national borders.

In 1995, Hubert Curien, then serving as president of the *Organization Européenne pour la Recherche Nucléaire* (CERN), described ITER as 'globalisation with hardware.'⁷ While I return to this point in more detail at this article's end, Curien rightly perceived that European fusion energy research in general and ITER specifically, exemplified a supranational, often transnational technological endeavor. Like transnationalism, globalization is a concept that historians of technology are integrating into their research with growing frequency both as a theoretical tool and as an actor category.⁸ In some cases, this work has focused on 'informational globalism,' in which transnational networks for communication and data sharing are constructed.⁹ The creation of global research programs, such as the International Geophysical Year (began 1957) or the World Climate Research Program (started 1980), in which professional or even amateur researchers participated, presents another facet of globalized technology and science.¹⁰ Debates associated with governing certain forms of globalized technologies, especially those related to biotechnology and the life sciences, are also aspects that historians have addressed.¹¹

In this essay, I consider ITER as a technological project that gradually became globalized. At various stages in the project's 30-year history, we discover processes whereby national borders became less important while social, economic, legal, and technological linkages created a shared social space for fusion research on an expanding scale. Transnational organizations, such as Euratom, the International Atomic Energy Agency (IAEA), and the European Community played an important role in the creation and management of technological facilities for European fusion research. At the same time, the European fusion community's practices included the creation and movement of a 'research ensemble' – materials, theories, techniques, equipment, technical staff, and monies – across national borders and between various research laboratories.¹² To this transnational flow, one can add an ideology, shared among leaders of the European fusion community, which placed a premium on unity, cooperation, and a coherent long-term strategy. Over time, European science managers integrated the research ensemble they had constructed into a larger international network of fusion researchers and associated funding agencies.

In tracing ITER's evolution into a globe-spanning, transnational technological project, we witness European scientists and science managers interacting with one another and their counterparts from other non-European universities and government laboratories.¹³ Although motivated by the wish to advance European fusion research and see that ITER was built in

Europe, scientists' interactions came with their own inter-European friction as national programmatic needs sometimes existed in conjunction with broader transnational and collaborative goals. Moreover, Europe's commitment to building an ITER-like device in collaboration with non-European partners waxed and waned in response to changing politics and national science policies in other countries, especially the USA.

Decentering the nation-state in this narrative by shifting to a broader supranational and transnational perspective affords us a new perspective on the practice of 'technopolitics.' Defined as 'designing or using technology to constitute, embody, or enact political goals,' Gabrielle Hecht initially used the term to address the question of 'what was French about the French nuclear program?'¹⁴ In her research, Hecht's primary concern was the co-production of technology and national identity from 1945 to 1975 – the *Les Trente Glorieuses* – when France enacted massive technological changes to regain its international standing, autonomy, and national pride. Nuclear weapons and the exploitation of nuclear power were central to the Gallic transformation as 'nuclear France' was built via state-sanctioned, top-down technocracy.¹⁵ In the 1950s, France pursued its goals of nuclear weapons and reactors even if it meant minimizing cooperation and knowledge sharing with transnational actors like Euratom.

When scientists and research managers started constructing a pan-European fusion research program in the late 1960s, similar reluctance on the part of some scientists presented an obstacle to overcome in order to fashion a cooperative and transnational program. ITER's history presents an opportunity to expand on Hecht's concept of technopolitics by taking it from the realm of national identity and politics to a larger international and transnational arena. Doing this also allows us to ask, for example, whether there was anything especially European about the region's approach to building facilities for fusion research.

After 1945, European scientists and governments enacted extensive cooperative efforts to create organizations and policies that support collaborative scientific research.¹⁶ Besides allowing European scientists to compete with and sometimes surpass their US counterparts in nuclear physics, astronomy, and aerospace engineering, scientific and technological cooperation was 'situated at the heart of the process of European economic and political integration.'¹⁷ The history of ITER and its antecedents gives insights into how contingencies and rationales for international scientific collaborations shifted over time, sometimes in ways not entirely within researchers' control.

With ITER and its forerunners, European research managers pursued a variety of political goals including long-term energy independence, international standing in the physics community, and the continued survival of scientific research programs dependent on building the 'next big machine.'¹⁸ Less apparent but present nevertheless were scientists' concerns about maintaining an independent European research and development program in the event that political support for an international fusion project collapsed. Fusion research managers also worked to coordinate fusion research efforts because they might foster greater European integration in terms of research and development.¹⁹

As an example of 'transnational technopolitics,' the history of ITER has the potential to inform us about the planning and persistence of large-scale technological projects that span significantly different historical periods. The project's international and collaborative nature germinated over a relatively long span of time. During this time – from the late 1970s to the early twenty-first century – geopolitical circumstances changed in marked ways. Scientists and engineers from Europe, the USA, the Soviet Union, and Japan began discussing a collaborative fusion facility in 1977 when a fragile *détente* between the two superpowers still existed. When Cold War tensions between the USA, the USSR, and Europe were

running high, the idea of international collaboration was revived again (with Europeans watching warily) at Reagan and Gorbachev's first summit meeting in late 1985. The engineering studies for ITER continued after the Cold War ended but the post-9/11 era brought new dimensions. International disputes about the US-led war in Iraq influenced debates about where ITER would be built while members of the EU were eager to display their growing power and unity.

This article presents the topic of international and transnational collaboration in fusion research as a three-part story. First, I first take up the question of transnational technopolitics by looking at the creation of a European fusion energy program which had ambitions beyond national projects pursued by individual countries. By deemphasizing national aspects, European fusion advocates presented their research community as a 'single body in its relations with other fusion programs in the rest of the world.'²⁰ In this manner, fusion research reflected larger trends in European politics that favored integration and cooperation while sometimes still existing in tension with national interests.

The story's second act unfolded as the Cold War gradually came to an end. By the late 1970s, convinced that transnational collaboration in fusion research was a valuable policy goal, leaders of the European fusion community succeeded in establishing a cooperative research program as well as a major facility for pan-European fusion research. As they began studying what their next big fusion machine should be, they had the option to collaborate with their Soviet, Japanese, and US counterparts or to focus instead on another European-only machine. High-level talks between François Mitterrand, Ronald Reagan, and Mikhail Gorbachev helped end this debate and prompted existing design studies to coalesce into the ITER project. While I mostly present the European perspective, I also consider the viewpoint of US scientists and policy makers. Indeed, this *pas de deux* was essential as parties on both sides of the Atlantic often developed their strategies in conjunction with and in reaction to one another.

The third act in my narrative concerns an issue endemic and sometimes fatal to many transnational technological collaborations: where to build it.²¹ As this article shows, the battle over ITER's site between 2000 and 2005 revealed fault lines in European claims for regional unity, the importance of regional economic needs, and the willingness of European politicians to threaten unilateral action as a negotiating position. The dispute over ITER's location reflected concerns more connected with prestige, returns on national R&D investments, regional economic development, and international affairs than with science or technology.

Historians of technology have long acknowledged that technological artifacts embody all sorts of politics. It should not be surprising to find that, paraphrasing Clausewitz, fusion research in Europe and in its global context was often a continuation of politics by other means. This included both international politics as well as negotiations concerned with more regional (European) and local (French and Provençal) issues. Researchers' pursuit of an international fusion energy facility required more than two decades worth of social and political engineering before construction could begin.²² What is surprising is the degree to which the desire for transnational integration and cooperation appears to have shaped the strategic thinking and policies of European fusion research managers. At a relatively early stage, researchers accepted the idea of pan-European integration and cooperation but found this goal sometimes counterbalanced by more parochial concerns. The ways in which plans for new fusion research facilities intersected with high-level international politics during and after the Cold War is just as surprising. While the activities of European fusion researchers reflected the political trend toward greater European integration, ITER was both advanced and used by European, Soviet, and US politicians in pursuit of other goals.

Act 1. Balancing national interests with transnational goals

Fusion energy research and high-level political maneuvering have been inextricably connected ever since scientists working on the Manhattan Project discussed fusion's potential as a weapon and energy source.²³ After World War II, the most active programs were in the USA and the USSR while initial European efforts remained quite modest. Military classification initially prevented the international exchange of scientific and technical information about fusion but these constraints began to loosen following the Eisenhower administration's 'Atoms for Peace' initiative.²⁴ By 1960, an international fusion energy community in which European researchers sought to play an increasingly prominent role had formed.²⁵

Fusion research in Europe and elsewhere belied any simple delineation between 'science' and 'technology.' The basic concept of producing energy by bringing together and fusing the nuclei of the lightest elements is itself straightforward but accomplishing it presents extraordinary technological challenges. In a fusion reaction, light atomic nuclei fuse together to form heavier products. When, for example, deuterium and tritium are sufficiently heated, they form an ionized gas. In this plasma, the electrons have been stripped from the atoms, making it electrically conductive. Because the nuclei have a positive electrical charge, they repel each other unless given sufficient kinetic energy by heating them to temperatures over 100,000,000 K. Ideally, a fusion reactor produces a burning plasma sufficiently self-heated by fusion-produced helium nuclei to become self-sustaining.²⁶ The long-term goal of the fusion research community is to use the heat from the fusion reactions to produce steam, drive a turbine, and generate electricity.

Western European plans to catch up with the fusion research programs already started by US, British, and Soviet researchers were formalized when the Treaty of Rome established the European Atomic Energy Community (Euratom) as well as the European Economic Community in March 1957.²⁷ Created as a supranational institution, Euratom's goals *vis-à-vis* the Rome treaty included the 'study of fusion with particular reference to the behavior of an ionized plasma under the action of electromagnetic forces and to the thermodynamics of extremely high temperatures.'²⁸ Despite this injunction, Euratom was initially more concerned with the industrial development of fission-based power and, as a result, less than 5% of its budget was set aside for fusion-related research.²⁹ This also reflects the fact that Euratom was established as a political entity in search of research programs whereas CERN, for instance, had clear research goals from the start and eventually acquired the necessary political support.

The European Commission asked an Italian scientist, Donato Palumbo, to manage Euratom's fusion program. Before moving to Brussels in 1958, Palumbo worked as a theoretical physicist at the University of Palermo where his research included studies of electron paramagnetic resonance.³⁰ Recognizing how much European programs lagged relative to those in the USA, the Soviet Union, or even the UK, Palumbo expressed a preference, as he put it years later, to 'provoke collaboration.' This was a goal that he worked steadily toward over the next three decades.³¹ Despite his modest budget, Palumbo believed that one way he could achieve greater European cooperation was to promote the exchange of scientific information and fusion researchers across national borders. To help facilitate this, Palumbo and Euratom oversaw the establishment of a *Groupe de Liaison* to formulate European strategy for fusion research. Each participating country contributed up to three scientists to this advisory body which formulated long-term programs for research.

