Rhyming history: How historical events shaped the debate around US science policy in the past and present

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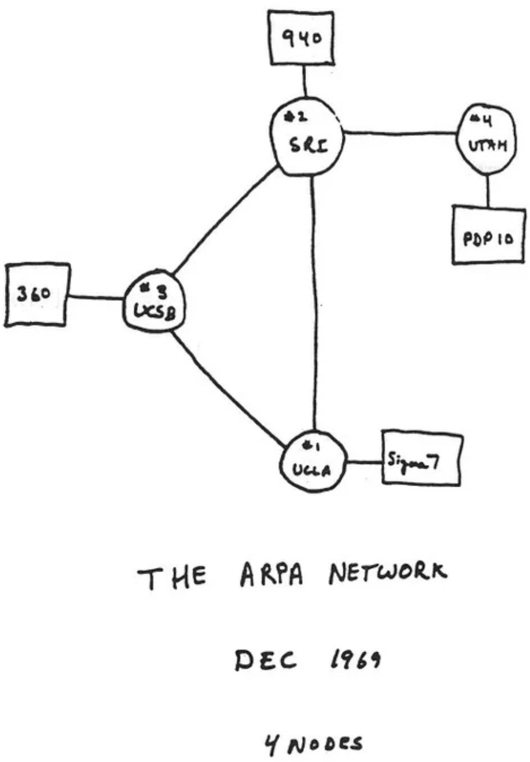

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Title page image: Sketch of the ARPANET (the Internet's precursor). It is ascribed as one Cold War's inventions [1].

1 Introduction

Note: This is a report I wrote for a technology and society class at the University of St. Gallen.

The launch of the Sputnik I satellite by the Soviet Union in 1957 is regarded as one of the most prominent examples of dedicated change of science policy following a single event [2]. In the aftermath of the launch, US-American scientific funding was vastly expanded, several research and development organisations were founded, and scientific education was promoted [2]. In fact, the founding of the National Aeronautics and Space Administration (NASA) is attributed as a response to the Sputnik launch [3]. Although the launch of Sputnik alone is now assumed to be less influential for a radical change of US policy, it posed a psychological threat of a technological and scientific superior Soviet Union to many Americans [4]. Appropriately, the situation in which a country unexpectedly recognises a technological deficit (typically with a historical event) has been colloquially referred to as *Sputnik Moments*[1] [5].

Such *Sputnik Moments* are, however, not singular. This paper aims to illuminate the relation of events, the following debate and influence on science policy, and finally, innovations following these changes using historical material. More specifically, the following research questions are examined:

1. How have Sputnik Moments influenced US science politics and policy in the past and present?
2. How is this influence expressed in terms of *exploration vs. exploitation* and *centralisation of science and technology*?
3. What conclusions can be drawn for the future of science policy?

In Section 2 several terms and concepts on the topic are introduced, the paper's situation and scope are defined, and the existing literature from Science and Technology studies (STS) is reviewed. In Section 3 the research questions are treated by examining three *Sputnik Moments* and follow-up questions discussed. In Section 4 a conclusion is drawn and key suggestions for future directions are formulated.

2 Background

> "Because reasoning about causes and effects is a very difficult thing, and I believe the only judge of that can be God."
>
> William of Baskerville in Umberto Eco's Name Of The Rose

According to ancient texts, the Greek mathematician Archimedes deterred a fleet of Roman ships during the siege of Syracuse using an array of mirrors, reflecting sunlight. Although Syracuse was eventually besieged by the Romans and Archimedes killed[2], the ancient texts report that the mirror weapon burnt the wooden Roman ships [7].

[1] Relating to Winner's *Do artefacts have politics?*, the Sputnik satellite has become a very politically charged artefact.

[2] It was on this occasion where Archimedes said *"don't disturb my circles"* in the moment before his death [6]

Although the account of Archimedes mirror weapon is far from secured, it is an early example that shows the exploitation of technology to gain an advantage in conflict.

The impact of single events on politics has not decreased since ancient Rome. Three days after the 2022 Russian invasion of Ukraine, German Chancellor Olaf Scholz announced a 100 billion special fund for the nation's military budget after it had been significantly reduced with the end of cold war [8, 9]. In debates about defence and military policy, almost always include the debate around technology and science, as well as military advantage that is often acquired by technological advantage [10]. In this light, the cold war's space race was not only scientific and about exploration, but also military. This interwoven relationship is evidently seen in Reagan's Strategic Defense Initiative (colloquially known as "Star Wars"), suggesting the use of space-based weapons as alternative to nuclear weapons [11]. Aphoristically, Heracles' *"War is the Father of all things* resembles this relationship between science and technology and military advantage and further relates to the "spontaneous invention" thesis introduced in the 2.2 section.

