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"Crucial? Helpful? Practically Nil?" Reality and Perception of Britain's Contribution to the Development of Nuclear Weapons during the Second World War

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ABSTRACT
When, in March 1940, two Jewish emigré physicists, Otto Frisch and Rudolf Peierls, composed a memorandum on the technical feasibility of an atomic weapon, few would have envisaged the significance of this six-page document. The technical blueprint for an atomic weapon, at the time assumed to be well beyond the realm of the possible, was to have a significant impact on the Anglo-American nuclear relationship, as it enabled British and American scientists to discuss at eye-level, the direction of nuclear weapons development, as it moved from theory to implementation.

In March 1940, Otto Frisch and Rudolf Peierls, two Jewish *emigré* physicists, who had settled in Britain after Adolph Hitler's rise to power, drafted a paper with significant impact on the development of the Anglo-American nuclear relationship. The so-called Frisch-Peierls memorandum, a six-page document, was at the same time a technical blueprint for a potential atomic weapon based on a nuclear chain reaction and a discussion of the potential moral implications of manufacturing and possessing such a weapon that essentially ruled out ever using it.[1] The memorandum contained the calculation of the critical mass of uranium, and it concluded that the amount of U235 required for a bomb was in the region of kilograms rather than tons, as had previously been thought. This finding was of significance not least because it moved the idea of a nuclear weapon based on a self-sustaining nuclear chain reaction into the realm of the – however remotely – possible. As such, it amplified the British voice in the Anglo-American discussions about the development of nuclear weapons; these would eventually lead to the Manhattan Project, the American-led development of the bombs dropped on Hiroshima and Nagasaki to end the war in the Pacific in August 1945. Yet, the official history of the Manhattan Project claimed that the British contribution to the successful development of the weapon was "in no

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sense vital" and the "technical and engineering contribution . . . practically nil",[2] an assessment that few of the protagonists of the so-called "British Mission on the Hill" would have shared.

The magnitude of the British contribution to the development of the first nuclear weapon may be disputed, but there is little doubt that nuclear co-operation and competition played a very significant role in the broader Anglo-American relationship. This bilateral relationship is a direct function of the perception and reality of the rise and fall of the power and prestige of those two countries – both in absolute and relative terms. Few comments capture the concerns of the British government with prestige, power, and the presumed "special relationship" between Britain and the United States more poignantly than the foreign secretary's, Ernest Bevin's, exasperated exclamation in October 1946 referring to the nuclear weapon: "We've got to have this thing over here whatever it costs . . .. We've got to have the bloody Union Jack on top of it".[3] This comment came hot on the heels of a telephone conversation with his American counterpart, James Byrnes. As Bevin explained, amongst the reasons why he felt it imperative for Britain to possess nuclear weapons was that he did not "want any other Foreign Secretary of this country to be talked to or at by a Secretary of State in the United States as I have just had in my discussions with Mr Byrnes".[4] At the time, the decision of nuclear weapons development was "framed in terms of cost versus credibility" within a "complex matrix of identity and security".[5] *Plus ça change*?

It is a truism that the Second World War transatlantic relationship, particularly the transatlantic nuclear relationship, was an unequal partnership founded on American superiority across most areas of engagement, and the nuclear relationship was amongst those areas where American superiority was most visible and pronounced. Yet, it was also this nuclear relationship to which Britain, arguably, had contributed more – and more creatively and significantly – during the war years than to most other areas. Still, when the administrative history of the development of nuclear weapons, *Atomic Energy for Military Purposes*, also known as the *Smyth Report* after its author, the American physicist Henry Wolf de Smyth, chronicled the Manhattan Project, Britain remained invisible. The perception of exclusive United States leadership would dominate the view of the nuclear weapons project being an essentially American enterprise, and – given the significance attributed to the atom bomb as the single most important jigsaw piece to bring to an end the Pacific War – an American success. Admittedly, the near unanimous jubilation on the part of politicians in the immediate aftermath of the detonation soon made way for a more nuanced and critical assessment of the decision to drop not one, but two bombs on a country whose surrender seemed secured already.[6] Nevertheless, few would argue with the enormity of the scientific achievement associated with the development of nuclear weapons. Thus, whilst the Americans were happy to claim it as their success, on the other side of the Atlantic, the British also laid claim to what they saw as their very significant contribution to the development of the atomic weapon. Following from the Frisch-Peierls memorandum and building on a frantically-paced effort to determine the feasibility of nuclear weapons in the year following its communication to the government – fed by fears that the German enemy would beat its Anglo-Saxon competitors to the goal – it was claimed that Britain's scientists actually "invented" the atomic bomb.[7]

The relative merits of those assertions are not only a matter of an accurate historical record, but also part of an evaluation of war-time and post-war political power politics and its impact on the historiography of the bilateral relationship. A characteristic of the historiography of Anglo-American relations and the related discourse about the special nature of this bilateral relationship is that the British tended to overplay both its significance as well as the British role within it, whilst the Americans tended to understate the importance of British contributions in any joint efforts.[8] How valid were the British claims about their creative input into the development of the atomic bomb or, conversely, how defensible is the American position that their dominance of the Manhattan Project in its more crucial phase when driving ideas and scientific insights towards the actual weapons production eclipsed the contributions of any other nation to the international effort? In other words, how does one balance Britain's claim to the intellectual property of an invention that political circumstances during and after the war prevented it from patenting with Americans claims that the British contribution was "in no sense vital" and actually "not even important"?[9]