From the outset, tensions existed between Euratom's support of national fusion programs and the desire of some researchers for a single, pan-European laboratory for fusion research.³² The European model for a high-profile cooperative research facility, of course,

was CERN. In 1954, twelve European governments established the laboratory to do basic research in particle and nuclear physics using complex and expensive particle accelerators.³³ At first glance, CERN would have also appeared to have been natural choice at which to base a collaborative fusion energy program, perhaps operating it jointly with Euratom.

However, plans for a joint CERN–Euratom study group were quickly scuttled when CERN representatives from countries which were not also part of Euratom balked. The UK, for example, opposed CERN–Euratom collaboration out of concerns that its then-strong national fusion program would be weakened as British researchers contributed to supranational European efforts. Other delegates pointed out that CERN’s charge was doing basic physics research with no emphasis on applications, technology development, or energy research.³⁴ Given the relatively immature state of European fusion research, science managers like Palumbo did not believe the time was yet right nor was it politically possible to mandate a single pan-European fusion facility.³⁵ Over the next decade, Palumbo, acting for Euratom and the Commission of European Communities, worked to nurture various national efforts. The tool he used was a series of contracts let out to national laboratories in several Euratom countries.³⁶

To help coordinate these activities, in the mid 1960s, Euratom set up a Committee of Directors, a more powerful advisory group populated by directors from the national laboratories which had fusion research programs along with Palumbo. Together with the *Groupe de Liaison*, this group worked out how the long-term research programs would be executed and helped coordinate the movement of Europe’s expanding research ensemble for fusion energy across national borders.³⁷ It is at this point that the European fusion effort begins to display the first halting signs of becoming a transnational collaborative effort. However, Palumbo and his colleagues recognized that this process would take time and likely have to built first on the strengths of individual national efforts. Moreover, at this point, these early transnational efforts were not done with the goal of collaboratively building a shared facility for fusion energy but simply establishing a common research community.

The late 1960s were not kind to European fusion programs. Overall, the community remained relatively small – about 650 people (not including technicians and support staff) split between scientists doing basic plasma physics research and more engineering-oriented people working to improve the performance of fusion machines. National leadership also changed hands as the UK’s program at its Culham Laboratory suffered a series of crippling budget cuts while Germany’s program prospered and grew. Meanwhile, French scientists struggled with severe university unrest, general strikes and their own budgetary issues.

In August 1968, Europe’s fusion research community finally received some welcome news. Soviet physicists announced that modifications made to their fusion machines showed significantly improved performance. In order to eventually generate useful energy, a fusion reactor uses carefully created magnetic fields to ‘trap’ the plasma created inside the machine’s vacuum chamber so that fusion reactions can occur.³⁸ The Soviets’ *tokamak* design – the Russian acronym for *toroidal kamera magnetik* (‘toroidal chamber with magnetic coils’) – magnetically confined a plasma into a doughnut-shaped space, producing higher temperatures, longer confinement times, and increased plasma stability.³⁹ Soviet progress on the tokamak helped refocus national fusion efforts in Europe and spurred them to compete more aggressively with other programs. After the Soviet results were confirmed, several Euratom members announced plans to build their own tokamaks as a step toward building an actual energy-producing reactor, a goal which appealed to policy makers in search of alternative energy supplies.

The Soviets’ announcement and the anticipated proliferation of national efforts gave Palumbo an opportunity to advance his goal of a more united European fusion program. In

the late 1960s, the *Groupe de Liaison* was developing its new strategic research plan. In advance of deciding this, Palumbo proposed that Europe's fusion community 'constitute a group for the preparation of a large joint venture' that would complement existing national efforts.⁴⁰ Several months later, the *Groupe* endorsed more specific plans to 'prepare preliminary designs for the various possible concepts of a future European tokamak.'⁴¹ The *Groupe's* new approach, which the European Commission approved, represented a compromise between supporting national facilities for fusion research and setting aside resources for a common collaborative project. The period in which Euratom and the European Commission only supported national projects came to an end as plans for a common cooperative venture, a development Palumbo had gradually built support for throughout the 1960s, got underway.⁴²

Several factors nudged the European fusion community toward building its major new fusion facility as a cooperative transnational effort. By 1970, the various national efforts in Europe were established, having gained experience with smaller fusion machines and the basic science underlying their operation. The cost of experimental fusion facilities was growing while, at the same time, there was a risk of duplication if individual countries expanded existing national programs. By pursuing a common venture, Palumbo and his colleagues hoped to stave off future battles for resources which might hold back European fusion research in general. The general enthusiasm for the tokamak design gave the *Groupe* and the Committee of Directors a general design objective. Finally, broader social and economic circumstances were changing. European citizens expressed growing anxiety about the environmental and economic effects of industrialization. When the *Torrey Canyon* ran aground in 1967, the black tide of oil which washed up on French and British seashores seemed to justify public concerns about Europe's energy dependence, concerns which subsequent oil shocks only intensified. In the 1970s, the possibility that fusion power might eventually reduce Euratom countries' dependence on fossil fuels helped policy makers and scientists justify new fusion facilities.⁴³

What emerged from the *Groupe's* discussions and studies was the Joint European Torus (JET) facility.⁴⁴ Based on a tokamak configuration, JET was billed as 'the centerpiece' in the European Community's fusion plans for the 1970s.⁴⁵ The goal researchers had for JET was to 'produce and study a plasma in conditions as close as possible to those needed in a thermonuclear reactor' and use the experience gained as a step toward the commercial exploitation of fusion energy.⁴⁶ Compared to early Soviet tokamaks, the JET device was quite large. The stainless steel sections of the toroidal vacuum chamber were estimated to weigh some 80 tons, for instance, and these would be surrounded by magnet coils weighing several hundred tons more. The cost was grand as well. One estimate, made before engineers had even started building the facility, gave construction costs at US\$210 million, a figure which doubled by the time JET was completed.⁴⁷ The European Community – which, by 1973, included the UK – shouldered 80% of JET's cost with the various member states making up the difference.

The move to build JET signaled a reorientation in the European approach to fusion from strictly national endeavors to a strategy that included transnational ones. In 1971, the Council of Ministers of the European Community gave their approval for a 'long-term cooperative project embracing all work carried out in Member States' in fusion research, with the final goal being 'the joint construction of prototypes with a view toward their industrial production and marketing.'⁴⁸ From this perspective, the focus of European nuclear efforts was as much about engineering and commerce as it was about science. Over the next two decades, Palumbo used this ministerial statement as a core principle for furthering transnational European fusion efforts.⁴⁹

In the mid 1970s, ambitions for joint European nuclear projects were not limited to fusion. As JET was getting underway, several European countries, with Euratom's oversight, began the European Fast Reactor (EFR) project. A breeder fission reactor designed to produce plutonium from uranium fuel, EFR became caught up in the conflicting national aims of its participants.⁵⁰ France, for example, saw breeder reactors as a way to leapfrog the USA in nuclear technology while the UK, which joined EFR later, had reservations about subsidizing Gallic techno-nationalism.⁵¹ Both Germany and France pursued breeder reactor projects within their own borders and the EFR effort eventually collapsed. For leaders of Europe's fusion community, the EFR could be seen as an object lesson in the dangers of allowing national efforts to obstruct transnational ones, an experience they wished to avoid repeating.

Large-scale projects like JET, which combined scientific research with sophisticated engineering and technology, required considerable political machinations in order to advance them from design to completion. One roadblock that typically emerges when building an international research facility is disagreement over its location (another factor that contributed to EFR's demise). Unlike an astronomical observatory, the performance of which is strongly affected by its location, a fusion reactor has few especial site requirements. Although JET's first design studies were completed by 1974, the Council of Ministers did not resolve the site issue until 1977. A story even circulated that the German chancellor, in gratitude for British assistance in resolving the hijacking of a Lufthansa plane, gave approval for the reactor's construction to proceed in Culham, just south of Oxford.⁵² The debates over JET's location foreshadowed even more contentious disagreements when scientists and politicians lobbied for ITER 25 years later.

The long impasse over JET's location suggested that the management of Europe's fusion research program needed reorganizing. The *Groupe de Liaison* was initially composed of scientists who were not always directly involved with their home countries' science policy process. The *Groupe's* failure to manage the JET site selection process, along with the fact that fusion facilities were becoming more complex and costly, helped catalyze the European Commission's decision to consolidate the entire management structure. Delegates to what eventually became the Consultative Committee of the Fusion Program ('Consultative Committee,' hereafter) included scientists and science managers from twelve European Community members in addition to representatives from the European Commission.⁵³

Once JET was underway, Euratom and the European Commission began to formulate strategic plans to coordinate the long-term direction of their fusion research programs. In a new 5-year plan, the European Commission stressed a strategy of 'joint action.'⁵⁴ Especial attention to a cooperative effort was needed because, in addition to the fact that projects like JET required resources beyond what individual countries could likely muster, budgets for competing programs in the USA were rising rapidly. Nonetheless, Europe's policy makers recognized that, despite progress toward creating a cooperative transnational endeavor, transforming fusion into a working energy source would still need a 'very long term effort ... Quick success is not to be expected.'⁵⁵

Act 2. The next big machine and Cold War politics

One trait symptomatic of certain fields of research like astronomy and high-energy physics is the proclivity for scientists and engineers to begin developing plans for their 'next big machine' before the current one has even started operating. This is done in part because of the long lead-times for securing the necessary political support, developing the requisite science case, and working out design parameters. Another factor driving this strategy, of course, is the desire of researchers and engineers for continuity of budgets and personnel in

order to maintain institutional security.⁵⁶ In this regard, fusion energy research in Europe was no exception.

Discussions about building the next big fusion facility began even before dignitaries attended JET's groundbreaking ceremony. In 1977, while fusion scientists still waited on the site decision, a planning team reported to the Consultative Committee that several technical hurdles remained before an actual demonstration power plant could be built. For example, scientists wanted to study the technical problems associated with producing and confining a burning plasma. There was also interest in exploring the possibility of using superconducting magnets to generate the confinement field. The European plan, however, called for building only one more large-scale international facility which would serve as the bridge between JET and an actual power-producing facility.

