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Science and Social Policy: Underpinning of Soviet Industrial Paradigms

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Preface

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text.

It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text

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UNIVERSITY OF CAMBRIDGE

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A PhD thesis

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Abstract.

Soviet policy-makers, in order to aid and abet industrialisation, seem to have chosen science as an agent for development. Soviet science, mainly through the Academy of Sciences of the USSR, was driving the Soviet industrial development and a key element of the preparation of human capital through social programmes and *politechnisation* of the society. This provided a broad set of the skills, including management and governance, multidisciplinary synthesis, and analytical ability which were required to ensure sustainable technical and industrial development.

This process of human capital development in the USSR could not take place without a particular Soviet social policy which was designed by the Party and Government and included the development of science, education, healthcare in synchronisation. The success was achieved due to the implementation of the large programme for human capital development in whose preparation both basic research and education played the critical role.

Science was regarded in the USSR as an indispensable tool for modernising the country, and, for the first time in world history, was recognised as a natural resource beyond the doctrine of Marxism which helped cope with the challenges, including industrialisation, WWII and the import substitution programme.

The investments in the development of fundamental science eventually paid off both nationally and later - at the global level. Many of the Soviet scientific discoveries started to appear as products in global households only decades after the Soviet collapse. Without many Soviet discoveries and developments, the current digital and industrial development would be hardly possible as they are integral parts of the global technology chains which constitute the modern hi-tech industry, economy, and most various markets.

Dedication

In loving memory of my parents,

Professors Turar Laumulin and Kira Davletgaliyeva,

Soviet scientists and geologists,

and

in dedication to my wife, Dr. Zaure Dushimova,

my son, Iskander, and my brother, Dr. Murat Laumulin

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I am extremely grateful to all the scientists and engineers interviewed from Cambridge, Greece, Kazakhstan, India, Russia, Ukraine, and the United States for their willingness to share their united philosophy and unique knowledge with the author. The contribution of the other scholars and policy-makers is not less valuable for this thesis. It could not have been completed without the support from my colleagues at the Centre of Development Studies, the Cambridge Central Asia Forum and my PhD fellows. Additionally, I should thank my supervisor of a long time ago, Nicolas Barr of the London School of Economics, for his trust in myself.

I would like to thank all my friends in the big space of the Eurasian continent, i.e. in Belarus, Britain, France, India, Italy, Uzbekistan, and, in particular, Kazakhstan and Russia, for their enormous assistance, encouragement, and interest. My special thanks are to Prajakti Kalra and her family for their friendship, hospitality and willingness to support.

I dedicate this paper to the loving memory of my parents who had been sharing their knowledge and passion for science through all their lives as well as to my family including my elder brother Murat, my dearest wife Zaure and her parents, my son Iskander in the highest appreciation of their love, patience, and understanding.

Chokan Laumulin.

Chapter 1 Introduction

In modern research, the development of the Soviet Union (the Union of Soviet Socialist Republics, or the USSR) has been the subject of significant debate since the first years of the Bolsheviks' coming to power and continued after the end of the USSR. To various extents, many scholars have agreed on the following.

Although in the Russian Empire factory industry was quite developed in St. Petersburg (Petrograd) and Moscow, the country was mostly backward and unindustrialised,[1] occupying 'a semi-colonial position relatively to the West,' especially to France and Germany in terms of the capital and heavy industry import.[2] Meanwhile, these two cities 'were no more than industrial "islands" in a vast agricultural sea,' according to Maurice Dobb.[3]

In Alexander Gerschenkron's account, 'Russia before the First World War was still a relatively backward country by any quantitative criterion,' [4] although the Russian industrialisation which began in the 1880s provided a record, in terms of the other European counterparts, economic growth of the annual 8 per cent throughout the 1890s that with ups and downs continued until 1914.[5] In its traditional race against time, Russia as a European country was a late-comer in the nexus of industrialisation whose pattern in many ways resembled that of Germany three decades earlier.[6] However, in the Russian case, it faced with many insurmountable institutional obstacles of the historical, political, economic and social character whose contradictions became evident and much more acute during WWI and the Russian Civil War.[7] In terms of the country's educated and innovative human capital, as well as labour, the backwardness was particularly apparent, which was worded by Gerschenkron in 1962 as follows:

> Russia on the eve of its great industrial spurt suffered from many disabilities. Its entrepreneurs were far too few; their time horizon was often limited, their

[1] Dobb, Maurice, 1953, *Soviet Economic Development Since 1917*, Routledge & Kegan Paul Ltd, London, first - As well, as confirmed by Nove, Alec, 1992, *An Economic History of the USSR. 1917-1991*, Third Edition, Penguin Books.
[2] Dobb, 37-8 (Kindle edition).
[3] *Ibid.*, 35.
[4] Gerschenkron, Alexander, 1962, *Economic Backwardness in Historical Perspective, A Book of Essays*, The Belknap Press of Harvard University Press, Cambridge, Massachusetts, 138; hereafter referred to as Gerschenkron.
[5] *Ibid.*, 129.
[6] *Ibid.*, 19.
[7] The Essay 6, Russia: Patterns and Problems of Economic Development, 1861-1958, *Ibid.*, 119-51.

> commercial customs backward, and their standards of honesty none too high. The influx of labor to industry was inadequate because of the institutional framework that had been imposed upon agriculture. Such labor as was available was uneducated, in Russia that tendency was particularly strong.[8]

Meanwhile and speaking of the scientific human capital development, the Tsarist Academy of Sciences was one of the notable institutions of this kind in Europe with high academic standards and a culture of creativity which was characterised by a very high level of development in theoretical science. However, as worded by Loren R. Graham, '[T]he opposition to the development of science offered by these three great inertial forces in the last 150 years of Russian history – government, church, and aristocracy – was immense.'[9] In pre-revolutionary Russia, applied science was less developed which can be explained by a low level of the Russian industry mostly controlled by foreigners.[10]

As Graham wrote about that period, '[I]ndustrial laboratories were practically non-existent. The faculty members of the universities often received their educations in Germany, where the prestige of pure science was also preeminent; in the manner of disciples everywhere, the Russian students often carried their teachers' views to extremes.'[11] Although Russia had a few prominent engineering schools established in the XIX Century, the Academy 'was still largely absorbed in the spirit of pure science'[12] with research in mathematics, chemistry, biology, geology, topography, and geography particularly developed.

The overall backwardness and contradictions in development led Russia to its defeat in WWI and the 1917 October Revolution. The industrial change which occurred to the Soviet Union within a quarter of a century transformed the country 'beyond recognition,' as worded by Dobb.[13] For instance, the output of electrical power, steel, and coal production increased dramatically from the negligible numbers of three or four per cent to from ten to fifty per cent of the output of such industrialised powers as the USA, Germany, and Britain in 1937, making the Soviet numbers comparable.[14] Similar results were achieved in agriculture.[15] As

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[8] *Ibid.*, 122-3.
[9] Graham, Loren R., 1967, *The Soviet Academy of Sciences and the Communist Party, 1927 – 1932*, Princeton University Press. 7; hereafter referred to as Graham.
[10] *Ibid.*
[11] *Ibid.*, 10.
[12] *Ibid.*, 11.
[13] Dobb, 290.
[14] *Ibid.*
[15] *Ibid.*, 284-9.

researched by Eugene Zaleski,[16] from 1920 to 1940 the total industrial production in the Soviet Union grew by almost 6.5 times, according to the Soviet Central Statistical Administration,[17] whereas the various Western sources estimated the growth from 2.63 times (Kaplan and Moorsteen)[18] to 3.5 times (Jasny).[19] The growth in the production of all civilian products, according to Nutter, was at a rate of 2.69 times.[20] Meanwhile, estimates of the growth in large-scale industry varied from 430 per cent by Hodgman[21] to 771 per cent in the Soviet statistics.[22]

Nonetheless, one can conclude, according to Gerschenkron of Harvard University, 'that the average annual rate of industrial growth in [the USSR] throughout the first ten years after the initiation of the First Five Year Plan was somewhere between 12 and 14 percent; the rate fell in the years immediately preceding the outbreak of the Second World War but rose again after 1945. Its high level was maintained far beyond the period of reconstruction from war damages. In the first half of the fifties, industrial output still kept increasing at some 13 percent a year.'[23]

As a result of its industrialisation, along with the Allies, in 1945 the Soviet Union defeated the Third Reich and Imperial Japan in WWII. As French historian of WWII Henri Michel outlined in 1975, 'Magnitogorsk has defeated the Ruhr,'[24] defining the role of Soviet industrialisation in the war.

After WWII, the Soviet Union established itself as a powerful economy and a prominent global actor. In particular, it provided significant cultural and economic aid and expanded trade with Third World countries including India and China. China was a primary recipient. In what can be considered as one of the most massive technology transfers in modern history, in the period from 1950 to the mid-1960s, the Soviet Union invested 7.7 per cent of its annual national income in the People's Republic of China, i.e. 'Soviet exports to assisted enterprises

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[16] Zaleski, Eugene, 1971, *Stalinist Planning for Economic Growth 1918-1932*, Chapel Hill, The University of North Carolina Press.
[17] *Ibid.*, 259-60, citing from *Promyshlennost SSSR* (Industry of the USSR), Moscow, 1957, 31-32.
[18] *Ibid.*, citing from Kaplan, Norman M., and Moorsteen, Richard H., 1960, Indexes of Soviet Industrial Output, RAND Research Memorandum 2495, Santa Monica, Calif., 235.
[19] *Ibid.*, citing from Jasny, Naum, 1951, *Soviet Economy During the Plan Era*, Stanford University, 22.
[20] *Ibid.*
[21] *Ibid.*, citing from Hodgman, Donald, 1954, *Soviet Industrial Production, 1928-1951*, Cambridge, Mass., 89.
[22] *Ibid.*, citing from *Promyshlennost SSSR*.
[23] Gerschenkron, 149.
[24] Michel, Henri, 1975, *The Second World War*, Andre Deutsch, 463.

totaled 9,409 hundred million rubles, of which equipment accounted for 8,394 hundred million rubles.'[25]

Overall, according to Roger E. Kanet, 'The decade from 1955 to 1965 witnessed a five-fold expansion of Soviet trade with the non-Communist states of Asia, Africa, and Latin America from 304 m. rubles (5.2 per cent of total trade turnover) to 1,743.6 m. rubles (11.9 per cent of total trade).'[26] In 1960 Soviet foreign trade was 10.072 billion rubles, and 5.0059 billion rubles was export.[27] The overall global export volume of trade in 1960 was USD130.09 billion[28] (the 1961 exchange rate of SUR0.9[29] per USD1 can be applied[30]).

Meanwhile, during the preceding period from the 1920s to 1940s, in the extremely restricted economic conditions the Soviet Union experienced enormous losses of human capital in wars, famines, emigration, and political repressions. For instance, the direct human losses of the Soviet population in WWII constituted 26,613 million people[31] which were accompanied by a temporary reduction of the birth rate and an increase in mortality.[32] However, in terms of such quantitative indicators as the size of the population and life expectancy, the increase shown below was achieved.

The population of the USSR was persistently growing except for WWII[33] and was more than doubled within 71 years of Soviet history from 137.727 million people at the beginning of 1920[34] to 291.1 million people in January 1991.[35] Within 70 years, urbanisation of the Soviet

[25] Zhang, B., Zhang, J., Yao, 2006, Technology Transfer from the Soviet Union to the People's Republic of China: 1949-1966, *Comparative Technology Transfer and Society*, 4 (2), 117; retrieved on 11 May 2019, https://muse.jhu.edu/article/201913; hereafter refereed to as Zhang.
[26] Kanet, Roger E., 1975, The Soviet Union and the Developing Countries: Policy or Policies, Vol. 31, No. 8, Aug., *The World Today,* The Royal Institute of International Affairs, 338.
[27] *Vneshnya torgovlia SSSR za 1960 god, Statisticheskii obzor* (*The USSR Foreign Trade in 1960, The Statistical Annual Directory*), 1961, VNESHTORGIZDAT, Moskva, 7.
[28] Trends in global export volume of trade in goods from 1950 to 2016 (in billion US dollars), *The Statistical Portal*; retrieved on 05.04.2018 from the Web, https://www.statista.com/statistics/264682/worldwide-export-volume-in-the-trade-since-1950/**.** The 1960 numbers are given in the denominated after 1961 SUR.
[29] SUR is the currency code of Soviet ruble as defined by The International Organization for Standardization (ISO), ISO 4217.
[30] Historical Official Exchange Rates, Soviet Ruble, *Wikipedia*, referring to a saved copy of the archive of the Bank of Russia; retrieved on 05.06.2018 from the Web, https://en.wikipedia.org/wiki/Soviet_ruble#cite_note-7.
[31] Andreev, E.M., *et al.*, 1993, *Naselenie Sovietskogo Soyuza, 1922-1991* (*The Population of the Soviet Union, 1922-1991*), Moscow, Nauka, 78; retrieved on 25.04.2017 from the Web: http://demoscope.ru/weekly/knigi/naselenie/naselenie_1922-1991.pdf; hereafter referred to as Andreev.
[32] *Ibid.*, 75-7.
[33] It was 196.617 million people in mid-1941 (*Ibid.*, 56) and 179.217 million people at the beginning of 1950 (*Ibid.*, 70).
[34] *Ibid.*, 14. Soviet Russia lost the territories of Poland and the Baltic States. At the beginning of 1914, the population of the Russian Empire (excluding Finland but including Poland and the Baltic states was 165.7 million people; *Rossiya, 1913*, *Statistiko-dokumental'nyi spravochnik* (Russia, 1913, Statistical Documentary

population from about 17 per cent in 1917 reached a balance between the urban and rural population in 1961; 'and by 1987 two of every three Soviet citizens were urban dwellers,'[36] marking 'a transition from a largely rural agricultural society to an urban industrial society.'[37] According to the Soviet/Russian economists Valentin Katasonov and Grigory Khanin, during Soviet industrialisation of the 1930s, the inflow of labour ensured less than a half of the Soviet GDP growth. Meanwhile, in the 1950s, in the conditions of the renewed immense growth mentioned above, an additional labour force constituted only 20 per cent of the growth, and the other 80 per cent were achieved through labour productivity.[38]

The average life expectancy in the USSR rose from 44 years in 1926-7[39] to a peak of 69.5 (64.5 for men and 73.6 for women) in 1971-2, according to the 1988 data,[40] or to 69.95 (66.1 for men and 73.8 for women) in 1965-6, according to the 1993 data,[41] made after some adjustments in the light of the new data available. Thus, by the mid-1960s, the Soviet Union eventually came close to the most developed nations of the world in terms of this social indicator.[42]

In terms of the other indicators of human capital and social development, education is critical. Throughout the 1930s and 1950s the following quantitative data became evident in the Soviet Union. As indicated in 1957 by Alexander Korol of MIT, in contrast to the figure of 8

Directory), 1995, the Russian History Institute, *The Russian Academy of Sciences*, Blitz, Saint Petersburg, 16; retrieved on 04.06.2018 from the Web, http://istmat.info/files/uploads/166/rossiya_1913_original.pdf.

[35] *Naselenie, Chast 1* (The Population, Part 1), *Narodnoye khozyaystvo SSSR v 1990 g., (Statisticheskii ezhegodnik) (People's Economy of the USSR in 1990 [Statistical Yearbook])* 1991, Moscow, Finansy I Statistika; retrieved on 05.06.2018 from the Web, http://istmat.info/node/443.

[36] Soviet Union, Urbanization, *Country Data*; retrieved on 06.05.2019 from the Web, http://www.country-data.com/cgi-bin/query/r-12479.html.

[37] *Ibid.*

[38] Katasonov, Valentin, 2019, *Sovietskaya industrlializatsiya – nekotorye itogi* (Soviet Industrialisation, Some Results), *Fond Strategicheskoi Kultury* (*The Fund of Strategic Culture*), 14 May; retrieved on 17.05.2019 from the Web, https://www.fondsk.ru/news/2019/05/14/sovetskaja-industrializacija-nekotorye-itogi-48181.html.

[39] Ed. Petrovsky, B. V., 1974-89, *Prodolzhitel'nost zhizni* (Life Expectancy), *Bol'shaya Meditsinskaya Encyclopaedia* (*Large Medical Encyclopaedia*), Vol. 21, 3d Edition, Moscow, Sovetskaya Encyclopaedia; retrieved on 23.03.2018 from the Web, http://xn--90aw5c.xn--c1avg/index.php/%D0%9F%D0%A0%D0%9E%D0%94%D0%9E%D0%9B%D0%96%D0%98%D0%A2%D0%95%D0%9B%D0%AC%D0%9D%D0%9E%D0%A1%D0%A2%D0%AC_%D0%96%D0%98%D0%97%D0%9D%D0%98; hereafter referred to as Petrovsky.

[40] Ryan, Michael, 1988, Life Expectancy and Mortality Data from the Soviet Union, *British Medical Journal* (Clinical Research Division), Volume 296, 28 May, 1513; retrieved on 25.04.2017 from the Web: http://www.jstor.org/stable/29530876?seq=1#page_scan_tab_contents; hereafter referred to as Ryan.

[41] Andreev, 95.

[42] *Ibid.*, 94.

million pupils in primary schools in the Russian Empire,[43] the total enrolment in Soviet schools reached its pre-war peak in 1940-1 with 34.5 million pupils.[44]

In higher education, in 1956 in the Soviet Union there were 34 universities and 730 institutes established mostly during the Soviet period and dedicated to research in the major fields and for the industrial needs or specialisations respectively.[45] The data showed that in 1955, enrolment in higher education institutions in the Soviet Union was 14 times higher in comparison with that of Russia in 1913-4, i.e. 1,865,000 students in 762 institutions (90-93 persons per 10,000 of the total population) vs. 117,000 students in the total enrolment in 95 institutions (83 persons per 10,000 of the total population) respectively.[46]

In particular, 'the budget allocations for education grew from 5.7 billion rubles in 1950 to 10.3 billion rubles in 1960, and for the healthcare and physical culture from 2.1 billion rubles in 1950 to 4.8 billion rubles, i.e. in 2-2.5 time for both assignments,' according to Khanin.[47]

The data of the development of the Academy of Sciences of the USSR (The Soviet Academy of Sciences, or the SAS) indicated that throughout the 1930s and 40s the SAS, according to Graham, 'was converted from a society of scientists [in Tsarist Russia] into an enormous governmental institution, endowed with both research and pedagogical functions, and spread throughout the Soviet Union.'[48] The SAS and its branches, consequently launched in 14 republics and other regions of the Soviet Union, interacted with multiple S&T and R&D units, design bureaus, enterprises and associations, various educational institutions in the coordination with *Gosplan* (the Central State Planning Committee) and some of the ministries,[49] and altogether represented 'one giant public sector,' as outlined in Paul M. Cocks' report.[50]

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[43] Korol, Alexander, 1957, *Soviet Education for Science and Technology*, The Technology Press of Massachusetts Institute of Technology and John Wiley & Sons, Inc., NY, Chapman & Hall, Ltd, London, 2; hereafter referred to as Korol.
[44] *Ibid.*, 22.
[45] *Ibid.*, 137-8.
[46] *Ibid.*, 131-2.
[47] Khanin, Grigory Isaakovich, 2002, *50-e – desyatiletie triumfa sovietskoi ekonomiki* (The 50s is the Decade of the Triumph of the Soviet Economy), *Svobodnaya Mysl' – XXI*, #5, 72-94; retrieved on 01.05.2018 from the Web, http://istmat.info/node/57531; hereafter referred to as Khanin I.
[48] Graham, 191.
[49] Cocks, Paul M., 1980, *Science Policy. USA/USSR. Volume II: Science Policy in the Soviet Union*, Report by research working group under the USA/USSR Joint Commission of Scientific and Technical Cooperation, 47-60; hereafter referred to as Cocks.
[50] *Ibid.*, 4.

According to Soviet statistics, the funding for science in the USSR constituted SUR0.3 billion in 1940,[51] SUR0.505 billion in 1950, SUR2,172 billion in 1960,[52] SUR6.9 billion in1965, SUR11.7 billion in 1970, SUR17.4 billion in 1975 to reach SUR21.3 billion in 1980.[53] In Cocks' account, the Soviet funding for science reached 5 per cent of the Soviet GNP in 1980.[54] It is important to stress out that the expenditures for the development of science were integrated into the overall social package. 27 per cent of the national income was allocated for the provision of the social policies in the USSR in 1980.[55]

Throughout the 1930s and 1950s, Soviet scientists like Pyotr Kapitsa (Piotr, or Peter Kapitza), Lev Landau, Nikolay Basov, Aleksandr Prokhorov, Nikolay Semyonov and some others made notable discoveries which, starting from 1956, were awarded with Nobel Prizes.[56] In October 1957 the USSR launched *Sputnik* into space, and in April 1961 it began the programme of the human space flights.

Considering that the nation became the pioneer in space exploration and that this sector required input from many other fields to be successful as the apex of a value chain, the Soviet space programme, as a part of the overall Soviet development, as evident from above, showcased a tangible and rapid progress in the social and health care system, education, industry, science, and technology. As acknowledged by James Peck, due to Soviet

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51 *Narodnoye khoziastvo SSSR v 1980 godu (Statisticheskii Ezhegodnik)* (*The People's Economy of the USSR in 1980 [The Statistical Yearbook]*), 1981, Moscow, Finansy i Statistika, 524.
52 *Narodnoye khoziastvo SSSR v 1967 godu (Statisticheskii Ezhegodnik)* (*The People's Economy of the USSR in 1967 [The Statistical Yearbook]*), 1968, Statistika, Moscow, 818.
53 *Narodnoye khoziastvo SSSR v 1980 godu (Statisticheskii Ezhegodnik)* (*The People's Economy of the USSR in 1980 [The Statistical Yearbook]*), 1981, Moscow, Finansy i Statistika, 524.
54 Cocks, 3.
55 *Narodnoye khoziastvo SSSR v 1980 godu, Statisticheskii Ezhegodnik* (*The People's Economy of the USSR in 1980, 1981, [The Statistical Yearbook]*), Moscow, Finansy i Statistika, 524.
56 Nobel Prizes and Laureates, Pyotr Kapitsa – Biographical, The Nobel Prize in Physics 1978, Pyotr Kapitsa, Arno Penzias, Robert Woodrow Wilson, *Nobelprize.org*; retrieved on 24.04.2017 from the Official Web Site of the Nobel Prize, https://www.nobelprize.org/nobel_prizes/physics/laureates/1978/kapitsa-bio.html; hereafter referred to as Kapitsa;
- The Nobel Prize in Physics 1962, Lev Landau, *Nobelprize.org*; retrieved on 04.06.2017 from the Web https://www.nobelprize.org/nobel_prizes/physics/laureates/1962/; hereafter referred to as Landau.
- The Nobel Prize in Physics, 1964, Nikolay G. Basov – Biographical, *Nobelprize.org*; retrieved on 04.05.2017 from the Web, http://www.nobelprize.org/nobel_prizes/physics/laureates/1964/basov-bio.html; hereafter referred to as Basov;
- The Nobel Prize in Physics, 1964, Aleksandr M. Prokhorov – Biographical, *Nobelprize.org*; retrieved on 04.05.2017 from the Web, https://www.nobelprize.org/nobel_prizes/physics/laureates/1964/prokhorov-bio.html; hereafter referred to as Prokhorov.
- The Nobel Prize in Chemistry, 1956, Nikolay Semyonov – Biographical, *Nobelprize.org*; retrieved on 12.03.2018 from the Web, https://www.nobelprize.org/nobel_prizes/chemistry/laureates/1956/semenov-bio.html; hereafter referred to as Semyonov.

development, in the discourse of global development from the 1950s, the word 'westernization' was replaced with 'modernization.'[57]

Nonetheless, most of the existing work evaluating Soviet development largely falls under the category of Cold War literature. As described by Sheila Fitzpatrick, a leading historian of the Soviet Union, in 2010:

> There was a deadening predictability about both American and Soviet writing on Soviet history, the one seemingly a mirror image of the other. On any given topic, the Soviet historians would say that the Communist Party, free of internal doubts or dissent, had planned every detail of the 'progressive' policy, which turned out to be a smashing success. American scholars, agreeing that the Party planned every detail, would call the policy misguided and ideological, and judge it a disaster. I always thought there must be some more interesting way of interpreting the Soviet Union than simply reversing the value signs in its propaganda.[58]

Both the perspective and language of the Cold War became clearly dominant in the literature on Soviet development, ignoring that in the first 25 years after the establishment of the USSR the international situation was pretty different to that after WWII, and making the perspective and language of the Cold War not directly compatible with those 25 years of development. Meanwhile, that period was crucial for the future Soviet success described above in establishing the base which defined and underpinned this progress.

Set against this background, the research question is formulated as follows: *How, in a quarter of a century, could such a backward country as the Soviet Union advance in its human capital and industrial development to an approximate level of the major powers of the era?*

In evaluating various sets and interconnections of the Soviet policies towards the development of the social and health care system, education, industry, science and technology as highlighted before, to address this unanswered question, the role of the Soviet science policy appeared particularly important. As outlined by Joseph S. Berliner, 'Given the economic

[57] Peck, James, 2006, *Washington's China: The National Security World, the Cold War, and the Origins of Globalism*, University of Massachusetts Press, 46-47; hereafter referred to as Peck.
[58] Fitzpatrick, Sheila, 2010, Spy in the Archives, *Meeting the Devil, A Book of Memoirs from London Review of Books*, London, William Heinemann, 292-3.

structure, a society with a long and honoured tradition in science, technology, and enterprise may be expected to generate a higher rate of innovation.'[59] Rather than being deeply rooted in this kind of the tradition, the Soviet case of innovation and, hence, development might have proven the importance of social, cultural and historical factors in which science and its possible connections to the other spheres of development including technology occupied a focal point.

Science remained nonetheless unidentified in the literature in relation to Soviet development in general and its social and industrial policies in particular. It would also seem important to draw an extent to which science and technology are interconnected. Meanwhile, 'the rate of technological innovation depends in part on the nature of the social arrangements by which economic decisions are made.'[60] Thus, science in the USSR is chosen as the key indicator around which construction of this research is built, to presumably shed light on the possible integrity of the Soviet science and social policies as well as their role in the Soviet human capital and industrial development.

To tackle the research question, the following strategy is to be deployed. The thesis is divided into three major parts – a theoretical one, a data chapter and an analysis which are combined into 6 chapters including the conclusion. Altogether with the introduction, the first part includes chapter 2 which consists of the literature review and methodology.

In the literature review, ten key voices on the subject are chosen. They can be divided into two camps, one of which takes the position that the Soviet Union stole or borrowed the know-how for development, while the other one argues for the indigenous development as a result of Marxist and non-market drivers of progress. The sharp difference of the views shows that this is not a settled question and there is a gap in what literature can inform the reader.

The methodology section explains why a qualitative analytical method is chosen. The interviewees are divided into those from within the Soviet system and successor systems, and those from the West who interacted with the system. The list of the insiders includes an assistant to Soviet leader Josef Stalin, an ex-deputy head of the *MIG* aviation design bureau, scientists and social researchers from Russia, Kazakhstan, and Ukraine. In the second group of interviewees who are outsiders to the Soviet system, there are notable scientists such as a

[59] Berliner, Joseph S., 1976, *The Innovation Decision in Soviet Industry*, First MIT Press Paperback Edition, 1978, 5; hereafter referred to as Berliner.
[60] *Ibid.*, 8.

former head of the Argonne National Laboratory in the US, which is a home of nuclear technology (he also used to be head of the Cavendish Laboratory/Department of Physics at the University of Cambridge), a former head of the Quantum Matter Group of the Cavendish Laboratory, CEO of the University of Cambridge Enterprise and other international physicists and engineers from the UK, the US, Canada, Greece and India.

In this section, the questionnaire is described, as well as explaining why the particular questions are formulated in relation to the thesis. The other main sources of information are identified as well, e.g. the reports, various policy documents, legal acts, personal and official letters, memoirs, and other papers. In addition, the structure of the access to information and the data limitations are explained, and the specific interpretive challenges are described.

The second part of the dissertation presents the data, and it consists of two parts in chapter 3. In the first one, the main data from the interviews are disclosed, starting with those who were inside the Soviet system and ranging to those who have only secondary knowledge of it. The second part of chapter 3 provides the information from various primary sources, e.g. Soviet official decrees, archives, and statistics used in the research. Due to the words length limit, some data obtained through interviews are also given in conjunction with the analysis in the further chapters. The data on the development of science in the Soviet Union are given with an emphasis on the role of Pyotr Kapitsa, a Soviet and Cambridge physicist and engineer, in the process of the policy development and deployment. His biographical details are provided in Appendix L.

The third part of the thesis presents an analysis in the following three chapters. Chapter 4 analyses the primary information obtained through the interviews and other sources in order to highlight the most prominent ideas related to the assumption that the fast-paced progress of Soviet development as indicated in the introduction could have resulted from a proper deployment of science and related social policy choices. Throughout this chapter, a particular example of the Soviet policies analysed through the respective data is Kazakhstan as an agricultural and nomadic society whose social, cultural and industrial transformation during Soviet industrialisation and afterwards is especially informative.

In this chapter, science, its driving forces and its role in development are discussed as well, and the delineation between the two notions of science and technology is emphasised. This is done in order to shed light on a presumably universal connection of fundamental science with modern industry through engineering and technology in the innovation chain, on the one hand, and in order to understand and explain that important role which the Academy of Sciences of the USSR played in Soviet development as indicated above, on the other. This, in turn, is followed by an analysis of the policy-making and implementation due to which the production of science and scientific personnel became enabled in the Soviet Union.

As mentioned above, Kapitsa contributed to this process. In order to highlight his ideas expressed in his correspondence with the Soviet policy-makers (including Stalin, Molotov, Khrushchev, Brezhnev and some others) and with some colleagues, as well as articles and speeches, Kapitsa's legacy is presented in comparison with the views of Vannevar Bush, a founder of NASA and other US technological institutions, written in a report to the American leadership in 1945. This complementary analysis can be found in Appendix M.

Chapter 5 concludes with a summary of the role of science and fundamental research in Soviet development and highlight some lasting Soviet contributions to global technological chains as well as discusses what happened in the post-war era.

Chapter 6 is the conclusion. The thesis aims to understand how Soviet policies were developed and how they brought specific results identified in the development of the USSR. Many countries, including some of the post-Soviet ones, are still searching for models of development which can accommodate local realities and global demands. Even those of the developing countries, like Russia or Kazakhstan, which are rich in natural resources, become highly dependent on global fluctuations which limit their progress and constrain their overall development. The example of the rapid industrialisation and human capital development of the Soviet Union in restricted conditions can presumably offer another model which could prove useful for them in constructing their social and industrial policy for the production of human capital and industry in some of the development models.

Chapter 2 Literature Review and Methodology

Chapter 2 looks at the literature on Soviet development policies in section 2.1 and explains the methodology used in this thesis in section 2.2.

2.1 Literature Review

The literature review aims at showing the gap mentioned in the introduction. Among many scholars writing on Soviet economic development, there is a significant debate which can be displayed on a continuum. The continuum can be divided into two groups conventionally designated as negative and positive ones towards the evaluation of the Soviet development as resultant from different sets of policies. The first group is a traditional economic approach evaluating Soviet technological development from the positions of the free market economy and pluralist politics. The second group is the scholars whose positive attitude towards the role of the science, as driven by the policies and non-economic factors, in Soviet industrial development can be displayed in a pretty broad range.

One end of the continuum could be represented by Anthony Sutton denying almost any indigenous Soviet innovation on the grounds of the inherent inability of the central planning system to produce innovation and explaining the Soviet technological development by exogenous reasons, i.e. technology transfer in this case.[61] The 1983 US Congress Report[62] is shifted much closer to the centre of this continuum, to be nonetheless more on the negative side. These papers form the first group of the sources in the literature review.

Julian Cooper on the state of Soviet technology,[63] Paul M. Cocks in the 1980 *Science Policy in the Soviet Union* report[64] prepared through the US-USSR Working Group on Science

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[61] Sutton, Anthony, 1968, *Western Technology and Soviet Economic Development 1917 to 1930*, Hoover Institution on War, Revolution and Peace, Stanford University, California, 348; hereafter referred to as Sutton I;
- Sutton, Anthony, 1971, *Western Technology and Soviet Economic Development. 1930 to 1945*, Hoover Institution Press; hereafter referred to as Sutton II;
- Sutton, Anthony, 1971, *Western Technology and Soviet Economic Development. 1945 to 1965*, Hoover Institution Press; hereafter referred to as Sutton III.

[62] V. Science and Technology, *Soviet Economy in the 1980's: Problems and Prospects. Part 1, December 31, 1982, Selected Papers Submitted to the Joint Economic Committee, Congress of the United States,* 1983, US Government Printing Office, Washington, 509-541; hereafter referred to as The 1983 US Congress Report. The three specific papers chosen for the consideration from this report are designated by their authors' names as well below.

[63] Cooper, Julian M., 1986, Technology in the Soviet Union, *Current History*, October 1, 85 (513); hereafter referred to as Cooper I;
- Cooper, Julian, 1979, Scientific And Technical Change in the USSR, *The Futures*, December, 471-81;

Policy, and Loren Graham on the relationship between the Academy of Sciences of the USSR and the Communist Party in 1927-32[65] would rather be positively-neutrally placed on the continuum mentioned above in regard to the development of science and technology in the Soviet Union. Dzhermen Gvishiani of *the Large Soviet Encyclopaedia*, who aspired to bring his view on the development of Soviet science and its importance for global development, is to be placed on a more positive side.[66] Alexander Korol of MIT, in his study of the Soviet education in science and technology,[67] provided plenty of the data for the Soviet social policy which would place him towards the positive zone. Both the representatives of the two space programmes, Morris Leroy Spearman of NASA[68] and Mstislav Keldysh, President of the Academy of Sciences of the USSR,[69] connected the Soviet scientific, technological and economic development to science and social policy, i.e. non-economic factors, and represent the other, very positive end of the continuum described. In addition, Soviet theoretical approach for its S&T policy is detailed in I.G. Kurakov's *Science, Technology and Communism, Some Questions of Development*.[70] All of them mentioned in this paragraph constitute the second group of the authors in the literature review.

- Amann, Ronald; Cooper Julian M.; Davies R.W., eds., 1977, The Most Comprehensive Study of Soviet Technology, *The Technological Level of Soviet Industry*, New Haven, Yale University Press;
- Amann, Ronald; Cooper, Julian M., 1986, *Technical Progress and Soviet Economic Development*, Oxford, Basil Blackwell;
- Amann, Ronald; Cooper, Julian M., eds., 1982*, Industrial Innovation in the Soviet Union*, New Haven, Yale University Press;
- Cooper, Julian, 1979, Western Technology in the Soviet Union, *Technology and East West Trade*, Library of Congress Catalogue Card Number 79-600203 For sale by the Superintendent of Documents, US Government Printing Office Washington, D.C. 20402 Stock No. 052-003 -00723-1, November, 205-42; hereafter referred to as Cooper II;
- Cooper, Julian, 1985, Western Technology and Soviet Economic Power, in Shaffler Mark E., *Technology Transfer and East-West Relations,* London, Croom Helm; hereafter referred to as Cooper III.

[64] Cocks.

[65] Graham. It should be mentioned here that in his other following books dedicated to other aspects of science in the Soviet Union, Graham's position was much more negative: Graham, Loren R., 1989, *Science, Philosophy, and Human Behavior in the Soviet Union*, Columbia University Press;
Graham, Loren R., Ed., 1990, *Science and the Soviet Social Order*, Harvard University Press, Cambridge, MA;
Graham, Loren R., 1993, *Science in Russia and the Soviet Union: A Short History*, Cambridge University Press.

[66] Gvishiani, D. M., 1976, *Nauka, Nauchno-technicheskyi potentsial SSSR* (Science, Scientific-Technical Potential of the USSR), *Bol'shaya Sovetskaya Encyclopedia* (*The Large Soviet Encyclopaedia*); retrieved on 26.06.2017 from the Web, http://bse.sci-lib.com/article107001.html; hereafter referred to as Gvishiani.

[67] Korol.

[68] Spearman was 'head of Langley's supersonic wind tunnels and […] a legendary person within the accomplishments of the NASA Langley facilities'; Morris Leroy Spearman, Langley Research Center, *NASA*; retrieved on 02.07.2017 from the Web, https://crgis.ndc.nasa.gov/historic/Morris_Leroy_Spearman.

[69] Keldysh, Mstislav, 1970, Lenin and Development of Science, *The UNESCO Courier*, 6-11; retrieved on 02.07.2017 from the Web, http://unesdoc.unesco.org/images/0018/001844/184442eo.pdf; hereafter referred to as Keldysh.

[70] Kurakov I.G., 1966, *Science, Technology and Communism, Some Questions of Development*, Pergamon Press; hereafter referred to as Kurakov.

Another body of research which is positively-neutral towards Soviet social policies such as Mervyn Matthews' one on Soviet education,[71] Alastair McAuley's one on socio-economic welfare and women's education,[72] and Grigory Khanin's one on socio-economic aspects of Soviet development[73] is incorporated into chapter 4.

2.1.1 Sutton and the 1983 US Congress Report

In *Western Technology and Soviet Economic Development*, Sutton argued for the overall backwardness of the Soviet Union and for its near total dependence on foreign technology in almost all industries, attributing Soviet technological and industrial achievements to the exogenous impact: '[T]he basic Soviet development strategy was to learn from that country considered to have the most advanced processes within a given field of technology and to leave no industrial sector without the benefits of this transfer process.'[74] From his point of view, 'No fundamental industrial innovation of Soviet origin has been identified in the Soviet Union between 1917 and 1965.'[75] The Soviet model was flawed from the origin because 'central planning [did] not foster […] an engineering capability to develop modem technologies from scratch, nor [did] it generate […] inputs (educational, motivational, and material) to achieve this objective'[76] which made the Soviet system intrinsically incapable of producing innovation and technology.

According to Sutton, in Soviet technological development, the role of foreign technological transfer in Soviet industrial development was evaluated as crucial and dominant. Sutton attributed Soviet technological progress to the Western system which in his historical references included Nazi Germany, Imperial Japan, the US, Great Britain or any other country where technology transfer to the USSR originated from[77] in different periods from 1917 to 1965. While considering Soviet development, he did not include historical, cultural and social factors, including education and healthcare.[78]

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71 Matthews, Marvey, 1982, *Education in the Soviet Union, Policies and Institutions since Stalin*, George Allen & Unwin Ltd; hereafter referred to as Matthews.
72 McAuley, Alastair, 1979, *Economic Welfare in the Soviet Union, Poverty, Living Standards, and Inequality*, The University of Wisconsin Press, George Allen & Unwin; hereafter referred to as McAuley I;
- McAuley, Alastair, 1984, Women's Education and Employment in the Soviet Union, The 2006 Edition, ed. by Acker, Sandra; Megarry, Jacquetta; Nisbet, Stanley, and Hoyle Eric, *World Year Book of Education 1984, Women and Education*, Routledge; hereafter referred to as McAuley II.
73 Khanin I.
74 Sutton I, 348.
75 Sutton III, xxv.
76 *Ibid.*, 423
77 Sutton II, 3.
78 Sutton I, 4.

The rise to power, according to the scholar, was driven by substantial transfers of technology from outside, which were either legal, or illegal, or in the form of the post-war reparations, or acquired in espionage.

He argued that the scientific achievements of the USSR were linked solely to a few names like Pyotr Kapitsa who, in turn, built his international reputation working in the University of Cambridge, a Western institution. To support his argument, Sutton connected the development of science across the innovation chain with the political concept of totalitarianism and complemented his theoretical assumption with the example of Vladimir Ipatieff,[79] a Russian chemist who emigrated to the US to become a notable worldwide contributor in the field of petroleum chemistry as follows:

> It is *not* that Russian talent is lacking […] The heart of the problem is the great weakness of totalitarian systems in the application of scientific advance to the industrial structure in any rational manner. No chemist, nor indeed any scientist, of Ipatieff's stature has emerged during the 50 years after the Bolshevik Revolution, despite the enormous funds poured into science and the comparatively comfortable conditions in which scientists live and work.[80]

Meanwhile, in the next volume, Sutton stated that 'there [was] no question that Soviet scientists were at least on par with Western scientists in 1940, and in some areas of theory they could have been slightly ahead'[81] without getting into any more detail.

According to Sutton, '[u]sually there are many inventions available for selection in any industrial system; but in practice only a few are applied to become innovations.'[82] In this view, science and technology represented changeable and replaceable variables to be assembled by the pieces into an innovation:

> The reader should bear in mind the distinctions made in this analysis between science and technology and between invention and innovation. Science is here defined as theory and laboratory development of theory, while

[79] Vladimir Nikolayevich Ipatieff, *Encyclopaedia Britannica*; retrieved on 12.03.2018 from the Web, https://www.britannica.com/biography/Vladimir-Nikolayevich-Ipatieff.
[80] Sutton II, 282.
[81] Sutton III, 231.
[82] *Ibid.*, xxv.

> technology is the selective application of scientific findings to industrial production. Similarly, invention is the process of discovery and the prototype development of discovery, while innovation is the selective application of invention to industrial production.[83]

As mentioned above, Sutton considered that the moderate technological advance the Soviet Union attained was due to exogenous ideas and imported know-how. However, he agreed that the Soviets '[…] invariably chose a more successful, low cost process. In the light of the history of technical transfers, the Soviet choice of Western techniques [had] been superb.'[84] Also the choice was executed rapidly and successfully 'at a low cost and in a relatively efficient manner.'[85] Sutton envisaged the following elements of Soviet industrialisation. Firstly, it was driven by 'simple, clear cut objectives […] to build new, gigantic, mass-production units to manufacture large quantities of simplified standard models based on proven Western designs.'[86] Secondly, 'technology, simplifications, standardization and duplication became the operational aspects of Soviet industrial strategy.'[87] Thirdly, this copying saved significant reserves in time and investment.[88] Fourthly, the resources from agriculture and consumer sectors were 'diverted into industrial and military construction.'[89] He concluded that the external technical assistance was 'the major causal factor in Soviet economic growth for the period 1928-45.'[90]

Soviet industrialisation, according to Sutton, was successful, and primarily driven by the fact that '[t]he Communist Party correctly recognized technology as the heart of economic development' and that '[t]he analysis made by the Party [was] correct.'[91] Meanwhile, the broad economic process of the speedy post-war recovery of the Soviet economy was attributed in this study mainly to the Lend-Lease injections of 1943-45[92] and reparations received as a result of WWII. Sutton assigned the post-war Soviet technological development to access received by the Soviet Union as a result of WWII to the resources of the fallen Third Reich not only in Germany but also in Eastern Europe, especially in Czechoslovakia and Poland, which became parts of the Soviet bloc after the war. The success of atomic

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83 *Ibid.*
84 Sutton II, 292.
85 *Ibid.*
86 *Ibid.*, 299.
87 *Ibid.*
88 *Ibid.*, 315-6.
89 *Ibid.*, 339.
90 *Ibid.*
91 *Ibid.*, 322.
92 *Ibid.*, 346.

technology was driven by the military contributions received from Germany (in both rocket-construction and nuclear technology)[93] as well as by a very successful Soviet global espionage network.[94] Sutton identified a couple of successful Soviet indigenous innovations, e.g. synthetic rubber and the blast furnaces, marked only three other successful Soviet industries, and placed them in the following table:

Table 1 **Indigenous Soviet Innovation 1917-65** (as seen by Sutton)[95]

1917 to 1930	1930 to 1945	1945 to 1965
Primitive tractors	Turbodrill	Electro-drill
	Alumina from nepheline	Aircraft
	Synthetic rubber; SK-B	*Sputnik*
	Once-through boiler	Medical sutures
	Machine guns	Electro-slag welding
		"Scaling up"

In Sutton's quantitative methodological approach electro-drill was counted in the same singular category as aircraft and *Sputnik*. The success of these industries was linked by Sutton to the personal preferences of the country's leaders:

> Soviet indigenous technical progress is concentrated in three industrial sectors: iron- and steelmaking (but not the steel rolling), electricity generation and high-voltage transmission, and rocket technology. It may be noteworthy that each of these three technologies was at one time pushed by dominant party personalities: Stalin, as his name implies, favored the iron and steel industry; Lenin of course was the force for the electrification of Russia; and Khrushchev was a force behind the development of rocket and space technology.[96]

The success in the sectors described was ascribed by Sutton to accidental factors of the personal involvement of the key political leadership. According to Sutton, in many sectors of

[93] Sutton III, 234-7.
[94] *Ibid.*, 233.
[95] *Ibid.*, 423.
[96] *Ibid.*, 362.

Soviet industry, Soviet technological development took place due to imported know-how and technology to become assembled 'scaled up' Soviet innovations. In his view, 'The Soviet problem is not that the nation lacks theoretical or research capability or inventive genius. The problem is rather that there is a basic weakness in engineering skills, and the system's mechanisms for generating innovation are almost non-existent.'[97] Referring to the examples of Ipatieff mentioned above and other prominent Russian scientists-émigré whose careers developed outside of the Soviet Union, Sutton suggested that 'the weakness is not in Russian scientific talent, but in a coercive system which stifles scientific achievement and provides no means for the rational application of technical progress'[98] and believed that the central planning system was the Soviet Achilles' heel.[99]

In a similar vein, the 1983 US Congress Report highlighted two historic waves of notable machinery imports in the USSR. The first large-scale one took place in the First Five-Year Plan of 1928-32 and showed a fourfold increase in comparison with the previous five years. After its peak in 1931, the imports sharply decreased. The second wave began in 1965 and gradually continued while being varied in different sectors of the economy. The investments for imports increased from 2 per cent of the total investments in the mid-1950s to 5.5 per cent of the investments in agriculture, electricity, steel, food processing and building materials by the late 1970s and up to one-third in the chemical industry by 1976. Afterwards, these numbers decreased although not dramatically.[100]

The report argued that 'throughout the post-Stalin period, the Soviets have emphasized the importance of science and technology in their economic development,'[101] aiming at achieving productive efficiency through the progress of the ongoing scientific and technological revolution (STR). However, the USSR remained inferior to the technologically developed Western countries, mostly due to its bureaucratically controlled planned system. According to the report, the Soviet system resisted any innovations which were, while being imposed from above, viewed as deviations of the Plan by bureaucrats in the vast R&D pyramid.

During this period from 1965 to 1983, in the policy implementation less attention was given to the development of fundamental science in comparison to that of applied science. For

[97] *Ibid.*, 422.
[98] Sutton II, 282.
[99] Sutton III, 423.
[100] Holliday, George D., 1983, Western Technology Transfer to the Soviet Union: Problems of Assimilation and Impact on Soviet Exports, *The 1983 US Congress Report*, 514-9; hereafter referred to as Holliday.
[101] Gold, Donna L., Overview, 1983, *The 1983 US Congress Report,* 509; hereafter referred to as Gold.

example, *The Inventor's Certificate* system established in 1931 was reformed into *The Socialist Patent System* of a more Western type in 1965 in order to incentivise the scientists, stimulate the development of R&D within the countries of the Council for Economic Mutual Assistance (CEMA) and facilitate Western imports.[102]

According to this 1983 report, the USSR and the Communist bloc benefited from the integration of CEMA science and technology as 'Soviet technological potential ha[d] increased overall by about 25 percent,'[103] the study read. This reform aimed at adopting the Soviet patent system to the Western standards, which would allow the Soviet Union the following: i) to earn hard currency through patent sales in the West; ii) to get access to the international innovations for monitoring and applications purposes and iii) to contribute to the efficiency of the CEMA cooperation. After the Soviet Union joined the Paris Convention for the Protection of Industrial Property in 1965, the number of the patents granted by the Western firms to the USSR rose dramatically from 52 in 1965 to 1,723 in 1970 and, consequently, to 2,448 in 1979.[104]

According to the study, all the measures stipulated above did not lead to the efficiency as expected, mostly due to both the rigid control of the state patent system and the bureaucratic reluctance. This could not help telling on the Soviet economic performance, slowing down the pace of the growth and pushing the Soviet economy towards the development of other earning hard currency sectors, like oil and gas production, metallurgy, *etc*. The currency was mostly needed to balance the debt with the Western countries of USD14 billion, accumulated by 1981 and resulted from the technology transfer.[105] On the other hand, the Soviet government had managed to decrease the growth of the deficit in the late 1970s and the early 80s.[106] This was achieved through a certain success of the import substitution programme in applying domestic R&D as well as increasing growth of the CEMA R&D investments (RDI). 'By 1980, more than 3,000 scientific and engineering institutes and organizations in the CEMA

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[102] *Ibid.*, 511.
[103] *Ibid.*
[104] Martens, John A., 1983, Soviet Patents and Inventors' Certificates, *The 1983 US Congress Report*, 538; citing from Artem'ev Ye. I. and Kravets L. G., 1977, *Izobretenie-Uroven' Tekhniki-Upravlenie (Invention – Level of Technics – Management)*, Moscow, Izdatel'stvo *Ekonomika*, 47; and Artem'ev Ye. I., 1980, *Tekhnicheskii progress izobretatel'stvo; patentno-litzenzionnaya Rabota (Technical Progress Invention; Patent and Licencing Work)*, Moscow, Akademiya narodnogo khoziaistva SSSR, 24.
[105] Gold, 512.
[106] *Ibid.*

countries were working on approximately 4,000 collaborative RDI projects,'[107] the report confirmed.

Although the Soviet technological system experienced multiple problems in assimilating foreign high-technology, their imports steadily increased from USD500 million and USD403 million for machinery orders and high-technology imports respectively in 1970 to USD7,034 million, USD3,800 million and USD2,985 million for machinery imports, machinery orders and high-technology imports respectively in 1976.[108]

According to the study, the Soviet Union had practically no import of high-technology from abroad in the period from 1932 to the early and mid-60s:

> Unlike the current period, however, the earlier period of intense interest on Western technology was short-lived. After peaking in 1931, machinery and equipment imports declined rapidly to the level that prevailed before the First Five-Year Plan. Soviet officials abruptly terminated technical assistance agreements and rapidly reduced the number of people traveling to and from the Soviet Union. From the end of the First Five-Year Plan to the early 1960s, the Soviet Union went through an extended period in which trade with the West was assigned a distinctly lower priority in Soviet economic plans.[109]

Even after 1965, the Soviet Union remained a relatively small importer of Western technology on a global scale. As calculated in the US Department of Commerce study, 'total Western exports of "high-technology" products to all countries in 1970 totalled $24,770.9 million. Of this, the Soviet Union imported $402.9 million, or less than 2 percent of the total. The Soviet share rose to over 2 percent in 1978 and 1979, before declining to approximately the 1970 share in 1980.'[110]

According to the report, due to the lack of the material incentives within the system, the following structural problems prevented the system from realising the innovation potential more efficiently:

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[107] *Ibid.*, 511.
[108] Holliday, 517.
[109] *Ibid.*, 515.
[110] *Ibid.*, 516.

> The necessary scientific and technological strides needed to facilitate continuous economic growth have not been made. Progress in this direction has been slow and incremental. Constraints, perhaps inherent in the Soviet system, have prevented the attainment of full scientific and technological potentials. A good deal of the Soviet scientific research and development continues to be conducted independent of the needs of industrial production; many inventions never reach the factory. Institutional barriers hinder necessary scientific interaction; no "invisible college" of scientists performs the function of disseminating research results. Soviet scientists in large part are financially secure and have little material incentive to focus on specific industrial needs. Moreover, industrial plant managers lack the incentive to incorporate new technology into their production schemes. The threat of failing to meet their production plan is too great for many to undertake the short-run risks associated with switching to new systems.[111]

The report expressed solidarity with the official Soviet policy for S&T development which was viewed as the only approach to keep up in the global technological and, hence – in the economic race, however, the reality was somewhat different. Scientists, although privileged in society, had few incentives to focus on specific industrial needs whereas the production sector had few incentives to try and apply innovations. Thus, the Soviet system although having both the innovation capacity and industrial base, was failing, according to the report, to transit towards a more balanced regime in the interaction of the state, industry, and academia for an effective innovation system.

In the next subsection, the second group of research representing more positive evaluations of Soviet technological development in conjunction with other, non-economic policies and factors is considered.

2.1.2 Non-Market Evaluation of Soviet Development

As written by Julian Cooper in 1986, ‘it is widely believed that the Soviet economy was extremely backward, even primitive, with respect to the technology of the United States, Japan or West Europe […] these perceptions do not adequately capture the richness of the

[111] Gold, The US Congress Report, 513.

technology in the Soviet Union,' and that 'Western technology is important, but by no means crucial [to] the economic strength and military might of the Soviet Union.'[112]

In his multiple papers on the scientific, technological and economic development of the USSR,[113] Cooper explored Soviet development in these three spheres with an emphasis on the defence and high-tech sectors, followed by a retrospective comment on the achievements and the problems inherited from the period of industrialisation. He emphasised the complexity of the multi-level pyramid involved in the production of Soviet S&T and R&D with approximately 1.5 million natural and social scientists involved. According to Cooper, in 1986, the following proportion lasted proportionally from the 1930s: ten per cent of them were engaged by the Academy of Sciences with its branches throughout the 15 republics to work in fundamental spheres with the concentration of the best minds in Moscow and a few other centres; 40 per cent – in higher education, this category had little to do with R&D; whereas the other half was involved in the industrial sector, and 500,000 out of them were employed in various R&D bodies for engineering and applied sciences.[114]

Cooper's sectoral analysis showed that the defence industry occupied a special place in Soviet development from the early 1930s. In many cases, the defence industry served as a trigger for the development of many other not directly associated activities in applied matters and in fundamental science. Cooper's papers stressed a high level of development of the defence industry in the Soviet Union, which was at par with that of the United States. According to him, 'the latest United States Department of Defense assessment of technological level in 24 deployed military systems puts the Soviet Union ahead of the United States in 4, equal in 7 and behind in 13.'[115] The Soviet defence sector, due to sanctions and security control, was the least dependent on transfer of foreign technology, being at the same time one of the most developed sectors in the economy.

Regarding the role of imported technologies for Soviet economic performance, Cooper wrote that multiples embargoes, imposed on the Soviet economy during the Cold War, had been playing a role of a trigger to develop domestic innovation in order to avoid the dependency on

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[112] Cooper I, 317.
[113] As referred in section 2.1 above.
[114] Cooper I, 319.
[115] Cooper I, 318, citing from United States Department of Defense, 1986, The FY1987 Department of Defense Program for Research and Development, Statement by the Undersecretary of Defense, Research and Engineering to the 99th Congress, 2nd Session, Washington D.C., February.

technology transfer.[116] Moreover, many of the technologies imported could not perform well in Soviet conditions due to discrepancies in output materials, differences in locations in the economic pyramids and technological chains, as well as distinct managerial and labour skills. According to Cooper, all of that caused a disappointment in the community of the Soviet experts. He concluded that '[t]hus it would be a mistake to regard Western technology as always representing a sure, direct path for the modernization of the Soviet economy.'[117] Instead, many efforts were applied by the Soviet Union in its last years to develop either indigenous technologies or those received from or developed jointly with the CEMA partners.

In Cooper's view, the country held a leading position in manufacturing a wide range of microprocessors, automated robots, numerically controlled machine tools, industrial lasers, powder metallurgy, composite materials, plasma technologies, and biotech. The assessment of these types of productions was difficult, as most of the initial technologies were hidden from view in the defence industry, whereas 'the more visible activities of civilian organizations did not reflect Soviet capability, heightening the impression of backwardness.'[118] According to Cooper, '[T]he Soviet Union is capable of successful technological innovation and can produce goods of a high technological level,'[119] emphasising that in the civilian sector the Soviet system in its very stratified economy faced problems of keeping up with the US and its allies in terms of production of consumer goods.

Paul M. Cocks' report[120] was written as a part of a series of bilateral agreements signed from 1972 in the fields of cooperation in science and technology between the US and the USSR. According to him, science was regarded in the USSR as 'an indispensable tool for modernizing'[121] the country, and, for the first time in world history, was recognised as a natural resource. The Kremlin's ideology and science were synonymous, and the scientific optimism inherited by Marxism from the XVIII Century enlightenment was 'more popular […] among the intellectuals in the Soviet Union than in Western states where the appeal of this model ha[d] diminished.'[122] Meanwhile, the SAS remained the last one of the XVIII Century European Academies still domineering in its nation's science.[123]

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[116] In variations, in Cooper III and Cooper I.
[117] Cooper I, 340-1.
[118] *Ibid.*, 320.
[119] *Ibid.*, 318.
[120] Cocks.
[121] *Ibid.*, 2.
[122] *Ibid.*
[123] *Ibid.*

According to Cocks, 'No government [was] explicitly committed to science and technical progress as that of the USSR,'[124] by contributing systematically notable portions of the budget to the promotion of research:

> While allocations for R&D rose in the US to 2.5 percent of the GNP in 1965 and have fallen ever since, official expenditures on science as a portion of national income have risen in the Soviet Union from 1.3 percent in 1950, to 2.7 percent in 1960, to 4.8 percent in 1975. If we add development activity at the enterprise level, which is not included in "official" science figures, then the total share of national income has probably been about 7 or 8 percent throughout the 1970s. While official allocations for science have tended to stabilize in recent years at around 5 percent of the national income, this rate is still significantly higher than that of any nation in the Western world.[125]

In the 1920s, the Soviet Union became the first country in history to try to formulate an integrated policy for science and technology, and '[i]t began conducting statistical and organizational surveys of scientific personnel and institutions a decade before other countries, including the United States.'[126]

Unlike the atomised and semi-independent structure of R&D in the US, the whole complex of the Soviet system represented a kind of giant public sector, as argued in the introduction.

