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Science, Technology, and Modernity

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Introduction

This year marks the 500th anniversary of the Reformation, specifically of Martin Luther nailing his 95 theses to the door of the church in Wittenberg. There can be no doubt that the Reformation had a profound and long-term impact on European civilization. Will there be agreement 400 years from now that Lenin's April Theses precipitated an event of world-historical significance?

That question is of course impossible to answer. This year's muted commemoration of the 100th anniversary of the October Revolution suggests the answer "no." After all, communist rule collapsed. But the reticence could mean different things: a passing desire to forget the Revolution; current uncertainty about how to commemorate it; a feeling that the collapse of communism has so far led to disappointing results. Whatever the explanation, this silence is both strange and troubling. The October Revolution was one of the most significant events of the 20th century, and we need to try to make sense of it and its consequences. What remains of communism; what is its legacy in the 21st (if not the 25th) century?

My topic is science, technology, and modernity. Science and technology occupy an important place in the history of all modern states, but their role was particularly significant in the Soviet case. Science and technology were integral to the Soviet claim to offer a vision of modernity that was superior to that of capitalism. Not only would science and technology flourish in the USSR, the Bolsheviks claimed; the Soviet system itself was consciously constructed on the basis of a scientific analysis of history.

Marx and Engels aimed to create a scientific account of the historical development of social formations, and their analysis of capitalism led them to the conclusion that it would be

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overthrown by a revolution in which the working class would come to power and create a new kind of society. The Bolsheviks maintained that they were guided in their actions by science (scientific socialism), not by unachievable ideals (utopian socialism). This was an important part of their claim to rule. It was of course social science they had in mind, not natural science; but the Russian term (*nauka*), like its German equivalent (*Wissenschaft*), covers both. Marxists – Engels and Lenin are notable among them – went to considerable efforts to demonstrate the continuity between social and natural science in terms of methodology (*the dialectic*) and philosophy (*materialism*). (See especially Engels's *Anti-Dühring* and Lenin's *Materialism and Empirio-criticism.*) Science and technology were integral to the Bolsheviks' claim to offer a vision of modernity that would transcend capitalism. They presented themselves as the true heirs to the Enlightenment project of applying reason to human affairs.

"Modernity" is a concept with many definitions. I use it loosely here to denote a society that is urban and industrial and committed to scientific-technical progress. "Modernity" has the advantage that it does not automatically set the Soviet experience to one side. This is important, because the categories in which we discuss Communism – Marxism-Leninism, or totalitarianism, for example – often emphasize that communism, or the Soviet experience, is something distinct from, opposed to, or wholly separate from, capitalism or democracy. This leads to a tendency to see the Soviet experience as sui generis; as something irrelevant to our concerns today. A lecture on science and totalitarianism, for example, might focus on the Lysenko affair. Important though that was, there is much more to talk about. That is why I have introduced the term "modernity" into the title of the lecture.

Did the Soviet Union develop a distinctive science and technology? Was the Soviet Union a technocracy? Did science flourish in the Soviet Union? What conclusions can one draw from the Soviet experience about science and technology? What conclusions can one draw from science and technology about the Soviet experience? Did Communism leave a distinctive mark on science and technology?

Technology and the Soviet state

Marxists foresaw that socialism would emerge from the contradictions of capitalism, and that it would inherit, and build upon, the science and technology generated by capitalism. But Soviet Russia, the first socialist state, found itself isolated, confronting a hostile world that was economically and technologically more advanced. When the prospect of revolution in Europe faded, the Soviet Union assumed the task of building "socialism in one country." In the late 1920s, as it launched its industrialization drive, it adopted the slogan of "catching up and overtaking the advanced capitalist countries in an economic and technological respect." Stalin spoke, in 1931, of Russia's traditional backwardness, and of its suffering at the hands of its enemies. "We are fifty or a hundred years behind the advanced countries. We must make good this distance in ten years. Either we do it, or they crush us."