Considerations for the next big machine also raised a number of long-term planning issues for Palumbo and his colleagues on the Consultative Committee. By the end of the 1970s, their fusion research program had matured into 'the flagship of European scientific research cooperation' and was competitive with US, Soviet, and Japanese efforts.⁵⁷ More than a dozen laboratories in Western Europe had fusion or plasma physics programs underway which together employed more than 1000 engineers or physicists. The European fusion community had grown as countries like Sweden and Switzerland joined the overall effort. Budgets reflected this growth – fusion energy was largest single research program in the European Commission's portfolio with annual funding over US\$220 million by the early 1980s.⁵⁸ Although Euratom still gave assistance to national fusion projects, Palumbo had achieved his initial goal of creating a coherent pan-European fusion program that presented itself as 'a single body in relations with other fusion programs in the world.'⁵⁹

The question that Palumbo and his colleagues faced was whether this 'single body' should build the next big fusion machine as a Europe-only facility or collaborate internationally on a shared fusion facility.⁶⁰ The Europe-only option – called the Next European Torus (NET) – was imagined as a cooperative transnational European project that would provide a bridge to a future commercial fusion reactor. In 1978, a small design team of scientists and engineers started to formulate possible design concepts for NET. Before these efforts gained any traction, however, a Soviet delegation proposed building an international 'Large Tokamak of the next generation' under the auspices of the International Atomic Energy Agency (IAEA).⁶¹ One factor motivating the Soviets was cost estimates for the next generation of fusion machines (US\$1 billion or more) which were beyond the resources of their national programs. The inability of Soviet manufacturers to produce the necessary high-precision components for their domestic program was another issue.⁶² The IAEA referred the Soviet proposal to its own advisory body which then organized a series of workshops to discuss cooperation between Europe, the USA, the Soviets, and Japan to build an 'International Tokamak Reactor.'⁶³

Faced with two options for their next big machine, European fusion scientists considered their relative advantages. The International Tokamak Reactor, or INTOR as it came to be called, received a 'cautious but favorable recommendation,' in part because Europe was geographically located in a 'central position' among the potential partners, making it a convenient place to host international meetings and perhaps even provide a site for the actual facility if the cooperative effort matured that far.⁶⁴ At the same time, continuing NET's design studies would strengthen Europe's hand by giving it more engineering experience while 'preserving the option of an independent European approach.'⁶⁵

The end result was that when the European Commission released a proposal for its new 5-year plan, it maintained a middle course of developing NET and INTOR in parallel, each project serving as a hedge against uncertainties associated with the other. While the

Consultative Committee gave priority to INTOR it was with the ‘understanding that the work was ... a good preparation for NET’ if the international effort failed.⁶⁶ Within a few years, some 60 physicists and engineers were working on NET’s basic design at the Max-Planck Institut in Garching.⁶⁷

The informal wait-and-see strategy turned out to be a wise one. For one thing, events like the Soviet incursion into Afghanistan in late 1979 signaled the end of détente and made US–Soviet cooperation politically untenable.⁶⁸ International relations aside, European scientists watched as US fusion research programs went through a sudden boom and bust cycle. In the late 1970s, US funding for fusion rose dramatically. Congress passed the ‘Magnetic Fusion Energy Engineering Act of 1980’ and expressed its wish to pump billions of additional dollars into US research efforts, promote international cooperation, and build a working fusion reactor.⁶⁹ Ambitious in theory, in practice the bill neither appropriated nor approved any extra money. As Palumbo told colleagues after meeting with US energy officials, the fusion bill was merely a ‘hunting license’ for US program managers to seek new funds.⁷⁰ Not surprisingly, when Ronald Reagan became president, the new administration dropped the Carter-era initiative and US funding for fusion (and non-defense related research in general) began to decrease.⁷¹

Funding issues aside, European fusion managers expressed reservations about the relative prioritization of their goals vs. what US science managers were interested in. Were US researchers proposing a fusion research collaboration in order to better understand plasma physics or as steps toward building a future power-generating device? The US researchers, as European researchers saw it, were more oriented towards basic science, a belief reinforced by George A. Keyworth, Reagan’s science advisor, when he visited the European Commission in May 1982. Keyworth said that the USA preferred to give priority to ‘the basic physics of fusion devices’ and believed international cooperation must follow a ‘pragmatic approach.’⁷² This pragmatism meant ‘strict and well organized’ exchanges of scientific information and personnel were preferable to the ‘launching of a major project on an international scale.’⁷³ This strategy, of course, would enable the USA to evaluate the competence of international rivals in fusion research and perhaps gain an advantage for future industrial use without committing itself to an actual long-term project.

Keyworth’s emphasis on basic science conflicted with the underlying long-term European goal of developing fusion technologies for energy applications and eventual ‘industrial production and marketing.’⁷⁴ Not surprisingly, the idea of a collaborative state-sponsored effort to develop energy-related technologies for civilian use posed ideological problems for the market-oriented Reagan administration. It also raised the issue of intellectual property rights. If fusion research primarily had a science focus, intellectual property was likely to be less of an issue, but the Europeans’ expressed interest in the eventual commercialization of fusion energy made the question of intellectual property more salient. Even if fusion as an energy source was not realized swiftly, there were likely to be new ‘patents and inventions arising from a large international project’ in areas such as materials, nuclear technologies, and other industrial areas.⁷⁵

At meetings with US and Japanese representatives, Palumbo and other science managers pointed out that their researchers had ‘patiently woven’ a transnational European fusion network over the past 15 years but such a thing ‘did not yet exist at the world level.’⁷⁶ Nonetheless, some US politicians indicated reluctance to support international collaborations which involved sharing manufacturing technology with the Soviets (a risk to national security) or the Europeans and Japanese (a risk to US economic competitiveness).⁷⁷ As one congressional staffer told *Nature*, fusion research was connected to larger Cold War political and economic issues – ‘There’s more to international cooperation than good intentions,’

he said, 'When we have some friction over steel or the pipeline [referring to disputes with Japan and West Germany over trade issues and a proposed pipeline between West Germany and the USSR] it's going to be tough to go on building billion dollar machines.'⁷⁸

Variability of the US research program in terms of goals and funding, conflicting statements from officials like Keyworth, and opposition from US politicians led European fusion managers to conclude that the US maintained a 'basic opposition' to collaborating on an international fusion research facility.⁷⁹ European fusion managers evaluated the question of NET vs. INTOR in light of the changing US position. For example, Jules Horowitz, a French physicist, pointed out that linking Europe's long-term plans to possible collaboration with the USA could have 'grave consequences' given the instability of the US program.⁸⁰ Despite progress made in sharing specific elements of the fusion research ensemble (namely technical information and staff) across the Atlantic, the Europeans expressed doubts that an international fusion facility built with US participation would ever be realized without the 'existence of a real political will.'⁸¹

Hints of new-found political will eventually appeared but came, rather unexpectedly, from heads of state and not laboratory directors. Some of the first signs showed at meetings of the Group of Seven in 1982 and 1983 when French president François Mitterrand urged greater international cooperation in technological areas, including nuclear energy and fusion research.⁸² This top-down advocacy for fusion technology development continued. In the fall of 1985, before the first summit between Reagan and Mikhail Gorbachev, Secretary of State George Schultz met with Soviet Foreign Minister Eduard Shevardnadze. At the suggestion of Evgeny Velikhov, a fusion physicist who advised Gorbachev on science, Shevardnadze proposed adding international cooperation in nuclear fusion to the agenda. Schultz, a former executive for Bechtel, a construction and engineering firm with long experience in energy-related projects, overcame Pentagon protests and secured White House approval to discuss the idea in Geneva.⁸³

As an arena for Cold War superpower collaboration, fusion made sense for several reasons. For one thing, an international research community and pathways for information exchange already existed. Second, clean energy via nuclear fusion offered the semblance of broad societal benefits. It also had the potential to put a more positive face on nuclear applications at a time when the superpowers' nuclear arsenals drew widespread global condemnation.⁸⁴ Finally, while technically possible, practicable applications of fusion energy still remained many years off, making it a fairly safe arena for US-Soviet collaboration in terms of technology sharing.

When the Geneva summit concluded, Reagan and Gorbachev issued a joint statement which was pure technopolitics. To further superpower cooperation and perhaps ease global tensions, the two leaders endorsed 'the potential importance of ... utilizing controlled thermonuclear fusion' and advocated 'practicable development of international cooperation' to achieve this.⁸⁵ When Reagan briefed Congress on his summit trip, he identified international cooperation in fusion as one part 'of a long-term effort to build a more stable relationship' with the Soviets and the two leaders repeated their backing for an international fusion reactor at subsequent meetings.⁸⁶

The push from the White House and Kremlin gave renewed momentum to some sort of international fusion project, presumably to be done under the auspices of the IAEA. It also prompted European fusion managers to reconsider the shifting political landscape.⁸⁷ With European studies for NET well underway, there was concern in some quarters that a renewed push for a major new international facility would prove a distraction. Paul-Henri Rebut, a persuasive French fusion scientist who shaped his country's fusion program before becoming JET's director, suggested that an international effort might ultimately 'have a

delaying effect on the European program' and highlighted the risk of basing the global fusion program on a one-machine strategy.⁸⁸ Claiming to see little future for national programs, Rebut – who was also a member of the Consultative Committee – expressed a preference for a Europe-only program. His sentiments indicated that, even among influential leaders of Europe's fusion program, full support for the international option was not yet fully established.

Palumbo worked to make sure his colleagues realized that if 'something had to be done, it had to be done without any risk to the coherence' he had crafted for the European fusion program.⁸⁹ Because 'too much reliance on USA/USSR politics' was risky and the US's position was still evolving, Palumbo insisted that the European fusion community be treated as '*one single entity*,' a position he reiterated when he visited Washington in April 1986.⁹⁰ Palumbo, who was approaching mandatory retirement from his European Commission post, explained that the key 'boundary condition' for European participation in an international effort was sustaining the 'coherence of the European Programme.'⁹¹

In March 1987, following a formal request from the USA to the IAEA, the potential international collaborators met in Vienna. After Hans Blix, the IAEA's Director General, welcomed the delegates to their exploratory meeting, science managers from Europe, the USA, Japan, and the USSR discussed their respective policy goals and positions for what the fusion community now called the International Thermonuclear Experimental Reactor (ITER). Following the pattern Palumbo's stewardship had helped establish, Europe's fusion community maintained its preference for unity and long-term strategy, as opposed to the opportunistic pursuit of partnerships by separate national programs and continued to see collaborative research facilities as a tool for fostering technological integration.