2.1 What is Science Policy?

In antiquity, China is an early example of large-scale application of scientific principles for the welfare as well as defence [12]. Ancient Greeks, along with Persians and others, laid scientific concepts that were later resumed by Islamic states until they were rediscovered in the European Scientific Revolution [13] starting around 1600. During the renaissance, the application of science for economic welfare or military advantage was not always recognised, and scientists often depended from wealthy patrons financing their endeavours. For example, Galileo Galilei was supported by the Medici who were interested in his work primarily for entertainment [14]. With Francis Bacon's contributions to modern science and as one of the initiators of the Royal Society, science was established as a part of the state [15], becoming more subject to public policy. With Great Britain as financiers of the Royal Society and with increasing importance of science due to the industrialisation, innovation was specifically promoted, as for example one of the first computers constructed by Charles Babbage in the early 1800s [16].

With the waves of democratisation of the nineteenth and twentieth century [17], the forging of science policy moved from the elites' backrooms into the public light and made it subject of public discourse. Today, science policy is concerned with steering the direction of scientific research and development to maximise benefit of society[3]. Practically speaking, the founding of scientific research, promoting education, or founding research agencies. The policy is determined by the political system, which is itself subject to current developments and the surrounding debate, as seen in the recent Corona pandemic [18]. With science policy as a central task of a state, it often decides on a significant part of the countries' budget. Research and development (R&D) spending differs among countries, and is typically in the range of 1 to 3% of GDP, as shown in Table 1.

2.2 Models of innovation

There exist many models to explain how innovation occurs, and how it is translated into useful products. Events in this paper can be analysed from interesting perspectives using two of these models.

[3]With the exception of few autocratic states.

Country	R&D spending in % of GDP
China*	2.14
EU	2.19
USA	3.07
Switzerland	3.37
Israel	4.94

Table 1: R&D spending of different countries [19]. *China intends to increase this number further [20].

The *linear model* [21] entails the idea that basic research produces new scientific discoveries (exploration), which are then applied by engineers by inventing device or processes (exploitation), which are finally consumed by society [22]. Although this model is considered flawed [22], it encapsulates a flow that is often observed in reality and allows one to construct simple causal chains[4]. Another model is the *diffusionism versus spontaneous innovation*-model. Diffusionism suggests that later inventions are merely applications or simple adaptations of technology that existed previously in the "standing on the shoulders of giants"-manner. Spontaneous innovation links an invention to a social need [23]. The two models can be loosely related to each other, since *existing technology* of the diffusionism is reflected in *basic science* in the linear model. The societal need as a motivator for spontaneous invention is reflected in the consumption in the linear model (see Figure 1).

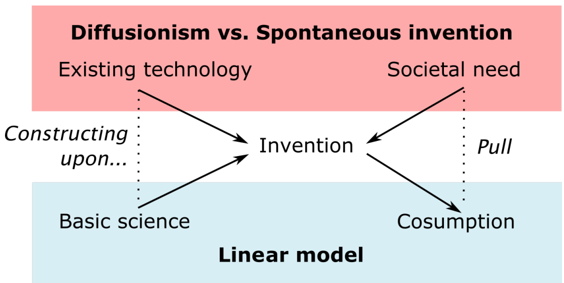

Figure 1: Two models of scientific progress and their relationship. *Existing technology* of the Diffusionism vs. Spontaneous invention model relates to *Basic science* of the linear model as both are constructing upon prior work. *Societal need* and *consumption* relate to each other as both act as pulling force for new inventions.

2.3 Methods and Related work

This paper's relation with STS is twofold: First, it relates science policy and innovation to the theme of *Exploration vs. Exploitation*. The second theme is *centralisation of science and technology*. Exploration vs. Exploitation refers to a conflict for scarce resources [24, 25], meaning that more resources given to one leaves fewer resources for the other. Exploration is understood as the experimental, discovering, nonconformant, and even playful parts [24]. Whereas exploitation includes activities concerned with refinement, increase of efficiency and productivity [24]. Emphasis on exploitation is typically associated with improved short-term performance, but long-term decrease.

[4]After all, models are always flawed, but they are intended to help understanding more complicated relations.

Conversely, the focus on exploration improves long-term performance, but hinders short-term gains [24]. A typical illustration could be a firm producing sophisticated printers that has emphasised exploitation: it has optimised their production processes to offer the devices at competitive prices and collected experience to make them highly reliable. However, the firm failed to explore business opportunities for products demanded in an increasingly paperless world and is now struggling to maintain its business.

