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Dreams in Cybernetic Fugue: Cold War Technoscience, the Intelligentsia, and the Birth of Soviet Mathematical Economics

ABSTRACT

This article positions the vogue for cybernetics as a key driver of the transformation of the institutional structures and epistemic order of Soviet technoscience that occurred in the 1950s and 1960s. Inseparable from the rapid growth of Soviet military science, Soviet cybernetics was both the result and medium of surprising recombinations of different forms of scientific and engineering expertise to create novel military technologies. Military computing was the point of entry for cybernetics, while its focal tasks—the bomb, rocketry, and radar—in turn shaped cybernetic understandings. The rapid growth and cyberneticization of these new areas of militarily driven science caused a tectonic transformation of the Stalinist articulation of science, technology, and politics. A crucial moment of these latter shifts, the article further suggests, was the transformation of Soviet economics into a properly mathematical economics. In a series of analogical transfers, mathematicians and engineers derived a radical vision of cybernetic communism from their specific military engineering tasks. Their encounter with reformist economics, mediated by computational utopias, enabled the transfer of advanced mathematical techniques, metaphors, and personnel from military science to the social sciences. This complex

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The following abbreviations and acronyms are used: CEMI, Central Economico-Mathematical Institute, Soviet Academy of Sciences; EGSVTs, United State Network of Computing Centers; Gosplan, State Planning Committee of the USSR; IPU, Institute of Problems of Automation and Remote Control; LEMM, Laboratory for Economico-Mathematical Methods; Mekhmat, Faculty of Mechanics and Mathematics, Moscow State University; NII, Scientific Research Institute; OPM, Department of Applied Mathematics, Steklov Institute of Mathematics, Soviet Academy of Sciences; SKB, Special Construction Bureau; TsAGI, Central Aerohydrodynamics Institute; TsNII, Central Scientific Research Institute; VTs, Computing Center.

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process constituted Soviet mathematical economics. Soviet cybernetics' challenge to the Stalinist order of knowledge and its attendant institutional reconfigurations thus opened up a critical space for political reflection for the Cold War era "scientific-technical intelligentsia" at the heart of the party-state.

KEY WORDS: mathematics, cybernetics, Cold War science, Thaw, intelligentsia, computing, mathematical economics, economic reform, perestroika

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In the wake of the Second World War, cybernetics facilitated a deep transformation of Soviet technoscience. Cybernetics, an aspiring universal science of "control and communication in the animal and the machine" (as Norbert Wiener subtitled his foundational 1948 book), experienced a moment of explosive growth, leaped over the Iron Curtain, and then almost as quickly seemed to disappear, while leaving traces in the science and culture of both East and West.[1] The Soviet chapter in the history of cybernetics has recently begun to be reassessed; nevertheless, the degree to which it was part and parcel of the creation of the postwar military-scientific complex remains little appreciated. In this essay I emphasize the military origins of Soviet cybernetics, for only by so doing is it possible to refocus attention from cybernetics' highly salient discursive patterns, terms, and metaphors toward then-novel engineering problems. This refocusing is crucial, I suggest, because these technoscientific tasks forced scientists and engineers of various stripes into fertile new collaborations. The technical and social details of applied research are not mere diacritics of radical transformations in Soviet science and political culture, rather they are the very mechanism by which these transformations occurred.[2]

The article consists of four sections. In the first, I briefly situate the transnational phenomenon of cybernetics, East and West, at the intersection of engineering and mathematics, before examining the context of Soviet military science in detail. I attribute the social power of Soviet cybernetics to its position in the structure of Soviet military science and to the dynamics of that

1. Norbert Wiener, *Cybernetics: Or Control and Communication in the Animal and the Machine* (New York: The Technology Press, John Wiley & Sons; Paris: Hermann et Cie, 1948).

2. In addition to published sources, this study is based upon on two years of ethnographic fieldwork carried out in the economics institutes of Moscow during 2010–2012. I conducted oral history interviews with, among others: Eduard F. Baranov, Yurii N. Gavrilets, Vladimir V. Kossov, Mark I. Levin, Boris Saltykov, Aleksandr I. Stavchikov, Viktor A. Volkonskii, Academic Valerii L. Makarov, and Academic Viktor M. Polterovich, all of whom worked at CEMI at various times; Emil B. Ershov, Lyubov Strichkova, and Gennadii Kuranov of Gosplan Research Institute; and Ilya B. Muchnik of IPU.

complex's growth in the post-Stalinist decades. The second section offers a narrative of how, under the umbrella of cybernetics, networks of mathematicians and engineers formed alliances that generated new kinds of knowledge in the process of developing novel technologies. Mathematicians with considerable practical experience modeling physical processes were drafted into the bomb project and drove the development of Soviet digital electronic computers. Defense engineers and early experts in computation became fascinated with cybernetics at the same time as they were turning computers from instruments of *calculation* to means of *control* of man-machine complexes—in the first instance, of anti-aircraft and anti-missile defense. In the third section, I summarize how cybernetics rearticulated the macro-relationship between science and technology in the institutional structure and epistemic order of Soviet science. Previous orthodoxy had it that science was mere handmaiden to technology, but now science could assert its own autonomy and productivity.

In Wiener's conception, cybernetics aimed to be much more than a technical science: it was to be at the same time a science of society. Economics, as the science of Marx, was the central (and arguably the only) Soviet social science. It was a privileged mode by which the Soviet polity worked out theoretical understandings of itself and its possible futures. In the Soviet Union, therefore, cybernetic reflection on social organization meant an encroachment onto the disciplinary field of economics. The encounter between economics and cybernetics was a watershed in the political epistemics of the Soviet Union, that is, in the way that Soviet socialism knew itself.

In the final section, I show how some cyberneticians immediately transferred their interpretations of anti-aircraft systems to the system in which they lived. A nonintersecting network of reform-oriented economists had already been imagining alternative forms of economic organization throughout the 1950s, a history I tell elsewhere.[3] As I show here, it was by allying with the military mathematicians and cyberneticians that these reform-oriented economists achieved institutional recognition and garnered resources. The highpoint of this alliance was a 1963 decree initiating planning of a never realized statewide computer network for economic management and control. However, the reform visions of cyberneticians and economists differed, hinging on their respective understandings of computers as instruments of control *versus*

3. Adam E. Leeds, "Spectral Liberalism: On the Subjects of Political Economy in Moscow" (PhD Dissertation, University of Pennsylvania, 2016).

instruments of calculation. This difference led to the breakdown of the alliance. Yet, I argue that across the temporary bridge provided by the idea of the computer network flowed personnel, metaphors, and techniques that transformed part of Soviet economics from a numerical, statistical, and verbal discipline to a proof-theoretic mathematical one. The field of economic knowledge production thenceforth would be polarized between the "political economy of socialism" and a "economic cybernetics" that could openly envision alternative socialisms.