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In the first place, catching up meant importing foreign technology. During the first FYP (1928-1932) machinery and plant were imported on a large scale. Later the Party emphasized the development of indigenous technology. That put a heavy responsibility on the scientists and engineers who had promised in the 1920s that investment in science would produce wonderful results. Abram Ioffe, director of the leading Soviet physics institute in the 1920s, had declared: "physics is the basis of socialist technology." Such claims had been easy to advance when economic recovery meant little more than the restoration of an economy destroyed by war. They were a more serious matter once the Party began looking to science to help it achieve the enormously ambitious goals it had set for the economy.

The 1920s were a period of optimism for science in the Soviet Union. The Bolsheviks would help scientists to carry out research, as long as the scientists were willing to contribute their knowledge to the Soviet cause. In the late 1920s and early 1930s, however, the Party tightened the screws, imposing rigorous political and administrative controls on the scientific community. It brought the Academy of Sciences under Party control and imposed censorship on it. Trips abroad were cut back and soon almost entirely forbidden. Political commitment was demanded. Party philosophers began to monitor scientific work in order to root out ideological deviations. What emerged from these years was a large, well-funded, Party-controlled R&D effort. The goal was still very much to use science to contribute to the economy. The Soviet Union may have spent more of its national income on R&D than any other country in the 1930s.

The Academy placed a new emphasis on engineering and applied research. The government introduced planning into science, over the objection of many scientists. At the first all-Union conference on the planning of scientific research in April 1931, Nikolai Bukharin, who after his removal from the Politburo in 1929 was given a position overseeing science and technology, called on scientists to think beyond their research to the application of scientific knowledge in industrial production. This summons rested on the belief that science did not grow by virtue of an internal logic, but in response to the technological demands that society placed on it.

"In the USSR, as nowhere else in the world, all the conditions have been created for the flourishing of science," Karl Bauman, the head of the Central Committee Science Department claimed in August 1936. But the Party did not think it was getting enough from science. In March 1936 it staged a conference on physics, at which Ioffe was roundly condemned for not doing enough to help industry. In December a similar conference was held on Agricultural Sciences in which geneticists and plant breeders were attacked for not doing anything to help agriculture, which was in deep crisis following collectivization: millions of people had died in famine in the early 1930s. The agronomist T.D. Lysenko won the favor of those responsible for agriculture by proposing methods that promised to improve crop yields. He cleverly exploited the language of Stalinist politics to undermine his opponents and attacked genetics ("Weissmanism-Morganism"). His administrative power grew in the late 1930s, and his main opponent, N.I. Vavilov, who had at first supported him, was arrested in 1940 and died two years later in prison in Saratov.

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The Bolsheviks attached the word "scientific" to things they approved of – scientific management, scientific atheism, and scientific communism, for example – and they claimed they were building socialism on scientific principles. But in general their approach to science was instrumental. Scientists and engineers did not escape the brutal repressions that Stalin inflicted on Soviet society in the 1930s. They could be identified as wreckers or saboteurs and, to take the example of genetics, a scientific discipline could be branded as fascist. And yet science and technology remained absolutely central to the Soviet enterprise.

Adam Ulam, one of the shrewdest American observers of Soviet politics during the Cold War, argued that the "main task" of Marxism was "political and economic modernization." One of its great appeals, he wrote, was that it was attuned to one of the two greatest tendencies of the industrial age: "worship of science and mechanization and their power to transform mankind." There was of course an industrialization drive to turn the Soviet Union into a great military-industrial power. Yet it is a mistake to reduce the Soviet experience to a drive for modernization. That misrepresents both the theory and the practice of the Soviet state. It underestimates the Leninist underpinnings of the revolution, with the Party as the vanguard of the revolution, determined to wage class war and to expropriate private property. It ignores the enthusiasm – even the millenarianism – of the Bolsheviks. It exaggerates the role of scientists and engineers, almost implying that they were equal partners – or even leaders – in this enterprise, which was certainly not the case. It also neglects the brutality and repressiveness of the Stalinist regime, which cannot be explained as short cuts to modernization and which, it can be argued, greatly hampered industrialization.