Many scholars suggest that exploration and exploitation are mutually exclusive, opposite extremes on a spectrum [25, 26]. This view is disputed, however. Gupta, Smith and Shalley [27] argue that exploration and exploitation do not necessarily compete, but may support each other as learnings from one can be utilised in the other[5] Nevertheless, the majority of authors agree that a *both*, exploration and exploitation are required for survival [24, 27, 25]. Still, there is no consensus about whether the two should be engaged simultaneously (ambidextrous), while others suggest to vary the emphasis on a temporal axis (punctuated equilibrium) [27]. While this debate is somewhat academic (and that there may be a yet undiscovered proposal to it), the exploration vs. exploitation is well known in computer science, and the two are typically treated as mutually exclusive [28]. The weight given on one of the two is an important problem for artificial intelligence applications [28]. The *exploration vs. exploitation* topic can also be related to the linear model of innovation, where basic science provides exploration and is then exploited to provide goods or services consumed.

The *centralisation of science and technology* describes the effect that efforts in research and development of technology are restricted on increasingly fewer topics and thus less diversified[6]. Centralisation in the context of information science is a well-studied topic of management [29, 30] and computer science [31, 32]. In the case of computer science, there have been several trends towards more centralised and again to more decentralised computing architectures [33]. The *Handbook of science and technology studies* [34] touches on centralisation of science and technology in several chapters, most notably in Chapter 12 (From "Impact" to Social Process), where the US science policy of a central funding pot, but decentralised research institutions, is noted. The literature reviewed until now typically uses the term *centralisation* to describe organisation and infrastructure, not for the conceptual breadth. Most resemblance with this texts' notion of centralisation of science technology is, however, found in the epistemological and meta-research literature drawing from concrete areas of research. Danchev et al. [35] found that in biomedical research, decentralised research communities using a diverse set of methods produced more reproducible results than centralised ones that utilise a very similar set of methods. Resnick [33] provides a bread overview of decentralised systems, using them to explain the workings of complex systems such as bird flocking, road traffic, clustering of stars, or market mechanics. Almost more importantly, he notes the human tendency to assume a central control instance and a single cause when exposed to patterns. Although it this contribution may seem too abstract to relate to this text, it helps to explain desired effects of decentralisation, such as robustness, or better exploration performance [36].

Methodologically, this paper draws from secondary historical sources, laws, letters, patents, newspapers and data, which are combined into the historical outline. Use of

[5] Which is itself another example of results from exploration made in in one are being exploited in the other.

[6] This could be reformulated as a over-emphasis on exploitation of few topics at the expense of exploration.

this media allows to vary the level of detail for the situation and later analysis. The material has various sources and is referenced on its appearance. Finally, the outline is then is analysed with respect to above topics.

3 Results

> "History doesn't Repeat Itself,
> but It Often Rhymes"
>
> Mark Twain

For this paper, three historical events and their consequences are analysed. (1) the German nuclear weapons programme during World War 2, which was feared to produce nuclear weapons, (2) the Sputnik crisis during the cold war, which spurred scientific innovation in the United States, and finally (3) a renewed competition between China and the US, along with allied nations in technological advantage.

3.1 The "Uranverein" Menace

The political [4], educational [37, 38], scientific and technological [1, 3] implications of the Sputnik launch have been extensively studied, and the term *Sputnik moment* is frequently used in political speeches [39], news articles and even for scientific publications [38, 40]. However, the *Sputnik moment* has, to the authors knowledge, not been applied to historical events prior to the space race, nor has it been characterised as a general concept. In the following subsection, the German nuclear weapons programme during World War 2, often referred to as *Uranverein*, is examined on its potential as a *Sputnik moment* that accelerated US-American, British and Canadian development of nuclear weapons and reactors[7]. On first glance, the German nuclear bomb shows similarities with the Soviet Sputnik launch: (1) the news reached the allied powers during wartime and were about a ideological enemy (although Nazi Germany had not declared war yet to United States), (2) not much secured information was available at the moment, possibly leading to overestimating Germany's capabilities, and (3) it was a scientific-technical topic, and not a direct demonstration of military capabilities. But first, a historical breakdown of the events is in order.