The SAS was centralised, which followed the overall tradition of power inherited from Tsarist Russia.[127] According to the report, '[c]entralization of R&D was regarded not only as a means of eliminating the duplication of effort and secrecy that were characteristic of capitalist states but also of making the most effective use of Russia's scarce S&T resources.'[128] However, as outlined by Cocks, the transition of the R&D decision from central policy to an individual rather followed a continuum.[129] According to Cocks, this policy expressed in a coordination of R&D efforts did not correspond with the Western image of the tight Soviet centralisation being rather 'a comprehensive and coherent national science and technology policy.'[130]

[124] *Ibid.*, 1.
[125] *Ibid.*, 3
[126] *Ibid.*, 6.
[127] *Ibid.*, 4-5.
[128] *Ibid.*, 5.
[129] *Ibid.*
[130] *Ibid.*

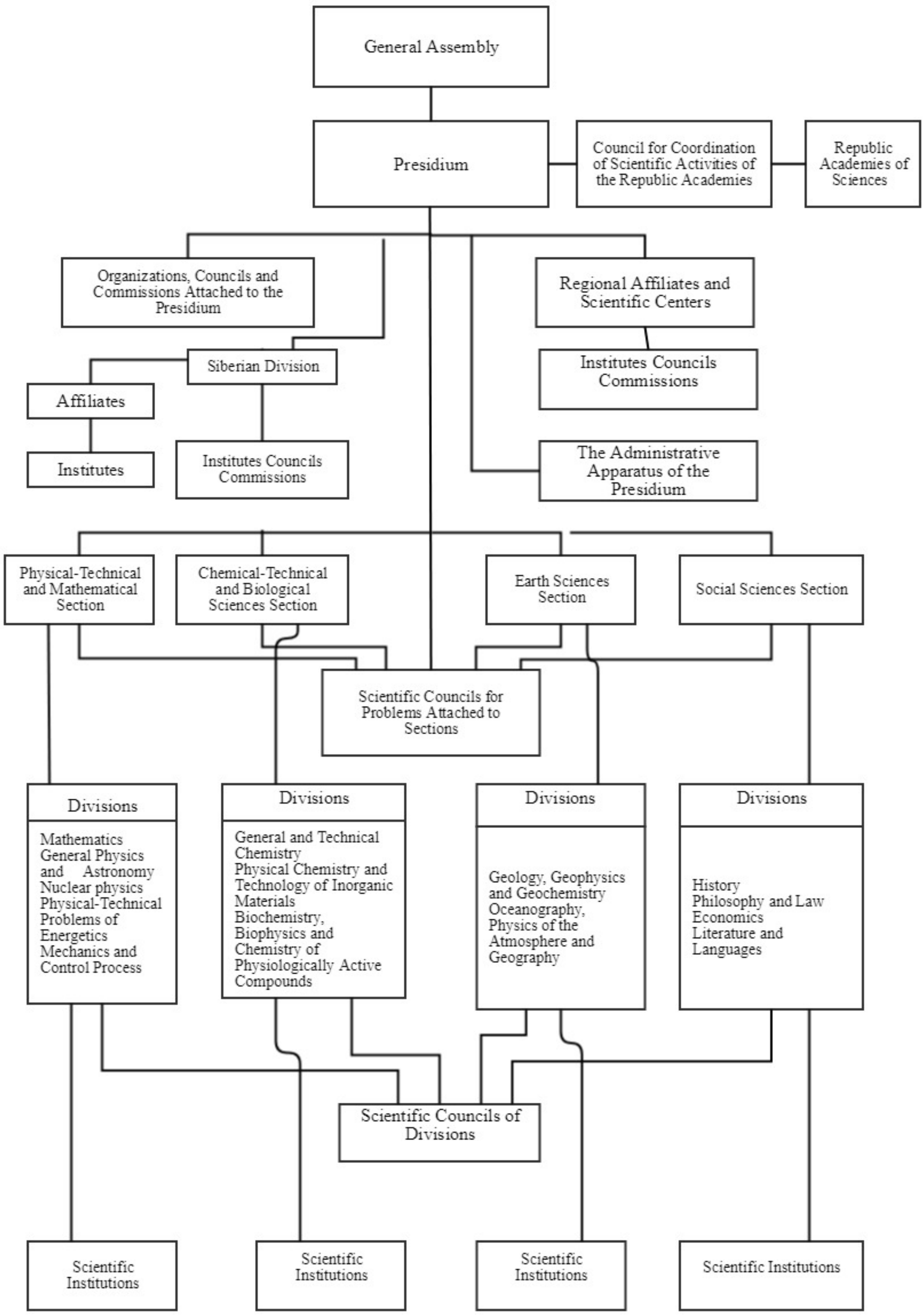
In the Soviet Union, the contradiction between the nature of the planned economy and the unpredictable character of fundamental scientific research was resolved through the establishment of the institution of the semi-independent SAS. Unlike the economy, science did not develop under the supervision of the State Planning Committee. In Cocks' view, 'activities under research, development, and innovation in the USSR were seen as 'too complex and numerous and the results too unpredictable and indefinite to be worth the effort of joining them into a single coherent plan.'[131] No attempts to integrate the S&T development into the planning system were undertaken until the mid-1950s. Cocks, however, viewed this as a flaw and commented the following on the development of engineering: 'Much like the American pattern, the Soviet R&D effort was structurally and administratively fragmented among multiple mission-oriented agencies with conflicting jurisdictions and interests.'[132] Meanwhile, a major problem of the Soviet S&T policy lay, according to Cocks, in translating of scientific findings into practical applications.[133]

Cocks observed that historically both Tsarist Russia and the Soviet Union fluctuated between two extremes in its relationship with foreign science, either imposing self-isolation or actively involved with cooperation and exchange in the times of its technological lag.[134] It happened periodically, beginning from the modernisation of Peter the Great in the XVII-XVIII Centuries, and occurred twice in the XX Century during industrialisation of the 1930s and *Détente* of the 1970s.[135]

Based on Soviet sources,[136] Cocks presented the following structure of the Academy of Sciences of the USSR:

Diagram 1 Structure of the Academy of Sciences of the USSR [137]

[131] *Ibid.*, 83, citing from Nolting, Louvan, 1978, The Planning of Research, Development, and Innovation in the USSR, US Department of Commerce, *Foreign Economic Report* No. 14, Washington, D.C., 1.
[132] *Ibid.*, 6-7.
[133] *Ibid.*, 10.
[134] *Ibid.*, 12-3.
[135] ' Détente (a French word meaning release from tension) is the name given to a period of improved relations between the United States and the Soviet Union that began tentatively in 1971 and took decisive form when President Richard M. Nixon visited the secretary-general of the Soviet Communist party, Leonid I. Brezhnev, in Moscow, May 1972,' Détente, *History*; retrieved on 07.12.2017 from the Web, http://www.history.com/topics/cold-war/détente.
[136] Gvishiani, Dzhermen, *et al*, 1973, *Osnovnye printsipy i obshchiye problemy upravleniya naukoi* (*Main Principles and General Problems of Science Management*), Nauka, 182-3.
[137] Cocks, 48.


General Assembly
Presidium
Council for Coordination of Scientific Activities of the Republic Academies
Republic Academies of Sciences
Organizations, Councils and Commissions Attached to the Presidium
Regional Affiliates and Scientific Centers
Siberian Division
Institutes Councils Commissions
Affiliates
Institutes
Institutes Councils Commissions
The Administrative Apparatus of the Presidium
Physical-Technical and Mathematical Section
Chemical-Technical and Biological Sciences Section
Earth Sciences Section
Social Sciences Section
Scientific Councils for Problems Attached to Sections
Divisions
Mathematics
General Physics and Astronomy
Nuclear physics
Physical-Technical Problems of Energetics
Mechanics and Control Process
Divisions
General and Technical Chemistry
Physical Chemistry and Technology of Inorganic Materials
Biochemistry, Biophysics and Chemistry of Physiologically Active Compounds
Divisions
Geology, Geophysics and Geochemistry
Oceanography, Physics of the Atmosphere and Geography
Divisions
History
Philosophy and Law
Economics
Literature and Languages
Scientific Councils of Divisions
Scientific Institutions
Scientific Institutions
Scientific Institutions
Scientific Institutions

The report also confirmed that the central Academy had branches in the other 14 Republics but the Russian Soviet Federated Socialist Republic (the RSFSR). It also had eight affiliates and centres in different regions and a dozen Academic Cities among which the Siberian Division of the Academy in Novosibirsk was particular. It enjoyed certain privileges and played the role of the RSFSR's academy. According to Cocks, '[U]nlike the discipline-oriented departments, it is governed by its own general assembly and presidium. It is administratively subordinate to both the USSR Academy and the Council of Ministers of the Russian Republic (RSFSR). Funding is provided by the RSFSR, which has no republic academy of its own. Thus, the Siberian Division has a certain measure of independence vis-a-vis the Soviet Academy.'[138]

The dynamics of the Academy's development (established in 1724) from the 1920s and 30s, and in particular the 1940s and 50s, can be seen in the following. The 1940s was the period when most of the national republican branches were established. The relative sizes of the branches can be estimated from the numbers of the scientific institutions, the numbers of the full and corresponding members as well as the numbers of researchers, including those with advanced degrees. The central Academy and the branches in the two Slavic republics of Ukraine and Belarus were the biggest and most developed ones where the largest portion of the national research was concentrated, followed by the branches in Uzbekistan and Kazakhstan in Central Asia, and Georgia and Azerbaijan – in the Caucasus. The other six branches were significantly smaller in size. The central Academy had 733 members whereas Ukraine had 300; Belarus, Kazakhstan, Georgia and Azerbaijan had over 100 of them, and the remaining 10 less than 100. It was also similarly reflected in other criteria including the numbers of scientific institutions. If the central and governing body had 244, Ukraine had 70, Georgia, Kazakhstan and Uzbekistan – more than 30, and the other 10 – less than 30. Belarus, Georgia, Kazakhstan, Uzbekistan and Azerbaijan had the largest numbers of researchers in relation to their populations.[139]

R&D research was accumulated in the urban centres as well as in the republican capitals, whereas only three cities, Moscow and Leningrad[140] in Russia and Kiev in Ukraine, held one-

[138] *Ibid.*, 49.
[139] *Ibid.*, 51-3, citing from *Narodnoye khozyaystvo SSSR za 60 let; yubileyniy statistichesky ezhegodnik* (The National Economy of the USSR for 60 years; Jubilee Statistical Yearbook), 1977, Moscow, 144; the full table of the USSR, Union Republic and Branch Academies of Sciences (at the end of 1976) can be found in Appendix H.
[140] Today it is called Saint Petersburg.

fourth of all the national scientific institutions and conducted 40 per cent of the overall research[141] which was nonetheless established throughout the Soviet Union.

The Academy of Sciences designed, planned, coordinated and functionalised all the regional R&D activity, including education, in cooperation with the *GKNT* (the State Committee for Science and Technology) and *Gosplan*. There were also specialised academies as a part of the overall scientific development in the Soviet Union such as the Academy of Agricultural Sciences under the USSR Ministry of Agriculture, the Academy of Medical Sciences under the USSR Ministry of Health and the Academy of Pedagogical Sciences under the USSR Ministry of Higher and Specialised Secondary Education for conducting research in the appropriate disciplines.[142]

In relation to science, technology, and innovation, Cocks believed that the system experienced problems of coordination and information exchange. The Soviets could not resolve some of the problems to like it was done by the American system by the 1960s, for instance, in terms of the system's perception of technology as a form of mechanical transfer. Instead of 'technology transfer,' 'innovation process' or 'commercialisation cycle,' the Soviet Union had its own a system of 'scientific and technological complex of work,' 'research-production cycle' and 'complex of preproduction work.' It was used extensively in the process of science planning and implementation from the 1960s,[143] facing situations when 'the economy ha[d] emerged to guide the planners.'[144]

According to Loren R. Graham, 'Within every society there exists "an environment for science" which to a greater or lesser degree, promotes the development of science by providing fertile soil for individual creativity.'[145] He continued that although 'the control of such factors as the philosophy of science can be attempted only by a society with very tight controls over intellectual life,' the Soviets were designing the optimum environment for the flourishing of science in providing of the maximum variables in their policy 'in the hope of facilitating this creativity […] No previous government in history was so openly and energetically in favor of science.'[146]

141 Cocks, 50.
142 *Ibid.*
143 *Ibid.*, 88.
144 *Ibid.*, 89.
145 Graham, 32
146 *Ibid.* 32-3.

Graham argued that the crucial period of the establishment of the SAS was in 1927-32 which established the following specifics. Firstly, the SAS developed as a centralised and hierarchical public body in which the development of research in the Republics' Academies of the USSR was supervised and coordinated from the centre not restricting research activities nevertheless and allowing the formers' certain autonomy. Secondly, in terms of its governance, although the SAS was subordinated to the Council of Ministers of the USSR (as called from 1946), it was quite autonomous from the Soviet political system. The Academy was obliged to provide annual reports to the Council of Ministers. The SAS was run by its own President who was periodically elected by the members of the Academy in secret ballot. Presidents, Members, and Academicians of the branches were elected locally to be approved in the Central Academy and the Central Committee (the *TsK*) of the Communist Party. Thirdly, in its development, the SAS did not belong to the planning system, although its activity was tightly coordinated with the system of *Gosplan* and overall Soviet economic development. Fourthly, its funding mostly came directly from the Soviet government and was largely based on the needs and demands of the SAS. Last but not least, according to Graham, 'the reason for this expansion was the enormous prestige and talent of the Academy, which far exceeded that of any other body in the Soviet Union.'[147]

This approach was in sharp contrast to that of Tsarist Russia as argued in the introduction. Although Russia had research in mathematics, chemistry, biology, geology, topography, and geography particularly developed, it, however, even in 1927, lacked management and coordination, and it was, unlike in other European leading countries of that time, unbalanced, relatively chaotic and not perfectly polished.[148] Graham concluded:

> Despite two centuries of governmental interference and control, the Imperial Academy of Sciences, as it existed in the first decades of the 20th century, was an institution of remarkable talent and achievement. In a country extremely backward educationally and only beginning its great development economically, the leading scientists were abreast of those in western Europe. […] To the communist reformers of Russia after 1917 this unique legacy became an opportunity which once seized and then transformed, resulted in a framework of scholarly research totally new in history.[149]

[147] *Ibid.*, 189.
[148] *Ibid.*, 14.
[149] *Ibid.*, 23-24.

According to Graham, the Academy had survived the turbulent times of the Civil War relatively well, although with some notable losses of human capital. At the first stage after 1917 the revolutionaries envisaged a new kind of socialist science which was supposed to emerge as part of a broader culture in society. It was to follow as a result of the inevitable transformation of culture, according to Marxism, as a derivative superstructure of the economic basis.[150] In Graham's account, the new characteristics of socialist science 'would include a new theory of the place of science in the society, a more fertile economic environment for technological growth, unprecedented governmental support for research, a superior organizational scheme of research institutes, and a methodology for the planning of science.'[151] Although the qualitative transformation for the new Soviet science to turn it into something completely new by its nature did not happen, the approach eventually led to building a new policy. As planning *of* science appeared impossible, planning *for* science became a viable option.[152]

According to Graham, the peak of the struggle between the two opposing approaches, i.e. the ideological one vs. the pragmatic one, and the moment at which the policy towards science changed occurred during the public debate between Nikolay Bukharin, a leading economic ideologist, supervising the development of science and technology in the government and an active proponent of the construction of 'new socialist science,' and Vyacheslav Molotov, the chairman of the government, at the All-Union Conference for the Planning of Scientific-Research Work in April of 1931.[153]

Concerning Marxism, Graham noted: 'The specific characteristics of scientific development in ancient China, the French Revolution, Renaissance, medieval period, Nazi Germany, and Soviet Russia cannot all be explained on the basis of the economic foundations of those societies. Furthermore, scientific and technological innovations are often not products of pressing material necessity.'[154] Thus, a significant theoretical mistake for the Marxists, according to Graham, was in their visions of the history of natural science when '[t]hey believed that natural science […] develops in response to the needs of material production.'[155]

150 *Ibid.*, 190-6.
151 *Ibid.*, 190-1.
152 *Ibid.*, 65.
153 *Ibid.*, 185-7.
154 *Ibid.*, 194.
155 *Ibid*.

In Graham's account, '[f]uture years would demonstrate ever more clearly that Soviet science, impressive as it became, would compete with the science of other nations on the same terms by which the scientists of those nations rated each other.'[156] After conducting plenty of surveys and statistical research in 1921-34, it was officially declared that natural sciences did not belong within the ideological superstructure.[157] Overall this pioneering research[158] laid the foundation of the international methodological approach of the modern scientific institutional organisation.

As a result, the SAS expanded during and after the industrialisation drive without falling under the purview of the planning system. Graham outlined that engineering became an integral part of the Academy's activities: 'Academy of Sciences' relationship to Soviet industry in the early thirties was in some ways similar to that of a large industrial research laboratory in the West serving a particular industry with one difference being the fact that in the Soviet Union the particular industry was the whole industrialization effort.'[159] Thus, altogether with the Party's guidance in all institutions and the total mobilisation of the society for industrialisation, the Soviet scientific programme was pragmatic and formidable.[160] In 1960, Alexander Nesmyanov,[161] President of the SAS, referred to the Academy as the 'director of the Soviet scientific orchestra.'[162]

According to Graham, science was viewed by Soviet officials as a key to modernise both the economy in unlocking the country's natural wealth and the national state of mind as opposed to the old and widespread religious mysticism.[163] They actively and openly supported science and sought an optimal balance between power and development following the Marxist principle of the unity of theory and practice.[164]

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[156] *Ibid.*, 192.
[157] *Ibid.*, 38 and 192.
[158] *Ibid.*, 45, referring to Ol'denburg, S. F., ed., 1926-34, *Nauka i nauchnye rabotniki SSSR* (*Science and Scientific Personnel of the USSR*), 4 vols., Leningrad; Shmidt O. Iu. and Smushkevich D. Ia., 1930, *Nauchnye kadry i nauchno-issledovatel'skie uchrezhdenia SSSR* (*Scientific Personnel and Scientific-Research Institutions of the USSR*), Moscow; see also Sergeevich L.V., 1926, *Zadacha sobiranya nauki* (*The Task of Organising Science*), Nauchnyi Rabotnik, September, 31-34.
[159] *Ibid.*, 207.
[160] *Ibid.*, 197.
[161] Chatt, J., Rybinskaya, M. I.,1983, Aleksandr Nikolaevich Nesmeyanov. 9 September 1899-17 January 1980, *Biographical Memoirs of Fellows of the Royal Society;* retrieved on 03.04.2018 from the Web, http://rsbm.royalsocietypublishing.org/content/roybiogmem/29/399.
[162] Graham, 197.
[163] *Ibid.*, 33.
[164] *Ibid.*, 38-43.

In *the Large Soviet Encyclopaedia* in 1976, Dzhermen Gvishiani argued that the Soviet S&T potential 'represent[ed] a dynamic combination of being implemented and not yet used objective capabilities and conditions for further growth of societal production. [...] The growth [of the potential] [wa]s one of the main conditions of socio-economic progress, provision of all-sided development of all members of the society and the utmost satisfaction of their material and cultural needs.'[165]

This research capacity in itself represented a significant progressive and productive force. According to the encyclopaedia, in 1975 there were 1.2 million of researchers within the overall number of 4 million of the personnel allocated for R&D, and 9,1 million – in the sphere of education and culture.[166] The number of the engineers in the economy reached 9.1 million. The overall number of the researchers in the USSR accounted to one-quarter of the total global number.[167]

In practical terms, it was partially reflected in the growing number of 'inventions and rationalisation proposals' (i.e. patents) based on S&T which grew from 591,000 in 1940 to 5,113,000 in 1975, of which those of the applied ones – from 202,000 to 3,977,000.[168] A direct economic effect of using these patents, in Gvishiani's account, was estimated in saving SUR90 million and SUR4,805 million respectively.[169]

According to Gvishiani, 16,600 new types of machinery and equipment were launched in the industrial production in 1971-5 against 8,400 in 1966-70.[170] The share of the economy formed by the science-induced technology was 31 and 36 per cent in 1970 and 1975 respectively.[171] The growth of the electronics industry, in particular, was notable in the form of the 'automated management systems' from 414 in 1966-70 to 2,364 in 1971-5. It conjured with 10 national, 86 particular industrial R&D and 93 territorial data processing centres and 166,000 people involved.[172]

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[165] Gvishiani.
[166] *Ibid.*
[167] *Ibid.*
[168] *Ibid.*
[169] *Ibid.*
[170] *Ibid.*
[171] *Ibid.*
[172] *Ibid.*

As outlined by Alexander Korol in *Soviet Education for Science and Technology*,[173] in the light of the unprecedented economic and technological development when science and engineering, in general, and physics, especially, became of particular importance, the Soviet educational system 'was mobilized to challenge and compete'[174] with the rest of the developed world. The Soviet education system (SES) was viewed as a foundation for Soviet achievements in physics and mechanical engineering, which were the main driver for Soviet economic development. According to this MIT scholar, 'It is critically important, therefore, for us to examine Soviet education, especially in the fields of science and technology.'[175]

In the system, ''[P]olytechnic' education for all up to age 17 was in 1919 proclaimed by the Communist Party as the objective and method of the Soviet School' was referred to a type of teaching 'by Marx and Engels which 'familiarizes one with the basic principles of all productive processes and at the same time gives the child of the adolescent [age] the skill of using the simplest tools employed in every branch of production,'[176] wrote Korol. In 1931 the term *polytechnisation* received concretisation of 'mastery of scientific fundamentals (in physics, chemistry, mathematics, native language, geography and other subjects)'[177] and it was established as a priority in the official educational policy-making as a conventional method of instruction, rapidly distributed throughout the SES:

> Every attempt to disassociate polytechnization of the school from a systematic and firm mastery of science – especially of physics, chemistry, and mathematics, the teaching of which must be based upon rigorously defined and carefully worked our syllabi and curricula and carried out in accordance with a firmly established school calendar – represents a most fundamental perversion of the concept of the polytechnic school.[178]

All the secondary school curricula contained a lasting balance between social sciences, science and other training such as music, art, and physical culture, and developing basic engineering and other skills, with a great emphasis on math and physics. Another important

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173 Korol.
174 *Ibid*., ix.
175 *Ibid*., 64.
176 *Ibid*., 27, citing from K. Marx and F. Engels, *Sochinenya* (Works), Russian Ed., Vol. 13, Part One, 199.
177 *Ibid*., 27, citing from *O nachal'noi i srednei shkole* (On the Elementary and Secondary School), 1931, September 5, *Direktivy VKP(b) i postanovleniya sovetskogo pravitelstva o narodnom obrazovanii za 1917-1947 gg.* (*Directives of VKP[b] and Regulations of the Soviet Government on People's Education in 1917-1947*), Vol. I, 8.
178 *Ibid*.

ingredient was concluded in the constant updating of the curricula with the involvement of leading scientists. For instance, in the two years after 1952, in accordance with the policy of the ‘polytechnization of schools,’

> […] in the lectures on general physics such topics as heat engines of different types, modern hydro-turbines, high-voltage transmissions, and technical uses of X-rays, ultraviolet rays, and gamma rays were treated in considerable detail. The courses in theoretical mechanics […] were adjusted to consider such topics as the technical aspects of friction, the influence of resonance on the performance of the machines, and the kinematics and dynamics of crank drive mechanisms. In teaching elementary mathematics, calculating skills were emphasized, graphic solutions of equations and inequalities demonstrated, and the topic of nomograms added.[179]

Korol provided a comprehensive study of the Soviet educational system with a detailed and historical overview, including mandatory high school education for years seven to ten, and also in various labour and rural schools with some differences for the 15 national republics of the USSR.

According to him, the only historical example of mass education in scale and structure, which can be compared with the SES, was the American educational system (AES). There were more differences than similarities between the two systems. The similarities included the numbers of years of attendance (10 in the SES vs. 12 in the AES) in high school and the structure of the S&T higher education, which was comparable to that of MIT, in Korol’s singular example. However, philosophy and practice differed dramatically. Whereas the American system relied on general education based on the principle of ‘the best specialized training for a certain selected few,’[180] the Soviet system relied on the polytechnic instruction in its curricula as quality of mass education. This orientation of the Soviet ten-year school’s curriculum for science and mathematics made it closer to its European analogues, especially the German one, *Oberrealschule*,[181] established though in the USSR within the ideological framework of Marxism-Leninism.

[179] *Ibid.*, 49.
[180] *Ibid.*, citing from Conant, James Bryant, 1948, *Education in a Divided World*, Harvard University Press, 65.
[181] *Ibid.*, 64.

The authors of the polytechnic instructions defined the right and proportional balance between knowledge, ability, and skills by incorporating engineering and technology into the school course of physics with 'metal fabrication, power generation and distribution, automation, radio, and railroad, automotive, and air transport' as well as 'the mastery of measuring technique – determination of weight, specific gravity, pressure, velocities, efficiency of machines, temperatures, specific heat, electric current characteristics, light and illumination intensities, and others.'[182] Similarly, the course of school mathematics was thoroughly and widely prepared as well as enriched with plenty of measurements and instrumentations of applied mathematics. The overall list of the polytechnic objectives included over 200 pages with every method, phase and element of the teaching process, known to date.[183] The polytechnic instructions continued to be updated in later years.[184]

According to Korol, between 1929 and 1955, the number of elementary seven- and ten-year schools throughout the Soviet Union was around 200,000 with 75,000 schools built and reconstructed after being damaged during the war.[185]

Korol provided plenty of data on the development of the system of Soviet higher education established during industrialisation. Many of them are important and given below in this thesis for the purpose of highlighting both the scale and character of the development of the Soviet education system from the 1930s to the 1950s which was a crucial period. As a result of this development, in 1955, those 33 universities, indicated in the introduction, were distributed throughout the diverse ethnic landscape of the other national republics of the USSR, including all the capitals of the 14 national republics and essential industrial and cultural centres in Russia, as well as in the capitals of some autonomous republics (Voronezh, Gorky,[186] Irkutsk, Rostov-on-Don, Saratov, Tomsk, Sverdlovsk,[187] Molotov,[188] Kazan in Tatarstan, Petrozavodsk in Karelia), Ukraine (Kharkov, Chernovtsy, Odessa, Lvov, Uzhgorod), Uzbekistan (Samarkand) and Estonia (Tartu).[189]

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[182] *Ibid*., 29.
[183] *Ibid*.
[184] *Ibid*., 31-2.
[185] *Ibid*., 38-9.
[186] It is called Nizhny Novgorod now.
[187] It is called Yekaterinburg now.
[188] It is called Perm now.
[189] Korol,156, compiled from 1955, *Spravochnik dlya postupayushchikh v vysshiye uchebnye zavedeniya v 1955 godu*, Moscow, Sovetskaya Nauka; all the names of the geographical locations are given as in the original; the full list of the locations, the numbers of faculties and the numbers of 'specialties' taught in each of the 33 Soviet state universities in 1955 can be found in Appendix F.

The principle of the prevalence of the polytechnic instruction became dominant in the system. In the 33 universities, there were 19 types of 232 faculties there. Overall, 145 out of them were dedicated to the disciplines in science and technology vs. 11 types of 85 faculties in humanities and social sciences.[190] The disciplines in physics and mathematics became the absolute leader with 7 faculties in physics, 25 faculties in physics-mathematics, 7 in mechanics-mathematics and 1 in natural sciences-mathematics, accompanied by 25 faculties in chemistry and 29 faculties in biology and related disciplines, 24 faculties in geology and others.[191] 40 faculties specialising in physics and mathematics were offering 33 courses in mathematics, 33 courses in physics, 14 courses in mechanics, 3 courses in astronomy and 2 courses in geophysics.[192]

According to Korol, in terms of the university enrolment by faculties at the beginning of the 1955-6 academic year in the USSR, among 115,652 students of all 33 universities, 25.64 per cent were enrolled for mathematics and physics and 31.52 per cent for the other scientific disciplines. This constitutes 57.16 per cent of the total university enrolment.[193]

In those 33 Soviet universities, the polytechnic instruction remained a dominant type of the education being nonetheless balanced with the humanities. Also, 19 polytechnic institutions specialising in science and technology were established in the country to cover a similarly extended geography.[194] This number included 392 'specilaities' taught at 132 faculties, with 7 faculties and 20.6 'specialties' in average per institute.[195] Altogether with 4 industrial institutes and 2 correspondence (*zaochnye*) institutions, this made the overall number of the higher education institutions specialising in technology and engineering equal to 25 with 167 faculties of 57 various types.[196] In addition, there were 16 'machine construction, machine tools and, tools, mechanical and auto mechanical institutes' established by the 1950s with 43 faculties and 78 'specialties' taught.[197]

[190] *Ibid.*, 157. The full list and number of all faculties within the 33 Soviet state universities in 1955 can be found in Appendix G.
[191] *Ibid.*
[192] *Ibid.*, 158.
[193] *Ibid.*, 204, citing from 1956, *Kul'turnoe stroitel'stvo v SSSR, Statisticheskii sbornik* (*Cultural Construction in the USSR, Statistical Compilation*), Moscow, Gosstroiizdat.
[194] Table 32, *Ibid.*, 159.
[195] *Ibid.*
[196] Tables 32-33, *Ibid.*, 159-61.
[197] Tables 34, *Ibid.*, 162.

In 1955, among 682 institutes[198] (considered by Korol) out of the overall number of 762 of the higher education institutions, there was a balance between the types of the educational instructions in the study process. 318 out of them specialised in the polytechnic disciplines, and 364 in the humanities.[199] Besides, 14 military schools were 'devoted to other branches of engineering [to] play a similarly important role in their respective fields of applied science.'[200]

The whole system was supervised by the single body, All-Union Committee on the Higher School (*VKVsh*), which became the Ministry of Higher Education in 1946. The Higher Attestation Commission (*VAK*) was formed as part of the Ministry of Higher Education and was in charge of granting academic degrees and titles. Korol stated that '[m]any observers of the educational scene in the Soviet Union have concluded that the degree of selectivity is high and that it is almost solely on academic merit,' although it happened fully only after the discriminatory denial of the parental class origin (bourgeois, or *kulak*) was removed in 1936.[201] Gender equality was also enormously advanced even in terms of modern times, as '[a]pproximately 55 per cent of the 1955 graduates were women, who constituted about 40 per cent of the graduates of schools for industry, construction, transport, and communications and about 80 per cent of the graduates of schools for teacher training.'[202]

According to the 1984 NASA report by Morris Leroy Spearman, *Scientific and Technical Training in the Soviet Union*,[203] the emphasis on science and technology was deeply rooted in Soviet philosophy and was driven by the goal to build communism and the theoretical base was briefly described as follows:

> For example, Karl Marx considered economy and technology to be directly proportional; Lenin related victory or defeat in war with the level of development of science and technology; Stalin said, 'The main thing is to have the Bolshevich desire to master technology.' Thus, to the U.S.S.R., the

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[198] *Ibid.*, 140-1; the table, entitled Number of Institutions of Higher Education Listed by Categories and Type of Instruction, USSR, January 1955, can be found in Appendix E.
[199] *Ibid.*
[200] *Ibid.*
[201] *Ibid.*, 173-4.
[202] *Ibid.*, 201.
[203] Spearman, M. Leroy, 1984, Scientific and Technical Training in the Soviet Union, *NASA Technical Memorandum 86252*, NASA-TM-86252 19840020656, June, Langley Research Center, Hampton, Virginia, 23665; retrieved on 15.05.2016 from the Web, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19840020656.pdf; hereafter referred to as Spearman.

> advancement of science to achieve and maintain technological superiority is a national objective.[204]

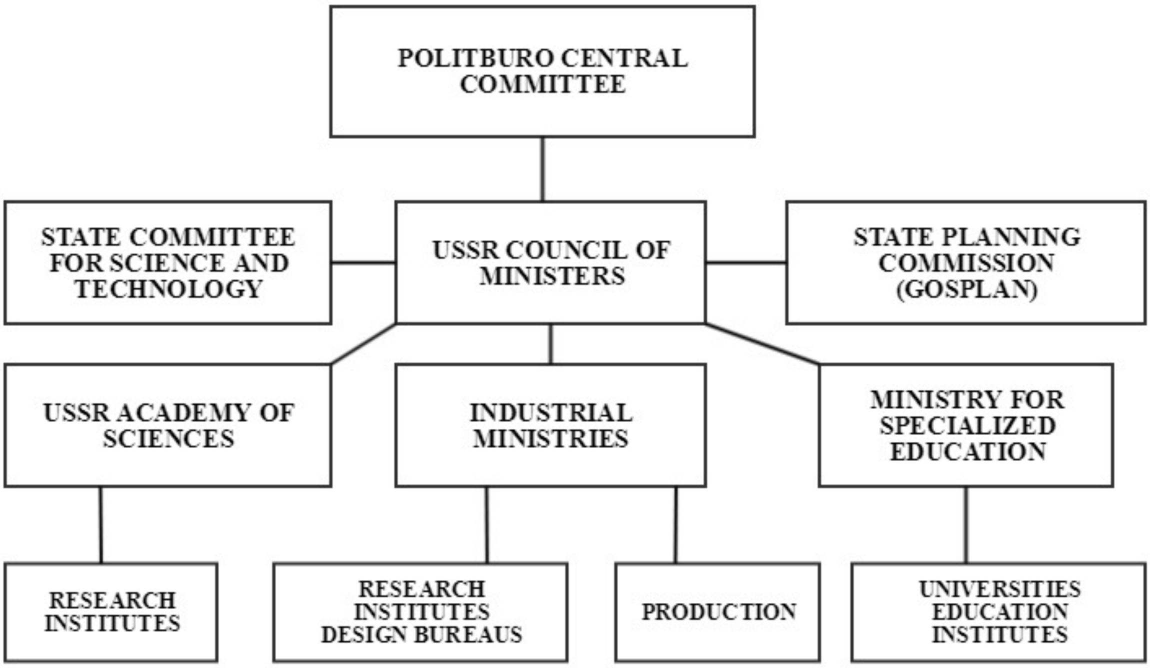
Spearman explained the nature of the Soviet technological policy in connection with scientific, cultural, educational and social development. The scientist emphasised the importance of the psychological and military upbringing for the Soviet system in which the technological education came first in the following statement:

> The Soviet Union recognizes that the foundation of their system depends upon complete dedication of the people to the state through thorough psychological training as well as through military training, and through specialized education in the broad fields of engineering, natural sciences, life sciences, social sciences, and education. The overall cultural development of the people has always been a stated concern of the Soviet government.[205]

He stressed the importance of both the elimination of illiteracy and the creation of the Soviet education system with the emphasis on S&T from the first days of Lenin in power, whose words 'there must be a veritable revolution – the entire people must go through a period of cultural development' were cited in the report.[206] The S&T development was institutionalised through the following structure of power:

Diagram 2 The USSR Scientific and Technical Organisation[207]

[204] *Ibid.*, 2; the word 'Bolshevich' is shown as in the original.
[205] *Ibid.*, 1.
[206] *Ibid.*
[207] *Ibid.*, 2.



According to Spearman, 'This organization shows the close relation between the government, the research institutes and design bureaus, industrial production, and the academic community. It is intended that this organization will assure that training, research, and production are directed toward the priority needs of the central government.'[208] This structure was ensured by Soviet law in which the Soviet Constitution played the primary role.

The functionality and interaction between the system's elements was underpinned by the fundamental rights, freedoms and duties of the citizens of the USSR as established in the leading national act, the Soviet Constitution, through the clauses on social development and culture privileges, in which the Article 26 read: 'In accordance with society's needs the state provides for planned development of science and the training of scientific personnel and organises introduction of the results of research in the economy and other spheres of life.'[209] It also implied that the system of education was designed to fit the overall purpose of the development of science.

The right to education was secured in the Constitution and ensured through the broad provision of all forms of education. Meanwhile, as described in the text:

[208] *Ibid.*
[209] *Ibid.*

> Guaranteed freedom of scientific, technical, and artistic work are proclaimed in Article 47 as follows: Citizens of the U.S.S.R., in accordance with the aims of building communism, are guaranteed freedom of scientific, technical, and artistic work. This freedom is ensured by broadening scientific research, encouraging invention and innovation, and developing literature and the arts. The state provides the necessary material conditions for this and support for voluntary societies and unions of workers in the arts, organises introduction of inventions and innovations in production and other spheres of activity.[210]

In accordance with Constitution, the Soviet system was obliged to create the conditions, incentivise its citizens to get them involved into development of science, technology, and culture (which were indicated as integrated phenomenon) as well as to facilitate the whole process in order to sparkle invention and innovation. The latter was viewed as a foundation of the production.

Spearman outlined ‘the basic principles of public education in the U.S.S.R., as established by legislation, as follows:

- Equality in obtaining an education, regardless of race, nationality, sex, religious attitude, or social status.
- Compulsory education (through 8 years in 1958; through 10 years introduced in 1975). State and public character of all educational institutions.
- Free choice of language – Russian or some other language spoken in the U.S.S.R. (Russian is essential, however, for those who aspire to advance in the party, government, military, etc.)
- Free tuition at all levels of education.
- A unified system of education and continuity of instruction at all institutions.
- Unity of instruction and communist upbringing between school, family, and society in raising the younger generation.
- Linking education of the younger generation to meet the requirements of life and of the building of a communist society.
- A scientific approach to education with constant improvement based on the latest developments in science, technology, and culture.

[210] *Ibid.*, 3.

- Humanism and high moral principles in education and upbringing.
- Co-education of boys and girls.
- Secular character of education ruling out religious influences.'[211]

The main features of the SES can be illustrated through the example of the Yeysk Higher Military Aviation School.[212] Spearman made use of the five Soviet textbooks on aviation to illustrate the developed level of the indigenous industry (the footnote below).[213]

According to Spearman, in engineering, 'the U.S.S.R. produced greater numbers of graduates at persistently growing rates compared to the U.S. which produced a smaller number of engineers at an essentially constant rate.'[214] He went on to say, 'The U.S.S.R.'s rate of growth and increasing number of graduates [in engineering] is readily apparent, having grown from about 100,000 in 1960 to over 300,000 in 1982. The U.S. rate of growth is imperceptible and the number of graduates has remained constant at about 50,000 for the past twenty years.'[215]

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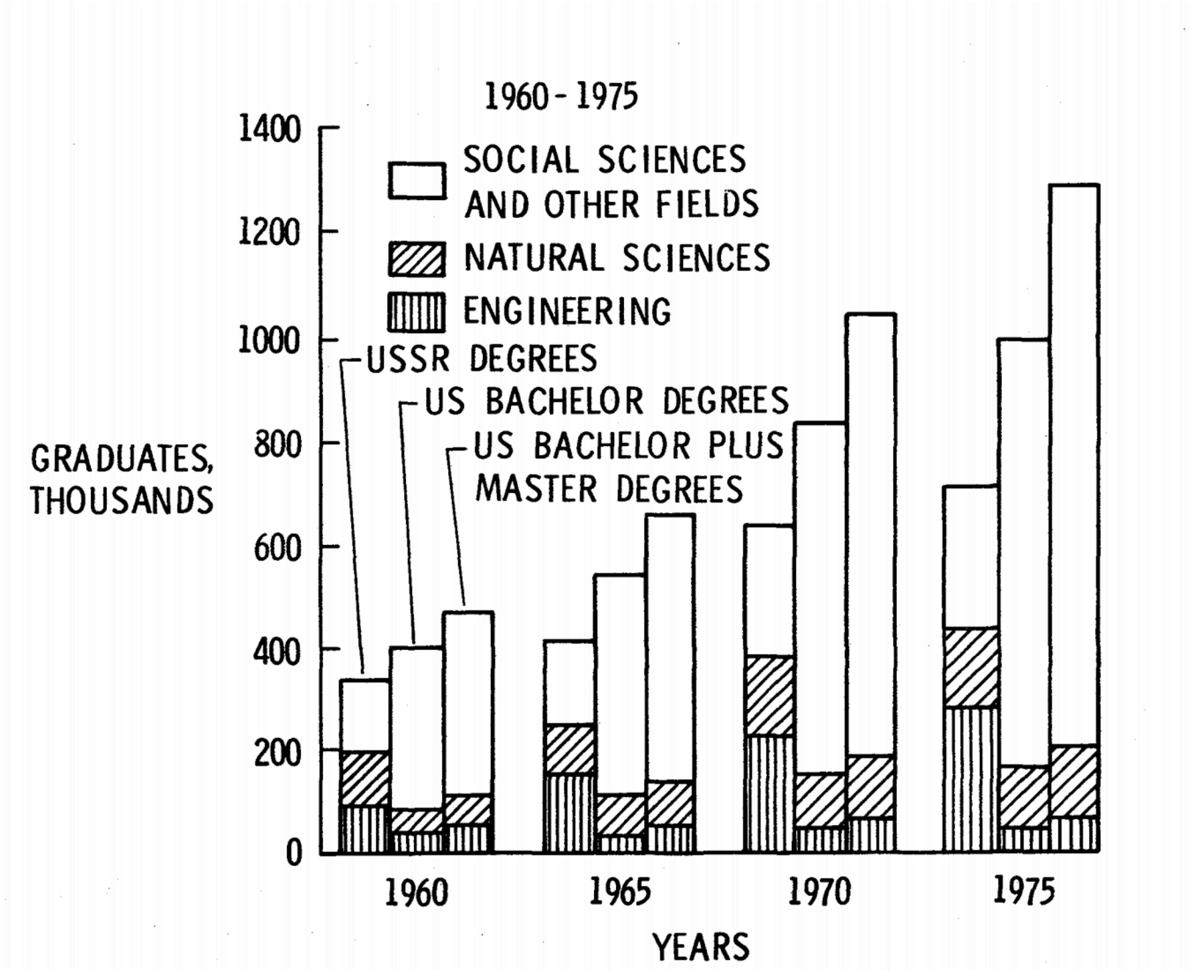
[211] *Ibid.*, 4.
[212] *Ibid.*, 9-10.
[213] *Ibid.*, 10-11, referring to the following:

- Aeromechanics of Aircraft by V. B. Baydakov and L. N. Ivanov-Emin, Moscow, 1965. Translated by USAF as FTD-MT-24-250-67. This book outlines the fundamentals of aeromechanics, properties of the atmosphere, characteristics of wings, modern methods of aerodynamic investigations, stability and control, aerodynamic and ballistic design. The book contains a section on interference effects including the theory and use of the transonic and supersonic area rule. The book is intended for use by students in technical aviation schools and medium-level technical personnel in the aviation industry. (It should be noted that there is ample evidence of the use of techniques such as the area rule in Soviet aircraft.)
- Control of Supersonic Aircraft by F. I. Sklyanskiy, Moscow, 1964. Translated by USAF as FTD-MT-65-89. This book contains sections on the equations of motion, stability and controllability, transonic and supersonic effects, supersonic aircraft design methods, control forces, automatic control systems, future control developments (including electric controls), deformation effects, and aspects of safety of flight and emergency control.
- Design Principles of Rocket-Ramjet Engines for Unmanned Flight Vehicles by B. v. Orlov, G. Vu. Mazin, et al, Moscow 1967. Translated y USAF as FTDMT-24-208-68. This book, intended for students of senior courses of technical universities, contains sections on the design and characteristics of inlets, internal ballistics of rocket-ramjet engines, propellants, operating and working characteristics of rocket-ramjet engines, design of rocket-ramjet flight vehicles, automatic control systems for engines, and fields of application.
- Vertical Landing and Takeoff Aircraft by V. F. Pavlenko, Moscow 1966. Translated by ASI as FSTc-HT-23-887-68. This book, intended primarily for students at military and civil aviation institutes, sets forth features of design and performance of a variety of types of VTOL aircraft. Attention is given to power plants as the most important and decisive factor in VTOL design, stability and control, transition flight, jet interactions, and safety. It is interesting to note that one of the concepts included for a composite power plant VTOL design is quite similar to the YAK-36 Forger aircraft that was deployed on the Kiev cruiser in 1976.
- Helicopters, Selection of Design Parameters by M. N. Tishchenko, A. V. Nekrasov, and A. s. Radin, Moscow 1976. Prepared for publication by W. Z. Stepniewski and W. L. Metz, International Technical Associates, Ltd. for AVRAOCOM, Ames Research Center, Contract No. NAS2-10062, April 1979. This book may be of direct use to practicing engineers or for an academic course on the design of rotary-wing aircraft. The book deals primarily with transport-type helicopters and covers optimization parameters, effectiveness evaluation, maximum-payload criteria, technological factors related to blade weight, and cost criteria. One figure in the book is of interest since it illustrates an eight-blade rotor hub, and the new Soviet Mi-26 Halo heavy-lift helicopter uses, for the first time, an eight-blade rotor.

The emphasis is in the original.
[214] *Ibid.*, 11.
[215] *Ibid.*, 12.

According to Spearman, overall, the USSR's progressive growth in the numbers of graduates and the growth rate for the fields of natural sciences exceeded that of the US as shown in the following figure:

Figure 1 US/USSR Higher Education Graduates by Specialisation, 1960-1975[216]



This was defined by an 'emphasis on engineering and natural sciences in the U.S.S.R. and emphasis on social sciences in the U.S. [which was] a reflection of the national priorities and objectives as perceived by the state in the U.S.S.R. and as perceived by the students and the schools in the U.S.'[217]

Spearman concluded the NASA memorandum with the following statement:

> At the heart of the matter, the Marxist view that economy and technology are directly proportional appears to be evident […] The intensity and the

[216] *Ibid.*, 15.
[217] *Ibid.*, 11

organization of the academics, coupled with practical work experience, and the persistent political indoctrination, provides the potential for a highly-educated and highly-dedicated Soviet in the work force, military, or government. In any event, if the state-controlled system can be maintained, the Soviet Union will continue to be a dominant factor that cannot be ignored in world political, economical, technological, and military matters.[218]

Overall, the NASA report outlined the connection between the development of the social and education base and the development of S&T on the one hand, and a Soviet leadership in technology on the other, emphasising the importance of technology for the economy.

In 1970 Mstislav Keldysh, President of the Academy of Sciences of the USSR from 1961 to 1975 and a leading scientific organiser of the Soviet space programme, made multiple statements in an article concerning Lenin's personal involvement in matters of setting science and education as national priorities for Soviet policy.[219] Keldysh directly connected the Soviet launch of *Sputnik* on 4 October 1957 to the Soviet education and science policy founded by Lenin who, 'from the first, realized the importance of the role that science was to play in the rebuilding of his country.'[220]

Referring to Lenin's article *Materialism and Empirio-criticism* (1909),[221] Keldysh observed:

> Our knowledge is relative, Lenin wrote, and knowledge of nature progresses by gradual improvement in scientific thought approaching ever closer to the truth. The great discoveries in physics at the turn of the century prove one thing, he said, namely, the inadequacy of the mechanistic concept. Matter does not "disappear" but manifests itself in new, more concrete forms, hitherto unknown, providing science with a deeper understanding of the physical properties of matter and the interrelations existing between its different states and conditions.[222]

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[218] *Ibid.*, 12. The words 'work force' and 'economical' are referred as in the in original.
[219] Keldysh, Mstislav, 1970, Lenin and Development of Science, Lenin and Education, Science, Culture, *The UNESCO Courier*, 6-11; retrieved on 02.07.2017 from the Web, http://unesdoc.unesco.org/images/0018/001844/184442eo.pdf; hereafter referred to as Keldysh.
[220] *Ibid.*, 6.
[221] Lenin V.I., 1909, *Materializm i empiriokrititsizm, Kriticheskie zametki ob odnoi reakzionnoi filosofyi* (*Materialism and Empirio-criticism, Critical Comments on a Reactionary Philosophy*), Moscow, OGIZ, Gosudarstvennoe izdatelstvo politicheskoi literatury, The 1946 Edition; hereafter referred to as Lenin, 1909.
[222] Keldysh, 6.

According to Keldysh, Lenin contributed to the philosophy of science which later developed into the foundation of the methodology of contemporary science[223] and emphasised the interconnection between social and natural sciences in the revolutionary's own words of 1922: 'Natural science is progressing with such speed and undergoing such revolutionary upheavals in every field that the sciences cannot do without philosophical conclusions.'[224] Keldysh continued citing Lenin to outline the importance of technology and culture for development in Soviet philosophy: '[T]he genius of man's mind was used to provide the benefits of technology and culture to a part of the population, depriving the others of the basic essentials, education and progress. Now, all the wonders of technology, all the conquests of culture are to be the heritage of all people.'[225]

Keldysh argued that Lenin's contribution was not limited to theory and emphasised Lenin's role in the establishment of Soviet science policy. In particular, the academician wrote, 'Lenin was deeply conscious of the tremendous importance of science for development. He kept a permanent eye on all matters having to do with the organization of scientific research in the Soviet Union, and lost no opportunity to promote the maximum use of science and technology to improve the standard of living of the population.'[226] Keldysh included in the article evidence of relevant Lenin's decrees and orders which established or expanded research in various disciplines including geology, physics, aviation, optics, and engineering.[227] In particular, '[t]he activities of the U.S.S.R. Academy of Sciences received his special attention. For Lenin, the participation of this scientific institution in the economic development of the country was of capital importance,'[228] wrote the academician.

In Soviet developmental policy, the role of the Academy of Sciences was viewed as prevailing 'in bringing about a revolutionary change in the advancement of the country […] to mark its entire later development. Within half a century, the little coterie of scientists it had been composed of before the revolution, became a scientific centre of the very highest importance which was to direct the development of the natural and social sciences throughout

[223] *Ibid.*, 8.
[224] *Ibid.*
[225] *Ibid.*, 9.
[226] *Ibid.*, 8.
[227] *Ibid.*, 9
[228] *Ibid.*

the nation.'[229] The institutionalisation and expansion of scientific research in the Soviet Union were outlined by Keldysh as follows:

> [In] 1917 the Academy had only one research centre which consisted of a few laboratories and museums. Today it controls 210 scientific establishments including 160 research institutes all of which are contributing to the development of modern science. With a complement of some 250,000 research workers, the Academy's personnel has multiplied one hundredfold and its present budget is astronomical when compared to the meagre sum expended in the earlier years.[230]

The policy led to the establishment of research in all the republics of the USSR, in which each Academy conducted research in the entire spectrum of modern disciplines, excelling at some particular of branch of research. For Ukraine they were cybernetics, solid state physics, geology, and physical chemistry; for Armenia – astrophysics; for Georgia – theoretical mechanics; for Uzbekistan – the chemistry of alkaloids; for Kazakhstan – the geological research; for Azerbaijan – the petrochemical studies; for Latvia – organic synthesis, *etc*.[231] Special attention was given to the development of fundamental research and the applied sciences in Siberia where Novosibirsk was developed as the coordinating centre. It took 'the lead in certain branches of Soviet research and […] won world recognition for its pioneering work. New branches of the Academy [were] established in the Urals, the Far East, and other parts of the country.'[232]

Meanwhile, '[t]he Academies of the Republics play[ed] a large part in solving particular regional problems. Those of Central Asia [paid] special attention to the scientific culture of cotton crops, the study of deserts and their exploitation and seismological problems.'[233] Keldysh pointed out that, apart from the SAS, research in agriculture, medicine and education was conducted in separate academies. He emphasised, in particular, 'the brilliant successes of Soviet mathematics, discoveries in the field of radio-electronics, Soviet contributions to the theory of solids, the theory of resistance, aerodynamics and mechanics,'[234] as well as in chemistry – to 'the development of the theory of chain reactions, contributions to organic

[229] *Ibid.*, 10.
[230] *Ibid.*
[231] *Ibid.*, 11.
[232] *Ibid.*, 10.
[233] *Ibid.*
[234] *Ibid.*

chemistry, and the chemistry of elementary organic combinations. Soviet scientists have shown the way towards the peaceful uses of nuclear energy and have enunciated the basic principles for the ultimate achievement of controlled nuclear reactions.'[235]

According to Keldysh, Soviet urban planning established the republics' Academy of Sciences in the national capitals as the central places of growth which had spill-over effects in other spheres of development. They were accompanied with around 800 establishments of higher education throughout the country which also carried out research in a wide spectrum of fields. One of the key characteristics of Soviet science was viewed in the close connection established 'between fundamental research and the resolution of economic problems of a practical nature. For their part, those scientific organizations that serve[d] the various specialized sectors of the economy participate[d] widely in helping to solve the great problems of science,'[236] concluded Keldysh, emphasising the primacy of research in modern economic development and the interconnection of science and production.

According to I.G. Kurakov's *Science, Technology and Communism, Some Questions of Development*, science was a direct productive force in the Soviet society:[237]

> The tasks of science should not be limited only to the study and analysis of natural and social phenomena. Scientists should not only explain such phenomena or discover the objective laws of the development of nature and society; they should also work out methods for their practical utilization in order to ensure the continual and rapid development of the productive forces of society and to create the material and technical basis of communism.[238]

In Kurakov's account, the mankind had been developing due to all the human knowledge accumulated, and if not for science, 'society would have to start its development all over again from the Stone Age. The tremendous material destruction in our country made by the Nazi invaders was overcome in a short time largely because we had men with an even higher level of knowledge than before the war.'[239] Thus, in his view, science played an irreplaceable role in material production and represented the main factor for the

[235] *Ibid.*
[236] *Ibid.*, 11.
[237] Kurakov, chapter 1, Science as a Direct Productive Force in Society, 1-13, and in particular, 1.
[238] *Ibid.*, 3.
[239] *Ibid.*, 8.

development of the productive forces in the period of full-scale communist construction in the USSR. Meanwhile, techniques, technology and the organisation of production derived from science defining labour productivity, according to Kurakov.[240]

While describing the methods and meaning of science, the scholar emphasised the essential social significance of knowledge. In his view, knowledge can be accumulated, primarily, through practice and experience, and 'secondly, through purposeful investigations, constructive studies and generalizations of practice, in other words through science, which is itself a generalization of practice. For a long time the type of knowledge that accumulated through practical experience was the sole source of knowledge in society […] In our time science represents the basic source of fresh knowledge and consequently, science is also the basic means of increasing the social productivity of labour.'[241]

According to Kurakov, the increase in labour productivity defined the growth of the national income stemming from the higher productivity of labour and making the volume of the total social product larger: 'As is well known, the growth of labour productivity is basically due to the application of new science and technology. Thus, the fulfilment of the targets for the growth of labour productivity, defined in the Programme of the C.P.S.U., depends largely on the development of science.'[242] This connected the development of both science and the Soviet society.

As a Soviet scholar during the times of the Cold War, he claimed the superiority of the Soviet economy over all the capitalist countries due to its prevailing number of labour with a high standard of knowledge as the result of the Soviet development of science and education as follows:

> Forty per cent of all workers and 23 per cent of the collective farmers in our country have received higher and secondary education. The total number of qualified engineers engaged in the economy of the U.S.S.R. amounted to 1,135,000 in 1960, as against 525,000 in the U.S.A. In the academic year of 1961/62 the number of students per 10,000 inhabitants amounted to 120 in

[240] *Ibid.*, 12.
[241] *Ibid.* 8.
[242] *Ibid.*, 35.

> the U.S.S.R. and to 111 in the USA; Japan had 63 in 1960/61, France 44 in 1959/60 and the Federal Republic of Germany 34.[243]

Meanwhile, Kurakov explicitly warned of the disadvantages of the existing Soviet system of material incentives claiming that the system was 'not sufficiently closely connected with the productivity of labour' and called for its fundamental change.[244] In particular, he wrote the following: 'The implicit slogan "fulfil the plan at any price" gradually came to be accepted by a considerable number of economists and managers and became a serious obstacle to the growth of the national economy.'[245] In his approach, as the improvement of planning was one of the basic tasks of science, the latter was to provide 'the continuous improvement of the plan indicators, of the methods for selecting the range and standard dimensions of the products to be produced, of the methods for fixing the annual rates of increase in the volume of production of each type of product' in order to solve a series of other urgent problems in planning.[246]

For instance, Kurakov indicated the examples for this in the production of new synthetic materials in the chemical industry and in the increase in the productive capacity of separate sections in the improvement of the quality of raw materials and fuel in the mining industry.[247] He classified the problems into fundamental, sectoral, territorial, inter-sectoral and inter-territorial ones. Kurakov attributed the leading role in resolving the fundamental ones to the SAS and envisaged its assisting roles on the different levels to the various committees or territorial governments of the extensive Soviet structure in resolving the rest of the problems.[248] In his approach, the role structure was dependant on the following structure of problems, themes and tasks:

> For instance, one of the directions in the improvement of the production of mechanical energy is the production of electricity by means of semiconductors, powerful solar batteries or other similar devices. The production of electricity by means of semiconductors is one of the problems in generating electricity by a fundamentally new method. This problem of semiconductors is then divided into a series of themes, for instance,

[243] *Ibid.*, 9.
[244] *Ibid.*, 15.
[245] *Ibid.*, 16.
[246] *Ibid.*, 37-8
[247] *Ibid.*, 71.
[248] *Ibid.*, 71-3.

> investigation of methods for obtaining germanium from coal and lignite, the production of high purity quartz, and so forth. Each of these is then sub-divided into separate tasks.[249]

Meanwhile, in his view, a continuous interaction of science and technology should be thoroughly planned in order to avoid delays in work as it had been increasingly done since 1949 and, in particular, since 1956[250] in planning the provision of the scientific infrastructure, materials and machinery as well as in training of the key scientific personnel.[251] He criticised the existing practice of the one-year scientific plans: 'As a rule it takes several years to elaborate most of the scientific themes. If the plans are limited to one year only, the various stages of the research work are often delayed, either due to lack of sufficient means for its next stage, or due to lack of people to continue the work, or because pilot plants are not set up in time, or for some other reason.'[252]

Kurakov provided an illustrative example of an early Soviet scientific discovery leading to a further development into technology and transforming Soviet and global industry and economy. It was the invention of synthetic rubber by the method developed by S. V. Lebedyev (Lebedev)[253] at the beginning of the 1930s.[254]

Kurakov stressed out the primary importance of basic research, without which rapid development of science and technology is impossible. As both the total costs or the economic potential for this kind of research work cannot be estimated in advance, as pointed out by him, it is not needed to define the economic potential for basic research activities. Meanwhile, the Soviet scholar particularly emphasised that '[f]unds for basic research must be allocated according to requirements, although it is known in advance that some of this work will be useless.'[255] He issued a warning that '[t]he slightest stagnation in science is immediately reflected in national economic development, reducing the rate of increase in the national income.'[256] In general, according to Kurakov, the lack of a

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[249] *Ibid.*, 72.
[250] *Ibid.*, 108.
[251] *Ibid.*, 109.
[252] *Ibid*.
[253] Sergey Vasilevych Lebedev, Russian Chemist, *Encyclopaedia Britannica*; retrieved on 18.05.2019 from the Web, https://www.britannica.com/biography/Sergey-Vasilyevich-Lebedev; hereafter referred to as Lebedev.
[254] Kurakov, 96. In more detail, this example is elaborated in subchapter 4.3 below.
[255] *Ibid.*, 116.
[256] *Ibid.*, 13.

successful solution of a certain problem in the field of science and technology can be explained by insufficient knowledge of the matter.[257]

2.1.3 Conclusion

The key points of this dissertation's literature review are the following. The variety of the views observed illustrates the gap in literature identified in the introduction and section 2.1 above. Some of the Western scholars like Sutton or those of the 1983 US Congress Report regarded Soviet development based on the economic indicators and pluralist political system of the Anglo-Saxon countries. Meanwhile, the other group represented by Soviet and American scientists and engineers viewed the Soviet technological development in connection to Marxist non-economic, historical, educational, and other social factors. However, none of the scholars considered in the literature review would combine all of the Soviet paradigms into the whole.