The strategy of "catch up and overtake" encouraged copying. There was on the part of the authorities a bias – widely noted by Soviet scientists – against original ideas, which tended not to receive support until it could be shown that analogous work was being done in the West. The authorities did not wholly trust their own scientists and engineers; the controls on science betrayed a fear of disloyalty and sabotage. These attitudes on the part of the Bolshevik leaders surely weakened the conditions for indigenous innovation. There was a strange kind of "not invented there" syndrome.

Technology after World War II

The Soviet Union did not have the kind of "science war" Britain and the United States or even Germany had. World War II was nevertheless a turning point for Soviet science and technology. At the end of the war Stalin decided to invest heavily in the new technologies the war had produced in other countries: atomic energy; ballistic and cruise missiles; radar; and jet propulsion. "I do not doubt," he said, "that if we render the proper help to our scientists, they will be able not only to catch up with but also to overtake in the near future the achievements of science beyond our country." Given the devastation the Soviet Union had suffered in the war, it took an enormous exercise of political will to devote large resources to these programs. (In 1951 the Soviet atomic project employed over 600,000 people, in-

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cluding about 200,000 in Germany exploiting the uranium deposits in the Erzgebirge.) But that of course was what the central planning system was designed to do – to enable the Party leadership to channel resources to the priorities that it decided upon. The atomic project was referred to in official documents as "Problem No. 1."

The priority of the new programs sprang from Stalin's belief that there would be another world war, arising out of inter-imperialist contradictions, in 20 or 30 years. Those postwar programs had help from espionage, from captured technology, and from German scientists and engineers taken to the Soviet Union after the war, but they were nonetheless a considerable achievement on the part of Soviet Union. They ultimately enabled the Soviet Union to attain strategic parity with the United States by the late 1960s – whether that was the right goal to pursue is another issue. They also laid the basis for what was perhaps the Soviet Union's most famous technological feat: Yuri Gagarin's flight in 1961 as the first man in space. On the basis of these programs, the Soviet Union built fission and fusion weapons, launched Sputnik, and organized a spectacular space program. The R&D community grew enormously. Great optimism about science and technology prevailed in the late 1950s and early 1960s. This was reflected in popular culture. See, for example Boris Slutskii's 1959 poem "Fiziki i liriki" (Physicists and Lyric Poets), which caught the spirit of the times. "Physicists it seems are honored, lyric poets are in the shade', the poem begins. The final lines note: "our rhythms vanish like froth and grandeur gradually merges into logarithms."

In the 1960s and 1970s the concept of the scientific-technical revolution became popular. It covered a whole range of issues to do with the impact of technology on society and the functions technology could perform. The Bolshevik ideology had lost a great deal of its appeal. The scientific-technical dimension of the Marxist-Leninist vision gained more prominence. It seemed that science and technology were the most revolutionary forces in Soviet society, now that ideological enthusiasm had waned. The optimism associated with the scientific-technical revolution was, however, tempered by the fact that the Soviet Union lagged behind the West in technological innovation. This was a matter of concern to the Soviet leadership. Various partial reforms were made in the central planning system in the 1960s and 1970s, but without any marked impact.

Early in the 1980s the party leadership decided, after years of putting off the idea, to devote a plenary session of the Central Committee to the scientific-technical revolution. Preparations were made, but the meeting was cancelled. Shortly after becoming General Secretary Gorbachev told a conference on science and technology: "an acceleration of scientific-technical progress insistently demands a profound *perestroika* of the system of planning and management of the entire economic mechanism." He made it clear that he thought the transition to technology-intensive economic growth should have taken place fifteen years earlier. Subsequent events showed, however, that he himself did not have an effective strategy for making that transition.

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Science

Let me turn now to science. In July 1931 the Soviet Union sent a delegation to London, to the Second International Congress of the History of Science and Technology. Bukharin led the delegation, which included Nikolai Vavilov and Abram Ioffe. The Soviet papers portrayed science in the Soviet Union as a "new science" developing in response to the problems presented by the construction of socialism. The most influential paper was perhaps that by Boris Hessen, who argued that Newton's *Principia* had been a response to the technical problems of the day in navigation, ballistics, and metallurgy. Its "physical content arose out of the tasks of the epoch, which were for accomplishment by the class entering into power [i.e. the bourgeoisie]." These papers inspired a group of left-wing British scientists to call for the planning of science so that it could be directed toward serving the needs of society. John Desmond Bernal called the Congress the "most important meeting of ideas that has occurred since the Revolution." Bernal's book *The Social Function of Science* (1939) drew on Soviet practice to make the argument that science should be directed toward the satisfaction of society's material needs.