As demonstrated elsewhere, the story of the wartime nuclear weapons development is complex,[10] combining the actions and interaction of two distinct communities. On the one hand resided politicians and policy-makers with nationally oriented security agendas in a global war and subsequently a global Cold War and, on the other, scientists with their largely transnational approach of advancing knowledge driven both by their desire to progress scientific understanding.[11] During the Second World War the two groups interacted more strongly than they had ever done before. As rapid scientific advances allowed sophisticated weapons development, politicians began understanding the need to refer to scientists in the decision-making processes, including those of a political nature.[12] This analysis discusses Britain's co-operation and competition in the Anglo-American nuclear relationship in the light of scientific collaboration and rivalry during the Second World War by placing the scientific developments in their international political context before assessing the post-war perception of these developments with regard to British and American interests in recording their version of events.

An understanding of the nuclear physics scientific community and its particular international composition lay in the 1930s. Following the creation of the nuclear model of the atom by Ernest Rutherford at the University of Manchester in 1911,[13] scientists turned their attention to the elucidation of the structure of the nucleus. A milestone in this endeavour was the discovery of the first uncharged subatomic particle, the neutron, in 1932 at Cambridge.[14] This was the first of several significant discoveries in what became known as the *annus mirabilis* of nuclear physics,[15] followed by the similarly momentous identification of the positron – the positively charged counterpart of the electron – by Carl Anderson and the first artificial disintegration of the nucleus by John Cockroft and Ernest Walton.[16]

Physicists began to discuss the possibility of using the neutron to force a nucleus to give up some of its enormous energy by splitting the atomic nucleus and thereby releasing further neutrons. Initially, one of the key figures in nuclear research, Rutherford, famously dismissed such expectations as "the merest moonshine",[17] but others contemplated at least a theoretical possibility of a self-sustaining nuclear chain reaction, arguing that the neutrons released in the fission process could then move on to produce further fission.[18] By the latter half of the 1930s, scientists had made significant progress in understanding the fission process. Lise Meitner and Otto Frisch in 1938 developed a qualitative theoretical explanation of the process,[19] and the identification of the relatively rare uranium isotope, U235, was the most promising candidate for fissionable material that would allow a self-sustaining chain reaction.[20] But despite these advances, many uncertainties and obstacles remained. Whilst proof of U235 as a fissile isotope emerged,[21] it was also clear that even if so, its separation from the much more common U238 would be difficult. Moreover, if required in large quantities, it would likely be prohibitively expensive,[22] and it would require "the efforts of an entire nation", which seemed "inconceivable".[23]

Of course, Britain was not the only country considering the possibility of harnessing nuclear power for weapons. In June 1939, Siegfried Flügge, assistant to Otto Hahn, the pioneering German radiochemist and researcher of radioactivity, published a paper in the German journal, *Naturwissenschaften*, entitled "Can nuclear energy be utilised for practical purposes?"[24] In this paper, amongst others, he explored the explosive potential of nuclear energy. When Germany, barely three months later, invaded Poland and unleashed a war on Europe and the world, the potential of the murderous National Socialist regime working towards a nuclear weapon sent shockwaves through the scientific community and, in particular, through the significant community of *émigré* scientists. Germany had been a driving force in nuclear physics and chemistry in the early twentieth century; but fear of Nazi persecution in the 1930s forced many young scholars to leave Germany and its Central European orbit. This created an extensive international scientific network of nuclear scientists and accelerated the transmission of ideas and discoveries. It also explains why, almost simultaneously, scientists with a great sense of urgency and mindful of the potential consequences of a powerful weapon in German hands did two things. They worked feverishly on a better understanding of the feasibility of a nuclear weapon and started conversations with politicians about the need to respond to this potential threat and/or opportunity on both sides of the Atlantic. Amongst others, they introduced the idea to the American president, Franklin Roosevelt, via his advisor, Alexander Sachs, in October 1939.[25] This initial approach was important in that it resulted in Roosevelt's agreement to set up a Government Advisory Committee on Uranium and thus fired the starting shot to the American nuclear weapons programme.[26] At the same time – as will become evident below – it was disappointing in that the president was not galvanised into immediate action that would have allowed nuclear scientists to focus on a research programme to make real and fast progress.

