Maintaining America's Competitive Technological Advantage: Cold War Leadership and the Transnational Co-production of Knowledge

*John Krige**
john.krige@hts.gatech.edu

ABSTRACT

This paper describes the mechanisms that shaped the transnational flow of knowledge about the gas centrifuge for uranium enrichment between British and American nuclear scientists and engineers in the 1960s. Through studying face-to-face encounters between researchers in laboratories on both sides of the Atlantic it places "coproduction" rather than "transfer" or "diffusion" at the epistemological core of the analysis of the circulation of knowledge across national borders. Coproduction, it is argued, takes place in an asymmetric field of force that was dominated by one of the poles, the United States. Washington could exploit London's historical dependence on it for nuclear materials and technology to gain access to advanced British research and development. American scientific and technological pre-eminence was not built upon an autarkic, self-contained research system. American global leadership was achieved by levering transnational collaboration with capable partners to enhance massive national investments in the production of knowledge, so pulling even further ahead of friend and foe alike.

It is widely accepted that the first two or three decades after World War II were marked by an asymmetry in economic, political and military power between the United States and the rest of the world. We should not forget, though, that there was also an asymmetry in scientific and technological knowledge between America and its allies and enemies. Maintaining that preeminence was already on the agenda before the war ended; it became a priority as the Cold war

* Georgia Tech Institute, GA, USA.

gained momentum. The quest for competitive technological advantage became embedded in domestic policies, and their supporting ideologies, that coupled scientific and technological leadership with the construction and consolidation of the national security state. Qualitative technological superiority was initially justified as the only way to hold back Soviet "hordes" in Europe without the mass mobilization and militarization of the home front. The threat posed in the 1950s by successive Soviet scientific and technological achievements called forth a broader and deeper American response. The security of the West, a budget that balanced military and civilian needs, and the protection of domestic liberties and pluralistic institutions, demanded a program of permanent preparedness. This was underpinned by ceaseless scientific and technological innovation. Federal sponsorship became an essential complement to the industrial research laboratory. The Federal government's R and D budget increased dramatically after the Korean War broke out, more than doubling to $1.3billion in fiscal year (FY) 1951 and more than doubling again to $3.1 billion in FY1953. It was given another enormous boost by the launch of Sputnik in 1957: a decade later it had almost quadrupled to $15 billion (Kevles 1990 a, 1990b). As Friedberg puts it,

> From the onset of the Cold War, top American decision makers tended to believe both that it was necessary for their country to seek a technological edge over the Soviet Union and its allies, and that such an edge could be achieved and maintained. These beliefs helped to keep technology at the forefront of American strategy and to sustain a massive four-decade flow of resources into research and development. (Friedberg 2000, p. 297)

The pursuit of scientific and technological pre-eminence was driven, in the first instance, by the conviction that nothing less could protect America from an existential threat. But there was more to it than Friedberg says. The cold war was not simply a binary struggle for military superiority between superpowers. Scientific and technological leadership was not only sought after to defend the homeland from a Soviet attack. It was also needed to enhance America's global reach, to fulfill «a sacred mission thrust upon the American people by divine Providence and the laws of both history and nature» (Hogan 1998, p. 15). The U.S did not merely seek a competitive edge over its archrival: it also sought scientific and technological superiority over its allies. As Cristina Klein has noted, from an American perspective, the Cold War was «as much about creating an economically, militarily and politically integrated "free world", as it was about waging a war of attrition against the Soviet Union» (Klein 2003, p.

16). Washington sought to integrate Western Europe into its global agenda by encouraging it to play its part in the anti-communist struggle, while also striving to contain its ambitions within an American-led world system. The challenge faced by U.S. policy makers in the 1950s and 1960s was not simply to combat Soviet communism; it was also to help rebuild Europe's scientific and technological strength, without unleashing demands for independence that would undermine their hegemony.