On the brink of war in 1938, the German physics community around the Kaiser-Wilhelm-Institute for Physics (KWI) celebrated a breakthrough: Otto Hahn, Lise Meitner, and Fritz Strassmann discovered nuclear fission [41]. Niels Bohr soon informed his American colleagues about this discovery, which was received with excitement [42]. Several years before, another German physicist, Werner Heisenberg, had been awarded the Nobel prize for the discovery of quantum mechanics [43, 41], and quickly became part of the *Uranverein*, attempting to exploit the newly discovered nuclear fission for energy production and possibly weapons [43]. With beginning of the war in 1939, KWI's research efforts were realigned to support the German war machinery and were led by Werner Heisenberg. Heisenberg's role is disputed: on one hand it is suggested that he deliberately decelerated the weapons arm of the research to prevent Germany from possessing nuclear weapons [43, 44], and on the other hand Walker argues that he was ambivalent about the plans and considered nuclear weapons to prohibit a Soviet siege of western Europe [41]. Nevertheless, Germany had disposal of large amounts of Uranium and an internationally respected physics community, despite an exodus ideologically unwanted scientists [43]. In this light, the Uranverein's programme, paired with little information, was seen as a danger by the Allies [41]. Among these scientists was Albert Einstein, who, together with other emigrated European scientists,

[7] I restrict the analysis on the Allies program for brevity and due to the availability on US artefacts of the time.

warned US president Roosevelt about the dangers of the atomic bomb, in particular by Hitler's Germany [41, 43]. Approximately at this time, the British nuclear weapons programme was more advanced than the American one, and the British offered them access to their research [42]. In response, the Office of Scientific Research and Development (OSRD) was founded in 1941, with Vannevar Bush as its director [45]. It had also been a response to a related Japanase nuclear weapons programme, and in 1942, the Manhattan project was formally approved, led by Robert Oppenheimer [42]. Information exchange on of the state of development in other countries was rudimentary, but nevertheless existed: While visiting Niels Bohr in Denmark, Werner Heisenberg and his physicist colleague Friedrich von Weizsäcker falsely assured Bohr that there was no German atomic bomb programme. Simultaneously, they covertly collected research of Bohr's group, and they learned that the United States had launched their own nuclear research programme. As as the Allies had kept a low profile since the war, they weren't aware of more details [41]. Meanwhile, another emigrated German physicist, Rudolf Ladenburg, warned one of his American colleagues about the German progress on atomic weapons[8]:

> Es mag Sie interessieren, daß ein Kollege von mir, der hier vor wenigen Tagen aus Berlin via Lissabon eingetroffen ist, die folgende Nachricht überbracht hat: ein vertrauenswürdiger Kollege, der in einem technischen Forschungslabor arbeitet, bat ihn uns davon in Kenntnis zu setzen, daß sich eine große Anzahl deutscher Physiker unter der Anleitung von Heisenberg intensiv mit dem Problem der Uranbombe beschäftigt; daß Heisenberg selbst die Arbeit so stark wie möglich zu verzögern versucht aus Angst vor den katastrophalen Folgen eines Erfolgs. Aber er ist gezwungen die Befehle, die man ihm gibt, auszuführen und wenn es eine Lösung des Problems gibt, wird es vermutlich in naher Zukunft gelöst. Deswegen gab er uns den Rat uns zu beeilen, wenn die USA nicht zu spät kommen wollen.

For some time, the Uranverein emphasised the application of their nuclear research for energy rather for weapons. Just in 1942, Werner Heisenberg gave lectures on nuclear weapons, and conceptual drawings (see Figure 2) show that the German group also cared about the atomic bomb [41]. Still, the German programme was severely underfunded, and in contrast to Wernher von Braun's V-missile development, Heisenberg did not request additional funding, personnel or materials, probably intentionally [43].

In 1943, Niels Bohr visited Los Alamos laboratory, in which most of the research of the Manhattan project was done. By then, the American government had declared it a top priority. In order to establish the progress on the German nuclear research, the Allies sent Moe Berg to a lecture Heisenberg held in Zurich. Berg hat the instructions to shoot Heisenberg in the case that the Uranverein was too far advanced [43]. With the loss of the Norwegian heavy water plant, on which the German scientists depended, the atomic bomb definitely had become out of reach [46]. At the end of the war, the German test reactor had been close to sustaining a chain-reaction (a step in which the Allies succeeded several years earlier), but the German physicists were captured by the Allies [36].