Around the same time, in early 1940, two other *émigré* physicists, German-born Peierls and Austrian-born Frisch, then at Britain's University of Birmingham, considered the question of the critical mass of uranium, the mass required to sustain a nuclear chain reaction. Summarised in the above-mentioned memorandum, their work suggested that the amount of fissionable material – U235 – needed for an atomic bomb based on a self-sustaining chain reaction was far less than previously assumed – previous beliefs held this to be in the order of magnitude of tons rather than kilos. As a result, a sphere of metallic U235 with a radius of more than 2.1 centimetres could be sufficient to be explosive, an amount that equated to approximately 1 kilogramme of U235.[27]

Given the immense technical difficulties of uranium isotope separation, this calculation had significant implications: a bomb was genuinely a theoretical and, quite possibly, a practical possibility, if only in the distant future. The period between the formulation of the Frisch-Peierls memorandum of February-March 1940 and the British decision to attempt to build a bomb in 1941 involved months of frantic scientific activity as well as science-policy conversations described in detail elsewhere.[28] Nonetheless, it is helpful to reflect on some of those developments to evaluate their consequences for Britain and the Anglo-American nuclear relationship.

Frisch and Peierls were very much aware of the significance of their calculations, but as enemy aliens, they were limited in their access to political circles. They passed their paper to their head of department, Professor Mark Oliphant, who in turn sent the memorandum to the chairman of the Committee on the Scientific Survey of Air Defence, Henry Tizard, and through him, Professor G.P. Thomson of Imperial College, at the time chairman of the government committee concerned with the possibility of a nuclear chain reaction. In contrast to the rather indigestible nuclear science portfolio that

Sachs had presented to Roosevelt six months earlier, Frisch and Peierls put into circulation a two-part document, "On the Construction of a 'Super-Bomb'", in which even the first "scientific" half was intelligible to the political audience with a lay interest in science. The more political second part, "On the Properties of the Radioactive Super Bomb", discussed the strategy of using a potential weapon. After explaining the release of radioactive substances, Frisch and Peierls described the indiscriminate nature of nuclear fall-out, thus prohibiting its use, despite the fact that the rationale for development was practically irresistible because of the danger that other Powers – most notably Germany – might develop it.

Although Tizard informed the War Cabinet that the probability of "anything of real military significance" was very low,[29] under Thomson's auspices, a government committee, the so-called MAUD committee, deliberated the possibility of military applications of the Frisch-Peierls findings. After initial scepticism,[30] the MAUD committee in its final reports in June and July 1941 endorsed the key insights from the Frisch-Peierls memorandum when concluding that the atomic bomb was feasible although very costly.[31]

In a 1986 essay, "Roosevelt, Churchill and the wartime Anglo-American Alliance", Reynolds mused that after one-half century of rhetoric, in part based on the British wartime premier, Winston Churchill, deliberately creating a myth about a special Anglo-American relationship depicting the wartime alliance as the "natural expression of an underlying cultural unity", there was still something mythical about the mutual relationship.[32] Decades on, historians still discuss controversially how 'special' the 'Lazarus-like' Anglo-American relationship is,[33] and whether its existence is more myth than reality.[34] Prior to the 'invention of the Special Relationship", mutual perceptions on both sides of the Atlantic were very different. Reynolds described British sentiments towards America as a mixture of doubt, hope, and fear: doubt that the partner across the Atlantic would provide immediate and reliable help if needed; hope that Washington would offer assistance in the long-term or in acute danger as in war; and fear that any support, if forthcoming, would ultimately compromise British independence. Similarly, American attitudes towards Britain were somewhat ambivalent. Whilst many Americans remained and to this day remain culturally Anglophile, this sentiment mixes with a desire to see America emancipated from the "Imperialist mother country". As Roosevelt summarised his impression of negotiations with the British: they "usually get 80% out of the deal and you get what is left".[35]

Given the magnitude of what was at stake after 1940, it is not surprising that nuclear matters were an area fought over with fervour during the crucial phases of the Second World War and immediate post-war period. This was true even in what was ultimately the most co-operative of the transatlantic ventures – the atomic bomb project. Even here, differences of outlook, political expediency, and political priorities adversely affected effective collaboration in what was a seesaw relationship where suspicion and trust, tension, and collaborative spirit superseding each other as priorities on both sides of the Atlantic changed as a function of military needs and political convenience.

In 1939–1940, the British needed to secure American support for their war effort. Especially during and after the Dunkirk losses and the fall of France in May and June 1940, Britain increasingly came to see American assistance as essential for survival. Yet, although Churchill, who had succeeded Neville Chamberlain as prime minister in May 1940, attested to some Anglo-American "mixing-up",[36] the British and American governments during much of the crucial summer 1940 engaged in an "uneasy bargaining game . . . exploring in a rather heavy-handed way how best to obtain support from each other".[37] Churchill knew that his bargaining power in attempting to move the United States from a policy of neutrality to one of non-belligerency was limited. Still, despite the desperate military situation, he was reluctant to trade scientific secrets unless the British could get "something very definite in return",[38] by which he meant "until the United States were much nearer war".[39] Whilst the scientists were rather keener to join forces with their counterparts in the United States, they, too, were cognisant of the fact that information transfer to the Americans carried the risk of losing control over the Project.[40] Despite such reservations, the Anglo-American mixing-up that Churchill had anticipated in the political sphere, did happen – for a short period – in the sphere of intelligence and scientific collaboration when Tizard went on a technology transfer mission of the most extensive kind. He was instructed to tell the Americans "everything that Britain was doing in the scientific field"[41] when he went to the United States between September and November 1940.