Soviet science in practice was, however, far removed from the ideal picture painted by the Soviet delegation and envisaged by Bernal. Let me look very briefly at three cases. The first is the Lysenko affair, which I have mentioned already. This affair raised the question: who has the right to define what constitutes "scientific knowledge?" It seemed for a period after World War II that Lysenko would lose his dominant position, but Stalin intervened to support him. In August 1948, during a conference on agricultural science that the Politburo had instructed Lyenko to organize, Stalin edited Lysenko's report, which was an outright attack on "Morganism-Mendelism," i.e. genetics, and allowed Lysenko to declare, at the final session: "the Central Committee has examined my report and approved it." Stephen Jay Gould later described this as "the most chilling passage in all the literature on twentieth century science." It marked Lysenko's complete triumph, with very damaging consequences for teaching and research in biology.

For many years the Lysenko affair was portrayed in the West as characteristic of Soviet or Stalinist science. We now know more about other disciplines, especially physics. One explanation for the Lysenko affair is that biology was vulnerable to outside intervention because of its internal disputes and its close relationship with the study of intelligence and race. That is certainly part of the story, but a structural element may be more important. Soviet agriculture was in a desperate plight. The geneticists and plant breeders, with their hybrid varieties could do little to help, because seed would need to be distributed to collective farms in the chaotic countryside. Stalin had proclaimed that practice was the true test of theory. This converted the crisis in agriculture into a crisis in biology. Lysenko's simpler methods, which did not require the annual distribution of seed to the farms, were adopted as a solution. Their effectiveness was very poorly monitored, but at least they did not involve even implicit criticism of collectivization. And besides, Lysenko's claim that acquired characteristics could be inherited was ideologically appealing.

The second case is physics, which was not strong in Russia before the revolution. Soviet physics grew impressively in the 1920s and 1930s, in spite of the effects of repression on individuals and institutes. Ioffe was criticized in the 1930s for not doing enough to help industry, but physics came into its own in the atomic age. Nevertheless, within months of Lysenko's success in August 1948, preparations began for a conference on the teaching of physics. Discussions in the organizing committee were sharp and bitter: physicists argued among themselves and with philosophers. The draft resolution did not attack physics as such but called for a "struggle against kowtowing and groveling before the West." What effect such a resolution would have had on physics we do not know, because the conference was cancelled some days before it was due to start.

It appears that leading physicists in the atomic project warned Lavrentii Beria (who was in charge of the project) and through him Stalin, that such a conference would interfere with the effort to build the bomb. (Besides, the divisions in the organizing committee could lead to a highly contentious meeting.) This is a plausible explanation, though there is no documentary evidence for it. In 1952 leading nuclear scientists did write to Beria to complain about an article that attacked quantum mechanics, stating that it would harm the teaching of physics and thus interfere with the atomic project. In neither case did Stalin utter a judgment on the science, as he had done with Lysenko. The authority of the Central Committee was not invoked either way.

In the late 1940s there were further discussions, in linguistics, physiology, and political economy, in which Stalin was deeply involved. He took the view that the Central Committee – essentially himself – could "have its own position on questions of science." But if that were the case, how would he know what the correct position was. "It is generally recognized," he wrote in his commentary on linguistics, "that no science can develop and flourish without a battle of opinions, without freedom of criticism." He reasserted Marxism's scientific status as the "science of the *laws governing the development of nature and society* ... the science of building communist society." But Marxism, he wrote, does not "recognize invariable conclusions and formulas." It is tempting to see Stalin wrestling here with a problem he himself had created: how could he use effectively the authority he claimed in science without destroying the science on which the power of the state was coming increasingly to depend. How could he know he was right?

