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The ways and means of ITER: reciprocity and compromise in fusion science diplomacy

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ABSTRACT

ITER (short for International Thermonuclear Experimental Reactor, and the Latin word for 'the way', as in 'the way to new energy'), a controlled thermonuclear fusion experiment currently being built in Cadarache, France, is one of the world's largest technoscientific collaborations. ITER's complex organisation is rooted in decisions taken during the early negotiation phase in the 1990s. This article focuses on this initial period of the ITER negotiations, showing the importance of reciprocity and compromise in the organizational decisions of the project. These decisions were enacted by actors and organisations who strived to keep ITER together through continuous 'backstage' diplomacy work. This work included finding acceptable compromises for the involved Parties on both a diplomatic and scientific level. Looking closely at such work reveals the entangled character of science and diplomacy in large international technoscientific collaborations, as well as the need for compromise to make a project like ITER materialise.

KEYWORDS

Fusion; ITER; science diplomacy; compromise; reciprocity; big science

> If you will be given as an experienced project manager [. . .] the task to execute this project, there is no way you will do it the way we are doing it at the moment. But the ITER Agreement, the ITER treaty, is a consequence of: this is how the Japanese think about it, this is how the Koreans think about it etc, etc. So, it's a compromise.
>
> Akko Maas, Knowledge Management Officer, ITER, 2018

Introduction

The construction of the controlled nuclear fusion experiment ITER (short for International Thermonuclear Experimental Reactor, as well as the Latin word for 'the way', as in 'the way to new energy'), currently underway in Cadarache, Southern France, is one of the largest technoscientific collaborations in the world today. The project is ambitious in scope as well as in aims: to build knowledge and ability in the fusion field in each of the nations involved while simultaneously constructing a functioning 'first-of-its-

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In addition to ITER documents published by the IAEA, I have use the ITER International Thermonuclear Experimental Reactor collection at the Historical Archives of the European Union in Florence (HAEU). The collection was donated to HAEU by Patrick McCray, of the University of California, Santa Barbara. In the footnotes I reference this material as ITER-plus the number of the file and the subfolder (when applicable).

kind' reactor. Building a machine such as ITER is, to say the least, a complicated process, where diplomacy, complex management, and negotiation are at the heart of the project. This is true not only for the top-level politicians who sign agreements regarding scientific collaboration on the so called 'front-stage', or the State level, of diplomatic action. It is also true for the science policy advisors, scientists, engineers, lawyers, economists, and managers working on the project, all the way down to the work site itself where German welders may work under Indian supervision following French nuclear-safety protocols. One might say that technoscientific diplomacy is performed there on a day-to-day basis. The aim of this article is to unpack the way in which actors and organizations have strived to keep the project together through the work of 'backstage' science diplomacy, enacted through reciprocity and compromise in the initial phase of the project.[1] I will discuss the consequences of early compromises as manifested in the scientific organization of ITER and show how scientific and diplomatic decisions are entangled in this process. In doing this, I argue that while grand gestures and perhaps grand conflict may go on at the front-stage of science diplomacy, on the backstage compromise is necessary in order to make a project like ITER materialize.

Reciprocity and compromise in science diplomacy

While the results of ITER are eagerly awaited by many, the project has also been heavily criticized.[2] One reason for criticism has been its organizational approach, as well as many delays and lack of efficiency. As late as 2015 an evaluation almost led to the end of the project, before a change in leadership and a revision of the project schedule.[3] Even ITER personnel admit that the way the project is conceived is, in many ways, unsatisfactory from a scientific and project management point of view.[4]

A case in point: ITER uses an in-kind system, where participants contribute by constructing parts of the reactor in their respective countries and then sending them for assembly to Cadarache. Around 85 to 90% of ITER project funds are given through in-kind contribution. This is a particularly high amount for projects of this scale. While an in-kind system is partially used in other big science projects, such as the ongoing construction of the European Spallation Source, the ITER machine is almost entirely built in this fashion, resulting in a network system with a weak central organization. In addition, since the aim is to increase knowledge for all participants, the same component is often built simultaneously by several different parties. The vacuum vessel, for example, is constructed in both Europe and Korea, and the same kind of magnetic coil is manufactured in both Russia and China. Akko Maas, Knowledge Management Officer at ITER, has commented regarding the construction of the vacuum vessel that it 'is the first safety barrier. If you would ask any scientist, technologist, or safety person what not to do, they will tell you, you have to have the vacuum vessel fabricated by one single entity'.[5] Yet, at ITER, it is not. One clue as to why the project was developed in this distributed fashion can be found in the initial citation from Maas: It represents a compromise, and it is based on an ideal of reciprocity.

The concept of reciprocity has been a core characteristic of diplomacy over time.[6] The ideal of reciprocity in this sense implies equality in exchange, a balance between parties of a negotiation. Everybody has to gain something and gain as equally as possible, although reciprocity does not imply that all parties involved are necessarily of equal standing.[7]

ITER is an example of so called specific reciprocity, namely 'situations in which specified partners exchange items of equivalent value in strictly delimited sequences'.[8] The attempts to make sure that reciprocity is ensured during the negotiation and construction of ITER has, in turn, resulted in quite a few compromises.

An example of such a compromise developed during the discussion of the siting, when the EU decided to propose the French site, Cadarache, as the EU candidate, thus bypassing the Spanish site, Vandellos. In order to ensure a certain measure of reciprocity for Spain, the European Agency for the Joint Undertaking, responsible for coordinating the EU's in-kind contribution to ITER, was placed in Barcelona instead of at the ITER site itself. Bernard Bigot, current Director General of ITER, reminisces a propos the choice of placing the Agency for the Joint Undertaking in Vandellos, that 'it was a trade-off. [...] But it was the price to pay in order to get out [of the situation]. And you can see how maybe [the] wrong decision could be taken, wrong decision from the point of view of technical matter, but it is the only way you could make the project move on'.[9] This idea, that compromise is the only way for the project to survive, is echoed by several members of the ITER leadership. As pointed out by G.S. Lee, current Deputy Director General of ITER, they had to 'do it this way, deliver this way, or not do it ... Either one is not very good, but the worst is not doing it'.[10]