COLD WAR TECHNOSCIENCE

Soviet cybernetics was the vehicle and result of interactions between engineering, mathematics, and physics that not only reconfigured all of these fields, but also transformed seemingly unconnected ones, including economics. This was the assembly of the postwar Soviet military-scientific complex. The articulations of science, technology, and politics are always historically specific, and the era of the Second World War and the start of the Cold War—the heyday of cybernetics—was a watershed in their ongoing co-constitution on both sides of the Iron Curtain.

Cybernetics was made possible, David Mindell has shown, by pre-existing engineering cultures—focused on control engineering, industrial automation, instrument making, analog computing, and communications technology.[4] Central cybernetic concepts of feedback, information, and system arose *within* the practical matrices of local engineering problems, and only subsequently did mathematicians generate more abstract and general representations of them. "Cybernetics" is the name for the mathematical synthesis of the nascent theorizations born in these engineering contexts. The postwar Soviet Union had very similar contexts, and saw very similar processes of abstraction and synthesis, and Soviet cybernetics was accordingly not merely a Western import. When, in June of 1960, Norbert Wiener gave his keynote address to the first congress of the International Federation for Automatic Control at the Moscow Polytechnical Museum, a mere two years after his *Cybernetics* had been translated into Russian, the auditorium to his astonishment was standing room

4. David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics* (Baltimore: Johns Hopkins University Press, 2002).

only. He was forced to repeat the lecture several days later.[5] Deep domestic engineering traditions make Wiener's reception intelligible.[6]

In this trans-Atlantic light, differences also become more visible. In the United States, cybernetics arose from control engineering and analog computing. But when Wiener's *Cybernetics* was becoming widely known in the USSR roughly ten years later, digital computing was already flowering, and those who championed the one championed the other. In the USSR, computer science was not called "cybernetics": rather, there was cybernetics, and one of its basic areas or strata of research was digital computing. Accordingly, computer *qua* calculating machine, rather than servomechanism, became the basic tropic resource.[7]

Other differences follow from general features of Soviet science: extreme centralization, Marxist-Leninist dialectical materialism as a philosophy of science, and the legacy of the Stalinist science wars. Under Stalin, Bolshevik political culture had permeated science.[8] Political culture requiring unanimity combined with a philosophy of science claiming a political ground of science to create the conditions for enforced monopolies within research areas. Marginalized or forbidden research areas thereby accumulated; later these would be reactivated as allies for cybernetics. In such a centralized system, the mathematicians who pushed cybernetics, having achieved administrative power, could leverage it to reorder the balances of power, prestige, and funding across disciplines. In the United States cybernetics was merely one heir to the engineering traditions amid other intertwined "systems sciences" or "cyborg

5. Y. I. Fet, *Rasskazy O Kibernetike* (Novosibirsk: Izdatel'stvo CO RAN, 2007), on 2531; Bernard Widrow, "Recollections of Norbert Wiener and the First IFAC World Congress," *IEEE Control Systems* 21, no. 3 (2001): 65–70.

6. Modest Gaaze-Rappoport, "O Stanovlenii Kibernetiki v SSSR," in *Ocherki Istorii Informatiki v Rossii*, ed. Dmitri Poslepov and Yakov Fet (Novosibirsk: Nauchno-Izdatel'skii Tsentr OIGGM SO RAN, 1998), 225–56; A.I. Apokin and A.Z. Chapovski, "The Origins of the First Scientific Center for Automation," *History and Technology* 8 (1992): 133–38; Mikhail Shkabardnia, *Priborstroenie—XX Vek* Moscow: Severshenno sekretno, 2004. Ilmari Susiluoto makes a different case that heretical Bolshevik theoreticians prepared the ground for cybernetics' reception, in *The Origins and Development of Systems Thinking in the Soviet Union: Political and Philosophical Controversies from Bogdanov and Bukharin to Present-Day Re-Evaluations* (Helsinki: Suomalainen Tiedeakatemia, 1982).

7. Slava Gerovitch, *From Newspeak to Cyberspeak: A History of Soviet Cybernetics* (MIT Press, 2004), 173–9.

8. Alexei Kojevnikov, "Rituals of Stalinist Culture at Work: Science and the Games of Intraparty Democracy circa 1948," *Russian Review* 57, no. 1 (1998): 25–52; Nikolai Krementsov, *Stalinist Science* (Princeton, NJ: Princeton University Press, 1997).

sciences"—operations research, systems analysis, control theory, among others. But in the Soviet Union cybernetics not only encompassed these, but also nurtured and translated mathematical economics, structural linguistics and semiotics, genetics, ecology, and others. To its enthusiasts it could embrace all of science. Cybernetics thus allowed a temporary but remarkable porosity of disciplinary borders to individuals, research groups, metaphors, mathematical tools, and instruments. This entailed an ambiguous challenge to the metadisciplinary position of Marxism-Leninism. Although usually careful to make formal obeisance to orthodoxy, cybernetics offered itself as an alternative scientific metalanguage. It thereby allowed the sidestepping of both the taboos sedimented over years of fighting and the official philosophers, political economists, and sundry ideologists who enforced them. This is the heart of the story told with extraordinary detail and sophistication by Slava Gerovitch.

These contexts help to understand the seemingly paradoxical nature of the Soviet cybernetic efflorescence, at once the spontaneous philosophy of the postwar military-scientific complex, vehicle for the de-Stalinization of science, and *lingua franca* of underground milieux of proto-dissidence. Understanding it as one or the other would replicate in the Soviet context the divergent interpretations of American cybernetics as a dystopian "ontology of the enemy"[9] or "closed world" of military command and control[10] *versus* as an organic moment of 1960s emancipatory counterculture in science.[11] The reflex to import this (itself questionable) dichotomization is a symptom of the difficulty of emplotting histories of Soviet society that do not depend for their narrative coherence on the basic vocabulary of liberal political culture: repression and liberation, state and individual, and so on. To the options with which this paragraph begins we should reply that Soviet cybernetics was neither one nor the other, it was all of the above, and that is because in the late 1950s and early 1960s they are not competing descriptions: these are partial perspectives on a single network within which scientists and engineers were trying to imagine alternative futures of the Soviet polity.