Tizard's mission was a rare example of unconditional international sharing of scientific knowledge, motivated at a particular time by political leaders' belief that such unconditional co-operation would not only facilitate scientific progress, it would also serve the national security interests of both Britain and the United States. Hence, despite considerable scepticism from within government circles, Tizard's famous "black box" that he took to Washington contained a wealth of valuable scientific secrets. Whilst only three of the official meetings of the Tizard mission dealt with nuclear weapons,[42] it is significant that one of the members of the MAUD committee accompanied Tizard; Cockroft shared the committee's findings with his American colleagues. Whilst the British at this point were ahead of their American counterparts regarding theoretical and experimental expertise, there was no doubt that with its extensive resources, the United States remained better placed to progress on any project that required larger industrial-scale facilities.

The attachment of a British Central Scientific Office to the British Supply Council in Washington and the establishment of a Liaison Office of the American National Defence Research Committee in London occurred in early 1941. Whilst these actions appeared to indicate that the scientists' lobbying for closer transatlantic scientific co-operation had trumped the scepticism of the political establishment in the first half of 1941, in reality Tizard's pleading with Churchill to expand collaboration fell on deaf ears.[43] Faced with a desperate military situation in Europe, Churchill's disappointment with the lack of American support for the British war effort dissuaded him decisively from supporting an intensification of Anglo-American nuclear collaboration through knowledge exchange. To enhance scientific-political communications, the British scientific establishment took the rather unusual step of electing Churchill a Fellow of the Royal Society,[44] a move signalling their awareness of the significance of playing the political game as much as advancing the sciences. Coming as it did around the same time as – in scientific circles, controversial – elevation of Churchill's scientific advisor, "Prof" Frederick Lindemann, to a peerage as Lord Cherwell, it symbolised how different parts of the scientific community, with greater or lesser success, fought for the ear of the prime minister.

By summer 1941, with the German invasion of the Soviet Union, the military and political situation for Britain changed dramatically. In addition, the indications from the other side of the Atlantic were that Roosevelt no longer believed that the United States could avoid entering the war,[45] and Churchill entertained high hopes for his meeting with the American president in August 1941 at Placentia Bay, Newfoundland. Around the same time, whilst being "quite content with the existing explosives", Churchill felt that he should not "stand in the path of improvement" in the form of nuclear weapons[46] and, following the conclusion of the work of the MAUD Committee and encouraged by Cherwell, he became the first national leader to approve an atomic weapons programme. However, whilst some amongst the scientific community considered close collaboration with the United States essential, Churchill's entourage regarded it rather less so, and the prime minister was happy to allow the issue of closer co-operation in nuclear research to drift in late summer 1941 after meeting with Roosevelt.

In contrast, the lack of any meaningful American response to the MAUD committee's reports that Tizard had shared earlier in the year disappointed the nuclear scientists.[47] That displeasure was amplified by the fact that the initial doubts about the feasibility of nuclear weapons slowly made way for an appreciation of the remote possibility that a weapon might be achievable – and, thus, in view of the significant technological challenges, American assistance would be required even more urgently given the impact the war had on Britain's industrial capacities. It is within this context that a second important scientific mission, that of Oliphant, took place. Oliphant, a member of the

MAUD committee, had pushed for a trilateral Anglo-Canadian-American collaboration, and whilst he assumed that some scientific research might continue in Britain, he regarded it necessary to move all industrial aspects of the work across the Atlantic.[48] In early August 1941, he flew to North America ostensibly to consult about the radar programme. But given his role in nuclear research, it was not surprising that within a few days of his arrival, he had made contact with Lyman Briggs, the chairman of the National Defence Research Committee [NDRC] Uranium Committee, and made a point of attending one of the committee meetings. As Oliphant put it in a letter to the chairman of the MAUD Committee, Briggs had a "mild mania about this secrecy business" and Oliphant took it into his own hands to ensure that the NDRC would be informed of the substance of the MAUD Committee's work.[49] Leo Szilard, one of the refugee NDRC members, commented on this move by saying: "If Congress knew the true history of the atomic energy project, I have no doubt that it would create a special medal to be given to meddling foreigners for distinguished services, and Dr. Oliphant would be the first to receive one".[50]

If Oliphant's initial consultations with the NDRC were important, even more crucial was his meeting in late September 1941 with E.O. Lawrence at the University of California, Berkeley, to whom he not only presented the Frisch-Peierls memorandum,[51] but through whom he also connected with the theoretical physicist, Robert Oppenheimer, who later had a leading position in the Manhattan Project. Interestingly, this approach to Oppenheimer in the form of an extensive memorandum had only a semi-official character in that Oliphant,[52] whilst sharing important details of the committee's work, specified that he had done so "as an individual and without any official status or authority in this matter".[53]

This extensive scientific exchange, embedded in science policy meetings, might explain why in October 1941 Roosevelt finally broke his silence over nuclear matters and the MAUD Committee reports. He wrote to Churchill suggesting that the two leaders should "correspond or converse concerning the subject . . . in order that any extended efforts may be coordinated or even jointly conducted".[54] This was a far-reaching offer of collaboration, conceivably on equal terms. Nevertheless, Churchill did not grace it with a swift response. The answer, when it came two months later, was a rather cool holding message that told Roosevelt that Churchill and his advisors were considering the matter.[55] In view of nuclear developments in the following years, this miscalculation of potential upsides of a near-equal nuclear weapons partnership must count as one of Churchill's graver errors in his manoeuvring of the transatlantic relationship.