Compromise is another central concept in diplomacy, where it has often been seen as a tool of a 'realist' mode of diplomacy.[11] To reach a compromise can be construed as a success, but also as a failure if we consider compromise in the sense of accepting standards that are lower than desirable. Meanwhile, despite its centrality, the concept has not been much explored in recent science diplomacy work. Those observers who consider science and diplomacy as radically different practices, often refer precisely to the tension between the supposed realist necessities of diplomacy as opposed to the idealist aspirations of science, and from that perspective, compromise may be a difficult topic to tackle.[12] For example, the central science diplomacy text published by the Royal Society and the American Association for the Advancement of Science (AAAS) in 2010 starts with the proclamation that science and diplomacy are not 'obvious bedfellows', since science is 'in the business of establishing truth, while the opposite may be true of diplomacy'.[13] Similarly, Turekian et al. point out that while science 'is neither inherently political nor ideological, but represents a type of universal language', diplomacy is 'characterized by dialogues, negotiation and compromise'.[14] However, if seen from somewhat less essentialist vantage points, diplomacy has both idealist and realist aspirations, insofar as they can be separated, and so does technoscientific work. In particular in large international technoscientific projects such as ITER, decisions need to be based on both a scientific and a diplomatic rationale, and often these two are entangled.[15] Thus, in order to understand the way the ITER project is organized, it is vital to explore its origins in reciprocity and compromise as well as the ways diplomatic and scientific rationales are entangled in the process of project negotiation.

As pointed out by political scientist Alin Fumuresco, 'compromise looks messy, the dreary stuff of day-to-day politics'.[16] This 'dreary' work of trying to reconcile the wills, means and materialities engaged in a large technoscientific project does not happen on the front-stage of science diplomacy. Instead, it happens on the backstage among the many actors on different levels working on the project and its design, from science and technology policy advisors to scientists working at research sites. For the purpose of this article, backstage diplomacy encompasses the practices and processes that both lead up to and deal with the consequences of front-stage diplomatic negotiations. This includes the work of the ITER council, the Management Advisory Committee and the Technical Advisory Committee, as well as the scientific work at the Home Teams and the Joint Central Teams. In this article, I will trace this work in the early history of the ITER project through the two separate so-named Design Activities, the Conceptual and the Engineering, taking place from 1987 to 2001.

The history of the ITER project has been told mainly by actors involved in the project over time from different countries through articles and informational material on the project. From the Russian perspective, the period that I will be covering has been described in the book *ITER: A decisive step* (ИТЭР: Решающий Шаг) published in 2004 by the Russian Ministries of Atomic Energy and of Education in collaboration with the Moscow State University.[17]

Two French monographs have also been published on ITER by actors involved in the projects. The first is *ITER: le chemin des étoiles*, by Robert Arnoux and Jean Jacquinot, which outlines the history of ITER up until 2006.[18] More recently, Michel Claessens, former head of communications of ITER, published a monograph on the history of ITER, while also engaging in some of the current debates.[19] In addition, there is an increasing amount of material discussing the pros and cons of the ITER project, including monographs, articles, podcast episodes, and the documentary 'Let There be Light' (2017).[20] A recent example is the book *Soleil Trompeur* by Isabelle Bourboulon.[21] In general, while these texts sometimes touch on the origins of ITER, they rarely delve deeper into the discussions taking place during the 1990s, but instead focus on the later developments regarding the siting procedure and construction start. This article will examine that earlier period more closely, to tease out the processes that lay the groundwork for the later developments.

Overall, ITER has so far not been the subject of much historical or social science research. One exception is Patrick McCray who has examined ITER as an example of a global research project and transnationalism in research, focusing on the role of the European Union.[22] McCray's description of the political game behind the siting procedure in the early 2000s, shows how fusion is used on the level of front-stage diplomacy, and highlights the tensions between national programs and international collaboration. These tensions are clear in the processes described in this article.

If largely absent from historical and social science literature, ITER has often been used as an example in recent science diplomacy literature. An article was dedicated to it in the first ever issue of the journal *Science & Diplomacy* in 2012, and it features in the first chapter of the only edited volume to date on science diplomacy.[23] It is further the first example in the recent and central volume on science diplomacy by Bruno Ruffini, and in the earlier mentioned monograph on the history of ITER, Michel Claessens classifies ITER as a diplomatic technology (*téchnologie diplomatique*).[24] In these texts, ITER is held up as an example of science diplomacy in the sense of diplomacy aiding science collaboration, as well as a successful large international collaboration. Of these authors, Claessens is the only one to scrutinize what being a 'diplomatic technology' might mean in more detail, focusing on the creations of scientific and diplomatic communities as well as technology and expertise.[25] The way ITER is used in this literature aligns with descriptions by Kaltofen and Acuto of how science diplomacy is often conflated with the idea of 'epistemic communities', leading to a rather superficial description of heterogenous and complex phenomena such as science diplomacy. They argue that one way of deepening the analysis would be to use a more practice-based approach.[26]

In the remainder of this article, I will focus on a time period in ITER history that I see as crucial for the set-up and organisation of the project, but which is generally glossed over in the earlier literature. Further, while McCray has shown the kind of rhetoric and processes that have been used on the front-stage of ITER negotiations, my analysis focuses on a different level of negotiations, and the decisions needed for the project to function in practice. The study also adds to the science diplomacy literature by focusing on practices of compromise and reciprocity, as opposed to ideas of science diplomacy as predominantly exchange of knowledge and expertise.

The road to ITER

The summit in Geneva in 1985 where Ronald Reagan and Mikhail Gorbachev met for the first time is often described as the starting point for ITER. Through lobbying by the scientific community from the Soviet Union and the US, and, in particular, through the close relation between Mikhail Gorbachev and scientist Evgenii Velikhov, fusion cooperation was put on the agenda of the meeting and during the planning phase Japan and the European Community (EC) also became involved. Thus, one of the results of the summit was an agreement to cooperate in the field of fusion.[27]

Historically, since the Geneva meetings in 1956 and 1958, when the main fusion (and nuclear) powers including the Soviet Union, the US and the UK, formally declassified their fusion research, fusion has embodied the possibility for reciprocity and cooperation in a high-profile area, without short-term risks.[28] The possibility to collaborate in an important and highly politicized scientific field while knowing that applicable results would only be forthcoming in the long term made fusion fitting for diplomatic relations. Historian Barbara Curli has pointed out that the gesture of declassification can already in itself be seen as using fusion cooperation as a tool for foreign policy.[29] In this vein, fusion also became one of the areas for US and USSR cooperation after the Geneva meeting in 1958.[30] During the Cold War, fusion research would repeatedly intersect with international, national and regional politics, and, as pointed out by McCray, often as a continuation of politics by other means.[31] The Geneva meeting of 1985 was no exception.