9. Peter Louis Galison, "The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision," *Critical Inquiry* 21, no. 1 (1994): 228–66.

10. Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, MA: MIT Press, 1996).

11. Andrew Pickering, *The Cybernetic Brain: Sketches of Another Future* (Chicago: University of Chicago Press, 2010).

The Soviet Postwar Military-Scientific Regime

That Soviet cybernetics was a creature of the military remains underappreciated.[12] Adding to the problem of still-secret archives, scientists who worked in military industrial institutes omit such work from their curricula vitae and even in interview often say only that they worked at a "closed organization" or "post office box" (*pochtovye iashchik*) (so called because military research and development institutes, regardless of the ministry to which they were officially subordinated, bore only numbers in place of names, appeared on no map, and did not have mailing addresses). Ethnographic fieldwork in Moscow only gradually revealed these prosopographical regularities. In the 1950s the number of young scientists and engineers sent to military institutes rose dramatically. These institutes also regularly gave contract work to Academy of Sciences institutes, also never mentioned in yearly reports. And in many cases, ostensibly civilian institutes were dedicated almost entirely to military research. At times, whole institutes were transferred from one sector to the other. (A major reshuffling happened in the early 1960s, described below.)

In the 1950s and 1960s, both military/ministerial and Academy institutes grew in size and number at a tremendous pace, absorbing an enormous wave of graduates.[13] Institutes were predominantly founded according to three patterns.[14] First, in both military-industrial science and the Academy, a division or laboratory (the two lower levels of administrative hierarchy) of a pre-existing institute could hive off into a new institute. Second, in the Academy (but not in industry) several laboratories in different institutes could launch a "scientific council," lodged at some level of the Academy administrative hierarchy, which

12. Military institutes mean those of "the nine," the ministries serving the military industrial complex: aviation, defense, shipbuilding, machine building, "medium machine building" (the nuclear industry), radio, electronics, electrotechnology, and chemicals.

13. Vladislav Zubok, *Zhivago's Children: The Last Russian Intelligentsia* (Cambridge, MA: Harvard University Press, 2009), on 124.

14. The Soviet research system divided in two: the Academy of Sciences was a hierarchically organized network of institutes, and the dozens of ministries each had their research institutes. Their greatest contact was through the Technological Sciences division of the Academy. (Educational systems were separate and did little research.) See Loren Graham, "The Formation of Soviet Research Institutes: A Combination of Revolutionary Innovation and International Borrowing," *Social Studies* 5, no. 3 (1975): 303–29; Robert A. Lewis, "Some Aspects of the Research and Development Effort of the Soviet Union, 1924–35," *Science Studies* 2, no. 2 (1972): 153–79, and "Government and the Technological Sciences in the Soviet Union: The Rise of the Academy of Sciences," *Minerva* 15, no. 2 (1977): 174–99; Alexander Vucinich, *Empire of Knowledge: The Academy of Sciences of the USSR (1917–1970)* (Berkeley: University of California Press, 1984); and Krementsev, *Stalinist Science* (ref. 8).

would subsequently become an institute gathering in the sponsoring laboratories. Third, in the military-industrial (but not the Academy) institutes, a factory could be upgraded to a design bureau (KB, *konstrukturskoe buro*), and a design bureau to an institute. This reflects the relatively technology-driven nature of these institutions, even when ostensibly engaged in fundamental science. (It also recapitulates the institute-design bureau-factory structure of industrial research and development.)

Because of this growth pattern "discipline" does not adequately capture the Soviet institutional organization of knowledge. Disciplines are anchored by the existence of parallel research groups. To the extent that disciplines remained salient, this was due to the analogous organization of the Soviet university system. But postgraduate education and socialization occurred at institutes with quasi-monopolies on their research areas. When university faculties and the research domains of institutes were relatively aligned with each other, some degree of disciplinarization still existed; when they were less so, especially in times of rapid change, "discipline" becomes a far less useful analytical category. In this context, network structure is not the subversion or secret of hierarchy, as the shadow economy was to the plan or *samizdat* to the unionized official arts, but only its obverse, a normal part of its internal communication and pattern of growth.[15]

In the postwar era, the best funded and thus most rapidly growing sectors were those of the three military crash programs, nuclear weapons, rocketry, and radar/anti-aircraft defense, each under a special Main Administration. These could cut across the vertical siloing of Soviet industry to secure scarce human and material resources. This administrative form, the megaproject, accordingly became invested with the grandest dreams of would-be reformers of all stripes. At the intersection of the three projects was computation, which, whether military or ostensibly civilian, served the Administrations' demand for a new level of computational power. The new institutes of these four sectors were integrally *extra*disciplinary spaces. Although Alexei Kojevnikov has noted that the imbrication of science with the state—"Big Science"—in the Soviet case predated World War Two, I argue that it was from these sectors that grew

15. Mark B. Adams, "Networks in Action: The Khrushchev Era, the Cold War, and the Transformation of Soviet Science," in *Science, History and Social Activism: A Tribute to Everett Mendelsohn*, ed. G. E. Allen and R. M. MacLeod (Norwell, MA: Kluwer Academic Publishers, 2001), 255–76; Linda L. Lubrano, "The Hidden Structure of Soviet Science," *Science, Technology, & Human Values* 18, no. 2 (1993): 147–75.

the Soviet analogue of what Pickering has called "the World War Two regime."[16] Their intersection was the epicenter of Soviet cybernetics.

The dynamics of the military-scientific complex have four important aspects. First, the sheer speed of the expansion granted the small generation of cybernetics' first proponents outsized influence over the much larger generation that they taught in the 1950s and 1960s. They inculcated values and modes of acting in enormous numbers of young scientists. (This is what justifies drawing broad conclusions from the study of these small groups.) Second, the institutes sedimented out of these networks were inherently extradisciplinary spaces because of the technological tasks that called them into being. This was the cybernetic efflorescence proper. But third, subsequent generations, those of the 1970s and 1980s, were socialized in already much more stable institutional environments, the localized subcultures of giant institutes. Their professional identities were formed more narrowly, and the universalizing ambitions of cybernetics thus had far less attraction. It was *for them* that cybernetics was mere "cyberspeak." Fourth, young scientists of the 1950s and 1960s ascended to newly created positions of institutional power very young, blocking the career trajectories of the following generations and creating pressures that would lead in some cases, including that of economics, to sudden reversals of power during the upheavals of perestroika.

