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COMMENT

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Past, present and future of fusion science diplomacy

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Science diplomacy has become an important dimension of international relations. Here, the author elaborates on the past, present and future of fusion science diplomacy and the role such big collaborative endeavors play in shaping the future of this field in the international political sphere.

Science diplomacy examines the role science, technology and innovation play in international policymaking and diplomacy. In the last decade, three dimensions of science diplomacy have been widely discussed[1].

The first is science in diplomacy, which deals with informing foreign policy objectives with scientific advice. One example is the Intergovernmental Panel on Climate Change (IPCC) established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide policymakers with periodic assessments on climate change and its environmental and socio-economic implications[2]. The scientific findings of the IPCC serve as the basis for international negotiations on actions to be taken by governments to combat climate change and have resulted in international agreements such as the Kyoto Protocol and the Paris Agreement.

The second is science for diplomacy, which leverages cooperation in science and technology to improve international relations and create bridges between nations. Examples include: the Abdus Salam International Centre for Theoretical Physics (ICTP), established with an agreement between the International Atomic Energy Agency (IAEA) and the Italian government in 1963[3]; and more recently the Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME), inaugurated in 2017 under the auspices of the United Nations Educational, Scientific and Cultural Organization (UNESCO)[4]. While the ICTP serves as a centre for promoting East/West cooperation as well as North/South partnership, SESAME brings together scientists in the Middle East and the Mediterranean Region. These initiatives contribute to building scientific and cultural bridges between societies and strengthening international relations through cooperation in science.

The third is diplomacy for science, which seeks to facilitate global science cooperation through diplomatic assistance, whether this is done in a top-down or bottom-up approach. Examples of this dimension include: the establishment of the Joint Institute for Nuclear Research (JINR) in Russia, spurred by the former Soviet Union government; the world's largest and most powerful particle accelerator—the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) in Switzerland, which operates since 2008 thanks to numerous political negotiations at multiple levels facilitating its financial approval[5]; and the Extreme Light Infrastructure (ELI)—a network of high-powered laser laboratories for both fundamental and applied research taking shape across Eastern Europe, and which has recently become a legal entity as the European Research Infrastructure Consortium (ERIC)[6].

Drawing on contemporary studies and through the examination of historical events, in the next sections, we explore the three dimensions of science diplomacy in nuclear fusion.

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Fusion science in diplomacy

The declassification of nuclear fusion research declared in 1958 was critical in setting the priority on fusion science in diplomacy, and it resulted in a strong impulse for collaboration between East and West in the post war era[7]. At the same time, the integration of nuclear fusion science cooperation in international relations was further facilitated by the IAEA's Scientific Advisory Committee (SAC), charged with the task of providing scientific and technical advice on the IAEA's programme and policies[8]. "The IAEA's SAC consisted almost entirely of the heads of the most powerful atomic energy authorities who, in several cases, doubled as their country's Governors on the Board. If SAC agreed on a specific recommendation to the Board, it was almost sure to be approved. This led Henry Seligman, the Secretary of SAC [and IAEA Deputy Director General], to suggest—tongue in cheek—that the Committee should be renamed the PAC—Political Advisory Committee!"[9].

Establishing the IAEA's Fusion Energy Conference series in 1961[10], the SAC left an important legacy to the fusion community. This conference provides an important stage that connects scientific advice and diplomacy to global fusion energy programme priorities. A short film about the history of this conference series is available online (https://www.youtube.com/watch?v=WgRksCC6x9k).

Two decades later, the advisory role of the SAC in nuclear fusion cooperation was left to the IAEA's International Fusion Research Council (IFRC). Formed in 1971 after consultations with IAEA's Member States governments delegations[11] and following the recommendations of a meeting panel[12], the IFRC in the 1970s and 1980s will serve as a catalyst for establishing improved international collaboration in fusion research. This will provide the momentum for developing a degree of consultation and planning leading to a coordinated, rather than simply cooperative, world fusion programme and that would otherwise have been difficult to achieve due to the Cold War.

Fusion science for diplomacy

It was during the détente that fusion science—similarly to space exploration—became a mechanism for increasing international relations between the USA and the former Soviet Union. Fusion science and space exploration offer "the attractiveness and influence both as a national asset, and as a universal activity that transcends national interests"[1] that science for diplomacy often draws on, otherwise referred to as the 'soft power' of science.

In 1970, Henry Seligman reflected on this in a letter to Rendel Pease, Director of the Culham Laboratory (today the Culham Centre for Fusion Energy): "[the Agency] could do something to get Nations together to start a more coordinated Fusion programme … I think the Americans and Russians are secretly looking for something which they could do together which has no war application, which is not, at this stage at least, patentable and which costs a lot of money. Therefore, I think that the political ground is favourable"[13].

It was not long until a study on the status of fusion research—conducted by the IFRC in 1977—concluded that, "In view of the widespread and rapid progress achieved in fusion since 1970 and of the growth of anxiety about future energy supplies, the Council is convinced that the time is ripe to make a large and aggressive effort towards the practical demonstration of fusion power at the earliest possible date. Such an effort is needed now and could be maximized by efficient world-wide co-operation and planning in this field. The Council therefore suggests that the IAEA make an important contribution to this goal by [inviting] the interested Member States and regional institutions to submit to the IAEA their estimates of attainable fusion research and development schedules with the objective of helping to co-ordinate the necessary efforts for a rapid and most economic way of achieving this goal"[14].