The knowledge/power nexus that was crucial to the American global project after World War II helped put in place what Bright and Geyer call a "regime of world order". What made this regime so different from its predecessors, and above all from the imperial project of the European colonial powers, was that a transnational flow of knowledge enabled the United States to move «beyond the extension of power *over* others toward a direct and sustained organization *of* others, simultaneously, and in many parts of the world» (Bright & Geyer 2005, p. 205). American scientific, technical and intellectual leadership, and the massive investment in education after the war that made that possible, were «as important as its economic and military power in making world order cohere and, more important, in developing and organizing the consent of subordinate participants» (Bright & Geyer 2005, p. 228). The postwar pursuit of an American-led regime of order was not a top-down project of command and obedience. It was an ongoing negotiated process in which science and technology were shared or denied in an asymmetric field of force defined by a knowledge-deficit between its partners and the United States. If this was hegemony, it was consensual not coercive (Krige 2006; Lundestad 1999).

The construction of a national security ideology in the first decade of the cold war pitted the conservative defenders of an older, anti-statist political culture against the managers of an emerging, technocratic, proministrative state (Balogh 1991). Both tried to «frame a public policy that would protect the American way against the dangers of regimentation». Within that shared frame of reference, «both associated their critics with the un-American other, both spoke in a language of ideological opposites, such as democracy or totalitarianism, [...] loyalty or disloyalty, isolationism or internationalism» (Hogan 1998, p. 18). Many leaders of the American scientific community were engaged in this struggle (Wang 1999). Adopting a pragmatic approach to international collaboration, they insisted that tight restrictions on scientific and technological exchange would undermine, not secure, the nation's competitive edge. They were emphatic that to retain American leadership they had to collaborate, not retreat behind high walls, both to raise the level of scientific and technological capability abroad (so as to share the burden of defense of the West) and to be in a position to draw on the best that others had to offer. Admittedly, by sharing what they knew they could strengthen their competitors; what they learnt abroad, however, also stimulated innovation at home. As early as 1949, in a famous standoff between Senator Hickenlooper and David Lilienthal, J. Robert Oppenheimer defended an embattled "socialist" AEC from charges of mismanagement and lax security.[1] Vigorously encouraging closer collaboration with Europe against those who sought to stop the export of radio-isotopes for research, Oppenhemier pointed out to the Congressional enquiry how much the continent had to contribute to the American research effort.

> If discoveries are made in Europe, we are in a better position to profit by them than the Europeans, because of our advanced technology, our good organization. [...] History again and again shows that we have no monopoly on ideas, but we do better with them than most other countries. (Oppenheimer, quoted in The Great Enquiry, 1949, pp. 227–228)

Fifty years later, the leaders of America's four main weapons laboratories, laboring under the accusation that they were lax on security, protested violently that

> The world is awash in scientific discoveries and technological innovation. If the United States is to remain the world's technological leader, it must remain deeply engaged in international dialogue, despite the possibility of the illicit loss of information. (Committee on Balancing Scientific Openness and National Security1999, p. 11)

Transnational collaboration in science and technology was not a threat to the American hegemonic project. On the contrary, it was essential to it – or so it was argued time and again by the American scientific community, including its weapons researchers (Krige 2010).

Diplomatic historians are increasingly calling for a better integration of science and technology into studies of international affairs (LaFeber 2000; Westad 2000). Indeed we are rapidly gaining a better understanding of the

[1] Lilienthal was the Chairman of the Tennessee Valley Authority from 1941–1946, when he was appointed chairman of the AEC. In 1940 he was ardent advocate of the state-driven planning of large technological/social projects. See Hughes (1989, p. 378).

many modes of articulation between American knowledge and global power, to cite the title of a comprehensive review by Engerman (2007). Modernization theory, too, is providing invaluable insights into how Western expertise was "transferred" to other countries, supplanting local knowledge and practices (Cullather 2004; Engerman, Gilman, Haefele, & Latham 2003; Latham, 2000). Though immensely valuable, these studies remain mostly Americo-centric: knowledge is produced in the United States, and is "diffused" by American or American-trained intellectuals and experts who deploy it to advance transformative agendas that cohere with Washington's goals abroad. The vector of knowledge is unidirectional: there is transfer and diffusion but there is no *circulation,* no recognition that knowledge production is an ongoing process that is sustained through transnational contact and exchange. Correlatively, the notion of "American" knowledge itself is not problematized. If "American" knowledge is *co-produced through transnational circulation* does it make any sense to speak of American knowledge at all – at least as regards its content? If knowledge flows across national borders, and is transformed in the process, does it not lose its national identity, becoming a complex hybrid whose various "national" components become woven so tightly together as to be almost indistinguishable from one another?