A narrative beginning from the explosive buildout of the Soviet military-scientific complex as a sociotechnical phenomenon—one producing novel patternings of social action in making and then living with new technoscientific ensembles—provides an alternative or at least a complement to Gerovitch's seminal account of the rise and decline of cybernetics. By understanding cybernetics as a discursive field, Gerovitch aimed to sidestep the mapping of a sharp science vs. ideology dichotomy onto that of freedom vs. repression, which had underlain the earlier historiography of "totalitarian" science. He transposed to the history of science the new cultural history of the Soviet Union as influenced by the work of Stephen Kotkin.[17] Cybernetics thus becomes a "cultural medium within which Soviet scientists lived and

16. Alexei Kojevnikov, "The Great War, the Russian Civil War, and the Invention of Big Science," *Science in Context* 15, no. 2 (2002): 239–75; Andrew Pickering, "Cyborg History and the WWII Regime," *Perspectives on Science* 3, no. 1 (1995): 1–48.

17. Michael David-Fox, "Multiple Modernities vs. Neo-Traditionalism: On Recent Debates in Russian and Soviet History," *Jahrbücher für Geschichte Osteuropas* 55, no. 4 (2006); Stephen Kotkin, *Magnetic Mountain: Stalinism as a Civilization* (Berkeley: University of California Press, 1995).

worked."[18] On the basis of this understanding, Gerovitch offers a narrative in which cybernetics wielded mathematical and algorithmic rigor against the obfuscatory "newspeak" of Stalinism, a politics via science, but ended up, under the dual pressures of rapid expansion across the sciences and of accommodation with power, becoming an equally labile *façon de parler* amenable to reproducing the status quo.[19] Content became pure form, and optimism gave way to disillusionment. Gerovitch thus fits cybernetics to a sophisticated version of the readily available narrative frame for the post-Stalinist history of the Soviet Union as reform thwarted, as "thaw" (*ottepel'*) becoming the diminished Stalinism of "stagnation" (*zastoi*). The arc of this "parabola" is what led Benjamin Peters to call cybernetics' story a "normal" Soviet one.[20]

This nullified history, a trajectory beginning and ending at the same altitude, is the result of the dematerialization of cybernetics *qua* discourse. But cybernetics was inseparable from the sociotechnical phenomenon of the military-scientific expansion: a novel, deep sociological transformation inextricably bound up with equally novel technological systems. The creation of large-scale technological systems, driven by and forming part of the continued process of Soviet state-building, brought together different sciences and engineering cultures for prolonged periods of time in new configurations. In the late Soviet era, some even posed the question of whether "the Soviet Union does not have a military-industrial complex, but is such a complex."[21] As a moment of this broader history, cybernetics had myriad consequences well past its heyday, from the technological infrastructure of Soviet life to the social imaginary of the last Soviet generations, from the articulation of the order of knowledge to the modalities of rule of the post-Stalinist state.

18. Gerovitch, *From Newspeak to Cyberspeak* (ref. 7), on 3, 6. Although some formulations of "discourse" insist on its materiality, in Gerovitch's it seems essentially linguistic: repertoires of terminology, rhetorical *topoi*, and genres of their deployment.

19. Philip Mirowski observed Gerovitch's emphasis on cybernetics *qua* discourse in his review, *Journal of Economic Literature* 42, no. 1 (2004): 214–15.

20. Benjamin Peters, "Normalizing Soviet Cybernetics," *Information & Culture* 47, no. 2 (2012): 145–75.

21. David Holloway, "War, Militarism and the Soviet State," *Alternatives: Global, Local, Political* 6 (1980): 59–92. For a balanced discussion of this question, see John Barber, Mark Harrison, Nikolai S. Simonov, and Boris Starkov, "The Structure and Development of the Defence-Industry Complex," in *The Soviet Defence Industry Complex from Stalin to Krushchev*, ed. John Barber and Mark Harrison (Basingstoke and London: Macmillan Press, 1999), 3–32.

MILITARY CYBERNETICS

Some Mathematical Preliminaries

If the mathematicians were the center of the cybernetic network, then the center of the mathematical network was the famous Moscow mathematical school, its core formed by the students of Nikolai N. Luzin (1883–1950).[22] Their positions at the flagship Steklov Institute of Mathematics have led to their applied work being overlooked. In the 1930s, these mathematicians, and those of other centers of research, including Leningrad and Gorky, became involved in the modeling and control of physical processes arising in engineering tasks. This work accustomed them to military-funded, interdisciplinary, and applied work in concert with engineers. Further, it conditioned their later intellectual courses in or alongside cybernetics.

Luzin made breakthroughs in mathematical analysis, descriptive set theory, the theory of functions, trigonometric series, and integration. He studied in Göttingen and Paris, forming enduring relationships with the major mathematicians of the day, before returning to teach in Moscow University's Faculty of Physics and Mathematics in 1914.[23] He worked in informal seminars and social gatherings as much as in the classroom, and his pedagogical practices would be reproduced across the decades, becoming both an interactional infrastructure and a conveyer of values.[24] Luzin and his students called their society, the mathematician's promised land of the 1920s, Lusitania.

But that ship went down: Luzin and his own teacher, Dmitri F. Egorov, were attacked during the 1930s.[25] Arrested in 1930, Egorov became ill in jail and died a year later, while Luzin took refuge in institutions of applied mathematics, first at the Central Aerohydrodynamical Institute (TsAGI), the

22. On Luzin and Egorov, see Loren Graham and Jean-Michel Kantor, *Naming Infinity: A True Story of Religious Mysticism and Mathematical Creativity* (Cambridge, MA: Belknap Press, 2009).

23. Judging from the affinities, Göttingen's mathematics culture affected Moscow's. See David E. Rowe, "Making Mathematics in an Oral Culture: Göttingen in the Era of Klein and Hilbert," *Science in Context* 17, no. 1–2 (2004): 85–129.

24. L. A. Lyusternik, "Molodost' Moskovskoi Matematicheskoi Shkoly," *Uspekhi Matematicheskikh Nauk* 22, no. 1(133) (1967): 137–61; 22, no. 2(134) (1967): 199–239; 22, no. 4(136) (1967): 147–85.