Moreover, during the 1970s, fusion research had entered a more hardware-focused phase.[32] Up until the end of the 1960s, several types of reactors were envisaged by research groups in different countries, making collaboration on a machine challenging. However, in late 1960s, the Soviets had an important breakthrough in their tokamak reactor design, causing scientists in other countries to turn to the same design.[33] The Soviet breakthrough led to a heightened interest in fusion technology, and this coincided with the oil crisis and new investments in alternative energy during the 1970s. As a result, three large tokamaks were constructed during the 1970s and came into operation in the late 1970s and early 1980s: the Tokamak Fusion Test Reactor (TFTR, created by the US in Princeton), the Japan Torus-60 (JT-60, by Japan in Naka) and the Joint European Torus (JET, by the EC in Culham).

JET was the first international cooperation around the construction of fusion hardware, a result of a European fusion network that had slowly been established over the 1960s, largely due to the diligent work of the director for the Euratom fusion program, Donato Palumbo. JET also became the first so called 'Joint Undertaking' of the European Communities, and such a setup is also being used for the common European engagement in ITER.[34] While the JET project in many ways showcased some of the problems that the international collaboration around ITER would later face, it paved the way for the possibility of the European Community entering ITER as a single, collective actor.

The heightened interest in fusion in the 1970s had prompted the International Atomic Energy Agency (IAEA) to form an International Fusion Research Council, and to gather information regarding the objectives of national fusion programs.[35] In 1978, the Soviet Union proposed an international tokamak collaboration under the auspices of the IAEA, with Japan, the US, the EC and the USSR participating.[36] This led to a number of workshops being initiated by the IAEA, but discussions did not lead to any concrete designs, and international cooperation around the peaceful uses of fusion came to suffer from heightened tension between the USSR and the US in the early 1980s.

Thus, in 1985, due to earlier collaboration, a research infrastructure, an international network and organization around fusion already existed, and even the start of a tokamak project including the US and the USSR. In the words of McCray, fusion 'made sense' as an 'arena for Cold War Superpower collaboration'.[37]

However, while the initial agreement in Geneva had been a grand political gesture, many actors still hesitated regarding such a large endeavor, and it would take until 1987 for the parties to meet and officially discuss the project.[38] Up until now, while scientific collaboration had taken place between national research groups, with the exception for JET, national programs had overall retained their autonomy in building larger devices. Thus, all involved actors had their own plans for larger tokamaks, so called 'next step' devices, and their national (and international in the case of the EC) programs competed with ITER for resources.[39] In Europe, the NET device was seen as the 'next step' for a fusion reactor, and its conception was developed in parallel to the ITER discussions.[40] Many in the European scientific community were also suspicious of ITER as a political project between the two superpowers and did not trust that it would become reality.[41]

A similar discussion on resource distribution took place in Japan.[42] After having undertaken smaller experiments during the 1950s and 1960s, in 1975, the Japanese government made the fusion program a prioritized national program. This resulted in JT-60, and the Japanese researchers worked on their own 'next step' machine called the Fusion Experimental Reactor (FER).[43] In the US, actors similarly hesitated due to the expected rivalry between the national programs and the larger one, but also due to a reluctance to participate in technological transfer with the Soviet Union.[44]

Despite these misgivings, global international cooperation was still seen by many actors as the only way to be able to build a larger demonstration reactor, since no one actor had the resources to do so independently.[45] Fusion is technoscience in the sense that new technologies are needed both to develop a fusion energy system and to produce knowledge on fusion. The research ensembles needed to undertake fusion research are resource-heavy, and 'visible, and accountable to other researchers and to the public, and so become more tightly coupled to diverse communities'.[46] Thus, as noted by historian John Krige in the case of CERN, international collaborations are often 'born more of pragmatic needs that of an idealistic commitment to "universality". These "needs" can be for scientific, technical, economic and even political support'.[47]

For example, cost estimates and an inability to nationally produce components for the next generation of fusion machines moved the Soviet Union to suggest the INTOR collaboration; as well, EC cooperation on JET was motivated by the fact that without Euratom support, the national programs in the EC were not likely to secure state funding.[48] Similarly, the Japanese government saw an opportunity with ITER to share the costs of building a demonstration reactor with other parties, and ITER was in the end re-conceptualized as a continuation of the Japanese program instead of competing with it.[49] This tension between the wills and reactor plans of different national research groups on one hand, and a perceived need for global cooperation to construct the next large fusion device on the other, would to a large extent shape the ITER project organisation.

Ways and means of a fusion reactor: building a structure of reciprocity

Two years after the public declaration of the Geneva summit, in March 1987, delegations from the US, the USSR, the EC (through Euratom) and Japan met in Vienna to initiate formal discussions at the invitation of IAEA Director General Hans Blix.[50] These formal front-stage diplomatic discussions set the framework for the ensuing backstage discussions at the level of the ITER council, and at ITER work during the Conceptual Design Activities [CDA] that were launched in 1988 and continued until December 1990. These discussions were central in forming a structure to ensure reciprocity between the Parties in a way that made sense on both a scientific and diplomatic level.[51] This would come to include reciprocity in the form of organizational power, financial responsibility, task division, scientific decision making and representation in terms of staff and work location. The decisions made during this period in turn heavily influenced the work during the Engineering Design Activities [EDA] that followed.

The organizational structure of the CDA included the ITER Council, the ITER Management Committee (IMC) and the ITER Science and Technology Advisory Committee (ISTAC).[52] Two members from each Party, including scientists and science policy administrators, were nominated to the ITER Council, responsible for the overall direction of the CDA (and later the EDA), and its execution.[53] All decisions in the Council were to be made unanimously.[54]

Krige has noted that the scientific ideal of many physicists is one of shared decision-making and power derived from experience and expertise. However, in reality there are often informal hierarchies in scientific collaboration, whether they are acknowledged or not, and in particular during the construction of a technical artefact decisions may need to be imposed from above to a considerable extent.[55] Such tensions between ideals of consensus and reciprocity in the sense of equal sharing of responsibility, and the actual practice of building a machine, would become more pronounced during the EDA, as we will see below.