My third case is cybernetics, defined by Norbert Wiener as the science of control in the animal and the machine. Cybernetics had a peculiar history in the Soviet Union. It was at first rejected as a "bourgeois pseudoscience" in the early 1950s, but rehabilitated in the mid-1950s, with the help of mathematicians working in the atomic project. The debate about cybernetics in the 1950s focused on a key question: who has the right to define scientific knowledge? The scientists objected to the role that "philosophers" played in making judgments about the correctness of scientific theories. A conference in 1957 essentially resolved the issue by requiring philosophers to know the science before passing judgment, though Lysenko, with Khrushchev's help, held on to some of his power until 1964. Cybernetics became a broad rubric for many different scientific interests, extending from computers and information theory to economic planning and ideas about reform of the state administration.

Cybernetics became an overarching framework for new branches of science (genetics was smuggled in too) and was adopted as a discourse in which political and scientific orthodoxies could be challenged. The term itself became much more popular in the Soviet Union than in Norbert Wiener's home country. It became the carrier of political hopes and ambitions, but those remained unrealized. Cybernetics specialists – A.I. Kitov and V.M. Glushkov in particular – put forward plans for nationwide computer networks in the 1960s and 1970s, but these were turned down. Ultimately the language of cybernetics was co-opted by the regime and rendered impotent. Rather than making politics more "scientific" and policy-making more technocratic, as the proponents of cybernetics had hoped, it was merged with, and largely suffocated by, the language of Marxism-Leninism.

At a closed Central Committee Plenum in December 1969 Brezhnev delivered a decisive rebuff to the reformist ideas of the cyberneticians and systems analysts: "No matter how good the systems of information and control created by specialists are – they are, though important, only auxiliary means for resolving problems of administration. The main thing – making decisions, working out the Marxist-Leninist line in the economy, in the social, ideological, and other spheres – remains the most important function of our party and our state. Problems of administration are in the first order political, not technical problems."

Dissident voices on science

In 1968 Andrei Sakharov published abroad his *Reflections on Progress, Peaceful Coexistence, and Intellectual Freedom*. In the opening paragraph he states that his views were formed in the milieu of the scientific-technical intelligentsia, which was very worried about the future of humankind. Their concern, he continued, was especially strong because what he called "the scientific method of directing politics, economics, art, education, and military affairs" had not yet become a reality. What did he mean by the "scientific method" in this context? His answer: "We consider 'scientific' that method which is based on a profound study of facts, theories, views, presupposing unprejudiced and open discussion, which is dispassionate in its conclusions." In other words, Sakharov took science as the model of politics, of a politics grounded in open debate and in reason.

Sakharov's decision to publish his essay abroad reflects a broader disappointment or disillusionment with science and its role in Soviet society. The crushing of the Prague Spring later in 1968 set back the cause of reform in the Soviet Union. A less optimistic view of science now appeared in Soviet dissident writings. Slanderer (klevetnik), a character in Aleksandr Zinoviev's novel *The Yawning Heights*, expresses the view that careerism has created a "moral and psychological atmosphere in science which has nothing in common with those idyllic pictures one can find in the most critical and damning novels and memoirs devoted to the science of the past."

The émigré science journalist Mark Popovsky painted a similar picture (which Sakharov believed contained an element of truth). Far from exercising a civilizing influence on Soviet society, science had come to embody the worst features of Soviet life: it was dominated by an overpowering bureaucratic apparatus; careerism, patronage and corruption were rife; there was a cynical disregard of ethics and morality; military and security considerations had first priority; the scientific community was riven by national antagonisms, and enmeshed in secrecy.

The whole question of science and technology was an important element in the debate between Solzhenitsyn and Sakharov in the 1970s. In his 1974 "Letter to the Soviet Leaders," Alexander Solzhenitsyn strongly attacked the path of development the Soviet Union had followed. "We have followed Western technology too long and too faithfully. We are supposed to be the 'first socialist country in the world,' one which sets an example to other peoples … and we are supposed to have been so 'original' in following various monstrous doctrines – on the peasantry, on small tradesmen – so why, then, have we been so dolefully unoriginal in technology, and why have we so unthinkingly, so blindly, copied Western civilization?"