Following this recommendation, the IAEA invited Member States to provide this information. The invitation suggested that "an international fusion study group should be formed now to examine the objectives and the main physical features of the next major device … [The IAEA] should appreciate receiving the views and comments of the authorities and institutions concerned"[15].

In their responses, countries including the USA, UK and Europe welcomed the general idea of further international cooperation in fusion, but one response stood out among the rest. The former Soviet Union submitted a concrete proposal which read in part: "The Soviet Union considers it important and timely to develop and build a next-generation fusion device on a multinational basis and under the auspices of the IAEA. The USSR considers that it would be appropriate to set up immediately a group of experts at the IAEA to study the problem and initiate a project"[16].

The IFRC, wishing to examine the Soviet proposal, set up a sub-group consisting of one representative from Europe, Japan, USA, the former Soviet Union and IAEA and headed by the Chairman of the IFRC. The International Tokamak Reactor (INTOR) workshop was born. The workshop was charged with the task of submitting a report to the IFRC describing the technical objectives and characteristics of the next-step fusion device.

Disregarding the purely scientific merits of the INTOR project, the idea of building a multi-billion-dollar device with worldwide participation and insulating it as far as possible from the vagaries of shifting national political positions was unique. The INTOR project was "unable to move on to the stage of engineering design and construction … [which] would have required political decision"[17] and the situation was likely complicated by the Afghanistan crisis of 1979 which ended the détente[18], but the INTOR idea sent a ripple out into the world.

Diplomacy for fusion science

The two decades of science diplomacy from the 1960s through the 1970s, first dealing with informing foreign policy objectives with fusion research and then leveraging cooperation in fusion science and technology to improve international relations, laid the geopolitical groundwork for a series of high-level talks, in the early 1980s, urging the expansion of international cooperation in fusion research. As observed by the US delegation later in 1987, "[T]hese meetings were important in that they involved some of the governments at a political and administrative level [including François Mitterrand, Ronald Reagan, and Mikhail Gorbachev, among others] and not just scientists concerned with technical matters"[17].

This top-down endorsement culminated in the joint statement released after the Geneva Summit in November 1985 between Reagan and Gorbachev, in which "[the two leaders] advocated the widest practicable development of international cooperation in obtaining this source of energy [fusion]"[19], and which showed how diplomacy can work in support of science[1,20]. This last political mark of encouragement launched a new unparalleled partnership in the history of international scientific collaboration, the ITER project—an international experimental fusion reactor currently under construction in France, with the aim of demonstrating the scientific and technological feasibility of fusion energy production.

In the wake of the Summit and years that followed, an extensive round of diplomacy by the IAEA furthered support for the proposed collaboration[21]. Later, when the ITER site negotiations stalled in the early 2000s, the IAEA's brokering role helped resolve difficulties in agreeing on the site location and cost

sharing. After one of the decisive meetings, IAEA Deputy Director General and head of the Department of Nuclear Sciences and Applications, Werner Burkart, wrote to his superior: "The service of the Agency as an honest broker [navigating ITER negotiations through the meetings] remain of utmost importance to all partners"[22].

Following 10 years of previous construction phases, which involved components design, site preparation and manufacturing of the key components across the world, the assembly of ITER commenced in 2020. The first stage of assembly will be finished in late 2024, followed by a period of integrated commissioning and testing to prepare for the first plasma experiments in December 2025. This will be followed by a shut-down of the machine and a further assembly phase. This means significant steps forward will be taken in the next five years, but it is still expected to take until 2036 to achieve ITER's ultimate goal: demonstration of the feasibility of fusion power at industrial scale.

Representing three continents, the ITER Members (China, Euratom, India, Japan, Republic of Korea, Russian Federation, and the United States) are working united in all the project phases while also sharing the generated knowledge. The importance of the ITER project—however—goes beyond the scientific and technical objectives and intellectual property of the project itself and extends to ITER non-Members holding technical cooperation agreements with the organization (these are Australia, Kazakhstan and more recently Canada). In the words of the Russian delegation during one of the ITER preparatory meetings in 1987: "On the political plane, international collaboration in the peaceful development of fusion power can help to provide a sound basis not only for further scientific and technological progress, but also for sustaining and developing a climate of confidence and more stable relations among States"[17].

ITER is the epitome of three-dimensional science diplomacy, with roots tracing back to the origins of international cooperation in fusion research[21] and synthesis of diplomacy for science[1,20] and science for diplomacy[18,23] in its raison d'être.

Looking forward

Nuclear fusion has the potential to be a game-changing source of sustainable energy, but the required large upfront costs for its realization often go beyond the budget of any government or organization. International cooperation and the IAEA have been instrumental in the history of fusion science diplomacy, facilitating global collaboration and coordination in this global challenge, but also helping contribute to building trust and understanding between nations, as well as improving relations and coalitions.

With a number of public and private organizations developing designs for fusion pilot plants[24], continued collaboration is essential for the development of requirements, standards and good practices relevant to the establishment of the necessary infrastructure that can contribute to the realization of this future energy source.

The invitation to Member States, organizations and industry made by IAEA Director General Rafael Mariano Grossi at the 28th Fusion Energy Conference, "[to support and jointly participate in an IAEA-coordinated] feasibility study that encompasses the full scope of fusion pilot plant criteria and produce a set of technology-neutral requirements for the safe, secure and economically sound deployment of future fusion reactors"[25], offers new areas of opportunity for fusion science diplomacy.

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Competing interests

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