While representatives of the Parties would work in a team at their home institutions (EURATOM for the EU, the Japanese Atomic Energy Agency for Japan, Department of Energy for the US and ROSATOM for the USSR), each of the home teams also sent ten representatives to do joint work in Garching, near Munich. This joint work did not have specific financing; the representatives were stationed there but paid by their home teams.[56]

The joint work was done at a European site, but the three main chairing positions were given to the other Parties. The role of ITER council chairman was given to John Clarke from the US Department of Energy; the ISTAC chairman to Boris Kadomtsev from the Kurchatov institute; and the Management Committee was chaired by Ken Tomabechi from the Japan Atomic Energy Agency, JAERI.[57] Thus, at this first stage, reciprocity was ensured through a rigorous division of organizational labor and responsibility.

Similarly, in terms of the scientific object at hand, the reactor, these first discussions were an initial attempt to reconcile the different ideas about what a 'next step' machine might entail, and thus ensure reciprocity in terms of scientific gain. Each Party had their own experimental reactors, differing in size, performance and shape, as well as what the reactor was supposed to do or not.[58] As pointed out by Denis Willson in his book about JET, 'an immense gulf' lies between the collaboration to construct a device designed for a particular research purpose, 'and any international cooperation to produce the prototype of any viable reactor'.[59] There are several ways to bridge such a technical and scientific gulf, and the Parties needed to find compromises that all could agree on, and which would benefit not only the ITER project as such, but each institution's own fusion research, in view of the tensions between the larger project and the national programs.

However, the 'gulf' between building a research device and an industrial prototype is not only technical.[60] In order to address the transition from the CDA to the EDA, in July 1989 the ITER Council decided to charter a working group to explore possible 'ways and means' for the EDA, to find the 'best reconciliation possible between technical, administrative and political needs and possibilities' on the way forward.[61] The discussions in the group regarded to a large extent reciprocity in terms of intellectual property, procurement, financial organization and siting.

Procurement was a central concern, as it determined the task division among Parties and the aim was to divide Research & Development (R&D) tasks and other contributions between the home institutions in a fair manner. Several models were initially discussed, some more 'centralized' and others 'decentralized'. The more centralized ones meant that a strong central team was responsible for the contract design with an open call for a tender and a selection from offered industrial contracts. The decentralized model, on the other hand, would mean that each of the home teams was responsible for an equal part of the R&D, even perhaps going so far as each Party contributing one quarter of the modules of each component.[62] While the EC had already used a centralized model at JET, and considered it to be more efficient than a de-centralized one, it seems as if other Parties found the competitive tendering policy difficult to comprehend and wanted a variant which allowed for less cash flow across frontiers.[63]

In the report of the Working Group, a kind of hybrid model was proposed as a compromise, where a general set of tasks was defined at the outset of the EDA, with the help of which the project Director would develop and propose an allocation of comprehensive packages to the Council. After allocation, the individual Parties would themselves organize the fulfilment of their work packages, either by their own personnel or by procurement from other sources. A Joint Central Team (JCT) under the leadership of the ITER Director would be responsible for design integration work. The working group also suggested a system that did not require transfer of funds across the Parties' boundaries, and would thereby be independent of exchange rates, labor rates, overhead rates and other similar complications.[64] This 'currency' so to speak was called the ITER

Unit of Account (IUA), or ITER credits.[65] Thus, both the task allocation system and the IUA became tools for equal division of labor and benefits between Parties with vastly different labor contexts. At the same time, this arrangement allowed for all Parties to engage in knowledge production, which was one of the main aims of the project. Thus, ideally, such a model would ensure reciprocity both in terms of scientific benefit, and in terms of amount of scientific work performed. In the EDA agreement, such reciprocity would be formulated as a 'principle of equality of the Parties with regard to their status in, their contributions to, and their benefits from the cooperation'.[66]

A more challenging issue proved to be agreeing on a Joint Central Team Site. The idea was to have a central team based at a single site during the EDA, to which personnel from the different Parties would be relocated.[67] In February 1991, new front-stage Quadripartite EDA Negotiations started that included the main actors from each institution involved, as well as formal diplomatic representatives from the Parties. The aim of the negotiation was to sign the EDA agreement. At the first meeting, three Parties proposed to host the JCT: Naka (Japan), Garching (Germany) and San Diego (US).[68] At the second negotiation meeting, it became clear that none of the Parties were willing to withdraw their offers, and the quantifiable comparison of the sites did not lead to a clear view of the best option.[69] Thus a new task force was created with the mission to investigate the consequences of dividing the JCT over two or even all three proposed sites.

The draft report of the task force concluded that a single-site solution would be the best solution but having two or three co-sites were also considered viable options. The risks of the latter solution, in comparison with the single-site solution, was the loss of strong central leadership and efficient communication needed for a project of the technical complexity and international charter of ITER, as well as increased cost-estimates and concerns regarding personnel recruitment.[70] The advantages of a multi-site solution were the close connection to each host Party's home program, as well as heightened visibility and support in the three countries. If successful, it could also provide a new model for international mega-projects, which was an ITER Council objective.[71] The connections to each home program as well as the heightened visibility was important in light of the earlier mentioned competition between the national programs and the international project. ITER could not be seen as a rival to the national programs, especially in terms of shared funding.[72] The list of disadvantages of a multi-site solution was, however, double the length compared to the list of advantages, although the delegates' view of the risk of a multisite-solution 'varied from small to significant'.[73]

Despite this, at the third meeting of the Quadripartite Negotiations, the negotiating parties accepted the solution of three co-centers 'of equivalent importance' as well as naming Moscow (the Soviet Union had not proposed to host a site) the formal seat of the ITER Council.[74] At stake in these discussions was the reciprocity between the Parties, as well as the control over the overall program and its connection to the scientific work of each home team. Considering the strong practical case for a single-site solution, it may be concluded that a diplomatic rationale rather than a scientific one underpinned this decision. Meanwhile, as pointed out above, the national research teams also had an interest in ensuring that the scientific work had a close connection to each national research program to legitimize the participation in the project. Further, the EDA would also mean a much higher economic stake than the CDA, and all Parties wanted to assure benefit from their investments.

The decisions to use a de-centralized procurement organization of ITER, as well as the split JCT are fundamental ones taken against a backdrop of efforts to ensure reciprocity in a large technoscientific project that exists in the tension between international cooperation and national research, between technoscience and politics, and between backstage and front-stage politics. While these decisions can be seen as necessary to ensure the project's development, they would also lead to complications during the EDA.