[8] NAARS, Record Group 227, S-I, Briggs, Box 5, Ladenburg Folder

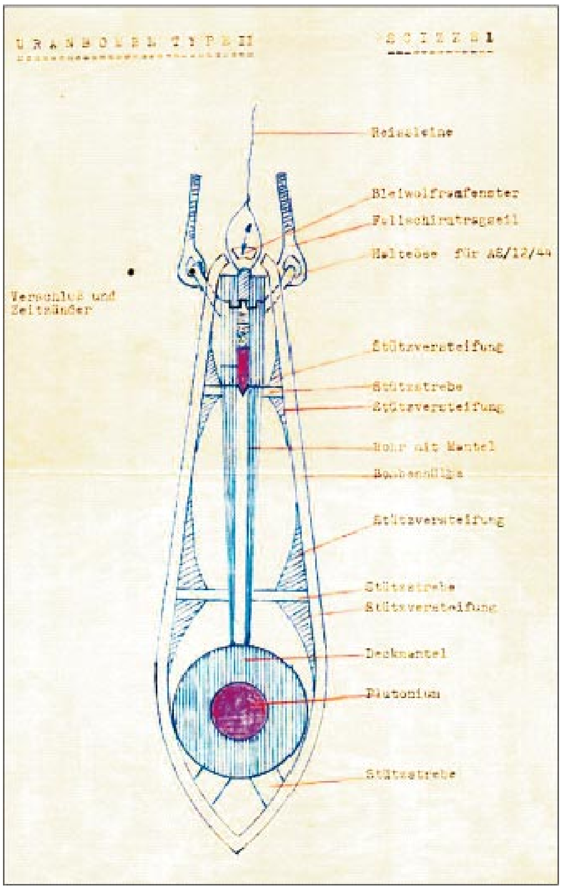

Figure 2: A conceptual drawing of an atomic bomb, made by the German research group [41]

3.1.1 Analysis

Today, it is not clear exactly how strongly the Uranverein spurred the Manhattan project. It is however known that Einstein's letter to president Roosevelt, and the dedicated effort of several European physicists familiar with the German efforts were essential to the Allies' response, and with that, their science policy during and after the war.

Richard Feynman, a young Physicist at the time, was inclined to join the Manhattan project as he feared the possibility of a German atomic bomb [47]. The Manhattan project is coined as one of the first *Big Science* programmes, as it concentrated in total almost 1% of the American workforce and had approximately a thousand-fold funding of the Uranverein [48]. Therefore, the Manhattan project serves as a formidable example for a centralised approach to science and technology, and it could be used to argue that major science ventures would best be encountered with this method. But, as suggested by Feynman [47], the Manhattan project was mostly concerned with *engineering* rather than *scientific* problems. Also, it had the fixed goal of producing an atomic bomb. Both of these conditions have little to do with radical innovation and exploration, but rather with exploitation of known fields. At the beginning of the Manhattan project, the exploration had already been done to most extend: Hahn, Meitner and Strassmann had discovered nuclear fission, ideas for separating isotopes[9] were already developed [36], and Enrico Fermi had already constructed a working fission reactor [43]. Interest-

[9] Isotope separation is an important task of any nuclear fission technology.

ingly, these feats were done in decentralised teams: the discovery of nuclear fission in Germany, details on isotope separation were obtained independently by Germans and Americans [36], and even chemical processes to produce heavy water were invented independently by American and German chemists.

3.2 The Sputnik shock

After the war, the United States were swift to propose new directions based on lessons learnt during the war. Two weeks before the Hiroshima atomic bomb was dropped, Vannevar Bush's *Science - The Endless Frontier* was published [49, 50]. It outlined a new science policy, moving away from science as a purely curiosity-driven venture, but as foundation of technological and industrial progress. The concept and language presented in the report resemble the linear model of science, with basic research exploring new directions and engineering and manufacturing exploiting discoveries. Another grand idea proposed in the report was a centralised government-funded science, thus placing more weight on science policy[10]. The result of the report was initially moderate: in 1950, the National Science Foundation (a successor to the OSRD) was founded, but given a small budget of 3.5 million USD (compared to a federal defence budget of 1 billion USD) [2]. Even in the following years, and despite the approaching cold war, the NSF remained poorly funded. Meanwhile, the NSF was still shadowed by the Department of Defense and its own research programmes, and was therefore no central institution to issue research grants.


RUSSIANS LAUNCH FIRST ARTIFICIAL MOON
HOFFA VICTORY CALLED CONGRESS CHALLENGE
185-POUND ORB SHOT IN SPACE 560 MILES, NOW CIRCLING EARTH

The San Diego Union — HOME EDITION
Russia Sends First Earth Satellite Around The World At 18,000 MPH
Red Troops Curb New Uprising Of Students In Poland
560-Mile Altitude Attained By 'Moon'
U.S. Experts Give Feat Quick Praise

New York Herald Tribune — European Edition
U.S. Views Satellite as Russian Victory
Fights Flare In Warsaw for Fourth Night
Russians Work on New One
Cold-War Effect Is Assayed
Braves Nip Yanks, 7-5, In Tenth
23-In. Sphere Looping World at 18,000 M.P.H.