The continuum mentioned in section 2.1 illustrates that some of the authors' attitudes of both groups towards Soviet development can be explained by their pretty natural biases due to their official positions during the Cold War. On the negative side, this can be the case for Anthony Sutton of the US Hoover Institution, who was doing his study in 1968-71, or for the 1983 US Congress Report. For example, Sutton did not mention Yuri Gagarin's name in his three volumes dedicated to the Soviet technological development and whose name did not appear in the Index to Volume III on the period of 1945-65.[258] The timing of the publishing is pretty indicative in this sense as well. Both studies were published at the two peaks of the Cold War before and after *Détente* of the 1970s and were possibly connected to the space race between the two superpowers and Ronald Reagan's coming to power in the US at the end of 1980 respectively. Meanwhile, the scientific report by Paul Cocks, written for the US National Science Foundation in the mid-1980 as a part of the mutual American-Soviet agreements of *Détente*, was more neutral in the evaluation of the state of the science and technology affairs in the Soviet Union.

The praising attitude of Dzhermen Gvishiani (a deputy chairman of the USSR State Committee for Science and Technology) or Mstislav Keldysh (an official member of the Central Committee (the *TsK*) of the Communist Party of the Soviet Union, or the CPSU) can

[257] *Ibid.*, 8.
[258] Sutton III, 457-82, 466.

be, on the one hand, partly explained by ideological reasons. On the other, such an explanation would not shed light on a similar approach undertaken by Morris Leroy Spearman of NASA or Alexander Korol of MIT, both of whom stood positively towards Soviet development. Therefore it would not entirely fit the ideological or policy-making framework. Cocks's, Korol's, Keldysh' and Spearman's positioning as that of the representatives of science and technology whose papers were addressed to the scientific community should be perhaps rather understood from the concept of the universalism of science beyond borders and political views which is going to be discussed in chapter 4. As seen from the literature review, the assessments of what particular sets of the Soviet policies led to the Soviet industrial development varied quite dramatically. This was defined by the differences in scholars' views on the role of science across the overall technology and innovation chain. The literature review illustrates that it is not a settled question and there is a gap which this thesis aims to fill in.

The next section is dedicated to the methodology employed for this thesis to try to resolve the dichotomy established and address the research question.

2.2 Methodology

As the primary research method, the qualitative approach is applied here which uses semi-structured interviews and archival work. The latter includes analysis of historical and primary documents for data collection.

In this thesis, qualitative study approaches are employed as best-suited to the analysis of those specific relationships of science with engineering, technology, and innovation across the overall industrial chain and in interaction with the particular sets of the various Soviet industrial and social policies in the development of the USSR. As seen from the literature review above, a quantitative methodological approach towards the technologies and their origin could not inform the reader in understanding of the drivers of Soviet development in full. In a similar vein, using quantitative methods towards Soviet social policies could be not enough to evaluate their possible effect on the formation of the human capital and industrial development.

Thus, the qualitative method is chosen as a useful way to evaluate the development policies of the Soviet Union in the context of the interaction between the state, academia, and industry.

Information from all three institutions has been used separately to provide qualitative evidence. It does not invalidate a quantitative approach. An important piece of the study is the information received from the interviews through the questionnaire. The latter was designed in order to collect the following information.

The full list of the questions for the interviewees can be found in Appendix A. The questionnaire was designed to shed light on science and its place in the interaction of the academia, state, and industry in Soviet development. In the literature review above, the scholars of both sides, like Sutton or Spearman, identified technology as a critical factor in Soviet development. However, their visions of the driving forces of the Soviet technological development varied quite dramatically. It raised questions on both the importance of technology transfer, and the role and place of fundamental research and education in relation to industrial research and technology. It requires a more profound analysis of the reasons of the Soviet industrial policy.

The Soviet state allocated tremendous funding and applied many efforts in developing the Academy of Sciences of the USSR and the national human capital through education and social programmes, connecting these allocations to the industrial development. This makes the notion of science tangibly identified as connected to technology in Soviet policy and requires the delineation between science and technology as two distinct notions within the terms of Research & Development (R&D). Thus, a research method of collecting primary data through interviews was used in order to fill in these gaps designated above.

The interviewees were divided into two groups. Unlike in the literature review above, the division was made not on the base of their attitude towards the sets of the particular Soviet policies but on the ground of the primary or secondary knowledge of the Soviet and successor systems from within or outside respectively. The questionnaire nonetheless remained identical for both of the groups.[259]

The first seven questions were designed to shed light on the following: i) the role of fundamental science in connection with economic development; ii) how discoveries in fundamental science may lead to disruptive and marketable technologies; iii) whether a sustainable technological development of large developed countries (or companies) was

[259] Appendix A.

clearly linked to a strong fundamental science research base; iv) and whether discoveries in science could be driven by market demand (as a search for practical and profitable solutions).

The other group of four questions was formed under the influence of the observation of the second group of the authors in the literature review above. It is about the Soviet industrial policy which used fundamental science for a rapid industrialisation and included the following topics: i) how crucial was technology transfer for the Soviet industrial development; ii) what was a Soviet science and technology contribution to global technological development; iii) and what was the respondent's attitude, speaking of any country's technological development, towards the idea to rely solely on technology transfer in order to achieve economic success instead of both educational and social structural reforms, as well as without developing an indigenous science and technology base. The question of Pyotr Kapitsa's contribution to global science and technology was addressed to those scientists who might have been familiar with his discoveries in their scientific activities in a similar field.

In the interviews of the first group of insiders from the Soviet system, the reconstruction of the historical context from a survivor of the era, Vladimir Nekrasov, was valuable and should be emphasised here. He was one of Stalin's last assistants (*referenty*) in 1952-3, and afterwards, head of the legal department of the Soviet and Russian Government (1953-97). The interview took place during three days in 2013-4 and was conducted in the form of a non-structured and unrecorded interview,[260] and so was an interview with Galym Abilsiitov. In a similar vein, an interview with Giorgos Tsironis of the second group was through a less structured questionnaire as being the first one of that kind with a scientist. Meanwhile, it helped the author both develop a better understanding of the topic and design the questionnaire at a later stage.

The first group also included the following interviewees: Galym Abilsiitov, a founding director of the Soviet R&D Centre for Laser Technology and a former and founding Minister for Science and New Technologies of the Republic of Kazakhstan;[261] Ovanes Mikoyan, a former deputy head of the *MiG*, the famous Soviet/Russian military aircraft

[260] Nekrasov, Vladimir, 2013-4, Three interviews at his *dacha* in Krasnovidovo near Moscow on 19-20 Nov 2013 and 14-15 Dec 2014; hereafter referred to as Nekrasov.
[261] The interview with Galym Abilssitov was held on 15.01.2016 at his house in Troitsk, near Moscow; hereafter referred to as Abilsiitov.

design bureau, which was one of the pioneers of the global jet aviation;[262] Robert Nigmatulin, Real Member (Academician) of the Russian Academy of Sciences (the RAS), Member of Presidium of the RAS, Director of P.P. Shirshov Institute of Oceanology;[263] the three following the Lomonosov Moscow State University's (the MSU's) Professors in physics, chemistry and political economy respectively from Russia, namely Alexander Vasiliev,[264] Andrey Kaul,[265] and Alexander Buzgalin;[266] physicist Viktor Eremenko (Ukraine and the Soviet Union);[267] as well as Yuri Zhukov, a leading Soviet/Russian historian.[268] In addition, some data from a joint interview with both Andrey Kaul and Alexander Molodyk (Russia)[269] are included for consideration in revealing some particular technical aspects and details in the development of a contemporary Russian high-tech firm.

Before detailing the second group of the interviewees from the outside of the Soviet system, it is necessary to mention the two following considerations of the difficulties emerged. Firstly, it was the loss of the interest in the studies on Soviet S&T in the West. In the conditions of a quarter of a century after the end of the USSR, these studies lost both the funding and the scholars. Among the survivors, only Julian Cooper (considered in the literature review)

[262] Mikoyan, Ovanes, the first deputy of the `General Director of the Russian Aircraft Corporation *MiG* and a son of Artyom Mikoyan, the founder of the *MiG*, formerly known as *Mikoyan & Gurevich Design Bureau*, two interviews took place on 12.12.2014 and 05.04.2017 in Moscow, Russia; hereafter referred to as Mikoyan.
[263] Nigmatulin, Robert Iskandrovich, Doctor of Physical and Mathematical Sciences (1971), Professor (1974), Real Member (Academician) of Russian Academy of Sciences (1991), Member of Presidium of Russian Academy of Sciences (2006), Director of P.P. Shirshov Institute of Oceanology (2006 - present*), Curriculum Vitae*; retrieved on 04.07.2017 from the Web, http://www.ocean.ru/eng/content/view/94/; the interview took place on 05.04.2017 in Moscow; hereafter referred to as Nigmatulin.
[264] Vasiliev, Alexander N., Chair of Low Temperature Physics and Superconductivity, Head of Solid State Physics Division, Faculty of Physics, *M.V. Lomonosov Moscow State University* (MSU); retrieved on 04.07.2017 from the Web, http://www.ml.pan.wroc.pl/assets/files/male-goscie/Vasiliev_CV-2016B.pdf; the interview took place the interview was recorded on 04.03.2017 at the Division mentioned above, the MSU, Moscow; hereafter referred to as Vasiliev.
[265] Kaul, Andrey, Laboratory of Coordination Compound Chemistry, Head of Laboratory: Professor Andrey Rafailovich Kaul, *Division of Inorganic Chemistry*; retrieved on 06.04.2017 from the Moscow State University Web Site, http://www.chem.msu.ru/eng/chairs2/inorg/welcome.html, and a scientific supervisor of the *SuperOx* company, both a visit to the company's production facilities and the interview took place on 07.04.2017 in Moscow; hereafter referred to as Kaul.
[266] An interview with The Moscow State University Professor of Political Economy Alexander Buzgalin, recorded on 09.05.2017 at the University of Cambridge; hereafter referred to as Buzgalin.
[267] Viktor Eremenko, Senior Fellow and Advisor to the Directorate of B. Verkin Institute of Low Temperature Physics and Engineering (ILTPE) of the National Academy of Sciences of Ukraine; retrieved on 03.07.2017 from the Web, http://www.ilt.kharkov.ua/cpuei2012/eremenko_e.html; the interview was recorded on 01.09.2016 in Kharkov, Ukraine; hereafter referred to as Eremenko. Unfortunately, this brilliant physicist passed away on 02.05.2017.
[268] Zhukov, Yuri Nikolaevich, Institut rossiyskoi istorii RAN (*The Institute of the Russian History, The Russian Academy of Sciences*); retrieved on 02.04.2017 from the Web, http://iriran.ru/?q=gukov. The interview was recorded on 03.04.2017 in Moscow; hereafter referred to as Zhukov.
[269] Molodyk, Alexander, Technical Director, *SuperOx*, both a visit to the company's production facilities and interviews took place on 07.04. 2017 in Moscow; retrieved on 21.04.2017 from the Web http://www.superox.ru/en/; hereafter referred to as Molodyk.

responded, who however concentrated his research on contemporary Russia having no longer interest to the subject of the Soviet Union after retiring.[270]

Secondly, as mentioned above, unlike social scholars' polar views, scientists' view on the role of Soviet science as well as its connection with the technological development was pretty unified despite belonging to the different camps of the Cold War. Thus, an insight from scientists and engineers became important for addressing the research question. In particular, this would be the case for those scientists who could have combined the experience of working in both the Soviet and Western systems and could share their visions. However, approaching them revealed a challenge, e.g. David (Dima) Khmelnitskii, both Soviet and Cambridge's physicist, refused to discuss the topic.[271] Instead, an interview with Timour Paltashev, a Soviet/Russian-US computer scientist, was recorded and placed to finalise both groups of the interviews. Paltashev graduated from the Kazakh Polytechnic Institute in 1978[272] and obtained two Soviet scientific degrees (*kandidat* and *doktor nauk*, i.e. PhD, in Computer Science) in 1987 and 1994 respectively from National Research University of Information Technology, Mechanics and Optics (ITMO), St. Petersburg, Russia.[273] He is full professor of the department of computer science & engineering of ITMO, and professor of the Northwestern Polytechnic University in California,[274] the USA, as well as a current AMD[275] Radeon Technology Group senior manager, involved in applied and industrial technology research & development, as well as in start-up activities in the US, Russia and Kazakhstan. He is familiar with the Soviet and post-Soviet technological development.

[270] In the correspondence, on 16.08.2016 Cooper wrote to the author the following: 'I am very sorry but I am now retired and my only involvement with university matters of any kind is my own personal research. This extends to students here in Birmingham as well as elsewhere. So, I wish you well with your research but will not read your [First Year] report. My work these days only relates to present-day Russia.'

[271] David Khmelnistkii; retrieved on 10.03.2017 from *the University of Cambridge*'s Website, http://www.tcm.phy.cam.ac.uk/~dek12/Welcome.html. In his letter of 13.03.2017, Khmelnistkii answered negatively to my request for an interview.

[272] Timour T. Paltashev, a AMD Radeon Technology Group senior manager, Professor of the University of California, Berkeley, the US and full professor of the department of computer science & engineering of National Research University of Information Technology, Mechanics and Optics (ITMO), St. Petersburg, Russia, and professor of the Northwestern Polytechnic University in California, the USA.; the interview was recorded on 01.06.2018 in Almaty and complemented in the correspondence on 06.06.2018 with his presentation, available in the Web, http://www.ifmo.ru/file/news/1481/electronic_industry_engineering_revival_ifmo_lecture.pdf; hereafter referred to as Paltashev.

[273] *National Research University of Information Technology, Mechanics and Optics*, St. Petersburg, Russia; retrieved on 03.06.2018 from the Web, http://en.ifmo.ru/en/ .

[274] *Northwestern Polytechnic University*, Fremont, California; retrieved on 03.06.2018 from the Web, http://npu.edu/.

[275] Advanced Micro Devices, Inc. (AMD); retrieved on 03.06.2018 from the Web, https://www.amd.com/en.

The second group of interviewees is the international scientists and engineers, such as Peter Littlewood (the UK, the US),[276] Gilbert Lonzarich (the US, Canada, the UK),[277] Tony Raven (the UK),[278] Siddharth Saxena (the UK, India, Central Asia, Russia),[279] James Jackson (the UK, the US),[280] Giorgos Tsironis (Greece, the US, Russia, Kazakhstan),[281] and Shashikumar Chitre (India, the UK, the US).[282] While their evaluations of the role of science across the overall industrial chain of the engineering, technology, and innovation is very valuable as the primary source, some of the interviewees' visions of Soviet development could be viewed as partial and secondary ones due to their natural biases deriving from their background and official positions of not being experts on this particular subject. However, a profound look into the scientific approach, as implied during an analysis of Soviet science in connection with global development in chapters 4 and 5, might amend this impression.

Thus, the questionnaire was designed to make an enquiry into the notion of science and its functionalities within the context of the industrial and overall development as well as to show the role of discovery in developing applications. The aim was to fill the gap in economic and business literature on fundamental science and its role in designing development policies in general and in the Soviet Union in particular as shown in chapter 3 and analysed in chapters 4 and 5.

[276] Peter B. Littlewood, a former head of both the Argonne National Laboratory, Chicago, USA, and The *Department of Physics/The Cavendish Laboratory*; retrieved on 04.03.2017 from the University of Cambridge Web Site, https://physics.uchicago.edu/page/peter-littlewood; the interview was recorded on 02.03.2017 via *Skype*; hereafter referred to as Littlewood.
[277] Lonzarich, Gilbert, 2017, *Replies to Chokan Laumulin's Questionnaire for a PhD thesis, Gilbert G Lonzarich, Cambridge, 26-05-2017*; hereafter referred to as Lonzarich.
[278] Dr. Tony Raven – Chief Executive, *The University of Cambridge Enterprise*; retrieved on 17.05.2017 from the Web, https://www.enterprise.cam.ac.uk/team/dr-tony-raven-2/; hereafter referred to as Raven-Bio. The interview was recorded on 24.03.2017 at the University of Cambridge Enterprise Office; hereafter referred to as Raven.
[279] Dr. Siddharth Saxena, *Department of Physics/The Cavendish Laboratory;* retrieved on 03.06.2017 from the University of Cambridge Web Site, http://www.phy.cam.ac.uk/directory/dr-siddharth-s-saxena, the interview took place in the Cavendish Lab on 05.07.2017; hereafter referred to as Saxena.
[280] Professor James Jackson, Former Head of Department, Professor, Geophysics, Geodynamics and Tectonics, Department of Earth Sciences, *University of Cambridge;* retrieved on 03.06.2017 from the Web, http://www.esc.cam.ac.uk/directory/james-jackson; Interviewed in the conference *Earthquake Without Frontiers*, organised by James Jackson in Almaty, Kazakhstan, September 2016; retrieved on 03.06.2017 from the Web, http://ewf.nerc.ac.uk/about-us/; as well as in the correspondence with the author on 29.02.2016; hereafter referred to as Jackson.
[281] Tsironis, Giorgos, P., Department of Physics, University of Crete, *Curriculum Vitae*; retrieved on 28.02.2017 from the Web: https://nls.physics.uoc.gr/sites/nls.physics.uoc.gr/files/files/gts_CV.pdf, the interview was recorded on 21.02.2017 in Cambridge; hereafter referred to as Tsironis.
[282] Shashikumar M. Chitre, Active Member, *the International Astronomic Union*; retrieved on 04.07.2017 from the Web, https://www.iau.org/administration/membership/individual/2603/, the interview was recorded on 07.06.2017 at Sheppard Flat, Churchill College, the University of Cambridge; hereafter referred to as Chitre.

More than half of the fieldwork was done in March-April 2017. The other half was distributed throughout five years. The interviews took place in Moscow during several trips there (December 2013, November 2014, January 2016 and March-April 2017), Kharkov in Ukraine (September 2016), Almaty in Kazakhstan (September 2016 and June 2018) and Cambridge in the UK. A *Skype* interview with Peter Littlewood in the US was recorded in April 2017. All of these 17 interviews described above were either audio-recorded or received in writing but three of them, i.e. that of Nekrasov who in the best tradition of the old Soviet *apparatchiks*' school allowed making notes only, that of Abilsiitov, and partially that of Jackson who emailed the author some of his thoughts shared during the conversations.

In addition to his eight-hour interview, Gilbert Lonzarich kindly emailed the author his short answers to the questionnaire. They are available in Appendix N. Consent from all the respondents was obtained. The conversations in both Russian and English lasted from 45 to 60 minutes with the exceptions of the case of the 8 hours mentioned just above and around 8 hours of the conversation with Nekrasov during the three days' stay at his place.

12 out of the 17 interviews were transcribed and 3 out of those 10 in Russian were translated in English using professional transcription services in English from both the UK and US, a transcription service in Russian from Kazakhstan, and a Russian translation bureau from Moscow to translate from Russian to English. The quality of both transcriptions and translations was double-checked by the author as a Russian native speaker whose first degree in journalism was taught in Russian. Some extracts from the other six interviews (with Eremenko, Nekrasov, Nigmatulin, Kaul, Molodyk, Paltashev) in transcriptions or audio-records were translated from Russian in English for this thesis by the author. Paltashev approved the transcript in English. In general, while collecting the evidence, the author's knowledge of Russian was imperative for the study not only to be able to conduct interviews but in order to locate new sources of information and new angles of knowledge of the Soviet system, not available in the English literature.

It should be mentioned that conducting research at such a globally acknowledged university as that of Cambridge significantly facilitated the access to the notable scientists from all over the world as seen from the overall list of the respondents. Many of them were directly working for Cambridge, some others were previously or currently associated with the university, while for the others, Cambridge's reputation in the global scientific community, including Russia, Ukraine, and Kazakhstan, was extremely helpful at establishing the contacts.

Another vital source of collecting primary data and evidence for the research was through reading primary literature in relation to Soviet development such as the theorists of Marxism-Leninism, Karl Marx and Friedrich Engels, theorist and founder of the Soviet Union, Vladimir Lenin, Soviet leaders and policy-makers including Josef Stalin, Vyacheslav Molotov and Nikita Khrushchev, Pyotr and Anna Kapitsa's letters and memoirs, Soviet economic and other statistical data as well as various legal acts. This was done in libraries of Cambridge (The Rayleigh Library of the Cavendish Laboratory, the Darwin College Library, the Marshall Library in Economics, and the Cambridge University Library), London (the British Library and LSE Library), Moscow (the Russian State Library, so-called *Leninka*) and Almaty (The National Library, so-called *Pushkinka*, and the National Academic Library, so-called *Akademka*) as well as online, and helped locating some important information as charted out in chapter 3 and analysed in chapters 4 and 5. Concerning the online sources, the references to the Nobel Prize Committee's website as well as other scientific bodies are largely used throughout the thesis in general and in the data chapter of the interviews in particular to confirm the interviewees' data and to inform the reader on the particular scientific discoveries related.

The following two challenges have been identified while doing the thesis. The first one relates to the author's limitation in education received through degrees in humanities and social sciences (journalism and European political economy), i.e. not in science or engineering. This was particularly important in the light of the fact that scientific knowledge is very structured in terms of its both depth and hierarchy. Observations of the overall industrial chain would require a significant understanding of the scientific philosophy and methodology which can be difficult without appropriate training, not to mention the specific knowledge related to particular disciplines in, say, physics or chemistry. However, one should specify that even in science, a biologist's knowledge in her discipline can hardly be fully applicable, for instance, to that of a physicist. Thus, in relation to this research, the understanding of the overall scientific principles, methodology, and philosophy is essential and can be achievable by a non-scientist.

The second challenge lay in connecting the different generations and overcoming the views established during the Cold War. As mentioned in the introduction, both the Cold War's philosophy and approach have significantly affected Soviet and post-Soviet studies, including the considerations of the periods before and after the Cold War and making the task of restoring the historical context doubly important for the thesis.

As well, it should be mentioned that Abilsiitov and Mikoyan avoided answering most of the questions related to technology possibly due to the high level of sensitivity of the subject and their involvement in the military sphere in the Soviet Union and Russia.

However, in tackling these issues mentioned above a careful and thorough consideration of the primary and secondary data, and evidence, as well as the application of the comparative and triangulation analysis of the information received from multiple sources, are to be employed to assist in addressing the research question.

Chapter 3 Data from Interviews and Other Primary Sources

This data chapter consists of two parts. In the first section, the data from the interviews are collected and organised as described in the methodology section above. The second section relates to the data derived from other various primary sources to address the research question, i.e. from a theoretical legacy of Marxism-Leninism, Soviet decrees, correspondence, policy reports, public speeches of the key Soviet policy-makers. Some data from economic and official social documentation and legal acts including the Soviet Constitution are considered in that section as well.

It should be reiterated that this section focuses on data to support the arguments being made, rather than the literature more generally used to inform the overall research on Soviet history in the context of development of science and technology. Many statements are to be analysed in further chapters in order to become more comprehensible and interconnected.

This chapter considers those data from the interviews and primary sources which are directly connected to the research question. Meanwhile, some other data received from the answers to the questionnaire and other primary sources, e.g. about the connection between science and industry, and the driving forces of science, or about Soviet contribution in global development and post-Soviet development, are given and analysed in chapters 4 and 5 respectively.

3.1 Interviews

In this section, the interviewees' answers to the questions are organised into two groups, from within and outside of the Soviet system. Meanwhile, there are two parts in the first group. In the first one, the interviews with the representatives of the Soviet state, industry, and academia are considered in relation to the research question in order to shed light on the Soviet policy which allowed the USSR to go through the rapid industrialisation and modernisation. Except for the unstructured interviews with Nekrasov, Zhukov, and Abilsiitov in subsection 3.1.1.1 below, all the other interviews were conducted following the questionnaire, as described in the methodology section of chapter 2 above and available in full in Appendix A.

It is important to note that in his interview Buzgalin, a former member of the *TsK* of the CPSU, described its official policy judged by American scholars as 'misguided and ideological.'[283] This policy nonetheless provided the Soviet broad funding of science and should be reflected in the thesis.

In the second section, the interviews from the international scientists outside of the Soviet Union are considered. The last interview in this data chapter is Timour Paltashev's, which is placed in subsection 3.1.3. He is both a Soviet/Russian and American scientist born and graduated with his first degree in Kazakhstan and can inform the thesis on both the questions designated as well as the post-Soviet S&T development in Russia and Kazakhstan in chapter 5.

3.1.1 Insiders from the Soviet System

The interviews of this group are organised in two parts. The first one includes the following people: Vladimir Nekrasov, head of the legal department of the Soviet government in the 1960s-90s; Yuri Zhukov, senior research fellow of the Institute of the Russian History of the Russian Academy of Sciences (the RAS); Robert Nigmatulin, Director of P.P. Shirshov Institute of Oceanology of the RAS; Galym Abilsiitov, the founding director of the R&D Centre for Laser Technology in the USSR and a former minister for science and new technologies of the Republic of Kazakhstan; and Alexander Buzgalin, professor of political economy of the Moscow State University (the MSU). The interviews are to inform the reader on relevant details of the historical context important for the thesis, some aspects of the implementation of Soviet policy, including Kazakhstan, as well as on the Soviet doctrine for the science policy. Also, the interviews below help to understand science in the relationships between the academia, industry, and state in Soviet development which is going to be discussed in more detail in further chapters.

3.1.1.1 Historical Context and Characteristics of Soviet Policy-Making

Vladimir Ivanovich Nekrasov worked in the Soviet/Russian government for nearly 45 years from 1952 to 1997 and provided details of the origin and deployment of the Soviet policy.

[283] Fitzpatrick (chapter 1).

Nekrasov was born in Tula (the RSFSR) in 1927 in the family of the head of the local police (*militsia*) who was from the working classes. In the late 1952 as a PhD student in Law at the MSU, Vladimir Nekrasov was chosen by the faculty dean to work for the Kremlin following Stalin's request to find him an additional personal assistant (*referent* in Russian, i.e. an official in charge of reporting and consulting on particular references) among the best PhD researchers at the faculty. In the evening of the same day when he was suddenly sent to the Kremlin without any explanations or preparations from his side, Nekrasov took part in his first large official meeting with high Soviet officials including Stalin. Afterwards, Nekrasov had a long career in the Soviet (and the Russian one after 1991) government from 1952 to 1997, mostly being at the position of head of its legal department.

During his long career, Nekrasov worked with all the Soviet leaders from Josef Stalin to Mikhail Gorbachev and the PMs, having made personal lifetime friends with Konstantin Chernenko[284] and Alexei Kosygin.[285] Nekrasov's and Molotov's *dachas* were next to each other, and the former spent many of his long holidays, which he as a high-level Soviet official was entitled to, in conversations with the latter throughout the 1960s and 70s.

According to Nekrasov, Stalin regretted *Kollektivizatsia* (the collectivisation) of the 1920s and 1930s in his discussions with Molotov about possible mistakes in Soviet policy. Regarding the political cleansings of the 1930s, Molotov meanwhile insisted that there was no choice as it was a *zeitgeist,* and wondered why this particular French word *les repressions* (*repressii* in Russian) was chosen to label the action. In Nekrasov's account, the purges nonetheless opened a career path for a new generation of technocrats at all levels of the Soviet system. Alexei Kosygin as a young and active director of a textile plant in Leningrad who had been noticed and promoted by Anastas Mikoyan[286] became *NarKom* (Minister) of textile industry at the age of 35 in 1939, representing this new Soviet elite as educated in the Soviet system and devoted to it.

With regard to Soviet policy-making, Nekrasov confirmed that, during Stalin's time from the 1930s, the *SovNarKom* (Council (*Soviet*) of Ministers) exercised more power even than the *VKPb* (the Communist Party) which changed with Khrushchev's reforms. The Government

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[284] Konstantin Chernenko, President of Union of Soviet Socialist Republics, *Encyclopaedia Britannica*; retrieved on 15.07.2018 from the Web, https://www.britannica.com/biography/Konstantin-Chernenko.

[285] Alexey Nikolaevich Kosygin, Premier of Union of Soviet Socialist Republics, *Encyclopaedia Britannica*; retrieved on 15.07.2018 from the Web, https://www.britannica.com/biography/Aleksey-Nikolayevich-Kosygin.

[286] Anastas Ivanovich Mikoyan, *Encyclopaedia Britannica*; retrieved on 15.07.2018 from the Web, https://www.britannica.com/biography/Anastas-Ivanovich-Mikoyan.

mostly consisted of the people educated in science and technology. Nekrasov believed that Stalin, as Chairman of the Soviet Government, considered Kosygin, his deputy in that period, as the next and technocratic leader of the USSR, and recalled that in one of the Government's meetings the former pointed to the latter as his successor.

Soviet policy's pursuit for the development of science and education was emphasised by Nekrasov throughout the interview. Scientists in the Soviet Union represented one of the most well-paid and key strata of the Soviet establishment. The elites of the academic community once they became Members and Academicians of the Academy of Sciences (including all 14 National Republican Academies) were granted personal chauffeur driven cars and were provided the best free housing in the same category with policy-makers and high-ranked Party's bureaucrats of both regional and national levels. They enjoyed other privileges, like access to luxury resorts, sometimes almost for free, especially when compared with their salaries. In Stalin's time, much of the professorship of science had most of these benefits as well. Corresponding with the Communist Party's policy line, most of these rules were implemented in practice by Mikhail Smertukov, Nekrasov's immediate boss, who had been in charge of the Soviet Government's managerial and administrative affairs at various positions for 60 years.[287]

The Soviet government poured generous funds into scientific infrastructure and development. Nekrasov witnessed that the broad funding of the Soviet Academy of Sciences in the 1960s was done on the basis from a one-two page note written by hand and presented annually by President of the Academy, Mstislav Keldysh, to Kosygin, a Soviet Premier.

In a similar vein, Yuri Nikolaevich Zhukov, Soviet/Russian historian and senior research fellow of the Institute of the Russian History of the Russian Academy of Sciences (the RAS), provided some of the following historical details in his interview.

According to Zhukov, Stalin continually emphasised the importance of the people with higher education for Soviet development. This kind of approach in policy was reflected in the following historical moments. Firstly, in February 1937, just prior to the height of the 1937-8 political purges campaign the engineer cadres were given immunity by Stalin's special

[287] Zhirnov, Evgenyi, 2011, *Gosudarstvo – eto on* (The State is Him), *Kommersant Vlast',* 22 August; retrieved on 04.05.2017 from the Web, http://www.kommersant.ru/doc/1752433.

order from any political accusations, which should be considered solely by the leading level of the Party's Central Committee, implying Stalin himself.[288]

Secondly, in early 1941 at the last Party conference prior to the Great Patriotic War (as WWII was called in the USSR), Malenkov in his report openly declared that the Party did not require such members, including those of the pre-Revolution times, who had no higher education. Instead, engineers, scientists, medical doctors, including non-Party members, were demanded by development. The report had been evidently observed by Stalin beforehand.

Thirdly, during WWII the engineers, technicians, and scientists were given immunity from being mobilised for military service in 1941-2. However in 1943 when the change in the war towards the victory was identified, those of them volunteered to war before were called off from the fronts by a special decree. It included universities' lecturers, professors, and students after the first year of the study.

Fourthly, the policy focussed on the formation of a new Soviet bureaucracy educated in science and technology. Georgy Malenkov's example is prominent. He graduated from the Bauman Moscow State Technical University (BMSTU) in energy engineering in the 1920s[289] to continue his political career to even succeed Stalin as the Chairman of the Council of Ministers in 1953 after the latter's death.

Fifthly, during the first and second Five-Year plans Soviet industrialisation was supervised on the levels of cities and regions mostly by the local first secretaries of the Communist Party whose educational background included only attending either three classes of church' school [or, alternatively, *Madaris* in the Islamic regions] or more often – Jewish *Cheder*. This implied education on the level of reading and writing skills only. As emphasised by Zhukov, many problems of industrialisation and afterwards derived from these incompetent people's attempts to interfere and run the industrialisation process.

As the historian stated, pre-revolutionary Russia had very few engineers, and their expertise was pretty narrow, whereas in the metallurgy industry, for example, foreign engineers, Belgian, French, English ones, in particular, were in charge. The Russian engineers were

[288] Zhukov, Yury, 2003, *Inoi Stalin. Politicheskye reformy v SSSR v 1933-1937 gg.* (*Another Stalin. Political Reforms in the USSR in 1933-1937*), Moscow, Vagrius, 369-70; hereafter referred to as Zhukov II.
[289] The Bauman Moscow State Technical University; retrieved on 25.04.2017 from the Web http://www.bmstu.ru/en/; hereafter referred to as the BMSTU.

present in either the military sector, like in the Putilov plant, or in the construction of the railways and bridges.

While referring to Kapitsa being awarded Stalin's Prize [of the 1st Degree] as early as in 1943 for the discovery of *superfluidity of liquid helium* [in December 1937 – January 1938],[290] Zhukov emphasised the following. Firstly, the Prize was established by Stalin to be funded not from the Government's budget but his savings resultant from the latter's publications in many languages of the Soviet Union. All of these significant revenues were collected in the fund established for this purpose. This defined the prize's title, in the historian's view.

Secondly, the procedure of awarding was set up as follows. According to Zhukov, in the *TsK* there were special departments including that of being in charge of science. They analysed the states of affairs in the appropriate disciplines by themselves or followed specific directives from Stalin to research a particular area of expertise. In doing so, they often attracted and relied on scientists from various scientific institutions to prepare reference letters. Stalin and the *Politburo* could always receive an objective and competent evaluation of a particular scientific discovery or a paper, i.e. of anything related to the development of science, as seen from the archives. Moreover, the history of science has revealed, as noted by Zhukov, that most of those evaluations were correct, unbiased and competent, like in Kapitsa's case, so that Kapitsa's contribution to physics was acknowledged by the 1978 Nobel Prize in Physics[291] [35 years after the Stalin's prize specified above].

Zhukov gave a high evaluation to the key Soviet policy-makers' overall competence in governing the state in general and managing science and technology in particular, as revealed in dealing with the SAS from the early the 1920s. Then the latter's development received special attention, and the various S&T and R&D institutions began being established in the Academy's expansion.

Concerning the role of the Communist party during industrialisation, Stalin, according to Zhukov, aimed at the Party's reformation. As the initial Bolsheviks' vehicle to seize and retain the power, it fulfilled its role. In the new conditions of the construction of socialism

[290] As referred to in section 3.2 below.
[291] Kapitsa's discovery was given a high evaluation by the scientists interviewed for this thesis as evident below, apart from his the 1978 Nobel Prize in physics.

in one country after the disillusionment for an immediate world revolution starting from Europe in the 1920s, another approach was demanded. In 1937 at the peak of the power struggle between the old revolutionaries of the Party, on the one hand, and the younger technocrats of the Government supported by Stalin and his group, on the other, as two opposite wings of the Party, Stalin tried to minimise the Party's role in Soviet development. In particular, he tried to organise the elections in *Verhovnyi Soviet SSSR* (The Supreme Council of the USSR, the Parliament) in which 'candidates could be two, three or more,'[292] (i.e. multiple candidates) including non-party members. It was designed to emphasise both the technocratic character of Soviet power and its shift from ideology and its dogmas towards further industrialisation, in Zhukov's opinion.

He emphasised Stalin's role in designing the science, culture and education policy for the national republics of the USSR and the establishment of the republican SAS branches as well as operas, theatres, art galleries, and various educational institutions there in the 1930s. This process aimed to develop and unify the overall national cultural level including the change of the alphabets in some languages from Latin introduced in the 1920s to Cyrillic (Kazakhstan, 1940). In parallel, this accompanied the establishment of the national republics within the borders designated, like in the case of the Kazakh SSR, founded as a separate republic within the USSR (not as a part of the RSFSR as before) on 5 December 1936.

A former director of the R&D Centre for Laser Technology, Galym Abilsiitovich Abilsiitov in his interview strongly emphasised Soviet policy implementation based on the doctrine to include representatives of the working classes from the national republics of the USSR and the ethnic minorities as much as possible in obtaining the higher education in the leading national universities by giving his example. It was indicative as he was born in 1940 in a tiny small village, consisting of a few houses, in the *Akmolinskaya oblast,* 14 km away from Akmola (currently Astana, the capital of Kazakhstan),[293] in a low-income family, which struggled to survive during the war times. Abilsiitov emphasised the high teaching standards of his high school established even in the remote rural steppe location of central Kazakhstan.

According to Abilsiitov, in 1958 an order came from Moscow to find ethnic Kazakhs to study physics at the MSU. Due to the high entry conditions in Moscow, a special quota was

[292] Zhukov II, 206; referring to *Pravda*, 15 October 1937.
[293] In March 2019, it was renamed into Nur-Sultan.

formed and a special commission was set up in Alma-Ata, the capital of the Kazakh SSR. He was chosen as one of the candidates and managed to enter this most prestigious Soviet university. Upon his graduation, Abilsiitov built up a successful career to become a deputy director of the Kurchatov Institute of Atomic Energy[294] in 1971-9, which is one of the world's leading research and development institutions in the field of nuclear energy. He supervised the construction of the academic city of Troitsk, near Moscow. In 1979 he became the founding director of the R&D Centre for Laser Technology and a leading figure of the Soviet military laser space technology. His research[295] is still a part of the academic course for laser technology at the engineering universities in Russia.

According to Robert Iskandrovich Nigmatulin, Real Member (Academician) of the SAS (from 1991), Member of Presidium of the RAS (from 2006) and Director of P.P. Shirshov Institute of Oceanology, this institute was established in 1946, and the decision for its establishment was taken by Stalin in December 1945, when the country was half-ruined after WWII. In 1947, the academician recalled while describing the *zeitgeist*, that when he went to primary school, half of his classmates could begin their study only at the age of 8 instead of 7 as they were weak and depleted from malnutrition. Also, more than one-third of them had lost their fathers at war.

Nonetheless, during WWII the S&T and R&D institutions were established by the orders of the Soviet leadership throughout the country, e.g. the Kazan Scientific Centre of the SAS[296] in Tatarstan (the RSFSR) in April 1945. Being an ethnic Tatar from the Republic of Bashkortostan (the RSFSR) by his origin, Nigmatulin emphasised that the Bashkir branch of the SAS,[297] which was established in 1951 in Ufa, had no record of science in history at all, unlike in Kazan, the capital of Tatarstan. According to Nigmatulin, Lenin established the Soviet science policy against all the odds aiming at exploring nature's laws. For example, in the conditions of the Civil War, Lenin founded the Institute of Geography of the RAS in 1918, noted the academician. The continuation of this policy was evident in 1947 in the establishment of the Nigmatulin's institute designed to explore the oceans.

[294] *The National Research Center Kurchatov Institute*; retrieved on 29.06.2017 from the Web, http://eng.nrcki.ru/.
[295] Abilsiitov, G.A., Golubev V.S., 1981*, Osnovnye problemy lazernoi tekhnologii i tekhnologicheskikh lazerov* (Main Problems of Laser Technology and Technological Lasers), Troitsk;
Abilsiitov G.A., 1991, *Tekhnologicheskie lazery, Tom 1* (Technological Lasers, Volume 1), Moscow, Mashinostroenie.
[296] *The Kazan Scientific Center of the RAS*; retrieved on 09.06.2018 from the Web, http://knc.ru/.
[297] *The Ufa Scientific Center of the RAS*; retrieved on 09.06.2018 from the Web, http://www.ufaras.ru/.

In the USSR, the funding of his institute coming from the military sector for the research of the underwater objects, signals, vibrations and noises as important for submarines could reach up to one third of of the institute's budget not differentiating between the fundamental and industrial research. Like in many other countries, the military funding contributed to the knowledge of the underwater acoustics as a fundamental scientific discipline. In 1987, the scientist was elected as Corresponding Member of the SAS and noticed how the priority of science in the overall Soviet policy sharply decreased in the late 1980s. Then the Academy started experiencing financial difficulties in the provision of the research infrastructure and equipment.

Overall, as confirmed by Nigmatulin, the funding for fundamental science was centralised and provided from the budget to the Academy of Sciences in Moscow which, in turn, distributed the allocations to its various institutes, branches and republican Academies in accordance with the preliminary annual scientific plans.

In Nigmatulin's vision, the main contribution of Soviet science to global development was, as a result of the successes of Soviet science, in the attention which the rest of the world started giving to social development [which can, therefore, foster the development of science]. Meanwhile, in the Soviet Union, the overall level of the allocations for social development, i.e. healthcare, education, science, and culture exceeded a quarter of the GNP in the early 1980s, according to Nigmatulin.

He outlined that the Soviet system was far from being perfect, especially in terms of running the economy with the administrative methods. An economy is always a dynamic system. In a similar vein, when the Soviet policy interfered with biology, the development of genetics was slowed down. However, the overall Soviet policy towards science was very favourable, allowing a great extent of personal freedom in research for scientists.

This high level of the personal freedom in combination with the highest wages attracted very talented people into science in general and in theoretical research in particular, whose share was significant in the overall development of the fundamental science, noted the scientist. It contributed to that high global status of the Soviet science. It was especially evident at international conferences frequently attended by Nigmatulin and his colleagues.

While in Soviet science, Nigmatulin was free in choosing subjects for his research, whereas nowadays the global approach towards science is mainly based on the project funding. In his view, however, all the knowledge accumulated in the fundamental science cannot be perceived solely through the approach of the immediate applications. Weak funding of science implies a weakness of industrial research, industry, and innovation as well as education, concluded the scientist.

Alexander Vladimirovich Buzgalin, professor of political economy at the MSU and a former member of the Central Committee of the CPSU in 1990-1, emphasised the importance of industrialisation for Soviet development in his interview.

Although by 1928, the USSR improved trade, developed small and medium-sized enterprises (SMEs) (*kustarnoe proizvodstvo*) and restored its economy mainly due to the introduction of the New Economic Policy (NEP) designed by Vladimir Lenin in 1921 as 'state capitalism' with many elements of market economy, it was not viewed by Stalin's group as an efficient method for rapid and heavy industrialisation. The latter required the concentration of capital, resources, and labour on a far larger scale. Based on this approach, the policy-makers abandoned the NEP for a rapid development.

According to Buzgalin, the development of science and research meanwhile was a vital and integral element of industrialisation. The Soviet doctrine for science policy was implemented as a methodological approach of Marxism through the allocation of the productive forces,[298] production relations and their manifestation, although science and technology were not clearly articulated there:

> The basic idea was that the future society would be the one in which a person would act as a controller and regulator within what is now called an 'automated production system.' The future of automated production is a person who carries out creative functions. It was in the Marx' economic manuscripts of 1857-59. However, the key idea is really fruitful, that […] the industrial production leads to a system where a person, as a scientist and a manager, acts, and all other functions are performed by the system. As for the Soviet theory, the idea of turning science into a direct productive force was a banality that was included in all the textbooks of the political

[298] Kurakov, chapter 1, Science as a Direct Productive Force in Society, 1-13, and in particular, 1.

> economy of socialism and scientific communism. Science was seen as something that creates social wealth directly and indirectly through application in the industrial process.[299]

According to Buzgalin, the approach subsequently developed in Soviet papers viewed capitalism, in particular, the market and capital, as forming a system of such productive forces that were oriented towards the production of goods and the extraction of profit. On the contrary, in the system of socialism, the productive forces, meanwhile, were inclined towards human production, human qualities, social development and solving problems related to the liberation of a person.

The understanding of working for some big task, a national or global goal, was important for Soviet scientists, continued the political economist. The space programme, atomic projects, and everything else were based on the assumption that there would not be another world war due to a global balance of power. For Soviet people including scientists, a general idea of moving in the right direction of the social progress and human development towards a society where poets and scientists would be the central figures was important, emphasised Buzgalin.

According to him, in the Stalin's period (and continued less and less in Khrushchev's and Brezhnev's times), the quality of life of an academician or a famous writer did not differ from that of a minister. Meanwhile, the basic wages of scientists had not changed since the early 1950s. At that time, a professor received SUR4,600 (SUR460 – after the denomination in 1961) monthly until 1991, whereas an average worker's monthly salary rose three times from SUR330 (minimum) to SUR1,000 in the same period. Meanwhile, in the post-war time, a professor could afford a luxury car, like *Pobeda* (Victory) at the expense of a few months' salaries, Buzgalin concluded.

In this subsection, the interviewees disclosed some specific context in which the formation and deployment of the Soviet science and development policy occurred. In the next subsection Soviet scientists' and engineers' interviews are to shed more light on the functioning of the Soviet science system from within and the details of their scientific activity.

[299] Buzgalin.

3.1.1.2 Soviet Scientists and Engineers

The interviews of this subsection are organised to inform the reader on the development of the particular areas of Soviet science and technology and include the following scientists and engineers: Ovanes Mikoyan, a former deputy head of the *MiG* aviation design bureau, the USSR/Russia; Viktor Eremenko, a scientist in the field of low temperature physics and a former director of the B. Verkin Institute of Low Temperature Physics and Engineering (ILTPE), the USSR/Ukraine; Alexander Vasiliev, chair of low temperature physics and superconductivity, head of solid state physics division, Faculty of Physics, the MSU, the USSR/Russia; Andrey Kaul, head of coordination compound chemistry laboratory, the MSU, and a scientific supervisor of the *SuperOx* company, the USSR/Russia; and Alexander Molodyk, technical director of *SuperOx*, Russia.

A former deputy head of the *MiG*, the famous Soviet/Russian military aircraft design bureau, which was one of the pioneers of the global jet aviation, Ovanes Artemovich Mikoyan, struggled to distinguish between pure science and engineering in his field, emphasising, nonetheless, the primacy of basic research in the chain:

> One generates the other. I consider that without fundamental science it is impossible to progress at all. Society cannot progress without developing fundamental science, not its own but the worldwide one. It is necessary, of course, first of all, to develop fundamental science, and applied science will keep developing, which will lead to the overall growth of technologies, industry, production and, simply, culture.[300]

He pointed out that, at least in the Soviet times, the *MiG* engineers had daily interaction with scientists, without whose expertise it would have been impossible to move forward. According to him, the development of the jet aviation was entirely dependent on science. Everything that was required to achieve the highest flight speed (for instance, heatproof materials), critically needed development in such research areas as aerodynamics, dynamics, material science, and others, which provided development of technologies in engine-making, radio-electronic industry, *etc*. The military paradigm ensured that the

[300] Mikoyan.

scientific institutions received secure funding, and both scientists and engineers pushed forward the aircraft making together.

Regarding the role of technology transfer, as the aviation engineer outlined, it had always been a part of the overall mutual and intertwined technology development for both sides of the Cold War. Sometimes it occurred illegally, or through the intelligence service. It was the case of a Soviet *MiG-25* supersonic interceptor illegally obtained by the American side in 1976. It was dismantled and carefully analysed before being returned to the Soviets from Japan.[301]

Overall, while developing the technologies received in the 1940s and 50s, Soviet scientists and engineers could enter another superior level in the S&T development, and in the aviation and cosmonautics, in particular. The primary approach, according to Mikoyan, was as follows. If the Americans had been detected in achieving a technology superiority lag of ten years in a particular aircraft, Soviet scientists and engineers, responding to the challenge, aimed at developing a Soviet machine with a 20 years margin in the development of technology, concluded the aircraft designer.

Viktor Valentinovich Eremenko was 'an outstanding Ukrainian scientist in the field of low temperature physics, whose scientific activity covers low-temperature magnetism, spectral and magneto-optical phenomena, magnetic phase transitions in antiferromagnets, superconductivity and the galvanomagnetic phenomena in metals, the exciton processes in antiferromagnetic, semiconducting and molecular crystals, […] The Editor in Chief for the journal "Low Temperature Physics" (1990), a member of the editorial board of the publishing house "Cambridge Scientific Publishers" (Cambridge, England),'[302] senior fellow and advisor to the Directorate of B. Verkin Institute of Low Temperature Physics and Engineering (ILTPE) of the National Academy of Sciences of Ukraine (NASU). He emphasised the following in his interview.[303]

According to Eremenko, the idea of abstract thought creating a material reality found its realisation at ILTPE where the best mathematical minds of high mathematics, geometry, and

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[301] Gordon, Yefim, 2008, *Mikoyan MiG-25 Foxbat: Guardian of the Soviet Borders* (Red Star Vol. 34). Hinckley, UK: Midland Publishing Ltd.
[302] Victor Eremenko, *B. Verkin ILTPE of NASU*; retrieved on 03.07.2017 from the Web, http://www.ilt.kharkov.ua/cpuei2012/eremenko_e.html.
[303] The interview was assisted with his son Andrey, a physicist as well.

math physics of Ukraine such as [Alexei] Pogorelov[304] or Vladimir Marchenko[305] continued the tradition of the physics and math faculty of the Kharkov University being socially and politically supported by both the university and the NASU. In establishing the institute, the academician [Boris] Verkin[306] could concentrate mathematicians,' physicists' and engineers' activity at one place.

Research in low-temperature physics was established in Kharkov first through the academician [Abram] Ioffe's[307] initiative who founded a lab for this research at the university. It developed further into a separate establishment under Prof. [Lev] Shubnikov's supervision in the 1930s. As outlined by Eremenko, Shubnikov was very internationally recognised, including at Cambridge.[308] Joint research in quantum matter has been conducted between Kharkov and Cambridge in parallel since, and in the 1960s, in particular. [Pyotr] Kapitsa was doing a similar thing up in Moscow. This kind of exchange has been continuing since and has been intensified in the last decade as many of the institute graduates are working abroad, especially in the US, as well as in Australia, Japan, Germany and Israel at present.

The applied research received a particular development in the 1960s following the demand from [Sergei] Korolev's[309] space programme to research behaviour of certain materials and devices in space as a demonstration of the demand deriving from the industry to work efficiently with science, and not vice versa, Eremenko emphasised.

Pyotr Kapitsa supported Eremenko's research with all means and was a man of broad interests including literature as well. In Eremenko's account, Kapitsa never followed the official line from above but recklessly tried to influence the science policy-making which sometimes was unsafe for him, like in the case of Landau (who was originally from Kharkov). The latter was

[304] Alexei V. Pogorelov (1919-2002), *B. Verkin ILTPE of NASU*; retrieved on 14.06.2018 the Web, http://www.ilt.kharkov.ua/bvi/personnel/pogorelov_e.html.
[305] Vladimir Aleksandrovich Marchenko, *School of Mathematical and Computational Sciences, University of St Andrews*; retrieved on 14.06.2018 from the Web, http://www-groups.dcs.st-and.ac.uk/history/Biographies/Marchenko.html.
[306] Verkin Boris Yeremyevich, *All-Fizika.com*; retrieved on 14.06.2018 from the Web, http://www.all-fizika.com/article/index.php?id_article=664.
[307] Abram F. Ioffe (1880-1960), *Ioffe Institute*; retrieved on 24.04.2017 from the Web, http://www.ioffe.ru/ioffe.html.
[308] Rotter, Helmut, 1997, Lev Shubnikov: Physics Pioneer, Landau Ally, Secret-Police Victim, 1 December, *Physics Today*, 50, 12, 95; retrieved on 14.06.2018 from the Web, https://physicstoday.scitation.org/doi/10.1063/1.882041.
[309] ESA, 2007, Sergei Korolev, Father of the Soviet Union's Success in Space, 9 March, *European Space Agency*; retrieved on 13.06.2018 from the Web, http://www.esa.int/About_Us/Welcome_to_ESA/ESA_history/50_years_of_humans_in_space/Sergei_Korolev_Father_of_the_Soviet_Union_s_success_in_space.

saved from the prison due to the former's efforts. Eremenko mentioned of Kapitsa, sending scientific references to Stalin after reading *Physical Review* and making notes for himself and Stalin. Although Stalin was not a physicist, Kapitsa had a chance to make sure that the former did read his letters sent after receiving a call on Stalin's behalf to continue the correspondence, as pointed out by Eremenko.[310]

The funding of the research in the Soviet era, according to him, was practically unlimited and was provided through the Academy of Sciences. It was driven by key Soviet policy-makers' understanding, conveyed to them by Verkin, of the importance of the research in low-temperature physics for Korolev's space programme. The funding for this purpose became the institute's main financial provision. Eremenko was convinced that, overall, science should be run by the people who are capable of understanding the importance of the fundamental research, physics and math in particular, for development, like in Verkin's case. Keldysh who also worked with Korolev was such kind of person as well, according to Eremenko.

Although financially unlimited in the SUR funding, the research was ascribed in the Soviet equipment and materials available whereas in the West their distinct kinds were produced. This determined the Soviet scientists' lag which was eventually developed in certain areas of research. However, the Soviet Union had something unique to offer, like the superconducting wire developed solely due to Eremenko's both research in superconducting materials with a high critical magnetic field, and magneto-optic and –spectral experiments, followed after experimenting in the impulse-magnetic fields. Eremenko prioritised the basic research over the applied science in his activity emphasising the former's fundamental importance.

By the 1960s a full cycle of the education for S&T was established in Kharkov starting from a republican specialised physics and math secondary school to higher education institutions. The school's founder was Ivan Fedorovich Bulba,[311] a WWII veteran, severely wounded then. While establishing the school, he managed to overcome the accusations of elitism as opposed to the overall Soviet policy of meritocracy. These efforts bore their fruits through delivering generations of scientists, especially in math and physics, who nowadays run many of the universities and scientific institutions not only in Kharkov but elsewhere in the post-Soviet

[310] More detail is provided in Appendices L and M.
[311] *Ivan Fedotovich Bulba*; retrieved on 14.06.2018 from the Web, https://www.proza.ru/2016/01/08/20.

space. According to Andrey Eremenko, Victor's son, more than 20 of his high school classmates continued their education by studying at the departments of physics and mechanical mathematics of the Kharkov University.

Both of the Eremenkos emphasised the importance of the interconnection and interaction of the social policy in healthcare and education, on one the hand, and the development of science, both fundamental and applied one on the other, for constantly accumulating a critical mass for the scientific development. In Kharkov, there were many institutions specialising in the applied sciences of various kinds including mathematics for managing flights, or physics of monocrystals as the examples. The NASU Institute for Problems of Cryobiology and Cryomedicine Issues[312] in Kharkov is a daughter's spinoff of ILTPE. The accumulation of the overall critical mass mentioned before which mainly started in the 1930s and continued through the 1970s, in the early 1980s began gradually fading away. However, even today the Ukrainian research in scintillation materials deriving from the studies of the monocrystals is a part of CERN.

Social provision of scientists in Kharkov in the Soviet Union was of high importance and was delivered at both the Moscow's and Ukrainian levels. The first one was larger and connected the research in Kharkov with that of Chernogolovka [an academic city] near Moscow. Then joint seminars were conducted on a monthly basis, and many scientists moved from Kiev or Kharkov to up there. Eremenko was invited continuously to do so however he preferred staying in Kharkov. This collaboration has been continuing through the present days.

Eremenko outlined the importance of culture and art for the human capital development, especially in mathematics or theoretical physics as the brightest manifestations of human intellect. During his directorship at ILTPE, from the 1960s he established an art gallery there and used to promote and support local artists by all means including the contribution of the art instruments, like foreign paints or Japanese brushes, he could bring from many international conferences to the painters. As well, at ILTPE there was a music hall for 500 seats in which various events were conducted on a regular basis. According to Eremenko, there were many examples of how enjoying music and watching art objects contributed to solving particular scientific problems or making discoveries.

[312] Institute for Problems of Cryobiology and Cryomedicine of the National Academy of Sciences of Ukraine; retrieved on 14.06.2018 from the Web, http://www.cryo.org.ua/ipk_eng/home_e.html.

In his interview, Alexander Nikolaevich Vasiliev (The USSR/Russia), chair of low-temperature physics and superconductivity, head of solid state physics division, Faculty of Physics, the MSU, outlined the following. According to him, in general scientists including himself prefer not thinking of the concepts broader than their particular research which is driven by pure curiosity.

Overall, as assumed by Vasiliev, in supporting science as driven by human curiosity the state is put into a painful and challenging position by admitting in its policy that it should fund this kind of a very expensive curiosity in the expectations of the ultimate, invisible, not tangible and uncertain applications which even the scientists involved cannot imagine themselves. This makes the planning of science impossible. Vasiliev also emphasised the importance of Soviet industrialisation in establishing the modern technological state.

A joint interview with Andrey Rafailovich Kaul (Russia), head of laboratory of coordination compound chemistry, division of inorganic chemistry, the MSU, and Alexander Molodyk, Technical Director, the *SuperOx* company, below, outlined Soviet development with the example of the technology of the *SuperOx* superconducting cable. The particular technology details are explained by Molodyk, whereas the questionnaire was answered by Kaul after the tour around the *SuperOx* plant in Moscow.

Superconductivity as *free motion of electrons*, once functionalised in the cables, allows transportation and storage of energy with zero loss as well as with a high concentration of large volumes of energy, such as that of industrial electrical grids, in the miniature cables, as explained by both scientists. Nowadays the technology is widely used in the energy and high-tech sector to eliminate bottle-necks in energy transportation for short distances of up to 800 metres. This length is dictated by today’s level of theoretical understanding (or rather the lack of the latter yet) of the superconductivity phenomenon, according to Molodyk. This defines the technological limits for the lengths of the cables in their production in the realm of the current understanding of the phenomenon. In other words, the maximal lengths, efficiency and production quality control depend on the size of the reels used in the production. Both Kaul and Molodyk believe that further research in this area could expand the knowledge, leading to wider and explosive usage of the technology.

However, this limited length already allows transportation of high volumes of energy within short and critical distances in aircrafts, high-tech advanced connections and those parts of the electrical grids, which can be in proximity of residential arrays, as the technology, unlike today's electricity networks, in harmless and environmentally safe, as highlighted by Molodyk. More importantly, it can prevent accidental power blackouts of any type, which used to be a part of life in the densely populated and highly industrial areas. Power outage put public and environmental safety at risk as well as required significant funding for energy back-ups in industries, hospitals and elsewhere. Spreading of this technology has a potential to end industrial power outages and create a significant global economic effect, outlined Molodyk.

As specified by him, the *SuperOx* company is a global leader in the production of superconducting cables, i.e. those of with the zero-loss transmission of electricity, and is one out of just five producers in the world. The company's clientele includes major energy companies, high-tech conglomerates and leading research institutions such as CERN (Switzerland), Airbus (the EU), University of Cambridge (the UK), MIT (the USA), Karlsruhe Institute of Technology (Germany), Paul Scherrer Institute (Switzerland), CNRS – The French National Center for Scientific Research (Grenoble, France), CEA – The Alternative Energies and Atomic Energy Commission (France), ICMAB – The Institute of Material Science of Barcelona (Spain), GSI – The GSI Helmholtz Centre for Heavy Ion Research (Germany), ENEA – The Italian National Agency for New Technologies, Energy and Sustainable Economic Development (Italy), Slovak Academy of Sciences and some others, undisclosed for this research.