A 'particularly challenging' project: the consequences of reciprocity

When the EDA started at the first ITER Council meeting in Vienna in September 1992, the set up was complex, to say the least. In addition to the ITER Council, the Home Teams (HT), and the Joint Central Team (JCT), now divided over three different Joint Work Sites, two permanent advisory committees, the Technical Advisory Committee (TAC) and Management Advisory Committee (MAC), were set up with the task to review the work of the JCT and the HT, and report to the ITER Council.[75] Each Joint team site had a deputy director elected for sites outside of their home countries.[76] Except for the Director and the Deputy Directors, each Home Team also had a Home Team Leader (HTL).

Activities continued to take place under the auspices of the IAEA, which provided not only an official multilateral body and a close connection to the rest of the nuclear community not directly involved in ITER, but also practical assistance with publications and economic administration.[77] Adding to the above was a plethora of contact persons, expert groups, special working groups, special review groups and specialized research groups, as well as contacts with industrial actors, and the fusion community at large. This complex set-up soon led to challenges and the need for compromises on several levels, as well as struggles between the Home Teams and the Joint Central Teams.

As a part of this complexity, the set-up of the EDA had a built-in tension between the idea of decision-making through consensus, and the delegation of authority needed to manage such a complex hardware project. The Ways and Means working group had emphasized the strong authority of leadership and clear management structure needed due to the division of the JCT, and the EDA agreement clearly stated that the Parties should 'refrain from giving any instructions to their members of the Joint Central Team that may introduce conflict with the Director's management authority'.[78] Meanwhile, the rules guiding procedures for the ITER Council, MAC, and TAC as well as Special Working groups proposed a decision-making process that would strive for consensus, and each Party had to speak with one voice. In the ITER Council, as well as most Special Working groups, all decisions were made unanimously, while the TAC and MAC could make majority decisions in the case that consensus was impossible.[79]

According to the de-centralized model of procurement and R&D tasks the principle of equality of the Parties would ideally also apply to the task division. Tasks were assigned through a process by which the director 'through close interaction with the Home Team Leaders' decided on appropriate task packages as well as which Home Team to assign it to and how many ITER units each task was worth. The larger task assignments were approved by the Council.[80] Task assignment procedures needed to be constantly discussed and negotiated in terms of new tasks, task package size, and lack of integration due to split or overlapping tasks among the Parties.[81]

In addition, national contexts affected the possibilities for Parties to fulfil their tasks. As an example, the Russian Federation remained in the ITER collaboration after the Soviet Union had dissolved, but the Party was clearly having trouble fulfilling both tasks and staffing, owing to the financial and political situation of the early Russian Federation as well as Russian academia at the time.[82] A guideline regarding 'Inadequate Performance by a Party on Design and R&D tasks' had been formulated, but in practice, the Parties could only work around this problem as best they could. Thus, while the rules of reciprocity were very clearly set, they could in this case be compromised if one of the actors could not fulfill their part of the deal. One reason for why such a compromise was possible was the long-standing trust-building between the Parties. It is important to note that the Parties involved in ITER were all there due to their prominence in fusion research, and many of the actors had collaborated before. The fusion community that had developed over time had also allowed for a certain trust-building and knowledge about the capacities of the other Parties. In such a community, certain compromise can be allowed for even though the participants do not fulfil exact specific reciprocity.[83]

The first years of the EDA were thus marked by the efforts of putting into place a functioning management structure for the project in view of the complex organization outlined above. These difficulties translated, among other things, into conflicts between the ITER Council and the Director, which would lead to the Director, Paul-Henri Rebut, stepping down in 1994, to be replaced by Robert Aymar.[84] Rebut later commented that he considered that the quest for compromise often overrode the real needs of the project.[85] The management issues, however, were not only due to tensions between the Director and the IC, but also to those between the Joint Central Team and the Home Teams. In his inaugural speech to the ITER Council, the new director described what he considered to be the conditions for achieving consensus in a technical project: That every Party and every actor in every Party accept that they will 'follow a decision taken in the interest of the project, rather than in accordance with its own proposal. It is the HT responsibility to find solutions for conflicting interests, but always to meet the needs of the project, the success of which is vital for their own national program'.[86] Aymar here pointed to the everyday compromises that needed to be made between ITER and the Home Team programs, a tension that had been present from the very start. The tension was eased by giving the Home Teams more influence on task assignment and overall research design, thus increasing the de-centralized decision-making.[87]

While Aymar's declaration that the success of ITER was vital for the national programs offers one way of seeing these developments, it was also true that the relevance of ITER to the national programs was necessary to the project's existence. In principle, the most concerning risk for the ITER collaboration, and one main rationale for all the ideals regarding equality and consensus, was the fact that if a Party did not feel it benefited, or achieved reciprocity, from the collaboration, it could simply leave.

As noted, each Party had their special interest to defend regarding what ITER should do, depending on national energy policy and research specialties. As an example, for Japan, fusion was perceived as an important technology to help fill an urgent perceived energy need in the country and their side was thus more invested in a machine that would quickly lead to industrial production. Meanwhile, in the US, many researchers were in favor of smaller scale experiments on already existing machines until some of the many unsolved scientific issues were handled, and the Department of Energy did not consider a new type of energy production as urgent.[88] Overall, the US was the Party whose national fusion efforts were the least devoted to tokamaks.[89]

These competing interests led to conflicts regarding the scientific specifications of ITER. The technoscientific discussions between the Technical Advisory Committee, Joint Central Teams and the Home Teams of the four Parties show different views on issues such as materials, blanket construction, physics, interpretations of safety parameters, heat calculations, and resources allocated to parallel solutions.[90] As an example, the issue of whether to construct a shielding blanket that would also breed tritium led to discussions on materials, how much resources to spend on breeding capabilities, and the organizational responsibility for its design. Over time a strategy developed that had the Joint Central Team designing a blanket shield in modules for the first phase of ITER performance, leaving the Home Teams on their own to design breeding blanket modules to be installed at a later phase.[91] This set up was strongly criticized at an early stage by the Russian TAC members, who argued that the goals of the EDA protocol (which included tritium breeding) could be jeopardized if the blanket program was set up this way.[92] The different views of the characteristics of the machine also affected the main issue of discussion: the size and cost. During the first years, the machine grew to large proportions in order to accommodate all the wishes of the Parties.[93]

Over the years, criticism of the project grew in the US and in 1998 that Party decided to leave the ITER collaboration. While the technical discussions and management issues were certainly part of the reason, the deciding factors for the withdrawal were national finances and politics.[94] In addition to the US leaving the collaboration, Japan, which had been considered the most likely country to host the machine, was assailed by financial crisis, and asked for a three-year delay for the planned construction phase.[95] Russia was still not financially able to contribute fully to a construction and was at this point not able to contribute with funds.[96] Moreover, at this point in time, oil prices had gone down, and many of the rationales for a fusion reactor both as a Cold War project and a way out of the energy crises were weaker.

