How to become a science superpower

In recent years, Great Britain has espoused the ambition to become a science superpower. Former Prime Minister Boris Johnson announced the Advanced Research and Invention Agency (ARIA) in 2019 (it was legally established on 25 January 2023), and created the National Science and Technology Council in 2021. In January this year science minister George Freeman reiterated the science superpower ambition, and chancellor of the Exchequer Jeremy Hunt has expressed it as turning the country into a new Silicon Valley. Earlier this month, the present Prime Minister, Rishi Sunak, made a further announcement along these lines, asserting that by 2030 Britain would be the "world's laboratory".

Such ambitions go back a long way. After pondering on the origins of the military might that enabled Spain to launch its Armada against Britain in 1588—news of which aroused fear and terror in the population (Thomas Hobbes is said to have been prematurely born when his mother heard about it)—Francis Bacon, sometime lord chancellor, evolved his idea that "Science discovery should be driven not just by the quest for intellectual enlightenment, but also for the relief of man's estate" [1,2], encompassing the development of military might, and in those days Spain certainly ranked as a superpower.

During the last century and a half or so, Great Britain, the USA, Germany, Japan and, perhaps most strikingly, the USSR (given its start with such unpromising material) have successively become superpowers, science superpowers or both. China has been both in past millennia, and is perhaps again both, while Great Britain and Germany no longer occupy such positions. The motivations and methods for achieving such status have been different. In Britain, the USA and Japan the primary driver seems to have been economic, with the development of military prowess serving to underpin commercial supremacy (e.g., the militarization of the East India Company). The realization of the achievement has been primarily in the hands of the private sector (including in Japan [3], despite the prominence sometimes given to government programmes). In Germany, on the other hand, the state has played a much more prominent rôle, such as in the foundation of the Kaiser Wilhelm institutes in the early years of the 20th century (later renamed after Max Planck), and in the tight control over the economy exercised by the government in the interval between the 1st and 2nd World Wars. In the USSR, Joseph Stalin perceived the existential threats to the country as a whole, and science and technology were given the highest priorities [4], above all for military ends, and with great success, not only in physics and chemistry but also in biology [5], albeit that the remarkable achievements in the latter were in contravention of international treaties.

Later, scientific prowess seems to been conceived as a shortcut to regaining economic supremacy. This recalls Albert Hirschmann's "maintenance compulsion" idea, whereby the effort required to master advanced technology would entrain and advance the entire economy [7]. I have myself previously advocated nanotechnology as an enabler of this process in developing countries [8], but there is little sign of the idea being taken up. And some countries, perhaps most notably Argentina, have signally failed to achieve military or economic excellence, despite formerly lavish state support of science [9]. Possibly this is because it remains wedded to the "linear" model of state-sponsored science technology innovation [10] which, as Terence Kealey has shown, results in the crowding out of private innovative enterprise [11,12].

The transition from the USSR, which was a veritable science superpower, greatly admired in the West, especially in the decade immediately preceding the 2nd World War [13], and following the 2nd World War successfully developing a hydrogen bomb only a few months after the USA, to the Russian Federation after 1991, in which science practically collapsed, provides an interesting case study. Very many scientists emigrated, mostly taking up academic positions in Western universities, and those who remained seem to have been among the leaders of the feverish kleptocracy that gripped the mood of the country.[1] The rich legacy of scientific innovation was left to be mined by the USA and other Western countries,[2] aided by agencies such as the International Science and Technology Center (ISTC) and the Science and Technology Center of Ukraine (STCU), which actually provided welcome funding lifelines to those scientists who remained to continue scientific work.

So why strive to become a science superpower, and how is it to be done? Military and economic supremacy have already been mentioned as goals, and no longer necessarily coupled, as shown by the example of modern Japan. The social function, "for the relief of man's estate", is much discussed by Bernal [13] but was not a

[1] E.g., Boris Berezovsky (see footnote 47 of ref. 14).
[2] For example, work on ultrahard materials [15], which form the basis of a US patent [16] and an entrepreneurial company, Primet Precision Materials Inc. in Ithaca (NY), founded to exploit it.