25. S. S. Demidov and V. B. Levshin, *Delo Akademika Nikolaia Nikolaevicha Luzina* (St. Petersburg: Russkii Khristianskii Gumanitarnyi Institut, 1999). The evidence about the Luzin trial does not allow conclusively disentangling the personal, political, and professional motives of the actors involved. My claims thus speak to effects, not motives.

centerpiece of the Soviet aviation industry, and then in 1939 at the newborn Institute for Automation and Remote Control (IPU), the world's first institute for control engineering and later a hotbed of cybernetics.[26] But the younger mathematicians, some ignominiously having turned on their teachers, survived relatively unscathed. The culture of Moscow mathematics, of the Russian intelligentsia—many mathematicians being from intermarried scientific dynasties—was thus not extinguished and did not have to be reinvented during the Thaw, as Vladislav Zubok argued was the case with the literary intelligentsia.[27]

A constellation of problems from fluid mechanics guided the mathematicians' research. Fluid mechanics, flowering because of early aviation, had long been on the border of pure mathematics, physics, and practical engineering. It was at the heart of military science both in this period and throughout the subsequent Cold War, requiring the collaboration of experimenters and theoreticians. It also employed the newest techniques of mathematical analysis, reciprocally driving their development.[28] In the first half of the twentieth century, the gap between the engineering art of hydraulics and the mathematical formalization called "hydrodynamics" was thereby rapidly closing. At the same time, the recentering of physics from the phenomenal to the atomic level was separating physics from mechanics and aligning the latter more closely with mathematics.[29] (This was reflected in the reorganization of the Faculty of Physics and Mathematics in 1933 as the Faculty of Mechanics and Mathematics, or "Mekhmat" for short.) For all these reasons, mechanics became key to negotiating the boundary between applied and pure mathematics.[30]

26. A. I. Apokin and A. Z. Chapovski, "The Origins of the First Scientific Center for Automation," *History and Technology* 8 (1992): 133–38. In 1969, it was renamed the Institute of Problems of Control.

27. Zubok, *Zhivago's Children* (ref. 13), especially 161–92. G. G. Lorentz claims Moscow mathematical culture was as much a product of the Silver Age as writers like Pasternak and Akhmatova, in "Mathematics and Politics in the Soviet Union from 1928 to 1953," *Journal of Approximation Theory* 116 (2002): 169–223, on 197–98.

28. Fluid mechanics was a core part of the curriculum in Göttingen, to which Lusitania was closely connected.

29. For an examination of these articulations—of science and the military, pure and applied science, science and technology—through the case study of Ludwig Prandt, see Michael Eckert, *The Dawn of Fluid Dynamics: A Discipline between Science and Technology* (Weinheim: WILEY-VCH Verlag GmbH & Co. KGaA, 2006).

30. Michael Eckert, "Fluid Mechanics: A Challenge for Mathematics Ca. 1900," in *Report No. 12/2013* (presented at "From 'Mixed' to 'Applied' Mathematics: Tracing an important dimension of mathematics and its history," Mathematisches Forschungsinstitut Oberwolfach, 2013), 55–58; Brittany Shields, "Mathematics, Peace, and the Cold War," this issue.

For present purposes, the most significant group was Sergei A. Chaplygin's theoretical department at TsAGI, including Mikhail A. Lavrentiev, Mstislav V. Keldysh, Lazar A. Lyusternik, Anatoly A. Dorodnitsyn, and Sergei A. Khristianovich. They studied problems of fluid dynamics, ballistics, and associated mechanical issues, such as wing flutter.[31] During the war Lavrentiev would study explosions and shock waves. Other mathematicians were working on related problems. Sergei L. Sobolev at the Seismological Institute worked on the propagation of waves in nonhomogenous media.[32] At the Geophysical Institute, Andrei N. Tikhonov studied electromagnetic methods of prospecting, while Andrei N. Kolmogorov led a group on turbulence.[33] Aleksei A. Lyapunov briefly worked at the Gas Prospecting Institute, and then the Institute of Experimental Medicine. Aleksandr A. Andronov led a group at his Radiophysics Faculty of Gorky University investigating radio and electrical networks. This Gorky group envisioned a science of nonlinear oscillations that would embrace many seemingly disparate areas of physics. They became tightly connected with theorists of control and analog computing at the Institute of Automation and Remote Control.[34]

As these mathematicians mathematically abstracted diverse problems of mechanics, understanding grew that these problems could be unified, that

31. Boris Aleshin, "Nachalo Tvorcheskogo Puty M.V. Keldysha—Rabota v TsAGI," *Za Nauku* 3 (2011); S. K. Betiaev, "K Istorii Gidrodinamiki: Nauchnye Shkoly Rossii XX Veka," *Uspekhi Fizicheskikh Nauk* 173, no. 4 (2003): 419–46; Mikhail Alekseevich Lavrentiev, "Opity Zhizni: 50 Let v Nauke," in *Vek Lavrentieva*, ed. N. A. Pritvits, V. D. Yermikov, and Z. M. Ibragimova (Novosibirsk: Izdatel'stvo CO RAN, 2000), 37–43.

32. S. S. Kutateladze, "O Nauchnoi i Pedagogicheskoi Deiatel'nosti S.L. Soboleva," in *Sobolev Sergei L'vovich (1908–1089): Biobibliograficheskii Ukazatel'*, 3rd ed., ed. S. S. Kutateladze (Novosibirsk: Izdatel'stvo Instituta Matematiki, 2008), 20–28; M. I. Vishik and L. A. Lyusternik, "Sergei Lvovich Sobolev (k Piatidesiatiletiiu so Dnia Rozhdeniia)," *Uspekhi Matematicheskikh Nauk* 14, no. 3(87) (1959): 203–14.

33. V. A. Ilin et al., "Tvorets Sovremennoi Prikladnoi Matematiki: K 100-Letiiu so Dnia Rozhdeniia Akad. A. N. Tikhonova," *Vestnik RAN* 76, no. 9 (2006): 813–21; A. A. Tikhonova and A. N. Tikhonov, *Andrei Nikolaevich Tikhonov* (Fizicheskii Fakul'tet Moskovogo Gosudarstvnenogo Universiteta, 2004). During the war, Kolmogorov also worked on ballistics. Albert N. Shiryaev, "On the Defense Work of A. N. Kolmogorov during World War II," in *Mathematics and War*, ed. Bernhelm Boos-Bavnbek and Jens Høyrup (Basel: Springer Basel AG, 2003), 103–07.