The *SuperOx* superconducting cable consists of the nine layers of the different materials providing the overall cable's functionality altogether. The photographs of the *SuperOx* superconducting cable from inside and of the layers of the different materials of the *SuperOx* in which the black layer is the superconducting rare earth compound can be found in Appendices I and J respectively.

As outlined by Kaul, this innovation is attributed to Soviet development and research in the following. The company was founded in 2006 as a classical spin-off of the faculty of Chemistry of the MSU, driven by research by Prof. Andrey Kaul and under his scientific supervision. Most of the employees and its management have been his graduates. The founder of the company, Andrey Vavilov,[313] a former Russian politician, is an economist by education; however, both his interest in and understanding of the high-tech sector were

[313] Vavilov, Andrey, *Lenta.ru*; retrieved on 21.06.2018 from the Web, https://lenta.ru/lib/14160897/full.htm.

predetermined by his graduation from a specialised physics and math high school in the USSR.

The technology is a production of a tape covered with a superconductor (it involves Zhores Alferov's research, the 1970s, marked with the 2000 Nobel Prize).[314] A superconductor is a rare earth compound, either from Russia or Kazakhstan. On the stage of the second layer, the coating is made with laser (related to Nikolay Basov's research of the 1950s, who received the 1964 Nobel Prize in Physics).[315]

According to Kaul, a scientific consultant and supervisor, and Molodyk, a technical director, the following is essential. Firstly, fundamental research is not only a founding stone, but a continuing part of the process as the company's progress is impossible without a constant affiliation and research at the MSU faculty of chemistry. Secondly, the process is based in its primary functions on the indigenous scientific and engineering advances. Thirdly, the imported equipment and technology play a secondary role and can be easily replaced with its domestic analogues. Fourthly, the patent regime is not critical and it is not used in the production. Fifthly, the delay of almost 15 years in the launch of the technology and innovation was caused by the collapse of the Soviet Union and the suspension at the edge of the destruction of both the academic activity and the functioning of the technological chains involved in the production. Kaul does not find market conditions to be critical for the company's emergence as well as for its functioning and considers that, if not for the disruption of the process, the technology would have been further developed and implemented in the Soviet Union at, most likely, a much greater both speed and on an industrial scale.

This kind of the particular superconductor was discovered in 1986, and as early as in 1987 the superconductivity research at the MSU was intensified in the aftermath of the joint decree of the *TsK* of the CPSU and the Soviet Government *On Superconductivity*, which provided a broad funding mostly due to the efforts of the academician Yuri Andreevich Osypian,[316] although the latter was not specialising in superconductivity. He used to be the

[314] The Nobel Prize in Physics 2000, Zhores Alferov, Herbert Kroemer, Jack Kilby, Zhores Alferov – Facts, Nobel Prizes and Laureates, *Nobelprize.org*; retrieved on 14.06.2017 from the Web, https://www.nobelprize.org/nobel_prizes/physics/laureates/2000/alferov-facts.html; hereafter referred to as Alferov.
[315] Basov.
[316] *Akademik Y.A. Osypian (1931-2008)* (The Academician Y.A. Osypian [1931-2008]), *ISSP RAS*; retrieved on 14.06.2018 from the Web, http://issp3.issp.ac.ru/main/index.php/ru/rasmember/osipyan.html.

Director of the Institute of Solid State Physics in Chernogolovka where the members of the *GKNT* prepared the decree. The process was followed by the introduction of the all-Union programme on the development of the superconductivity research which was divided into three parts, i.e. physics and electronics, chemistry, and engineering. After three years the funding decreased to cease existing after the collapse of the USSR.

Kaul pointed out that the symbiosis of Soviet science and engineering was in many ways driven by the opportunity for the scientists to create something independent. This approach was nurtured in Soviet science, which resulted in the appearance of the technology given.

Molodyk mentioned Kapitsa's contribution to the development of physics of low temperature and particularly emphasised the importance of the science policy designed by Stalin for the development of the research of this phenomenon.

This joint interview concludes the series of the primary data collected from the representatives of the Soviet state, industry, and academia to transit for the consideration of the interviews taken from the international scientists and engineers outside of the USSR in the next subsection.

3.1.2 Outsiders from the Soviet System

In this subsection, the data from the notable international scientists are considered through the questionnaire to shed light on Soviet development. As indicated in the methodology section, it is important to note that all the interviewees' experience is not limited to a single nation and the research they do involves from two to four and more countries, like in the case of Tsironis who apart from Greece has been actively involved in research in Russia, Kazakhstan and Britain, or Siddharth Saxena doing so in across the borders of the UK, Italy, India, Russia, Kazakhstan, Uzbekistan and other Central Asian nations.

Thus, the following scientists have been interviewed for the thesis. They are Giorgos Tsironis, Department of Physics, vice-rector of the University of Crete (Greece); Shashikumar M. Chitre (India, the UK), a Cambridge and Indian mathematician and astrophysicist; Peter Littlewood, Director of Argonne National Laboratory (the US) and a former head of the Cavendish Lab/Department of Physics, the University of Cambridge (the UK); Gilbert G. Lonzarich, head of the Quantum Matter Group at the Cavendish Laboratory of Cambridge (Canada, the UK, the US); Tony Raven, head of the University of Cambridge Enterprise (the UK); and Siddharth (Montu) Saxena, an experimental physicist at the Quantum Matter Group, the Cavendish Laboratory, the University of Cambridge (India, the U.K and the other countries designated above).

Giorgos Tsironis, Department of Physics, University of Crete, (Greece), graduate of the University of Athens and the University of Rochester, New York (Master's and PhD), spent a couple of years at the University of New Mexico, after which he was a research fellow at the University of California San Diego, the US. His last appointment in the US was at the University of North Texas.[317] He is a theorist in condensed matter physics, physics of nonlinear dynamics, as 'complexity that involves multiple interaction systems,' according to himself. They are conveyed from very fundamental phenomena of condensed matter physics to industrial, societal and all scale outputs. It is little disciplinary research, founded on the basic principles of the condensed matter physics, as explained by Tsironis.

Without commenting much on Soviet development, Tsironis brought an example of [the academician and biologist Trofim] Lysenko[318] and the interference of the ideology in genetics named as 'bourgeois science,' which, due to the doctrine of materialism imposed, led to a disaster, as any external doctrine should not determine how everything might work. It could in some cases be correct, however in relation to biology, Lysenko tried to experiment based on this premise. It did not work, and for many years the development of biology was lagged behind in the Soviet Union.

In an analogy of the market forces, continued the physicist, this is a counter-productive example of how either the society or ideology or market force or anything interferes too much and is put before science. On the other hand, from his general impression about the history of science and technology in the Soviet Union and from knowing people of the Soviet Union, it seemed to Tsironis that it was understood to a large extent there that basic science can generate knowledge which leads to technology. For that reason, the Academy of Sciences [of the USSR] was a prestigious and important body because the society understood that it could rely on science to be better-off in life and other things.

[317] Tsironis.
[318] Ings, Simon, 2016, 'How did anyone dare insult Comrade Lysenko?,' *Stalin and the Scientists, A History of Triumph and Tradegy. 1905 – 1953*, London, Faber & Faber, 340-66, hereafter referred to as Ings.

In terms of technology transfer, Tsironis addressed to Vannevar Bush,[319] an advisor to F.D. Roosevelt, who wrote a report[320] on the connection between science and technology by the end of WWII. He had a statement there of the importance of basic research and technology for the nations' sovereignty and ability to defend themselves. In Tsironis' opinion, indigenous know-how in science is essential although this would depend on a scale of a country. Nonetheless, a nation should have a stratum of people with knowledge in science and technology which is very important for the country to be able to develop. One cannot bring everything from outside and not think of tomorrow, believed the scientist and brought an example of agriculture in which a dependence on foreign companies in seeds can put sovereignty at stake. According to Tsironis, having know-how on basic aspects of science and technology is really a developmental apex for any country.

In Tsironis' view, every country has its group of scientists who move around. A decent salary is vital for them however it is not the most important question, unlike some stable conditions where scientists can work in, operate without too much bureaucracy and obtain not negligible but substantial funding. In order to have long-term success in science, they need a stable environment and a reasonable amount of funding.

Thus, in the scientific development, a constant and quiet environment for scientists to work was defined by Tsironis as essential. Meanwhile, social policy should be smart enough to involve people into science, and science policy should be designed by good scientists in order to set up the rules and provision of basic funding, as well as to exclude an unnecessary intervention. In his view, education and the existence of scientific infrastructure for experimenting are viable as well.

Shashikumar M. Chitre (India, the UK), a Cambridge and Indian mathematician and astrophysicist, marked with the highest Indian civilian Padma award,[321] an Active Member of *the International Astronomic Union*,[322] in his interview emphasised the importance of the literacy issue in the national policy-making in an early Soviet development.

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[319] Dennis, Michael Aaron, 2016, Vannevar Bush, American Engineer, *Encyclopaedia Britannica*; retrieved on 24.05.2017 from the Web, https://www.britannica.com/biography/Vannevar-Bush; hereafter referred to as Bush-Bio.

[320] Bush, Vannevar, 1945, *Science, the Endless Frontier*, National Science Foundation, Washington DC, reprinted July 1960; hereafter referred to as Bush. Appendix M.

[321] Press Information Bureau, 2012, Government of India, *Padma Awards Announced*, 25 January; retrieved on 09.06.2017 from the Web, http://www.pib.nic.in/newsite/erelease.aspx?relid=79881#.

[322] Chitre.

According to him, overall in science policy, due to the psyche of the people in a particular country, one does not necessarily apply some of the practices which are not acceptable to the society. In the Soviet Union, they could implement it and became not depend on merely technology transfer after WWII as he explained:

> They developed their technology because the educational foundation was so strong that they could develop and put *Sputnik* up in space before the Americans. All the Americans were surprised. It was 1957, which was very commendable and incorrigible that they mastered the space technology to […] put the satellite. It was a breakthrough which in a way triggered the United States' space programme. That was what prompted John Kennedy to make the statement that before this decade is out, the 1960s, America should put a man on the moon and bring him back safely.[323]

In the Soviet Union, they strengthened the university as the foundation [for the development]. Not all of the graduates come into science necessarily but, having learned in the university for five years in various basic sciences courses, they could go into administration or management, and they would have a feel of how to manage science. It is the polytechnic instruction, like in the USSR, or in France as a prime example with the French polytechnic institute. According to Chitre, he 'admire[d] the Soviet Union that they took that step of being self-sufficient. That was possible only because they had a very solid basis. The basis has to be really firmed up at the level of secondary education schools or tertiary school, and post-[graduate education].'[324] This became possible due to a high level of education and self-education of the key Soviet policy-makers. Discussing Stalin who did not receive a proper scientific training [apart from a year or two at a geophysical observatory] but had a deep understanding of science, Chitre brought an example of [Yakov] Zel'dovich, a Soviet physicist who was not trained formally as well, but picked up everything practically by himself to contribute a lot to the development of nuclear energy.[325]

While talking about Kapitsa and the transfer of the Mond laboratory from Cambridge into the USSR in 1934-6 with Rutherford's active involvement, Chitre noted that both Lord Adrian

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[323] *Ibid.*
[324] *Ibid.*
[325] Yakov Zeldovich Dies, A Top Soviet Physicist, 1987, *The NY Times*; retrieved on 22.06.2018 from the Web, https://www.nytimes.com/1987/12/05/obituaries/yakov-zeldovich-dies-a-top-soviet-physicist.html.

[the 1932 Nobel Prize recipient in Physiology[326]], a future Master of Trinity College, and John Cockcroft [the 1951 Nobel Prize recipient in Physics[327]], a future Master of Churchill College, in later years stated in their Cambridge lectures attended by Chitre that they had assisted to the laboratory's transfer.

Peter Littlewood is Director of Argonne National Laboratory (the US) and a former head of the Cavendish Lab/Department of Physics, the University of Cambridge (the UK) who did his PhD there in 1980.[328] His research in theoretical physics and condensed matter physics 'has focused on the dynamics of collective transport; phenomenology and microscopic theory of high-temperature superconductors, transition metal oxides and other correlated electronic systems; and optical properties of highly excited semiconductors. He has applied his methods to engineering, including holographic storage, optical fibers and devices.'[329]

In his interview, Littlewood found quite a lot of parallels between the USSR and the US as their research was driven by the military paradigm. As pointed out by him, one of the best institutes in the Soviet Union was the Institute of Radio Engineering and Electronics in Moscow [established in 1953].[330] According to him, 'they did some absolutely world-leading science,' but nonetheless, the reasons for this were very much that this was a military technology and they wanted to develop it there, just as in the US.

Littlewood noted that previously industry and technology goals were set in a consensus way. In the Soviet Union, they had five-year plans, maybe less so in the West but nonetheless there was a very strong consensus to push for all of those things, and that was what created modern information technology, and so now, the business coming on to the market are things that people can make money out of but mostly have no redeeming social value, according to him.

Littlewood emphasised that the main product of science is scientists. Generations of students and postdocs who have acquired ways of thinking and tools would make analogies and take

[326] Nobel Prizes and Laureates, The Nobel Prize in Physiology or Medicine 1932,
Sir Charles Sherrington, Edgar Adrian, *Nobelprize.org*; retrieved on 09.06.2017 from the Web, https://www.nobelprize.org/nobel_prizes/medicine/laureates/1932/; hereafter referred to as Adrian.
[327] Nobel Prizes and Laureates, The Nobel Prize in Physics 1951, John Cockcroft, Ernest T.S. Walton, *Nobelprize.org*; retrieved on 09.06.2017 from the Web, https://www.nobelprize.org/nobel_prizes/physics/laureates/1951/.
[328] Littlewood.
[329] Peter B. Littlewood, Department of Physics, *The University of Chicago*; retrieved on 04.03.2017 from the Web: https://physics.uchicago.edu/page/peter-littlewood.
[330] Institute of Radio Engineering and Electronics; retrieved on 15.07.217 from the Web, https://mpei.ru/lang/en/structure/Institute_of_Radio_Engineering_and_Electronics/Pages/default.aspx.

from one subject to another one and create something different and new which is important. There was a little bit of separation between Soviet physics and the West; there was a distinct Landau school which is a way of thinking. However, that way of thinking could maybe be applied to from obscure things like superconductors to more practical things like magnetism.

According to him, human capital is critical for development because, of course, not all of the Kapitsa's students are going to go on to become research professors. They will go off into other parts of the economy, taking their skills and their way of thinking with them.

Regarding technology transfer, in the short term, one may think to get successes, but one of the problems with that is that if there is no a scientific base of people who can absorb the technologies, the technology transfer does not happen very well, continued the physicist. The first thing is there has to be some level or receptivity, and that depends on people, their training, their understanding and their abilities to work with this, and so that the main thing that one can actually get are gains from educational and social reforms which are reflected in the ability of a country to absorb technology.

About Soviet development, Gilbert G. Lonzarich, professor of physics (decorated with the highest award for his research in superconductivity)[331] and a former head of the Quantum Matter Group at the Cavendish Laboratory of Cambridge, who was nominated for the 2018 Oliver E Buckley prize for 'his groundbreaking experiments and physical insight that has established a new framework for discovery and understanding of emergent states in superconducting, magnetic and ferroelectric systems alike,'[332] stated the following in his interview:

> Soviet science and technology has brought us the space age. This is a monumental contribution not only to the history of civilization, but that of life on earth itself. In general, the Soviet Union invested heavily in both fundamental science and technology and has many contributions of worldwide importance. I am particularly aware of contributions in metallurgy and materials science and in theoretical physics, particularly in the field of

[331] Professor Gilbert Lonzarich to be Awarded the Kamerlingh Onnes Prize, Department of Physics, the Cavendish Laboratory, *University of Cambridge*; retrieved on 27.05.2017 from Web, http://www.phy.cam.ac.uk/news/professor-gilbert-lonzarich-to-be-awarded-the-2015-kamerlingh-onnes-prize.
[332] *Lonzarich' Nomination for the 2018 Oliver E Buckley prize*, The Cavendish Lab / Department of Physics, University of Cambridge.

> superconductivity. The theories that we use in practice in the field of superconductivity depend heavily on the seminal works of Soviet scientists. I personally use Soviet theoretical inventions on a regular basis.[333]

Meanwhile, technology transfer, in Lonzarich' view, should not permanently restrict the development of the nation's own science and technology base without which a nation could remain in a subordinate position. 'This will lead to a state of mind that will prevent the nation's unique genius from flourishing,' continued the scientist explaining that the dominant powers would wish smaller nations to remain so.[334] Achieving economic success solely through technology transfer without funding the educational and social development through structural reforms would ensure that subordinate status to become for such smaller nations permanent on the 'road to serfdom,' emphasised Lonzarich.[335]

Tony Raven, head of the Cambridge Enterprise,[336] the special entity of the University of Cambridge launched to 'help students and staff commercialise their expertise and ideas,'[337] joined the Cambridge Enterprise as Chief Executive in December 2011. After graduating in physics from Manchester University, he obtained his MSc and DPhil from the University of Oxford. Raven is a Fellow of the Institute of Physics and a Member of the Institute of Directors and was involved in launching a range of successful start-ups.[338]

According to him, the social aspect is critical in science, and it always has something to do with the environment which pushes creativity, and sometimes very differently with the same people. In terms of the role of the technology transfer in development, Raven explained the latter is impossible unless the receiving side's technological and scientific competence is as good as that of the source of the import.

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333 Lonzarich; Appendix N.
334 *Ibid.*
335 *Ibid.*
336 Raven-Bio.
337 The University of Cambridge Enterprise; *University of Cambridge*; retrieved on 1.06.2017 from the Web, https://www.enterprise.cam.ac.uk/who-we-are/.
338 'Previously he was Director of Research & Innovation Services at the University of Southampton, where he helped establish Southampton's international reputation as a leading entrepreneurial university, creating a portfolio of 11 spin-out companies with four listings on the London Stock Exchange […] He worked at Rutherford Appleton Laboratories and Osaka University before joining Cambridge-based PA Consulting in 1983. In 1985 he was a founder of Summit Technology, the market leader in laser refractive surgery, which was acquired by Nestlé Alcon in 2000 for $893 million. In 1987 he co-founded Cambridge-based Sagentia Group plc, a technical and management consultancy which is listed on the London Stock Exchange. In 1991 he founded Diomed Inc, a pioneer and world leader in therapeutic medical diode lasers, and served as CEO and Deputy Chairman until 2000;' – Raven-Bio.

In his view, it is challenging to enter new industrial areas, not knowing anything about them and being not capable even of hiring a good advisory because one could not know what a good one looked like:

> Without that understanding of the science moving into, it [would be] difficult even to know how to start. They say that the first thing is you need to find an expert, but you do not know what an expert looks like. It is where a lot of consultancy fails as well. You get someone external to tell you what to do but you do not really understand what they have told you.[339]

Thus, the capacity to absorb, according to Raven, is vital for development.

According to Siddharth (Montu) Saxena, an experimental physicist at the Quantum Matter Group, the Cavendish Laboratory, Cambridge,[340] science is a reservoir of knowledge from which practical solutions of engineering, technology, and innovation are drawn. Indeed often to further science one has to develop new instrumentation and methods which is very much in the technology and innovation realm. Equally missing pieces and new needs in technology require digging back into the scientific reservoir. However, the quality and breadth of that reservoir intrinsically affect the quality of technology that is derived from it. It will be a very limited reservoir if it only relied on directed need-based understanding to fill it.

As outlined by Saxena, the core of science remains as the curiosity-driven pursuit of understanding natural phenomena and as a quest to translate the strange into familiar. It also brings up the question of the difference between discovery and invention and requires the delineation between the notions of science and technology.

Saxena firmly agreed with the notion that the primary process that leads to sustainable technological development of large developed countries (or companies) is clearly linked to a robust fundamental science research base and illustrated it with the following example: 'Many electronic devices in use today globally contain materials invented in the Soviet Union including Kazakhstan.'[341]

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[339] Raven.
[340] Saxena.
[341] *Ibid.*

Saxena's interview concludes the subsection above in which international scientists have disclosed their views on the nature of the driving forces in science and the connection between the notions of science, engineering, and technology in general and in their particular fields.

3.1.3 Insight from Both Systems

In concluding both subsections above of the interviews with those from inside and outside of the Soviet system, Timour Paltashev's vision is provided in representing both Soviet/post-Soviet and Western systems as that of full professor of the department of computer science & engineering of National Research University of Information Technology, Mechanics and Optics (ITMO),[342] St. Petersburg, Russia, and professor of the Northwestern Polytechnic University in California,[343] the USA, as well as a current AMD[344] Radeon Technology Group senior manager, involved in applied and industrial technology research & development as well as in start-ups activity in the US, Russia, and Kazakhstan.[345] He graduated from the Kazakh Polytechnic Institute[346] (Alma-Ata, the Kazakh SSR, the Soviet Union, Paltashev's hometown) in 1978 and obtained his both degrees of PhD and Doctor of Sciences in computer engineering at ITMO in 1987 and 1994 respectively.

According to him, investments in the development of fundamental science become immediately justified in dealing with natural and technogenic disasters providing the expertise required, as seen in the examples of Japan and the USSR. In the absence of the school of nuclear physics in Japan, the reactor in Fukushima after the 2011 accident keeps producing radiation whereas the Soviet Union could localise the source of radiation in Chernobyl in 1986 due to the deep Soviet expertise in this discipline.

Paltashev outlined that Soviet industry was based on and constructed by research. For example, in Kazakhstan and Uzbekistan, the state policy brought exogenous research from the other developed parts of the USSR before and during, in particular, WWII to establish and develop the indigenous schools of basic research as the drivers of the industrial development

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342 *National Research University of Information Technology, Mechanics and Optics*, St. Petersburg, Russia; retrieved on 03.06.2018 from the Web, http://en.ifmo.ru/en/ .
343 *Northwestern Polytechnic University*, California; retrieved on 06.06.2018 from the Web, http://www.npu.edu/.
344 Advanced Micro Devices, Inc. (AMD); retrieved on 03.06.2018 from the Web, https://www.amd.com/en.
345 Paltashev.
346 *The Satbayev Kazakh National Technical University*; retrieved on 03.06.2018 from the Web, http://kaznitu.kz/en; hereafter referred to as the SKNTU.

and the centres of the knowledge and expertise in various fields including those dealing with natural disasters.

According to him, in Soviet development, the implementation of the principle of the particular importance of fundamental science for the industrial development received special attention during WWII. It occurred due to the need of the improvement of both the quality of the industrial research established mainly throughout the 1920s and 30s, as resultant from the industrial technology and production of the massive preceding technology transfer, e.g. in the steel industry and aviation turbines in particular. The problem became even more acute in the light of facing the nuclear weapon challenge of the creation of the own super-weapon as a counter-measure. It was the Soviet Atomic Bomb Project which was totally related to the development of fundamental science in general and nuclear physics in particular and in which Abram Ioffe [or Joffe], 'the father' of the Soviet physics school, played a crucial role of concentrating of the dispersed physicists' knowledge in one place. During WWII and in the post-war period, for the USSR, unlike for the US, it was a matter of the nation's survival, continued the scientist.

He emphasised that, in terms of the role of the technology transfer for this project, the development of the Soviet Bomb went in both directions, i.e. the implementation of the exact copy of the American Bomb (as an illegal technology transfer via intelligence service) and an own self-engineered Soviet device. Both of them exploded, noted Paltashev.

Regarding the technology transfer, in the industry, in general, it is impossible to reproduce both new technology and a new product simultaneously. Once the technology is transferred, an old product is produced first. Once the former is adopted, a new product could be developed and produced which is a widespread industrial practice, as stressed out by him:

> During industrialisation, technology transfer was very important for Soviet development and the Government's policy was correct in doing the following. It purchased a plant on turn-key-solutions or technology of full cycle and hired experts to launch it and teach Soviet personnel.[347]

According to Paltashev, a main technology transfer trap lies within a possibility of being refused with further import. Any credible government tries to get rid of the imported critical

[347] Paltashev.

parts and components in its telecommunications infrastructure. The latter means survival in the modern world. The same is relevant for the infrastructure electronics of all the critical industries, e.g. in the energy sector, machinery, and transport, *etc*. The price of the civilisation can be measured in two days without electrical power. The approach is based on the understanding that, in case of an emergency, 70 per cent of the functions in a particular infrastructure should remain working.

Brain drain can be performed in two ways: either by transferring the experts or by assigning them with own tasks. Technology transfer is important for establishing an original technology to reproduce goods and develop own new products in the next generation, in Paltashev's view.

He outlined that technology transfer is limited in time. Once performed, it cannot function longer than for 30 years without being developed; it is a single-use action and useless if the overall industrial, marketing, logistics, research, and education infrastructure is not established. Universally, development of research and technology is driven by human capital which derives from education. Meanwhile, development of education requires a comprehensive social approach.

Paltashev emphasised the quality of Soviet education for science and technology at the example of *Phystech*, or MFTI, The Moscow Institute of Physics and Technology,[348] established by Pyotr Kapitsa in 1946.[349] Today there it is ordinary practice for its graduates to obtain their PhDs at leading global universities, including Princeton, Stanford or Berkeley in the US.

Paltashev noted that Kapitsa, Rutherford's man, is an iconic figure in science. The fact that he could have made such a scientific and engineering career in both worlds of the West and the USSR demonstrated his incredible talent apart from his and his son's contribution in science. His fate became the evidence of the non-dominance of the ideological approach for the Soviet leadership in the science and technology policy. Some of Kapitsa's public views alternative to the official Party's line on Soviet development were either ignored or forgiven by the system due to the prevailing importance of Kapitsa doing his business.[350] The main contribution in

[348] *MIPT, the Moscow Institute of Physics and Technology*; retrieved on 04.06.2017 from the Web, https://mipt.ru/en/; hereafter referred to as MFTI.
[349] Appendix M.
[350] Appendices L and M.

establishing the Soviet school of physics is credited to Abram Ioffe and Pyotr Kapitsa. The Soviet Atomic Project came from Ioffe's school. The name of Kapitsa should always be associated with Ioffe, as it is in the US scientific community, where the former is not that known, and Ioffe is a leading and founding figure of the Soviet school of physics, concluded this Soviet/Russian/American scientist originally from Kazakhstan.

Paltashev's interview concludes the section of the interviews. The next section of the data chapter is dedicated to the factual evidence obtained from primary literature relevant to address the research question.

3.2 Data from Other Primary Sources

As mentioned in the methodology section of chapter 2, the data and theoretical research from various primary literature sources have been used for this thesis, including the theorists of Marxism-Leninism, the speeches, decrees and articles of the key Soviet policy-makers such as Stalin, Molotov, Khrushchev and others, Soviet legal acts and statistical documents as well as some memoirs and correspondence. Some other data, like those from the memoirs of Anna Kapitsa, Pyotr Kapitsa's wife, as well as his correspondence with the Soviet leadership, are considered in Appendices L and M and analysed in comparison with Vannevar Bush's report to Roosevelt, which is a legitimate primary source as well. Last but not least, the data from the Nobel Prize Committee's website as well as other scientific institutions are widely used throughout the thesis to illustrate the interviewees' data and analysis. Thus, the study of the primary sources reveals the following data.

The Soviet development policy was in line with Marxist-Leninist ideology. The driving force for productivity in the Soviet Union became technical progress which was key to forming a socialist society, as per the Marxist theory of political economy. In terms of economic theory, the latter was based on the classical British economic theories, e.g. 'division of labour' by Adam Smith,[351] David Ricardo's labour theory of value[352] as well as Thomas Robert Malthus' demographic research on growth and surplus of population.[353] Karl Marx

[351] Smith, Adam, 1776, *An Inquiry into the Nature and Causes of the Wealth of Nations*, Edwin Cannan, ed. 1904, Library of Economics and Liberty; retrieved on 9.03.2018 from the Web, http://www.econlib.org/library/Smith/smWN1.html.
[352] Ricardo, David, 1817, *On the Principles of Political Economy and Taxation*, 1821, Library of Economics and Liberty; retrieved on 9.03.2018 from the Web, http://www.econlib.org/library/Ricardo/ricP.html.
[353] Malthus, Thomas Robert, 1798, *An Essay on the Principle of Population,* Library of Economics and Liberty; retrieved on 09.03.2018 from the Web, http://www.econlib.org/library/Malthus/malPop.html.

combined and developed these theories into his teaching on the role of surplus value,[354] including labour, to be socialised for the overall increase in productivity in the socialist society. Unlike Malthus, Marx viewed the primary cause of the labour growth in economic, not biological terms. According to Marx, technical progress changes the means and modes of production (constant capital) in order to increase productivity, labour and the rate of surplus value (variable capital).

This theory was primarily used by the Bolsheviks in transforming the backward Russia, whose state of affairs was described by Vladimir Lenin in his 1913 article as follows: 'There is no other country in Europe so barbarous in which the masses are robbed to such an extent of education, light and knowledge [...] No other country in Europe has remained in this condition; Russia is the exception.'[355] Lenin prioritised the role of education in the new main policy line as follows:

> We can build communism only on the basis of the totality of knowledge, organisations and institutions, only by using the stock of human forces and means that have been left to us by the old society. Only by radically remoulding the teaching, organisation and training of the youth shall we be able to ensure that the efforts of the younger generation will result in the creation of a society that will be unlike the old society, i.e., in the creation of a communist society.[356]

The policy for education started on 9 November (27 October) 1917 by forming the People's Commissariat for Education with Anatoly Lunacharsky as its head.[357] This step became the foundation stone for the preparation of the programme to eliminate illiteracy, or *Likbez*. By signing a decree *On Liquidation of Illiteracy among the Population of RSFSR* in 1919,

[354] Marx, Karl, 1867, *Capital, A Critique of Political Economy, Volume I, Book One: The Process of Production of Capital*, First English edition of 1887 (4th German edition changes included as indicated) with some modernisation of spelling, Progress Publishers, Moscow, USSR; retrieved on 09.08.2018 from the Web, https://www.marxists.org/archive/marx/works/1867-c1/.
[355] Lenin, Vladimir, 1913, The Question of Ministry of Education Policy, *Lenin Collected Works*, Progress Publishers, 1977, Moscow, Vol. 19, 138.
[356] Lenin, Vladimir, 1920, The Tasks of the Youth Leagues, Speech Delivered At The Third All-Russia Congress of The Russian Young Communist League, 2 October,
First Published: Pravda Nos. 221, 222 and 223, October 5, 6 and 7, 1920, *Collected Works*, Volume 31; retrieved on 12 May 2019 from the Web, https://www.marxists.org/archive/lenin/works/1920/oct/02.htm#1.
[357] *Sobranie uzakonenii I rasporiazhenii rabochego i krestianskogo pravitel'stva* (*Collection of Legalisation and Orders of the Workers 'and Peasants' Government*), Division one. Petrograd, 1917, No. 1, art. 1.

Lenin launched the *Likbez* campaign, which aimed at making everyone from 8 to 50 years old to become literate in her native or Russian languages.[358]

In parallel, the Central Commission for the Improvement of the Life of Scientists (*TsEKUBU*) under the SNK of the RSFSR as the executive body of the Soviet government was created according to the resolution of the *SNK* of the RSFSR of December 6, 1921 'On improving the life of scientists' signed by Alexander Tsyurupa (as the chairman of the *SNK*) and Nikolay Gorbunov.[359] This body's task was 'to create working conditions for the scientific, technical and creative intelligentsia of Russia in war communism.'[360] It existed in its original form until 1931 when it was transformed into the Commission for Assistance to Scientists at the *SNK* of the USSR which worked until 1937.[361]

The *GOELRO* plan of the electrification of the country designed by Lenin became a kind of the first big Soviet industrial plan, a precursor and necessary prerequisite for further industrialisation which was worded by him as follows: 'Communism is Soviet power plus the electrification of the whole country, since industry cannot be developed without electrification.'[362]

The XIV Congress of the All-Union Communist Party (Bolsheviks) during 18–31 December 1925 placed the task of turning the USSR from a country dependent on imports into a self-sustaining heavy industry producer.[363] As evident from the literature review and the previous section, foreign involvement became the main factor of Soviet industrialisation, during which, the ideological constraints were abandoned for cooperation between two opposite systems. This was officially recognised by the country's leaders, including Stalin and Molotov. In particular, Stalin proclaimed the following:

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[358] *Dekret SNK o likvidatsii bezgramotnosti sredi naselenia RSFSR, 26 dekabrya 1919* (The SNK Decree About Liquidation of Illiteracy in Population of the RSFSR, 26 December 1919)*, Gosudarstvennyi arkhiv Rossiyskoi Federatsii* (The State Archive of the Russian Federation), F, R-130, Op. 2. D. 1, 38.
[359] *Komissiya Sodeystviya Uchenym (KSU) pri Soviete Narodnykh Komissarov SSSR. 1921 – 1937* (Commission of Assistance to Scientists (CCU) at the Council of People's Commissars of the USSR. 1921 – 1937), *Rusarchive*; retrieved on 17.07.2019 from the Web, http://guides.rusarchives.ru/browse/gbfond.html?bid=203&fund_id=1153241.
[360] *Ibid*.
[361] *Ibid*.
[362] Lenin V.I., 1920, Our Foreign and Domestic Position and Party Tasks, Speech Delivered To The Moscow Gubernia Conference Of The R.C.P.(B.), November 21, *Collected Works*, 4th English Edition, Progress Publishers, Moscow, 1965, Vol. 31, 408-26; retrieved on 15.07.2017 from the Web, https://www.marxists.org/archive/lenin/works/1920/nov/21.htm.
[363] Stalin, J. V., The Fourteenth Congress of the C.P.S.U.(B.), *Works, Vol. 7*, 1925 Foreign Languages Publishing House, Moscow, 1954; retrieved on 3 July 2018 from the Web, https://www.marxists.org/reference/archive/stalin/works/1925/12/18.htm.

> Of course, we could have used the 3,000,000,000 rubles in foreign currency obtained as a result of a most rigorous economy, and spent on building up our industry, for importing raw materials, and for increasing the output of articles of general consumption. That is also a 'plan,' in a way. But with such a 'plan' we would not now have a metallurgical industry, or a machine-building industry, or tractors and automobiles, or aeroplanes and tanks. We would have found ourselves unarmed in the face of foreign foes.[364]

Molotov, number two in the Kremlin's hierarchy, admitted in his 1935 official report that '[i]n a complicated international situation, competition and, at the same time, a collaboration of two opposite systems happens.'[365] Industrialisation took place within two five-year plans of 1928-32 and 1933-7. The main funding sources for the first plan were identified as follows: the light industry and agricultural sector, the monopoly from the overseas trade, the taxation of the SME, tax duties on alcohol imposed, and the loans from the population.[366] In 1931 while trying to justify an increasingly growing pressure of the industrialisation on the population, Stalin declared that 'we are fifty or a hundred years behind the advanced countries. We must make up this distance in ten years. Either we do it, or we shall go under.'[367]

In 1931, *polytechnisation* of the Soviet education aiming to support the industrialisation development became the leading education instruction at the SES as evident from the 1931

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[364] Stalin, Josef, 1935, Address Delivered in the Kremlin Palace to the Graduates From the Red Army Academies, on May 4, 1935. *Pravda*, 6 May 1935, from Stalin, Josef, *Problems of Leninism, Foreign Languages Press*, Peking, 1976, 767-74, Source: Works, Vol. 14, Red Star Press Ltd., London, 1978; retrieved on 3 July 2017 from the Web, https://www.marxists.org/reference/archive/stalin/works/1935/05/04.htm.

[365] Molotov, Vyacheslav, 1935, *Iz doklada Predsedatelia Sovieta Narodnykh Komissarov SSSR na VII siezde Sovietov 28 yanvaria 1935 goda* (From the Report of the Chairman of the SNK of the USSR on the VII Congress of the Soviets on 28 Jan 1935), *Ministerstvo Inostrannykh Del SSSR, Dokumenty Vneshnei Politiki SSSR* (*Ministry of Foreign Affairs of the USSR, The Documents of Foreign Policy*), Izdatelstvo Politicheskoi Literatury, Moscow, Vol. 18, 1973, 43.

[366] *Doklad tovarischa Molotova o vtorom pyatiletnem plane razvitiya narodnogo khoziastva SSSR. Zasedanie pyatnadtsatoe 3 fevralia 1934 g., utrennee. XVII s'iezd VKP (b). 26 yanvaria - 10 fevralia 1934 г. Stenograficheskyi otchet* (Report by the Comrade Molotov on the Second Five-Year Plan of People's Economy of the USSR, The session 15, 3 Feb 1934, in the Morning. *XVII Congress of VKP[b].*, 26 Jan – 10 Feb 1934, Verbatim report), 1934, Partizdat; retrieved on 17.05.2015 from the Web, http://www.hrono.info/vkpb_17/15_1.htm.

[367] Stalin, Josef, 1931, *O zadachakh khoziastvennikov* (The Tasks of Business Executives), Speech Delivered at the First All-Union Conference of Leading Personnel of Socialist Industry 1, February 4, *Works, Vol. 13*, 1930 - January 1934, Foreign Languages Publishing House, Moscow, 1954. First published in *Pravda,* No. 35, February 5, 1931.

directive of the *VKP(b)* (the Communist Party)[368] based on Stalin's views. His following writings that 'our industry would be lifted to a height beyond the reach of the industries of other countries,' if 'the majority of workers should raise their cultural-technical level to the level of engineering-technician personnel,' and the emphasis of the importance of combining both theoretical knowledge and skills in opposition to 'a sterile training in trades – 'technicianism'' are cited in there.[369] The references to Stalin as well as his cult in Soviet life was named as 'the cult of personality' in the Soviet political terminology by Nikita Khrushchev in his 1956 Report on the XX Congress of the Communist Party of the Soviet Union.[370]

In prioritising polytechnisation in Soviet development, in 1940 Stalin, while learning about both Soviet delegation's inspection of the German aviation and reports on the unpreparedness of the Soviet aviation before a possible war, gave the following and not that widely known definition of Soviet power:

> What is the Soviet power? […] If any problem arises that does not contradict the laws of physics, mechanics and chemistry, and its solution is necessary for the Motherland, then it will be solved — that is what Soviet power.[371]

Meanwhile, by the end of the 1930s, the goal of industrialisation was achieved. According to *Gosplan's* (The State Planning Committee) official report, the USSR had become the largest European and the second global industrial power after the US in terms of industrial output, having reduced imports rapidly to the level of just 1 per cent of GDP.[372]

The period from the 1930s to 50s in its different stages was characterised by the mixed forms of the social organisations. Apart from the dominant state ownership, as evident from

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[368] *O nachal'noi i srednei shkole* (On the Elementary and Secondary School), 1931, September 5, *Direktivy VKP(b) I postanovleniya sovetskogo pravitelstva o narodnom obrazovanii za 1917-1947 gg.* (Directives of VKP[b] and Regulations of the Soviet Government on People's Education in 1917-1947), Vol. I, 8.
[369] *Ibid*., citing from Stalin, I.V., 1952, *Ekonomychekiye problemy sotsializma v SSSR* (Economic Problems of Socialism in the USSR), Moscow, Gospolitizdat, 28.
[370] Khrushchev N.S., 1956, *O kul'te lichnosti i ego posledtviyakh* (*On the Cult of Personality and its Consequences*), Report on the XX Congress of the Communist Party of the Soviet Union, 25 February, published in 1989, *Izvestia TsK KPSS*, N. 3.
[371] Petrov, I.F., 1992, *Aviatsia i viya zhizn'* (*Aviation and All Life*), Moscow, Izdatel'skii Otdel TsAGI, 50.
[372] *Itogi vypolnenia vtorogo pyatiletnego plana razvitiya narodnogo khozyaystva Soyuza SSR* (*Results of the Execution of the Second Five Years Plan of People's Economy of the USSR*), 1939, Moscow, Gosplanizdat; retrieved on 01.07.2017 from the Web, http://istmat.info/files/uploads/32068/itogi_vypolneniya_vtorogo_pyatiletnego_plana_0.pdf.

the official economic reports, the production share of capitalistic and private industry in the GNP was reduced from 17.6 per cent in 1928 to 0.2 per cent in 1937.[373] Cooperative industry in the form of the collective ownership, so-called *Arteli* (the artels), kept playing a decreasing but notable role in the total GNP with the following numbers: 13.9 per cent in 1928, 9.5 in 1937, 8.2 in 1950, 8 in 1955, 6 in 1958 and 1959, 3 in 1960.[374] It was reduced substantially and disappeared from the new and extended forms of the statistical reports during and afterwards Khrushchev's era from 1962.[375]

In terms of the Soviet population's literacy, the following was achieved, as seen from the All-Union Soviet censuses of 1939 and 1959. By 1939 the male literacy reached 90.8 per cent and female literacy 72.5 per cent, which, as an example, constituted 89.7 per cent in the RSFSR, aged 9-10, according to the 1939 Soviet census.[376] It is important to note that by the 1950s the initial goal of almost 100 (98.5) per cent literacy of the entire population was reached and stabilised.[377]

In terms of the Soviet higher education policy, the establishment of the leading national universities was closely supervised by the high political leadership, as indicated in the two following examples among many others. The National University of Science and Technology *MISIS* (mentioned in Tsironis' interview before) was established in 1930 by a direct decree by Stalin and it was carried his name till 1962 (*Moskovskyi Institute Stali Imeni J.V. Stalina*, Moscow Institute of Steel named after J.V. Stalin).[378]

In 1947 upon Stalin's personal proposal the Government took a decision to construct the Lomonosov Moscow State University's new colossal building and massive campus in central Moscow.[379] The construction of the MSU large campus was begun with Stalin's and

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373 *Narodnoye khozyaystvo SSSR v 1960 godu (Statisticheskii ezhegodnik) (People's Economy of the USSR in 1960 [Statistical Yearbook])*, 1961, Gosstatizdat TsSU SSSR, Moscow, 213.
374 *Ibid.*
375 *Narodnoye khozyaystvo SSSR v 1961 godu (Statisticheskii ezhegodnik) (People's Economy of the USSR in 1961 [Statistical Yearbook])*, 1962, Gosstatizdat TsSU SSSR, Moscow.
376 *Vsesoyuznaya perepis' naseleniya 1939 goda, Tablitsa 12, Gramotnost, obrazovaniye i obuchenue po vostrastnym gruppam, chislo sostoyavshikh v brake* (All-Union census of the population of 1939, Table 12, Literacy, education and learning in various groups, the number of the married)*, RGAE. F. 1562. OP. 336, D 640.*
377 *Vsesoyuznaya perepis' naseleniya 1959 goda, Tablitsa 7, Raspredelenie naseleniya po vozrastu i urovnu obrazovaniya (*All-Union census of the population of 1959, Table 7*,* Distribution of the population in age and educational level)*, RGAE. F. 1562. OP. 336, D. 1591-94.*
378 *MISIS, National University of Science and Technology*, Moscow, Russia; retrieved on 17.07.2017 from the Web, http://en.misis.ru/ - formerly the Stalin Moscow Institute of Steel, established in 1930; hereafter referred to as MISIS.
379 Stalin J.V., Chadaev Y., 1947, *Postanovlenie Sovieta Ministrov SSSR O Stroitelstve v g. Moskva Vyjujetazhnykh zdanyi* (Decision of the Council of Ministers of the USSR On Construction of Multi-stories

Chadaev's decree on behalf of the Soviet Government on 15 March 1948[380] and finished on 1 September 1953.

Central Asia was regarded as the most backward region of the Soviet Union, and the first results of the policy of human capital development can be shown through the illustrative example of Kazakhstan in the following data, taken from the economic and statistical official reports of the era.

In the republic, the overall number of the engineers which was counted as 746 and ethnic Kazakh among them as 14 in 1915 reached 2,882 in 1927.[381] Due to a set of measures on the formation of the new national *intelligentsia* in Kazakhstan, its number by 1930 grew 8 times from 22,500 to 177,900 people.[382] In 1932, 12 R&D institutes, 15 experimental stations, 186 hydro stations, and labs were established.[383] Additionally, 4,300 people from Kazakhstan were studying at the universities and scientific institutions of Moscow, Leningrad, Kazan, Tomsk, Kharkov, Omsk, Astrakhan, and other cities.[384] The number of the researchers grew steadily. For example, as described in the All-Soviet Union census poll in 1926, in Kazakhstan there were 47 lecturers and professors, 58 the authors and editors, and 143 librarians and museum workers. In 1931 the number of the researchers was 324, and by 1932 it increased to 558.[385]

In 1933 the *Politburo* of the *TsK* issued a decree to establish two leading higher education institutions of Kazakhstan, i.e. the Kazakh Mining-Engineering Institute[386] and the Kazakh State University[387] which were established in 1934, and to develop an extensive programme of preparing specialists of medium levels for various industries.[388] Overall 12 higher

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Buildings in Moscow), January, Stalin J.V., Consolidations, Vol. 18, 2006, Informazionno-Izdatelskyi Tsentr *Soyuz*, 430-2.
[380] Stalin I., Chadaev Y., 1948, *Postanovlenie Soveta Ministrov SSSR O stroitel'stve novogo zdaniya dlya Moskovskogo gosudarstvennogo universiteta, 15 marta* (The Decree of the Counsel of the Ministries of the USSR About Construction of a New Building for the Moscow State University, 15 March) 2006 Edition, *Collected Works*, Tver', Soyuz, 460-1.
[381] *Sotsialistichekoye stroitel'stvo v KazSSR* (*Socialist Construction in the Kazakh SSR*), Statistical compilation, 1960, Alma-Ata, 239.
[382] *Narodnoye khozyaystvo Kazakhstana* (*People's Economy of Kazakhstan*), 1930, № 3-4, Alma-Ata, 17, 19.
[383] *Kul'turnoe stroitelstvo Kazakhskoi SSR* (*Cultural Construction of the Kazakh SSR*), 1960, Statistical Compilation, Alma-Ata, 90.
[384] *Ibid.*
[385] *Ibid.*
[386] The SKNTU.
[387] The Al-Farabi Kazakh National University; retrieved on 03.07.2018 from the Web, http://www.kaznu.kz/en.
[388] *O podgotovke kadrov dlya Kazakhstana (Utverzhdeno Politburo TsK VKP[b] 19.X.1933 g.), Prilozhenie N5 k p. 44/25, PB N148* (*About Preparation of Personnel for Kazakhstan [Approved by Politburo TsL VKP[b] 19.10.1933, Attachment #5 to 44/25, PB #148]*), RGASPI, F.17, OP., 3, D 933, 45-6.

education institutions were established in the 1930s in Kazakhstan as well as the Kazakhstani base of the Academy of Sciences of the USSR in 1932 which was converted into a branch in 1938 and became established as the Academy of Sciences of the Kazakh SSR in 1946.[389]

As evident from an announcement below published by the Kazakh State University in 1955 inviting applications to compete for academic appointments, the polytechnic instruction was founded there as a leading one. The priority was given to such following scientific subjects as, for instance, physics or mathematics, and the teaching process included the most diverse spectrum of various disciplines:

> Kazakh State University Named after S.M. Kirov, of the USSR Ministry of Higher education, announces a competition for the following positions:
>
> Department Heads, professors or: general physics, higher algebra, physical chemistry, Russian language, foreign languages, history of the USSR, psychology and pedagogy, physical education and sports, foundation of Marxism-Leninism, philosophy, industrial economics, general history higher geometry, and oil and gas geology;
>
> Docents and Senior Teachers in the Departments of general physics, higher algebra, physical chemistry, Russian language, foreign languages, history of the USSR, psychology and pedagogy, physical education and sports, foundations of Marxism-Leninism, philosophy, optics and spectroscopy, differential equations, theoretical mechanics, economic geography, physical geography, general geology, oil and gas geology, Russian literature, general history (medieval and ancient), economic statistics, finances and credit, bookkeeping-accounting, organization of Soviet trade, and commodities study;
>
> Assistants and Teachers in the Departments of: general physics, physical chemistry, Russian language, foreign languages, physical education and sports, foundation of Marxism-Leninism.[390]

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[389] The National Academy of Sciences of Kazakhstan, *The Electronic Encyclopaedia*, Tomsk Polytechnic University; retrieved on 15.07.2017 from the Web, http://wiki.tpu.ru/wiki/%D0%9D%D0%B0%D1%86%D0%B8%D0%BE%D0%BD%D0%B0%D0%BB%D1%8C%D0%BD%D0%B0%D1%8F_%D0%B0%D0%BA%D0%B0%D0%B4%D0%B5%D0%BC%D0%B8%D1%8F_%D0%BD%D0%B0%D1%83%D0%BA_%D0%9A%D0%B0%D0%B7%D0%B0%D1%85%D1%81%D1%82%D0%B0%D0%BD%D0%B0.

[390] Announcement by the Kazakh State University Named after S.M. Kirov, of the USSR Ministry of Higher education, *Kazakhstanskaya Pravda*, April 29, 1955, 4.

In terms of social policy, a large number of the social privileges were proclaimed in the last two out of the three constitutions of the USSR[391] as well as other legal acts.

All three constitutions cover three periods of the lifespan of the Soviet Union in 1924, 1936 and 1977. They are closely associated with the names of the leaders – Lenin, Stalin and Brezhnev respectively. Whereas the 1924 Constitution was dedicated to the establishment of the new state and, unlike the later ones, lacked a detailed chapter of citizens' individual social rights, it defined public hygiene as a constitutional act[392] and obliged the state to be its main guarantor and provider. The state policy played an increasing role in the society in subsequent years. Most of these social benefits which were introduced in Stalin's Constitution were reinforced in the Constitution of 1977 and would be detailed in chapter 4.

As considered in the literature review and the interviews, in Soviet development the SAS played a significant and distinct role, which was defined by many notable scientists. The members of the Academy elected Head of the Academy on the democratic basis as evident from the RAN's protocol of Alexander Karpinsky's elections in May 1917.[393] This principle continued during the Soviet rule.

Another aspect that should be mentioned with about the state of affairs in Soviet science during Stalin's time is the existence of so-called *sharashkas*, which was an informal name for the Experimental Design Bureaus (*Opytnye konstruktorskie buro*, or OKB), secret R&D laboratories in the Soviet *Gulag* camp system. The imprisonment mostly affected, due to unclear and disputable reasons, the aviation and rocket industry, including Andrey Tupolev, the future founder of the Tupolev aviation design bureau (which designed the first supersonic passenger jet in 1968 to be launched on the regular route between Alma-Ata and

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391 Chapter X, Fundamental Right and Duties of Citizens, *The 1936 Constitution of the USSR*, 1936; retrieved on 04.03.2017 from the Web:
http://www.departments.bucknell.edu/russian/const/36cons04.html#chap10;
- Chapter 7: The Basic Rights, Freedoms, and Duties of Citizens of the USSR, *Constitution (Fundamental Law) of The Union of Soviet Socialist Republics)*, 1977; retrieved on 04.03.2017 from the Web:
http://www.departments.bucknell.edu/russian/const/1977toc.html.

392 q, 1, Chapter I, Attributions of the Supreme Organs of Power of the Union, *The 1924 Constitution of the Union of Socialist Soviet Republics*, 1924; retrieved on 04.03.2017 from the Web,
http://constitution.sokolniki.com/eng/History/RussianConstitutions/10266.aspx.

393 *O izbranii A.P. Karpinskogo presidentom Rossiyskoi akademii nauk, § 173, 8 zasedanie ot 15 maia 1917 goda* (About the Election of A.P. Karpinsky as the President of the Russian Academy of Sciences, § 173, the 8th meeting of 15 May 1917), 1917*, Protokoly Ekstraordinarnogo obshchego sobrania Rossiyskoi akademii nauk (Protocols of Extraordinary General Meeting of the Russian Academy of Sciences),* SBbF, RAN, 212; hereafter referred to as Karpinsky.

Moscow among many other achievements),[394] and Sergey Korolev, the future chief engineer of the Soviet Space programme,[395] as well as some others. Meanwhile, the study of such primary sources, as the decree by the Ministry of Internal Affairs of the USSR, confirmed that the overall number of these specific laboratories was limited to five.[396]

With regard to the influence of the Soviet military paradigm on the development of fundamental science, the statement by Nikolay Basov[397] below is notable. Basov was the 1964 Nobel Laureate in Physics for the discovery of laser. In his interview to an American physicist Arthur Guenther[398] in 1984 in Moscow, Basov strongly denied the alleged connection of the advance to the pressure of any apparent war or military needs:

> As far as masers and lasers are concerned, then of course, one should mention that the centimeter waves used in radiolocation had been the creation of the war. The radio engineering and radio physics were well represented at our laboratory as radio astronomy and radio spectroscopy. But we were dealing with those problems without any connection with military investigations. In our investigations we aimed at creation of such radiation sources that would continuously cover a wide range of centimeter waves (just with that purpose we studied the synchrotron radiation). That was necessary for the atmospheric investigations, for the analysis of various substances and their properties in the cm wavelength region. One didn't feel any war spirit in the laboratory.[399]

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394 The Editors, 1998, Andrey Nikolayevich Tupolev, Soviet Aircraft Designer, 20 July, *Encyclopaedia Britannica*; retrieved on 26.06.2017 from the Web, https://www.britannica.com/biography/Andrey-Nikolayevich-Tupolev.

395 The Editors, 1998, Sergey Pavlovich Korolyov, Soviet Scientist, *Encyclopaedia Britannica*; retrieved on 26.06.2017 from the Web, https://www.britannica.com/biography/Sergey-Pavlovich-Korolyov.

396 Kruglov, S., 1949, *31 Prikaz ministra vnutrennikh del Soyza SSSR* (*31 Decree by the Minister of the Internal Affairs of the Union of SSR*), N001020, 9 November, Moscow; retrieved on 26.06.2017 from the Web, http://www.memorial.krsk.ru/DOKUMENT/USSR/491109.htm.

397 Basov.

398 In Memoriam: Arthur H. Guenther, 2007, OSA Mourns the Loss of Arthur H. Guenther, 21 April, *The Optical Society*; retrieved on 04.07.2017 from the Web, http://www.osa.org/en-us/about_osa/newsroom/obituaries/earlier/arthur_guenther/.

399 Basov, N.G., 1984, *Oral Histories Interviews*, Interviewed by Arthur Guenter, 14 September, American Institute of Physics; retrieved on 04.06.2017 from the Web, https://www.aip.org/history-programs/niels-bohr-library/oral-histories/4495.

Meanwhile, in his paper *Soviet Science: Thirty Years*,[400] Sergey (Sergei) Vavilov,[401] the third President of the SAS in 1945-1951 and a younger brother of Nikolay Vavilov,[402] depicted the involvement of the Soviet scientists in WWII as follows:

> Despite the difficult and unaccustomed conditions, science kept pace with the country's increased requirements: Soviet men of science were to be found everywhere — in the air force, the navy, the artillery, the engineers, the railway troops, the hospitals, the war plants, the collective farms. And everywhere they offered help and counsel. Soviet science may claim its share in the victory of the Soviet Army.[403]

Sergey Vavilov emphasised a high level of Russian science developing from the XVIII Century and its connection with that of Europe. According to him, 'Russia in the nineteenth century had many brilliant scientists and could pride herself upon a lengthy roll of momentous discoveries and inventions; but, with only rare exceptions, she had no systematically developing national science.'[404] As well, '[T]he Russian scientists were constantly haunted by a sense of futility, of unwantedness, of divorcement from their native soil — the inevitable consequence of old Russia's social order and of the tsarist government's fatuous disregard of science.'[405]

Vavilov described the process of the transformative expansion of science in the USSR through the SAS. He highly praised the role of the policy-makers in this process which occurred, in his account, in the full accordance with the teaching of Marxism-Leninism and widely involved planning for science:

> And the complete dedication of our science to the service of the people and the state has made planning in science an absolute necessity. That is one of the chief distinguishing features of science! in the socialist: state. Such

[400] Vavilov S.I., 1948, *Soviet Science, Thirty Years*, Foreign Language Publishing House, Moscow; retrieved on 11.05.2019 from the Web, https://www.marxists.org/archive/vavilov/1948/30-years/x01.htm; hereafter referred to as Vavilov.
[401] Bolotovski, Boris M., Vavilov Yuri N., Shmeleva, Alevtina P., 2004, Sergei Vavilov: luminary of Russian physics, *CERN Courier*, 12 November; retrieved on 11.05.2019 from the Web, https://cerncourier.com/sergei-vavilov-luminary-of-russian-physics/.
[402] Section 4.3.
[403] Vavilov.
[404] *Ibid.*
[405] *Ibid.*

> planning includes not only scope — institutions, personnel, equipment — but also content, *i.e.,* the themes of scientific research.[406]

Nonetheless, Vavilov clearly stressed out the unpredictable character of the development of science and delineated it from the planning economic system:

> The plan of scientific development in a socialist state must, of course, link up with the state economic plan; but it should not be forgotten that the prospects opened up by the constant growth of science will often considerably exceed the prospects outlined in economic planning. Science has its own peculiar logic of development, a logic which it is essential to take into account. Science must always work ahead, accumulating reserves for the future; only then will it be working in its natural element.[407]

Thus this citation of Vavilov, President of the SAS, concludes the section of the primary literature sources as well as the overall data chapter. The next chapter is an analysis which is based on the data from the interviews and primary sources.

[406] *Ibid.*
[407] *Ibid.*

Chapter 4 Analysis of the Data

This chapter addresses the dichotomy in the views on the drivers of Soviet development and while answering the research question on how within 25-40 years such an initially backward country as the Soviet Union whose development was wrecked in various cataclysms could catch up in the level of the human capital and industrial development with the industrial powers of that time and lead in some areas. The following approaches to build an analytical framework up are identified in looking over the data from the chapter 3 to constitute three sections of this chapter and to be continued in the next chapters.

Firstly, an evaluation of the importance of the exogenous impact, i.e. the foreign expertise, transfer, control, and development of technology, for Soviet industrialisation is required. The latter was viewed by many scholars as a crucial factor in the establishment of the USSR as a global actor after WWII.

Secondly, disclosing the first approach would help define the role of the Marxist social factors to have been either a façade for the technology transfer or the essence of the Soviet industrial policy. The latter needs to be analysed in conjunction with other Soviet social policies that became recognised in the data chapter previously.

Thirdly, in the intertwined character of the industrial development with that of the human capital, it would require to understand to what extent, on the one hand, the establishment of the Soviet education and social base was viable for Soviet industrialisation, and if the development of the indigenous science and engineering was important to industrialisation, on the other.