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prominent feature of the USSR.[3] Nevertheless, science undoubtedly had a civilizing influence there [17]; indeed it was probably the main source of real refinement, which makes its effective abandonment in modern Russia all the more tragic. Bacon's other purpose, intellectual enlightenment, is the more important motivation when one considers man's spiritual interests—note Spinoza's view that it is man's highest function to know and to understand the objective world and its laws [18]. These diverse motivations can, at least to some degree, coexist.

And how is it to be done? The most obvious route, which is the one being followed by the UK government, is to pour public funds into science, despite all the evidence that this is not an effective method [11,12]. Bernal rightly points out that science and technology yield a return on investment of hundreds of percent [13], and devotes much space to analysing why, notwithstanding, private investment is inadequate, hence public funding is needed. At least part of that analysis applies to the conditions prevailing when Bernal wrote (just before the outbreak of the 2nd World War); in the USA and Japan these attractive returns were and are well exploited by the private sector and there is (relative to Europe) less public funding in the USA, and even less in Japan.

The problem in the UK seems to be that there are too many alternative channels yielding even better returns [19]. Many of these channels are linked to construction and central and local government planning [20,21]. Such practices are carried to extremes in modern Russia where, for example, a municipality may commission a contemporary sculpture for installation in a public space for, say, 50 000 USD; the sculpture is then procured online (e.g., from Alibaba) for 5000 USD—an easy return of 1000%, especially if one happens to own a construction company.

Hence, the *first action* required to achieve science superpower status is to close these alternative channels.

The *second action* is to eliminate the stultifying bureaucracy that so greatly encumbers science nowadays. In its 2022 Autumn Statement the government made a commitment to invest 20 000 million GBP per annum in research and development by 2025. There are about 10 000 full (ordinary) science and engineering professors in British universities; if this sum were simply allocated evenly among them, they would each get an annual allowance of 2 million GBP. One should be able to assume that someone who has achieved professorial rank in an established British university is fully capable of sensibly spending such funds, which could be used for equipment, consumables, doctoral student stipends, salaries for assistants etc. It would also encourage collaboration for the efficient sharing of expensive apparatus, and for joint ownership of even more expensive apparatus. In addition, one could save of the order of 100 million pounds each year by abolishing the posts of the army of officials in organizations like UK Research and Innovation that currently administer the complex processes of grant funding, and the scientists themselves will find they have significantly more time for actual research, no longer having to deal with the bureaucracy of grant applications and the like.[4] The decision to enact such a distribution would constitute a great leap forward for British science. Not all of the projects on which the money was spent would be successful—but as Thomas J. Watson remarked, "the way to succeed is to double your failure rate". The presently minutely scrutinized output of public grant-funded research ensures that is successful—and mediocre [22].[5]

Switzerland is often neglected in assessments of science power, probably because its population is too small for it to appear in rankings based on country size. Yet, in terms of scientific output *per capita* it may be the leading nation in the world,[7] hence deserves scrutiny with a view to learning lessons.[8]

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[3] Although, officially, the USSR Academy of Sciences' programme of work was exclusively devoted to civilian projects connected with improving the life of the people (ref. 13, pp. 225–226).
[4] There should be very severe penalties for any misuse of these research funds, such as permanent exclusion from the scientific community.
[5] Sir William Ramsay wrote that "the restriction of the Teutons will relieve the world from a deluge of mediocrity" in 1915 [23]—a rather unfair remark,[6] presumably inspired by the 1st World War then in progress—but "mediocrity" could well be applied to the European Union's vast "Horizon" research and technical development programme, in which nevertheless many British scientists clamour to be allowed to participate.
[6] Indeed, Ramsay seems to have had a very happy and productive experience during his doctoral studies in Tübingen [24].
[7] Sweden, with an even smaller population, is in a similar position.
[8] British commentators are more likely to look to Singapore as an example (presumably because of its British connexion).

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