In early 1942, when a British delegation of scientists visited America to investigate possibilities of further co-operation, they found that the tables had already started turning with regard to nuclear weapons work.[56] Although the sense remained that the Americans still had not made the nuclear question a top priority,[57] they stood more advanced than their British colleagues and, with every passing month of Anglo-American non-collaboration, the balance of progress shifted further in favour of the United States. The Japanese attack on Pearl Harbour in December 1941 had focussed American minds and helped accelerate the nuclear programme. Progress in America with its wealth of resources – both material and human – was now very clearly outstripping that in Britain. Therefore, it is hardly surprising that when in his first face-to-face conversation with Roosevelt on nuclear matters in June 1942, Churchill suggested that Britain and the United States should "at once pool all our information, work together on equal terms, and share our results if any equally between us",[58] the president was no longer interested. Having refused to collaborate whilst they were ahead in the scientific game, the British had now lost their bargaining power and had to settle for nuclear co-operation almost exclusively on American terms.

By md-1942, John Anderson, the Lord President of the Council and minister responsible for overseeing Britain's nuclear weapons project, and Cherwell came to share the view of Wallace Akers, the director of Tube Alloys, the research and development programme tasked with implementing the findings of the MAUD Committee. It would be necessary to merge the British and American nuclear efforts to maximise the chances of beating Germany to nuclear weapons.[59] Not only that, Anderson also left no doubt that the currency of British – theoretical – nuclear weapons knowledge was fast losing its value and "unless we capitalise it quickly … we shall be outstripped".[60]

Nevertheless, throughout 1942, not only had the bargaining power in the Anglo-American nuclear relationship shifted dramatically; the atomic bomb project within the United States increasingly came under the control of the military. This decision exacerbated the shift away from a culture of fairly unrestricted information exchange to a limited and strictly controlled transfer of scientific and technical information, as the Project came to be seen more of a national American programme than an international collaborative enterprise.

Churchill was largely unaware of the consequences of this internal shift. His meeting with Roosevelt in June 1942 led him to put great faith in the president's expression of willingness to continue far-reaching co-operation in 1942. But the direct communications between the two leaders were not much liked by the American scientific or, indeed, military administration that spent much of the latter half of that year counter-steering.[61] That same period saw an intensification of nuclear theoretical and experimental research and, significantly, Roosevelt's secret agreement to fund the Manhattan Project. It demonstrates the increased sense of urgency in the highest echelons of government, similarly visible in the appointment of General Leslie Groves, a soldier as well as an engineer, as the director of the Project: this appointment left no doubt about the military being in command. The shift was clearly visible, too, in early 1943 in a "Memorandum of the Interchange with the British and the Canadians".[62] The document was explicit in limiting the information flow to British and Canadian collaborators, only including them in the very limited areas where their contributions were of benefit to the Project.

Whilst many Americans involved in science policy were in broad agreement that keeping the British partners at arm's length best served American interests, the most powerful person in the White House, the president, needed reminding of the need to hold the line on the nuclear information policy.[63] As his closest advisors knew, the greatest risk of a *volte-face* on his part lay in the direct exchanges between him and Churchill. This would happen at the first Quebec Conference in August 1943. By that time, Churchill understood the consequences of Britain shut out of any meaningful Anglo-American nuclear collaboration. Not only did this have the potential to slow down the pace of progress of the American project and thus risk the West "los[ing the war] if Germany completes the work first",[64] but there was also concern about the medium- to long-term consequences for Britain if it did not possess nuclear know-how after the war. Unsurprisingly, and in keeping with his inclination to rely on high-level diplomacy, when a meeting with the NDRC chairman, Vannevar Bush, and war secretary, Henry Stimson, in early summer 1943 did not lead to the desired Anglo-American nuclear rapprochement, Churchill reverted to top-level discussions at Quebec to recalibrate the nuclear relationship. And, indeed, in return for agreeing that the Allied landings in Normandy, planned for the subsequent year, would take place under American command, Roosevelt re-ignited the collaboration on nuclear weapons for the duration of the war. The "Agreement Governing Collaboration between the Authorities of the U.S.A. and the U.K. in the Matter of Tube Alloys" determined full and effective co-operation to bring the atomic bomb project to fruition.[65] Furthermore, both parties agreed never to use nuclear weapons against each other, not use them against other states without each other's consent, and not pass on information to other countries without each other's consent. Where the agreement gave Churchill rather less than he and his political advisors had hoped was in the area of post-war exploitation of the research results. Britain found itself forced, unilaterally, to make very significant concessions on post-war commercial applications that were essentially a disclaimer of any interests in industrial and commercial exploitation beyond what the American president agreed "to be fair and just and in harmony with the economic welfare of the world".