Fourthly, it would require shedding light on the character of the relationship between science, engineering, and technology, in order to understand what connection the Soviet science policy being closely integrated with the various Soviet social policies had with the development of engineering and technology.

Last but not least, this would lead the research to address the notion of what Soviet science was in its features, manifestations and internal driving forces in relation to global development.

4.1 Soviet Industrialisation and Technology Transfer

Russia's defeat in WWI resulted in the 1917 Revolutions which were followed by the Civil War. It demonstrated that Russia needed modernisation and a dramatic change of policy in order to both survive and to be able to address its current and future challenges, as seen from Lenin's articles and speeches above. The Bolsheviks, armed with Marx' political theory of the hegemony of the working class and inspired by the ideals of the French Revolution such as *Liberté, égalité, fraternité*, were keen to modernise the former Russian Empire and change the course of global history. Meanwhile, Marx's economic theory of productive forces, as outlined by Buzgalin, did not provide much detail on the development of technology and industry in terms of a new industrial revolution occurred in the early XX Century. Thus, the actual implementation of the Soviet industrial policy can inform the reader more than its official concept.

Once the *GOELRO* energy plan designed by Lenin (as seen from the decree in the previous chapter) was implemented, big industrial projects became a distinct feature of Soviet development. According to Buzgalin, in the Soviet science policy, the involvement in the projects of both the national or global importance was a driving and motivational force for scientists and other participants. The scale of the two first five-year plans continued this approach established in the implementation of the *GOELRO*.

In terms of the role of the exogenous technology transfer in industrialisation, both Zhukov and Paltashev outlined that in the 1920s the USSR could not have enough of qualified engineers to perform industrialisation within the time constraint dictated by the pressure of another inevitable, in Stalin's view (as shown in section 3.2), and impending war. The constraint resulted in a sharp political struggle between two groups of the Communist Party. Nonetheless, despite a low competence of many old revolutionaries trying to resist and run industrialisation at the industrial locations, Stalin's technocratic government could have implemented industrialisation and won in the political struggle within the *VKP(b)*, according to Zhukov. As a result, by the end of the 1930s, *polytechnisation* was established as the primary approach in education, management, governance and elsewhere. As confirmed by both Zhukov and Nekrasov, the human capital in science and technology was cherished and nurtured by the system.

In this new expansionist industrial policy, the ruling group demonstrated a high level of expertise in choosing useful technology or finding correct approaches towards its adoption as confirmed by Paltashev in chapter 3 or by Sutton, as an opponent of the Soviet system (considered in the literature review). In particular, Sutton worded this as follows: '...there was a clear recognition of the place of technology. The machine was the Marxian engine of progress.'[408] As detailed by Paltashev, the Soviets purchased plants 'on turn-key-solutions or technology of full cycle and hired experts to launch it and teach Soviet personnel.'[409] According to him, the technology transfer for the reproduction of an old product was successfully adopted by the Soviet industry, after which new products were developed and produced.

Therefore, the external input of the expertise and technology was essential for Soviet industrialisation, as confirmed in Zhukov's and Paltashev's interviews, on the one hand. However, the following should be taken into consideration on the other.

Firstly, technology transfer has been a widespread industrial practice implemented by all the historical actors, including the US before the USSR or South East Asian countries after the USSR, and excluding Britain that was the pioneer of industrialisation, according to Paltashev.[410] In this sense, one can conclude, therefore, that the speed and results, i.e. the success of the process itself, in other words, is valuable for this analysis.

Secondly, as pointed out by Littlewood, Lonzarich, Tsironis and, in particular, Raven and Paltashev, a success of technology transfer to a large extent is determined by a preparedness of the particular recipient to accept, adopt, sustain and develop the import, otherwise, it could not last for decades. According to Raven, the recipient's competence in S&T should be as good as that of the exporting side. Even once assimilated successfully, the horizon of the use of technology is limited to 30 years as the maximum (Paltashev). Meanwhile, as seen from the literature review, the second wave of the transfer, although not that large as that of the 1930s, which started in the 1960s was not that successful mostly due to a significant incompatibility of Soviet technology to its new Western analogues.[411] Thus, the technology transfer in the industrialisation of the 1930s was successfully assimilated as well

[408] Sutton I, 318.
[409] Paltashev.
[410] *Ibid.*
[411] Gold; Holliday; Cooper in chapter 2.

as largely independently developed as seen by the development of the Soviet microelectronics (Paltashev) or aviation industry (Mikoyan).[412]

Thirdly, overall from the very beginning, the correct technological approach towards choosing and assimilating foreign technology mentioned above and demonstrated by Soviet industrial managers would have been impossible without their deep level of the expertise in the matters of S&T, as implied by the scientists interviewed such as Raven, Lonzarich, Tsironis, Saxena, and Littlewood.

On the one hand, this expertise as confirmed by Zhukov was provided by the previous 'Tsarist' scientific and engineering personnel which pledged to the new Soviet power, like the first president of the Russian Academy of Sciences under the Soviet rule, Karpinsky, mentioned in section 3.2 and considered in more detail below, who became the first president of the SAS.[413] On the other hand, this level of the managerial expertise derived from the knowledge obtained within the Soviet education and S&T system, as evident from the biographies of Malenkov or Kosygin, highlighted by Zhukov and Nekrasov respectively.

Last but not least, the Soviet Union managed to avoid the trap of the technology transfer which was described by Lonzarich, Paltashev for this thesis, and Kapitsa. Even in 1936, the latter, in his letter to Stalin, described the Soviet Union, in terms of technology, as 'the full colony of the West.'[414] The development of the indigenous research and education became a considerable contribution to the national technological sovereignty, which allowed the USSR together with the Allies to win WWII as well as to consequently conduct independent foreign policy as a global actor in the conditions of the Cold War afterwards. This had not happened if the dependence on the technology transfer, in particular from the US which, according to Sutton, was the main contributor to Soviet industrialisation, would have remained in place.

One should mention a positive impact of war (both WWII and partially the Cold War) on the Soviet technological advance and engineering choices, as well as the organisation and efficiency of production processes.[415]

[412] As also seen from Cooper.
[413] Section 4.3.
[414] Appendix M.
[415] Howe, Christopher, 2019, *VIVA, Chokan Laumulin's Thesis*, 2 May, Centre of Development Studies, University of Cambridge; hereafter referred to as Howe, 2019.

Thus, in evaluating any industrial transfer in general, and that of Soviet industrialisation in particular, an actual engineering capacity to absorb and develop technology is critical implying the importance of education and research.

4.2 Soviet Social Policies

In addressing the second approach on identifying such possible driving forces of Soviet industrialisation and development as research and education, the following aspects of the establishment of the Soviet social system in which education was an integral part of the overall package of the Soviet social policies should be taken into consideration, therefore.

4.2.1 Soviet Education

As Tsarist Russia was not an industrialised country, its working class was underdeveloped and tiny. As seen from the decree on education in section 3.2 and Nigmatulin's example of the establishment of the Institute of Geography in 1918, Lenin and the Bolsheviks' government viewed research and education as the national priorities for Soviet development from the first days in power. One of the first things enacted was the introduction of a multi-purposed integral policy for education that started virtually on the second day after the October Revolution. The act became the cornerstone of the Soviet education policy and included the preparation of specialists for industrialisation in the longer-term, in particular, in the sphere of science, engineering, and technology, as one of its most important goals.

The need to create human capital and labour as the driving forces of future industrialisation predetermined the universal and meritocratic character of the Soviet educational system. The latter became evident from Eremenko's, Nigmatulin's and Abilsiitov's interviews which indicated that education and research were established in the areas where it had either been underdeveloped (Ukraine and Tatarstan) or never existed (Kazakhstan and Bashkortostan), and became accessible to almost all the strata of the Soviet society (both Nigmatulin's and Abilsiitov's biographies) in its most extended geography and remote locations.

The achievement of the total literacy of the population was viewed as a necessary precursor for the process of 'Socialist Construction' which implied the involvement of the masses into the development of science and technology and was underpinned by the expansion of all the forms of education from primary to post-graduate ones.

The network of high schools, technical high schools, higher education and research institutions were introduced throughout the large territory of the country. Considering the total number of the population of 178.3 million in 1914[416] and 195.2 million in 1940[417] respectively, the school enrolment, as shown in the introduction, rose roughly four times in both absolute and comparative terms. The average of the education longevity in years of the high school population older than 9 years old grew five times from 1,112 in 1917 to 5,442 in 1947 to reach 8,833 in 1987.[418]

Another critical indicator to assess the quality of the educational process worldwide is pupil-teacher ratio which in the Russian Empire was 34 to 1, and in the Soviet Union by 1955-6 it gradually came to 17 to 1 with 'an enrolment of 28.1 million pupils and 1,655,000 teachers in the regular schools.'[419] Notably, this ratio continued thereafter, and in 1989 it was 16 to 1.[420]

Unlike in Tsarist Russia, where education had been rather a privilege of the high classes and clergy, in the USSR it became classless, mostly free of charge[421] and compulsory.

In particular, the Central Asian republics were transformed. As a result of the programme of *Likbez*, in 1939, Kazakhstan, for instance, reached the level of 61.5 per cent[422] from two per cent which had been recorded before the October Revolution.[423] More importantly, this rapid

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416 The figure varies from 164 to 181 million, according to different sources. This figure is cited from *Territoria i nasselenie* (Territory and Population), 1915, *Statistichekyi ezhegodnik Rossii 1914 g. God odinnatsatyi* (Statistical Annual of Russia of 1914. The Eleventh Year), Tipographia Shtaba Petrogradskogo voennogo okruga (Publishing House of Headquarters of Petrograd's Military District), Petrograd, 26, 58.
417 Andreev.
418 Mironov, Boris N., 1991, The Development of Literacy in Russia and the USSR from the Tenth to the Twentieth Centuries, *History of Education Quarterly*, Vol. 31, No. 2 (Summer, 1991), 244.
419 Korol, 43.
420 *Russia Education Restructuring Support Project*, 1999, The World Bank, Washington, DC: World Bank, 1.
421 'Mostly' is referred to the period from 1940 to 1952 when the annual fee of 200 rubles for studying in the 7-10 grades of secondary school was introduced with the month average worker's pay of 380 rubles in order to presumably increase the prestige of the secondary high school. The practice was fully abandoned in 1956. Korol, 42.
422 Bakanov S.A., Zhumashev R.M, 2002, *O tempakh likvidatzii negramotnosti v 1926 – 1939 godakh* (*On the rate of elimination of illiteracy in Kazakhstan in 1926-1939),* Repozitary of E.A. Buketov Karaganda State University, 143; retrieved on 19.09.2018 from the Web, http://rep.ksu.kz/bitstream/data/103/3/Bakanov_Zhumashev.pdf.
423 This figure is taken from a secondary source, i.e., Betkenbaeva, Sh. K., 1983, *Bor'ba za osuschetvlenie leninskogo dekreta o likvidatsii bezgramotnosti sredi nasseleniya v kazakhskom aule (1917-1940 gg.)* (*Struggle for implementation of Lenin's decree on elimination of illiteracy in Kazakh Aul [countryside] [1917-40]*), PhD dissertation, Alma-Ata, Introduction; retrieved on 15.05.2017 from the Web, http://www.dissercat.com/content/borba-za-osushchestvlenie-leninskogo-dekreta-o-likvidatsii-bezgramotnosti-sredi-naseleniya-v#ixzz3Ys0Ekx4M. This number was widely used in Soviet research, after the independence of

rise of literacy was made not only in terms of quantity but also in quality. The Soviet youth, despite their gender, were taught mathematics, physics, chemistry, biology and all the range of the subjects, which could have been considered modern and advanced. In Abilsiitov's case, that knowledge received in a rural Soviet school in northern Kazakhstan made sufficient for him to enter and graduated in physics from the most prestigious Soviet university (the MSU).

The *polytechnic instruction* for education proclaimed in 1919 (chapters 1 and 3) and introduced in the early 1930s as an Soviet analogue of both the German *Oberrealschule* and French polytechnic education systems (mentioned by Chitre), as considered by Korol and in section 3.2, became the logical continuation as well as the necessary prerequisite for the overall development of science and research in the united system of education and science for the purpose of industrialisation and development.

The table 2 below is designed to illustrate the place of the polytechnic instruction mentioned above in the Soviet secondary high school curricula. The basic curriculum introduced in 1934 remained mostly identical throughout the different periods of Stalin's, Khrushchev's or Brezhnev's eras. The table indicates the place of mathematics, S&T subjects among other disciplines in grades from 8 to 10. It is extracted from three tables of the ten-year curricula at different periods in which the first and second ones mark the transition from the Stalinist period, and the third one reflects a later Soviet stage (they can be found in Appendices B, C and D respectively). One can see that in all three periods there was a balance between mathematics and S&T subjects (including manual training and shop work),[424] on the one hand, and humanities (including Russian and Russian literature, history, logic, geography, psychology, native and foreign languages), on the other, with a

Kazakhstan some scholars increased it to 5 and 8 per cent, which is still very low. However, it should be noted that the literacy in Russian only was likely considered in Soviet sources.

[424] The real richness of the polytechnic instruction is detailed by Korol as follows: 'The abilities and skills to be emphasized in a polytechnic approach instruction in mathematics are comprehensively and minutely listed, including the following:

… rapid mental and written computation; ability to round-off numbers and to check results of operations; ability to use tables, handbooks, abacus, and slide rule; ability, in reading formulas, to understand the direction of change in its numerical value with given change in its component parts; ability readily to plot points corresponding to the given coordinates and to write coordinates of given points and otherwise to use graph paper; ability to use scales, measuring tapes and chains, compass, calipers, triangles and squares, protractors and simple geodetical instruments; ability to take field measurements and to make field layouts, compute areas and volumes by direct measurements or from maps and drawings, to lay out plots of land of given sizes, to determine elevations and contours, to make diagrams and sketches; the skill of analysing and synthesizing special forms; ability to formulate and solve equations in working out various technical and economic problems; ability to carry out bookkeeping, budgetary, and cost computations –

'and so forth';' Korol, 29.

prevalence of the former ones. The curricula were complemented with hours for physical development and in the earlier grades with singing and drawing (art) as well as the study of the USSR Constitution.

Table 2 Mathematics, Science and Technology Subjects in Three Schools Curricula for Grades 8-10 in Three Periods

Subject	1952-3		1955-6		1983-4	
	Hours Per Week	Per Cent	Hours Per Week	Per Cent	Hours Per Week	Per Cent
Mathematics	18	18.4	18	18.2	16	15.1
Physics	9.5	9.7	11.5	11.6	12	11.3
Chemistry	7.5	9.7	8.5	8.6	8	7.5
Biology	4	4.1	3	3	6	5.7
Astronomy	1	1	1	1	1	1
Drafting (Engnrg.)	3	3.1	3	3	6	5.7
Manual Training and Shop Work			6	6.1	6	5.7
Total	43	46	51	51.5	55	52

The table indicates that there was little difference in the school's curricula in the period from 1952 to 1984. In terms of the polytechnic subjects, it is important to emphasise that the establishment of the curriculum occurred during the expansion of the human knowledge in physics and chemistry as scientific disciplines which found their appropriate updates in the Soviet school curricula, according to Korol in the literature review.

The prevalence of the polytechnic approach in the curricula is seen in the S&T subjects occupying around 50 per cent there along with humanities and sport (physical culture). Meanwhile, a proportional balance between mathematics, science, and related disciplines, on the one hand, and the humanities and cultural subjects, on the other, as well as sport, aimed altogether at harmonious development of Soviet children's human and physical capital.

Regarding the place of the polytechnic instruction in the Soviet higher education system, the data from Table 3 below indicate the prevalence of the science and technology institutions in the numbers of the higher education institutions (including those of the correspondence instruction[425]). In 1955 fundamental science was mostly studied in universities (33) and engineering and technology in specialised polytechnic institutions (25) as well as in hundreds of other entities related to medicine, technology or industry. However, it is important to remember that as well science was a significant part of technology courses and curricula in the 14 engineering and military institutions,[426] as evident from the curriculum of the Yeysk Higher Military Aviation school in which, among other scientific subjects, higher physics was a part of three first years out of four.[427]

Table 3 Number of Institutions of Higher Education Listed by Categories, January 1955[428]

Categories	Total	Total
1. Universities	33	
Institutes:		
2. Polytechnic and industrial		25
3. Power, Electrotechnical, Radiotechnical, and Physiotechnical		7
4. Machine construction, Shipbuilding, Aviation, Polygraphic, and Motion Picture Engineering		26
5. Geologic, Mining, Oil, Peat, and Metallurgical		24
6. Chemical technology		9
7. Food and Fishing Industries		11
8. Light Industries		7
9. Engineering-Construction, Geodetic, and Automotive Highways		25
10. Hydrometerological		2

[425] Table 40, *Ibid.,* 203.
[426] *Ibid.*, 140-1; the table, entitled Number of Institutions of Higher Education Listed by Categories and Type of Instruction, USSR, January 1955, can be found in Appendix E.
[427] Spearman, 9-10.
[428] Constructed from the table, entitled Number of Institutions of Higher Education Listed by Categories and Type of Instruction, USSR, January 1955, Korol, 140-1, (Appendix E). The table constructed includes the resident type of instruction only.

11. Transport and communication		25
12. Agriculture and Forestry		106
13. Medical		75
Subtotal for Science, Technology, Industry and Medicine		318
14. Economics		22
15. Law		5
16. Art		46
17. Pedagogical		206
18. Historic Archives and Library		72
18. Physical Culture		13
Subtotal for Humanities and others		364
Total	33	682

The 12 categories (including 32 subcategories[429]) of the institutes with the polytechnic instruction, including the medical institutes, demonstrate the whole spectrum of the industrial disciplines which were taught in all its diversity throughout the USSR and which were covering the latest scientific and industrial developments of that era. Spearman in the literature review specified the high quality of the Soviet higher education for S&T. This is also implied by the international scientists interviewed in recognition of the Soviet knowledge and expertise in their respective scientific fields which would have been unthinkable without an appropriate education base in place.

As outlined by Tsironis, Littlewood, Chitre, and Saxena, a significant part of the university graduates in S&T do not continue their careers directly in the sphere as a general rule, becoming a valuable human capital for governance, management, economy or elsewhere. This was applicable in the Soviet case, as seen from Malenkov's or Kunaev's[430] biographies. As well, in both engineering and pedagogy, courses of mathematics and physics occupied the central place making science the focal point of the study process.[431] Thus, the polytechnic instruction was a driving force of both the Soviet higher education system and overall development of the USSR.

[429] Appendix E.
[430] Details of Kunaev's biography are given in subsection 4.2.2.
[431] Korol, 235-56.

Meanwhile, the education policy could not be a success without the development of the leading national universities which established the guiding principles of teaching and research and sat goals for the whole industry of education and research. This process was under the personal control of the key political leadership as seen in section 3.2 from the example of *MISIS* and the establishment of the Lomonosov Moscow State University's campus in central Moscow. Both of the universities are cutting-edge global research centres in the XXI Century, as confirmed, on the one hand, by Tsironis and Saxena collaborating with *MISIS*, and Vasiliev and Kaul in the data on their research at the MSU, on the other.

As higher education was free and students were given modest stipends, the Soviet system was designed to educate as many people as possible from across all the social strata, classes and genders which implied a deployment and provision of a whole set of some other social policies considered below.

4.2.2 Various Soviet Social Policies

The Soviet Government applied tremendous efforts in integrating the masses into intellectual activity as a part of the Soviet development programme which resulted in an unprecedented change in the social structure. It aimed at forming such a social environment which as an ecosystem would be favourable towards developing human capital for various and interconnected spheres of education, culture, and research with a particular emphasis on science and technology.

In particular, as McAuley wrote: 'The Soviet experiment has been instructive. It has shown that a determined government can bring about radical changes in social behaviour – as the Soviet government has managed to reverse the traditional disparity in the educational attainment of men and women.'[432] Women being equalled in all the civil rights became a significant source of human capital for Soviet development in which the state policy tried to establish all the conditions for incentivising and incorporating them into labour, management, governance, education, and research, including the space programme.[433]

It is important to emphasise the integral and comprehensive character of the Soviet social policy aiming at the human capital development. It included most various elements such as

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[432] McAuley II, 209.
[433] Sharp, Tim, 2018, Valentina Tereshkova: First Woman in Space, 22 January, *Space.com*; retrieved on 17.07.2018 from the Web, https://www.space.com/21571-valentina-tereshkova.html.

the establishment of both the free healthcare system enhancing all the Soviet population with the effective primary health care and the solidarity pension system in which 'the retirement age was set at 60 for men and 55 for women.'[434] As a result, which was described in the introduction, the Soviet population was more than doubled within 70 years and its average life expectancy rose from 44 years in 1926-7 to 69.95 (66.1 for men and 73.8 for women) in 1965-6.

In particular, in Kazakhstan, the Kazakh population grew from 3,713,394 in 1926[435] to 6,534,616 in 1989,[436] whose average life expectancy at birth eventually reached 68-9 (64 for men, and 73 for women) in 1985-6.[437]

The 20-year period from 1938-9 to 1958-9 is also characterised by a significant decrease in children's mortality which is another vital social indicator to measure development. Its index measured in the ratio of the babies deceased at the age younger than one year to 1,000 newly born in 1959 became 40.6 against 181.5 in 1940, i.e. it went down four times.[438] In particular, this was connected to the extensive introduction of the sulfamide medications and antibiotics. In general, all these social achievements would have been impossible if not for a very extensive and a functioning system of free primary health care especially in the field of preventive diagnostics.

The global importance of the Soviet achievements in primary health care was *de facto* fixed in the *Alma-Ata Declaration*[439] in Almaty (formerly Alma-Ata), Kazakhstan (formerly the Kazakh Soviet Socialist Republic of the USSR), in 1978 at the World Health Organization (WHO) conference which was the first international declaration stressing the importance of primary health care. This healthcare model was adopted as a standard since then by the

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[434] Russia will raise pension ages that date back to Stalin, *The Economist*, June 30th, 2018; retrieved on 20.08.2018 from the Web, https://www.economist.com/europe/2018/06/30/russia-will-raise-pension-ages-that-date-back-to-stalin.

[435] *Vsesoyuznaya perepis' naselenia 1926 goda* (*All-Union Census of the Population of 1926*), Moscow, Izdanie TsSU Soyuza SSR, 1928-29; retrieved on 10.09.2018 from the Web, http://www.demoscope.ru/weekly/ssp/rus_nac_26.php?reg=1476.

[436] *Rabochii arkhiv Goskomstata Rossii, Tablitsa 9c, Raspredelenie naselenia po natsional'nosti i rodnomu yazuku* (Working archive of Goskomstat of Russia, Table 9c, Distribution of the population by nationality and mother tongue); retrieved on 10.09.2018 from the Web, http://www.demoscope.ru/weekly/ssp/sng_nac_89.php?reg=5.

[437] Ryan, 1513.

[438] Dmitrieva R.M., Andreev E.M., 1977, *Snizhenie smernosti v SSSR za gody Sovetskoi vlasti* (Reduction of Mortality in the USSR during the Years of the Soviet Rule), Collection of Articles, *Brachnost,' rozhdaemost,' smernost' v Rossii i v SSSR* (*Marriage, Birth Rate and Mortality in Russia and in the USSR*), Statistika, Moskva.

[439] Declaration of Alma-Ata, International Conference on Primary Healthcare, 6-12 September 1978, Alma-Ata, USSR, *World Health Organization*; retrieved on 25.04.2017 from the Web, http://www.who.int/publications/almaata_declaration_en.pdf.

member countries for the WHO as the key to achieving the goal of *Health For All*, at first, only for developing countries and for all other countries five years later. One of the sections in the declaration underlined the role of the state in providing adequate health and social measures to be taken.

This section's call for *Health For All* became a campaign for the WHO in the coming years. *Health for All* was defined as the accomplishment by all peoples of the world by the year 2000 of a level of health that would allow them to lead a socially and economically productive life. In the spirit of social justice, the declaration urged governments, international organisations and the global community to set this up as a principal social goal.[440]

In chapter 3 Nigmatulin emphasised that attention which the world started paying to the connection of social development to successes of science due to the Soviet policy. On the other hand, this was the interconnection. According to World Health Organization in 2018, the *Alma-Ata Declaration*, 'endorsed at that conference, formed the foundation for the last 40 years of global primary healthcare efforts,'[441] which could not have occurred if not for Soviet science.

In terms of material welfare and personal consumption, both of them, according to McAuley, 'did not carry a high priority in the early five-year plans,' [442] although the issue of general poverty was rather successfully addressed. Furthermore, in later years after 1955, the Soviet Union undertook various measures on poverty reduction to raise the population's living standards and reduce inequality, considering welfare as of important social value.

'[A] decent provision for the poor is the true test of civilization,'[443] McAuley concluded in 1979, continuing that 'the USSR bids fair to become more civilized that the rest of Europe'[444] to indicate the success of this policy after WWII.

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[440] *Ibid.*
[441] From Alma-Ata towards universal health coverage and the Sustainable Development Goals, 2018, *World Health Organization*; retrieved on 19.08.2108 from the Web, http://www.who.int/primary-health/conference-phc.
[442] McAuley I, 3.
[443] *Ibid.*, 317.
[444] Khanin I.

This was expressed in a significant increase in the Soviet people's living standards and personal consumption. Khanin noted that if in the early 1950s the level of consumption of basic food products such as meat, milk, sugar, vegetables, and fruits was rather typical for a developing country, by the 1960s as the result of the double growth, it reached the level of the developed countries, and the malnutrition practically disappeared.[445]

Meanwhile, a similar growth, according to Khanin, was in the consumption of the expensive apparel materials made of cotton, silk, and leather.[446] In particular, the growth of the sales of personal watches, home radio-electronics, bicycles and motorbikes, sewing machines was rapid.[447] Although the production of the TV sets, fridges and washing machines was low, they were becoming more and more available to Soviet people.[448] The financial stabilisation resulted in the reduction of some retail prices with overall low inflation.[449] More importantly, the Soviet Union reached or almost reached the level of the developed countries in the provision of housing and the life expectancy as shown in the introduction and above. The working hours were reduced to 40 hours per week, political cleansings were abandoned, and cultural life was developing.[450]

Although the market of consumer goods in the USSR was not as developed as in the other countries of the first world, the main human needs like housing, education, or healthcare were all provided for free. At their basic level, modern consumer needs like affordable and comfortable traveling and having basic consumer goods and electronics were satisfied.

All of these mentioned above allowed Khanin to conclude that 'in the 1950s a new country, free from poverty and pretty prosperous in the world's standards, although not rich, emerged for its own citizens'[451] to stipulate that within 30-40 years the Soviet Union changed from an agricultural, sickle and plough economy into an industrial powerhouse and a modern knowledge economy due to its set of the science, education, social and industrial policies merged together and successfully deployed.

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445 *Ibid*.
446 *Ibid*.
447 *Ibid*.
448 *Ibid*.
449 *Ibid*.
450 *Ibid*.
451 *Ibid*.

As mentioned in chapter 1, this was accompanied by a constant growth for social expenditures making this policy a vehicle for the overall Soviet development.

As seen from the analysis of the Soviet Constitutions mentioned in section 3.2, the following social rights were guaranteed by Stalin's and Brezhnev's Constitutions and relentlessly pursued in the policy, i.e. those to eight hours working day and an annual leave paid; the employee's right not be fired upon an administration's initiative without Trade Union's or the Party's consent; to be employed, where graduates of special professional educational institutions had the right to obligatory employment with housing provided; to free general and professional high and higher education; to free access to nursery, kindergarten and children's camps; to free medical care; to free medical resort's treatment; to free housing; to free or privileged transportation to the workplace or place of study; to a three year maternity leaf paid; to free social welfare for a child under one year age; to free milk supply for babies under three years old. A detailed consideration of the provision of all the policies designated above would go far beyond the purpose and abilities of this thesis. However, one should emphasise that 27 per cent of the national income was allocated for the provision of these social policies in the USSR in 1980, as argued in chapter 1 and mentioned by Nigmatulin.[452] It should be stressed out that the funding of science was an integral part of this package.

The policies were social innovations of the time and became a robust platform for the transformation and unification across the enormous territory of the USSR. The embracement of such generous social package became possible due to the state's rapidly increasing presence in the economic life in order to accumulate the resources needed for industrialisation. It was not coincidental that these social duties and guarantees (as well as the growth in real wages in the industry) were introduced in 1936 as a result of the First Five-Year Plan. It was the stage at which the Soviet state could afford such an act under the conditions of a highly centralised and socialised, according to Marx, economy. The New Economic Policy (NEP) became negligible and industrialisation was soon accomplished.

As a result of its science, education, social and industrial policy finally combined during industrialisation, in the post-WWII period, the Soviet Union developed such high tech industries as space programme, nuclear energy, computing, electro-energetics, black metallurgy, continuous casting of steel, the production of hovercrafts and others which are

[452] Nigmatulin.

considered in chapter 5. Khanin noted that the period was characterised with rapid structural changes in the economy expressed in the urbanisation, the development of new industries such as radio-electronics, chemical one, aviation, the reconstruction of the railways system and the emergence of new scientific productions (rare metals, for instance), coming from the development of the S&T institutions.[453]

These many various policies were assembled in a whole set and promoted in Soviet cultural policy under the key features of the primacy of collectivism over individualism and the establishment of high moral principles in society. This policy was known in Soviet arts and literature as the concept of 'socialist realism.' It should be however emphasised that the Soviet cultural policy was by no means restricted solely to this. It was accompanied by a rich and comprehensive programme of developing fine arts and literature in Russian and multiple other languages of the national republics and minorities along with classical music and the famous Russian ballet. Opera, ballet theatres and art galleries were established throughout the country, as mentioned by Zhukov at the example of Kazakhstan.

In 1934 a pretty vast theatre of opera and ballet was founded in Alma-Ata, Kazakhstan,[454] as well as in all the other capitals of the national republics in addition to large galleries and museums of arts.[455] In the case of Kazakhstan, a whole cohort of artists emerged as a result of this policy, 'Socialist in content, national in form' (Stalin).[456] These people remain unmatched in Kazakh culture even today and include names such as Abylkhan Kasteev[457] in art, Kulyash Baiseitova[458] in opera, Ahmet Zhubanov[459] in classical and traditional music, Mukhtar Auezov[460] in literature, or Shaken Aimanov[461] in cinema as well as many others.

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453 Khanin I.
454 The Kazakh State Academic Theatre of Opera and Ballet named after Abay; retrieved on 30.06.2017 from the Web, http://www.gatob.kz/en/.
455 The Shevchenko Kazakh State Gallery was established in Alma-Ata 1935, which, altogether with the Republic Museum of Decorative and Applied Art (established in 1970), merged into The A. Kasteyev State Museum of Arts; retrieved on 30.06.2017 from the Web, http://www.gmirk.kz/index.php/en/.
456 Stalin J. V., 1925, *O politicheskykh zadachakh universiteta narodov Vostoka, Rech na sobranii studentov KUTV, 18 maya 1925 g.* (On Political Tasks of The Universities of the Peoples of the Orient, Speech in the meeting of the students of KUTV, 18 May 1925), *Sochinenia* (*Works*), Moscow, Gosudarstvennoe izdatel'stvo politicheskoi literatury, 1952. Vol. 7,138.
457 *Abylkhan Kasteev*; retrieved on 21.12.2017 from the Web, https://web.archive.org/web/20110722142440/http://oyu.kz/en/authors/kasteyev_a.html.
458 *Kulyash Baiseitova*; retrieved on 21.12.2017 from the Web, https://en.wikipedia.org/wiki/Kulyash_Baiseitova.
459 *Ahmet Kuanovich Zhubanov*; retrieved on 21.12.2017 from the Web, https://ru.wikipedia.org/wiki/%D0%96%D1%83%D0%B1%D0%B0%D0%BD%D0%BE%D0%B2,_%D0%90%D1%85%D0%BC%D0%B5%D1%82_%D0%9A%D1%83%D0%B0%D0%BD%D0%BE%D0%B2%D0%B8%D1%87.
460 Mukhtar Auezov, Prominent Figures, *Kazakhstan History Portal*; retrieved on 21.12.2017 from the Web, http://e-history.kz/en/biography/view/5.

Within less than 20 years after the October Revolution, a range of artists of the highest standards of the European culture appeared from scratch in Kazakhstan as well as in the other national republics. The development and cultural policy in all the republics were in contrast to the policies of either the Russian Empire or other colonial powers of the time. This ensured a support and even enthusiasm in a majority of the Soviet population.

As mentioned above, one of the most important aspects of the social policy was the elimination of the inequality in gender, social or ethnic origin, although it was not routed out completely. The discrimination of the Tsarist elite and rich peasantry was significantly smaller, compared to the development and career opportunities, which were accessible to the masses in the population. Moreover, most of the family members of the 'enemies of the people,'[462] including those of the first Bolsheviks repressed in the 1937-8, managed to get through the system to obtain education or pursue academic and other careers, including political offices.

Turar Ryskulov, an ethnic Kazakh of humble origin, is an example of the Soviet policy based on meritocracy and internationalism. Ryskulov, although he was executed in 1938 during the purges, had built an impressive political career to reach the level of the number two in the government of the Russian Soviet Federative Socialist Republic (the RSFSR), the largest and key entity within the USSR[463] which is the Russian Federation now.

The bureaucracy became the most important element of the implementation of this policy. According to Peter Nolan, 'a key point of the modernisation drive was the creation of a professional government administration.'[464] In contrast to the lifestyle of the previous Tsarist elite and even that of the first revolutionaries who were the first generation of Soviet bureaucrats,[465] the newly introduced modest lifestyle of society, including Stalin (as

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[461] Shaken Aimanov Kenzhetaevich, *National Digital History of Kazakhstan*; retrieved on 15.02.2018 from the Web, http://e-history.kz/en/biography/view/154.

[462] This expression was applied to those repressed in the 1930s for political reasons in the USSR. It was borrowed from the lexicon of the French revolution, when the royalists were named as *ennemi du peuple*. In turn, it had been taken from Roman law, implying the execution of the public enemy, *hostis publicus,* as the outlaw and equalling her to the armed enemy soldier at war.

[463] Kozhakhmetov G. Z., Botagarin R.B., 2013, *Gosudarstvennaya i politicheskaya deyatel'nost' Turara Ryskulova v Kazakhstane v 20-30-t gody XX veka* (State and Political Activity of Turar Ryskulov in Kazakhstan in the 1920s – 30s of the 20th Century), *Vestnik KarGU*; retrieved on 15.07.2017 from the Web, https://articlekz.com/article/6199.

[464] Nolan, Peter, 1995, Political Economy and the Reform of Stalinism: The Chinese Puzzle, *The Transformation of the Communist Economies against the Mainstream*, Edited by Ha-Joon Chang and Peter Nolan, St. Martin's Press, 407; hereafter referred to as Nolan, 1995.

[465] Khanin G. I., 2008, *Ekonomicheskaya istoria Rossii v noveishee vremya*, *Tom 1, Ekonomika SSSR v kontse 30-kh godov* (*Economic History of Russia in the XX Century, Vol. 1, Soviet Economy from the End of the 1930s*

described by Nekrasov and Zhukov) and the new Soviet technocrats, contributed to the formation of a more equitable social milieu. Both Nekrasov and Zhukov brought examples of Kosygin and Malenkov respectively as two Soviet leaders whose careers were defined by their education in S&T.

Similarly, Dinmukhamed Kunaev (or Kunayev), a leader of the Communist Party in the Kazakh SSR, graduated as a mining engineer from the Institute of Non-Ferrous and Fine Metallurgy in Moscow in 1936. He became the deputy head of the republican government at the age of 32 in 1942, the head of the local Academy of Sciences at age 40 and the first secretary of Kazakhstan's Communist Party in 1960-2 and 1962-86. Under his leadership, Kazakhstan continued becoming a highly industrialised and culturally developed Soviet republic.[466]

One should mention the name of Kanysh Satpaev (or Satbayev), the first president of the Academy of Sciences of the Kazakh SSR and the founder of both Soviet metallogeny as a scientific discipline and the Kazakh school of geological sciences. His both humble origin and career is another example of the Soviet science, education and national policies combined.[467] Keldysh in chapter 2, Saxena in chapter 3 and Jackson[468] emphasised a global significance of Kazakh geology.

Geological sciences, mining, and metallurgy helped develop Kazakh SSR's economy and continue to determine Kazakhstan's economy today. In terms of its both economy and territory, Kazakhstan is the second largest country after Russia among the post-Soviet states lagging behind Russia, Ukraine, and Uzbekistan in terms of the population. The extraction and processing of natural resources is the main contributor to its current GDP of USD133.657 billion which exceeds those of the other Central Asian countries combined (Uzbekistan – USD67.22 billion; Turkmenistan – USD38.18 billion; Tajikistan – USD6.952 billion, and Kyrgyzstan – USD6.551 billion),[469] or that of Ukraine (USD93.27 billion).[470]

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to 1987), Novosibirsk State Technical University, Novosibirsk, 13-19; retrieved on 22.06.2017 from the Web, http://istmat.info/files/uploads/56774/hanin_g.i._-_ekonomicheskaya_istoriya_rossii_v_noveyshee_vremya._tom_1.pdf; hereafter referred to as Khanin II.

466 Vronskaya, Jeanne, 1993, Obituary: Dinmukhamed Kunayev, 24 August, *The Independent*; retrieved on 15.07.2017 from the Web, https://www.independent.co.uk/news/people/obituary-dinmukhamed-kunayev-1463084.html.

467 Satpaev Kanysh Imantaevich (1899-1964), *Unesco.kz*; retrieved on 25.04.2017 from the Web, http://old.unesco.kz/heritagenet/kz/participant/scientists/satpaev.htm.

468 Jackson.

469 World Bank, 2016; retrieved on 28.09.2017 from the Web, https://data.worldbank.org/indicator/NY.GDP.MKTP.CD.

Thus, the Academy of Sciences was a primary source of human capital not only for science but industry and politics as well. It is essential to point out that Kunaev came to power in Kazakhstan from the position of the president of the Academy of Sciences of the Kazakh SSR being fully trained and qualified in the matters of industry, science, and technology. Being intertwined with the development of Kazakhstan, Kunaev's biography above is indicative as an example of how various Soviet policies, i.e. social, national, industrial, science and technology ones, were juxtaposed in a whole comprehensive set aiming at the development of a particular Soviet republic to contribute to the overall development of the USSR.

Meanwhile, as shown from these examples and the other data above, in the Soviet development policy science likely was a critical element without which the technology transfer and Soviet development would have been impossible. Research was considered as the necessary prerequisite and determinant for industrialisation, as well as the foundation of the social change as evident in the example of Kazakhstan. In the USSR, the overall social stability, job security, high educational and healthcare, as well as the high societal status of education, science, and culture, formed the environment favourable towards the formation of the valuable scientific human capital.

As seen from the data, the Soviets expanded the base for the scientific upbringing of students in the overall education system, on the one hand; and on the other invested intensively in the development of cutting-edge science and the appropriate infrastructure necessary. In terms of efficiency, such general allocation of the direct investments for R&D required the deployment of an appropriate particular social policy aiming at both providing widespread access to knowledge and developing a scientific culture in the Soviet society.

4.2.3 Access to Knowledge and Libraries

Scientific publishing is a critically important means of knowledge exchange in the development of science in general. In the USSR, leading foreign scientific articles and journals were persistently translated into Russian and published in various Soviet research journals. Their overall quantity reached 119, 15 out of which had been established in the

[470] *Ibid.*

Russian Empire, and 104 in the Soviet period.[471] A majority of the Soviet scientific journals were founded in the period of Stalin's time and its immediate aftermath, i.e. from 1934 to 1959.[472] Many of them, like *Zhurnal Eksperimental'noi I Teoreticheskoi Fiziki* (*ZhETF*) (The Journal of Experimental and Theoretical Physics [JETP]),[473] that was established in 1931, or *Yadernaya Fizika* [474] (Physics of Atomic Nuclei),[475] have been published simultaneously in both Russian and English (the JETP since 1955 and the latter since its establishment in 1965). Some of the journals were additionally published abroad in English, like *Fizika i Tekhnika Poluprovodnikov* (Physics and Technics of Semiconductors) – in the US as *Soviet Physics, Semiconductors* by The American Institute of Physics;[476] or *Paleontologicheskyi Zhurnal* (Paleontological Journal)[477] – in the US by Pleiades Publishing, Inc.[478] The translation was provided by the Soviet publishing house *Nauka* (Science). Established in 1923 under the title of *the USSR Academy of Sciences Publishing House* (renamed in 1963), it eventually became the largest scientific and research publisher in the world.[479]

All the scientific literature and journals considered have been largely available in the vast network of the libraries, created and persistently expanded from the first days of the Bolsheviks in power. Literally on the second day after the October Revolution, on 9 November 1917 Lenin held a meeting with *Narkom* of Enlightenment (Minister of Education) Lunacharsky on the organisation of the librarian business in the country.[480] From then every year of the calendar was marked with the appropriate policy decrees and the

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[471] *Nauchnye Zhurnaly v SSSR* (Scientific Journals in the USSR), *Wikipedia*; retrieved on 11.06.2017 from the Web, https://ru.wikipedia.org/wiki/%D0%9A%D0%B0%D1%82%D0%B5%D0%B3%D0%BE%D1%80%D0%B8%D1%8F:%D0%9D%D0%B0%D1%83%D1%87%D0%BD%D1%8B%D0%B5_%D0%B6%D1%83%D1%80%D0%BD%D0%B0%D0%BB%D1%8B_%D0%A1%D0%A1%D0%A1%D0%A0, in which the total number of 124 is mistakenly indicated. However, a further study reveals that four out of 124 journals mentioned were established after 1991, and one of the journals was, in fact, a Soviet children's magazine. The rest of information indicated was double-checked, and that is why this Wikipedia's article was used for the indicative purpose.
[472] *Ibid.*
[473] *The Journal of Experimental and Theoretical Physics*; retrieved on 11.06.2017 from the Web, http://jetp.ac.ru/; hereafter referred to as ZhETF for the publications in Russian, and JETP – in English.
[474] *Yadernaya Fizika* (Physics of Atomic Nuclei); retrieved on 11.06.2017 from the Web, http://journals.ioffe.ru/journals/2.
[475] Physics of Atomic Nuclei, *The SpringerLink Database*; retrieved on 11.06.2017 from the Web, https://link.springer.com/journal/11450.
[476] Soviet Physics, Semiconductors, *The WorldCat Database*, retrieved on 11.06.2017 from the Web, http://www.worldcat.org/title/soviet-physics-semiconductors/oclc/1766265.
[477] *Paleontologicheskyi Zhurnal* (Paleontological Journal); retrieved on 11.06.2017 from the Web, http://www.maik.ru/ru/journal/palrus/.
[478] Paleontological Journal; retrieved on 11.06.2017 from the Web, http://pleiades.online/ru/journal/paleng/.
[479] Sikorsky N. M. (Ed.), 1982, *Nauka* (Science), *Knigovedenie* (Bibliology), *Ensyclopedicheskyi Slovar'* (Encyclopedic Dictionary), Sovetskaya Ensyclopedia, 664.
[480] Abramov K. I., 1980, *Istoria bibliotechnogo dela v SSSR* (History of Librarian Business in the USSR), Kniga, Moscow, 336.

events of opening the libraries throughout the USSR.[481] Among many of them the most significant were those two of *VTsIK SSSR* (the All-Union Executive Committee of the USSR) which systemised the organisation and established the expansion of the libraries on more regular basis in March 1934[482] and which launched the State Fund of the *Narkompros* (the Ministry of Education) in 1943 for rebuilding of the libraries destroyed during the WWII by Nazi occupation[483] respectively.

In 1914, in the Russian Empire, the number of the libraries was limited to 13,876,[484] and they represented mostly private libraries, whose funds were contributed primarily by the general public in the form of mainly non-academic literature.[485] Those libraries were poorly equipped, bad-lit and serviced by non-trained volunteers. In addition, they were tightly controlled by the church and police censorship.

In the 1920s and 30s, the libraries were opened in all other republics of the USSR. For instance, in Kazakhstan, the first large library was established on 12 March 1931,[486] and their overall number grew from 2 in 1914 to 578 in 1976.[487] In 1935 a special national higher education institute of librarian business was established in Kharkov, Ukraine.[488] The most indicative period of the growth of the numbers of the mass and scientific libraries happened in 1930s when their number grew from 115,542 with almost 300 million books in 1934[489] to 280,000 with 520 million books by 1941.[490] This process was invariably accompanied by the growth of the number of the scientific libraries, which were 16,000 (with 112,5 million of books) in 1934,[491] as well as by the establishment of bibliology (librarian business) for the preparation and education of the specialists, and the constant improvement of the conditions and quality of the libraries.

As a result of this consistent policy, by 1976 the total number of the mass libraries in the USSR reached the global record of 131,354 with the total number of books of

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[481] *Ibid.,* 336-43.
[482] *Ibid.*, 339.
[483] *Ibid.*, 340.
[484] *Ibid.*, 327.
[485] *Ibid.*, 90-1.
[486] *Ibid.*, 338.
[487] *Ibid.*, 327.
[488] *Ibid.*, 339.
[489] *Ibid.,* 234.
[490] *Ibid.*, 257.
[491] *Ibid.*, 241.

1,541,179,000 and average 603 per citizen in the contrast to state of these affairs in the Russian Empire, where the last two indicators were 9,442,000 and 6 respectively.[492]

One of the most important features of this policy was the development of the scientific and specialised libraries for the professional audience. The following table indicates it.

Table 4 Number of Scientific and Specialised Libraries in Types, and their Book Funds (at the beginning of 1976)[493]

Types of libraries	Libraries	Their books (in Thousands)
Scientific, of R&D entities, of central design bureaus	4,060	504,096
Of higher educational and specialised high educational entities	5,357	596,151
Of educational entities of professional technical training and various courses	6,920	104,639
Of entities of industry, construction, transport and communication	16,507	242,887
Of central and local organisations and entities	20,838	450,862
Of healthcare entities and sports organisations	3,389	20,714
Of organisations and entities of agriculture and others	7,351	99,447
Total	**64,422**	**2,018,826**

One can see the prevalence of the scientific and technical literature over the other types of books available in the USSR, i.e. 2 billion vs. 1,5 billion in total. Even considering a significant share of the political propaganda books, presumably included in the first number, the overall dominance of the scientific and technical literature cannot be questioned, especially in the light of the fact that this type of the literature was also widely presented in the mass libraries as well. Meanwhile, from a cultural point of view, the libraries in the

[492] *Ibid.*, 327.
[493] *Ibid.*, 329.

USSR were popular public places and spending time there was a consistent feature of the Soviet lifestyle.

4.2.4 Culture of Science in the Soviet Society

Overall, a high status of science and education in a progressing society is a necessary prerequisite for development. It is achieved through popularisation of science and enlightenment of both the public opinion and the policy-makers to create such a socio-ecological system in which science, as well as culture, is viewed as the most vital instrument to progress in all senses. This kind of environment is a gracious field for science and culture to recruit their followers for advances to be made for benefits of a society and all mankind. This culture as the cult of knowledge and science in all their manifestations was exceptionally well developed and supported in the USSR through multiple books, films, TV programmes as a significant part of the overall policy as analysed below.

Both the audience and circulations of the books by such science fictions authors as the Strugatsky brothers reached millions,[494] for example. The circulation of such a scientific popular monthly magazine as *Nauka i Zhizn'* (Science and Life),[495] established in 1890 and reborn in October 1934, reached 3 million in the 1970s and 80s and became one of the most popular Soviet mass media. Its circulations were as follows: № 1/1950 — 50,000; № 1/1958 — 180,000; № 8/1985 — 3,000,000; № 1/1990 — 2,700,000; № 1/2007 — 44,225.[496]

Various other multiple science magazines such as *Znanie – Sila*[497] (Knowledge is Power), *Yunyi Technik*[498] (Young Technician), *Tekhnika Molodezhi*[499] (Technology of Youth), *Yunyi Naturalist*[500] (Young Naturalist) and many others were of tremendous popularity. The same can be referred to TV-programmes, and in particular to the one called *Ochevidnoye-Neveroyatnoye* (Evident but Incredible) by Sergey Kapitsa, a Pyotr Kapitsa's son, and a Soviet physicist and demographer.

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494 von Geldern, James (2014), 1968: Strugatsky Brothers, *Seventeen Moments in Soviet History*, Macalester College; retrieved on 04.05.2014 from the Web, http://soviethistory.msu.edu/1973-2/strugatsky-brothers/.
495 *Nauka I Zhizn'* (*Science and Life*); retrieved on 04.05.2017 from the Web, https://www.nkj.ru/.
496 The data are extracted from the magazine's last cover page.
497 *Znanie – Sila* (Knowledge Is Power); retrieved on 04.05.2017 from the Web, http://www.znanie-sila.su/.
498 *Yunyi Technik* (The Young Technician); retrieved on 04.05.2017 from the Web, http://xn-----6kcwbqeldsdd4a9ag6b6f6b.xn--p1ai/.
499 *Tekhnika Molodezhi* (Technics of Youth); retrieved on 04.05.2017 from the Web, http://technicamolodezhi.ru/.
500 *Yunyi Naturalist* (TheYoung Naturalist); retrieved on 04.05.2017 from the Web, http://unnaturalist.ru/.

Sergey Kapitsa became an influential public figure in the Soviet Union and the post-Soviet Russia with his tireless efforts at popularising science, emphasising its importance for the future of not only a single country but for the global development and continuing his father's public activity. His TV-programme was launched in the air in 1973 and continued till 1994, and with breaks – till 2012, the year of Sergey Kapitsa's death.[501] The tremendous popularity and longevity of the programme which spanned 40 years was the evidence of the vivid public interest and the high-status science possessed in the Soviet society.

The Soviet film industry launched dozens if not hundreds of movies in different years dedicated to science and education, e.g. either to school teachers (*We'll Live Till Monday*, 1968),[502] or to geologists (*Letters Never Sent*, 1960),[503] or to physicists (*Nine Days in One Year*, 1962).[504] Many of these films won prestigious international awards, like the last one – The Crystal Globe award in 1962.

The immense high status of the polytechnic education in conjunction with those difficulties of the exams and studying to obtain a polytechnic degree was reflected in the popularity of a romantic short movie *Navazhdenie* (Strange Impression) of a slapstick comedy film, titled *Operation 'Y' and Shurik's Other Adventures*.[505] It became the absolute leader of the distribution in 1965 and was viewed by 69.6 million viewers.[506]

It is important to stress out that all of the magazines were established or gained the second life in the late 1920s or mostly in the early 1930s, in relation to the state policy for industrialisation. Subscriptions to some of those magazines sometimes were even limited and hard to obtain. This indicated that level of the national aspiration for knowledge which had been prospering in the Soviet Union from the first to the last day of the country's existence.

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[501] Scientist, TV Host Sergei Kapitsa Dies, 14 August 2012, *The Moscow Times*; retrieved on 03.05.2017 from the Web, https://themoscowtimes.com/articles/scientist-tv-host-sergei-kapitsa-dies-17016.

[502] We'll Live Till Monday, 1968, *IMDb*; retrieved on 04.05.2017 from the Web, http://www.imdb.com/title/tt0062907/.

[503] Letters Never Sent, 1960, *IMDb*; retrieved on 04.05.2017 from the Web, http://www.imdb.com/title/tt0053106/.

[504] Nine Days in One Year, 1962, *IMDb*; retrieved on 04.05.2017 from the Web, http://www.imdb.com/title/tt0054803/.

[505] *Operatsia 'Y' i drugyie prikluchenia Shurika*, 1965, (Operation 'Y' and Shurik's Other Adventures), *IMDb*; retrieved on 11.06.2017 from the Web, http://www.imdb.com/title/tt0059550/, the film itself is retrieved on 11.06.2017 from the *Mosfilm*'s Web Site, https://www.youtube.com/watch?v=JZ-bjMWuBt4.

[506] *Operatsia 'Y' i drugyie prikluchenia Shurika, SSSR*, (Operation 'Y' and Shurik's Other Adventures, USSR), *KinoExpert*; retrieved on 11.06.2017 from the Web, http://www.kinoexpert.ru/index.asp?comm=4&num=291.

This national aspiration was supported in Soviet policy by various measures. Thus, the *Znanie* (Knowledge) Society was established in 1947, explained as 'The Society for the Spread of Political and Scientific Knowledge.' Although being formally autonomous, it was controlled by the Central Committee of the Communist Party for propaganda and, more importantly, for distribution of scientific knowledge through a network of museums, planetaria, a publishing house, and public lecture service.[507] In the table below the enormous figures of the lectures' attendance are given. Although these numbers were criticised in Western literature for being exaggerated,[508] they nevertheless could not help impressing the reader, e.g. in 1975 23 million lectures were read to 1.19 billion of the attendees.

Table 5 Figures of Attendance at *Znanie* Society[509]
(all figures in millions)

Znanie Society	1950	1960	1970	1975
Lectures	0.9	9.9	18.2	23.0
Auditors	89.0	631	951	1,190.0

As seen from above in this section, the certain societal conditions had been established in the Soviet society due to vigorous pursuit of the policy for the development of education and research. According to Nigmatulin in chapter 3, one of the pioneering Soviet achievements was the global recognition that science and social development could be directly interconnected and developed through a policy. According to Cocks and Graham in the literature review, this resulted in science becoming a 'natural resource' which can be cultivated. Altogether this, in turn, identifies and confirms the role of the Marxist social factors as the drivers of Soviet development in addressing the second and third approaches as shown at the beginning of this chapter.

However, it requires to look over the development of the Soviet science policy in more detail. This also could help better highlight this interconnection mentioned by Nigmatulin above between science and social development. It is particularly important as many of the various Soviet policies, as analysed above, were directed at the development of the human

[507] Matthews, 192.
[508] *Ibid.*, 192-3.
[509] Extracted from Table 6.4, Mass Indoctrination Systems, *Ibid.*, 191.

capital in which science was viewed as both an apex and an instrument for the overall Soviet and global progress.

4.3 Soviet Science Policy

By 1940, while the resources were limited and successes hard earned, Soviet policy of investing in education and improving literacy across the Soviet Union had already begun to bear fruit, as has been shown in the examples of Kazakhstan above. In general, this policy provided a productive return from the extensive investments in the creation of the social and cultural environment as an ecosystem for nourishing human capital in close coercion of the interaction of the state, industry, academia, and culture.

The case of Kazakhstan is chosen for this thesis as one of the most evident examples of the Soviet cultural, social and industrial transformation in the process of the nation-building and development. Prior the 1917 October Revolution this second largest after Russia terrain of the Russian Empire was inhibited by the nomadic people whose indigenous name was even unknown outside[510] and whose vast territory was 'divided in administrative sense into two parts. One was controlled from Orenburg in Siberia, the other from Tashkent in Central Asia.'[511] In 1920 it was formed as an autonomous republic within the RSFSR with the capital in Orenburg, and in 1936, as emphasised by Zhukov in section 3, it became the Kazakh Soviet Socialist Republic with the capital in Alma-Ata (former Verny)[512] which is the Republic of Kazakhstan now.

In the republic, whose level of literacy was around two per cent or so and where the overall number of the ethnic Kazakh engineers and scientists was counted as 14 in 1915,[513] without higher education institutions at all and a decent library, the industrial demand for specialists grew in such quantities and became so much more sophisticated in quality and variety, that a single university out of dozens of those higher education entities established the in 1930s

[510] 'The Russians originally called the Kazakhs 'Kirgiz' and later Kirghiz-Kaisak to distinguish them from the Kyrgyzs properly. In the 17th century, Russian convention seeking to distinguish the Qazaqs of the steppes from the Cossacks of the Imperial Russian Army suggested spelling the final consonant with "kh" instead of "q" or "k", which was officially adopted by the USSR in 1936,' The Kazakhs, *Wikipedia*; retrieved on 20.08.2018 from the Web, https://en.wikipedia.org/wiki/Kazakhs;
- *Postanovlenie TsIK KazASSR i SNK KazASSR ot 5 fevralia 1936 goda 'O russkom proiznoshenii i pis'mennom oboznachenii slova 'kazak'* (Resolution of the TsiK KazASSR and SNK KazASSR of February 5, 1936 'On Russian pronunciation and the written designation of the word 'Kazak'), February 6, 1936, *Kazakhstanskaya Pravda*.
[511] Laumulin, Chokan; Laumulin, Murat, 2009, *The Kazakhs, Children of the Steppes*, Global Oriental, 95.
[512] *Ibid.*
[513] Section 3.2.

in two decades found possible to announce a competition for such specialties as general physics, higher algebra, physical chemistry, geology, optics and spectroscopy, higher geometry, and others, as evident from the announcement of the Kazakh State University in section 3.2. As seen from the statistical data in section 3.2 as well, the number of researchers grew up rapidly from dozens to hundreds, and eventually to thousands to be engaged with R&D at dozens of the research and higher education entities, including the local Academy of Sciences. It was established in 1932 and notably expanded in the 1930s and 40s. As a result, according to Cocks in chapter 2, in Kazakhstan, the ratio of the number of the researchers to the population size was among the highest ones in the USSR. It indicated the magnitude of the social and industrial change occurred to this nomadic society.

In 1967 the well-paid and highly socially positioned stratum of the Soviet scientists reached the number of 69,200 people in the system of the SAS, i.e. in fundamental science, out of a total of 770,000 scientists. It constituted 8.9 per cent of the overall population, or 10-12 per cent combined with the number of the universities' researchers, which became approximately equal to the overall number of the researchers in the USA in the same period[514] and kept increasing to overrun the US by the 1980s (Spearman).

The development of science and research can be identified as the apex of the overall national Soviet development, as extensively evident from the data on the massive and increasingly growing allocations of the state funds for the Soviet Academy of Sciences. It conducted the broadest spectrum of fundamental research[515] from the geological studies, like in Kazakhstan (as confirmed by Keldysh, Jackson and Saxena), and the activity of the sun in astrophysics (as confirmed by Chitre) to specific notions in physics, like superfluidity discovered by Kapitsa, or underwater acoustics (Nigmatulin) among many others.