34. Chris Bissell, "A. A. Andronov and the Development of Soviet Control Engineering," *IEEE Control Systems* 18, no. 1 (1998): 56–62; Chris Bissell, "Control Engineering in the Former U.S.S.R.: Some Ideological Aspects of the Early Years," *IEEE Control Systems* 19, no. 1 (1999): 111–17; Amy Dahan Dalmedico, "Early Developments of Nonlinear Science in Soviet Russia: The Andronov School at Gor'kiy," *Science in Context* 17, no. 1–2 (2004): 235–66.

diverse physical processes could be susceptible to similar modeling strategies (pointing toward the synthesis of continuum mechanics).[35] Two consequences for the mathematicians followed from this prewar work. First, the conceptual similarities underlying the mathematical generalizations—especially regarding the problems of stability, phase transitions, and nonlinearity, and the technical apparatus of differential equations—predisposed the mathematicians to find cybernetics interesting and intelligible (even as many of them, such as Keldysh himself, would later view askance its grander pretensions). Secondly, as many of the problems did not admit of analytic solution, these researchers became *nolens volens* early developers of numerical methods, and thus proponents of computing technology.[36]

Critical Mass

During and immediately after the war, the key members of the mathematicians' network became central to nuclear weapons development.[37] They

35. See Gérard A. Maugin, *Continuum Mechanics Through the Twentieth Century: A Concise Historical Perspective* (Dordrecht: Springer, 2013), and especially 167–99 on Soviet contributions.

36. On the American case, Amy Dahan Dalmedico, "L'Essor Des Mathématiques Appliquées Aux États-Unis: L'Impact de La Seconde Guerre Mondiale," *Revue d'Histoire Des Mathématiques* 2 (1996): 149–213; Amy Dahan and Dominique Pestre, "Transferring Formal and Mathematical Tools from War Management to Political, Technological and Social Intervention (1940–1960)," in *Technological Concepts and Mathematical Models in the Evolution of Modern Engineering Systems: Controlling, Managing, Organizing* (Basel: Birkhauser Verlag, 2004), 79–100; Tinne Hoff Kjeldsen, "New Mathematical Disciplines and Research in the Wake of World War II," in Boos-Bavnbek and Høyrup, *Mathematics and War* (ref. 33), 126–52. For an international survey, see Reinhard Siegmund-Schultze, "Military Work in Mathematics 1914–1945: An Attempt at an International Perspective," in Boos-Bavnbek and Høyrup, *Mathematics and War* (ref. 33), 23–82.

37. Sobolev worked under Igor V. Kurchatov, the leader of the bomb project, at the Academy Laboratory No. 2, 1945–48. S. S. Kutateladze, "Sobelev i Bomba," *Nauka v Sibiri* 9 (2008): 6. It was founded in 1943, in 1949 renamed the Laboratory for Measuring Instruments, and is now the Institute of Atomic Energy. Keldysh (with Tikhonov's group from the Institute of Theoretical Geophysics) organized the computational effort. This group became the Department of Applied Mathematics (OPM) of the Institute of Mathematics in 1953, a central node for the network. Lyapunov, Israel M. Gelfand, and Dorodnitsyn, among others, all worked there. In 1966, it became the Institute of Applied Mathematics. Keldysh was simultaneously scientific director of NII-1 (1946–1961), the "Chief Theoretician" to rocket designer Sergei P. Korolev's "Chief Engineer." V. A. Kitov, "Prezident Akademii Nauk SSSR M. V. Keldysh. 100 Let so Dnia Rozhdeniia," 2011, http://www.ras.ru/keldysh/about.aspx (accessed 29 Aug 2016). Leonid V. Kantorovich led the Leningrad Department of the Institute of Mathematics (LOMI) working on calculations of critical mass (1948–49). V. S. Vladimirov and V. N. Kublianovskaya, "Vychisleniia Dlia Atomnogo Proekta," in *Leonid Vital'evich Kantorovich: Chelovek i Uchenii*, ed. V. L. Kantorovich, S. S. Kutateladze, and Y. I. Fet, vol. 1 (Novosibirsk: Izdatel'stvo CO RAN, 2004), 153–60.

thereby became both closely allied with the academically and politically powerful physicists and integrally involved in developing electronic digital computers. Initially, brigades of girls with Mercedes and Rheinmetall calculators performed the computational work. The First Main Directorate created an Interdepartmental Commission on Computing Technology to coordinate and devise means to speed it up.[38]

Two new establishments were founded in 1948. At Lavrentiev's behest, the Academy founded the Institute of Precision Mechanics and Computer Technology (ITMVT).[39] The Ministry of Machine Building and Instrumentation founded its competing Special Construction Bureau 245 (SKB-245), on the basis of the Moscow Tabulating-Analytical Machine Factory.[40] Both initially focused on analog mechanical and electrical computing equipment, mostly for the Main Artillery Directorate and TsAGI. But these tools were inadequate to the computational demands of nuclear research.

The mathematicians took upon themselves the challenge of creating the computers that the project demanded. Over the next two years, via a special commission of the Technological Sciences Division of the Academy chaired by Keldysh, and Lavrentiev's lobbying of Khruschev, the mathematicians took over ITMVT. Lavrentiev (1949–1952) and Lyusternik (1949–1955) became director and department director, respectively, and in 1950, they brought Sergei A. Lebedev, a specialist in modeling high-voltage power networks, to Moscow.[41]

Lebedev had already been working on a digital electronic computer, the Small Electronic Computing Machine (MESM), at the Energy Institute of the Ukrainian Academy with the active support of Lavrentiev (then the Vice President of the Ukrainian Academy).[42] At ITMVT he began developing the

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Aleksandr S. Kronrod, Luzin's last student, ran the computational center at Laboratory No. 3 under Lev D. Landau (1950–55). Founded in 1945, from 1958 it has been the Institute for Theoretical and Experimental Physics. Vladimir Tikhomirov, "A. S. Kronrod (1921–1986)," *Matematicheskoe Prosveshchenie* 3, no. 6 (2002): 49–54.

38. Hiroshki Ichikawa, "Strela-1, the First Soviet Computer: Political Success and Technological Failure," *IEEE Annals of the History of Computing* 28, no. 3 (2006): 18–31.