Despite these very significant concessions, the Quebec Agreement paved the way for Anglo-American co-operation and was instrumental in enabling British scientists to continue nuclear research at a time when Britain's Tube Alloys project was under threat. The ink had hardly dried on the diplomatic paperwork when a core group of the team that would later form the "British Mission on the Hill" – Chadwick, Francis Simon, Oliphant and Peierls – arrived in Washington to restart what would be a fruitful collaborative scientific effort, but one still hampered by a political and administrative culture war.

As indicated above, the official American version of the British contribution to the eventual development of the first atomic weapons was one of little, if any, significance. It is worth considering this assessment in the light of individual recollections from both sides of the Atlantic and in the light of what is now known about the work that was completed as part of the industrial machinery that supported the nuclear weapons research and production effort.

Two core observations stand out. The first is that the effort was huge and the British mission small. American efforts to beat the Germans to the production of the first atomic bomb developed at a pace and scale that few would have believed possible. Whilst the Los Alamos, New Mexico site where bomb development occurred never really lost its character as a mix of a makeshift army base and oversized temporary lab halfway up a mountain,[66] within a year of its launch, it had several thousand people working on site that, by the end of the war, swelled to around 125,000.[67] This central hub, code-named "Site Y", was supplemented by the similarly impressive "Site X", the Oak Ridge Site in Tennessee, a 59,000 acre site devoted to the production of fissile materials needed for the bomb. At the height of the operation in summer 1945, it employed close to 75,000 workers.[68] A third site, "Site W", located on the Columbia River at Hanford, Washington and devoted to the production of chemicals required for plutonium production, would ultimately employ almost 51,000 people,[69] giving further credence to one scientist's early assessment that building an atomic bomb "couldn't be done without turning the whole country into a factory".[70] The British mission was part of this effort, but their contingent was only a minute fraction of the overall workforce. The head count hardly went beyond double digits

The second observation concerns punching above one's weight, in the sense of individual contributions. Even if the "Mission on the Hill" never exceeded about 30 scientists, many agreed that the British contribution was noteworthy. Despite his keeness to see the Manhattan Project as an American military enterprise, Groves acknowledged that British research on the Hill was "substantial". The British scientists made "invaluable" contributions, and following the detonation of the atomic weapons in August 1945, he conveyed to the British mission his "appreciation for their own great contributions to the success of our project".[71] Refugees to Britain such as Frisch, Peierls, Egon Bretschner, Klaus Fuchs, George Placzek, and Joseph Rotblat worked alongside British physics heavyweights such as Chadwick, Anthony French, James Hughes, Derick Littler, William Marley, Donald Marshall, Philip Moon, William Penney, Michael Poole, Harold Sheard, Tony Skyrme, Ernest Titterton, and James Tuck.[72] The concentration of talent in this group was considerable. The head of the British mission Chadwick, the discoverer of the neutron, had won the Nobel Prize for this achievement in 1935. Sometimes referred to as the "Oppenheimer of Britain", Penney brought to the Manhattan Project detailed knowledge of hydrodynamic waves, both shock waves and the more familiar ocean – gravity – waves, essential for the study of the damage effects from the blast wave of the atomic bomb. Alongside Oppenheimer, John Von Neumann, "Deke" Parsons and Norman Ramsey, he would become one of the five members of the Los Alamos "brains trust", a strategic decision-making body that contributed prominently to the direction of the entire programme. He was one of only two representatives from Los Alamos – and the only Briton – to be part of the Target committee that drew up the list of targets for the atomic bombing of Japan.[73] Other notable contributions included G.I. Taylor's work on the effect of underwater explosions on different materials and structures, on rocket shapes, and shaped explosive charges. This work contributed significantly to the understanding of nuclear implosions and explosions, and it was essential for the accurate calculations of the atmospheric phenomena tested at the Trinity bomb test site, including the height of the explosion, the mushroom cloud, and the effect of the wind on the distribution of particles.[74] Another essential contribution came from Frisch: the so-called Dragon's Tail, an experiment that helped determine the exact amount of enriched U235 needed for the U235 bomb.[75] This was of exceptional significance as it averted the need to field test the uranium bomb.[76]

These individual inputs are telling, but as striking is that almost one-third of the long-term members of the British mission – Peierls, Bretschner, Frisch, Moon, Penney, and Plazcek – led research groups at Los Alamos. And all the members of the British mission, without exception, continued their illustrious scientific careers in high-level roles upon their return to Britain at the end of the war.

Taking both the small size of the British contingent on the Hill, as well as the significance of individual roles and achievements, two conclusions emerge. First, the United States would have achieved their target of producing a nuclear weapon ahead of the German enemy, with or without British support; and second, the impact of the group of scientists from Britain who participated in the Manhattan Project was far greater than their numbers might suggest. Thus, writing Britain out of the history of the Manhattan Project is no more accurate than the assessment that British input was a *sine qua non* without which the Project would not have succeeded. A more exact and nuanced assessment will take into account the different priorities that scientists and politicians in the two countries had at different times and will evaluate those against both the geopolitical, political, financial, economic, scientific, and military power Britain and the United States had at crucial decision-making times.