With plans for ITER starting to take shape, Europe's fusion community wondered how they might contribute to it without having to raid the technical staff and resources allocated to NET. One way to navigate between ITER and a pan-European effort would be ensure that ITER's design closely resembled what NET's engineers were already developing. To this end, the Consultative Committee decided 'NET should be taken as a focal point for the ITER collaboration' and recommended the two projects have similar performance specifications – namely the ability to initiate a controlled and sustained burn of a deuterium-tritium mixture.⁹² The 'only way to prevent damage to NET,' claimed the project's leader, was to 'make ITER specifications converge to those of NET.'⁹³ Daniel Cribier, a French Committee member and elder member of the fusion community, urged an even more circumspect approach, advising that European work on ITER receive a 'low profile' so that Europe's long-term fusion plans would not be overly 'influenced by fluctuating international policies.'⁹⁴ A slower pace would give the Consultative Committee and the European fusion community it represented time to 'satisfy itself that it *did* want ITER to succeed.' It was important, Palumbo said, that the 'fusion community and the politicians saw ITER in the same light.'⁹⁵

After considering their strategy, the Consultative Committee approved the formal agreement, made in October 1987 under the auspices of IAEA, that committed Euratom to three-year conceptual design study for ITER.⁹⁶ At this stage, Europe's fusion leaders had some unique resources to offer the ITER collaboration. One was their technical experience operating JET, which was arguably the world's most advanced fusion reactor at the time. Palumbo and his colleagues also had the experience of establishing and managing JET as a pan-European undertaking. Although some critics said the European community took a long time to reach consensus, the result was a 'balanced, well-coordinated' program that appeared 'fairly well-disciplined' compared to the more *ad-hoc* nature US effort.⁹⁷

Even though they had formally agreed to support ITER, Europe's leading fusion researchers privately expressed caution. 'Large advertising about ITER' might serve the US

and Soviet Union's immediate political goals, opined Cribier to Klaus Pinkau, a German physicist who became the Consultative Committee's chair in 1990, but if the ITER collaboration collapsed, it would be 'an ill turn for the European fusion interest.'⁹⁸ A failure of ITER at the technical level, Pinkau agreed, would 'be interpreted as a failure of fusion' in general and surely affect the fortunes of any future European fusion efforts. At the same time, he said 'we must have a strategy in case ITER succeeds politically We want it to happen in Europe Already now, the remainder of the world gazes at us in amazement over our lack of capability to grasp our chances.'⁹⁹

Throughout the 1980s, Europe's fusion research community maintained a cautious balance between building its next big fusion machine as a Europe-only effort and pursuing it via a broader international collaboration. A primary goal throughout this period was ensuring that European unity and cohesiveness remained intact. However, the appropriation of fusion energy research by political leaders like Mitterrand, Reagan, and Gorbachev was a variable science managers like Palumbo could not control. While top-down advocacy from heads of state did not itself create ITER, it proved an essential ingredient in nudging the European fusion community toward international collaboration.

Act 3. Sushi or Bouillabaisse?

Before he retired in 1986, Palumbo addressed colleagues at a fusion conference in Brussels. Drawing on his Catholic upbringing, he remarked that fusion technologies would endure 'a prolonged stay in purgatory' before they could produce usable energy. 'However,' he continued, 'we know that the sojourn in purgatory can be curtailed not only by penitence on the part of the sinner but also by payment for indulgences.'¹⁰⁰ Although church theologians had long speculated about the size of indulgences needed to secure one's release from purgatory, Europe's fusion scientists found the wait and expense for their next machine to be considerable.

Engineers initially conceived of ITER as a massively scaled up version of the basic tokamak design, albeit with innovations such as superconducting magnets, new alloys, and a 'blanket' inside the vacuum chamber where tritium could be produced. However, even as engineers designed ITER, the original techno-political rationale for it – scientific cooperation between the USA and the Soviet Union – disappeared when the socialist state collapsed and the Cold War ended.¹⁰¹

Between 1988 and 1998, ITER's four partners carried out design studies which cost more than US\$1.1 billion, about a third of which came out of the European fusion budget. By 1998, a welter of concerns on the part of the US research community had emerged. These included ITER's rising costs, claims that it would not achieve its technical goals, frustrations with the lengthy design process, and a political climate disinclined to allocate large amounts of money to support an international energy-related project. These resulted in the US dropping out of the ITER fusion project.

Even within Europe, the political winds supporting the project shifted frequently and erratically throughout the 1990s. The situation alarmed seasoned European fusion scientists like Rebut who, having led some of the ITER design efforts, watched as NET was sidelined in favor of the international option.¹⁰² By 1999, only Europe and Japan remained as the primary parties interested in building ITER, but its hefty price tag – estimated at the time topped US\$10 billion – necessitated some lowering of researchers' ambitions.¹⁰³ One major design compromise came from paring back ITER's scientific goals. Originally, ITER would achieve 'plasma ignition' where the heat to sustain fusion would come entirely from energetic neutrons and alpha particles produced by the reaction inside the 8.1-meter tokamak

chamber. Instead, researchers settled for a scaled-back fusion machine (dubbed 'ITER-Lite' by some) which had the more modest goal of producing a burning plasma inside a 6.2-meter chamber with some of the heat provided by alpha particles and external power sources providing the rest, but the smaller version was still estimated to cost some US\$4 billion.¹⁰⁴

ITER's re-design set the stage for Act 3 of the project's fusion of technology and politics. As any real estate agent knows, the most important variable in selling a property is location, a truism that also applied to ITER. A 5-year stalemate over where to build the megaproject brought ITER back into the arena of international technopolitics. With Japan and Europe competing to host the project, the main issues initially were global prestige, regional economic benefits, and, for European leaders, expressing the unity of the newly formed European Union (EU). However, after 2001, the emergence of a new global conflict – the 'war on terror' – brought new political factors into play.

By 2000, scientists believed they had narrowed ITER's location to two possible countries. Canada proposed the shores of Lake Ontario, a site that appealed to some policy experts who believed building the facility there might entice the USA to rejoin the ITER project.¹⁰⁵ Japan, meanwhile, was so keen to host ITER that it offered to pay a substantial fraction of the project's cost for the privilege. The choice, ITER's director at the time said, had little to do with engineering and instead involved 'financial, political, and social' issues.¹⁰⁶

In July 2000, France complicated the situation when its atomic energy commission announced that it too would bid to host ITER. France proposed building the fusion facility next to its nuclear research center in Cadarache, half-hour's drive from Aix-en-Provence. Cadarache already hosted a number of nuclear research machines including the Tore Supra, an advanced French fusion facility built and operated with support from Euratom.¹⁰⁷ The fact that France already had strong domestic support for its nuclear power program, ITER observers believed, would lessen the chance of embarrassing public protests against an experimental thermonuclear reactor. France's bid, observers noted, could also help cement European political support for ITER which would imaginably plummet if the project went to Canada or Japan.

Domestic economic issues helped motivate France's lobbying to host ITER. Economists predicted that the project might generate thousands of jobs in the rural region around Cadarache. Broader issues of French industrial policy also were a factor. After years of centralized 'high tech Colbertism' based on grand, state-sponsored projects, the French government under President Jacques Chirac was starting to formulate a new policy which would support regional areas of technological innovation.¹⁰⁸ In these 'clusters of competitiveness' (*pôles de compétitivité*) particular areas of technical excellence and expertise would be encouraged. Cadarache had hosted French nuclear-related research projects for decades and there was hope that ITER might foster a new *pôle de compétitivité* in Provence oriented toward renewable energy research just as the JET had catalyzed profitable technological spin-offs in the Oxford region. ITER could help link high-tech industries in southern France with those in Spain and Italy while complementing Chirac's new approach to regional industrial policy. Some French policy makers imagined ITER could eventually become an engine for Provençal economic development, perhaps creating a 'fusion valley' in reference to California's Silicon Valley.¹⁰⁹

Observers predicted that ITER's partners would pick a site by the end of 2002. However, two developments prevented this and instead pushed ITER onto the international stage once again. First, in the spring of 2002, Spain's Ministry of Science announced that it also wanted to host ITER. Spain's bid was somewhat quixotic. The country was a relative newcomer to Europe's transnational fusion research program and, historically, it had less experience in fusion research. However, Spain's economy was booming and national funding for research was rising.¹¹⁰ The Spanish bid, however, gave the impression that Europe's

fusion community was not as organized or united as it might appear. As Robert Aymar, ITER's outgoing director, said, 'Why accept a European site when they can't make a decision?'¹¹¹ To those 'watching from Moscow, Peking, Washington, or Tokyo,' an editorial in *Le Monde* said, 'the Franco-Spanish duel looks like a quarrel of another age.'¹¹² For ITER's growing roster of partners – South Korea and China joined the project in 2003, seeing it as an investment in alternative energy – it suggested the need for firm EU leadership.

While diplomats in the EU tried to sort out the 'Franco-Spanish duel,' the second development took place: a US-led coalition invaded Iraq in March 2003. Spain contributed soldiers to the multi-national force while France and Germany – countries dismissed by Secretary of Defense Donald H. Rumsfeld as 'old Europe' – did not. Condemnation of France in the US media was widespread, sentiments expressed by the House of Representatives' 'freedom fries' resolution, but what did US sentiments about 'old Europe' have to do with an international fusion project?¹¹³ The answer: one month before the Iraq war started, the Bush administration announced that the USA would re-join the ITER collaboration.¹¹⁴

With French-American relations deteriorating, US Secretary of Energy Spencer Abraham visited Spain in May 2003 and came 'perilously close' to endorsing that country's bid.¹¹⁵ At a press conference in Madrid, Abraham claimed his visit was made at Bush's request and demonstrated 'the level of interest we have' in building ITER in Spain.¹¹⁶ European politicians and policy makers immediately protested that the USA was using the location of ITER to punish France and reward Spain over the Iraq conflict. Abraham's comments appeared all the more inappropriate to European observers as the USA was only a 10% partner in the international project.

To decide which site would compete against Japan's offer (Canada had dropped its bid for financial reasons) the EU appointed a special commission. Spain presented itself as a scientific newcomer challenging the 'natural order' of Europe and claimed it offered a better financial deal.¹¹⁷ To make its point, the Spanish government offered to double its contribution – offering upwards of US\$1 billion – to the project. Advocates for France, however, claimed the Cadarache site would allow researchers to take advantage of decades of fusion experience. As one science writer quipped, by the fall of 2003 the choice looked like it 'could go ITER way.'¹¹⁸

In late November, after leaders from France and Spain lobbied prime ministers Tony Blair and Silvio Berlusconi, the EU decided in favor of France. Spain was not entirely spurned. As a consolation prize, the EU committee offered to locate ITER's European administrative offices in Barcelona. As *Le Monde* reported, the EU's choice of France as a challenger to Japan was '*l'Europe de la science a triomphé de celle de l'argent*' – European science over Spain's money.¹¹⁹ Whether or not science had indeed trumped money, politicians recognized that the site decision could stand as a proxy for larger questions of European unity. At least one Spanish policy maker grumbled about yet 'another demonstration of the power of the French–German axis' while an Italian diplomat said the compromise showed Europe could 'speak with one voice.'¹²⁰

The choice over where to build the multi-billion dollar fusion project was now between France and Japan or, as *The Economist* framed it, to bouillabaisse vs. sushi.¹²¹ The EU continued to tout the benefits of the Cadarache site while the Japanese government proposed that ITER be built at Rokkasho, a remote northern fishing village where Japan's Atomic Energy Agency already operated several nuclear facilities. With ITER's engineering and design teams idling, the stalemate continued throughout 2004 as each side upped its *ante* in order to win the project.

Debates about the ITER site choice continued to provide a platform to express views toward international foreign policies. In January 2004, Secretary of Energy Abraham

visited Japan which had recently deployed a battalion of non-combat troops to southern Iraq. This time, Abraham snubbed France more directly. 'I am proud to say that the United States strongly supports building ITER in Japan,' the Secretary of Energy said, praising the merits of the Japanese site.¹²² His comments in both Spain and Japan showed international technopolitics at work as the Bush administration saw ITER (as did Mitterand, Reagan, and Gorbachev) as another lever to advance foreign policy goals that had nothing to do with science.