39. On the basis of the Department of Precision Mechanics of the Institute of Machine Sciences (with 13 people), the Laboratory of Electromodeling (19 people) of the Energy Institute, and the Department of Approximate Calculation from the Mathematics Institute.

40. In 1958, renamed the Institute of Electronic Mathematical Machines.

41. Ichikawa, "Strela-1" (ref. 38), 21–24.

42. Gregory D. Crowe and Seymour E. Goodman, "S. A. Lebedev and the Birth of Soviet Computing," *IEEE Annals of the History of Computing* 16, no. 1 (1994): 4–24.

MESM's successor, the Big Electronic Computing Machine (BESM). SKB-245 initiated a competing digital electronic computer, the Strela. The dark horse, a third group working with hardly any institutional support but with Sobolev's personal patronage was Isaak S. Bruk's Laboratory of Electro-Systems at the Energy Institute of the Academy, finishing first with the M-1 and M-2 computers.[43]

Sobolev immediately pressed the M-1 into service at Laboratory No. 2 in 1951. Laboratory No. 2 built its own small computer, the TsEM, operational from 1953.[44] The first users of the MESM in 1952 were from the Steklov Institute's Department of Applied Mathematics (OPM) under Keldysh, and in 1954 it took delivery of the first Strela.[45] The next seven Strelas were destined for other centers of the nuclear project.[46] The first BESM was installed in the new (only ostensibly civilian) Academy Computing Center (VTs) under Dorodnitsyn in 1955. On November 22, 1955, the mathematicians from OPM stood alongside the physicists at the Semipalatinsk proving ground to witness the explosion of the hydrogen bomb.

The Cybernetic Colonels

Concurrently, the chair of higher mathematics of the Artillery Academy of the Ministry of Defense, held by Lyapunov, was ground zero to another explosion. Lyapunov gathered a circle of bright engineers who became central to Soviet cybernetics, including Nikolai P. Buslenko, Modest G. Gaaze-Rappoport, Mikhail D. Kislik, Anatoly I. Kitov, Nikolai A. Krinitskii, Ivan B. Pogozhev, Igor A. Poletaev (who had been sent to MIT at the end of the war to study radar), and Sergei I. Vilenkin.[47] Many of them also commuted

43. In 1958, it became the Institute of Electronic Control Machines (IECM) of the Academy.

44. Boris N. Malinovskii, "Mikhaylov's Unusual Computer," in *Computing in Russia: The History of Computer Devices and Information Technology Revealed*, ed. Georg Trogemann, Alexander Nitussov, and Wolfgang Ernst (Braunschweig: Vieweg, 2001), 125–26.

45. Boris N. Malinovskii, *Pioneers of Soviet Computing*, 2nd ed., 2010, http://www.sigcis.org/files/SIGCISMC2010_001.pdf, on 13–14.

46. VTs-1 of the Main Artillery Administration, VTs of the Academy of Sciences (founded 1955 on the basis of OPM, with Dorodnitsyn as director), VTs of Moscow State University, KB-11 at Arzamas-16 (Andrei D. Sakharov's employer), and NII-1011 (Chelyabinsk-70). Kitov, "Prezident Akademii Nauk SSSR" (ref. 37).

47. Ivan B. Pogozhev, "On Po-Dobromu Prochno Ob'edinial Lyudei," in *Aleksei Andreevich Lyapunov*, ed. N. A. Lyapunova and Y. I. Fet (Novosibirsk: Nauchno-Izdatel'skii Tsentr OIGGM SO RAN, 2001), 100–105; Ivan B. Pogozhev, "Slovo Ob Uchitele: A. A. Lyapunov v Moei Zhizni," in the same, 378–82; A. I. Poletaev, "'Voennaia' Kibernetika, ili Fragment Istorii

to Moscow to take evening classes with Kolmogorov. Kitov found an English copy of Wiener's *Cybernetics* in the classified library of SKB-245 in 1952. He spoke about cybernetics at seminars around Moscow, military and civilian, even while it was still officially a "bourgeois pseudoscience." Through these mathematically adept military engineers cybernetics entered the wider mathematics world.

In 1952, Kitov defended the USSR's first dissertation on programming at Scientific Research Institute 4 (NII-4), and that same year founded the first military computation center at the Artillery Academy.[48] Becoming independent as Computing Center 1 (VTs-1) in 1954, Kitov led it until 1960, with Krinitskii and Buslenko among his deputies.[49] It often worked jointly with OMP, including on calculations for the space program.[50] (Lyapunov had positions at both institutions.) VTs-1 became the center of military computing. Scientists and engineers trained there had founding and leadership roles at all subsequent military computation centers.[51] Some members of Lyapunov's study group continued their military careers, but by the mid-1960s most had transferred out of the military to leading roles in civilian institutes, carrying cybernetics with them.[52]

In 1953, Kitov gave a presentation on cybernetics to the Scientific-Technical Council on Radioelectronics, at the request of its chairman, Admiral Aksel'

Otechestvennoi 'Lzhenauki'," in *Ocherki Istorii Informatiki v Rossii*, ed. Dmitrii A. Poslepov and Yakov I. Fet (Novosibirsk: Nauchno-Izdatel'skii Tsentr OIGGM SO RAN, 1998), 515–31.

48. This important institute (founded 1946) moved from ballistics and offensive rocketry to ICBMs and space flight, and led anti-ballistic missile research. Kitov's dissertation was entitled "Programming tasks of long range external ballistic rockets."

49. Krinitskii was deputy head of Gosplan's VTs (founded 1959) from 1971 to 1981. Buslenko spent his entire career in the military, working in turn at VTs-1, VTs-4/TsNII-45, TsNII-27, NII-101/Institute of Automatic Apparatuses. Simultaneously, in the civilian world, he founded and led kafedras at the Moscow Institute of Physics and Technology ("Fiztek") and the Moscow Institute of Oil and Gas ("Kerosinka"), two important educational institutions of the new intelligentsia.

50. Vladimir P. Isaev, "Rol' VTs-1 MO SSSR Na Nachal'nom Etape Osvoeniia Kosmosa," 2011, http://www.computer-museum.ru/histussr/vc1_kosmos.htm (accessed 29 Aug 2016). NII-4, the center of the space program, acquired its own computing center in 1959, with two M-20 computers. "Mesto i Rol' Vychislitel'nogo Tsentra v Strukture NII-4," http://www.vcnii4.narod.ru/VCentr.html (accessed 24 April 2014).