Andrei Sakharov, who was to receive the Nobel Peace Prize in 1974 for his work in defense of human rights, responded to Solzhenitsyn. "The very division of ideas into Western and Russian is incomprehensible to me. In a scientific, rational approach to social and natural phenomena, ideas and concepts are divided into true ones and fallacious ones." He was especially critical of Solzhenitsyn's attitude to progress. Progress for Sakharov was inevitable. The scientific and democratic regulation of the world economy and all social life, including the dynamics of population, is not, he wrote, a utopia but a very real necessity.

"Progress is possible and innocuous only when it is subject to the control of reason," Sakharov said in his Nobel lecture. "The important problems involving environmental protection exemplify the role of public opinion, the open society, and freedom of conscience." Similarly, disarmament required trust between states, and trust would be possible only with greater openness in public life. In this context human rights were crucial, because only if human rights were guaranteed would the conditions exist for the open debate and discussion needed for the creation of an informed public opinion: a public opinion that could ground power in reason and ensure the openness that was essential for a secure world.

The Chernobyl nuclear disaster in 1986 cast doubt, in the most dramatic way, on the authorities' claim to be able to manage science and technology. It also weakened of the standing of the scientific-technological elite, which had offered constant reassurances about the safety of nuclear power. Iu.B. Khariton, who was from 1946 to 1992 the scientific director of the main Soviet nuclear weapons institute (the equivalent of Los Alamos), made a remarkable statement. He was invited in 1994 to go to the United States to give a lecture in memory of J. Robert Oppenheimer, his American counterpart. He very much wished to go, but ill heath prevented him from doing so. Khariton sent the text of a lecture ending with the following passage:

"Conscious of my own participation in the remarkable scientific and engineering achievements that have led to human mastery of a practically inexhaustible source of energy, today, at a more than mature age, I am no longer certain that humanity is mature enough to be the master of this energy. I recognize our involvement in the terrible death of people, in monstrous damage inflicted on the nature of our home, the Earth. Words of repentance will not change anything. Please God, those who come after us will find ways, will find in themselves the firmness of spirit and the decisiveness, while striving to do the best, not to do the worst."

Khariton was no dissident, but this is a very sobering assessment of humanity's capacity to direct technology to good ends.

Soviet Science and Technology

The Soviet Union made a massive effort to become a leading scientific and technological power. It built up the largest R&D community in the world. It had major successes, most strikingly in space. It did not, however, succeed in overtaking the advanced capitalist world in technology, even in the military field, which received the highest priority. It nevertheless did enough to pose a formidable military challenge to the United States and NATO. The artifacts – the nuclear warheads, the missiles, and the weapons systems – survived the collapse of the Soviet Union.

The Soviet Union did not develop a separate "socialist" science and technology if the content of the science is taken into account. This is not to deny differences of emphasis in research or different schools influenced by social or philosophical currents such as dialectical materialism or the Orthodox religion, but it is hard to claim that a distinctive socialist science and technology emerged to rival that of the West. Those early ambitions were not realized. After the collapse of the Soviet Union many former Soviet scientists went to work in foreign universities and research institutes.

There were, nevertheless, distinctive features of the organization of science and technology in the Soviet Union. Some of these supported science: generous funding; strong secondary education; the high value placed upon science in the society. Some hindered science: political controls; restrictions on travel, even though they were eased after the mid-1950s; restrictions on the public discussion of issues raised by science and technology, e.g. the safety of nuclear power plants; and in the latter years a shortage of computers to support the kind of research that required the analysis of large amounts of data. The centrally planned economy also imposed obstacles to technological innovation.

The Soviet Union was not a technocracy. Scientists and engineers enjoyed high status in Soviet society and acquired more prestige in the 1950s, as the successes of the nuclear, missile, and space programs became publicly known. There were, however, many points of tension between the Party and the scientific community (as embodied in the Academy of

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Sciences) even after Stalin's death. Lysenko's influence and the fate of cybernetics can serve as examples.