My aim in this paper is to use a brief case study of the coproduction of knowledge between British and American nuclear scientists in the 1960s as a platform for further reflection on the knowledge/power nexus in the Cold War. In particular I want to show how American leadership was not simply built on the production of knowledge at home and its diffusion, transfer or imposition abroad. Instead I shall argue that U.S. leadership was sustained by its capacity to collaborate productively, and on its own terms, with others, exploiting the threat to withdraw support in some areas as a political weapon to gain access to sensitive information in others. I shall also suggest that our failure to "see" these processes of coproduction is due to the "blinkers" imposed by restricting studies of knowledge production to a national framework. The dominance of that framework, a framework that eclipses the kinds of transnational transactions that matter so much to U.S. scientists, reflects the inflated importance attributed to the bounded nation state as the only significant unit of analysis in the Cold War.

The Co-production of Knowledge: U.S.–U.K. Collaboration in Developing Gas Centrifuges for Uranium Enrichment in the 1960s[2]

Background. The idea of using gas centrifuges spinning at very high velocities to separate the fissile U^{235} (an isotope of uranium) from the far more abundant U^{238} had already been looked into during the war. The principle was simple: the concentration of the heavier isotope would increase from the center of the cylindrical vessel to the wall, and by extracting the slightly enriched mixture at an appropriate point on the radius and recycling it many times through centrifuges connected in series (a cascade) one could significantly improve the concentration of fissile material in the mix. (This is the technology currently used by Iran, of course). To implement this scheme in practice proved extremely difficult, however. In 1960 a report by Gerard Zippe, an Austrian who was released by the Soviet Union in 1956, and spent three years on centrifuge development at the University of Virginia, described a design of stunning simplicity (Scott Kemp 2010). This led to a brief burst of international publication in the open literature before all work on centrifuges was once again classified, reflecting its great potential.

Zippe's design promised to democratize the technology of uranium enrichment (and to facilitate nuclear proliferation). From an intelligent interpretation of his work it emerged that one could produce about 50kg/year of uranium enriched to a few percent with 10,000 centrifuges that occupied some 40,000 square feet.[3] These were relatively modest demands compared to the needs of the gas diffusion process that was developed in the Manhattan project and that was the dominant technique for uranium enrichment for the first two decades after the war. Gas diffusion was technologically complex and extremely costly, requiring a large scale effort beyond what most countries could afford so as to benefit from economies of scale, as well as access to cheap electricity. It was only implemented at enormous expense in countries with military programs like the U.S., Britain and France. For civil purposes most countries had to buy enriched uranium or use natural (unenriched) uranium for their reactors, this being less efficient and involving larger capital start up

[2] My interest in this was sparked by Twigge (2000) and Schrafstetter & Twigge (2002).

[3] Letter, Franklin, 11 March, 1968, FCO10/207, The National Archives, Kew, London (hereafter TNA).

costs.[4] Centrifuge technology promised to change all that. Its commercial exploitation did not depend as much on economies of scale, nor did it require huge amounts of cheap electricity.

In spring 1968 the Dutch publicly announced that they were moving ahead with a small prototype centrifuge plant. Officials from the Federal Republic of Germany reported that they too were actively looking into the technique, but that their efforts were still at the experimental stage. The British Atomic Energy Authority (UKAEA), which had invested about £2 million in research and development at the time, was so impressed with the prospects that it decided to abandon plans to extend its gas diffusion plant at Capenhurst in England, and to add a centrifuge separation facility instead.[5]

Sir Solly Zuckerman, the Chief Scientific Adviser to the British government was particularly taken with the prospects of centrifuge technology. It would not only provide enriched uranium for Britain's military and civilian needs considerably more cheaply than gas diffusion – as much as 15-20% on one estimate.[6] This revolutionary new development would also «help end our dependence on the United States in the key field of the supply of enriched uranium», all the more important, he felt, because «there is nothing they may not do to maintain their present monopoly» in enriched fuels for civil purposes.[7]