Despite this, work was continued by the remaining Parties to produce a final report in 2001, but with a cut to the cost of the design of fifty percent, thus reducing the technical objectives.[97] This meant reducing the size of the tokamak as well as compromising on what had been one of the main scientific objectives of the machine, namely to reach ignition in a burning plasma, thus making the plasma sustain itself indefinitely.[98]

During the EDA, many of the structures of reciprocity that had been set up for ITER turned out to be problematic for the everyday work of the project. The entanglement between different technical, economic and social interests within and outside of the project as well as the real fear of Parties withdrawing from the collaboration had to be handled at every step of the way, resulting in compromises on all levels.

Conclusion

The history of international collaboration on fusion research shows how cooperation has always been entangled with and carried out through diplomatic and political means. However, as both the scientific and diplomatic character of the collaboration has changed over time, so have the ways that actors have been forced to consider reciprocity and compromise. In particular, as the more collaborations turned multilateral and hardware oriented, the more economic, political and scientific compromises needed to be made.

In the case of the early history of ITER, this meant arranging for reciprocity in order to ensure both political and scientific participation. Based on such reciprocity, the Parties strived to make as optimal as possible decisions from both a diplomatic and a scientific point of view that all Parties could accept. Meanwhile, in such a project, diplomatic and scientific decisions are entangled. These decisions were made through compromise during the everyday grind of backstage scientific and diplomatic work on different levels of ITER. They needed to accommodate tensions between the aims of the project itself and those of the national research teams, as well as between the will to create and share new scientific knowledge on the one hand and build a working industrial machine on the other. They were also dependent on the different social, political and economic contexts of the participating Parties.

While compromises were made on the levels of organization, scientific practice, and the characteristics of the machine, certain economic issues were more difficult to compromise on. Economic issues instead led to a complete reimagination of the machine, as well as, in the case of Russia, a Party not being able to contribute financially. In the case of the US, economy was cited as the main reason for the Party to leave the collaboration. On the other hand, it is important to note that the US also was the Party who had the least investment in the particular technical solution proposed in the project. Thus, they counted the least on reciprocity in terms of scientific return.

The consequences of the entanglement between diplomatic and scientific decisions continue to show in the ITER project today. After the EDA ended in 2001, the siting and further ITER negotiations would take six more years, and during this time the US re-joined the project, while three other Parties, Korea, China and India, joined.[99] At this point ITER has become one of the largest scientific collaborations in the world, and it may thus be seen as a successful compromise in terms of the achievements of the project so far. Meanwhile, many organizational structures of the early period of the project have remained, including the de-centralized model, and the current in-kind system which resembles the task assignment procedure. Leadership issues as well as the management complexity of the geographical split between the Home Teams, ITER institutions and the ITER site itself have continued to haunt the project and affect its work. The de-centralized organization, in particular, was one of the main points of discussion during the assessment in 2015. Thus, this organisation can also be seen as risking compromising the project and its goals. Nevertheless, it is clear that the current organizational and scientific set-up of ITER cannot be fully understood unless it is put in a historical context of both diplomatic and scientific compromises.

Notes

1. For the concept of front-stage and backstage diplomatic actors, see Kyrtsis and Rentetzi, “From Lobbyists to Backstage Diplomats,” in this issue.
2. See most recently Isabelle Bourboulon, *Soleil Trompeur*.
3. Clery, “New Review Slams Fusion”; and Butler, “ITER’s New Chief.”

4. Interviews with Bernard Bigot, G.S. Lee and Akko Maas. Paul-Henri Rebut expresses a similar position in an interview with Isabelle Bourboulon. Bourboulon, *Soleil Trompeur*, 65.
5. Interview, Akko Maas.
6. Jönsson and Hall, *Essence of Diplomacy*, 28; and Spies, *Global Diplomacy*, 8.
7. Jönsson and Hall, *Essence of Diplomacy*, 50–51.
8. Keohane, "Reciprocity in International Relations," 4.
9. Interview, Bernard Bigot.
10. Interview G. S. Lee.
11. Black, *A History of Diplomacy*, 190–191.
12. Kaltofen and Acuto, "Science Diplomacy," 10–11; and Smith, "Advancing Science Diplomacy."
13. Royal Society and AAAS, "New Frontiers of Science Diplomacy," 1.
14. Turekian et al., "The Emergence of Science Diplomacy," 4.
15. In their book on ITER, Robert Arnoux and Jean Jacquinot have tellingly called one of the chapters "Tout le monde doit gagner" (Everybody has to win), and they point out the importance of consensus, compromise and reciprocity for the project during the sometimes harsh negotiation processes; Arnoux and Jacquinot, *ITER*, 130.
16. Fumurescu, *Compromise*, 5–6.
17. Golubchikov, ИТЭР: Решающий Шаг.
18. Arnoux and Jacquinot, *ITER*.
19. Claessens, *ITER*.
20. Aung-Thwin and Royko, *Let There be Light*.
21. Bourboulon, *Soleil Trompeur*.
22. McCray, "Globalization with Hardware."
23. Harding et al., "International Fusion Energy Cooperation"; and Turekian et al., "The Emergence of Science Diplomacy."
24. Ruffini, *Science and Diplomacy*, 1; Claessens, *ITER*, 290.
25. Claessens, *ITER*, 289–290.
26. Kaltofen and Acuto, "Rebalancing the Encounter," 19–20.
27. Josephson, *Red Atom*, 200–201; and McCray, "Globalization with Hardware," 292–293.
28. See Bromberg, *Fusion*, chapter 5 and 6; Josephson, *Red Atom*, 175–176. According to Bromberg, this realization "dissolved much of the sense of rivalry among scientists," and fusion thus became a subject to collaborate around which was potentially high gain, but low risk in terms of giving away classified material. Instead, as was later expressed by the Soviet physicist Lev Artsimovich, it was commonly agreed that the challenges of fusion were so large that "worldwide collaboration is needed for progress." One might thus say that the declassification served to establish a reciprocity, making it clear that the central actors would gain equally from collaboration. Artsimovich is cited in Jacquinot, "Fifty Years in Fusion and the Way Forward," 3.
29. Curli, "Italy, Euratom and Early Research," 64.
30. Josephson, *Red Atom*, 176.
31. McCray, "Globalization with Hardware," 289.
32. Bromberg, *Fusion*, 250.
33. Tokamak is an acronym for the Russian name тороида́льная ка́мера с магни́тными кату́шками, toroidal chamber with magnetic coils. It is a fusion reactor in which the plasma is contained by magnetic coils in a toroid, or doughnut shaped chamber. The tokamak became a central fusion technology, although other variants, such as Stellarators, have continuously been developed in parallel.
34. Shaw, *Europe's Experiment in Fusion*, ix–xi.
35. McCray, "Globalization with Hardware," 291; and Willson, *A European Experiment*, 17.
36. Josephson, *Red Atom*, 201; and McCray, "Globalization with Hardware," 291.
37. McCray, "Globalization with Hardware," 293.
38. Claessens, *ITER*, 42; "Report on the first meeting of the ITER technical Working Party, May 1987" (Iter-7). Initially, the discussion also concerned which parties would be included,