The New York Times — LATE CITY EDITION
SOVIET FIRES EARTH SATELLITE INTO SPACE; IT IS CIRCLING THE GLOBE AT 18,000 M. P. H.; SPHERE TRACKED IN 4 CROSSINGS OVER U. S.
HOFFA IS ELECTED TEAMSTERS' HEAD; WARNS OF BATTLE
COURSE RECORDED
560 MILES HIGH
Device Is 8 Times Heavier Than One Planned by U.S.

Figure 3: A selection of newspapers' covers following the Sputnik launch in 1957. As the concept of satellites has not been well established, and descriptions as "artificial moon" are used.

Scholars today agree that the Sputnik launch was not completely unexpected and acting as sole driver of an ensuing public science offensive [4, 2]. The US government had already planned on expanding education in STEM fields and announced the launch

[10] It is an interesting coincidence that the two major ideas of Bush's report are congruent with the two topics that are analysed in the historical examples.

of an own satellite [2]. However, Sputnik had reached a critical role as a propaganda vehicle: its flight path covered populated areas, Soviet engineers had outfitted the satellite with a simple radio signal that could be received by simple receivers, and its surface was polished to make it better visible [4]. The debate was vehement (see Figure 3), revolving around the fear that the United State were technologically inferior, and as the government had just recently centralised science policy, public opinion found an outlet: the NSF's budget was further increased, the later Defense Advanced Research Projects Agency (DARPA), which was essential for the invention of the Internet, and NASA were founded [3]. Furthermore, education funding was increased by a factor of six [51] via the National Defense Education Act (NDEA) [52]. The increase of a factor higher than ten [49] in central science funding led into the space race, culminating in the lunar landing in 1963 [53].

3.2.1 Analysis

While science funding was radically centralised in the 1950s after Bush's suggestion [49], grants to science projects on the small scale and research directions on the large scale were mostly decentralised [2]. This approach was different from the Soviet one, in which not only funding, but also decisions on research directions were taken centrally. One advantage of this system was that speculative, research projects could be realised, if the researchers managed to persuade funding officials. This "carte blanche" strategy seemed to be ambivalent: on one hand, it allowed scientists to explore their areas without direct fiscal pressure, on the other hand, their exploration may also have been strongly restricted by the project scope. Meanwhile, the American model rewarded short-term research through patents and government orders for finalised products, such as RADAR devices. In fact, the US government had fears that if inventors of parts of the atomic bomb patented them, they could exercise control over the use of nuclear weapons. As a result, it offered the scientists to patent and buy their ideas, keeping them in secret and in possession of the government [54, 47]. The Soviet science policy was moreover more capable to allocate extreme amounts of workforce and funding to projects, even intervening in the national economy [2], but allowing effective exploitation of discoveries. The central Soviet model had its drawbacks, too: If the central authorities missed research opportunities, the deficits were sometimes not repairable.Computer technology is a prominent example, where the Soviets abandoned their programmeme in order to reverse engineer American IBM machines [2].

Coining the American science policy as central is too simplistic: while the funding derives from the central federal budget, grants are issued via a broad hierarchy consisting of several institutions, which themselves have several branches. This decentral nature, as well as the freedom of the institutions, can be found in Bush's *Science - The Endless Frontier* [50] (emphasis by the author):

> ... (3) The agency should promote research through contracts or grants to organizations *outside* the Federal Government. It should not operate any laboratories of its own. (4) Support of basic research in the public and private colleges, universities, and research institutes must *leave the internal control* of policy, personnel, and the method and scope of the research *to the institutions themselves*. This is of the utmost importance. (5) While assuring *complete independence and freedom* for the nature, scope, and methodology of research carried on in the institutions receiving public funds, and while retaining discretion in the allocation of funds among such institutions, the

> Foundation proposed herein must be responsible to the President and the Congress.

Furthermore, it also recognised the necessity to support speculative, high-risk projects:

> Basic research is a long-term process - it ceases to be basic if immediate results are expected on short-term support. Methods should therefore be found which will permit the agency to make commitments of funds from current appropriations for programs of five years duration or longer.

It is also interesting that the trade-off between exploration and exploitation was understood at the time, as indicated in the original NDEA law, referred to as *discovery of new principles* and *mastery of modern techniques* [52]:

> The defense of this Nation depends upon the mastery of modern techniques developed from complex scientific principles. It depends as well upon the discovery and development of new principles, new techniques, and new knowledge.

By implementing Bush's linear model of science, the trade-off was elegantly resolved: basic research and exploration with no direct pay-out was governmentally funded, while the exploitation was mostly left to the industry.