I have found no evidence that the EU responded by promoting its French site with extra vigor as a way of protesting US foreign policy or Abraham's interference, but the fault lines over ITER's location directly reflected national views about the US-led Iraq invasion: Russia and China supported the EU's bid and opposed the Iraq war while the US and South Korea favored a location in Japan. Meanwhile, editorials and news reports reflected dissatisfaction with ITER's continued politicization. An article in *The Economist*, no friend to big state-driven projects, asked whether ITER was a 'boon' or just a scientific 'boondoggle' caught in the web of international politics. Across the Channel, the satirical French daily *Le Canard Enchaîné* mocked the project's political travails and pointed out that decades of European fusion research had produced 'zéro kilowatt' of usable energy.¹²³

In response to the stalemate, the EU, led by France, threatened to build ITER as a European-only project.¹²⁴ 'We have to have ITER,' said French prime minister Jean-Pierre Raffarin, 'even if we do it ourselves.' To back up this gambit, France announced it would double its contribution to the project: about 20% (some US\$1.1 billion) of ITER's estimated total cost on top of the 40% the EU was already committing. There was some irony with EU's go-for-broke strategy, given the condemnation European leaders directed toward the Bush administration *ca* 2003–2005 for its unilateral, 'go-it-alone' approach on matters of Iraq, national security, arms control, and environmental issues.

Finally, in May 2005, French President Chirac, who had met recently with Japan's Prime Minister Koizumi, proudly announced, 'We will have it at Cadarache!'¹²⁵ Displaying some of the Gallic bluster for which he was known, Chirac boasted to reporters that, after France secured increased EU support for the project, 'we then imposed ourselves with Russia, China, everyone. Do you imagine that happens all by itself?' he asked, 'It happens because France has a voice that is listened to, certainly respected, even if sometimes it grates a little.'¹²⁶

Details gradually emerged that explained how France and Japan had reached an agreement on what was now being called the 'most expensive science experiment on earth.'¹²⁷ This suggested a tremendous windfall for Japan even if it lost the prestige of hosting ITER on its own territory. Part of the deal involved creating an additional third category of participation other than just 'host and "non-host."' While the EU and France would pay for about half of ITER's construction costs, as a 'privileged non-host,' Japan would get 20% of the industrial contracts, including more of the high-tech components, in exchange for paying only 10% of the project's cost. In addition, the EU would share the cost of a new fusion-related facility, estimated to cost an additional US\$1 billion, which would be built in Japan. Finally, 20% of the project's scientists would come from Japan and the 'privileged non-host' would get to choose ITER's first director.

Following the official announcement of the ITER site agreement in late June 2005, Dominique de Villepin, France's newly appointed prime minister, said science and engineering could be drivers for the country's economic growth and linked France's industrial policy of '*pôles de compétitivité*' to ITER. If France could do this within its own borders, de Villepin said, perhaps other countries could follow suit and together create pan-European centers of technological excellence.¹²⁸ On the same day that de Villepin's article appeared,

President Chirac toured the fusion facility's new home in Cadarache. After extolling the scientific prestige and new jobs ITER would bring to France, Chirac noted its broader significance for Europe. 'It is also,' he said, 'a great success for Europe. This success proves that when Europe is united, when it is ambitious, it is at the forefront of innovation and progress.'¹²⁹

In June 2005, however, Chirac was especially eager to find evidence of European unity and his own political leadership in fostering it. A month earlier, French voters had rejected a European Constitution by a wide margin. This was an embarrassing political defeat for Chirac which raised questions about claims for European unity. Chirac's statements at Cadarache and de Villepin's call for a common European approach to innovation policy that followed France's example should be read in this context.¹³⁰ In this framing, ITER – an international collaboration governed by transnational organizations like the IAEA – helped justify French national and regional industrial strategies while also symbolizing France's role in helping forge European unity.

Conclusion: globalizing fusion

At a symposium held in 1986 to honor his contributions to creating a European fusion community, Donato Palumbo reminded colleagues to 'resist the temptations offered by national solutions which could endanger the coherence and perhaps the very existence of our program.'¹³¹ They apparently listened. A vision of a cooperative fusion energy program, overseen by supranational organizations like Euratom and the IAEA, continued to guide European fusion researchers after Palumbo's retirement. As scientific ministers fought over ITER's location with memos and press conferences, European leaders proposed, even threatened, building it as a European-only machine to obtain political leverage and perhaps as an expression of European power and unity. Through 'strong arm European diplomacy,' European policy makers eventually managed to win the ITER project, although at great expense and by resorting to unilateral tactics that they had criticized the Bush administration for.¹³² Nevertheless, the goal of building a transnational technological effort for fusion energy helped unite Europe's national research programs and foster a greater sense of European integration and cooperation.¹³³

In their review of technology as a tool for European integration, Misa and Schot asked how technologies helped fashion a pan-European identity.¹³⁴ With the case of ITER and its predecessors, we see leaders of the European fusion community balancing national needs with their efforts to create a cooperative supranational effort that 'presents itself as a single body' to other national research programs. Over time, national projects as well as a shared research ensemble of people, theories, techniques, funding, and equipment were used to help support the broader pan-European effort. For example, France's Tore Supra fusion device, which entered service in 1988, served as a test-bed for ITER-related technologies such as superconducting magnets. In Germany, another midsized tokamak produced information on plasma-wall interactions for ITER. Other countries participating in ITER operated their own fusion machines which had similar payoffs in terms of technical experience which benefited ITER.

When promoting their 'single body' strategy, Palumbo and his colleagues were acting less like French, Italian, or German scientists and more like European researchers in the denationalized space they established around their diverse fusion research facilities.¹³⁵ This process was neither quick, seamless or inevitable. The dispute between France and Spain over ITER's location showed the sometimes tenuous nature of this constructed 'European' identity as Spanish policy makers chafed about the presumed 'natural order' of Europe and

the dominance of France and Germany in European science and technology. Transnational cooperation did not always trump national ambitions.

Palumbo, again speaking as an elder statesman for the fusion community, also cautioned European scientists and engineers to ‘avoid thinking that the solution of our problems can be in hands of the ambassadors and foreign ministers.’¹³⁶ While the Sicilian physicist was specifically calling for researchers to better understand the underlying physics of their fusion machines, his comments reflected another dimension. ITER only emerged as a viable international project after receiving endorsements from leaders like Reagan, Gorbachev, and Mitterrand, politicians who saw international fusion research as a vehicle to reach other goals. Such political attention can have unexpected consequences. In this case, it helped drive the European fusion community toward what became ITER. After the terrorist attacks on the USA in September 2001, ITER was used by another generation of leaders to score political points unrelated to scientific or technological cooperation. In this sense, rank-and-file researchers in the international fusion community, whether they were American, Japanese, or European, lost some control over their instrumental destiny.

As it had during the Cold War, the technopolitics of ITER and fusion research in the early twenty-first century spilled well outside national boundaries to inhabit a scale and scope beyond what Gabrielle Hecht has so ably described. In this international arena, researcher managers encountered a host of foreign policy goals and multi-national security issues. At the same time, the technopolitics of ITER trickled down to the local level as France lobbied to host ITER in part to spur regional economic development and clusters of high-tech industry. Regardless of whether Provence becomes a ‘*place d’une pôle fusion,*’ the Chirac government used ITER if only in a modest fashion to help promote a new turn in French industrial policy.

For scientific communities participating in ITER, the project is, of course, tremendously expensive but still modest when compared to the cost of new high-speed train lines in France or an American aircraft carrier. Little direct evidence suggests that political leaders like Chirac or Bush were interested in the scientific or technological aspects of fusion energy research *per se* or its costs.¹³⁷ Some sense of this appears in a cartoon published by a French anti-nuclear group after the selection of Cadarache. ‘It is marvelous that we have won ITER!’ Chirac says with an arm around a fox-like Villepin, ‘And now will you explain the machine to me?’ While recognizing ITER as a potential path to fusion energy production, Chirac focused as much, if not more, on European leadership, French prestige and Provençal economic development.¹³⁸

A similar situation existed across the Atlantic. Other than a minor speech made when the USA was trying to sway the site decision, Bush rarely, if ever, described fusion energy as a key part of America’s long-term energy portfolio. In 2004, when Bush was running for reelection against Senator John Kerry, he linked support for ITER to its being built in Japan.¹³⁹ However, after France was chosen instead of Japan, ITER appears to have fallen off his administration’s radar, at least at the presidential level. As president, Bush proposed several energy initiatives – futuristic cars that might run on hydrogen and fuel made from plants like switch grass – but increased support for nuclear fusion was not one of them. Political leaders going all the way back to Eisenhower often saw fusion research in general as a vehicle to advance other political goals.

Nonetheless, there were people within the governments of France, the USA, and ITER’s other partners who maintained an interest in fusion as a possible energy source decades down the road. If ITER helps pave the way for viable fusion reactors later in this century, governments not invested in it will likely suffer economic, technological as well as prestige implications. Participation in ITER, therefore, offered a way, for governments, especially

those with rapidly growing economies and populations like India and China, to hedge their bets against uncertainty by investing in an alternative energy technology albeit one whose practicable realization remains decades away. For countries like China, India, and South Korea, participating in a megaproject like ITER (like having a national space program) can also serve as a symbol of national prestige and a marker of modernization.

European strategy for fusion research since the early 1970s aimed to achieve stable funding and consistent long-term plans. Future energy needs provided a rationale for Europe's investment in ITER and other fusion facilities as scientists promoted fusion energy as a potential path to clean and abundant power. However, even in the European context, urgency over energy needs varied throughout ITER's long history and fusion advocates tended to frame it not in near-term scenarios but as meeting energy needs which were decades over the horizon. For example, in 1980 and 1983, the European Commission requested external reviews of its fusion research program 'in the world context.'¹⁴⁰ The first report highlighted the need for fusion energy to mitigate the 'economic and political vulnerability' of relying on foreign energy sources. However, just three years later, the availability of North Sea oil sources and better-than-expected conservation efforts meant that Western Europe's energy problems were 'considered less urgent by the public and by some political authorities.' Therefore, it was Europe's energy needs a half-century or more down the road that fusion advocates referred to when they requested funding. As one researcher said in 1990, 'Europe is looking at the long term, which is sensible. We do not need fusion immediately. But we will.'¹⁴¹ (Representatives from China and India expressed similar sentiments when their countries joined ITER.) The EU's continued dependence on foreign energy sources and public concerns about global warming have remained a reliable staple in scientists' arguments in favor of ITER.¹⁴²

The willingness of the European Community to set long-term goals and strategies distinguishes its fusion research programs from those of the USA. US fusion research oscillated unpredictably, typically in response to immediate concerns about energy. Oil shocks and environmental concerns about traditional energy sources catalyzed the US fusion funding bubble of the late 1970s, for example. A few years later, with the price of oil much reduced, the sense of public urgency dissipated and the Reagan administration halted and then reversed the growth of the fusion research budget. Two decades later – following the Enron scandal, rolling blackouts in California, concerns about 'peak oil' scenarios, and instability in energy prices after the 11 September terrorist attacks – the Bush administration rejoined the ITER project in part because of concerns for the USA's energy security.¹⁴³ Because a long-term US strategy for energy-related research remained elusive throughout several presidential administrations, funding for fusion never achieved the same stability that existed across the Atlantic. Other factors were the continual tension in the US between funding its national fusion programs and joining international ones like INTOR and ITER as well as the issue of whether nuclear fusion was about scientific research or technology development.