Zuckerman also emphasized that this was an ideal candidate for a tripartite venture in scientific and technical collaboration with the Dutch and the Germans. «We are all beginners» he wrote «and in effect we are all starting in on the basement». Sharing knowledge could only to be mutually advantageous, since «for all we know their design of the centrifuge is better than ours [...]».[8]

A joint venture had important foreign policy ramifications too. In a much publicized speech British Prime Minister Harold Wilson had suggested that

[4] "Aide Memoire on Centrifuge Classification", 18 October, 1968, PREM13/2555, TNA. See also Memo "Uranium Enrichment by the Gas Centrifuge Process," Foreign and Commonwealth Office to Sir Evelyn Stuckburgh, Rome, 12 June, 1968, FCO16/252, TNA.

[5] Memo Solly Zuckerman to the Prime Minister, "Centrifuge Collaboration," 27 November, 1968. The Germans had also developed a 'nozzle process' for enrichment but their research was in an early stage, Memo Anthony Wedgwood Benn to the Prime Minister, 9 April, 1068, both in PREM13/2555, TNA. Active efforts were being made in Europe, then, to develop alternative techniques to gas diffusion.

[6] This was the view of Sir John Hill, Chairman of the UKAEA since 1967, Memo I.T. Manley, "Centrifuge Collaboration," 3 July, 1969, HF19/25, TNA.

[7] Memo Solly Zuckerman to Prime Minister, 15 October, 1968, PREM13/2006, TNA.

[8] Memo Solly Zuckerman to Sir Burke Trend, 6 December, 1968, PREM13/2555, TNA.

Britain wanted to take the lead in «European-wide co-operation in producing advanced technological products for an international industrial market, on a commercial basis».[9] The European centrifuge project fit the bill perfectly. It could also count on the support of the State Department. The Johnson administration was deeply concerned about the technological gap that had (putatively) opened up between the two sides of the Atlantic in the 1960s. Reporting to the President in December 1967 an interdepartmental committee concluded that the gap was «a current manifestation of the historical differences between Europe and the U.S. in aggressiveness and dynamism, reflecting the American frontier past and its restless quest for progress and change». While it was essentially up to the Europeans to resolve this problem themselves, the U.S. could take specific measures to help, notably, «assist European initiatives toward intra-European technological cooperation in space science and technology, *in atomic energy*, and in the application of computers in research, industry, and government» (my emphasis).[10] The Anglo-Dutch-German centrifuge enrichment project seemingly fused British and American foreign policy considerations in Europe in a most attractive way.

The Co-Production of Knowledge: Who Contributed What? The success of the tripartite European venture depended crucially on American support. This was because, between late in 1960 and early in 1965 scientists and engineers in the two laboratories of the atomic energy agencies had worked together on developing the gas centrifuge, whereupon the U.S. partner unilaterally withdrew from the effort. The work done together was classified, and any decision to divulge it required U.S. approval according to Article IX(c) of the Anglo-American bilateral Agreement for Cooperation in the Civil Uses of Atomic Energy (1955). In terms of this Article «No material, equipment, device or restricted data», and «no equipment or device which would disclose any restricted data» could be passed by the U.K. to a third party without the permission of the party from which it was received.[11] The British now intended

[9] This is the way Wilson presented it to German Minister Stoltenberg, Extract from a meeting in Bonn, 12 February, 1969, PREM13/2555, TNA.

[10] "Memorandum From the Interdepartmental Committee on the Technological Gap to President Johnson", Washington, December 22, 1967, *FRUS, 1964-1968, Volume XXXIV, Energy, Diplomacy and Global Issues*.

[11] Summarized e.g. in "Anglo/U.S. Relations in the Nuclear Field", Paper prepared for Cabinet Ministerial Committee on Nuclear Policy, Centrifuge Collaboration, 19 May, 1969, CAB134/314, TNA.

sharing what they knew with their continental partners. Would they be passing on anything that they had learnt from the U.S. which was restricted under Article IX(c), and for which they therefore needed special permission?