The Frisch-Peierls memorandum clearly displayed a keen awareness on the part of the authors about the political and moral implications of the development and production of a nuclear weapon, with a degree of clarity that even led them to discuss the morality of its potential use. Of far lesser concern were the intellectual property rights of individuals, groups, or nations. Most scientists, whilst not oblivious to the fact that scientific endeavour was firmly embedded in political soft and hard power considerations, were far less concerned than political leaders with the question of intellectual ownership and commercial rights throughout the war and, crucially, in the post-war period. Anybody following closely recent attempts of political leaders of some nations claiming SARS-CoV-2 vaccine development successes as national successes and a sign of victory over nations knows that in most cases these are international scientific endeavours. The claim of scientific greatness can be effective in determining the victory narrative and how much impact it can have on political developments. Post-war Anglo-American negotiations as part of wider geopolitical and economic negotiations bore striking similarities. Herein lies – at least in part – the explanation of how the common perception of the atom bomb as an American rather than joint international success emerged.

A recent exegesis takes issue with the widely held view that there was a special Anglo-American nuclear relationship during the Second World War.[77] It argues instead that as soon the feasibility of nuclear weapons became credible – and, simultaneously, as soon as an understanding that American military-industrial prowess would be required to make the theoretical possibility a defence reality – the United States took a monopolistic approach to the nuclear project. As such, the historiography sees the 1946 *Atomic Energy Act*, better known as the McMahon Act, by which the United States effectively closed the door to meaningful nuclear collaboration with other countries, as a pivotal moment in the Anglo-American nuclear relationship. It has created a "myth that McMahon was an unexpected and significant point of disconnection in Anglo-American atomic affairs".[78] Indeed, this historiography asserts that the end of the Second World War saw a marked change in the Anglo-American relationship.[79] However, whilst agreeing broadly on the significance of McMahon as pivotal, this newer assessment argues less that this was a disconnection from earlier policies, but that it put on a legal footing a relationship that during the years of wartime crisis and (summit) diplomacy had been operating more strongly at the level of personal interactions at the highest level. As Reynolds argued persuasively: whilst at times close, the Anglo-American relationship was also one of "persistent rivalry"; but even more important, it operated at multiple levels with co-operation meaning different things to different people at different times and being pursued differently and differentially throughout the war and the post-war years.[80]

The development of Anglo-American nuclear co-operation was not dissimilar to the development of Anglo-American relations more generally. Strategic, psychological, economic, and political considerations and suspicions influenced the formulation of policies. American, British, and Canadian political leaders expressed an intention to internationalise control of atomic energy and, in their joint Washington Declaration of 15 November 1945, stated their belief that "the fruits of scientific research should be made available to all nations", whilst offering to exchange "fundamental scientific information ... with any nation that [would] fully reciprocate".[81] Nonetheless, "full and effective co-operation" never materialised beyond basic scientific research only. Such collaboration never included development, design, construction, and operation of nuclear plants and, in fact, was limited to what the Americans would refer to as "mutually advantageous ad hoc arrangements".[82]

The Quebec memorandum foreshadowed such a restrictive interpretation of mutual collaboration, and indeed, the 1946 *Atomic Energy Act* formalised this more restrictive American knowledge exchange policy. Specifically, the Act prevented "the transfer of information about technical processes and restricted data", such as the production of fissionable material, to other nations including Britain.[83] Similar to the debates during the war in Britain between internationalist scientists, on one hand, and politicians more concerned with exploitation of scientific achievements, on the other hand, the bill determining control over atomic energy in the United States was the result of a debate between the American military seeking to preserve the secret of the bomb. through a national Atomic Energy Commission, on the one hand, and the Federation of Atomic Scientists who lobbied for civilian control and was less concerned about knowledge exchange, on the other. The Act was a compromise: the arguments of civilian over military control in the McMahon Act persuaded Roosevelt's successor, Harry Truman[84]; but, significantly, the cessation of meaningful and far-reaching technology transfer, based on political considerations on the part of Congress,[85] amplified the perception of the United States owning the intellectual property of atomic weapons.

Because of the *Atomic Energy Act*, British and other non-American scientists, some of whom were still working at Los Alamos, no longer had access to documentation and reports that they had been able to utilise without restrictions before. This was likely to focus British minds on their own nuclear enterprise. Although many would have preferred continued collaboration with the Americans unimpeded by provisions of the McMahon Act, others came to see the exclusion as a blessing in disguise because it forced Britain's hand with regard to developing independent nuclear capabilities. Just prior to the passing of the *Atomic Energy Act*, in a conversation with the

American ambassador in Britain, Prime Minister Clement Attlee communicated that Britain would seek to build its own nuclear plants if the Act were be passed.[86] Formally taken in January 1947, this decision came not least out of a concern of Britain's vulnerability to external threats, but also in consideration of Great Power states. As Reynolds pointed out, Bevin spoke in 1947 for many when he declared that Britain was still a Great Power,[87] and that the government still "regarded ourselves as one of the Powers vital to the peace of the world".[88]

Yet, the shift in the Anglo-American balance of power had become painfully visible in strategic and military decision-making during the war, and even more so in the post-war years. The realities of administering the peace displaced Britain's euphoria of winning the war. Both the McMahon Act, but even more so the abrupt end to Lend-Lease, demonstrated the fragility of Britain's post-war position, especially in the face of increasing hostility from the Soviet Union. Bearing this in mind, the British post-war nuclear programme served two purposes that, on the face of it, appeared almost contradictory. On the one hand it aimed to provide Britain with a safety net, as it was not clear that the US could be relied on unconditionally for support in Europe and against the Soviet Union. Hence the desire, in Bevin's words, to have "the bloody Union Jack flying on top" of a nuclear weapon. Conversely, on the other hand, the programme was also designed as a means of reviving an Anglo-American nuclear partnership, by offsetting Britain's weakening position elsewhere.