Europe's focus on long-term planning, stable funding, and the development of transnational research programs and cooperative facilities makes its fusion research efforts resemble its other 'megascience' research programs in astronomy and high energy physics.¹⁴⁴ For example, astronomers established the European Southern Observatory in 1962. Modeled after CERN, it adopted a top-down management and planning strategy in order to steadily build more and larger telescopes.¹⁴⁵ This approach contrasts with the more pluralistic but far less unified approach in the USA. Although not adopted immediately, the European fusion community gradually embraced a similar strategy of pursuing shared international facilities. However, an astronomical observatory is very different from a fusion energy facility in

terms of economic and societal returns. Countries contribute funding to fusion research because the science is compelling but also because they hope to realize technological advances, obtain strategic advantages in future energy-related applications, and create commercial opportunities.¹⁴⁶

Finally, I would like to revisit physicist Herbert Curien's observation that ITER was 'globalization with hardware.' Curien made his observation at a 1995 workshop when ITER's design studies were still underway and countries like India and China had yet to join the project. Yet, even at that relatively early stage in ITER's history, it was a perceptive comment from a French scientist who had led international research organizations for much of his career. With the notable exception of international space projects, European scientists at the time imagined globalized research largely in terms of networks. Curien's colleagues cited climate studies, oceanography, and polar research as examples of successful programs which have 'no institutionalized organizational form in Europe.'¹⁴⁷ As Curien said, 'We have some examples of global [network-oriented] programs but not that many with hardware.' ITER differed from previous globalized research projects as a scientific community whose governments eventually represented half of the world's population cooperated to build a specific research device.

As a 'hardware project,' ITER broached a scale that made some scientists uneasy. The idea of organizing such a sprawling transnational project to build a fusion facility meant placing their fates in the hands of people removed from the research community. At the same time, some European researchers expressed concerns that the 'globalization' of fusion might threaten the coherence and unity that they had slowly and incrementally established. Paul-Henri Rebut, for example, remained skeptical about the 'one-machine' approach where all of ITER's partners, so far as international legal agreements were concerned, were assumed to be equal. At the 1995 workshop, Rebut, the former director of JET said, 'If you want to go to globalization, you have to do it step by step; it is preferable to go for a world [research] programme ... and not directly to a single project.'¹⁴⁸ In other words, Rebut suggested building a globally integrated research network first, before moving on to 'hardware.' Recent reports claiming that costs for ITER may spiral to as much as US\$20 billion (with the EU's share alone ballooning to US\$9 billion) suggest that the concerns of people like Rebut did not lack merit.¹⁴⁹

From its inception, ITER and its predecessors were enmeshed in politics at many levels, from the regional and national to the global. First conceived as a tool to improve relations between Cold War superpowers, ITER became an opportunity for 'Old Europe' to project an image of unity and a tool to reward countries if they aligned themselves with American foreign policies. ITER, like international fusion research itself, was often about technological development carried out on a global scale and often pursued in conjunction with other objectives. At times, these related to international politics such as Bush's policy for Iraq or Chirac's ambitions for a more united Europe. At other times, economic interests held sway as ITER provoked discussion about US patent rights, French industrial policy or Japanese manufacturing contracts. Whether ITER is actually 'the way' to a viable future energy source remains to be seen. However, ITER's past already reveals a history of fusion, not of light elements, but of technological ambitions and politics of all kinds.

Author's note

Many sources cited in this article were retrieved using on-line data bases. French newspaper articles were recovered using either their respective web sites (some, like *Le Monde.com*, only give access for a fee) or the LexisNexis Academic database. Where possible, links to specific URL's

and original page numbers are given. Another major source was documents from the European Commission. The European Commission Historical Archives' policy is that only documents older than 30 years are available for public access. However, Professor John Krige shared documents he collected in 1999–2000 from scientists and managers' working files within the European Commission. Their identification markings indicate an origin in the Directorate General XII (Science, Research, and Development) at the European Commission, Brussels; they date from 1980 to 1989. Here, they are cited with the abbreviation of 'DG/EC.' Additional documents on nuclear fusion and European science policy were drawn from the Archive of European Integration (cited here as 'AEI'), a collection managed by the University of Pittsburgh and available on-line at <http://aei.pitt.edu/>. Copies of all sources cited in this article are in the author's possession. Research for this article was conducted with the assistance of fellowships in 2008 and 2010 from the Camargo Foundation, the Albert and Elaine Borchard Foundation, and the *Institut Méditerranéen de Recherches Avancées* (IMÉRA). Finally, I wish to acknowledge the excellent help from Samantha Rohman, an undergraduate research assistant, translation help from Micah Alpaugh, and generous advice from Robert Arnoux, Frank Baumgartner, Samuel Bordreuil, Matthew Eisler, Jacob Darwin Hamblin, John Krige, and Roger Malina. I share credit for resulting improvements with them while demerits for errors remaining are entirely mine.

Notes

1. Fowler, *The Fusion Quest*. Since Fowler's popular account, the project has dropped the lengthy acronym and simply is called ITER. For an overview of ITER, see Arnoux and Jacquinet, *ITER: Le Chemin Des Étoiles*.
2. Jacques Treiner and Sébastien Balibar, 'Iter, Un Projet Pharaonique,' *Le Monde*, 28 September 2005.
3. The only technoscience projects, to date, that rival ITER's cost are CERN's Large Hadron Collider, the International Space Station, and various space astronomy projects such as the Hubble Space Telescope.
4. For example, van der Vleuten, 'Towards a Transnational History' and papers in a 2005 issue of *History and Technology*, especially Misa and Schot, 'Inventing Europe.' For some specific studies taking this approach which also focus on European aspects, see Wormbs, 'A Nordic Satellite Project' and Nielsen and Knudsen, 'Troublesome Life of Peaceful Atoms.'
5. A helpful overview of the varied uses of this 'broad, fluid term' is van der Vleuten, 'Towards a Transnational History.'
6. For two early presentations, see Nye and Keohane, 'Transnational Relations and World Politics' and Crane, 'Transnational Networks in Basic Science.'
7. Comment made during a 1995 round table discussion, in Florence, Italy, about European research cooperation; presented in Krige and Guzzetti, *History of European Scientific and Technological Collaboration*, 476.
8. Like transnationalism, globalization is a broad concept that, as Held et al. (*Global Transformations*) note, runs the risk of being 'the cliché of our times.' The theoretical literature on globalization, is vast and I will not attempt to delve into here. Examples of recent scholarship in the history of science and technology that explicitly consider globalization both as a theoretical framework and actor category are essays in Krige and Barth, *Global Power Knowledge*.
9. Hewson, 'Did Global Governance'; Slotten, 'Satellite Communications, Globalization.'
10. Edwards, 'Meteorology as Infrastructural Globalism'; Hamblin, 'Hallowed Lords of the Sea'; McCray, *Keep Watching the Skies!*
11. Gaudillière, 'Science, Technology, and Globalization.'
12. For more discussion of a research ensemble, see Hackett et al., 'Tokamaks and Turbulence.'
13. A note on my use of the word 'European.' Here, it taken to mean those members of the European fusion community, a group that grew in size and membership over time from its original six members that, in the 1960s, represented much of Western Europe – Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany.
14. From Hecht, 'Technology, Politics, and National Identity,' 256. A more extensive treatment appears in Hecht's excellent book *The Radiancance of France*.
15. In addition to Hecht's work, see Bess, *The Light-Green Society*. For another view of de Gaulle's pursuit of a nuclear France and the Gallic transformation after 1945, see Peyrefitte, *C'était De Gaulle*. France's scientific and technological transformation is presented in Gilpin, *France in the Age*.

16. A good overview of this topic is Krige, 'Politics of European Scientific Collaboration' while Krige's *American Hegemony* develops the theme of Europeans' interaction with American researchers and funding patrons in much more detail. Another perspective on Cold War international cooperation in science is Hamblin, 'Visions of International Scientific Cooperation.'
17. Krige, 'Politics of European Scientific Collaboration,' 888.
18. The theme of 'building the next big machine' was explored by several scholars at a session organized by Patrick McCray and Robert W. Smith at the 2001 Annual Meeting of the History of Science Society.
19. Trischler and Weinberger, 'Engineering Europe.' Also, see the 'Technology and the Making of Europe, 1850 to the Present (Inventing Europe)' project sponsored by the European Science Foundation (<http://www.esf.org/index.php?id=386>; accessed 1 April 2010).
20. From p. 2 of 'Discussion Document for a Proposal for a Research and Training Programme (1982–1986) for the European Atomic Energy Community in the Field of Controlled Thermonuclear Fusion,' n.d. but from 1981; DG/EC.
21. A point made by Trischler and Weinberger, 'Engineering Europe' and reinforced by studies of CERN and other European research facilities.
22. In this sense, we can see ITER and its predecessors as a case of 'heterogeneous engineering'; Law, 'Technology and Heterogeneous Engineering.'
23. Bromberg, *Fusion*.
24. Hewlett and Holl, *Atoms for Peace and War*. Although Eisenhower had *fission*-based nuclear power in mind when he gave his 1953 'Atoms for Peace' speech, this gradually expanded to include *fusion* power as well.
25. Krige, 'The First Twenty Years of Nuclear Fusion Research.' My thanks to Krige for sharing this draft with me.
26. Once the necessary temperature is reached – about 40,000,000 K for a deuterium–tritium reaction – in theory no external source of power should be needed to maintain the plasma temperature. There is also a period of time necessary for a plasma to be confined at a given density and temperature in order to break even in terms of power consumed and produced.
27. Euratom was founded as a supranational organization with six original partners. In 1967, Euratom was merged with the European Coal and Steel Community and the European Economic Community to form the European Community although each legally existed separately. The implementation in 1993 of the Maastricht Treaty created the European Union and the Communities were absorbed into this 'first pillar' of the EU. Euratom, however, still retains a distinct legal existence. For Euratom's founding, debates about its early role in fostering European integration, and its relation with USA, see Krige, 'Peaceful Atom as Political Weapon.'
28. From Annex 1 to Article 4 of the Treaty Establishing the European Atomic Energy Community (signed 25 March 1957); available from http://eur-lex.europa.eu/en/treaties/dat/12006A/12006A_AN1.htm (accessed 21 April 2010).
29. Palumbo, 'Work of the European Commission.'
30. EPR is a technique analogous to nuclear magnetic resonance except that it is the spins of electrons rather than atomic nuclei that are utilized to study chemical compositions.
31. Palumbo, 'Work of the European Commission,' 1466.
32. In a sense, this is analogous to the tension between national nuclear power programs in Europe and the promotion of Euratom, a supranational entity, by US and European diplomats in the 1950s; Krige, 'Peaceful Atom as Political Weapon.'
33. Hermann et al., *History of CERN*, vols 1 and 2. European research cooperation is described in Guzzetti, *European Union Research Policy* while an erudite perspective on US–European interactions is given by Krige, *American Hegemony*.
34. The debate over the CERN-Euratom study is described in Krige, 'First Twenty Years of Nuclear Fusion Research'; also Guzzetti, *European Union Research Policy*.
35. Palumbo, 'Work of the European Commission,' 1466.
36. For example, Palumbo established his first contract in 1959 with France's *Commisariat à l'Énergie Atomique* (CEA) with Euratom contributing two-thirds of the funds to support a French national fusion program.
37. Shaw, *Europe's Experiment in Fusion*, 5–12; also, Willson, *A European Experiment*.
38. When the deuterium and tritium fuse, they produce helium nuclei, an energized neutron, plus some energy. To produce power, the energy produced must be able to be recovered in some useful form. The neutrally charged neutrons, for instance, can migrate through the plasma and be absorbed by the walls of the reactor where they can transfer their energy as heat.