It took nine months of sometimes acrimonious exchanges between Washington and London to resolve this issue. The immensely rich documentation that addresses itself to the core concern of the authorities (whether the British had in fact learnt significant new knowledge from the U.S., and what to do about it if they had) also reveals the multiple modes whereby information was co-produced between the partners. In other words, in what follows we will not only get a glimpse of high level policy making between government officials. We will also hear (indirectly) the voices of scientists and engineers who actually worked with each other on centrifuge science and technology. We will thus gain considerable insight into the messy process of knowledge-in-the making, we will see how knowledge is co-produced in an encounter between two partners who bring different experiences and skills to the table (Raj 2008).

Before the British made any move towards The Hague or Bonn, they tried to establish just what it was they had learnt from the Americans.[12] John Hill, the then-chairman of the Atomic Energy Authority (UKAEA), pointed out that both the U.K. and the U.S. had started from Zippe's published, unclassified design, but that it took a lot of additional work to turn that into a device that could be used for mass production on an economic scale. Many solutions to this problem had been explored together. One in particular was of interest: an American suggestion that a so-called "dished end cap" be used to compensate for the contraction in the length of the centrifuge's body when it spun at extremely high speeds. However – and the British were emphatic about this in December 1968 – this concept had been conveyed to them informally by their U.S. partners during a fifteen minute conversation. They were not granted access to American secret reports, they said, and they had to devise the theory for themselves. Thus, the design of the end cap in the prototype British machine (Mark I), in Hill's view, was entirely indigenous.[13]

On 5 and 6 December, 1968, senior delegations met in Washington DC.

[12] Draft memo by UKAEA, attached to PNO(C)(68)12, 19 December,1968, Cabinet Official Committee on Nuclear Policy. Sub-Committee on Gas Centrifuge, "Interpretation of Article IX(c) of the 1955 Civil Bilateral Agreement", CAB 134/3125, TNA.

[13] "Anglo/U.S. Relations in the Nuclear Field," Paper prepared for Cabinet Ministerial Committee on Nuclear Policy, Centrifuge Collaboration, 19 May, 1969, CAB134/314, TNA.

The British took a broad-brush approach to the question of sharing centrifuge technology, defining the problem as one of national security.[14] The Americans were not unsympathetic but were more concerned to know precisely what information Britain wanted to share with the Dutch and the Germans in their joint venture. In response, it was noted that while the exchange of information between the partners was bound to have affected the general thinking of both, this surely did not mean that the whole of the U.K.'s centrifuge technology was subject to restrictions in terms of Article IX(c). Instead, in the U.K.'s eyes, a reasonable interpretation of Article IX(c) was that «no *specific* information or reports which had been conveyed during the Anglo/American exchanges and no *specific* design features *directly* developed from these exchanges, should be transferred to the Dutch or the Germans without American consent» (my emphasis). Since they were emphatic that the exchange of information on the end cap had been no more than a general conversation that had lasted for 15 minutes, the British concluded that none of the data that they proposed to share with the Europeans was U.S. restricted data.[15]

The AEC officials who met with the British in December were pleased at U.K. efforts to proceed collectively with their continental partners. They did not have the authority, however, to decide whether or not the information that had been shared between scientists and engineers in the two countries in the early sixties was restricted or not. This was up to the (Congressional) Joint Committee on Atomic Energy, and there was no guarantee that they would interpret the British request in a favorable light. As a matter of fact the Committee was in an irritable and suspicious mood as regards U.S.–U.K. exchanges in the nuclear field.[16]

The British Ministry of Defense and the Embassy were extremely worried by the attitude of the Joint Committee. Above all they did not want to go ahead with the centrifuge programme in Europe against U.S. wishes for fear of

[14] The debate briefly described here took place under the shadow of the signature (1 July, 1968) and coming into force (5 March, 1970) of the Nuclear Non-Proliferation Treaty (NPT).

[15] PNO(C)68 2nd Meeting, Cabinet Official Committee on Nuclear Policy. Sub-Committee on Gas Centrifuge, 11 December, 1968. "Report of Washington Discussion". CAB 134/3125, TNA; PNO(C)(68)12, 19 December, 1968, Cabinet Official Committee on Nuclear Policy. Sub-Committee on Gas Centrifuge, "Interpretation of Article IX(c) of the 1955 Civil Bilateral Agreement", CAB 134/3125, TNA; Telegram Sir P. Dean, Washington D.C. to London, 6 December, 1968, "Gas Centrifuge: Anglo-U.S. Talks", PREM13/2555, TNA.