since the US opposed involvement of IAEA, and the USSR opposed the involvement on the EC as one single actor. “International cooperation on fusion. Mission of Messrs. Palumbo and Melchinger to Washington on 10/11 April 1986” (Iter-6.1).
39. “Comments on Next Step Design studies with reference to NET, April 87” (ITER-7).
40. See for example “Status of NET design, January 1989” (ITER-9.1); “Canevas de L’intervention de R. Aymar au CCFP no 37, September 1989” (ITER-9.2).
41. McCray, “Globalization with Hardware,” 293.
42. Interview, Eisuke Tada.
43. “The Japanese Nuclear Fusion Program,” 4.
44. “International cooperation on fusion. Mission of Messrs. Palumbo and Melchinger to Washington on 10/11 April 1986” (iter-6.1); Crawford, “Soviet-U.S. Fusion Pact Divides Administration.”
45. “Record of the meeting of the Experimental nuclear reactor (ITER) Quadripartite Initiative Committee (QIC).” March 1987 (IDS 1), 1.
46. Hackett et al., “Tokamaks and Turbulence,” 749.
47. Krige, “Some Socio-historical Aspects,” 243.
48. “The Soviet Magnetic Confinement Fusion Program,” iii, 4; and Willson, *A European Experiment*, 48.
49. See note 42 above.
50. “Record of the meeting of the Experimental nuclear reactor (ITER) Quadripartite Initiative Committee (QIC). March 1987” (IDS 1), 1.
51. I will be using “Parties” capitalized when indicating the four delegations taking part in the negotiations.
52. “Report of the ITER technical working group. September 1987” (IDS 1), 40.
53. “ITER definition phase report, Attachment 1” (IDS 2), 23. The council included two representatives from the European commission, Paolo Fasella, who was Director General for the European Commission responsible for research, and Charles Maisonnier the commission representative in the EC’s Consultative Committee for the European Fusion Programme (CCFP). The Japanese members were Katsuhisa Ida, from the Japanese Science and Technology Agency and Shigeru Mori from the Japanese Atomic Agency Research Institute (JAERI). The US representatives, John Clarke and James Decker were both from the Department of Energy, while the USSR sent Evgenii Velichov from the Kurchatov Institute, and Nikolai Cheverev from the State Committee on Utilization of Atomic Energy (SCUAE).
54. “Rules of procedure for the ITER council during the Engineering design activities” (IEDS 3), 33.
55. Krige, “Some Socio-historical Aspects,” 248–249.
56. “ITER definition phase report” (IDS 2), 9, 13.
57. “ITER definition phase report, Attachment 1” (IDS 2), 23.
58. Interview, Eisuke Tada; Interview, Akko Maas; McCray, “Globalization with Hardware,” 294. Issues Tada mentions include the shape and the level of performance of the reactor. Akko Maas has also confirmed that there were discussions around, for example, the number of coils and how to position the diverters. McCray has described how the European fusion community wanted to assure that ITER and NET achieved similar performances.
59. Willson, *A European Experiment*, 35.
60. Ibid.
61. “Charter for the IC Ways and Means Working Party” (IDS 8); “Exploration of Ways and Means for an ITER Engineering Design Phase” (ITER-9.1), 3.
62. “Exploration of Ways and Means for an ITER Engineering Design Phase” (ITER-9.1), 10.
63. “Summary minutes of the 38th meeting of the CCFP, October 1989” (ITER-9.2).
64. “Initial report of the Ways and Means working group” (IDS 8).
65. “Guidelines for implementation of Design and Technology R&D tasks, IC 2-ROD, Attachment 7” (IEDS 3).One IUA was set at the equivalent value to 1000 USD at January 1989 values, and would be attributed to each design or technology R&D task, in

order to be able to compare its scope and cost between the Parties. In the JET project, the existing EC Unit of account was used for the same purpose. Willson, *A European Experiment*, 26–27.