The policy was particularly accelerated during WWII when many of the republican and other branches of the SAS were established, as detailed by Cocks. It should be particularly emphasised that science, as driven by curiosity pursuit to grasp the nature's laws, is described by Lonzarich, Saxena, Tsironis, Chitre, Vasiliev, Nigmatulin and others. Furthermore, while looking over the Nobel Prize speeches, one can find out that many of

[514] Khanin II, 220-1, citing from *Narodnoye khoziastvo SSSR v 1967 godu* (*The People's Economy of the USSR in 1967*), 1968, Moscow, 810–811.
[515] *Ibid.*

the laureates in various scientific fields from different times, countries and cultures named curiosity as the driving force of their discoveries contributing to global development.[516]

In supporting research and establishing the research infrastructure, the Soviet state encouraged scientists' curiosity even during the harsh war conditions as seen from Basov who conducted research on centimetre waves leading to the fundamental discovery of laser (section 3.2). This policy directly connects the Soviet development to that of the rest of the *civilised nations* whose characteristics were defined by John Stuart Mill in 1848.[517] Moreover, this barely tangible and important connection between scientists' curiosity as their immaterial aspiration to learn the nature's laws, on the one hand, and technology and industry, on the other, is what underpins the successes of the modern technological and industrial development of the OECD countries. Their significant contemporary allocations for R&D in relation to their GDPs[518] cannot still reach the 1980 Soviet record of 5 per cent and more of the GNP (Cocks, chapter 2).

At this point it is required to draw out the differences between two very interconnected but distinct concepts of knowledge in science and technology, as *propositional* ('knowledge of what') and *prescriptive knowledge* ('the knowledge that prescribes certain actions that constitute the manipulation of natural phenomena for human material needs' or 'production') respectively.[519] According to Joel Mokyr, '[a]n increase in the set of prescriptive knowledge, allowing society to produce cheaper and better products is at the heart of the economic growth

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[516] Appendix K.

[517] 'Of the features which characterise this progressive economical movement of civilised nations, that which first excites attention, through its intimate connection with the phenomena of Production, is the perpetual, and so far as human foresight can extend, the unlimited, growth of man's power over nature. Our knowledge of the properties and laws of physical objects shows no sign of approaching its ultimate boundaries: it is advancing more rapidly, and in a greater number of directions at once, than in any previous age or generation, and affording such frequent glimpses of unexplored fields beyond, as to justify the belief that our acquaintance with nature is still almost in its infancy. This increasing physical knowledge is now, too, more rapidly than at any former period, converted, by practical ingenuity, into physical power'; Mill, John Stuart, 1848, General Characteristics of a Progressive State of Wealth, *Principles of Political Economy with Some of their Applications to Social Philosophy,* Oxford, Oxford University Press, 7th Edition, 1988, 66.

[518] In absolute numbers, according to the Organization for Economic Cooperation and Development's (OECD) *2015 Science, Technology and Industry Scoreboard: Innovation for Growth and Society Report*, in 2013 the US spent $433 billion on R&D which only constitutes 2.7 per cent of GDP putting the US on the 10th position in world ranking and lagging behind the following countries: Israel (4.2 per cent), South Korea (4.1 per cent), Japan (3.5 per cent), Finland (3.3 per cent), Sweden (3.3 per cent), Denmark (3.1 per cent), Switzerland (3 per cent), Austria (3 per cent) and Germany (2.9 per cent); Harrington, Rebecca, 2016, These 9 Countries Spend a Greater Share of Money on Science than the United States, *Business Insider UK*, May 1; retrieved on 01.05.2017 from the Web, http://uk.businessinsider.com/american-science-funding-statistics-vs-world-2016-2?r=US&IR=T/#9-germany-29-of-its-gdp-1; hereafter referred to as OECD.

[519] Mokyr, Joel, 2002, *The Knowledge Society: Theoretical and Historical Underpinnings*, Northwestern University, Presented to the Ad Hoc Expert Group on Knowledge Systems, United Nations, New York, Sept. 4-5, 2; retrieved on 15.09.2017 from the Web, http://unpan1.un.org/intradoc/groups/public/documents/un/unpan011602.pdf.

process.'[520] Unlike in the current economic methodology not delineating between the allocations for fundamental and industrial research within the overall expenditures on R&D, in the Soviet approach, the massive funding of the Academy of Sciences of the USSR, as shown in the introduction, clearly and primarily aimed at the development of fundamental science.

As a more detailed example of an early Soviet scientific discovery and its further development, pivotal for technology and both Soviet and global industry, it could be the invention of synthetic rubber mentioned by both Sutton and Kurakov in the literature review. This example is indicative in terms of both how an initial Tsarist time's research was successfully developed in the USSR and how it contributed to the Soviet import substitution programme during industrialisation and beyond.

In 1910 at St. Petersburg Imperial University,[521] while 'researching processes by which small molecules combine to form large ones, Lebed[y]ev produced an elastic rubber from butadiene.'[522] The initial flawed method although tried by both Russia and Germany in WWI was abandoned by both sides in favour of natural rubber whose supply, however, from the British colonies was restricted. After founding the Laboratory for Petroleum Refining in 1925, Lebedyev (who became director of the Laboratory of Synthetic Rubber in Leningrad [1928–30] and academician of the SAS in 1932) developed his process of obtaining butadiene from ethyl alcohol which was used not only by the Soviet, but also the German, rubber industry.[523] As a result, 'by 1940 the Soviet Union had the largest synthetic rubber industry in the world, producing more than 50,000 tons per year.'[524]

After WWII and based on Lebedyev's research, the Soviet Union developed another method of the synthetic rubber production from divinyl. As explained by Kurakov:

> Divinyl is the basic intermediate product (monomer) in the production of general purpose synthetic rubber. Divinyl is used as raw material for the production of the most current rubber sorts for the tyre industry and other

[520] *Ibid.*, 3.
[521] Leningrad State University (LSU) in 1924-91 and St. Petersburg State University (SPBU) now; retrieved on 22.05.2019 from the Web, http://english.spbu.ru/.
[522] Lebedev.
[523] *Ibid.*
[524] The Rise of Synthetic Rubber Industry; *The Encyclopaedia Britannica*; retrieved on 22.05.2019 from the Web, https://www.britannica.com/science/rubber-chemical-compound/The-rise-of-synthetic-rubber.

> branches of industry. Special polymerization methods can be used to produce, on the basis of divinyl, SKD rubber of regular structure with valuable properties.[525]

At first, divinyl was produced from alcohol made from foodstuffs, and later, from synthetic alcohol obtained from oil gas ethylene, as outlined by Kurakov.[526] A more promising method of producing divinyl from butane was developed and, at the beginning of 1960, at the Sumgait synthetic rubber plan in Azerbaijan, the first industrial plant to produce divinyl from butane by a double-stage process was founded.[527] This technology was consequently used in other synthetic rubber plants constructed.[528] Meanwhile, as continued by Kurakov:

> Acetaldehyde is an important intermediate product in the production of several synthetic materials. It is used primarily in synthetic rubber plants as an obligatory addition to the alcohol mixture in the production of divinyl by the Lebedyev method. Acetic acid, used to produce acetate silk, and several plastic solvents and plasticizers can also be derived from acetaldehyde. At present acetaldehyde is manufactured from acetylene, which is in its turn produced from carbide.[529]

Research was carried out in the Lomonosov Institute of Light Chemical Technology in Moscow[530] and 'in the Synthetic Alcohol Research Institute ha[d] shown that when a palladium catalyser [wa]s used, acetaldehyde can be obtained through direct oxidation of ethylene, which [wa]s a considerably cheaper product than acetylene.'[531]

In another example, in 1936 Ioffe claimed that his 'Physicotechnical Institute of 1918 had become a network of fourteen institutes and three higher technical schools, with 1,000 scientific workers of whom about one hundred could be considered major independent scientists.'[532] They, in turn, made the following, according to Ioffe, contributions to the

525 Kurakov.
526 *Ibid.*
527 *Ibid.*
528 *Ibid.*
529 *Ibid.*
530 It is now Moscow State University of Fine Chemical Technologies named after M.V. Lomonosov (traditional abbreviation *MITHT*); retrieved on 18.05.2019 from the Web, https://english.mirea.ru/.
531 Kurakov, 96.
532 Holloway, David, 1994, *Stalin and the bomb, The Soviet Union and Atomic Energy 1939 – 1956,* Yale University Press, New Haven & London (Kindle Edition), 16-7; hereafter refereed to as Holloway; citing from *Izvestia Akademii Nauk SSSR, Seria fizicheskaia*, 1936, no. 1-2, 24-6.

Soviet economy: '[A]n acoustic method for measuring stresses; new methods for studying the structure of steel and alloys; the invention of new insulating materials; the protection of electric lines and high-voltage transformers; works on polymers and artificial rubber; and new method of biological measurement.'[533]

Thus, the examples above are illustrative in terms of the following: i) how basic research driven by scientist's curiosity to understand how small molecules can combine to form large ones in Lebedyev's case, could lead to the emergence of technology and Soviet and global industry significantly affecting war, politics and economy; ii) as a demonstration of both consistency and progression of the Soviet industrial policy largely supportive of the development of basic research as its integral part; iii) and how the policy of developing basic research can relatively quickly lead to some tangible engineering, technological and industrial results.

It should be emphasised that such a specific Soviet approach which proved its efficiency within a concise period of time could not have emerged as a result of the market forces. As seen from the data, the USSR if continued developing within the New Economic Policy as 'the state capitalism' (Lenin), could not perform industrialisation at the scale and terms occurred. It required a massive concentration of the capital and resources to be socialised, according to Marx, and distributed to the strategic areas of development. The latter included not only the purchase of the equipment, plants or expertise from outside but above all implied the deployment of the significant social programmes including education and research.

The philosophy of the new policy in the words of Felix Dzerzhinsky, who established the *VChK* (as the predecessor of the *KGB*) and who was the chairman of the Supreme Council of the National Economy, was formulated in 1926 as follows:

> Therefore, when it is said that because of the shortage of resources we should halt our investment projects, or reduce them to a certain level, then I assert that, I, as chairman of the Supreme Council of the National Economy,

533 *Ibid.*, 17, citing from *Ibid.*, 21.

> will struggle against such an opinion to the end because it is fundamentally incorrect.[534]

As seen from the data on the *Arteli* in section 3.2, semi-private SME's were notably present in the Soviet economy until 1960 but did not play a significant role in either the heavy industrialisation or the development of science and technology or education. Moreover, as implied by Michel in chapter 1, if not for industrialisation, the Soviet Union could have hardly won over The Third Reich and Japan in WWII. Meanwhile, Tsarist Russia which had been unindustrialised was defeated by Germany in 1918 and Japan in 1905 in its two previous wars respectively.

The Soviet model of the interaction of the state, industry, and academia was underpinned by the development of social welfare for the formation of human capital. It was put in such forefront in the overall policy including the industrial one that the Soviet Union called itself as a 'socialist country,' unlike the Western terminology in which it was regarded as a communist one. Meanwhile, socialism with its focus on social development and socialisation of property was considered, according to the Marxist political theory, as a transitional phase to communism, i.e. a money-, property- and classless society, in which knowledge production would take the central place, as outlined by Buzgalin. This prioritised science and technology in development and preparation of human capital through social policy, including education, healthcare, and others as well as could explain the role the ideological platform played in the Soviet science policy.

Thus, the Marxist policy and Marxist drivers of development should be considered as very critical factors for Soviet industrialisation. In this sense, technology transfer was a technical factor chosen as the most effective means for industrialisation in which the institutional ability established via the comprehensive social and education programmes to assimilate and develop technology was crucial.

On the other hand, although Marx defined the role of technical progress in production as crucial, he did not elaborate on the origin of technology in detail, as confirmed by Buzgalin. Most economic theories, including Marxism, could not explain the phenomenon of Soviet development in full missing the connection, on the one hand, between science, engineering, technology and innovation, and social development and science, on the other. While some

[534] Ellman, Michael, 2014, *Socialist Planning*, Cambridge University Press, 10.

of them, like the *Triple Helix Systems of Innovation*,[535] can be used as an analytical tool for Soviet development from the position of the unity of governmental, industrial and academic policy in designing a national *industry of discovery* (Sumner Slichter),[536] crucial for innovation and development, these theories do not consider the USSR as a full case study as followed from the dichotomy in scholars' views of both sides in the literature review.

With the establishment of the Academy of Sciences of the USSR, the development of science in the Soviet Union was an important application of the Marxist socialised surplus value in order to increase overall productivity and amplify the surplus value. A more in-depth look at the Soviet industrial policy reveals that without the contribution of science, the Soviet Union would have been unable to industrialise and develop as rapidly as it did.

The state-funded Soviet academia was tightly involved in socio-economic development in the form of providing knowledge, expertise, skills and the human capital for the overall system and coevolving with its other elements, including the state governance at different levels of the industrial development, to improve the overall national functionality. From industrial and social perspective, science, apart from its direct purpose of discovery, was employed to establish the Soviet industrial (*GOSTs*), healthcare and other various state standards as the unified system of certification.[537]

According to Nigmatulin and Paltashev, the Soviet academia was established in regions without a higher education capacity making the very integrated environment for academia technology transfer and performing relocation of the human capital to stimulate arts/technology-based economic development as also evident from the example of Kazakhstan above and the other republics as seen from the literature review. The process implied bringing together all sets of intellectual activities into the societal consensus process for a knowledge-based regime and was characterised with the provision of the access to the resources required to implement a project, including the various infrastructure for the development of education and research as well as the cultural development. This also provided solutions to conflict or crisis situations as seen from the Paltashev's example of Chernobyl.

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[535] Ranga, Maria, and Etzkowitz, Henry, 2013, *Triple Helix Systems: An Analytical Framework for Innovation Policy and Practice in the Knowledge Society*, Stanford University; retrieved on 15.09.2017 from the Web, https://triplehelix.stanford.edu/images/Triple_Helix_Systems.pdf; hereafter referred to as Ranga & Etzkowitz.
[536] Bush, 315.
[537] Foltran, Luca, 2016, *Russian and Eurasian Custom Union Markets - Guideline to Food Contact Materials (FCM) and articles designed to contact food substances,* 28; retrieved on 19.08.2018 from the Web, https://www.kobo.com/us/en/ebook/russian-and-eurasian-custom-union-markets-guideline-to-food-contact-materials-fcm-and-articles-designed-to-contact-food-substances-1.

Soviet industrialisation launched initially on the exogenous technology transfer could rely on the academic base which was instituted in the 1930s and eventually provided domestic national expertise, knowledge, skilled labour and proximity to sources of knowledge and expertise. Meanwhile, it was important, according to Berliner, that '[t]he effect of central financing of R & D [wa]s that a major input required for innovation [wa]s available to the user at a price of zero.'[538]

The Soviet state was the engine for the production of human capital. On the national level, the endogenous base of research replaced the exogenous expertise in the Soviet import substitution programme during industrialisation. On the regional levels, a similar strategy was deployed by the Communist Party sending specialists from Moscow, Leningrad or Kiev to Kazakhstan and the other Soviet national republics to foster knowledge creation to be later supplemented by the local indigenous academia, as noted by Paltashev. In other words, the use of expertise from 'outside' in order to spur local knowledge production was a part of the Soviet policy and can be viewed as a development paradigm in the region(s).

Meanwhile, widely known is Stalin's support of the academician and biologist Trofim Lysenko[539] and his interference in genetics which as well as cybernetics, both were named as 'bourgeois sciences,' as mentioned by Tsironis and Nigmatulin in chapter 3. Genetics as a new scientific discipline, most likely, suffered due to its close association with the race theory of Nazi Germany and due to this reason was strongly opposed by the official Bolsheviks' ideologists in 1935 in the book edited and published by Nikolay Bukharin.[540]

Cybernetics, as a discipline, was gradually rehabilitated from 1947 and even became so developed in later years that a few different programmes, from 1958 to 1964, were combined to the programme of the academician Viktor Glushkov of *Obshchegosudarstvennaya Avtomatizirovannaya Systema Ucheta i Obrabotki Informazii* (All-State Automated System of Accounting and Processing of Information, i.e. Administration of Economy), or the *OGAS*, which, if implemented and finished by 1990, as initially planned, could have become a Soviet version of the digital Web.[541]

538 Berliner, 173.
539 Ings, 340-66.
540 Uranovsky Y., M., 1935, Marxism and Natural Sciences, from Bukharin N.I., and others, *Marxism and Modern Thought*, George Routledge & Sons, 171.
541 Peters, Benjamin, 2016, *How Not Network a Nation: The Uneasy History of the Soviet Internet*, Cambridge, Massachusetts, The MIT Press, 112.

Genetics suffered more and could become restored as a scientific research discipline of biology and medicine only after the Stalin's death. However, it should be noted that if development of cybernetics was underpinned by the advanced and globally acknowledged school of Soviet mathematics, genetics was not that theoretically advanced and was not possessing a large-scale research base, although it was supported and developed by a prominent botanist Nikolay Vavilov and some others. He dedicated his life and activity to study and improvement of wheat, corn, and other cereal crops as well as the creation of Leningrad's seed bank, and was arrested in 1940 to die in prison three years later.[542] Meanwhile, an important aspect, while considering the Soviet science policy, is that all the subjects of modern sciences in all their research varieties were represented throughout the vast network of the SAS.

Concerning the *sharashkas* mentioned in section 3.2, their existence was promoted and quite largely exploited in pop- and mass media culture, including the film industry, or such novel by Aleksandr Solzhenitsyn as *The First Circle*[543] due to, likely, the importance of the aviation and rocket industry during the Cold War. However, the overall number of these specific laboratories as shown in section 3.2 was limited to five in 1949. This, if compared to the total number of the various Soviet research, engineering design and construction entities of 1,700 in 1945,[544] it can be regarded as not significant. It should be rather understood from the position of the secrecy and security issues, surrounding the aviation and rocket industry, or the Soviet Atom Bomb project whose strategic importance for the national security was specified by Paltashev in chapter 3.

Meanwhile, in his interview, Littlewood at that moment being head of the US Argonne National Laboratory, home of nuclear technology as a part of the Manhattan Project (as mentioned in chapter 1), frankly outlined the following. In the US, the research which propelled the early days of Silicon Valley was special research in communications technologies and, in particular, in radar and microwave. It came out of the WWII effort and was very much associated with military preparedness to bomb the Soviet Union.[545] He

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[542] Ings, 297-302.
[543] Solzhenitsyn, Aleksandr I., 1969, *The First Circle*, Toronto, New York, London, Bantam Books.
[544] Khromov, Gavriil, 2002, *Rossiyskaya akademia nauk, istoria, mify, real'nost* (The Russian Academy of Sciences, History, Myths, Reality), 7, *Otechestvennye zapiski*; retrieved on 27.06.2017 from the Web, http://magazines.russ.ru/oz/2002/7/2002_07_24.html; hereafter referred to as Khromov.
[545] Brown, Anthony Cave (Ed.), 1979, *Operation World War III: Secret American Plan ("Dropshot") for War with the Soviet Union in 1957*, Arms & Armour Press.

continued that there was a lot of investment in what became the hardware of IT that came from the military side, connected to companies, which had military contracts in the US.[546]

In general, Littlewood thinks it is the myth actually how the US economy works. In his view, 'the mechanisms were somehow different however the US was far from being a free market, and there was a lot of directed economic development in the US, driven by either large corporations or by the government in a way which is rather different from the view that there is kind of a free market which is pulling everything.'[547] This explains the similarities between both American and Soviet industrial development driven by science and technology, as noted by him in chapter 3[548] and evident in both Bush's and Kapitsa's almost identical policy recommendations.[549]

It is interesting to emphasise that the SAS was a unique entity within the Soviet system due to not being an element of the planning as well as the principle of its governance. In May 1917,[550] a notable geologist Alexander Karpinsky[551] mentioned in section 3.2 was elected in secret ballot as President of the Russian Academy of Sciences (RAN) to be transformed into the SAS in 1925. This democratic procedure never changed during the existence of the SAS (the RAN again from 1991), until quite recently, 2017. As Gavriil Khromov, a Soviet-Russian astronomer and a historian of science wrote:

> In 1925, despite the ambiguous attitude towards the Academy from the public and even prominent bureaucrats of the Narkompros [the People's Commissariat of Education], its 200th anniversary was solemnly celebrated. By that date a new academic chapter was adopted. It secured both the right of the academicians to elect independently their own president and the new name – the Academy of Sciences of the USSR. […] High specialists were few and they were highly valued.[552]

Karpinsky was elected two more times as the president of the SAS until his death in 1936. As an evidence of the high status, science held in the Soviet establishment, his funeral was

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546 Littlewood.
547 *Ibid.*
548 *Ibid.*
549 Appendix M.
550 Karpinsky.
551 *Birthday Anniversary of Alexander Karpinsky, Founder of the Russian Geological Research School, First Elected President of the Russian Academy of Science*, Presidential Library; retrieved on 26.06.2017 from the Web, http://www.prlib.ru/en-us/History/Pages/Item.aspx?itemid=780.
552 Khromov.

organised as the high national honour ceremony to be attended by the political leadership, including Stalin, and the body was buried in the Kremlin Wall Necropolis among the national heroes[553] to become the eldest representative there by birth and despite the fact that the official ideology was very reluctant in glorifying of the representatives of the old Tsarist regime.

Additionally, in the opinion of Pyotr Kapitsa, a central intellectual figure of this thesis, the Academy played a vital role of moral authority in the Soviet society.[554] In the Soviet development of science, as mentioned by Paltashev in chapter 3, two figures of Soviet physics stand out, i.e. Abram Ioffe and his former student Pyotr Kapitsa, who are known for their scientific discoveries as well as for their influence on policy-making. Ioffe is considered as 'the father of Soviet physics,' whereas Kapitsa influenced generations of Soviet leaders in informing on the connection between science and modern industry for the formation of the national institution of science.

The Soviet industrial policy was developed not only within the realms of Marxism-Leninism but was also formed under influence of such international scientists and engineers as Abram Ioffe, Pyotr Kapitsa and others. This is corroborated in the US as well where Vannevar Bush and other international scientists explained the role of science in a modern progressing industrial society at the time. Both Bush and Kapitsa emphasised the role of science as the primary source of knowledge and the starting point of growth for engineering, technology (including technology transfer) and innovation, hence development, in almost identical expressions. Their policy recommendations to the political leadership of their respective nations are given in a comparative consideration in Appendix M as a factual addition to the formation of Soviet development as being universal and integrated with that of the world, and the US, in particular, with some details of Pyotr Kapitsa's life and legacy (Appendix L) to enrich this research.

Indeed Soviet development can be observed through the prism of those Ioffe's words of 1927 about a very close relationship between physics and industry in which 'all forms of industry are nothing but various sections of physics or chemistry applied and exploited on a

[553] Shalaeva G.P. (Ed.), 2003, *Kto est' kto v mire* (Who is Who in the World), Olma Press, Moscow, 647.
[554] Ossipov, G. V., 2013, *Rossiyskaya Akademia Nauk – Tri Veka Sluzhenia Otechestvu* (*The Russian Academy of Sciences, Three Centuries of the Service to the Fatherland*), ISPI RAN, Moscow, 88.

large scale.'[555] In his other article of 1951, one can find a continuation of this approach explaining the following: 'Physics is a foundation of technical progress, physics is a reservoir from which new technical ideas and new technology are drawn. At a given stage of development, research in physics transmits into important technical achievements.'[556] It would not be an exaggeration to emphasise here that this theoretical understanding was the foundation stone of the Soviet industrial policy.

It is important to note that Ioffe was not alone in thinking this, this approach was equally appreciated and well understood abroad and was accepted by foreign scientists as seen from Bush's report. In addition, in Korol's account, in 1954 this Ioffe's article prompted a vibrant dialogue and discussions in the USA, where Nathaniel H. Frank, head of the Physics Department at MIT, emphasised the dual role of physics, which, on the one hand, was viewed in its connection with engineering, and on the other, as a purely scientific discipline. According to him, it is 'one of the greatest intellectual achievements of mankind, and the impact of the growth of science on social and political ideas has been such that a proper understanding of our present day culture and problems is difficult to attain without an adequate scientific background.'[557] This philosophy reflecting the unity of science across the borders laid in the foundation of the Soviet science and education policy as a genuine driving force of the industrial and socio-economic development as analysed above.

The policy implementation can be illustrated by the following interesting example which is connected to the scientific figures of both Abram Ioffe and Pyotr Kapitsa. During the Russian Civil War, in 1921 the delegation of Soviet physicists including Ioffe as the head and Kapitsa visited Cambridge. The visit happened, despite Soviet Russia not being officially recognised by Britain, and became possible due to the solidarity of the scientists of both sides. While initiating the proposal to renew the international connections and anticipating an albeit unknown although a desirably positive outcome for Soviet development, Lenin's government found resources to fund Ioffe's trip as well as the purchase of a series of expensive equipment along with Kapitsa's extended stay abroad in

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[555] Joffe, A., 1927, Physics and Technology, *Science at the Crossroads, Papers Presented to the International Congress of the History of Science and technology Held in London from June 29th to July 3rd, 1931 by the delegates of the USSR,* 1931, Frank Cass and Co.; retrieved on 26.06.2017 from the Web, https://www.marxists.org/subject/science/essays/joffe.htm.

[556] Ioffe, A.F., 1951, *O prepodavanii fiziki v vysshei technicheskoi shkole* (On the Teaching of Physics in Higher Technical Schools), *Vestnik vysshei shkoly*, N10, 16, hereafter referred to as Ioffe I.

[557] Korol, 257, citing from the address given by N.H. Frank at the Annual Meeting of the American Society for Engineering Education at Urbana, Illinois, on June 15, 1954.

the continuing hardships of the Civil War.[558] It demonstrated, therefore, policy-makers' sufficient level of an adequate scientific understanding mentioned above by Frank.

Returns from these investments were significant, both nationally and globally. The Ioffe Institute in Petrograd received much of the laboratory equipment that was later used to establish other scientific institutions.[559] And more importantly, in Cambridge, the scientific figure of Pyotr Kapitsa was finally formed whose theoretical, technological and industrial legacy for Soviet and global development is highlighted throughout the thesis. The circumstances of his not entirely voluntary decision to stay in the USSR in 1934 are provided in Appendix L to illustrate that importance the Soviet policy-makers including Stalin gave to both the national development of science and the role science played in industrialisation. Meanwhile, Kapitsa's policy-advising activity played a particular role in the formation of Soviet policy which is analysed in this thesis.

4.4 Conclusion

The core of the Soviet policy implemented which underpinned of the technological, industrial and economic development was a comprehensive development of all fields of science delivered in the form of the ideology of Marxism-Leninism. Whatever interpretation may be put on the motivation and humanitarian aspects the policy-makers had been pursuing in teaching and applying science as good opportunities in the doctrinal 'scientific-atheistic upbringing' of the Soviet nationals, those policy-makers, according to Korol, were 'clear and realistic in assessing the role of physics [science in general] as the base for technical progress.'[560] Science as a driving force of productivity had a central place in the socialist way of production on the road to the communist society, following the Marxist economic theory.

However, the policy implementation in practice exceeded the theoretical framework of Marxism and was not dogmatic. According to Cocks in the literature review, in the 1920s the Soviet Union became the pioneer in formulating policy towards science and technology as a whole. As a result, the Academy of Sciences became a unique Soviet entity functioning

[558] Ioffe A.F., 1951, *O fizike I fizikakh: stat'i, vystuplenia, pis'ma* (About Physics and Physicists: Articles, Speeches, Letters), Nauka, 313-4, hereafter referred to as Ioffe II; retrieved on 26.04.2017 from the Web, http://old.pskgu.ru/ebooks/ioffe/ioffe_7_04.pdf.
[559] *Ibid.*, 314.
[560] Korol. 257.

largely independently from political control and being economically autonomously from the central planning committee of the USSR.

This implied in-depth and sophisticated scientific understanding of the universal connection between fundamental research and development including economy by the policy-makers. The universality of this concept in the modern technological development was shown above.

Thus, one can conclude that Soviet industrialisation was indeed based on technology transfer from outside, however, its success was nonetheless defined by the high level of the Soviet managerial and engineering expertise. This became doable due to the following five critical and interconnected factors.

Firstly, it is the development of the Soviet education system, especially for science and technology, which prepared specialists of different levels to run and develop technology. Secondly, education was an integral part in the deployment of the comprehensive set of the various social policies. Thirdly, the development of science as a universal and irreplaceable reservoir of knowledge, expertise and human capital derived from and was underpinned by the Soviet socio-ecological system of the human capital development resultant from the social policies analysed above. Fourthly, the establishment of such an integral and substantial policy within a short span of history could not have become possible in the free market conditions implying an evolutionary development. The Soviet state which used the theory of Marxism for socialising national resources could have distributed them into strategic directions which enabled the Soviet Union to meet the most difficult challenges. Last but not least, in implementing its policies, Soviet policy-makers and scientists revealed the unity in their same vision of science as the driving force of modern technological development that was not enhanced by Marxism.

It is particularly interesting that all of the international scientists and engineers interviewed or those considered in the literature review (Spearman, Keldysh) and here (Ioffe, Kapitsa, Bush and Frank) shared the same vision despite sometimes being actively involved into the appropriate policy-making in their home countries. This had to imply standing on the different ideological positions. Instead all the scientists and engineers, the physicists, in particular, have been demonstrating internationalism and their adherence to those, according to the founder of quantum physics, Max Planck, in 1916, ‘domains of intellectual and moral life that lie beyond the struggles of nations, and that honourable cooperation in the cultivation of these international cultural values and, not less, personal respect for citizens of enemy states [that] are indeed compatible with ardent love and energetic work for one's own country.'[561] This citation reveals the philosophical universality and integrity of Soviet development with the approach spread among scientists across time and borders in which science is viewed as the domain beyond the traditional economic imperatives as well as the basis of modern global development.

Furthermore, the successes of Soviet science which defined the Soviet industrial and other development would have been impossible without an unprecedented and the most extended social programme which included various aspects from the development of healthcare to education above all aiming at the human capital development, as analysed above. The Soviet approach combined both science and social policy for the human capital development as the driving force for the rapid modernisation and industrialisation of the country. This addresses the research question and concludes this chapter.

Chapter 5 is to inform the reader better on the particular contributions of the Soviet science and technology to global development to highlight the universal character of science in general, and to emphasise the connection of Soviet development with the world.

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[561] Heilbron, J. L., 1987, *The Dilemmas of an Upright Man: Max Planck as a Spokesman for German Science*, University of California Press, 78.

Chapter 5 Soviet Science and Global Development

This chapter connects Soviet development with the global development of science and technology in more detail and consists of three sections. The first one is dedicated to the unity of Soviet and global science evident through Soviet-international scientific cooperation and publishing. The examples of some Soviet scientific and technological contributions to global development are shown in the second section and detailed with some modern developments. In particular, one is that of the high technology industry and the other one of consumer goods. The third section analyses Soviet development in the post-WWII period as resultant from the set of the policies considered previously in the thesis.

Science can develop only if the industry of discovery is established as a national institution in the interaction of the state, industry, and academia as disclosed in the previous chapter. The certain societal conditions to meet due to which the Soviet industry of discovery became operational were considered there as well. Meanwhile, science, according to Bush and Kapitsa,[562] if secluded in a solely national paradigm cannot develop making the international collaboration and exchange of knowledge one of the most significant ingredients of the scientific development within the overall global unity of science which is the subject of the next section.

5.1 Soviet-International Scientific Cooperation and Publishing

The concept and understanding of the unity of science at a global scale can help explain that high level of the international scientific cooperation, the Soviet Union had been actively involved in, as evident from the interviews.[563] In their public activity, scientists emphasise the philosophical unity and universalism of science as based on the most fundamental intrinsic human values. Meanwhile, science in their vision is viewed and applied as a natural platform for a productive dialogue among communities, nations, and people separated by conflicts or ideologies. History knows some fruitful examples of such cooperation between the USSR, on the one hand, and Great Britain or the US, on the other. Pyotr Kapitsa's discoveries, who happened to be both Cambridge and Soviet physicist, or the Soviet-American mutual space programme *Soyuz-Apollo* during the times of *Détente* in the 1970s were the examples.

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[562] Appendix M.
[563] Nigmatulin, Littlewood, Lonzarich, or Chitre.

History of the Soviet Union revealed some other examples of such international cooperation mentioned above. The Soviet doctrine of the science development implied the full integration of the Soviet science into the increasing process of globalisation with the understanding of the impossibility to resolve the increasing challenges of the global problems in terms of the environment, nuclear energy, space, and oceanic exploration, food crises, and global decease control without 'a rational application of the international cooperation in science and technology.'[564]

It should be particularly emphasised that this doctrine clearly envisaged that central role science played in global political development: 'The most important significance of the international scientific relations also lies in the fact that they have an ever increasing influence on political relationships between states, promoting international security, creating an atmosphere of trust and mutual understanding among peoples.'[565] The Soviet Union was a member of 600 various international organisations, out of which 320 were in S&T, apart from its participation in most of the S&T programmes of the global organisations such as UN, UNESCO, UNIDO, ISO, WHO, IES and many others, including multiple forms of direct cooperation between scientists and research entities.[566] Thus, the Soviet Union had been implementing the concept of science as *soft power*[567] considered as the most effective instrument of global influence and collaboration. As Pyotr Kapitsa fairly noted: 'The history invariably demonstrates that those countries with a significant international influence have, in the first place, a profound science.'[568]

After being implemented at the national level, the Soviet space programme became increasingly international to involve other nations into the process. The first cosmonauts of Afghanistan, Austria, Bulgaria, Cuba, Czechoslovakia,[569] France, Germany (the German Democratic Republic), Hungary, India, Mongolia, Poland, Romania, and Syria travelled in space through the Soviet programme. This was driven by understanding that the

[564] Gvishiani.
[565] *Ibid.*
[566] *Ibid.*
[567] This term was coined by Joseph Nye, an American political scientist of Harvard University, who disclosed it in his article in 2012 in the following sentences: 'the best propaganda is not propaganda' and 'credibility is the scarcest resource;' Nye, Joseph 2012, China's Soft Power Deficit To Catch Up, Its Politics Must Unleash The Many Talents of its Civil Society, 8 May, *The Wall Street Journal*; retrieved on 03.05.2017 from the Web, https://www.wsj.com/articles/SB10001424052702304451104577389923098678842.
[568] Kapitsa, Pyotr (Arranged by P. Rubinin), 1989, A letter to N. Bohr, 22 October 1945, *Kapitsa. Pis'ma o nauke. 1930-1980* (Kapitsa. Letters about Science. 1930-1980), Moskovskyi rabochyi, Moscow, 314; hereafter referred to as Kapitsa I.
[569] To be divided into the Czech and Slovak Republics in 1993.

involvement of these nations into the sophisticated technological development of the space programme can help them in their developmental paths to boost and expand their national policies of development in S&T, culture, education, and economy.

The Soviet Union played a key role in the founding and development of the scientific, research and education, as well as industrial base in China.[570] The volume of the Soviet aid to China was so large that even after the Sino-Soviet split in 1956, according to Christopher Howe, '[d]uring the 1960s, the [Chinese] economy was still completing and absorbing the Soviet projects started between 1953 and 1959 and there were few resources for new developments.'[571] In addition, the Soviet aid to China's cultural and human capital development was significant and took an important place in Chinese development.[572]

For instance, as a result of an extensive and intense programme of the scientific cooperation in high technologies between the two countries in the 1950s[573] and after 10 years after its establishment, the Chinese Academy of Sciences (CAS) launched the Institute of Computing Technology on 17 May 1959:[574]

> Overall, the Soviet Union played a very important role in transferring computing technology that the Chinese could not develop on their own. The Soviet Union provided all technical drawings and data, as well as key electronic components, and parts for the early computers. In addition, Soviet experts guided test modeling and the establishment of the Chinese research institute.[575]

As also acknowledged in this Chinese research:

> Soviet experts helped the CAS to establish more than 40 labs or research groups and made important contribution in such fields as atomic energy and

[570] Zhang, 122-44.
[571] Howe, Christopher, 1978, *China's Economy, A Basic Guide*, New York, Basic Books Inc. Publishers, 64; hereafter referred as Howe.
[572] Insun, Zhao, 2003, *Ekonomicheskaya pomoshch Sovietskogo Souyza Kitaiskoi Narodnoi Respublike v 1949-1959 gg* (*Economic Aid of the Soviet Union to People's Republic of China in 1949-1959*), PhD dissertation in History, Moscow Automobile and Road Construction State Technical University, (MADI); retrieved on 05.06.2018 from the Web, http://www.dissercat.com/content/ekonomicheskaya-pomoshch-sovetskogo-soyuza-kitaiskoi-narodnoi-respublike-v-1949-1959-gg.
[573] Zhang, 131-4.
[574] *Ibid.*, 134.
[575] *Ibid.*

> physics, computing technology and mathematics, and chemistry and applied chemistry. Lanthanon and other rare elements, electronics, precision optical instruments, mechanics research, oceanography, and comprehensive survey equipment also were supplied by the Soviet government. To varying degrees, specialists from the USSR provided aid to other fields such as astronomy, automation, electrotechnology, and organic chemistry.[576]

According to Howe, the SAS instructed the CAS in 1953 that they allocated 2/3rds of the resources to applied projects and 1/3rd - to basic research.[577] The applied projects were mainly requests from the ministries.[578] Overall, the Soviet contribution to China was first in establishing the system followed by the concrete aid in science planning, and then education and training, including access to Dubna, *etc*.[579] The Chinese were also very impressed by the Gagarin's feat which as 'an impact by example,' spurred them on, as emphasised by Howe.[580]

Thus, the current scientific and technological successes of the People's Republic of China are in many institutional ways grounded in the Soviet assistance of the 1950s. Furthermore, in developing its current *The Belt and Road Initiative* (BRI) which involves an unprecedented and growing number of the countries, China follows the Soviet example in placing research as an essential piece of its international cooperation.[581]

In the universe of science, in the realm of unbounded discussions and free exchange of ideas, academic freedom and travelling are essential. In contrast to the political and social environment, Soviet scientists were enjoying the benefits of freedom of speech and were allowed to travel abroad to a much greater extent than their ordinary compatriots. In the library and on the bookshelves of the Cavendish laboratory in Cambridge one can find out plenty of the scientific publications which unconditionally demonstrate that the Iron Curtain was not an obstacle for both foreign and Soviet scientists to write and publish the articles in journals across both sides of the Iron Curtain as well as to travel for work and conferences

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[576] *Ibid.*, 142.
[577] Howe, 2019.
[578] *Ibid.*
[579] *Ibid.*
[580] *Ibid.*
[581] 'The University Alliance of the Silk Road (UASR) [was] established in 2015 and now [is] claiming to involve 150 universities across 38 countries,' Baker, Simon, 2019, Is China's Belt and Road Initiative Boosting Academic Links?, 14 May, *The Times Higher Education*; retrieved on 14.05.2019 from the Web, https://www.timeshighereducation.com/news/chinas-belt-and-road-initiative-boosting-academic-links?utm_source=THE+Website+Users&utm_campaign=6aa32c4b8c-EMAIL_CAMPAIGN_2019_05_13_01_59&utm_medium=email&utm_term=0_daa7e51487-6aa32c4b8c-62116905.

from the West to the Soviet Union, and vice versa. Many of the articles were not only published but also written by scientists while being physically abroad.[582]

One can trace these various personal interactions in any field of science of that time and beyond in multiple journals' articles, book, and interviews, including those chosen for this thesis. This phenomenon could even find its reflection as a separate subject of academic literature.[583] Thus, in the reality of the Iron Curtain, the existence of the restrictions was not a crucial factor in the free exchange of information and, more importantly, new knowledge.

The fall of the Iron Curtain revealed that most of those around not less than 150,000 Soviet and post-Soviet scientists[584] emigrated in the period from 1991 to hitherto have been extremely adoptive to working in the foreign environment in terms of the content of their research after having overcome certain difficulties of cognitive, methodological and social character.[585] It also revealed that the Iron Curtain had been erected from its both sides. It often occurred that '[…] many of the results published in Russian were repeatedly 'rediscovered' abroad without the references to the Russian publications mostly not intentionally but due to ignorance.'[586] Nonetheless, the significant number of the Soviet scientists in immigration demonstrated that the Soviet science and education base was in unity with the global development, like Khmelnitskii, mentioned in the methodology section, or Paltashev.

This unity is underpinned by education. Without studying fundamental disciplines, the development of S&T is impossible which makes education, in particular in high school, a critical element of modern development. As outlined by Paltashev,

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[582] Joffe, Abram, 1956, Heat Transfer in Semiconductors, Proceedings of the International Conference on Electron Transport in Metal and Solids, *Canadian Journal of Physics,* 1342;

Shoenberg, David, 1938, *Superconductivity*, Cambridge University Press, the preface is written in February 1938 at the Institute for Physical Problems, Academy of Sciences of the USSR, Moscow, X;

Landau, Lev and Lifshitz, Efim, 1958, Institute of Physical Problems, USSR Academy of Sciences, *Quantum Mechanics: Non-relativistic Theory*, Pergamon Press, London - Paris;

2nd General Conference, 1972, *European Physical Society*, Taylor & Francis Ltd;

Shoenberg, David, 1986, *Magnitnye Ostsylliatsyi v Metallakh* (Magnetic Oscillations in Metals), Mir, Moscow.

[583] Byrnes, Robert F., 1976, *Soviet-American Academic Exchanges, 1958-1975*, Indiana University Press.

[584] Prostakov, Sergey, 2013, *S nachala 1990-ikh iz Rossii uekhalo 150 tychiach uchenykh* (Since the Beginning of the 1990s 150 Thousand of Scientists Have Left Russia), 16 August, *Russkaya Planeta*; retrieved on 13.06.2017 from the Web, http://rusplt.ru/fact/s-nachala-1990h-iz-rossii-uehalo-150-tyisyach-uchenyih.html.

[585] Zukerman, A., M., 1998, *Integratsia rossiyskikh uchenykh v mirovuu nauku, ikh adaptatsia k usloviam raboty v SShA, 1990-e gody* (Integration of Russian Scientists into the Global Science, Their Adaptation to Working Conditions in the USA, the 1990s, *IIET RAN, Godichnaya nauchnaya konferentsia 1998*, IIET RAN 1999, 259-62; retrieved on 13.06.2017 from the Web, http://www.ihst.ru/projects/sohist/papers/tsuk98i.htm.

[586] *Ibid.*, 259.

> The knowledge in science and technology is required in global industry, and that is why post-Soviet specialists are still demanded there as, unlike for instance in India and China before, the fundamental disciplines, to begin with, were studied in Soviet high school properly. Watching the destruction of this kind of education in the post-Soviet space including Russia and Kazakhstan is sad, however, in the today's Russia, they have tried to reverse the process.[587]

According to Paltashev, physics, chemistry, mathematics, biology, mechanics and other fundamental disciplines are going, at any rate, to underpin global development in the large hierarchically structured pyramid of human knowledge making, in his view, the current debate around the development of education groundless. This defined the easiness with which Soviet scientists integrated abroad and which can be additionally illustrated at the two following examples out of so many more available.

Firstly, it is the Google, Inc., an Internet giant, ranked as the 4th biggest company by market capitalisation by the Financial Times Global 500 Index (2015).[588] One of the Google's founders, Sergey Brin, and his parents (who were mathematicians and influenced him a lot) were émigré from the Soviet Union. Moreover, the parents, graduates of the MSU Faculty of Mechanics and Mathematics, independently on their attitude towards the Soviet Union, brought him up as 'a successful American by the canons of the Soviet Scientific school.'[589]

Secondly, it is the success of Israel as a global leader in terms of its GDP allocations on R&D (Chapter 4). Israel's S&T achievements would have been impossible if not for 1.03 million[590] of the émigré from the USSR, as recognised in an official Israeli report: *'We can therefore conclude that the 'technological revolution' of the 1990s, the rapid growth of the GDP and the impressive expansion of the hi-tech industry, resulting in Israel's emergence*

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[587] Paltashev.
FT 500, 2015, *The Financial Times*; retrieved on 13.06.2017 from the Web, https://www.ft.com/ft500.
[589] Birger, Pyotr, 2014, *10 Samykh Vliatel'nykh Biznesmenov Kremnievoi Doliny Rodom iz SSSR* (10 of the Most Influential Businessmen of the Silicon Valley Have Been Originally from the USSR), 26 February, *Slon Magazine*; retrieved on 13.06.2017 from the Web, https://republic.ru/biz/1062129/.
[590] Maltz, Judy, 2015, How the Russians Changed Israel, One, Two, Three, Four – We Opened Up the Iron Door, *The Haaretz*; retrieved on 13.06.2017 from the Web, http://www.haaretz.com/st/c/prod/eng/25yrs_russ_img/.

as a developed, post industrial country by the end of the decade, is definitively identified by many Israelis as the result of the 'aliyah wave' of that same decade.'[591]

Although in its foundation Soviet science was organised as a universal phenomenon, it nonetheless revealed some cultural specifics related to Soviet social life. According to Alexander Migdal, a Soviet and American theoretical physicist:

> When I moved here [the US], my productivity has grown up. However, I know that a majority of the ideas, which I keep developing here, were born there, in 'food queues' [of the USSR].[592] All, what we, theoreticians, need is a pencil and a bit of paper plus an opportunity to discuss own ideas with colleagues. We used to have it all in the Landau Institute: indeed I have never seen a better place to work than our institute in the early 70s.[593]

Alexander Migdal is known for his contributions to the theory of critical phenomena, quantum chromodynamics and conformal field theory; he was head of computer physics laboratory at the SAS, who moved from the Landau Institute of Theoretical Physics in Moscow to Princeton University in the late 1980s.

The unity of the scientific world beyond the Iron Curtain was best expressed in scientific publishing as shown in subsection 4.2.3 above.

Cross-publishing with foreign authors was not an unusual thing, and the Soviet journals occupied their solid and tangible niche in the global scientific network. It was primarily the case for those publications of those Soviet breakthroughs which had a serious worldwide impact for the development of science and technology. For example, it is the invention of laser, initially published in Russian in an article under the title in English of *Application of Molecular Beams for Radiospectroscopic Study of Molecular Rotational Spectra* by N.G.

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[591] Khanin, Vladimir (Ze'ev), 2010, Aliyah from the Former Soviet Union, Contribution to the National Security Balance, Position paper, presented on the behalf of the Israeli Ministry of Immigrant Absorptions to the 10th Annual Herzliya, *Conference Balance of Israeli National Security*, February, Jerusalem, 10, the emphasis is as stated in the original; retrieved on 13.06.2017 from the Web, http://www.herzliyaconference.org/_Uploads/3046Aliyah.pdf.

[592] It is worth noting that food queues returned in Moscow in the middle of *Perestroika* campaign in 1988-9 whereas food rationing in the USSR was abandoned in 1947, and in Britain, for example, in 1954.

[593] *Pravda*, 19 December 1993, cited from Mendkovich, Nikita, 2007, *Nauka v SSSR i Rossii* (Science in the USSR and Russia), 04.09, *Poliarnaya Zvezda*; retrieved on 19.06.2017 from the Web, http://zvezda.ru/economics/2007/09/04/nauka_ross.htm#9.

Basov and A.M. Prokhorov, at the *ZhETF* in 1954.[594] It was translated into English by Morris D. Friedman, Inc. for NASA as *Use of Molecular Beams for the Radio-Spectroscopic Study of the Rotational Spectra of Molecules*.[595] One can further, using the Google scholar online service, search both titles of the article to find out 188 citations for this first Soviet translation by the JETP,[596] and 119 for a slightly different NASA translation.[597] A simple Google search produces 1,370,000 results.[598] Among the citations, there is a plenty of research up-to-date in various disciplines such as physics,[599] medicine,[600] as well as engineering[601] and others. At the same time, a Google scholar search for the names of Basov and Prokhorov names together produces in terms of the citations 3,310 results.[602]

An identical search on the name of Alferov produces 18,800 results,[603] and his various articles on semiconductor heterostructures, for whose discovery Zhores Alferov received the Nobel Prize in Physics in 2000,[604] produces 6,500 results[605] with hundreds of the

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[594] Basov, N. G. and Prokhorov A. M., 1954, *Primenenie Molekuliarnykh Puchkov Dlia Radiospektroskopicheskogo Izuchenia Vrashchatel'nykh Spektrov Molekul* (Application of Molecular Beams for Radiospectroscopic Study of Molecular Rotational Spectra), v.27, no. 4 (10), *ZhETF*, 431-8.

[595] Translation Number B105, Morris D. Friedman, Inc, NASA Library; retrieved on 11.06.2017 from the Web, https://ia600302.us.archive.org/9/items/nasa_techdoc_19880069071/19880069071.pdf.

[596] A Google Scholar search; retrieved on 11.06.2017 from the Web, https://scholar.google.co.uk/scholar?hl=en&as_sdt=0,5&q=Application+of+molecular+beams+for+radio+spectroscopic+study+of+molecular+rotational+spectra.

[597] A Google Scholar search; retrieved on 11.06.2017 from the Web, https://scholar.google.co.uk/scholar?q=Use+of+Molecular+Beams+for+the+Radio-Spectroscopic+Study+of+the+Rotational+Spectra+of+Molecules&btnG=&hl=en&as_sdt=0%2C5.

[598] A Google search; retrieved on 11.06.2017 from the Web, https://www.google.co.uk/search?q=Application+of+molecular+beams+for+radio+spectroscopic+study+of+molecular+rotational+spectra&rlz=1C5CHFA_enES712GB714&oq=Application+of+molecular+beams+for+radio+spectroscopic+study+of+molecular+rotational+spectra&aqs=chrome..69i57.359j0j7&sourceid=chrome&ie=UTF-8#safe=active&q=Application+of+molecular+beams+for+radio+spectroscopic+study+of+molecular+rotational+spectra.

[599] Slighter, Charles P., 1996, *Principles of Magnetic Resonance*, Corrected 3d Printing, Springer; retrieved on 11.06.2017 from the Web, https://books.google.co.uk/books?hl=en&lr=&id=jF3xCAAAQBAJ&oi=fnd&pg=PA2&ots=nYlR9PoezT&sig=yMUoA4jgs2C2WM3_D37bsI3BSYw#v=onepage&q&f=false.

[600] (Ed.) Bogdan Allemann I., Goldberg D.J., 2011*, Basics in Dermatological Laser Applications*, Basel, Karger AG; retrieved on 11.06.2017 from the Web, https://www.karger.com/Book/Toc/255134.

[601] Gambling, W., A., 1975, Laser and Optical Electronics, *Radio and Electronic Engineer*, Vol. 45, Issue 10, October, 537-42; retrieved on 11.06.2017 from the Web, http://ieeexplore.ieee.org/abstract/document/5269116/?reload=true.

[602] A Google Scholar Search; retrieved on 12.06.2017 from the Web, https://scholar.google.co.uk/scholar?as_sdt=1,5&q=basov+prokhorov&hl=en.

[603] A Google Scholar Search; retrieved on 12.06.2017 from the Web, https://scholar.google.co.uk/scholar?q=alferov+&btnG=&hl=en&as_sdt=1%2C5.

[604] Alferov.

[605] A Google Scholar Search; retrieved on 14.06.2017 from the Web, https://scholar.google.co.uk/scholar?q=alferov+semiconductor+heterostructure+&btnG=&hl=en&as_sdt=1%2C5.

citations in many disciplines, such as applied physics,[606] chemistry,[607] electronics,[608] and others.

The same is relevant for many other Soviet advances. This illustrates the unity of the world science in which the Soviet publications keep holding a significant and well-deserved position.

Overall, publishing of scientific and popular-science literature in the Soviet Union reached the record of the 2,451 titles with the total numbers of 83,2 million copies in 1981, after having grown consistently through all the Soviet period to reach, for example, 13 million copies in 1940 and 70 million copies annually in 1970-5.[609] All this printing was highly demanded and purchased by Soviet citizens mostly through subscription.

By the mid-1980s the Soviet Union was replaced from being the second global scientific contributor in terms of journal publications to hold the fourth global position behind the US, the UK and Germany with 774,700, 184,800 and 170,700 respectively with the number of publications on science reached 164,200.[610] It was followed by the sharp decrease to 137,400 by the early 1990s.[611] One can see how the *Perestroika* campaign of Mikhail Gorbachev was accompanied by this significant decline in the numbers of research and publications.

As mentioned above, in the hierarchical pyramid of knowledge in science and technology, the development is achieved through a sequential accumulation of knowledge. This would

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[606] Mimura,Takashi, Hiyamizu, Satoshi, Fujii, Toshio, and Nanbu, Kazuo, 1980, A New Field-Effect Transistor with Selectively Doped GaAs/n-AlxGa$_{1-x}$As Heterojunctions, Vol. 19, Number 5, *Japanese Journal of Applied Physics*; retrieved on 14.06.2017 from the Web, http://iopscience.iop.org/article/10.1143/JJAP.19.L225/meta.
[607] Zhang, Jinshui, Zhang, Mingwen, Sun, Rui-Qing, and Wang, Xinchen, 2012, A Facile Band Alignment of Polymeric Carbon Nitride Semiconductors to Construct Isotype Heterojunctions, *Angwendte Chemie*, 7 Sept., Volume 124, Issue 40, 10292–6; retrieved on 14.06.2017 from the Web, http://onlinelibrary.wiley.com/doi/10.1002/ange.201205333/full.
[608] Grundmann, Marius (Ed.), 2002, Nano-Optoelectronics: Concepts, Physics and Devices, *Springer*, Berlin; retrieved on 14.06.2017 from the Web, https://books.google.co.uk/books?hl=en&lr=&id=o-hODezkW_8C&oi=fnd&pg=PA1&dq=alferov+semiconductors+heterostructure+electronics&ots=AoI_n2e9ws&sig=V8WJSHw2qWhO4KHC_Majw2vK8fE#v=onepage&q=alferov%20semiconductors%20heterostructure%20electronics&f=false.
[609] Vaganov, A., 2007, *Nuzhna li Nauka dlya Populiarizatsii Nauki* (Whether Science is Needed for Popularisation of Science), 7, *Nauka i Zhizn'*; retrieved on 13.06.2017 from the Web, https://www.nkj.ru/archive/articles/11016/; hereafter referred to as NKJ.
[610] Marshakova-Shaikevich, I., 1995, *Vklad Rossii v razvitie nauki* (*The Russian Contribution to Development of Science*), Yanus, Moscow, 77-8; retrieved on 19.06.2017 from the Web, http://www.rfbr.ru/rffi/ru/books/o_62063#19.
[611] *Ibid.*

be analysed in the next section at some examples of Soviet contribution to the world's development.

5.2 Soviet Contribution to Global Science and Technology

Modern global development is driven by science-induced technology, which has been transforming human lives at an unprecedented rate. The semiconductor industry is a stark example of science-induced technology. It shows, on the one hand, how research driven by curiosity transforms global life, and on the other, it illustrates the Soviet contribution to this kind of transformation.

Firstly, according to the statistics of the Semiconductor Industry Association (SIA), 'representing US leadership in semiconductor manufacturing, design, and research,'[612] in 2015 global semiconductor industry sales totalled USD335.2 billion.[613]

Secondly, something for which there was no apparent or obvious demand in economic terms as outlined by Saxena,

> was discovered purely due to inherent curiosity for how electrons behaved in semiconducting materials. This is made tangible in the form of a transistor, which is a semiconductor device and is the fundamental building block of all modern electronics. In this particular example, the understanding of the principles of electrical conductivity unveiled the foundations of the electronic components and systems which are now pervasive in all forms of human activity. This means, for instance, that the global capitalisation of the Internet and digital industry would have been unachievable if not for some particular advances in science and engineering, which are, meanwhile, perceived as granted or imminent today.[614]

Meanwhile, some Soviet scientific and technological advances contributed significantly to the development of this industry. Thus, the discovery of laser technology by Nikolay

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[612] Rosso, Dan, 2016, Global Semiconductor Sales Top $335 Billion in 2015, *Semiconductor Industry Association*; retrieved on 06.07.2017 from the Web, https://www.semiconductors.org/news/2016/02/01/global_sales_report_2015/global_semiconductor_sales_top_335_billion_in_2015//.

[613] *Ibid.*

[614] Saxena.

Basov[615] and Aleksandr Prokhorov[616] in the Soviet Union and Charles Townes[617] in the US in the 1950s, stressed out by Tsironis in chapter 3, as well as the invention of semiconductor junctions in 1927 by Oleg Losev[618] in the Soviet Union (25 years prior to the invention of the transistor), determined the development of the telecommunications and computer industry of today. The introduction of semiconductors created a lateral dimension in the industrial economy of scale after 1960 and replaced the industrial application of the previous cumbersome computer and expensive prototypes based on vacuum tubes.

The Soviet Union won nine Nobel prizes in Physics, in areas such as the discovery of lasers or semiconductor heterostructures which underpin the basis of the global modern economic growth and wellbeing. The Nobel Prize is a blunt instrument to evaluate the successes of science and it does not fully comprehend the richness of scientific research, however, it is nonetheless indicative. As Hermann Grimmeiss of the Royal Swedish Academy of Sciences, which awards Nobel prizes, said about Soviet contribution of the discovery of the hetero-structures by Zhores Alferov:[619] 'Without Alferov, it would not be possible to transfer all the information from satellites down to the Earth or to have so many telephone lines between cities.'[620]

According to Paltashev, the modern industry of the mobile telecommunications and devices as a part of the global business and social revolution is the development of the Hz transmission devices of the early 1960s used for military and satellite purposes. The basic research and discovery of semiconductor heterostructures by Zhores Alferov in the USSR of the 1960s,[621] followed by the development of technology in decreasing the sizes of the devices in parallel to the application of the high-frequency range, established the foundation which allowed the boom of the mobile telecommunications industry from the 1990s.[622] Meanwhile, as outlined by Kaul in chapter 3, Alferov's research among some others define the *SuperOx* superconducting cable technology as well.

615 Basov.
616 Prokhorov.
617 Townes.
618 The Biography of Oleg Losev, *Nanobuisness.org*, 2015; retrieved on 04.05.2017 from the Web, http://www.nanobusiness.org/the-biography-of-oleg-losev.html;
- Rako, Paul, 2011, Oleg Losev, LED Inventor, and What We Did Before Transistors, The Crystadyne Oscillator, 11 February, *The EDN network*; retrieved on 04.05.2017 from the Web, http://www.edn.com/electronics-blogs/anablog/4311235/Oleg-Losev-LED-inventor-and-what-we-did-before-transistors-the-Crystadyne-oscillator. Also, as confirmed by Saxena.
619 Alferov.
620 BBC News, 2000, Russian and Americans Share Hi-Tech Nobel, 10 October, *Sci-Tech*; retrieved on 12.06.2017 from the Web, http://news.bbc.co.uk/1/hi/sci/tech/965528.stm.
621 Alferov.
622 Paltashev.