3.3 A new technological race?

Switzerland is not known for large scale. It is one of the smallest countries in the world, with an appropriately small population [55]. Still, it houses the world's largest and most powerful particle accelerator at CERN[56]. Traditionally, such a "Big Science" project could be imagined to be in the United States. By a narrow margin, this would have been the case with the US-American *Superconducting Supercollider* (SSC). However, in the 1990s, with the United States as "winners" of the Cold War and seemingly without competition, political interest in science had decreased, and a dry-worded answer is reported to have been decisive to abort the project [57]. At that time, the SSC had already consumed nearly 4 billion dollars and the cancellation cost another billion dollars [57]. This decision was consistent with a trend in US-American science policy: Since the height of the cold war in the mid-1960s, expenditure for research and development had been decreasing (see Figure 4). Although the USA still has one of the large research and development spendings (see Table 1), an increasingly large portion of it is now dedicated to research on health (see Figure 5), which is partially explainable by the maturing of the *Baby Boomer* generation born in the late forties and fifties [58]. Furthermore, an increasing amount of non-health spending is provided by the private industry. In 2020, Amazon, Alphabet, Apple, Microsoft and Facebook[11] spend a sum of almost 127 billion USD [59], representing a fifth of the US' 2019 spending in total R&D [60]. Including the high-tech industry spawned in California, the immense R&D spending during the space race has returned to the United States economy several times [2].

Two years after the 2008 financial crisis, US president Barack Obama called for the need for a new *Sputnik moment*, referring to China's and India's rapid rise as industrial nations and science and technology hot spots, along with their advanced technical

[11] Interestingly, most of these companies have their origins in the 1960s Silicon Valley, which developed due to Cold War public science spending.

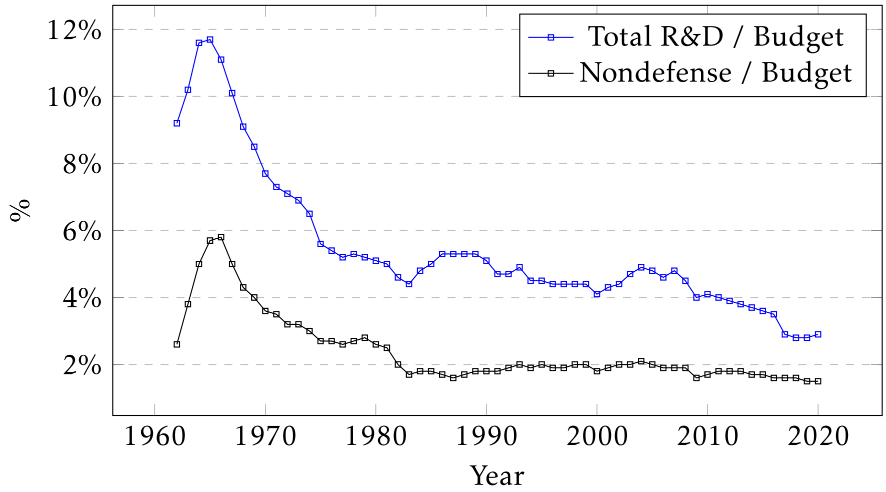

Figure 4: R&D as a Percent of the Total US Federal Budget [61]

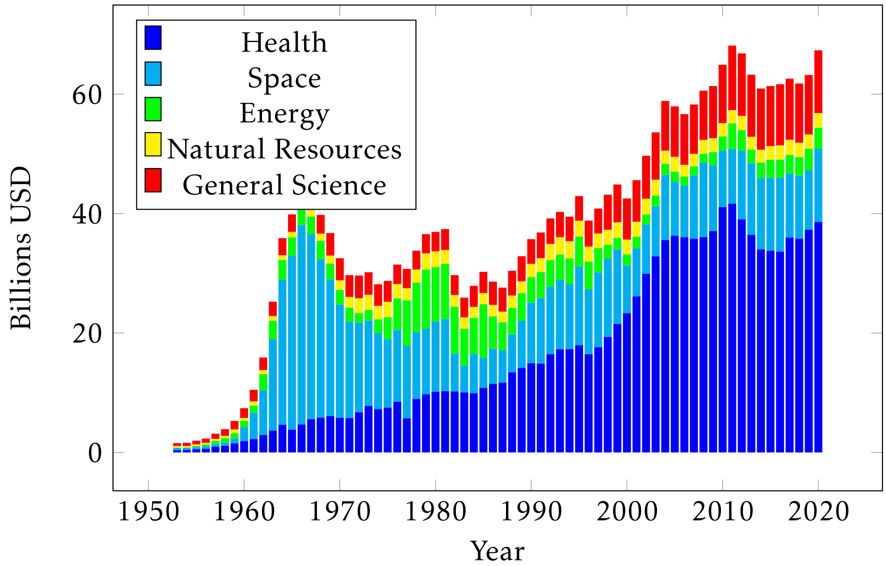

Figure 5: Trends in US non-defence R&D by function, in constant 2020 USD [61]