39. Chapter 9 of Bromberg, *Fusion* and Gough and Eastlund, 'Prospects of Fusion Power.' By driving an electric current through the plasma, a magnetic field is generated which wraps around the hot matter and confines it while other magnets external to the torus generate additional confining magnetic forces. Other fusion designs use similar toroidal configurations to achieve magnetic confinement. For example, in the early 1950s at Princeton University, physicist Lyman Spitzer developed a magnetic confinement design which took a basic torus but twisted the doughnut shaped tube 180 degrees to make two tori with magnetic fields running in opposite direction. This design, with a shape resembling a pretzel, was called the 'stellarator' and was refined for decades in the USA as well as in Germany and Japan.
40. Palumbo, 'Work of the European Commission,' 1469.
41. Shaw, *Europe's Experiment in Fusion*, 19.
42. 'Euratom's Future Activities,' April 1969 report presented to the Commission of European Communities; AEI.
43. This also applied to traditional fission reactors. For example, following the 1973 oil shock, France's prime minister quadrupled the size of his country's nuclear power program; see Bess, *The Light-Green Society*, 94–5.
44. The meaning of the 'T' in the name was subject to some debate. The director of the Garching laboratory, for instance, had reservations about tokamak design and argued for a stellarator design which is also based on a toroidal geometry – hence 'torus' instead of 'tokamak.' This also reflected a professional divergence between researchers who were more interested in small-scale plasma physics research and those inclined to large-scale engineering projects.
45. 'The JET Project,' *Research and Development Bulletin*, no. 125/76, released 1976 by Commission of European Communities, Information Directorate Generale; AEI.
46. *Ibid.*
47. Lubkin, 'Four New Tokamaks.'
48. Donato Palumbo, 'European Fusion Program,' talk given at Conference on Industry's Role in the Development of Fusion Power, New York, NY, 4–6 May 1981; AEI.
49. Palumbo, 'Work of the European Commission.' Palumbo signaled his interest in greater pan-European collaboration by suggesting that JET's management include representatives from non-fusion organizations such as CERN and even the European Launch Development Organization. Although Palumbo's colleagues vetoed this plan, he clearly harbored ambitions to assemble a broad coalition of European research organizations. Shaw, *Europe's Experiment in Fusion*, 28.
50. Fjaestad, 'Why Did the Breeder Reactor Fail?' Also see Marth, *European Fast Reactor Cooperation*.
51. Trischler and Weinberger, 'Engineering Europe,' 52–3. For French breeder reactor goals, Hecht, 'Technology, Politics, and National Identity.'
52. This is recounted in 'A Tale of Two Jets,' *The Economist*, 22 October 1977, 58. One stipulation of the site agreement, according to Shaw's book on JET (*Europe's Experiment in Fusion*), was that any international successor to JET would not be built in the country where the reactor was located.
53. This was first done in April 1976 with the creation of Consultative Committee on Fusion which was superseded by the Consultative Committee of the Fusion Program. Shaw, *Europe's Experiment in Fusion*, 57–8 and 'Communication from the Commission to the Council Concerning the Creation of a Consultative Committee of the Fusion Program,' 19 December 1979 report to the European Commission; DG/EC.
54. Palumbo and his colleagues had formulated these in the 1960s but, during the confusion national fusion programs experienced in the late 1960s, the practice stopped. To help coordinate fusion R&D in both national as well as transnational efforts like JET, the new five-year plans were to be reviewed every three years with the idea of fostering continuity. A new five-year plan was adopted in March 1976 by the Council of European Communities.
55. 'The European Community Programme in Thermonuclear Fusion and Plasma Physics,' *Research and Development Bulletin*, no. 126/76, released 1976 by Commission of European Communities, Information Directorate Generale; AEI.
56. Examples from astronomy and physics are described in Collins, *Gravity's Shadow*; Smith and McCray, 'Beyond the Hubble Space Telescope'; and Hoddeson, Kolb, and Westfall, *Fermilab*.
57. Dickson, 'Nervousness in Europe's Fusion Labs.'
58. *Ibid.* In 1982, the EC announced it would raise fusion funding from 900 to 1400 million ECUs (European Currency Units) over five years. An ECU was equal to about £0.56 which itself was worth about US\$1.00; Becker, 'European Fusion Sustained.'

59. Emphasis added; from a December 1980 Council of Ministers resolution concerning the EC fusion program; cited in draft of 'A Proposal for a Research and Training Program (1982–86) for the European Atomic Energy Community in the Field of Controlled Thermonuclear Fusion,' 22 May 1981; DG/EC. Scientists and science managers typically justified the various national projects as contributing expertise and experience to the overall transnational effort: 'Report of the European Fusion Review Panel,' 3 December 1981, submitted to the Commission of European Communities; DG/EC.
60. From this point on, I use 'international collaborations' to reference those that involved plans for European collaboration with other nations such as the USA or the Soviet Union. The European efforts were, of course, already international but managed and funded by supranational organizations such as Euratom and the European Commission.
61. Formed in 1957 and based in Vienna, the IAEA started taking a greater interest in fusion research in the 1970s. In 1972, for example, the IAEA established its own fusion advisory group with scientists from major national programs. In 1982, this group included the USA, the USSR, the UK, Euratom, France, West Germany, Italy, the Netherlands, Sweden, and Australia.
62. Some rationales for Soviet interest in international fusion collaboration are given in the Central Intelligence Agency's 'The Soviet Magnetic Confinement Fusion Program: An International Future,' a formerly classified report prepared in July 1990; available from <http://www.foia.cia.gov/> (accessed 27 May 2010); my thanks to Jacob Darwin Hamblin for pointing this out to me.
63. Stacey, *Quest for a Fusion Energy Reactor*. A series of design workshops emerged from this but these were more 'brainstorming sessions instead of a dedicated design effort' according to the CIA's 'The Soviet Magnetic Confinement Fusion Program: An International Future' report, 3.
64. 'International Cooperation in Fusion,' undated draft document from 1982; DG/EC.
65. 'A Proposal for a Research and Training Program (1982–86) for the European Atomic Energy Community in the Field of Controlled Thermonuclear Fusion,' 1981, 26–7; DG/EC. Becker, 'Fusion Research,' 188.
66. From 'Report of the European Fusion Review Panel,' 3 December 1981, 19, submitted to the Commission of European Communities; DG/EC.
67. Dickson, 'Nervousness in Europe's Fusion Labs.'
68. A good deal of tension was rooted in early 1980s technopolitics including concerns over air traffic safety following the Soviet downing of a South Korean airliner, disputes over a Soviet–West German pipeline, Reagan's announcement of the Strategic Defense Initiative, as well as the planned deployment of US intermediate range ballistic missiles to Europe.
69. Robinson, 'Fusion Energy.'
70. 'Summary Minutes of the First Meeting of the Consultative Committee of the Fusion Program,' 8 January 1981; DG/EC.
71. Robinson, 'Slower Magnetic Fusion'; Norman, 'Reagan Budget.' The bill's sponsor, Michael McCormack (D-Washington), was defeated for reelection in 1980.
72. 'Aide-Mémoire – International Cooperation in Fusion Research,' 28 June 1982; DG/EC.
73. Ibid.
74. Donato Palumbo, 'The European Fusion Program,' talk given at Conference on Industry's Role in the Development of Fusion Power, New York, NY, 4–6 May 1981; AEI. This divide was noted as recently as 2010 in a conversation I had with Hiroshi Matsumoto, an ITER official, who noted that in the USA fusion research is often seen as physics whereas in Japan and Europe it is largely seen as engineering done for eventual energy applications; 26 May 2010, personal communication to author.
75. 'Proposed Agenda: Versailles Summit Follow-On Meeting for Fusion,' n.d. but sometime summer 1983; DG/EC.
76. 'Opening Statement of the EC' in 'Agenda and Statements, Versailles Summit Follow-On Meeting,' 29–30 September 1983; DG/EC.
77. During the first term of the Reagan administration, the USA proposed the Space Station Freedom and the Superconducting Supercollider (SSC), both initially as US-only efforts. Space Station Freedom, of course, later became the International Space Station while Congress ended the SSC partly because it failed to attract international partners; Kevles, 'Big Science and Big Politics.'
78. Shapley, 'US Seeks Foreign Links.'
79. "Aide-Mémoire – International Cooperation in Fusion Research,' 28 June 1982; DG/EC. Perceptions of the USA as an unreliable partner were reinforced when US Department of Energy and the European Commission discussed the possibility of jointly collaborating on a Fusion