Moreover, today's global functioning of the telecommunications industry would be impossible without Soviet advances in other areas of science. Many of the elements and materials that are produced from the land of Russia and Kazakhstan due to the research of Soviet geology are critical for the world's development: firstly, in terms of only for global energy supply as, for instance, in oil and gas industry; and, secondly, as inseparable parts of the global technological supply chains. According to Saxena in chapter 3, materials invented in the Soviet Union, including Kazakhstan, constitute an integral part of the modern global electronics industry. For instance, the example of the element *erbium*, produced in Kazakhstan, is indicative as its small volumes are especially important for optical fibre communications apart from being used in medical laser and other technologies.[623]

Such broad-ranging input into global production is closely linked to the Soviet scientific, technical and educational development, and the development of the Soviet geology and mining industry, which required preparation of specialists, development of the scientific method of prospecting and beneficiating ores and then refining these to the level required for use in technical products. Prior to the Soviet era, those advances of the mineral resources in Central Asia and Siberia were either unknown or weakly exploited mainly as raw commodities. This input into technological production is not likely to be noticed by the end consumer and thus remains uncelebrated, while a radio or TV set containing these components is what is recognised as a technological triumph.

To continue the list, the scientists interviewed for the thesis emphasised the following contributions of the Soviet science and technology in their fields and beyond.

Vasiliev outlined the three following kinds of the Soviet contributions, e.g. on the largest scale they were the first humans in space and the first industrial reactor in nuclear energy; on a smaller scale – being nevertheless very important – the discoveries of superfluidity, laser, gravitational waves, a range of new elements, like *dubnium* named after Dubna [an academic city]; and that of *metamaterials* by [Viktor] Veselago,[624] still alive,[625] whose breakthrough is very underrated (as mentioned by Tsironis below as well). Regarding the discoveries of the

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[623] Saxena.
[624] Veselago, Victor G., 1967, The Electrodynamics of Substances with Simultaneously Negative Values of ε and μ, *Uspekhi Fizicheskikh Nauk* (Advances of Physical Sciences), July, Volume 92, Number 3. Retrieved on 28.02.2017 from the Web: http://ufn.ru/ufn67/ufn67_7/Russian/r677e.pdf; hereafter referred to as Veselago.
[625] Viktor Veselago passed away in September 2018.

lower levels, Vasiliev outlined superconductivity in metallic hydrogen under the room temperatures and high pressure applied which was predicted a long time ago, and which was discovered by [Mikhail] Eremets [and Alexander Drozdov][626] recently. This opens a room for a large filed of practical applications in the energy transportation and is what [Andrey] Kaul is busy with, as pointed out by Vasiliev. Meanwhile, he concluded with the statement that, in his view, the Soviet Union was an important element of the global balance required for development.[627]

Among the Soviet contributions to global technological development, Kaul emphasised Kapitsa's superfluidity of helium, Basov's laser, Alferov's diodes, and electrochemical microplasma oxidation at the example of *SuperOx*. He noted that many Soviet and Russian discoveries were developed in the West, and very often the results were used and patented abroad by someone else, like in the examples of a method of obtaining electrochemical coatings under very high voltage, called microplasma coating, and of the technology of Atomic Layer Deposition (ALD) which was later developed in Finland. However, many more could not develop at all due to the lack of the publications in foreign journals and, more importantly, due to 'the Achilles' heel of the Soviet/Russian science' which was the poor instrumentation provision, rooted in the weak instrumentation construction industry, outlined the chemist.[628]

Tsironis has had an affiliation with *MISIS*[629] for a few last years and collaborated with a strong experimental group there that focuses on low-temperature physics and applications and has discovered a new metamaterial for an ultra-efficient laser.[630] He emphasised the basic concept of metamaterials in optics with the negative index of refraction which was first formulated by Viktor Veselago[631] in 1967-8. By 2000 it was developed by Sir John Pendry[632] of the Imperial College[633] in London, continued Tsironis. This opens up room for

[626] Eremets, Mikhail, and Drozdov, Alex, 2015, Superconductivity for Siberia, 24 December, *Nautilus*; retrieved on 14.06.2018 from the Web, http://nautil.us/issue/31/stress/superconductivity-for-siberia.
[627] Vasiliev.
[628] Kaul.
[629] MISIS.
[630] Shramkova, O.V., Tsironis G.P., 2017, Nonreciprocal nonlinear wave scattering by loss compensated active hyperbolic structures, Scientific Reports, *Nature*, 22.02.; retrieved on 13.03.2017 from the Web: http://www.nature.com/articles/srep42919.epdf?author_access_token=Gxb3YCSGOItjzUvX-mrMu9RgN0jAjWel9jnR3ZoTv0P5wSocOROzqHnczSe9mibdDhk6ainEMhW8hGNd7q7v2zvCTXQKTH1t0Bp0ORadQaond1L_eVRrGLALdtA3jqjs; hereafter referred to as Shramkova/Tsironis.
[631] Veselago, Victor G., 1967, The Electrodynamics of Substances with Simultaneously Negative Values of ε and μ, *Uspekhi Fizicheskikh Nauk* (Advances of Physical Sciences), July, Volume 92, Number 3. Retrieved on 28.02.2017 from the Web: http://ufn.ru/ufn67/ufn67_7/Russian/r677e.pdf.
[632] Pendry, John, 2000, Negative Refraction Makes a Perfect Lens, *Physical Review Letters*, 85 (18).

the future development of optics and beyond as metamaterials are materials engineered to have properties that have not yet been found in nature, and they are an integral part of the current modern industrial revolution.[634]

According to him, Veselago proposed the specific way of how this happened, and David Smith showed it was possible.[635] This field skyrocketed in the 2000s when many of the problems and many of engineering aspects were solved. Nowadays, this field is being driven to a smaller scale when these metamaterials would also have quantum properties. As outlined by Tsironis, the whole field is in the quantum realm now. In his view, this idea will determine new types of approaches and will possibly lead to new quantum forms of engines and, definitely, quantum computers and, perhaps – down the line – to new quantum equipment.[636]

Meanwhile, if this technology works, it has a potential to affect the technology world significantly, assumed the scientist. He outlined that many of these basic techniques for cooling and refrigeration associated with this development came from Cambridge starting also with Kapitsa. Veselago's concept of metamaterials is a vivid example of how one intellectual idea, belonging to a Soviet scientist in this particular case, may form a new technological and, in future, industrial reality. This idea once it first appeared, was just a theory, however, in 30 years, it was proved, as envisaged by Tsironis.[637]

In Chitre's field, the Soviet Union created advanced schools which influenced the development of astronomy, especially from the 1960s onward with such names as Zel'dovich mentioned in chapter 3 and [Victor] Ambartsumian[638] among some others. According to Chitre, he is a great admirer of Zel'dovich who developed some fundamental thoughts:

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633 Sir John Pendry did his both undergraduate study and PhD at the University of Cambridge; Pendry John, 1969, The application of pseudopotentials to low energy electron diffraction.
(PhD thesis), *University of Cambridge*; retrieved on 13.09.2018 from the Web, https://ethos.bl.uk/OrderDetails.do;jsessionid=F75C93D1A00BB670094358074843173E?uin=uk.bl.ethos.468650.

634 Tsironis.

635 This led to the establishment of the Metamaterial Commercialization Center at Intellectual Ventures (IV) in Bellevue, Washington with the leading role of Duke University; Professor David R. Smith to lead the Metamaterials Commercialization Center at Intellectual Ventures, 2013, 21 January, Center for Metamaterials and Integrated Plasmonics, *Duke University,* retrieved on 06.07.2017 from Web, https://metamaterials.duke.edu/news/professor-david-r-smith-lead-metamaterials-commercialization-center-intellectual-ventures.

636 Tsironis.

637 *Ibid.*

638 Victor Amazasp Ambartsumian (1908 - 1996), *American Astronomical Society*; retrieved on 22.06.2018 from the Web, https://aas.org/obituaries/victor-amazasp-ambartsumian-1908-1996.

> Essentially the concept is that the energy source of the celestial object, like of a sun. Sun at the centre is the huge temperature of 15 million degrees, so thermal energy is there. Nuclear energy is there. Sun is rotating. The rotational energy is there. Sun has magnetic fields, so magnetic energy is there. They are huge objects, so the energy contained is large. These are all intrinsic energies.[639]

As outlined by Chitre, Zel'dovich and his school brought the idea that in a compact object like a neutron star, its gravitational potential is very deep. It attracts matter from outside, so when that matter falls into this deep gravitational potential web, it is an extreme link in the resource. It is not internal to the body, but neutron star is there. It provides the gravitational potential, and the matter falling gets heated, concluded the astrophysicist.[640]

Littlewood worked closely with Soviet scientists over a long period and emphasised that 'the quality of Soviet science in [his] field was absolutely unparalleled.' According to him, they were world-leading in many areas, and one of the reasons they were very good at that was that they were being bankrolled for particular purposes broadly to support Soviet technology efforts. Meanwhile, the Soviet Union could never make a consumer product, in his view. The problem always seemed to him at least is that the flexibility of the market economy means that people can find markets for technologies which are unexpected that drive things.[641]

According to Littlewood, in terms of innovation, a very close connexion between the market, between products and other things is desirable, e.g. in a well-defined product like a TV set or a tank.[642] In the Soviet Union, technology was clearly there and was clearly strong. In his view, the problems of the Soviet economy were political and not scientific.[643] Meanwhile, assessing the Soviet science and technology contribution to global technological development, Littlewood commented as follows:

> I think if you go back to the very fundamentals, taking my own field, condensed matter physics, probably a huge fraction of leading scientists who invented that field were Soviet scientists working off one of the very

[639] Chitre.
[640] *Ibid.*
[641] Littlewood.
[642] *Ibid.*
[643] *Ibid.*

> fundamental levels. [Apart from] Kapitsa there were many others, Landau, of course, and many of them who later moved to the West, Kartsov, Gor'kov, people like Keldysh, and so all of that generation beginning in the 30s and going through to the 50s and 60s provided some of the founding principles of modern science in that area.[644]

Their breakthroughs did not necessarily drive the technology development. Littlewood thinks that much of what is done in science is to develop tools and the tools are used for something else, and things build on top of each other. Meanwhile, in terms of building on the ideas about how materials work, the methods that one could use, the mathematics one could do, the whole idea of topics which connected to radio electronics and radio engineering, fundamental understanding of process at that level, and of course, all of them play into semiconductor technology and play into superconductors, optics and many things, outlined the scientist.[645]

Thus, nanoscience, materials science, in Littlewood's account, did not exist in 1920.[646] There were times when scientific communication between the West and the Soviet Union was rather weak, and there were places where actually developments were happening in the Soviet Union ahead of where they were happening in the West, but the lack of communication meant actually that often Western scientists did not know what was going on and discovered about it later, in his view: 'This was not research which was necessarily secret, it was just that in a day without the Internet. Journals were published in Russian. It took six months for them to get translated into English, so [that] communities would be separated.'[647] Littlewood remembered that in the early 80s at Bell Lab, where there were groups of Soviet scientists coming and visiting the West, 'and the opportunity for [him] to talk to some of these giants was tremendous.'[648] For instance, there were powerful both the Landau and St. Petersburg schools in the Soviet Union which were important for global science, as he concluded.[649]

Meanwhile, the scientific figure of Paltashev represents this St. Petersburg's school. In his account, three main Soviet S&T contributions in global development are as follows:

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644 *Ibid.*
645 *Ibid.*
646 *Ibid.*
647 *Ibid.*
648 *Ibid.*
649 *Ibid.*

> Firstly, it is nuclear physics and nuclear energy technology, including nuclear synthesis technology, and available globally only in two regions, Europe and Russia, with the dominance of the latter. Secondly, it is missile technology and rocket construction which have defined the development of the overall world's rocket missile technics and fuel. Thirdly, it is a technology of new material design and new materials which both remain mostly unknown globally so far due to the military character of the technology.[650]

Paltashev provided an example of the interconnection of the modern technology chains involving Soviet/Russian research. In Saint Petersburg a Polytech University's start-up, CML (*CompMechLab*),[651] he is involved with, is modelling and re-designing car-makes, and car-crashing testing for many global car giants, including most of those of the German car industry, Porsche in particular, as well as Tesla and some other companies in the US. Using the technology of 'the digital twin,' they are able both to model a car with all the components virtually and to plan its further production digitally. It is the *Industry 4.0* concept. This engineering is made at the university's department of the applied mathematics and is undoable without fundamental science, i.e. mathematics and physics of materials in this case. There they have developed their mathematical algorithms and instruments which once conjured with all the traditional car making engineering allows a digital reproduction of the full project design, modelling and production cycle. This is unique for the industry. Unlike in the electronic industry which was digitalised in the 1990s, this is how digitalisation works in chemistry and other industries up to date, according to Paltashev.[652]

Some other examples below out of many can also demonstrate the contribution of the Soviet scientists to the global social, technological and industrial development.

The continuing expansion of the modern digital reality in all its countless applications of the technological solutions is based on the rocket and satellite industry, pioneered and developed in the USSR, as a constituent technological foundation for the development of computing and telecommunications. This was named by Lonzarich as 'a monumental

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[650] Paltashev.
[651] CML, *CompMechLab*, Engineering Center, *Center of Computer-Aided Engineering* of SPbPU, Educational, research and innovation laboratory *Computational Mechanics*, Computational Mechanics Laboratory, LLC, Polytech-Engineering, LLC; retrieved on 07.07.2018 from the Web, http://en.fea.ru/.
[652] Paltashev.

contribution not only to the history of civilization, but that of life on earth itself'[653] and explained by him as follows:

> The Soviet Union will be remembered for millennia for pioneering this area, long after the world has forgotten the political and economic history of the period. No nation will ever win the space race, since it is endless, but one Nation will be remembered for having started it.[654]

In terms of economy of scale, this industry forms not only the industrial sector of the various productions but also the post-industrial sectors of the global, regional and local service economies, including banking, tourism, trade, shipping or many others. These Soviet scientific and technological breakthroughs massively underpin the contemporary global cultural dimension of the Internet, the television industry, cinema, popular music, mass media, and social networks. In an increasingly enlarging diapason, the digital development affects such important basic interconnected human activities as research, education, and healthcare.

While either driving a car, a train, a ship or a plane, or making telephone calls, or traveling, or ordering food, or booking a Holiday, or studying, or even being sick almost every woman and man on Earth becomes progressively dependent in nearly any activity of her/his on various devices or gadgets. Computers and telecommunications fulfil many of people's needs as well as serve as the foundation of the modern technological development in the era of the communication revolution.

The current American leadership in space exploration is literally driven by the particular Soviet achievement in the form of the rocket engine RD-180, 'which powers the first stage of the Atlas V, [and] has enjoyed outstanding technical performance since its introduction in the short-lived Atlas III line in 2000. No domestic rocket engine that uses liquid oxygen (LOX) and kerosene propellants has anywhere near the same performance,'[655] as written in The Space Review. This engine is the development of the RD-170 which was used in the launch of the *Buran* (Snowstorm, or Blizzard) Soviet reusable spacecraft shuttle in 1988 in the expendable *Energiya* (Energy) rocket, a class of super-heavy launch vehicle.

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[653] Chapter 3.
[654] Lonzarich, Gilbert, 2019, *Chokan's Thesis – Suggestions from Gil [Lonzarich]*, 9 May, University of Cambridge.
[655] Foust, Jeff, 2014, Replacing the RD-180, May 12, *The Space Review*; retrieved on 03.08.2017 from the Web, http://www.thespacereview.com/article/2512/1.

Brian Harvey wrote, that '[t]he last Soviet deep space mission had been stunning. Two spaceships had been sent to Venus, where probes had already landed on the planet, drilling and analyzing its rocks, while other probes had made radars maps,'[656] and that 'the launch of the most powerful rocket in the world, the Energiya'[657] was so impressive that '[a] CIA briefing conceded that the Soviet Union now had the means to send people to Mars.'[658] By the end of the 1980s, the Soviet leadership in the space race was recognised by the US in the 1986 Jane's Spaceflight Directory 453-page report on the development of the space programmes in both nations.[659] According to its editor Reginald Turnill, 'The Soviets are so far ahead of the US in space experience that they are almost out of sight.'[660]

Meanwhile, the advances of the Soviet S&T in the field of nuclear energy, mentioned by Paltashev, contributes to the global balance of energy, which so notably defines the realm of the world's economy and geopolitics. The innovation and technology of the production of commercial electricity, a market commodity, from nuclear power, became possible with the construction of the first grid-connected nuclear power station in Obninsk, the USSR, in 1954.[661] An application of this technology in the form of the first nuclear-powered icebreaking surface ship in the USSR, *The Lenin*,[662] in 1957-9 opened the Arctic for year-around naval navigation on the Northeast Passage and made exploration of the significant regional reserves of natural resources possible for future global development.

Another example is the US, which is the world's largest producer of commercial nuclear power to generate more 30 per cent of the total global nuclear energy.[663] In 2012 more than 28 per cent of the uranium supply came from the post-Soviet countries of Russia (13%), Kazakhstan (11%), Uzbekistan (4%) and Ukraine (included into the category of four

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656 Harvey, Brian, 2007, *The Rebirth of the Russian Space Program, 50 Years After Sputnik*, *New Frontiers*, Springer, 6.
657 *Ibid.*
658 *Ibid.*
659 Turnill, Reginald, ed., 1986, *Jane's Spaceflight Directory*, Jane's Pub. Co., London.
660 Clines, Francis X., 1986, Publication Give Edge in Space to Soviet, June 17, Science, *The New York Times*; retrieved on 01.08.2017 from the Web, http://www.nytimes.com/1986/06/17/science/publication-gives-edge-in-space-to-soviet.html?mcubz=1.
661 Kotchetkov, Lev, 2004, Obninsk: Number One, *Nuclear Engineer International*, 13 July; retrieved on 04.05.2017 from the Web, http://www.neimagazine.com/features/featureobninsk-number-one.
662 Maiden Voyage Of Russian Atomic Icebreaker Lenin, 1960, *British Pathé*; retrieved on 04.05.2017 from the Web, http://www.britishpathe.com/video/maiden-voyage-of-russian-atomic-icebreaker-lenin.
663 Nuclear Power in the USA, 2017, updated on 28 July, *World Nuclear Association*; retrieved on 01.08.2017 from the Web, http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.aspx.

countries of 3%),[664] where this industry was developed in the Soviet time. Combined, the supply from these four post-Soviet countries was the largest source of uranium for the US.

The growing importance of the achievements of Soviet geology mentioned above is visible through the prism of the current industrial revolution in all its aspects. For instance, a number of metals are crucial components of various high-tech technologies, including the production of batteries. Today half of the global demand for cobalt is coming from the production of the electric vehicles, including *Tesla*, and it is estimated of 103,500 tonnes with the supply of 104,000 tonnes in 2016, with Congo being a major supplier.[665] This situation promises to bring a deficit for cobalt and restricts the growing expansion of the battery usages. Meanwhile, Russia and Kazakhstan produce 6,000[666] and 300 tonnes[667] of cobalt per annum respectively for their industry and have a serious potential to increase the production from the reserves discovered due to development of Soviet geology. This indicates the lasting contribution and a future possible impact of one of the fields of Soviet science, geology, on the pace of the energy revolution, as both of the countries have all the periodic table in their bowels of the earth.

Rare earth metals, which are abundant in both Russia and Kazakhstan,[668] become of the increasingly growing significance, as they are the most crucial parts of the new high-tech industries. The BBC report states the following:

> [The] rare earth metals along with minor metals such as lithium and tantalum are now just as important as the traditional base metals and precious metals. 'The colour red on a MacBook Pro screen is made from europium; the colour green is because of a metal called terbium; touch screen technology relies on indium,' explains David Abraham, author of a book called The Elements of Power. 'A lot of these metals have only been

[664] The US relies on foreign uranium, enrichment services to fuel its nuclear power plant, 2013, 28 August, *US Energy Information Administration*; retrieved on 01.08.2017 from the Web, https://www.eia.gov/todayinenergy/detail.php?id=12731.
[665] Hardy, Ian, 2017, Could You Cope with Smartphone Rationing?, *BBC News*, 13 June; retrieved on 20.06.2017 from the Web, http://www.bbc.co.uk/news/business-40248405; hereafter referred to as The Cobalt Report.
[666] Cobalt, World Mine Production, by the Country, *Index Mundi*; retrieved on 20.06.2017 from the Web, https://www.indexmundi.com/en/commodities/minerals/cobalt/cobalt_t8.html.
[667] Kazakhstan Cobalt Production By Year, United States Geological Survey (USGS) Minerals Resources Program, *Index Mundi*; retrieved on 21.06.2017 from the Web, https://www.indexmundi.com/minerals/?country=kz&product=cobalt&graph=production.
[668] Laumulin, Turar Muratbekovich, 1977, *Redkometallonosnye struktury v geotektonogenakh Kazakhstana* (*Rare-Metalliferous Structures in Geotectonogens of Kazakhstan*), The Institute of Geological Sciences, AN KazSSR, Alma-Ata, Nauka.

> discovered in the past 100 years. We've had a long time to play with copper and iron. But we are just beginning to understand the power of these newer materials.'[669]

An example of what role rare earth metal play in the energy revolution, defining such a field, among many, as superconductivity and how it is intertwined with the Soviet development is illustrated below in more detail at the example of a Russian company *SuperOx*, described in the joint Kaul's and Molodyk's interview in chapter 3. It will be followed by an example of the latest development in the *Samsung* TV set production by which would not be possible without Soviet fundamental research.

5.2.1 Two Examples of Soviet Scientific Contribution to Global High-Technology Chains

As pointed out by Molodyk in chapter 3, the *SuperOx* technology allows transportation of high volumes of energy within short and critical distances in aircraft, advanced high-tech connections and those parts of the electrical grids, which can be in proximity of residential arrays, as the technology is harmless and environmentally safe. As evident from the list of the clientele there, the technology is increasingly used in the global high-tech sector.

A possible economic effect from the usage of this technology for preventing blackouts is difficult to overestimate. For instance, among multiple examples one can recall the blackout in India in 2012, which affected more than 600 million people[670] and the Northeast blackout in the North America in 2003 with more than 50 million people affected,[671] causing colossal economic losses in infrastructure, communications, power generation, water supply, transportation, healthcare and other various industries. Spreading of this technology has a potential to end industrial power outages and create a significant global economic effect.

As seen from the interview's data in chapter 3, the *SuperOx* technological development has occurred in the full accordance with the basic operational principles of science and engineering as envisaged by Bush, Kapitsa and the other scientists in this thesis. Firstly,

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669 The Cobalt report.

670 BBC News, 2012, Hundreds of Millions Without Power in India, *BBC News*, 12 July; retrieved on 21.04.2017 from the Web http://www.bbc.co.uk/news/world-asia-india-19060279.

671 CBC, 2003, 2003: The Great North America Blackout, 14 August, *The National*, CBC Digital Archive; retrieved on 21.04.2017 from the Web http://www.cbc.ca/archives/entry/2003-the-great-north-america-blackout.

fundamental research and education at the MSU Faculty of Chemistry is the foundation and integral part of the process. Secondly, the latter is based in its primary functions on the indigenous scientific and engineering advances. Thirdly, the exogenous equipment and technology are not critical. Fourthly, the patent regime is not used in the production. Fifthly, the development of the technology occurred in Soviet non-market conditions whereas market conditions contributed to its emergence as an innovation.

Although the example of *SuperOx* is unique, it should be viewed somewhat as a confirmation of a typical pattern, rather than an exemption, of how a scientific and technological core for new global supply chains is being formed, especially in the light of its criticality for both development and functionality of the energy sector. Meanwhile, the latter becomes a central, crucial element of the new industrial revolution. This company is an example of the relationship between educational and social policy to texture the appropriate environment for the development of human capital for scientific and engineering breakthroughs, leading to technology and innovations to form critical determinants of a new economy.

Another example of the Soviet scientific contribution to global technology and innovation as mentioned above can be found in a market of consumer goods. In 2016 *Samsung Corp.* presented a TV's technology of Quantum Dots (QD), which revolutionised TV image at a new level and which, in terms of technological leaps could be compared with the previous advances from CRT TVs (cathode ray tube) in black and white into coloured transmissions, and within the latter a transition from CRT, LCD (liquid crystal display), LED (light emitting diode), HD (high definition), 3D (three dimensions) to QD display technology. According to a BBC report, '… [q]uantum dots were officially discovered by Russian physicist Alexei Ekimov in the early 1980s and American chemist Louis E. Brus in 1982.'[672] Here is how the report describes the essence of the discovery:

> The two scientists found that breaking a material with semiconductor properties into nano-sized particles, particles that are slightly bigger than water molecules, brings out an entirely new property within the material.

[672] Three Quantum Dot Secrets That Have Kept Us Entertained for Centuries, 2016, *BBC StoryWorks*, 16 December; retrieved on 10.01.2017 from the Web, http://www.bbc.com/storyworks/future/samsung-tvs-quantum-leap/futuristic-solutions. While in the UK, the report can be retrieved from the Samsung Web Site as well, http://www.samsung.com/global/tv/news/Three-Quantum-Dot-Secrets.html.

> They discovered the colour of the light emitted by each particle varied according to their sizes, making them capable of replicating all of the colours in the prism range. What caused this phenomenon was the change in the band gap energy, one of the most important properties of a semiconductor.
>
> This means, if the size of a quantum dot can be minutely adjusted, quantum dots can be used to create all the colours of the rainbow, perfectly.[673]

The QD technology is an explicit example that development of high-tech, including that of consumer goods, is driven by scientific advances. Both of the scientists, whose discovery defines this product, back in the 1980s could not think of *Samsung Electronics* (which came into existence for such an industry only in 1990) to launch a new generation of TV sets on the market in 2016, and they could not anticipate such a discourse.

It is especially true for Alexei Ekimov of the USSR, which was a planned economy and was so far away from free market conditions. It, nonetheless, has had a lasting effect on the global technology development through its scientific base. Also, this discovery is quite a notable example out of millions of how satisfaction of a basic human quality, 'the holy curiosity' (Einstein),[674] to grasp nature's perfect functioning turns out to become of service for future generations of people worldwide, and for the global modern entertainment industry in this particular case.

Thus, it is also crucial to note that these discoveries were born out of the pure pursuit of understanding natural phenomena and that they were not driven by a particular practical demand and were made possible by the science and social policy engineered in the Soviet Union. These examples illustrated, firstly, the contributions of Soviet science and innovation to the development of global S&T today, and secondly, the connection between science and industry where economic mechanisms do not drive scientific development.

5.3 Soviet Post-War Development

[673] *Ibid.*
[674] Appendix K.

According to this thesis, in the Soviet system, the state social policy played an important role in connecting the society with the academia and industry and making rotate all the centres including the state itself. As specified there as well, science policy was an integral part of the overall social development.

As well, as outlined by Buzgalin, in practice, the establishment of the science cities and university centres like Novosibirsk's *Akademgorodok*, Pushchino, Dubna in the Soviet Union became a certain mould of a new social organisation with some elements of the material and technical base of communism actually created. The government funded it at large-scale with a relatively soft control over the expenditure of the funds run by the scientists in the conditions of the relative autonomy of the centres. The management under the Party's control was performed through the Party's committees which were consisted mostly of the same scientists, noted the economist. Altogether with guaranteed employment and wages, 2-3 times higher than on the average in the country, it created a new social atmosphere of the creative activity. The creative work was the basic idea for this post-industrial production and provided the following: i) self-motivation; ii) the elimination of the boundary between free and working time; and iii) the transition of the social relations in the category of the non-alienated ones, as he emphasised.[675]

Meanwhile, Kaul believed that the particular atmosphere of the open-minded culture and moral climate knowledge shared among scientists was a distinguishing feature of Soviet science driven by scientists' enthusiasm and a specific scientific romantic passion for an adventure and curiosity as the primary force. In his and Tsironis' view, although funding is essential in science, placing materialistic motivation or overpaying the personnel could seriously damage the process.[676] It found its reflection in the overall Soviet science and social policy being tightly juxtaposed into each other.

The multi-angled social policy included the socio-cultural aspects analysed in chapter 4 and being melted with the Soviet science policy it can be identified as the innovation core of Soviet development. Sergey Kapitsa, mentioned in chapters 3 and 4, illustrated the interconnection of the elements of the innovation system in the time framework in the following diagram:

[675] Buzgalin.
[676] Kaul; Tsironis.

Diagram 3 Science, Society, Education, and Innovation

	SCIENCE AND SOCIETY	
EDUCATION	>>>	INNOVATION
^	|	|
Fundamental Science >	Applied Science >	Production and Economy
TIMING: 100 years	10 years	1 year
MONEY: 1	10	100
MOTIVATION: Cognition	Benefit	Development and Profit

'Interaction of Science, Education, and Industry in the modern world. The arrows ^ indicate at flows of information.'[677] It should be emphasised that the information can also circulate in all the directions among all the elements of both the sequence and the drawings.

This diagram is not that different from the other scientists' models of innovation and development. In particular, in his interview, Saxena placed the relations between science, engineering, and technology into the dependence on society, education and culture, leading altogether to the emergence of innovation in the establishment of modern industry, economy, and finance, and summed their functions up in the brackets in the following sequence:

> Ecosystem (social and education development) ---> Science (grasping principles of the nature) and Culture (a distinct form of human intellectual activity) ---> Engineering (application of science) ---> Technology and Innovation (making engineering useful for public good and/or commercial gain) ---> Industry, Economy and Finance (contribution to development).[678]

In these models, education is an important link in development usually providing with the innovation results in 100 years. In the case of space exploration, the Soviet Union, however, could squeeze this term through its social policy into 40 years which lied between the beginning of Lenin's policy on 'enlightenment of the masses' in October 1917 and

[677] Kapitsa, Sergey, 2010, *Sub'ektivnye zametki ob innovatsyi* (Subjective Notes on Innovation), *Ekonomicheskie strategii (Economic Strategies)*; retrieved on 10.11.2014 from the Web, http://www.inesnet.ru/wp-content/mag_archive/2010_04/ES2010-04-kapitsa.pdf?fbclid=IwAR1pRLtmMV14lSN8R3ciKjJKM1toRU8ni5vg7xxf3haxvMH0Lcof_p9aA8A.

[678] Saxena; the sequence was elaborated together with Chokan Laumulin. This linear sequence is chosen to indicate a general dependence as in reality meanwhile the process does not exclude both reverse influence and flows of information.

Sputnik's launch in October 1957 whose global importance was expressed by Lonzarich (chapters 3 and 5).

According to Paltashev, like in the US, the Soviet rocket design construction was rooted in German technology received through reparations, and at a later stage, it developed from as a missile anti-air bombing system (like that of around Moscow with nuclear technology) into *Sputnik*.[679] He emphasised that for the USSR it was a question of the nation's survival which was indicated by Littlewood as well in chapter 4.

As a result from the shock of the realisation for the Americans that a satellite can be a nuclear rocket able to achieve the territory of the US, the systems of the US education and S&T development were reformed to respond the Soviet challenge, as confirmed by Paltashev and Chitre.[680] Both of them emphasised that the US funding attracted was colossal which resulted in the Apollo moon landing mission of 1969. Thus, the space race gave impetus to modern science and technology.[681]

Meanwhile, after the mid-1960s among the flaws of the Soviet development in S&T Paltashev identified the following. Firstly, it was a division between fundamental and applied sciences in practice despite the massive Soviet efforts to connect them through the establishment of the diverse engineering landscape of the various design bureaus, labs, associations and other institutions around and inside the SAS. Secondly, in the seven levels of engineering,[682] the first two levels of the consequential applied science and experimental engineering were in many ways substituted with reverse engineering for copying samples of technology transfer (both of legal or illegal character). Thirdly, on the level 6 of low- and

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[679] Paltashev.

[680] Paltashev; Chitre.

[681] *Ibid.*

[682] ' Fundamental science is similar to a God mounting over the surrounding engineering of the following seven levels in the vertical system of science and engineering:

1. Fundamental Science (Basic Research) provides applied science and engineering with the scientific apparatus, theoretical and experimental solutions.
2. Applied Science (Engineering, or Industrial Research) finds ways and designs models for solving pressing problems, understandable to engineers.
3. Experimental Engineering develops experimental samples, models, and prototypes of products on the basis of achievements of applied science or the inventor's ideas.
4. Production Engineering develops a production version of the product and production technology for guaranteed reproduction of the properties of the products in mass production (also known as know-how).
5. Adaptive and Optimization Engineering tunes technology up for the configuration of the particular manufacturing plant and optimizes production costs.
6. Low- and Large-Scale and Mass Production Engineering reproduces products with the properties guaranteed and the quality controlled in one or several plants.
7. Service Engineering develops and reproduces service models, special equipment and materials supporting the long life cycle and the safe operation of technologically sophisticated products;' Paltashev.

large-scale, and mass production engineering the philosophy of producing cheap and poor quality products became dominant. The reverse engineering going top-down in combination with the country's autarchy revealed as the dead end for the electronic industry in the USSR. In general, reverse engineering for modern ultra-large integral schemes is extremely difficult or impossible, in Paltashev's account.[683]

From the micro-electronics industry, Paltashev provided an example of how fundamental science and engineering can be intertwined and juxtaposed into each other, making their separation almost impossible.[684] In 1987 TSMC[685] was established as a 50/50 JV with Philips Semiconductors.[686] They founded a plant in Taiwan. The company started designing chips on the base of that era's machine languages. The Taiwanese side learned the production and in the 1990s bought the Philips' share in the company. Nowadays TSMS technology is superior to that of Intel as 7 nanometres technology *vs.* 10 nanometres base node size technology respectively, and TSMS is investing USD14 billions in R&D including basic research in particular.[687] The latter is explained by their production processes which are now developing on the level of fundamental science as the effects emerging are completely unknown in spheres of material science, chemistry, physics and other disciplines. For instance, many processes of semiconductors' behaviour can be modelled - however on the level of 5 nanometres something new begins. This is also an example of how the development of engineering drives science. Overall, progress in the semiconductor industry is impossible without fundamental science.

For the purpose of the objectivity, it should be mentioned that not all engineers share Bush's or both Kapitsas' vision on the primacy of fundamental science across the innovation chain based on the assumption of the corporate R&D units and industrial research to be the central birthplace of a new technological knowledge due an enormous complexity of the technology chains. For example, this assumption corresponds with the visions of such American scholars as Donald Stokes in his *Pasteur's Quadrant. Basic*

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[683] Paltashev.
[684] *Ibid.*
[685] Taiwan Semiconductor Manufacturing Company, Limited also known as Taiwan Semiconductor, is the world's largest dedicated independent (pure-play) semiconductor foundry; retrieved on 07.06.2018 from the Web, http://www.tsmc.com/english/default.htm.
[686] Now NXP semiconductors; retrieved on 07.06.2018 from the Web, https://eu.mouser.com/philips-semiconductors/.
[687] 2018, TSMC to invest $14 billion in R&D at Hsinchu facility, April 27, *Reuters*; retrieved on 07.06.2018 from the Web https://www.reuters.com/article/us-taiwan-tech-tsmc/tsmc-to-invest-14-billion-in-rd-at-hsinchu-facility-idUSKBN1HY0HH.

Science and Technological Innovation,[688] or very recently - in *Cycles of Invention and Discovery: Rethinking the Endless Frontier*[689] by Venkatesh Narayanamurti and Toluwalogo Odumosu of Harvard University. These academics challenge Vannevar Bush's vision of priority of basic research across the entire science-engineering-technology chain, insisting on the priority of engineering in the chain and claiming that, since the post-war period, described by Bush, the chain's methods have changed. However, both Bush and Kapitsa were also very prominent innovative engineers and founders of many global high-tech industries and institutions[690] so their united vision is perceived as fundamental for this research.

Unfortunately, the general success stories of the USSR in science and technology is ignored widely in the current policy-making in the vast space of the former Soviet Union which makes a striking contrast to the actual state of these affairs in the USSR itself, according to Saxena, Nigmatulin, and Paltashev.[691]

To conclude this chapter, it is important to emphasise that in the policy developing science in the Soviet Union as the core for the industrial growth the policy-makers followed the philosophy which was beyond the ideologies and which manifested its everlasting universality and integrity. As outlined by Graham considered in the literature review, the specific characteristics of scientific development in general, and in the Soviet Union in particular, cannot be understood on the ground of the economic foundations of the societies, and innovations are not necessarily products of 'pressing material necessity.'[692] The evidence presented above indicates that this philosophy was well-understood by the Soviet policy-makers on different levels and this could explain the three following things, i.e. that pragmatism in the science policy, the distinct status the Academy of Sciences and scientists possessed in the Soviet Union as well as the persistence of the policy in the time framework.

Thus, after developing the modern methodology of the scientific organisation first and establishing the global record in funding research, the Soviet Union became a leading

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688 Stokes, Donald E., 1997, *Pasteur's Quadrant: Basic Science and Technological Innovation*, Brookings Institution Press, Washington D.C.
689 Narayanamurti, Venkatesh, and Odumosu, Toluwalogo, 2016, *Cycles of Invention and Discovery: Rethinking the Endless Frontier*, Harvard University Press.
690 Appendices L and M.
691 Saxena; Nigmatulin; Paltashev.
692 Graham, 194.

country whose science and technology achievements keep contributing to global development. The Soviet human capital and industrial development resulted from the science, education and social policy which became the crucial factor of Soviet modernisation and the reason for the Soviet success on the international arena as summarised in the next, concluding chapter.

Chapter 6 Conclusion

This concluding chapter aims at combining the research results by elaborating on the theoretical findings of the thesis in order to finalise addressing the research question. This would be followed by a consideration of particular theoretical and practical implications. Also, the chapter would discuss the validity of the propositions and highlight possible prospects of future research.

The language and images of the Cold War have affected social research on Soviet development on both sides. In many ways, the Soviet studies fell victim to propagandistic approaches preventing the researcher from an unbiased study of the pre- and during WWII period when the configurations of the political actors on global arena had been dramatically different. Meanwhile, this period was crucial in terms of establishing the Soviet Union's social, educational, industrial and research base which allowed the nation to meet the challenges, to play catch up with the developed countries, to lead in some areas of development and even to provide various aid to the newly emerged Third World after WWII.

The Soviet Union formed its multi-dimensional and pioneering policy in the conditions of the scarce resources of the mainly agricultural economy of the Russian Empire, whose vast territories represented an almost medieval way of life (from a social perspective) after the defeat in WWI, caused by the backwardness of the country. The massive Soviet campaigns for eradication of illiteracy as well as the establishment of education and research throughout the largest country, performed under the umbrella of the newly born Soviet identity, aimed to transform and unite the society, various in its religions and indigenous ethnic origins, through development, as evident at the example of Kazakhstan in the thesis.

The industrial development was initiated through the implementation of the *GOELRO* energy plan, followed by the system of the five-year plans. Following Marxism, the centralisation of the resources socialised was a logical action dictated by the need to accumulate them in one place for further distributions into the most strategic directions, chosen as the locomotives of development.

During the Cold War, scholars' views on the reasons of the Soviet successes varied widely, e.g. from Sutton almost totally denying any Soviet endogenous technological achievements to

Gvishiani solely praising them and using a vague methodology to justify 'economic effects' from the patents.

Both sides were ideologically motivated in ignoring different angles. Sutton as the most profound case did so in basing his judgement entirely on the economic market point of view, considering Soviet development exclusively as technology transfer driven and missing the importance of the research, education and social policy for the development of technology. Meanwhile, many of the Soviet scholars emphasising the Marxist non-economic and social factors avoided, on the other hand, discussions of the exogenous impact during Soviet industrialisation and instead concentrated on the class struggle and the dogmatic postulates of the inevitability of 'the victory of the socialist productive forces' to explain the modern 'relations of production' (Marx).

The arguments could reach the level of absurdity as it took place with Sutton who rejected acknowledging the lion's share of the Soviet scientific advances (including Nikolay Semyonov, the 1956 Nobel laureate in Chemistry,[693] the discipline in which, according to Sutton, no significant Soviet figure emerged);[694] almost ignored the Soviet space programme, and placed *Sputnik* and aircraft (with thousands of their technologies of many military and civil types, and around 100 of various types of Soviet civil aircrafts produced annually during the Cold War[695]) in the same innovation category as electro-drill on the unconditional ground of the improbability of the Soviet planning system for innovation due to the intrinsic flaws. Meanwhile, in his Cold War language, the words 'West' and 'Western' were widely used and applied to the period of the 1920s and 30s, and, in particular, to the period of WWII of 1939-45 when the USSR, Great Britain and the US used to be the allies at war against Germany, Japan, Italy, and other 'Western' countries.

More importantly, Sutton viewed any technological development in general as fundamentally driven by the particular economic factors, i.e. the free market forces. In this approach, entrepreneurship was viewed as the driving force for innovation in seeking profitable and practical solutions as chosen from the various technologies available and pushing, therefore, science and technology forward. His view on science being about the development of theory to be tested in laboratories and technology as 'the selective

[693] Semyonov.
[694] Chapter 2.
[695] Hartley, Keith, 2014, *The Political Economy of Aerospace Industries: A Key Driver of Growth and International Competitiveness?*, Edward Elgar Publishing, 21.

application of scientific findings to industrial production'[696] was questioned by both the fundamental and applied physicists interviewed for this thesis, who clarified that science is about the development of understanding of basic principles tested and parameterised by conducting experiments.[697]

As well, in attributing, for instance, the Soviet Atomic Project solely to the exogenous impact, Sutton completely ignored the Soviet school of physics created by Ioffe almost from scratch.[698] It had been conducting thorough nuclear research, both of experimental and theoretical character, since the 1920s and especially in the 1930s when nuclear physics had purely theoretical value.[699]

Meanwhile, the fact that in the post-war period the Soviet Union boasted breakthroughs in space exploration, nuclear energy, and some other extraordinarily innovative and specialised high-tech industries required another explanation for Soviet development beyond the technology transfer and the market or class struggle factors. After more than 25 years after the dissolution of the Soviet Union, an impartial re-evaluation of Soviet development was required and the research question for this thesis became formulated as follows: *How in a quarter of a century could such a backward country as the Soviet Union advance in its human capital and industrial development to an approximate level of the major powers of the era?*

In addressing it, what emerged as substantial is that, in Marx' language, the industrial 'basis' defining the 'relations of production' as 'superstructure' was identical for both 'capitalism' and 'socialism,' although it was viewed in both systems as the opposite to each other as being driven by either the market forces or planning respectively. It placed the identification of that industrial driving force, likely, equal for both systems, as a pivotal approach for this study.

Meanwhile, the dichotomy from social scholars' opinions began disappearing while reading the literature by the scientists and engineers. They looked united in their evaluations of the drivers of the modern industrial development including the Soviet Union. The drivers were science and education.

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[696] Chapter 2.
[697] Saxena, Lonzarich.
[698] Holloway.
[699] *Ibid.*

Indeed while studying the literature further, it was identified that the Academy of Sciences of the USSR as the source of knowledge possessed a unique and privileged status in the Soviet system. It was not a part of the planning mechanism and represented a democratic institution whose leadership was elected in secret ballot by the academicians.

Furthermore, as became evident, the Soviet Union was the pioneer in elaborating the modern scientific methodology in the 1920s and the global leader in the budget allocations for R&D which, while gradually and persistently growing, exceeded 5 per cent of the GNP by 1980 to remain the global record up to date. It is essential to highlight that although science was officially recognised as distinct from the Marxist theory,[700] within the SAS it had been developing in harmonisation, although not without problems, with the humanities and social sciences. For example, the academician Sergey Oldenburg (Ol'denburg), who was permanent secretary of the SAS and mastered the Soviet pioneering methodological approach of the scientific organisation,[701] was an orientalist, an indologist, by his education and research specialisation.[702] As well, this fact, on the one hand, illustrates a possible important role, social scientists can play in science, and, on other, responds to the challenge of the author being a non-scientist as described in the methodology section.

The Academy's expansion throughout the vast territory of the USSR included all 15 republics of the nation, covered all the spectrum of research, attracted the most talented youth and turned the Soviet Union into the second leading scientific country in the world after the US. Unlike there, science in the USSR, however, was set up against the planning economy and society in contrast to the US market economy and pluralist politics, being, nonetheless, the universal phenomenon. Evidently, the development of science and education in the USSR became 'the strategic investment object'[703] of the socialised national product for the overall development.

In addressing the research question further to highlight the propositions on the connection between science and industry, on the one hand, and the establishment and interaction of the Soviet science, education and various social policies juxtaposed in the whole integral set, on

[700] Graham, chapter 2.
[701] *Ibid.*
[702] Birthday Anniversary of Sergey Oldenburg, Academician Orientalist, One of the Founders of the Russian School for Study of Indian Culture, *Presidential Library*; retrieved on 22.05.2019 from the Web, https://www.prlib.ru/en/history/619575.
[703] As described by Dzerzhinsky, chapter 4.

the other, it required studying new data. They were obtained from two kinds of the primary sources, i.e. the interviews and various documents related to the era.

The data revealed that the Soviet Academy of Sciences' main focus of the research was fundamental science which was universally driven in its development by scientists' curiosity and had no direct connection to practical applications. In relation to the Soviet school of nuclear physics, Holloway described it as follows:

> What drew Soviet physicists to nuclear research in 1932 was not the promise of practical results but the prospects of interesting physics. They may have hoped that their work would prove useful, but they thought that practical applications, if they ever resulted, were far in the future.[704]

The expansion of the Academy which began after the 1917 October Revolution and received a particular drive in the 1930s after formulating the science policy methodology mentioned above, was not slowed down in the 1940s in the hard conditions of WWII. In this sense, the example of Basov's research was particularly indicative. It began during the war being driven by scientist's curiosity to explore the properties of the cm waves 'without any connection with military investigations. […] One didn't feel any war spirit in the laboratory.'[705] However, this led to the discovery of laser without which the modern technology is unimaginable, and undoubtedly contributed to the post-war status and the military might (Abilsiitov's both research and career) of the Soviet Union and so did, of course, Soviet nuclear research mentioned just above.

During the 1930s, the exogenous technology transfer was implemented as the most effective in those conditions means to industrialise the Soviet nation through the income accumulated in the centralisation and redistributed for the strategic directions. Meanwhile, generous funds reaching 27 per cent of the Soviet GNP by 1980 were allocated on a revolving basis for the development of the indigenous education, culture, primary health care and, more importantly, fundamental science and varied research which established the successful import substitution programme through the development of the endogenous human capital.

[704] Holloway, 46.
[705] Chapter 3.

In the USSR, fundamental science was the source of expertise and the reservoir of knowledge for the development of engineering and technology including that one obtained through the transfer. Following those Ioffe's words of 1927 in chapter 4, all forms of Soviet industry were founded as 'various sections of physics or chemistry applied and exploited on a large scale.' Also, science became employed in founding the vast Soviet education base as well as the primary health care system and other social programmes which altogether contributed to the development of the national human capital. The latter, in turn, was acquired by industry, culture, science, and elsewhere. In particular, the scientific and technological training was mastered for preparing the Soviet management and governance.

The investment in education and technology was directly relevant to the rapid Soviet development in the early years, whereas the investment in basic research was essential in the longer run. Therefore, the value of this investment in fundamental research in the first years was primarily in drawing in talent in the field of science that could then potentially be channelled into the technological, managerial and governing sectors, on the one hand. On the other, non-material dividends of boosting morale, self-confidence and pride in the emerging nation to become the most progressive and civilised one as well as to tangibly contribute to global development and lead the mankind's progress one should not be equally excluded. As well, after WWII, a driving factor was scientists' motivation to retain the world's balance of power and prevent another even more destructive war.

The establishment of such a science policy implied policy-makers' high educational level and the data confirmed it. Furthermore, in the 1930s, the establishment of the *polytechnisation* as the leading approach for the Soviet education, management, governance, lifestyle, and culture was accompanied by the intense political debates and power struggle before and during industrialisation. As a result, the massive exogenous technology transfer was successfully assimilated and developed turning the Soviet Union into the modern technological nation.

The vast system of education to enhance all modern aspects of human knowledge was established in the Soviet Union to reach its most ultimate territory. As mentioned above, the priority was given to the *polytechnic instruction* whereas the education was free,[706] universal, profound and accessible for all the strata of the Soviet society despite gender, social[707] or ethnic origin.

[706] With the exemption for the short period described in chapter 4.
[707] *Ibid*.

This was accompanied by the establishment of the effective system of the primary health care which allowed the Soviet Union by 1965 to reach the level of the developed countries in terms of life longevity and the other indicators related and which is still praised at WHO. By the same period, the quality and living standards of the Soviet citizens reached the indicators which were closer to those of the developed rather than those of the developing countries. As a result, this policy led to the establishment of concept of Three Worlds in global development in which the word 'westernization' was replaced by 'modernization' in the 1950s, as argued in the introduction.

All of this mentioned above would have been impossible if not for science. The pursuit of this policy with science in its centre remained its intact and distinct quality which had been constantly, closely and relentlessly monitored and nurtured by the Communist Party through any unfavourable conditions.

Regarding technology transfer, it has been a standard industrial practice after British industrialisation. The analysis revealed that the most important indicator to evaluate a possible success of any technology transfer would be an importing side's ability to adopt, sustain and develop further the technology received which is impossible without an equally developed research and engineering base in place. The latter, meanwhile, occurred in the Soviet Union due to the development of the extensive social programmes introduced in the 1930s as the platform for human capital development.

According to the concept of the *Triple Helix Systems of Innovation* mentioned in subchapter 4.3, in the Soviet 'statist' regime, the overall system's development can be achieved through the rotational interaction of the two overlapping centres of the helices of the industry and academia being both inscribed in the dominant centre of the helix of the state policy.[708] This thesis argues for the science and social policies being juxtaposed into the whole set is one of the most significant components of the Soviet developmental policy. This distinct Soviet innovation model allowed the country not only to perform industrialisation in the record time but also to escape from the trap of technology transfer which has been widely used in the struggles of nations as an effective means of control and subordination. This is the case of Soviet industrialisation.

[708] Ranga & Etzkowitz, 7.

Thus, in its foundation, Soviet development was resultant from the establishment of research and education across the whole range of the scientific disciplines at a large scale, as well as the extensive national social and educational policy to include the development of culture, education, various social institutes, and effective primary health care. Altogether they were forming the appropriate ecosystem, or environment, for nurturing the valuable scientific human capital as the apex of the entire process. The latter was reflected in that exceptionally high status of science and scientists in the Soviet society. The status was built up by various measures which received a particular impetus in the period from the 1930s to 50s.

This thesis studies science as the inception point of the modern industry and technology basing on the case of the USSR as well as tries to connect the phenomenon of science across innovation chain to non-economic factors in the context of both the Soviet policy and the unity of global development. This approach, to the researcher's knowledge, is not present in most of the economic analyses and social research on the Soviet Union published up to date. Whereas various aspects of the Soviet industrial, science or social policies are considered in the Western academic literature, there is no source which would combine them in one analysis which, possibly, defines a theoretical contribution and a novelty of the thesis.

Meanwhile, a thorough analysis of Soviet development from this perspective could help consider the evidence on the lasting and profound contribution of Soviet science and technology to global progress in premising capitalisation of many international companies, industries, and markets.

The institutionalisation of the industry of discovery, in which satisfaction of scientific curiosity is pivotal for the key OECD countries in their R&D allocations, endorses the fact that this is a process valuable for national wellbeing. Meanwhile, these OECD countries are mostly the nations leading in their expenditures on R&D, with the US being foremost in the absolute number of allocations as it similarly took place in the Soviet Union. In proportional relation to their GDP's expenditures, most of the OECD and some developing countries, South Korea and China, in particular, have been increasingly doing this kind of the investments aspiring to outperform the Soviet record.[709]

[709] Gross Domestic Spending on R&D Total, % of GDP, 2000 – 2017, *OECD Data*; retrieved on 14.09.2018 from the Web, https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm; hereafter referred to as OECD.

More importantly, the current economic methodology does not delineate between science and technology in the term of research and development (R&D) whereas in the development of the Academy of Sciences of the USSR, the priority was given to fundamental science (or basic research), as the precursor and necessary prerequisite, in Marxist language, for applied science (industrial research, or engineering), technology, and innovation as the core of the modern industry and overall development. In paraphrasing Graham's words, not only no previous but also subsequent government in history has ever been so openly and energetically in favour of science so far.[710]

Indeed, science was regarded in the Soviet Union as a natural resource, an irreplaceable instrument of the country's modernisation and a key to the international relationship.

It is also important to note that in the interaction of the state, industry, and academia many of the most developed countries fall in practice into the category of a laissez-faire innovation regime, 'characterised by limited state intervention in the economy (e.g. the US, some Western Europe countries), [in which] industry is the driving force, with the other two spheres as ancillary support structures and limited roles in innovation: university acting mainly as a provider of skilled human capital, and government mainly as a regulator of social and economic mechanisms.'[711]

This regime has evolved through 'natural and historical conditions,' whereas developing nations in the XX and XXI Centuries have had to play catch up in their pursuit of rapid development of academia and industry. As Peter Nolan emphasised, '[I]n 2009, after three decades of capitalist globalization, firms from developing countries were almost entirely absent from the list of the world's top 1,000 firms in terms of R&D spending.'[712] This *status-quo* compels developing countries to adopt the 'statist' Soviet innovation model mentioned above in which the governmental policy is the driving force, even despite possible 'errors on a scale impossible in economies organized by less centralized and interventionist means,' according to Howe.[713]

Therefore, the example of the Soviet Union is particularly significant for many developing nations. Its 'proven ability to carry backward countries speedily through the crisis of

[710] Chapter 2.
[711] Ranga & Etzkowitz, 6.
[712] Nolan, Peter, 2012, *Is China Buying the World?,* Polity Press, 50.
[713] Howe, xx.

modernization and industrialization,'[714] as worded by the White House National Security Council of the US, was appealing for them and affected global development to a large extent, as argued above and also evident from the modern successes of China.

For the nations of Eurasia and worldwide, modernisation still implies organisation of fundamental research as a vital and comprehensive strategic paradigm to embrace the challenges and find new places in the formation of the new technological and industrial age. As mentioned in the introduction, in their models of development, developing countries including those rich in natural resources become highly dependent on global fluctuations or exogenous technology which limit their progress and restrict overall development. In this sense, this research can possibly help elaborate on an approach to accommodate local realities and global demands and should be continued by the author.

A modern system of science as the industry of discovery emerged in the territory of the USSR during the Soviet period. The Soviet experience gave the world the first examples of the particular policy over the processes of the creation and implementation of the national 'scientific and technical potential,' as worded in the Soviet terminology when this approach was not yet even formed in the rest of the world. This policy allowed the nation to go through the enormous challenge of WWII as well as to establish the new world post-colonial order, in which the independent development of India and China, among others, become possible and which, as well, could be a part of the author's further research.

The Chinese system, as shown in chapters 1 and 5, was industrially institutionalised after the Soviet model with the research and education base at its centre to have recently become the second largest global economy. Following the Soviet industrial model in consequently expanding and developing its research (that reached 2.129 per cent of the GDP in 2017),[715] the nation reached a globally leading position in many disciplines and outperformed the US in the number of the scientific publications in the same year.[716]

The Soviet successes considered in this thesis would have been impossible without the creation of the indigenous social and educational base and the introduction of science-induced multiple technologies in the economy, national and global life to reach new levels of prosperity and development. However, by no means, the development of science and

[714] Peck, 47.
[715] OECD.
[716] Littlewood.

research should be viewed as a panacea in development without embracing other challenges.[717] *Perestroika* of the USSR is a vivid statement for this. Even the Soviet leadership in such most technological human endeavour as the space exploration with the developed education, science, and technology base in place could not prevent the collapse of the country from happening. It makes the question of designing a more comprehensive and flexible set of new policies for developing countries even more acute which, in turn, is not doable without employment of science and research.

As argued in Soviet research (chapter 2), in the modern world, '[t]he slightest stagnation in science is immediately reflected in national economic development, reducing the rate of increase in the national income.'[718] This is the advice which is not to be ignored in any economy, in particular considering that science could be perceived as a key, although not fully visible instantly, driving force of a modern society. Overall, a particular nation is developed to the extent its both culture and intellectual knowledge are developed.

Nowadays, at the time of the new industrial age, science becomes increasingly important as the only human instrument with which it might be feasible to meet new challenges emerging. In this sense, a relatively short, although dramatic, history of the Soviet Union and its interconnected and multi-faceted policies driven by research and social development could contribute to the formation of unprecedented future solutions, as science is the very human instrument, which by its cognitive nature is determined to explore, explain and deal with the unknown.

[717] *Ibid.*
[718] Kurakov, 13.

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Appendix A List of Interviewees, Abstract and Questionnaire

Galym Abilsiitov (Russia), the founding director of the R&D Centre for Laser Technology in the USSR and a former minister for science and new technologies of the Republic of Kazakhstan; the interview took place on 15.01.2016 at his house in Troitsk, near Moscow.

Alexander Buzgalin (Russia), a political economist of the MSU and a former member of the Central Committee of the CPSU in 1990-1; the interview was recorded on 09.05.2017 at the University of Cambridge.

Shashikumar Chitre (India and the UK), Shashikimar M. Chitre, Active Member, *the International Astronomic Union*; retrieved on 04.07.2017 from the Web, https://www.iau.org/administration/membership/individual/2603/; the interview was recorded on 07.06.2017 at Sheppard Flat, Churchill College, the University of Cambridge.

Viktor Eremenko (Ukraine), Senior Fellow and Advisor to the Directorate of B. Verkin Institute of Low Temperature Physics and Engineering (ILTPE) of the National Academy of Sciences of Ukraine; retrieved on 03.07.2017 from the Web, http://www.ilt.kharkov.ua/cpuei2012/eremenko_e.html; the interview was recorded on 01.09.2016 in Kharkov.

James Jackson (the UK), Professor James Jackson, Former Head of Department, Professor, Geophysics, Geodynamics and Tectonics, Department of Earth Sciences, *University of Cambridge*; retrieved on 03.06.2017 from the Web, http://www.esc.cam.ac.uk/directory/james-jackson; interviewed in the conference *Earthquake Without Frontiers*, organised by James Jackson in Almaty, Kazakhstan, September 2016; retrieved on 03.06.2017 from the Web, http://ewf.nerc.ac.uk/about-us/; as well as in the correspondence with the author on 29.02.2016.

Andrey Kaul (Russia), Laboratory of Coordination Compound Chemistry, Head of Laboratory: Professor Andrey Rafailovich Kaul, Division of Inorganic Chemistry, *The M.V. Lomonosov Moscow State University*; retrieved on 03.06.2017 from Web Site, http://www.chem.msu.ru/eng/chairs2/inorg/welcome.html.

Peter Littlewood (the UK, and the US), a former head of both the Argonne National Laboratory, Chicago, USA, and The Department of Physics/The Cavendish Laboratory, the University of Cambridge; retrieved on 04.03.2017 from the Web: https://physics.uchicago.edu/page/peter-littlewood; the interview was recorded on 02.03.2017 via Skype.