[16] Telegram British Embassy, Washington D.C. to Foreign and Commonwealth Office, 12 May, 1969, PREM13/2556, TNA.

retaliation in a range of more or less related issues. These included the provision of low-cost enriched fuel for nuclear submarine propulsion, as well as amendments to existing civil agreements for reprocessing irradiated fuel then being discussed.[17] America's "leadership" in all matters nuclear, and Britain's dependence on it, provided Congress with a political weapon that it could use to thwart independent initiatives by its closest ally if deemed to be contrary to U.S. interests.

March–June, 1968. The British Case Collapses. The next meeting of the British and American officials of the two atomic energy organizations occurred in March, 1969. This time the U.S. team was fully prepared to challenge the British position.[18] They were emphatic that the British had underestimated the extent of the help they had been given. The American contingent insisted that there had been a great deal of discussion on end cap design in the U.S.–U.K. exchanges, and that it was difficult to imagine that some of this discussion was not embodied in the ultimate UKAEA device. The British were not persuaded: they insisted that the design that they discussed together with their American colleagues was not unique. The British were also reminded that they had been given information by the U.S. on how to improve the design of the bottom bearing of the rotor supporting the centrifuge's cylinder. At the end of meeting the head of the U.S. delegation said that to better assess the American contribution to the British device it might be useful if they could see the United Kingdom centrifuge project at first hand.

The British were deeply distressed by the demand for visual access. For one thing, the design of their centrifuge was the centerpiece of their contribution to the proposed tripartite collaboration. Dutch and German partners would assume that it was of solely British provenance. They would feel betrayed, and would certainly not share their most important information, if this core data had already been given to the Americans. «A "dished end cap"», Zuckerman wrote, «should not be allowed to become a barrier to a major European political policy which the American government has not only endorsed but also

[17] "United States/United Kingdom Relations in the Nuclear Field", attached to memo Sykes to Killick, 1 April, 1969, FCO55/269, TNA.

[18] "Centrifuge Technology", Record of the United States/United Kingdom Talks Held in the Cabinet Office, London, on the 4 and 5 March, 1969, FCO55/265, TNA.

encouraged».[19]

Many in the Cabinet were also convinced that the main reason for the American demand for visual access was not the protection of national security – the terrain on which London had hoped to situate the debate – but commercial interest. As Zuckerman put it to Prime Minister Wilson, «the Americans are out to dominate the world market for nuclear fuel. Were we to allow them access [to our Mk I centrifuge] they might well pick up ideas from our production model which could make a real difference to their commercial exploitation of the centrifuge in third countries, if not in the USA».[20] For these reasons alone Sir Solly was determined not to yield to American pressure, even if that meant antagonizing the Joint Committee and perhaps jeopardizing the civil and military U.S.–U.K. agreements then under review.

The British case was dealt a lethal blow by their own, more systematic enquiries into just what information had passed between their scientists and engineers when they were collaborating under the restricted regime in the early sixties. A three-man panel reporting late in May concluded unequivocally that the British design of the end cap incorporated U.S. restricted data that could not be transmitted to the Dutch or the Germans.[21] After a further round of discussions, in July 1969 the British authorities, their case seriously weakened by the new revelations of their own internal investigation, and under assault from the AEC, finally agreed that an American team could have visual access to the Mark I production prototype of their gas centrifuge.

But the British conceded more. During a visit to the laboratories at Capenhurst, USAEC officials were also given a full and frank presentation not only of the centrifuge itself, but «also of the U.K.A.E.A.'s production plans, their machine trials and testing programs, their experimental workshops, and other associated facilities».[22] The British authorities also accepted to keep the USAEC informed about their programme for advanced research and

[19] Memo Zuckerman to Prime Minister, "Centrifuge Collaboration. Enquiry by Lord Penney, Sir Alfred Pugsley and Mr. T.C. Hetherington", 2 June, 1969, PREM13/2556, TNA.

[20] Memo Zuckerman to Prime Minister, "Centrifuge Collaboration. Anglo-United States Relations in the Nuclear Field", 21 May, 1969, PREM13/2556, TNA.