Science did flourish in the Soviet Union, in spite of the obstacles put in its way. Scientific disciplines proved to be very resilient. Even when personal contacts had all but ended, from the mid-1930s to the mid-1950s, Soviet scientists kept in touch with foreign counterparts through the scientific journals. And even when teaching and research were largely stopped in genetics after the 1948 meeting, it appears that researchers did not abandon what they knew. They bided their time, until the revival of their science became possible.

Did the Soviet Union collapse because of backwardness in science and technology? Some argue that it was Ronald Reagan's challenge – the Strategic Defense Initiative (Star Wars) – that caused the Soviet Union to collapse. I do not think that is true, because the Soviet Union could find ways to overcome such an Anti-Ballistic Missile system, which was in any case never built. But there is a broader argument to be made: that Soviet involvement in the strategic arms race created a vast military-industrial complex that not only stimulated advances in military technology, but also distorted the Soviet economy. It depended on a centrally planned economy that could be directed toward specific goals but was not as innovative as the market economies of the West. If one thinks of the relationship between Soviet socialism and Western capitalism as a competition to encourage science and foster technological innovation, then the Soviet Union was falling behind in the 1970s and 1980s, the years that later came to be called the period of "stagnation."

Conclusion

Less than six months after the collapse of the Soviet Union, Vaclav Havel claimed that the end of communism signified the end not only of the 19th and 20th centuries but also of "the modern world as a whole." The modern era, he wrote, had been dominated by the belief that "the world … is a wholly knowable system governed by a finite number of universal laws that man can grasp and rationally direct for his own benefit." The end of the illusion, in other words, was not just the end of communism, but the end of modernity too. This is a sweeping claim, too large for discussion here, but one thing to note is that Havel saw communism as the perverse extreme of scientific rationalism, not as something wholly separate from western capitalist society. When we think about science and technology, we should pay heed to the Soviet experience.

I asked at the beginning of this lecture how we might judge communism in 400 years. That question assumes that the human race will still exist then. In order to survive, we face many challenges, some of which spring from science and technology: nuclear war; climate change; pandemic diseases caused by superbugs. Sakharov believed strongly that scientific-technical progress needed to be matched by spiritual growth among human beings. On the basis of his own experience with science and technology in the Soviet Union, he raised questions that are

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important not only in the Soviet context, but also more generally as we think about science and technology.

The first is the relationship between science and politics. Sakharov wrote to political leaders recommending particular courses of action, but later came to the conclusion that that was not enough: there had to be public discussion and understanding of the issues. He shifted the focus away from the individual scientist's responsibility – important though that is – to the broader question of the world's capacity to cope with the great challenges that we face. The key question then is whether scientific communities are capable of making sure that societies have the capacity to deal with the enormous challenges we face, many of which are, at least in part, the consequence of scientific and technological progress. How well organized are we to do this? And how best can this be done in a public sphere which is changing rapidly as the result of the development of technology – for example in social media? Sakharov would surely have thought seriously about this latter question.

A second, and related, question is how is science to maintain its authority, so that it can be effective in responding to the challenges we face? That question is not confined to the Soviet Union, since the authority of science is widely challenged on many issues in the United States – on climate change, for example. It was certainly an issue in the Soviet Union, where the right to say what constituted scientific knowledge was sharply contested. Societal trust in science is not to be taken for granted. Governments in the West can reject scientific advice on the grounds, for example, that the science underpinning the advice is a hoax. What are the implications for science of that kind of rejection of the authority of specialist communities to define scientific knowledge? How can they perform the role of helping society deal with the challenges that we face if unwelcome advice can be shrugged off?

The third question, closely related to the first two, has to do with the ethics of science. Scientific research confronts us with complex ethical questions, relating, for example, to privacy, threats of mass violence, or genetic editing. Have we the capacity to make those ethical judgments? Sakharov wrote: "scientific-technical progress will not bring happiness if it is not complemented by extraordinarily profound changes in the social, moral, and cultural life of mankind." Havel believed that the world needed "generally held values" or what he called "self-transcendence." These are very challenging statements.

The Soviet experience with science and technology – the Soviet version of modernity – is not irrelevant to our own concerns in the post-Soviet world, and is therefore worthy of careful attention. The reflections by Havel and Sakharov on the Soviet experience leave us with serious challenges to try to address.

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