- Materials Irradiation Test facility to be built at the Hanford, Washington site only to have the USA suddenly defer further work on it; letters between Donato Palumbo and Alvin Trivelpiece (22 September 1983 and 11 November 1983); DG/EC.
80. 'Summary Minutes of the Third Meeting of the Consultative Committee of the Fusion Program,' 7 April 1981.
 81. 'Opening Statement of the EC' in 'Agenda and Statements, Versailles Summit Follow-On Meeting,' 29–30 September 1983; DG/EC.
 82. A sense of Mitterand's goals are found in his 5 July 1982 report '*Technologie, Emploi, and Croissance*'; available from <http://www.g8.utoronto.ca/summit/1982versailles/index.html> (last accessed 30 April 2010); also Dickson, 'Scientific Cooperation' and Dickson, 'A Political Push.'
 83. Gwertzman, 'Soviet Reactor Bid'; Boffey, 'Summit Statement Brings New Life'; and Crawford, 'Soviet–U.S. Fusion Pact.'
 84. Ironically, similar motivations were behind Eisenhower's 'Atoms for Peace' program; Hewlett and Holl, *Atoms for Peace and War*.
 85. 'Joint Soviet–United States Statement on the Summit Meeting in Geneva,' 21 November 1985; available from <http://www.reagan.utexas.edu/archives/speeches/1985/112185a.htm> (accessed 1 May 2010).
 86. Ronald Reagan, 'Address Before a Joint Session of the Congress Following the Soviet–United States Summit Meeting in Geneva,' 21 November 1985; available from <http://www.reagan.utexas.edu/archives/speeches/1985/112185c.htm> (accessed 1 May 2010). In 1987, Reagan and Gorbachev 'affirmed the intention of the U.S. and the USSR to cooperate with the European Atomic Energy Community (EURATOM) and Japan, under the auspices of the International Atomic Energy Agency, in the quadripartite conceptual design of a fusion test reactor'; available from <http://www.reagan.utexas.edu/archives/speeches/1987/121087a.htm> (accessed 5 May 2010).
 87. Crawford, 'Soviet–U.S. Fusion Pact.'
 88. Norman, 'JET.'
 89. 'Summary Minutes of the 27th Meeting of the Consultative Committee of the Fusion Program,' 19 June 1986; DG/EC.
 90. 'Mission report – International Cooperation in Fusion,' 10–11 April 1986 (emphasis in original); DG/EC. According to Palumbo, Alvin Trivelpiece, head of the DOE's Department of Energy Research, reported that the Soviets preferred to see France, Germany, and the UK as individual potential partners rather than a single entity focused on a common goal.
 91. 'Mission report – International Cooperation in Fusion and Supporting Documents,' 10–11 April 1986; 'Expanded Multilateral Fusion Cooperation,' 3 June 1986 (no author listed but likely written by Palumbo); both DG/EC.
 92. 'Summary Minutes of the 30th (Extraordinary) Meeting of the Consultative Committee of the Fusion Program,' 29 April 1987; DG/EC.
 93. Comments by Romano Toschi in 'Summary Minutes of Special Meeting of the Consultative Committee of the Fusion Program,' 4 September 1987; DG/EC.
 94. 'Summary Minutes of Special Meeting of the Consultative Committee of the Fusion Program,' 4 September 1987; DG/EC.
 95. *Ibid.* Emphasis in original.
 96. The IAEA's role was to act as the party with which the various partners made their quadripartite agreement; the agency hosted meetings of the ITER Council and also provided modest support for project administration. Its involvement, of course, brought another significant transnational player into the global fusion research community. 'Records of the First Meeting of the ITER Council,' 21–22 April 1988; DG/EC.
 97. Cherfas, 'Europe: Betting Heavily on Fusion.'
 98. 24 February 1988 letter from Cribier to Klaus Pinkau; DG/EC.
 99. 3 March 1988 letter from Klaus Pinau to Daniel Cribier.
 100. Donato Palumbo, 'Artsimovich Memorial Lecture: Origin and Role of Cooperation in International Fusion Research,' July 1980 address to IAEA 8th International Conference on Plasma Physics and Controlled Nuclear Fusion Research; available from http://www.ofes.fusion.doe.gov/More_HTML/Artsimovich/Palumbo1980.html (accessed 4 May 2010).
 101. Glanz and Lawler, 'Planning a Future' and Goodwin, 'Budget Surplus.'
 102. The specific reasons are unclear and the DG/EC records for this period are inaccessible because of the 30-year access restriction set by the European Commission Historical Archives. In 1997, *Nature* reported that NET had been abandoned by 'the mid-1980s' but there is evidence from

- other science journals that the program continued until at least 1990; Cherfas, 'Europe: Betting Heavily on Fusion.'
103. Russia remained an official partner but its economic difficulties during the 1990s limited its participation. Canada also joined the project in the late 1980s but as an associate member participating as a member of the European team. Glanz, 'Requiem for a Heavyweight' and Redfearn, 'Reduced ITER Design.'
 104. Instead of producing some 1500 MW of power in 1000 second bursts, engineers downscaled ITER's performance goals to 400 MW of power in 400 second bursts. Redfearn, 'Reduced ITER Design.'
 105. Feder, 'Downsized Fusion Reactor.'
 106. Quote from Robert Aymar, who directed ITER from 1994 to 2003 before becoming Director General of CERN, in Feder, 'Downsized Fusion Reactor.'
 107. Feder, 'Fusion Community Cheers.'
 108. Cohen, *Le Colbertisme High Tech*; Goodman, 'Tech Development.' The ways which French industrial policy tried to foster integration throughout the EU is explained in Cohen, 'Industrial Policies in France.' Cohen's article also notes the irony in which French top-down *dirigisme* was still used to promote regional initiatives.
 109. 'Fusion thermonucléaire: la ministre de la recherche promeut activement le site de Cadarache,' *Le Monde*, 28 June 2003; 'Les Enjeux du Pôle Scientifique ITER,' *La Tribune*, 28 September 2003, 25; 'La région PACA revendique ses compétences dans l'énergie,' *Les Echos*, 26 May 2006, 4.
 110. 'Spain: The Morning After,' *The Economist*, 6 November 2008; available from http://www.economist.com/surveys/displaystory.cfm?story_id=12501087 (accessed 6 May 2010).
 111. Feder, 'Europe Wrestles.'
 112. 'L'Europe en fusion,' *Le Monde*, 23 November 2003.
 113. Proposed by Rep. Robert W. Ney (R-Ohio) in March 2003. France responded by noting that 'French' fries originated in Belgium and Ney later resigned from Congress after pleading guilty in a lobbying scandal.
 114. Reasons for this are unclear. One rationale given by the Bush administration was that fusion was part of its long-term energy strategy; National Energy Policy Development Group, *National Energy Policy*.
 115. Editors, 'Don't Mention the War'; Brumfiel and Butler, 'U.S. Support for Spain.'
 116. Spencer Abraham, 'Press Conference remarks,' 1 May 2003; available from <http://www.embusa.es/ratoabraham.html> (accessed 5 May 2010 via Internet Archive).
 117. Feder, 'Europe Wrestles.'
 118. Clery and Bosch, 'Panel Tells E.U. It Could Go ITER Way.' Also, 9 September 2003 'ITER Site Analysis Group Report,' chaired by Sir David King; available from <http://fire.pppl.gov/> (accessed 10 May 2010).
 119. Ricard, 'Les Européens choisissent.'
 120. Clery, 'E.U. Puts France in Play' and Ricard, 'Les Européens choisissent.'
 121. 'Bouillabaisse Sushi,' *The Economist*, 5 February 2004; available from fire.pppl.gov/iter_economist_020504.pdf (accessed 8 May 2010).
 122. 'Remarks by Secretary of Energy Spencer Abraham,' 9 January 2004; available from fire.pppl.gov/abraham_japan_010904.pdf (accessed 10 May 2010).
 123. 'Bouillabaisse Sushi,' *The Economist*, 5 February 2004; 'Les chercheurs nous embarquent pour ITER,' *Le Canard Enchaîné*, 28 January 2004.
 124. Feder, 'Barring ITER Site Consensus' and Buck, 'Paris Urges EU.'
 125. Reported by the *Agence France-Presse*, 4 May 2005 and summarized in *The Tocqueville Connection*, an on-line news aggregation service; available from http://fire.pppl.gov/iter_tocqueville_050405.pdf (accessed 11 May 2010). Chirac's success was certainly aided by the intervention of EU research commissioner Janez Potočnik who also met directly with top Japanese leaders.
 126. Ibid.
 127. Clery and Normile, 'ITER Rivals Agree.'
 128. De Villepin, 'Une nouvelle Europe politique.'
 129. 'Remarks by Prime Minister Jacques Chirac,' Cadarache, France, 30 June 2005; available from www-fusion-magnetique.cea.fr/actualites/2005-06-30-discours_jc.pdf (accessed 10 May 2010).
 130. Sciolino, 'French Voters.'
 131. Palumbo, 'Work of the European Commission,' 1472.

132. 'Is Fusion the Best Way Forward?' Reuters technology column presented by CNN.com, 30 June 2005; available from <http://www.cnn.com/2005/TECH/06/29/vision.fusion.reut/index.html> (accessed 11 May 2010).
133. Although it is beyond the focus of this article, it is worth noting that opposition to ITER also attracted the participation and attention of various transnational groups. For example, organizations like the Sierra Club and Greenpeace objected to ITER and fusion facilities in general and, after 2005, the transnational anti-nuclear group *Sortir du Nucléaire* actively campaigned against ITER in France.
134. Misa and Schot, 'Inventing Europe.'
135. Krige, 'Politics of European Scientific Collaboration,' 916–17.
136. Palumbo, 'Nature and Prospects.'
137. 'ITER: Un Soleil Artificiel 'a Portée de Main,' 2007 brochure; available from www.sortirdunucleaire.org (accessed 11 May 2010).
138. 'Remarks by Prime Minister Jacques Chirac,' Cadarache, France, 30 June 2005; available from www-fusion-magnetique.cea.fr/actualites/2005-06-30-discours_jc.pdf (accessed 10 May 2010).
139. Editors, 'Bush and Kerry.'
140. 'Report of the European Fusion Review Panel,' December 1981 and 'Report of the European Fusion Review Panel II,' March 1984; both DG/EC.
141. Cherfas, 'Europe: Betting Heavily on Fusion.' An interesting question, beyond the scope of this essay, would be to evaluate how fusion research has appeared in Europe's long-term energy strategy, either as a real option or as a rhetorical tool to justify continued funding.
142. For example, in November 2008, I attended a 'science café' in Marseille featuring two scientists from ITER. Recurrent themes throughout their talks were ITER as a 'sustainable energy' project and fusion power as a way to avoid doing business with foreign energy suppliers. Similar themes can be found throughout ITER's promotional materials; see www.iter.org. To be fair, not all European scientists share this view – French physicist and Nobel laureate Pierre-Gilles de Gennes was an outspoken critic of fusion research while environmental groups have claimed that money spent on ITER would be better invested in solar and wind power.
143. White House press release, 30 January 2003; available from <http://www.presidency.ucsb.edu/ws/index.php?pid=224&st=&st1=>. Also, 'Energy Secretary Abraham Visits,' *Hotline: Newsletters of the Princeton Plasma Physics Laboratory*, 13 February 2003; available from <http://fire.pppl.gov/>. Both accessed 1 June 2010.
144. This is not to say, of course, that European funding for fusion research did not experience its own vicissitudes. In 2000, for example, Europe's fusion program had its funding reduced in part because the EU's budget leader was a member of Germany's Green Party, a group generally opposed to nuclear-related research. Shore and Cross, 'Maintaining Funding.'
145. McCray, *Giant Telescopes*, 180–1.
146. For a meta-narrative, focused on the USA, of how science and technology were used as tools for global leadership, see John Krige, 'The Arsenal of Knowledge,' forthcoming in *Centaurus*. My thanks to Krige for sharing an advance copy of this.
147. 1995 comment from Christian Patermann, then Deputy Director General of the German Ministry of Research and Technology; presented in Krige and Guzzetti, *European Scientific and Technological Collaboration*, 476.
148. Ibid.
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