[21] "Report of Enquiry Relating to Restricted data on Centrifuge Design and Construction [...]", 30 May, 1969, FCO55/268, TNA; Letter Zuckerman to Prime Minister, 2 June, 1969, PREM13/2556, TNA.

[22] PN(69)14, Cabinet Ministerial Committee on Nuclear Policy, "Gas Centrifuge Collaboration. Extent of Agreement Reached. Note by the Minister of Technology", 17 November, 1969, CAB134/3121, TNA.

technology, and they invited a small U.S. team to come over and see which, if any of its aspects might be restricted under Article IX(c) of the joint U.S.–U.K. agreement. With these conditions met, in October the Joint Committee agreed that, exceptionally, the UK could share centrifuge end cap technology with its Dutch and German partners in a collaborative European programme.[23] Summarizing the dispute over centrifuge technology in his diaries twenty years later, Tony Benn, the Minister of Technology, wrote that what he had suspected «but had never been properly told, was that we have an arrangement with the Americans under which we are absolutely tied hand and foot to them, and we can't pass any of our nuclear technology over to anybody else without their permission.The harsh reality is that de Gaulle is right» (Benn 1998, p. 127).

Reflections on a Transnational History of Science and the Cold War

This case study has explored the processes whereby *knowledge was made* at the interface between qualified nuclear scientists and engineers in the United States and in Great Britain. The analysis provided an insight into the material practice of co-production, the dynamics of the process whereby two partners learnt from each other between 1960 and 1965. In also showed the strategies used by the USAEC to regain some control over the independent British effort pursued in the following three years. By combining legal arguments with veiled threats to withdraw support from important sectors of the British civil and military programmes, the U.S. used its vast lead in nuclear knowledge to extract major concessions from its ally. In fact American nuclear scientists re-inserted themselves into the European enrichment project as it began to take shape in 1969, if not directly, then by demanding access to both current and future developments. The ensuing transparency of the European project was intended to ensure that the U.S. maintained short-term control over its trajectory on the grounds that it *might* use classified American material. It was also intended to ensure that U.S. laboratories retained a broad understanding of subsequent European advances as centrifuge technology was improved. Thus even as British scientists, engineers and policymakers tried to break loose of their historical entanglement with the U.S., so they were obliged to yield critical knowledge to their rival, knowledge that could inject new ideas into the AEC's centrifuge program, perhaps accelerating its development and

[23] "American Aide Memoire", 1 October, 1969, CAB134/3121, TNA.

even its commercialization. American overall scientific technological leadership was deployed as a political weapon to browbeat the British into submission. Washington's capacity to influence the nuclear programmes of other states, and to enter new markets open to buying relatively simple and cheap centrifuge enrichment, was enhanced. Britain's hope of taking the lead in the development of a major new technology and of breaking the U.S. monopoly on the provision of enriched uranium was badly dented.

This story can be read exclusively from the perspective of U.S.–U.K. diplomatic relations. For Britain, it describes a re-equilibration in the balance of its relationships between America and Europe. This involved distancing itself from Washington in the interests of drawing closer to the continent, of undermining «the European contention that we are shackled to the American chariot» as Zuckerman put it.[24] It was also symptomatic of a dilution of the "special nuclear relationship" between Washington and London, that Zuckerman (though not Secretary of State for Defense, Denis Healey) regarded as illusory by the late 1960s.[25] For the U.S., the story highlights the maturing contradiction between its strong support for an integrated Europe and its urge to establish an American-led regime of world order. The Johnson administration actively encouraged the development of collaborative technological projects in strategic domains like the nuclear and space to close the "technological gap" between the two sides of the Atlantic. At the same time the very success of its policies threatened the dilution of the global influence that it was intent on preserving. As Ninkovich has put it, one of the abiding themes of American foreign policy in the 20thC has been the recognition that

> The very forces that made progress possible – technology, trade, a global division of labor, and interdependence, – also made possible the system's destruction if pushed in the wrong direction and not checked. The greater the degree of integration, the more explosive would be the disintegration produced by a runaway modernity. (Ninkovich 1999, p. 66)

The deep animosity between British Premier Wilson and U.S. President Johnson, along with the loss of legitimacy engendered by the debacle in Vietnam, only hastened that "disintegration". The maneuvers described in this paper to rein in the European centrifuge project in the late 1960s can be read as an attempt to "check" the pull of a world system moving "in the wrong

[24] Memo Zuckerman to the Home Secretary, 10 March, 1969, PREM13/2555, TNA.
[25] Memo Zuckerman to Prime Minister, 15 October, 1968, PREM13/2006, TNA

direction" as seen from Washington, as a struggle to reconcile a time-hallowed policy for postwar Europe with the need to curb "runaway modernity".