and scientific education [39]. Authors agree that the USA-China relation regarding science is different in several aspects than with the Soviet Union. China is economically and scientifically strongly connected with the world and it has learned from the dangers of centralisation in the Soviet union [40]. With China's tight techno-economical relations, reports about forced technology transfer, industrial espionage, intellectual property theft, and market manipulation [40, 62, 63] represent an additional difference. Furthermore, the debate around scientific and technological progress is silenced by ongoing crises as the COVID-19 pandemic [40] and the Russo-Ukrainian War, relativising the effect of proclaimed *Sputnik moments* in the past years. From a political view, the US-China competition is however more similar to the US-Soviet one. Its restricted policy for personal and expression may pose a challenge in encouraging further innovation [62], a problem encountered and resolved by the Soviets by allowing members of the Soviet Academy of Sciences more intellectual freedom and decoupling from state universities [2].

3.3.1 Analysis

With addition of the Internet, the proliferation of English as the *lingua franca* of science and the more interconnected and global trade, the environment of science, technology, and innovation has changed. Furthermore, there is an increasing gap between basic science and its application in the industry, weakening the transfer of value from theory to practice, distancing exploration from exploitation. Still, Bush's model in *Science - The Endless Frontier* is the design for modern science policy in most countries [64]. Regarding a centralised strategy for scientific focus, China is not faced with the same risk of missed research opportunities as the Soviet union, as it can catch up faster thanks to international cooperation. Still, it profits from advantages of centralisation as the long-term support of high-risk, high-payout projects, or the allocation of massive workforce and capital.

In the *exploration vs. exploitation* aspect, China has a powerful position once again: thanks to international collaboration, research and know-how acquisition, it could (and earlier did) skip the exploration and directly engage in exploitation by creating and producing products. Despite the favourable exploitation position, the authors suggest that China is on par with the United States in science and technology [65, 64], showing that it is capable of exploration, too.

3.4 Discussion

Discovery and invention are processes more similar to art than science. They cannot be mechanically executed, nor strictly organised. By allowing space for exploration, they can, however, be fostered, but the goal of exploration is always unknown. Scientists in antiquity hoped for wealthy patrons, financing their exploration, often in return for short-term gratification in form of entertainment. Without knowing the value in the research, its potential remained mostly untapped, and value was created by exploiting more mundane and better known principles. After a century with an unprecedented wealth of discoveries [66] and governmental involvement in science, we observe a return to a more private contribution to R&D and therefore an interest in short-term rewards. Simultaneously, research topics converge, with the science community becoming more centralised [1] and increasingly dictated by few influential players in the private economy [67]. This centralisation is worrisome, with the dire consequences known since from the Soviet-era centralised science policy. Information is spreading faster, flowing more continuously and disturbed by more noise than during the space race and before, and therefore, diminishing the "shock" value upon learning from an important event such as the *Sputnik* launch. With an ongoing climate crisis [68] the rise of China as non-democratic technological giant [40], and issues of social inequality [69], there is need for new ideas, discoveries and inventions. Throughout history, a shock – a *Sputnik moment* – was often necessary to foster innovation, not seldom involving a war or the threat thereof. By allowing more exploration and intellectual freedom, converging basic research and its application in industry, increasing governmental spending with confidence in the returns, and faring new directions into uncharted research areas, a modern adaptation of science policy could continue what Vannevar Bush envisioned more than sixty years ago.

4 Conclusion

> ”The finding is not in the future – it is there, where you do not look.”
>
> Jiddu Krishnamurti

In this text, the influence on US-American science policy from the perception of historical events in the vein of ”A belief may be larger than a fact” is analysed. Three examples, the development of an atomic bomb development under the Hitler regime, the launch of the Soviet Sputnik satellite, and the 21st century competition between the US and China era examined with respect to the *exploration vs. exploitation* trade-off and the *centralisation of science and technology*. Following profound changes in information and goods exchange in the last decades, I find that science and technology is faced with new challenges often unchecked by ”modern” science policy drafted in the sixties. Significant events like the Sputnik launch have lost their teeth in the public debate due to new ways we share information, the private economy has centralised their influence in research, with their own science policies directed towards short-term rewards and a decreasing breadth of research areas. Learning from history, this text suggests a closer collaboration between basic and applied research and a new wave of governmental science funds while preserving intellectual freedom and liberty of research organisations.

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