66. "ITER EDA agreement and protocol 1" (IEDS 1), 8.
67. "Exploration of Ways and Means for an ITER Engineering Design Phase" (ITER-9.1), 10–11; "Initial report of the Ways and Means working group" (IDS 8), 19.
68. "Standardizing the comparison of ITER EDA site proposals, July 1991" (IEDS 2).
69. "Report of the Quadripartite EDA negotiators" (QEN-2) working group on the exploration of a multiple-site approach to the ITER EDA, May 1991" (IEDS 2).
70. "Report of the Quadripartite EDA negotiators" (QEN-2) working group on the exploration of a multiple-site approach to the ITER EDA May 1991" (IEDS 2). Both the US and the USSR delegations were concerned about recruitment if the multi-site solution were to be implemented, pointing out the unclear managerial structure, as well as the prospect of traveling and moving between sites over a period of 6 years, which was previewed for the EDA work. The Japanese delegation, on the other hand did not think this would be a problem for recruitment.
71. The idea that ITER is not only a way to cooperate around fusion, but a new model for international work which can help solve other important global issues continues to be voiced today by for example the Deputy Director of ITER, G.S Lee. Interview, G.S. Lee.
72. See above page 6-7; Written communication from Akko Maas.
73. "Report of the Quadripartite EDA negotiators' (QEN-2) working group on the exploration of a multiple-site approach to the ITER EDA May 1991" (IEDS 2), 49.
74. "Fourth Quadripartite EDA negotiations meeting, Attachment 3, Understandings" (IEDS 2); "Press guidelines for the signing of the ITER EDA agreement and protocol 1" (IEDS 2), 115.
75. "Rules of Procedure for the ITER Council during the Engineering Design Activities" (IEDS 3), 33; "Rules of Procedure for the ITER Technical Advisory Committee during the Engineering Design Activities (IEDS 3), 73; Rules of Procedure for the ITER Management Advisory Committee during the Engineering Design Activities" (IEDS 3), 77.
76. Fourth Quadripartite EDA negotiations meeting, Attachment 3, Understandings (IEDS 2). The San Diego work site would be headed by the Russian Valery Chuyanov, the Naka site by the French Michel Huguet and the Garching site by the American Ron Parker. Paul-Henri Rebut, who had earlier been the director of JET, became director of ITER with Yasuo Shimomura as co-director.
77. For example, when it became clear early in the EDA that joint funds were needed to cover the extensive traveling that would have to be undertaken between the different Joint Work Sites, as well as for other joint expenses for the JCT's, a joint account was established and administrated by the IAEA. "Decision of the ITER council to establishment of a trust fund" (IEDS 4), 47; "Record of the eight hundred and thirteenth meeting of the IAEA Board of Governors, Vienna 8 June 1993" (IEDS 4), 53.
78. "Fourth Quadripartite EDA negotiations meeting, Attachment 3, Understandings" (IEDS 2).
79. "Rules of Procedure for the ITER Technical Advisory Committee during the Engineering Design Activities" (IEDS 3), 73; "Rules of Procedure for the ITER Management Advisory Committee during the Engineering Design Activities" (IEDS 3), 77; "Guideline for the SWG-1" (IEDS 3), 21. Since the EC was one Party through Euratom, consensus had to be reached within Euratom on all issues.
80. "Main structure of the ITER Joint Central Team" (IEDS 3), 26; "Guidelines for the Implementation of Design and Technology R&D tasks" (IEDS 3), 63. The issue of how credit value for tasks instantly became a point of discussion between the JCT and the Home Teams, who wanted more credits for building up new facilities or upgrading old ones, while the JCT considered that ITER credits should only be assigned for the part of the upgrade or facility of import for ITER. "TAC recommendations on the Director's proposals" (IEDS 2), 67; "MAC recommendations on the Director's proposals" (IEDS 2), 69.

81. See for example "MAC report and advice, IC-6" (IEDS 6), 139; "ITER R&D Programme Developments and Task Sharing proposals" (IEDS 6), 187; "MAC report and advice, IC-5" (IEDS 6), 59.
82. See for example "ITER EDA status report to IC-6" (IEDS 6), 110. The Russian Federation did not have a Joint Work Site, which meant that less of the joint funds were spent there, something that was also addressed. "Meeting 8 record of decisions, July 1995" (IEDS 8), 15–16.
83. Krige mentions trust-building as one condition for the successful collaboration at CERN. Krige, "Some Socio-historical Aspects," 241. My Interviewees also emphasize the trust-building ongoing between the Parties.
84. IC-6 Record of Decisions, July, 1994 (IEDS 6), 97. Traces of this tension can be seen in for example, Letter from Velikhov (IC Chairman) to P-H Rebut (Director), 5 January 1994; and the answer from P-H Rebut from January 11 1994 (IEDS 6), 75–76.
85. As quoted by Jaquinot, "Fifty Years in Fusion," 116.
86. "Address to the ITER Council by R. Aymar, 27 July 1994" (IEDS 6), 114.
87. "Address to the ITER Council by R. Aymar, 27 July 1994" (IEDS 6); "MAC report and advice, IC-6" (IEDS 6), 147. See also the set-up of the research projects in "Detailed Design Report, Cost Review and Safety Analysis" (IEDS 11), 145. The Technical advisory board had earlier pointed out a need for improvement in regard to empowerment of the co-centers of the Joint Central Team and their interaction with the home team and the fusion community. "TAC report to IC-5" (IEDS 6), 50.
88. "The Japanese Nuclear fusion program," 3. Sessler et al. "Build the International Thermonuclear." McCray also notes this division, quoting a discussion with ITER official Hiroshi Masumoto regarding the fact that fusion research in the USA is often "seen as physics whereas in Japan and Europe it is largely seen as engineering done for eventual energy applications." McCray, "Globalization with Hardware," note 74.
89. In a report from 1985 the CIA reported that Japan, Western Europe and the USSR devoted in the area of 80% of their fusion programmes to tokamak research in the early 1980s, whereas the same number in the US was 30%. "The Japanese Nuclear Fusion Program," 3.
90. See for example, "MAC report and advice, IC-5" (IEDS 6), 61; Letter from Prof. E. Adamov to Dr. P Rutherford, 9 December 1994 (IEDS 6), 229; "TAC report to IC-4," (IEDS 4), 85. The TAC also comments that the physics used in the ITER outline design report is not one that has received sufficient acceptance in the fusion community, and that this is a problem. "TAC report to IC-5 (IEDS 6)," 51–52.
91. "TAC report to IC-7" (IEDS 6), 220; "ITER Interim Design Report. Cost Review and Safety Analysis" (IEDS 8), 41; "ITER Detailed Design Report, Cost Review and Safety Analysis" (IEDS 11), 140, 144, 146.
92. Letter from Prof. E. Adamov to Dr. P Rutherford, 9 December 1994 (IEDS 6), 229.
93. The TAC had expressed concerns over the cost already early on, as well as cautioned against expanding the major radius to over 7.75 m or less. "TAC report to IC-4" (IEDS 4), 85; "TAC report to IC-5" (IEDS 6) 49–51. Still, in the Detailed design report from 1996, the major radius had been expanded to 8,1 metres. "ITER Detailed Design Report, Cost Review and Safety Analysis" (IEDS 11), 131. Meanwhile, Aymar is quoted in Claessens saying that the reason the machine became so big to begin with was due to the demands of USA and the USSR. Claessens, *ITER*,45.
94. Hardison et al., "International Fusion Energy Cooperation"; and Goodwin, "Budget Surplus and Congressional Boosters."
95. Glanz and Lawler, "Planning a Future Without ITER."
96. Redfearn, "Europe, Japan Finalizing Reduced ITER Design."
97. "EIC-1 Record of Decisions, June 1998 (IEDS 5)," 116.
98. "ITER-FEAT Outline Design Report, January 2000" (IEDS 20), 31; Redfearn, "Europe, Japan Finalizing Reduced ITER Design."
99. For the siting and continued negotiations see Claessens, *ITER* and McCray, "Globalization with Hardware."

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