Although the British had taken the decision to build nuclear weapons independently as soon as it had become clear that the wartime collaboration would not survive into the post-war era, nuclear sharing as an aspiration was never off the table for British scientists or decision-makers. It was clear to many that whilst British scientists had been involved in the Manhattan Project in prominent positions that gave them privileged access to knowledge, considerable efforts were necessary in the practical application of this knowledge (which was fragmented due to the compartmentalized nature of work in the Manhattan project), in designing and producing components with unusual accuracy requirements, and particularly in producing the fissile material.[89]
Thus, the decision to develop nuclear capabilities was as much about independence as it was about interdependence, as behind the scenes the British continued to try to renegotiate nuclear sharing whilst strengthening their negotiating position through continued nuclear development. Arguably, this strategy of building strength independently to become if not an equal then at least a serious partner in nuclear negotiations eventually paid off. Once British "will and capability to develop nuclear weapons" had been demonstrated, the Americans wished "to have as much control over their potential use as possible".[90]

In the fast-moving world of the developing Cold War, the context of Anglo-American relations, too, changed rather dramatically, as both countries responded decisively to the Berlin Blockade with the Anglo-American Airlift in 1948–1949. More significantly still, the loss of the American nuclear weapons monopoly after the first Soviet atomic explosion in 1949 demonstrated that Anglo-American military and nuclear collaboration remained in both countries' interest. In one analysis: "Both sides wished to co-operate – but meant different things by co-operation – and to retain their independence of action".[91] As a result, little genuine progress in nuclear collaboration occurred for several years. It was not until after the first British nuclear tests in 1952, the election that year of Dwight Eisenhower as American president, and the first Soviet thermonuclear explosion in 1953 that Anglo-American negotiation about nuclear sharing gained sufficient momentum to shift thinking in a way that would allow an amendment of the McMahon Act. In August 1954, Congress amended the *Atomic Energy Act* of 1946 to allow more nuclear collaboration with countries that had made significant contributions and advances in nuclear research. In 1955, as a result, the United States and Britain signed a co-operation agreement,[92] another step towards the final repeal of the McMahon Act and its replacement by the Anglo-American bilateral agreements in July 1958 and May 1959.[93]

In the 1960s, for the first time, Britain undertook a serious effort to record formally its contribution to the development of the atom bomb with its official history, *Britain and Atomic Energy*. It published key documents that initiated much of the British work on the Bomb, including the Frisch-Peierls memorandum, and the British effort evaluated on the bases of access to classified documents. However, this detailed study did little to balance the assessments on the other side of the Atlantic. In contrast to his comments of appreciation of the British contribution to wartime nuclear collaboration in the immediate post-war period, Groves, in his 1963 memoir, *Now it Can Be Told*, did not recall any direct British contribution "to our success in achieving the bomb", referring to the transatlantic partner merely as "helpful".[94]

It is often difficult to quantify the contributions of individuals to collaborative projects, and it is even more difficult to determine with any degree of precision the contribution of a small group of scientists to a project of the size of the enormous multilateral effort of the Manhattan Project. There is no doubt that the size of the American contribution to the Project was unparalleled, and by the end of the Second World War, America had spent in excess of $2 billion on the development of an atomic industrial complex run by the United States Army. The Americans provided most of the financial backbone of the enterprise, and they undertook by far the largest part of the work during the second half of the war. In comparison, the contributions of other partners and other nations were modest. Yet, whilst the United States clearly dominated the Project with its financial, industrial, economic, and scientific might, without British participation, the time-scale of the delivery of a functioning weapon may well have been different; and the question arises whether the weapon would have been operational in August 1945. Once reaching the Anglo-American-Canadian decision to develop a nuclear weapon, the task of the Los Alamos teams was to do so in the shortest possible time. British scientists played a significant role in the early stages of the British and subsequently American nuclear project and were a potent force in moving the scientific project from university laboratories in either county into the industrial-military sphere. Arguably, the scientific-political interactions in the early 1940s, in Britain, the United States, and the bilateral interactions were of significance here. An international scientific community pushed the frontiers of science. Scientists did so without regard to national boundaries in international collaborations driven by their desire to use scientific progress for the good of the many, no matter where. In the 1940s, the nuclear enterprise found its home in the United States. But for the majority of scientists and others working with Americans, the main concern was that the Project would be a success – it was of little consequence "whose" success it would be.

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