By focusing in detail on the procedures whereby scientific and technical knowledge of centrifuges for enriching uranium was co-produced, this paper seeks to move beyond a more traditional analysis of the exercise of American power in the Cold War by bringing non-state actors into the heart of the analysis. Scientists and engineers at laboratories in Capenhurst in the U.K. and at Oak Ridge in the U.S. are mostly faceless in my archival sources. But their expert opinions are constantly appealed to by high-level state officials, or the members of the USAEC who have to make national policy. It is only through the prism of their diverse forms of face-to-face interaction (discussing ideas, sharing blueprints and technical reports, visiting each other's laboratories, displaying prototypes) that we can see how together they made knowledge, and how that knowledge and its embodiment in a centrifuge and its end cap could be at the heart of a diplomatic squabble between the two countries.

The various channels – written and visual – through which knowledge flowed between the partners has emphasized the poverty of a "model" of knowledge "diffusion" or "transfer" that sharply distinguishes production from circulation, and that denies or at least restricts the agency of the "recipient". As we have seen, and as in fact the British insisted, the exchange at the scientific level was *mutual.* Knowledge was co-produced in a messy process that defies easy analysis. American hegemony does not spring only from «organizing the consent of subordinate participants». It is enhanced by the U.S.'s capacity to use their scientific and technological pre-eminence as a political weapon to extract the best from what others have to offer, and to make rapid and effective use of it by virtue of the «American frontier past and its restless quest for progress and change» (*sic*).

To recognize co-production is to acknowledge interdependence. The postwar dominance of American science and technology, and the determination to retain a global leadership that was underpinned by a dynamic research system, has led historians to think of American knowledge production as self-sustaining and autarkic. This is not the way scientists see it, at least not when challenged to defend their international linkages. Time and again, and notably when under threat from administration officials and Congressional members deeply concerned to protect national security, leading scientists and science administrators have insisted that, on the contrary, American scientific and technological prowess was enhanced by drawing on a global pool of knowledge.

Scientific and technological interdependence has also been eclipsed because the Cold War elevated scientific and technological achievement to a matter of national pride and international prestige: scientific and technological prowess became key markers of national power (Edgerton 2000; 2007). A French reporter was stunned by what he heard when covering the first sounding rocket campaign in the Sahara desert in 1959 being led by young space scientist Jacques Blamont. The rockets had been built by members of Wernher Von Braun's team who had settled in France immediately after the war and they were doing the countdown in German (Blamont 2001). When the State Department was scrambling to discredit Communist China's prestige after it had successfully tested its first nuclear weapon in 1964, leading Indian physicist and scientific statesman, Homi Bhabha suggested that U.S. press releases emphasize that the "Chinese" bomb could not have been built without Soviet help. In a postwar climate which emphasized inter-state rivalry, and in which scientific and technological achievement became markers of national prestige, nationally-based if not nationalistic narratives "inevitably" held center stage.

History as a professional discipline, Curthoys and Lake remind us «was constituted to serve the business of nation building, and has accordingly very often seen its task as providing an account of national experience, values and traditions, thus helping forge a national community» (Curthoys & Lake 2005, p. 5). Transnational history, by contrast, studies «the ways in which past lives and events have been shaped by processes and relationships that have transcended the borders of nation states». It is interested in understanding «ideas, things, people and practices which have crossed national boundaries» and its language reaches for «metaphors of fluidity, as in talk of circulation and flows (of people, discourses, commodities), alongside metaphors of connection and relationship» (Curthoys & Lake 2005, p. 6). In this paper these metaphors have been fused in the notion of co-production, here not in contradiction with the pursuit of American global leadership, but constitutive of it. To better grasp the place of America in the world, we need to understand the place of the world in America.

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