Gilbert Lonzarich (the US, Canada, and the UK), Quantum Matter Group, the Cavendish Laboratory of Cambridge, and the laureate of the 2015 Kamerlingh Onnes Prize[719] (which is the highest award in the field of superconductivity).

Alexander Molodyk (Russia), Molodyk, Alexander, Technical Director, *SuperOx*, both a visit to the company's production facilities and interviews were on 07.04. 2017 in Moscow; retrieved on 21.04.2017 from the Web http://www.superox.ru/en/.

Ovanes Mikoyan (Russia), the first deputy of the `General Director of the Russian Aircraft Corporation *MiG* and a son of Artyom Mikoyan, the founder of the *MiG*, formerly known as *Mikoyan & Gurevich Design Bureau*, two interviews took place on 12.12.2014 and 05.04.2017 in Moscow, Russia.

Vladimir Nekrasov (Russia), Stalin's assistant (*referent*) in 1952-3, and afterwards, a member of the Soviet and Russian Governments at various legal positions in 1952-97, including being head of the legal department of the Soviet Government, The Council (*Soviet*) of Ministers of the USSR. Three interviews at his *dacha* in Krasnovidovo near Moscow on 19-20 Nov 2013 and 14-15 Dec 2014.

Robert Nigmatulin (Russia), Doctor of Physical and Mathematical Sciences (1971), Professor (1974), Real Member (Academician) of the Russian Academy of Sciences (1991), Member of Presidium of the Russian Academy of Sciences (2006), Director of P.P. Shirshov Institute of Oceanology (2006 - present*), Curriculum Vitae*; retrieved on 04.07.2017 from the Web, http://www.ocean.ru/eng/content/view/94/; the interview was recorded on 05.04.2017 in Moscow.

Tony Raven (the UK), Chief Executive, *The University of Cambridge Enterprise*; retrieved on 17.05.2017 from the Web, https://www.enterprise.cam.ac.uk/team/dr-tony-raven-2/

[719] As referred to in chapter 3.

Giorgos Tsironis (Greece), Department of Physics, University of Crete, *Curriculum Vitae*; retrieved on 28.02.2017 from the Web: https://nls.physics.uoc.gr/sites/nls.physics.uoc.gr/files/files/gts_CV.pdf; the interview was recorded on 21.02.2017 in Cambridge.

Alexander Vasiliev (Russia), Chair of Low Temperature Physics and Superconductivity, Head of Solid State Physics Division Faculty of Physics, *The M.V. Lomonosov Moscow State University*; retrieved on 04.07.2017 from the Web, http://www.ml.pan.wroc.pl/assets/files/male-goscie/Vasiliev_CV-2016B.pdf, the interview was recorded on 04.03.2017 at the Division, the MSU, Moscow.

Yuri Zhukov, Senior Research Fellow of the Institute of the Russian History of the Russian Academy of Sciences (the RAS); the interview was recorded on 03.04.2017 in Moscow.

Abstract. A system, which brought together science, technology, industry, education and social policy, played a fundamental role in the emergence of the USSR in the global arena after WWII as an advanced industrial and technological actor. A key goal of this research is to operationalize academic insights, related to the relationship between science, engineering, technology, and innovation in conjunction with educational and social policy, into practical frameworks, as evident in the success of the Soviet industrial policy. Unlike a conventional consideration of innovation tools, as emerging from the economic mechanisms, this paper tries to establish and understand the connection from **Science** (as grasping principles of nature) to **Engineering** (application of Science) and to **Technology and Innovation** (making Engineering useful for public good and/or commercial gain) in the Soviet import substitution policy. Development of science, education and social policy is considered here as a game-changing factor as it replaced the practice of the technology transfer prevalent during and after industrialisation drive of the 1930s. A new high technological reality of microelectronics, nuclear energy, space exploration programme and other phenomena which emerged as a result of the sophisticated intertwining of science and technology as well as social policy. The thesis aims to understand how these various policies were developed independently and brought together to achieve specific aims of the Soviet national development.

1. Often these days, in both mass media and conventional economic thought, the role of fundamental science is not viewed in connection with economic development. As a scientist, do you have an opinion on this?
2. In your view, do fundamental science and engineering relate to each other?
3. In my abstract above I conjecture that science drives the process of industrial development. In your opinion, how do discoveries in fundamental science lead to disruptive and marketable technologies?
4. Would you agree or disagree that the main process that leads to the sustainable technological development of large developed countries (or companies) is clearly linked to a strong fundamental science research base?
5. Today economic planners and management schools strongly believe in (and teach) the notion that science is a product of the Market and discoveries in science are driven by market demand (search for practical and profitable solutions). In other words, scientific discoveries result mainly from the pursuit of profit and efficiency. To what degree would agree or disagree with this notion?
6. Do you think that today's digital informational revolution has speeded up the process?
7. The following questions are dedicated to the Soviet industrial development, and the first one I would like to ask you, if possible, is as follows: to what extent was the Soviet technological development different to those of other developed countries, if true? Were there any substantial differences to the US, Western European, Japanese or any other approaches in dealing with the S&T development?
8. In your opinion, how crucial was technology transfer for the Soviet industrial development?
9. What is a Soviet science and technology contribution to global technological development?
10. In terms of any country's technological development, what do you think of the idea to rely solely on technology transfer without developing its own science and technology base?
11. Another question is when talking about technological development about an opinion which is getting more widespread, especially in the countries, which are not so developed. Policy-makers often defend the idea of technology transfer – 'Why would we need to fund this development, it requires structural reforms, both educational and social when it would be simpler to achieve economic success through technology transfer?' What would you say?
12. In my research, the figure of Pyotr Kapitza occupies a central place. What do you think of his contribution to global science and technology?

Appendix B

Table 6 Ten-Year School Curriculum, 1952-1953[720]

Total Hours of Instruction by Subject
For the First Seven Grades, Hours per Week, Total Hours for Grade VIII Through X, and Total for Grades I through X, in class hours of 45 Minutes Each and in Per Cent

Subject	Hours I-VII	Hours per week[721]			Total Hours and Per Cent			
					VIII-X		I-X	
		VII	IX	X	Hours	Per Cent	Hours	Per Cent
Russian Language and Literature	2,508	5.5	6	5	544.5	16.8	3,052.5	31.6
Mathematics[722]	1,518	6	6	6	594	18.4	2,112	21.8
History	3,135	4	4	4	396	12.3	709.5	7.3
USSR Constitution	66	…	…	…	…	…	66	0.7
Geography	346.5	3	2.5	…	181.5	5.6	528	5.5
Biology	313.5	2	2	…	132	4.1	445.5	4.6
Physics	165	3	2	4.5	313.5	9.7	478.5	5.0
Astronomy	…	…	…	1	33	1.0	33	0.3
Chemistry	82.5	2	2	3.5	247.5	7.7	330	3.4
Psychology	…	…	2	…	66	2.0	66	0.7
Logic	…	…	…	2	66	2.0	66	0.7
Foreign Language[723]	363	3.5	3.5	4	363	11.2	726	7.5
Physical Culture	396	2	2	2	198	6.1	594	6.1
Drawing (Art)	198	…	…	…	…	…	198	2.0
Drafting (Engnrg.)	33	1	1	1	99	3.1	132	1.4
Singing	132	…	…	…	…	…	132	1.4
Manual Training	…	…	…	…	…	…	…	…
Shop Work	…	…	…	…	…	…	…	…
Total	6,435	32	33	33	3,234	100.0	9,669	100.0

[720] Korol, Table 12, 58, citing from E.N. Medinskii, *Narodnoye obrazovaniye v SSSR*, 74 and 86, and table 10.
[721] Classes are held 6 days a week, 33 weeks a year.
[722] Algebra and Geometry, grades VI through X; Trigonometry, grades IX and X.
[723] English, German, or French, depending on availability of teachers.
Note: Fractional figures show the average of two semesters.

Appendix C

Table 7 Ten-Year School Curriculum, 1955-1956[724]

Total Hours of Instruction by Subject
For the First Seven Grades, Hours per Week, Total Hours for Grade VIII Through X, and Total for Grades I through X, in class hours of 45 Minutes Each and in Per Cent

Subject	Hours I-VII	Hours per week[725]			Total Hours and Per Cent			
					VIII-X		I-X	
		VII	IX	X	Hours	Per Cent	Hours	Per Cent
Russian Language and Literature	2,343	5.5	4	4	445.5	13.6	2,788.5	28.8
Mathematics[726]	1,386	6	6	6	594	18.2	1,980	20.5
History	264	4	4	4	396	12.1	660	6.8
USSR Constitution	…	…	…	1	33	1.0	33	0.3
Geography	297	2.5	3	…	181.5	5.6	478.5	5.0
Biology	297	2	1	…	99	3.0	396	4.1
Physics	165	3	4	4.5	379.5	11.6	544.5	5.6
Astronomy	…	…	…	1	33	1.0	33	0.3
Chemistry	66	2	3	3.5	280.5	8.6	346.5	3.6
Psychology	…	…	…	1	33	1.0	33	0.3
Logic	…	…	…	…	…	…	…	…
Foreign Language[727]	363	3	3	3	297	9.1	660	6.8
Physical Culture	462	2	2	2	198	6.1	660	6.8
Drawing (Art)	198	…	…	…	…	…	198	2.1
Drafting (Engnrg.)	33	1	1	1	99	3.1	132	1.4
Singing	198	…	…	…	…	…	198	2.1
Manual Training	330	…	…		…	…	330	3.4
Shop Work	…	2	2	2	198	6.1	198	2.1
Total	6,402	33	33	33	3,267	100.0	9,669	100.0

[724] *Ibid.*, Table 11, 57, citing from *Narodnoye obrazovaniye*, No.7, July 1955, 4, and Table 9.
[725] Classes are held 6 days a week, 33 weeks a year.
[726] Algebra and Geometry, grades VI through X; Trigonometry, grades IX and X.
[727] English, German, or French, depending on availability of teachers.
Note: Fractional figures show the average of two semesters.

Appendix D

Table 8 Curriculum by 1984[728]

Completed secondary school. – The standard curriculum for completed secondary school is:

Subject	Hours per week by grade									
	1	2	3	4	5	6	7	8	9	10
Native tongue	12	10	10	6	6	3	3	2		
Literature				2	2	2	2	3	4	5
Mathematics	6	6	6	6	6	6	6	6	5	5
History				2	2	2	2	3	4	3
Natural History		2	2	2						
Geography					2	3	2	2	2	
Biology					2	3	2	2	2	
Physics						2	2	3	4	5
Foreign Language					4	3	3	2	2	2
Chemistry							2	2	3	3
Physical training	2	2	2	2	2	2	2	2	2	2
Manual training	2	2	2	2	2	2	2	2	2	2
Music	1	1	1	1	1	1	1			
Fine Arts	1	1	1	1	1	1				
Drafting						1	1	1		
Astronomy										1
Social Science										2
Optional							2	4	6	6
Total	24	24	24	24	30	30	32	34	36	36

[728] Spearman, 6.

Appendix E

Table 9 Number of Institutions of Higher Education Listed by Categories and Type of Instruction, USSR, January 1955

Column E gives the number of residence schools which also have an evening department. Column C gives the number of resident schools which also have a department for instruction by correspondence.[729]

Categories and Subcategories	Total	Number of Schools by Types				
		Resident			Even-ing only	Corres-ondenc e only
		Total	E	C		
I. Universities	33	33	2	27	…	…
Institutes:						
II. Polytechnic and industrial		23				
1. Polytechnic	20		15	6	…	1
2. Industrial	5		4	2	…	1
III. Power, Electrotechnical, Radiotechnical, and Physiotechnical		7				
1. Power	3		1	…	…	1
2. Electrotechnical	2	…	2	…	…	…
3. Radiotechnical	2	…	2	…	…	…
4. Physiotechnical	1		…	…	…	…
IV. Machine construction, Shipbuilding, Aviation, Polygraphic, and Motion Picture Engineering		26				
1. Machine construction; machine tools and tools; mechanical; and automotive	16		12	…	1	1
2. Shipbuilding	2		2	…	…	…
3. Aviation	7		7	…	…	…
4. Polygraphic	3		1	…	…	1
5. Motion Picture Engineering	1		…	1	…	…
V. Geologic, Mining, Oil, Peat, and Metallurgical		24				
1. Geologic; mining oil; and peat	15		8	2	…	…
2. Metallurgical and mining metallurgical		24				
VI. Chemical technology	9	9	6	1	…	…

[729] Korol, 137-8.

VII. Food and Fishing Industries		11				
1. Food industries	9		5	2	…	1
2. Fishing industries	4		…	…	…	1
VIII. Light Industries		7				
1. Light industries	3		2	1	…	1
2. Textile	5		5	…	…	…
IX. Engineering-Construction, Geodetic, and Automotive Highways		25				
1. Engineering-construction	19		10	8	…	1
2. Geodetic	2		…	1	…	…
3. Automotive highway	6		4	2	…	1
X. Hydrometerological	2	2	…	1	…	…
XI. Transport and communication		25				
1. Railroad transport	13		11	…	…	1
2. Water transport	4		1	4	…	…
3. Marine and navigation	4		…	3	…	…
4. Civil air fleet	1		…	1	…	…
5. Communications	5		2	3	…	1
XXII. Agriculture and Forestry		106				
1. Agricultural	63		…	52	…	1
2. Zootechnical,[730] milk and veterinary	21		…	7	…	…
3. Mechanization and electrification of agriculture	7		1	5	…	…
4. Hydromelioration and land management	6		…	4	…	…
5. Forest and forest technology	11		6	8	…	1
XIII. Economics		22				
1. Economics	8		7	…	…	1
2. Finance Economics	9		6	…	…	1
3. Trade Economics	3		3	1	…	…
4. Engineering economics	3		3	1	…	…
XIV. Law	6	5	…	5	…	1[731]
XV. Art		46				
1. Architecture and industrial art	3		…	…	…	…
2. Visual arts	9		…	1	…	…
3. Music conservatories	21		7	2	…	…
4. Theatre and motion pictures	13		…	1	…	…
XVI. Medical		75				

[730] *Ibid.* Soviet term for animal husbandry.
[731] *Ibid.* Has 14 affiliated branch institutes.

1. Medical	65		…	…	…	…
2. Stomatological	2		…	…	…	…
3. Pharmaceutical	8		…	4	…	…
XVII. Physical Culture	13	13		9	…	…
XVIII. Pedagogical, Historical Archives, and Library		278				
1. Pedagogical	206		31	173	…	4
2. Pedagogical, foreign languages	19		1	14	…	…
3. Library, literature, historical archives	5		3	4	…	…
4. Teachers [732] (two-year course)	52		…	17	…	…
Total	762	737	17 5	376	3	22

[732] *Ibid.,* of these in addition to the evening regular course, six also have an affiliated (*filial*) evening school in a different location.

Appendix F

Table 10 Number of Faculties and Number of 'Specialties' Taught in Each of the Thirty-Three State Universities, USSR, 1955[733]

Ref. No.	Name [location]	Faculties	'Specialties'
1.	Azerbaidzhan [Baku]	7	20
2.	Byelorussian [Minsk]	7	13
3.	Vil'nyus	7	18
4.	Voronezh	6	13
5.	Gor'ki	4	8
6.	Dnepropetrovsk	4	8
7.	Erevan	8	20
8.	Irkutsk	7	14
9.	Kazan'	7	17
10.	Kazakh [Alma-Ata]	7	18
11.	Karelo-Finish [Petrozavodsk]	5	9
12.	Kiev	12	22
13.	Kirgiz [Frunze]	7	14
14.	Kishinev	6	13
15.	Latvia [Riga]	8	24
16.	Leningrad	12	41
17.	L'vov	11	22
18.	Molotov	7	14
19.	Moscow	12	36
20.	Odessa	6	10
21.	Rostov-na-Donu	5	13
22.	Saratov	8	13
23.	Central Asia [Tashkent]	8	19
24.	Tadzhik	5	11
25.	Tartu [Estonia]	5	18
26.	Tbilisi	10	26
27.	Tomsk	7	14
28.	Turkmen [Ashkhabad]	5	11
29.	Uzhgorod	5	9
30.	Uzbek [Samarkand]	4	7
31.	Ural [Sverdlovsk]	6	13
32.	Kharkov	8	15
33.	Chernovtsy	6	11
	Total number in 33 universities	232	534
	Average per faculty	…	2.3
	Average per university	7	16

[733] *Ibid.*„ 156, compiled from 1955, *Spravochnik dlya postupayushchikh v vysshiye uchebnye zavedeniya v 1955 godu*, Moscow, *Sovetskaya Nauka*; all the names of the geographical locations are given as in the original.

Appendix G

Table 11 List and Number of All Faculties within the Thirty-Three State Universities, 1955[734]

Faculty	Number
1. Physics	7
2. Physics-Mathematics	25
3. Mechanics-Mathematics	7
4. Natural Sciences-Mathematics	1
5. Natural Sciences	2
6. Chemistry	27
7. Biology	14
8. Biology-Chemistry	1
9. Biology-Soil	14
10. Geology	15
11. Geological exploration	1
12. Geology-Geography	8
13. Geography	15
14. Medical	3
15. Agricultural	1
16. Engineering Construction	1
17. Forestry Engineering	1
18. Mechanical	1
19. Technical	1
20. Economic	12
21. Journalism	3
22. History	16
23. History-Law	1
24. History-Philology	15
25. Law	14
26. Philology	18
27. Philosophy	3
28. Oriental	2
29. Foreign Languages	2
30. Foreign Languages and Literature	1
Total number of resident facilities	232
Evening faculties	2
Correspondence (*zaochnye*) faculties	27

[734] *Ibid.*, 157.

Appendix H

Table 12 The USSR, Union Republic and Branch Academies of Sciences (at the end of 1976)[735]

Academy	Year Founded	Number of full and corresponding members	Number of Scientific Institutions	Number of full-time scientists	With Advanced Degrees	
					Doctors of Sciences	Candidates of Sciences
USSR Academy of Sciences	172[736]	733	244	42,951	3,943	18,785
Ukrainian SSR Academy of Sciences	1919	300	70	12,250	904	5,753
Belorussian SSR Academy of Sciences	1928	126	32	4,736	187	1,336
Uzbek SSR Academy of Sciences	1943	92	30	3,545	189	1,509
Kazakh SSR Academy of Sciences	1945	129	31	3,736	183	1,541
Georgian SSR Academy of Sciences	1941	106	38	5,356	344	1,778
Azerbaydzhan SSR Academy	1945	102	28	4,242	249	1,704

[735] Cocks, 51-3, citing *Narodnoye khozyaystvo SSSR za 60 let; yubileyniy statistichesky ezhegodnik* (*The National Economy of the USSR for 60 years; Jubilee Statistical Yearbook*), 1977, Moscow, 144; the transcriptions of the titles are given as in the original.
[736] 'The Academy was opened in 1725,' *Ibid.,* 51.

of Sciences						
Lithuanian SSR Academy of Sciences	1941	49	11	1,555	60	724
Moldavian SSR Academy of Sciences	1961	41	19	895	59	521
Latvian SSR Academy of Sciences	1946	51	16	1,688	76	744
Kirgiz SSR Academy of Sciences	1954	44	18	1,460	68	515
Tadzhik SSR Academy of Sciences	1951	46	17	1,262	51	512
Armenian SSR Academy of Sciences	1943	88	31	2,898	182	933
Turkmen SSR Academy of Sciences	1951	46	14	883	40	410
Estonian SSR Academy of Sciences	1946	42	13	952	63	532
USSR Academy of Arts	1947	127	4	349	16	131
All-Union Academy of Agricultural Sciences imeni	1929	203	169	11,315	497	5,660

Lenin						
USSR Academy of Medical Sciences	1944	254	42	5,488	929	3,262
USSR Academy of Pedagogical Sciences	1943	127	14	1,687	128	809
RSFSR Academy of Communal Economics	1931	--	5	428	10	206

Appendix I

Figure 2 **Photograph of *SuperOx* Superconducting Cable from Inside**

Appendix J

Figure 3 Photograph of Layers of Different Materials of *SuperOx* Superconducting Cable from Inside

The black layer is the superconducting rare earth compound.

Appendix K Curiosity in Science

- ‘I have no special talents. I am only passionately curious,’[737] as well as

- ‘The important thing is not to stop questioning; curiosity has its own reason for existing. One cannot help but be in awe when contemplating the mysteries of eternity, of life, of the marvelous structure of reality. It is enough if one tries merely to comprehend a little of the mystery every day. The important thing is not to stop questioning; never lose a holy curiosity’[738] by Albert Einstein,[739] a developer of the theory of relativity, which is a one of two pillars of modern physics (the other one is quantum mechanics), and the 1921 Nobel Prize Laureate for ‘his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect;’[740]

- ‘He doesn't care about whether it will lead to something useful, whether a breakthrough can be expected, whether it will lead to more funding. He just follows his curiosity’[741] by Hitoshi Nakatogawa, a biologist at the Tokyo Institute of Technology, on the 2016 Nobel Laureate in Physiology or Medicine Yoshinori Ohsumi for his discoveries that ‘opened the path to understanding the fundamental importance of autophagy in many physiological processes, such as in the adaptation to starvation or response to infection;’[742]

- ‘Our backgrounds, and the experience that has shaped us as scientists, are very different. We were born, and we grew up, on opposite sides of the globe. What we

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[737] Einstein, Albert, 1952, To Carl Seelig, his biographer, March 11, Einstein Archive 39-013. A similar sentiment was expressed in a letter to Hans Muehsam, March 4, 1953. Einstein Archive 38-424, collected and edited by Calaprice, Alice, with a foreword by Freeman Dyson, 2000, *The Expanded Quotable Einstein*, Princeton University Press; retrieved on 25.05.2017 from the Princeton University Press Web Site, http://press.princeton.edu/chapters/s6908.html.

[738] Willis, Joseph S., 2001, *Finding Faith in the Face of Doubt: A Guide for Contemporary Seekers*, Quest Books, 58.

[739] The Nobel Prize in Physics 1921 Albert Einstein - Biographical, *Nobelprize.org*; retrieved on 25.05.2017 from the Web, http://www.nobelprize.org/nobel_prizes/physics/laureates/1921/einstein-bio.html.

[740] The Nobel Prize in Physics 1921,
Albert Einstein – Facts, *Nobelprize.org*; retrieved on 25.05.2017 from the Web, http://www.nobelprize.org/nobel_prizes/physics/laureates/1921/einstein-facts.html.

[741] Van Noorden, Richard, and Ledford, Heidi, 2016, Medicine Nobel for Research on How Cells 'Eat Themselves,' Japanese Biologist Yoshinori Ohsumi Recognized for Work on Autophagy, 3 October, *Nature*; retrieved on 25.05.2017 from the Web, http://www.nature.com/news/medicine-nobel-for-research-on-how-cells-eat-themselves-1.20721.

[742] The Nobel Prize in Physiology or Medicine 2016 Yoshinori Ohsumi, *Nobelprize.org*; retrieved on 25.05.2017 from the Web, https://www.nobelprize.org/nobel_prizes/medicine/laureates/2016/press.html.

have in common is a lifelong curiosity about the shapes, and changes in shape, of entities […] and a lifelong conviction that this curiosity will lead us closer to the truth of chemical processes, including the processes of life'[743] by John Cornforth, the 1975 Nobel Prize Laureate in Chemistry 'for his work on the stereochemistry of enzyme-catalyzed reactions'[744] on himself and his co-laureate, Vladimir Prelog;

- 'Innovation, driven by curiosity, the desire to find out something new, is one of the fundamental attributes of mankind. We did not go to the Moon because of wisdom, but because of curiosity. This is part of human instinct, it is true for all civilizations, and is unavoidable'[745] by Carlo Rubbia, The 1984 Nobel Laureate in Physics for the 'decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction' in the field of experimental particle physics;[746]

- 'I think a very big curiosity [drove me into science]. I'm very curious and I like to understand things and not only science but also other things where I just try to find out why things work or how things work. Science and nature caught my attention'[747] by Christiane Nüsslein-Volhard, The 1995 Nobel Prize in Physiology or Medicine for the 'discoveries concerning the genetic control of early embryonic development;'[748]

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743 Nobel Prizes and Laureates, John Cornforth's speech at the Nobel Banquet, December 10, 1975, *Nobelprize.org*; retrieved on 25.05.2017 from the Web, http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1975/cornforth-speech.html.

744 The Nobel Prize in Chemistry 1975, John Cornforth, Vladimir Prelog, John Cornforth – Facts, *Nobelprize.org*; retrieved on 25.05.2017 from the Web, https://www.nobelprize.org/nobel_prizes/chemistry/laureates/1975/cornforth-facts.html.

745 Catapano, Paola, 2014, Carlo Rubbia: A Passion for Physics and A Craving for New Ideas, 23 September, *CERN Courier*; retrieved on 25.05.2017 from the Web, http://cerncourier.com/cws/article/cern/58540.

746 The Nobel Prize in Physics 1984 Carlo Rubbia, Simon van der Meer, Carlo Rubbia - Facts, *Nobelprize.org*; retrieved on 25.05.2017 from the Web, https://www.nobelprize.org/nobel_prizes/physics/laureates/1984/rubbia-facts.html.

747 The Nobel Prize in Physiology or Medicine 1995, Edward B. Lewis, Christiane Nüsslein-Volhard, Eric F. Wieschaus, 2003, Transcript from an interview with Professor Christiane Nüsslein-Volhard, Nobel Laureate Physiology or Medicine 1995, at the 53rd meeting of Nobel Laureates in Lindau, Germany, 30 June-4 July 2003. Interviewer is freelance journalist Marika Griehsel, *Nobelprize.org*; retrieved on 25.05.2017 from the Web, https://www.nobelprize.org/nobel_prizes/medicine/laureates/1995/nusslein-volhard-interview-transcript.html, hereafter referred to as Nüsslein-Volhard.

748 The Nobel Prize in Physiology or Medicine 1995, Edward B. Lewis, Christiane Nüsslein-Volhard, Eric F. Wieschaus, *Nobelprize.org*; retrieved on 25.05.2017 from the Web, http://www.nobelprize.org/nobel_prizes/medicine/laureates/1995/.

- ‘People go into science out of curiosity, not to win an award’[749] by Venkatraman Ramakrishnan, President of the Royal Society, Fellow of Trinity College, Cambridge, and the 2009 Nobel Prize Laureate in Chemistry for ‘for studies of the structure and function of the ribosome.’[750]

[749] Nobel Prizes and Laureates, The Nobel Prize in Chemistry 2009, Venkatraman Ramakrishnan, Thomas A. Steitz, Ada E. Yonath, Venkatraman Ramakrishnan – Biographical, From Chidambaram to Cambridge: A Life in Science, *Nobelprize.org*; retrieved on 25.05.2017 from the Web, https://www.nobelprize.org/nobel_prizes/chemistry/laureates/2009/ramakrishnan-bio.html.

[750] Nobel Prizes and Laureates, The Nobel Prize in Chemistry 2009, Venkatraman Ramakrishnan, Thomas A. Steitz, Ada E. Yonath, Venkatraman Ramakrishnan – Facts, *Nobelprize.org*; retrieved on 25.05.2017 from the Web, https://www.nobelprize.org/nobel_prizes/chemistry/laureates/2009/ramakrishnan-facts.html.

Appendix L Life and Legacy of Pyotr Kapitsa

Pyotr Kapitsa was a Soviet and Cambridge physicist and an engineer, the 1978 Nobel laureate in Physics 'for his basic inventions and discoveries in the area of low-temperature physics.'[751] In the 1930s-70s, Kapitsa wrote his letters to the Kremlin, around 50 out of which were addressed to Stalin, Khrushchev and Brezhnev, and 250 to other policy-makers and some of Kapitsa's international colleagues. The most significant of them were published in 1989 in Russian[752] and a year later in English.[753] Possibly due to the collapse of the Soviet Union, these letters, which influenced the Soviet political leadership, have not yet been addressed considerably in academic literature. Kapitsa was also a widely known public figure for his speeches and public lectures for a general audience.

As mentioned in chapter 4, Kapitsa arrived in Cambridge in 1921 as a member of an official Soviet delegation in the time when Russia was in the end of the Civil War. Despite the scarcity of the funds available, the Bolsheviks were very keen in the execution of their policy of the development of science and education.

Afterwards, Kapitsa travelled annually between England and the USSR until he was detained in Moscow to work for his country in 1934. The rapid change of his lifetime and traveling plans was interpreted in British and international newspapers as forceful. However, studying Kapitsa's correspondence[754] with his mother as well as with his superior and the head of the Cavendish laboratory, Professor Ernest Rutherford, allowed stating that Kapitsa was intending to do this at a certain stage of his life. He rather possibly objected the manner, in which the detention had been performed, than the decision itself.

According to *A Hundred and Forty Talks with Molotov: from Chuev's Diaries*, Vyacheslav Molotov recalled that it was one who initiated the process to detain Kapitsa in the USSR which was accepted by Kapitsa with neither enthusiasm nor dissatisfaction. What is curious in this story is that the idea, according to Molotov, came to him from the academician and

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[751] Nobel Prizes and Laureates, The Nobel Prize in Physics 1978, Pyotr Kapitsa, Arno Penzias, Robert Woodrow Wilson, *Nobelprize.org*; retrieved on 23.04.2017 from the Web, https://www.nobelprize.org/nobel_prizes/physics/laureates/1978/.
[752] Kapitsa I.
[753] Compiled and edited by Boag, J.W., Rubinin, P.E., and Shoenberg D., 1990, *Kapitza in Cambridge and Moscow, Life and Letters of a Russian Physicist*, North Holland; hereafter referred to as Kapitsa II.
[754] Kapitsa I.

physiologist Ivan Pavlov, the 1904 Nobel laureate in Physiology or Medicine,[755] who was known for his anti-Soviet position but who managed to place the strategic national interests above his hostility towards the ruling regime.[756] The final decision was made by Josef Stalin, after a special meeting of the *Politburo* on Kapitsa. Stalin gave an order by a telegram from Sochi on 21 September 1934 to detain Kapitsa in the Soviet Union.[757]

Meanwhile, the best indicator of Kapitsa's real intention to return to his home country could be the fact that even after living in England for 13 years and becoming a Fellow of the Royal Society, he had retained, against all the odds, his Soviet citizenship. Although in his wife Anna's recollections, she stated the opposite about Kapitsa's personal feeling of his forceful return to the USSR, one could assume that he was rather unhappy about the particular manner in which his return happened than, perhaps, the true nature of the event itself. Here is how Anna Kapitsa described their family's difficulties concerning the Soviet citizenship:

> I knew Pyotr Leonidovich' [Kapitsa's] true feeling and knew that he could never stay in England forever, tearing away from his motherland. The fact that during all the years in England he remained a Soviet citizen was strongly troubling for everything, starting from the London Royal Society and including all our life in Cambridge. They approached him for a countless number of times, saying that it was inconvenient. And for Rutherford it was an act of bravery to have, support in any way and promote the Soviet citizen.[758]

While in Cambridge, for his research Kapitsa had designed and launched The Mond Lab, opened with pomp by Stanley Baldwin, a former (and the next) British Prime-Minister,[759] in February 1933, which was purchased by the Soviet Government after Kapitsa's return in

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[755] Nobel Prizes and Laureates, The Nobel Prize in Physiology or Medicine 1904, Ivan Pavlov, *Nobelprize.org*; retrieved on 04.06.2017 from the Web, http://www.nobelprize.org/nobel_prizes/medicine/laureates/1904/.

[756] Chuev, Feliks, 1991, *Sto sorok bessed s Molotovym: iz dnevnika Chueva* (*A Hundred and Forty Talks with Molotov, from Chuev's Diaries*), Moscow, Terra, 459; hereafter referred to as Chuev.

[757] Kapitsa E.,L., Rubinin P., E., 2005, *Dvadtsatyi vek Anny Kapitsy, Vospominaniya, pis'ma* (*The Twentieth Century of Anna Kapitsa, Memoirs, Letters*), Agraf, Moscow; retrieved on 19.06.2017 from the Web, https://unotices.com/page-books.php?id=118830; hereafter referred to as Anna Kapitsa.

[758] *Ibid.*, 14.

[759] Stanley Baldwin was three times PM between 1923 and 1937; The Editors, 2018, Stanley Baldwin, Prime Minister of United Kingdom, 30 July, *The Encyclopaedia Britannica*; retrieved on 07.08.2018 from the Web, https://www.britannica.com/biography/Stanley-Baldwin.

1934.[760] In 1936 it was already delivered and assembled at the Institute for Physical Problems, especially established earlier in Moscow in 1934 for Kapitsa to run and to become what is now the P.L. Kapitza Institute for Physical Problems.[761] The fact of the purchase of this high-tech lab as well as the speed with which this process happened evidently indicated that during 'the irreconcilable struggle between socialism and imperialism' (Stalin) the leadership of two nations was driven by more pragmatic needs than the ideological rhetoric.

According to Chitre, Lord Adrian, the 1932 Nobel Prize recipient in Physiology,[762] stated in his later lectures at Cambridge that he had been actively involved in the lab's transfer.[763] Pyotr Kapitsa mentioned Adrian's involvement in his letter to Anna. Adrian was in Leningrad and Moscow, taking part in the XV International Congress of physiologists (1,500 scientists from 37 countries, August 1935) and brought a message from Kapitsa to Cambridge.[764] The fact of the Congress is also worth highlighting in the light of the unity of Soviet science with global development and the main principles of science able to develop in open academic exchange.

Regarding Kapitsa's return in the USSR and the transfer of the Mond lab from Cambridge to Moscow in the 1930s, Littlewood pointed out that there was a very stressful situation associated with Kapitsa:

> In Cambridge and with Cavendish he was obviously a brilliant scientist and innovated enormously in Cambridge. When he went back to the Soviet Union under pretty complicated circumstances, there was even an understanding that his colleagues in Cambridge should not publish things ahead of him. There are these famous stories about helium which he clearly had worked on, understood superfluid helium and really made major discoveries there, which were brilliant but was unable to publish that work in a hurry and his British colleagues stepped back from publishing their own results to allow him to get credit. As a personal character, he was a very major one as an individual, in

[760] Kapitsa I; in particular 1 and 83, a photograph is available in the Web (retrieved on 07.08.2018), https://profilib.net/chtenie/78176/petr-kapitsa-pisma-o-nauke-1930-1980-lib-83.php.
[761] Pyotr Leonidovic Kapitza, *The P.L. Kapitza Institute for Physical Problems*; retrieved on 26.06.2017 from Web, http://www.kapitza.ras.ru/history/PLKapitza/main.html.
[762] Adrian.n
[763] Chitre.
[764] The letter to Anna on 19 August 1935 from Moscow, Anna Kapitsa.

> fact, in establishing this new field. It has often been individual Soviet scientists who occupied sort of a very strong place in building these bridges one way or the other.[765]

According to Littlewood, there were contacts all of the time, and it was recognised by those people who were smart on both sides that having the scientific connexions would have built fabric which would enable collaborations to come in better times politically.

As outlined by him, superfluidity and superconductivity are not very visible in terms of technology, however, every MRI magnet has superconducting coils in it. Some of these technologies are hidden behind all of this. Littlewood thinks that the biggest impact of all of that stuff is conceptual. He is looking forward to another generation to start to build technologies out of magnetism and quantum systems. He has reasons to believe, that this is beginning to emerge in an unknown yet way. However, the flow from understanding superfluidity to the understanding of superconductivity to Bose condensation of cold atoms to lasers to eventually to the manipulation of quantum mechanics is an unbroken thread.

According to Littlewood, at the CERN magnet, this circle, a tube, operates on Bose superconductivity and [Kapitsa] superfluidity. They need superfluid helium to cool as well. Superfluidity in many ways is an extraordinary concept, which opens a scientific mind to the possibility of collective phenomena and thinking about collective phenomena in a very different way than one would have done. The big idea, which comes out of something like superconductivity is that of emergence. Superfluidity is that atoms are put together, and collectively the sum is qualitatively different from the parts.

Upon Kapitsa's return, in parallel to his academic activity, Nikolay Gorbunov, who was in charge of the SAS' administrative affairs, appointed Kapitsa to be responsible for the technical provision for the SAS, having immediately identified his managerial ability. In addition, the appointment was needed by Kapitsa to be accommodated in the new Soviet working environment among his colleagues, who were, sometimes, not very friendly to the newcomer. Gorbunov was a prominent hereditary engineer, and, more importantly, a former secretary to Lenin, as described by Pavel Rubinin, a long-term secretary to Kapitsa.[766] Gorbunov's position as the Secretary to the SAS is another evidence of that high role which

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[765] Littlewood.

[766] Rubinin, P. E., 1994, *Svobonyi Chelovek v Nesvobodnoi Strane* (Free Man in Not Free Country), *Vestnik Rossiyskoi Akademii Nauk*, Volume 64, N6, 508.

was given to science in Soviet policy-making considering the overall weight anything related to Lenin's figure had had.

Regarding Kapitsa's correspondence, it would be interesting to note about the direct feedback Kapitsa received from Stalin which was mentioned by Eremenko in chapter 3. Kapitsa was sent two letters from Stalin, acknowledging the receipt of all the correspondence and encouraging him to continue it. In a telephone conversation, Malenkov, the Communist Party's secretary, summoned the academician for more letters to be written for Stalin and the Government. In one of his letters Stalin says:

> From Stalin. Moscow 4 April 1946.
> Comrade Kapitza, I have received all your letters. There is much that is instructive in them and I should like to meet you at some time to have a chat.[767]

It should be added that, during the campaign of the political purges in 1937-8, Kapitsa revealed a high level of personal courage in communicating directly with Stalin and Molotov to save from prison both physicist Lev Landau,[768] a future laureate of the 1962 Nobel Prize in Physics 'for his pioneering theories for condensed matter, especially liquid helium,'[769] and physicist Vladimir Fock,[770] who eventually became known 'for his seminal contributions in quantum mechanics and the general theory of relativity.'[771]

Also, some of Kapitsa's letters helped resolve particular problems and apply the administrative resources for this.[772]

In particular, in a long letter to Molotov,[773] which described the process of the creation of liquid oxygen, the method discovered by Kapitsa himself, he stressed the rise of productivity to be achieved in all the factories, in which turbines could be used, with the

[767] Kapitsa II, 378.
[768] Kapitsa, 1938 and 1939, Letters to Stalin, Molotov and Beria on 28 April, as well as on 6 and 26 April accordingly, *Ibid.*, 348-50.
[769] Nobel Prizes and Laureates, The Nobel Prize in Physics 1962, Lev Landau, *Nobelprize.org*; retrieved on 04.06.2017 from the Web, *Nobelprize.org* https://www.nobelprize.org/nobel_prizes/physics/laureates/1962/.
[770] Letters to Mezhlauk and Stalin on 12 February 1937, Kapitsa I, 124-7.
[771] Kojevnikov, Alexei, 2008, Vladimir Aleksandrovich Fock, Russian Mathematical Physicist, *Encyclopaedia Britannica*; retrieved on 04.06.2017 from the Web, https://www.britannica.com/biography/Vladimir-Aleksandrovich-Fock.
[772] For example, the following letter out of many similar ones, i.e., A Letter to Stalin, 25 Nov 1945, Kapitsa I, 237-48; Kapitsa II, 372-78
[773] A Letter to Molotov, 20 April 1938, Kapitsa I, 165-74.

new machine designed for oxygenation. This machine was two times cheaper than its German analogue. Although Kapitsa believed that patents did not contribute to development, he emphasised the need to patent this particular technology. This letter gave a start to an intensive correspondence on this subject with Stalin and others, which lasted for years. As a result of this first single letter, a special workshop was designed at a plant in Moscow by Molotov's order to test the technology,[774] and the patent work began. In later years this move brought a stream of patent revenues from abroad.[775]

What is more significant, this method of oxygenation was used industrially in WWII and saved the lives of hundreds of thousands of wounded Red Army soldiers in war hospitals, when Kapitsa was head of an official body, *Glavkislorod* (Department of Oxygen Industry), practically in the rank of minister.[776]

According to Lonzarich, he had 'the great pleasure of interacting with Kapitsa on the latter's occasional visits to Cambridge and 'ha[s] heard a great deal about him from [his] mentor David Shoenberg, who was one of Kapitsa's first students. Kapitsa will be forever known for his fundamental discovery of superfluidity in liquid helium, but this was only a part of his overall outstanding contributions to science and technology, which has been widely reported and celebrated in the literature.'[777]

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[774] Kapitsa I, 189.
[775] A Letter to Vavilov, 23 May 1948, *Ibid.*, 280.
[776] Pyotr Leonidovic Kapitza; retrieved on 26.06.2017 from the P.L. Kapitza Institute for Physical Problems Web Site, http://www.kapitza.ras.ru/history/PLKapitza/main.html.
[777] Lonzarich.

Appendix M Science Policy Advising by Bush and Kapitsa

Vannevar Bush was an electrical engineering Professor from the Massachusetts Institute of Technology (MIT), in addition to being in different years the first scientific advisor to the American President, F.D. Roosevelt, the chairman of the Office of Scientific Research and Development (OSRD), the National Defense Research Committee (NDRC), the National Advisory Committee for Aeronautics (NACA), which would be in later years transformed into the National Aeronautics and Space Administration (NASA), as well as a coordinator and initiator of the Manhattan Project, who prepared in 1945 his report to the American President, *Science, The Endless Frontier*,[778] mentioned by Tsironis in chapter 3.

Bush articulated the vitality of basic research, also-called pure, or fundamental research, for a nation in the following famous statement:

> Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science. Today, it is truer than ever that basic research is the pacemaker of technological progress. [...] *A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill.*[779]

For example, if comparing Bush's statement from above on the significance of science, with one from Kapitsa's letter to a Soviet leader, Nikita Khrushchev, with whom Kapitsa continues the succession of the correspondence with Stalin, one can read the following: 'Really advanced science, by studying the laws governing the natural world around us, will search for and create fundamentally new avenues for the material and spiritual development of society.'[780] The same idea, in another statement by Bush, is formulated as follows:

[778] Bush.
[779] *Ibid.*, cited from Bush, Vannevar, Science: The Endless Frontier, Lynchburg College Symposium Readings, Classical Selections on Great Issues, 1997 Edition, *Volume VIII. Science, Technology and Society*, University Press of America, 20; hereafter referred to as Lynchburg College. The emphasis is in the original.
[780] Kapitsa II, 400.

> Pure research is research without specific practical ends. It results in general knowledge and understanding of nature and its laws. This general knowledge provides the means of answering a large number of important practical problems, though it may not give a specific solution to any one of them. The pure scientist may not be at all interested in the practical applications of his work; yet the development of important new industries depends primarily on a continuing progress of pure science. One of the peculiarities of pure science is the variety of paths which lead to productive advance.[781]

Both of them propagated the primacy of fundamental research in modern technological development as the only way to new knowledge and the provision of scientific capital as 'the fund from which the practical applications of knowledge must be drawn' (Bush) which 'studying the laws governing the natural world around us, will search for and create fundamentally new avenues for the material and spiritual development of society' (Kapitsa) citing from their statements above.

According to them, pure research is the basis of technological progress which provides the nation 'its competitive position in world trade, regardless of its mechanical skill' (Bush). In this process, the nation benefits from scientific activity studying nature's laws with no quest for any practical and immediate solutions.

The scientists' unity in their views can be outlined in the following principles vital to the development of science. Firstly, it is the importance of the international contacts needed for the scientific development as well as that of the reduction of both the secrecy and dependency on international patenting to a minimal level, as expressed in a letter from Kapitsa to Niels Bohr.[782] Similarly Bush expressed the importance of internationalism for scientific development in the following: 'The Government should take an active role in promoting the international flow of scientific information.'[783] He relentlessly called for revising the policy on the secrecy in the post-war reality as well as for re-establishing international contacts, above all, with the Soviet Union[784] in order 'to secure a high level of

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[781] Bush, 81.
[782] Kapitsa I, 236. Although the letter is addressed to Niels Bohr, a fellow Danish physicist, it is well-worth to remember that this correspondence was not only read but also approved by the top officials of the USSR as one related to the creation of the Soviet Atomic Bomb.
[783] Bush, 22.
[784] *Ibid.*, xiv.

employment, to maintain a position of world leadership – the flow of new scientific knowledge must be both continuous and substantial.'[785]

Secondly, it is the exclusion of the national industrial development from the dependence on foreign technology as seen from Bush's statement on the nation's mechanical skills above. This idea was expressed by Kapitsa in the correspondence with Malenkov,[786] Molotov, and Stalin. It would be interesting to note that the latter read the letter to Molotov prior to receiving it separately and he as evident forced Molotov behind the scene to continue the interaction with the scientist, which would become very fruitful. Meanwhile, Kapitsa wrote to Stalin in December 1936 regarding the trap of the technology transfer: 'All our industrial development is based on the takeover of the foreign experience. […] I should say directly, that with regard to the progress of science and technology we are the full colony of the West.'[787]

The scientist emphasised the importance of the development of the indigenous school of science and technology in order to reduce dependence on the 'capitalistic countries,' to have an ability to progress, and illustrated this with the example of a large, albeit unnamed, British company he used to consult and which used to receive equipment from the USA. He explained how a team of researchers and engineers was put together to understand the new technology in order for the company to have the freedom to develop. Thus, Kapitsa explained, once the technology was transferred, if properly understood, it could be developed without further dependence on the transfer. Otherwise, according to him, the situation would resemble a high school in which the students were taught to swot up on the subject having their ability to think and innovate suppressed.

One can compare these statements with the two following and similar citations of Bush's report, the one at the beginning of this piece above and this one:

> First, the intellectual banks of continental Europe, from which we formerly borrowed, have become bankrupt through the ravages of war. No longer can we count upon those sources for fundamental science. Second, in this modern age, more than ever before, pure research is the pace-maker of technological progress. […] In the next generation, technological advance

[785] *Ibid.*, 10.
[786] A letter to Malenkov, 26 June 1946, Kapitsa I, 268.
[787] Kapitsa I, 121.

> and basic scientific discovery will be inseparable; a nation which borrows its basic knowledge will be hopelessly handicapped in the race for innovation.[788]

Thirdly, it is the reliance of the local cadres and the national technology in development in order to become a truly advanced country, as addressed by Kapitsa in letters to both Stalin and Molotov,[789] and in Bush's report on the deficit of the local human capital and able students.[790]

Fourthly, it is the application of the efforts from the state for the promotion of the importance of science for the whole process of the development for the masses to understand and take part in the process. Kapitsa wrote to Stalin in 1937, aiming at the state to undertake the following actions: i) similar to the policy, existing in Britain, to launch the organisation of museums and exhibition of science; ii) to promote science and progress through the film industry; iii) to organise an appropriate popular literature and scientific lecturing; iv) to encourage and develop scientific journalism; v) to popularise science in high school.[791] All the large funds allocated for this purpose, according to Kapitsa, 'would be repaid in ten or fifteen years by a rise in a whole level of science in the Soviet Union.'[792]

Bush also emphasised the importance of promotion of science for the nation[793] in multiple statements throughout his report, including this one: 'The general public is still far from a true understanding of the nature of basic research and of the fundamental difference between science and technology,'[794]

or the following one:

> We therefore urge that the Federal Government take a more active interest in promoting scientific research, and in assuring that the Nation gain there – from the benefits of increased security and increased welfare. We are convinced that the most effective way for the Federal Government to serve

[788] Bush, 78-9.
[789] A letter to Stalin, 25 Nov 1945, Kapitsa I, 239, and A Letter to Molotov, 6 April 1943, Kapitsa I, 118.
[790] Just two indications out of many others, Bush, 26, 74.
[791] A Letter to Stalin, 10 July 1937, Kapitsa I, 135-43.
[792] Kapitsa II, 342.
[793] Bush, 26, 74 and throughout the report.
[794] Waterman, Alan T., 1960, Introduction, Reissue, Bush, Vannevar, 1945, *Science, the Endless Frontier*, National Science Foundation, Washington DC, ix; hereafter referred to as Waterman.

> these purposes is to provide to our educational institutions and research institutes support for basic research and training for research. By so doing, the Government will increase the flow of new knowledge and the supply of young scientists trained in research. It is on this new knowledge that applied science must build, and it is from the ranks of those trained in research that the leaders in applied science must come.[795]

It would be interesting to observe that Bush pointed out, unlike the state of affairs in the Soviet Union, the lack of an American

> national policy for science. The Government has only begun to utilize science in the Nation's welfare. There is no body within the Government charged with formulating or executing a national science policy. There are no standing committees of the Congress devoted to this important subject. Science has been in the wings. It should be brought to the center of the stage—for in it lies much of our hope for the future.[796]

Fifthly, Kapitsa relentlessly stressed the importance of both the creation of special comfortable living and working conditions for scientists as well as that of the increase of the scientists' social status. In 1935 he complained in a letter of 14-16 February to his wife, that '[t]here is no respect to original scientific thinking here at all. The title of either Professor, or Academician is not respected.'[797] In his letters to Stalin in 1937 Kapitsa emphasised the need for, apart from material conditions, 'a creative productive element,' i.e. an ecosystem, to be created for scientists and engineers to come from.[798] However, ten years later (this period included four years of the devastating war), in 1946 Kapitsa thanked Stalin for rapidly increasing an average monthly wage for the Soviet professorship. It reached 9,000 rubles (5,000+4,000) which allowed the scientists to work and live without being 'being distracted for anything but science.'[799]

Bush was also caring about the material provision for the American scientists. However, in the different conditions of the American economic reality, it was expressed in the need to

[795] Bush, 74.
[796] *Ibid.*, 12.
[797] Anna Kapitsa.
[798] A Letter to Stalin, December 1936 – January 1937, Kapitsa I, 120-4.
[799] A Letter to Stalin, 10 March 1946, Kapitsa I, 251-3.

increase the number of scholarships for science undergraduates and graduate fellowships.[800] Bush particularly emphasised that '[i]f ability, and not the circumstance of family fortune, is made to determine who shall receive higher education in science, then we shall be assured of constantly improving quality at every level of scientific activity.'[801]

Sixthly, it is the reduction of the bureaucratic pressure to zero and the increase of the academic freedom as described by Kapitsa to Stalin in the USSR.[802] The same universal idea important for science was expressed by Bush in the following statement: 'Scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown. Freedom of inquiry must be preserved under any plan for Government support of science.'[803]

Seventhly, both of the enlighteners in their calls to their national leaders, Stalin and Roosevelt, summoned for special attention to education in science and engineering. In particular, Kapitsa was known for his contribution to this field in founding one of the leading Soviet higher educational institutions, *Phystech*, or MFTI, The Moscow Institute of Physics and Technology,[804] in 1951, whose quality of education was emphasised by Paltashev in chapter 3.

Meanwhile, its principles were described by Kapitsa in his letter to Stalin in 1946. Quite remarkably and due to Kapitsa's affiliation with Cambridge, they resemble those of this university. These distinguishing principles were characterised with the following. The teaching process of students by researchers should be performed on the individual basis on the latest equipment with the involvement of the students from years 2 and 3 into the scientific research activity, which would allow them upon graduation 'to possess modern methods of theoretical and experimental research and to have sufficient engineering knowledge to resolve technical tasks.'[805]

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[800] Bush, 7-8.
[801] *Ibid.*, 25.
[802] A Letter to Stalin, 10 March 1946, Kapitsa I, 251-3.
[803] Bush, 12.
[804] MFTI.
[805] Kapitsa, Sergey P., ed. Kapitsa, E.L., Balakhovskaya T., 2008, *Moi Vospominaniya* (*My Memoirs*), ROSSPEN, 145

In parallel, Bush indicated the importance of the government to concentrate its efforts on the formation of education on the purpose of basic research[806] and described this philosophy in the following way:

> Several factors combine to emphasize the appropriateness of universities for research. The university as a whole is charged with the responsibility not only of maintaining the knowledge of the past and imparting it to students but of contributing to new knowledge of all kinds. The scientific worker is thus provided with colleagues who, though they may represent widely differing fields, all have an understanding and appreciation of the value of new knowledge, […] much of which can arouse opposition because of its tendency to challenge current beliefs and practices.[807]

[806] Bush, 74.
[807] *Ibid.*, 90.

Appendix N Replies to Chokan Laumulin's Questionnaire for a PhD thesis

by Gilbert G Lonzarich, Cambridge, 26-05-2017

1. Often these days, in both mass media and conventional economic thought, the role of fundamental science is not viewed in connection with economic development. As a scientist, do you have an opinion on this?

Reply. There is a large body of evidence supporting the view that fundamental science often leads to technological applications. This is especially true for the fields of condensed matter physics, materials science and metallurgy, chemistry, biology and, indeed, all of the "higher" sciences. Some of the research in more fundamental areas such as particle physics, astronomy and cosmology may appear to be more remote from applications. However, the ideas that have arisen in such fields have found applications in producing ways of thinking and mathematical techniques that can be applied to the higher sciences. There are also spin-off developments in these more fundamental areas of research that have changed industry in many ways.

The goal of basic research is to develop theoretical frameworks that not only allow us to understand or interpret observed phenomena, but, perhaps more importantly, that allow us to make reliable predictions. These predictions are not only essential in the design and development of our industries, but they are also invaluable in guiding us to new discoveries in a never-ending process of scientific evolution.

It is possible that many individuals have failed to recognise the role of fundamental research because many years of development are often required to bring a new scientific idea into the engineering fields. It is easier to see the links that exist between engineering and our economy than the links that exist between fundamental science and industry.

2. In your view, do fundamental science and engineering relate to each other?

Reply. These two areas are deeply interconnected. Fundamental science leads to ideas that are eventually taken up in engineering areas and in a similar way engineering developments lead to advances taken up in fundamental science. For example, the discovery and understanding of superconductivity led to the development of highly powerful magnets that are now being used in medical imagers throughout the world (to name only one of many applications). Moreover, this engineering development has led to the construction of the giant supercollider such as that at CERN that has changed our understanding of the universe (recently via the discovery of how the mass of particles and indeed of every known object in the world has arisen). This is an example of the interconnectedness of fundamental science and engineering – in short, one feeds off the other and vice versa.

3. In my abstract above I conjecture that science drives the process of industrial development. In your opinion, how do discoveries in fundamental science lead to disruptive and marketable technologies?

Reply. I have attempted to answer this question under 1 above. However, I can add an example out of a vast number for your interest. Fundamental research into the nature of electricity led to the discovery in Cambridge and elsewhere of the existence of the electron that lies behind many physical, chemical and biological processes. This discovery involved the invention of the electronic valve also known as the vacuum tube, which gave us radio, television, radar and more. Soon after came the discovery of the quantum nature of matter. This in turn led to the invention of the transistor, which replaced the electronic valve and brought us the telecommunications and computer age. All of this arose from fundamental research discoveries and their theoretical understanding.

It is astonishing to those who are familiar with the history of science and technology that there should be a lack of greater awareness of the monumental contributions that fundamental research has made to our society.

4. Would you agree or disagree that the main process that leads to the sustainable technological development of large developed countries (or companies) is clearly linked to a strong fundamental science research base?

Reply. I would unconditionally agree. My reasons have been stated above.

5. Today economic planners and management schools strongly believe in (and teach) the notion that science is a product of the Market and discoveries in science are driven by market demand (search for practical and profitable solutions). In other words, scientific discoveries

result mainly from the pursuit for profit and efficiency. To what degree would agree or disagree with this notion?

Reply. It is likely that small-scale invention and development are driven by market demand, but that truly major scientific developments arise through a different process. This may not be fully understood but it involves the scientists' natural curiosity to explore and understand the natural world. A realistic view might be that the funding bodies are primarily motivated by economic or political needs, while scientists are primarily motivated by other factors that may be difficult for the funding bodies to understand. In order to maximize productivity it may be crucially important that the planners have a realistic understanding of what actually motivates research scientists themselves.

6. Do you think that today's digital informational revolution has speeded up the process?

Reply. An obvious advantage of the information revolution is that scientists are now able to access publications instantly and remain up to date with developments in their field. Another advantage is the ease with which researchers can communicate with each other across the world. This has led to the development of something like a collective mind that has no parallels in history. This integration of the scientific community might, however, hinder the independent development of ideas. This is not unavoidable because researchers have the option to turn off the links if they wish to do so to enable them to develop their own thinking independently. The main obstacle to this independent development is that academic institutions and funding bodies tend to favour individuals who are closely integrated within the international community. The age of the lone explorer and inventor may therefore be at an end.

7. The following questions are dedicated to the Soviet industrial development, and the first one I would like to ask you, if possible, is as follows: to what extent was the Soviet technological development different to those of other developed countries, if true? Were there any substantial differences to the US, Western European, Japanese or any other approaches in dealing with the S&T development?

Reply. I have insufficient information to provide a helpful reply.

8. In your opinion, how crucial was technology transfer for the Soviet industrial development?

Reply. As above.

9. What is a Soviet science and technology contribution to global technological development?

Reply. Soviet science and technology has brought us the space age. This is a monumental contribution not only to the history of civilization, but that of life on earth itself. In general, the Soviet Union invested heavily in both fundamental science and technology and has many contributions of worldwide importance. I am particularly aware of contributions in metallurgy and materials science and in theoretical physics, particularly in the field of superconductivity. The theories that we use in practice in the field of superconductivity depend heavily on the seminal works of Soviet scientists. I personally use Soviet theoretical inventions on a regular basis.

10. In terms of any country's technological development, what do you think of the idea to rely solely on technology transfer without developing its own science and technology base?

Reply. Technology transfer is always desirable unless its effect is to permanently restrict the development of the nation's own science and technology base. Without such a base, it seems likely that a nation would be destined to remain in a subordinate position. This will lead to a state of mind that will prevent the nation's unique genius from flourishing. It is easy to understand that the dominant powers would wish smaller nations to remain in a subordinate position.

11. Another question is, when talking about technological development about an opinion which is getting more widespread, especially in the countries which are not so developed. Policy makers often defend the idea of technology transfer – 'Why would we need to fund this development, it requires structural reforms, both educational and social, when it would be simpler to achieve economic success through technology transfer?' What would you say?

Reply. This is the advice that seems likely to be given by some who wish to ensure that subordinate status will become permanent. The arguments may seem convincing at first sight, but they are likely to lead to the "road to serfdom".

12. In my research the figure of Pyotr Kapitza occupies a central place. What do you think of his contribution to global science and technology?

Reply. I had the great pleasure of interacting with Kapitza on his occasional visits to Cambridge and I have heard a great deal about him from my mentor David Shoenberg, who was one of Kapitza's first students. Kapitza will be forever known for his fundamental discovery of superfluidity in liquid helium, but this was only a part of his overall outstanding contributions to science and technology, which has been widely reported and celebrated in the literature.