51. V. A. Kitov, "VTs-1/TsNII-27 MO SSSR," 2010, http://www.kitov-anatoly.ru/organizacii/vc-1.htm (accessed 29 Aug 2016); Georgii Mironov, "Pervyi VTs i Ego Osnovatel'," *Otkritye Sistemy* 5 (2008): 76–79.

52. Kislik worked at NII-4 and VTs-4/TsNII-45, and Gaaze-Rappoport and Poletaev at NII-5 (focused on anti-aircraft systems), where they would be rejoined by Kitov in the 1960s, while Vilenkin and Pogozhev worked at military proving grounds.

Berg, who led the radar megaprogram.[53] Berg had a pre-existing interest in control science, having participated in the first All-Union Conference on Automation and Remote Control in 1935 under the auspices of what became the Institute bearing that name, and he was to become an enthusiastic patron of cybernetics.[54] The immediate effect of Kitov's report was the founding in 1955 of VTs-2, the Naval Computing Center (later part of TsNII-24), and VTs-3, the Air Force Computing Center (later TsNII-30), which became important think tanks for systems analysis and operations research.

While nuclear research kick-started digital computing, anti-aircraft and antirocket research, radar, and rocketry would be its next frontiers, and the colonels were at the vanguard.[55] The multiplying military institutes worked out different aspects of complex weapons systems, integrating scientific and engineering specialities in entirely new ways. They overlapped at the computing centers, which not only performed calculations and developed computer hardware and software to knit together the weapons into systems, but also began to reimagine decision-making at the interface of man and machine. "Cybernetician" (*kibernetik*) as an identity was anchored in this *extra*disciplinary environment. (Mathematicians based in the Academy were far less likely to self-identify as such, even when they worked on related problems.) The colonels gave their scientific and engineering tasks cybernetic interpretations; reciprocally, those tasks motivated propagandizing cybernetics as a general theory of scientific socialism beyond the "post office boxes."

Man-Machine Systems: From Calculation to Control

If the nuclear project midwifed electronic digital computers, anti-aircraft and antiballistic missile rocketry brought together the novel technologies of radar, rocketry, and computation in a new way. They forced development of real-time networked systems and decision support systems. Whereas the first

53. Poletaev's friend from his visit to MIT, K. N. Trofimov, then Berg's assistant, connected them. Trofimov became an important patron of operations research and computerization in command and control.

54. For Berg's dizzying list of overlapping military and scientific positions of authority in the 1940s–1950s, see Yu. N. Erofeev, "Ot Radiosviazi Do Radiolokatsii," in *Aksel' Ivanovich Berg*, ed. Y. I. Fet (Moscow: Nauka, 2007), 23–51; E. V. Markova, "Kiberneticheskii Period Tvorchestva Akademika A. I. Berga," in *Aksel' Ivanovich Berg*, ed. Y. I. Fet (Moscow: Nauka, 2007), 52–88.

55. Cybernetician Ilya Muchnik cautioned the author that although the flagship technology was radar, from the point of view of cybernetics, the problem was the more generalized one of modeling and engineering sensing and perception.

military computers in the nuclear project performed numerical *calculations*, here the issue had become one of *control*.

The organization of work was entirely different from the small teams of mathematicians working on nuclear calculations. Hundreds of programmers worked to realize operational requirements past the edge of what seemed technologically possible. Computers had to yoke together radar and missiles into a system that could seamlessly alert, track, launch, guide, and destroy in a matter of minutes.[56] To provide coverage over extended areas, these multi-component systems had to be combined into the first Soviet computer networks. In the late 1950s, ITMVT began work on System-A, the first antimissile system, with an M-40 computer based on the BESM at its heart, and in March 1961, it shot a missile out of the sky, the first such feat by any military. This effort led a wave of networked defense systems.[57]

In these man-machine systems—and more and more systems came to seem analogous—the engineers converged on the problem of engineering decision-making itself. A core cybernetic insight was that any goal-directed system could be described in the same terms, man or machine. Automation and intelligence were intersubstitutable (the manned space program, for instance, aspired to completely automated missions).[58] Here again there were pre-existing projects and devices ripe for cybernetic reinterpretation. Naval fire control systems, for instance, combined the inputs of multiple sensors, transformed by analog computers, into a decision context for the gunner. Quickly they expanded into systems for tactical decision-making, on first the ship and then the battle group level.[59] Decision-support systems,

56. V. V. Lipayev, "Razrabotka Boevikh Programm v NII-5," *PC WEEK/RE* 40 (1999), and "The Development of Military Programming at the 'Institute N 5'," in Trogemann et al., ed., *Computing in Russia* (ref. 44), 211–14. On control computing and its civilian use, cf. Shkabardnia, *Priborstroenie* (ref. 6), 454–64.

57. Boris Nikolaevich Malinovskii and E. N. Filinov, "Mikhail Alexandrovich Kartsev and the 'M' Computer Series," in Trogemann et al., ed., *Computing in Russia* (ref. 44), 205–10; Vsevolod S. Burtsev, "Distributed Systems: The Origins of Computer Networks in the USSR," in Trogemann et al., ed., *Computing in Russia* (ref. 44), 215–20; I. A. Sokolova, *Igor' Aleksandrovich Mizin—Uchenye, Konstruktor, Chelovek* (Moscow: IPI RAN, 2010); Slava Gerovitch, "InterNyet: Why the Soviet Union Did Not Build a Nationwide Computer Network," *History and Technology* 24, no. 4 (2008): 335–50.

58. Slava Gerovitch, "Stalin's Rocket Designers' Leap into Space: The Technical Intelligentsia Faces the Thaw," *Osiris* 23 (2008): 189–209.

59. On Soviet naval fire control and combat data systems, sometimes called "second captains," see Norman Friedman, *The Naval Institute Guide to World Naval Weapon Systems*, 5th ed. (Annapolis, MD: Naval Institute Press, 2006), on 85–88.

implementations of multicriteria choice theories combining aspects of systems engineering, operations research, and artificial intelligence, spread to tactical troop control, procurement, and theater-level strategic modeling.[60] Alongside providing computational support for other organizations, research and development of such systems became a primary occupation of military computing centers.[61] Virtually doubling the nexus of computation at the intersection of rocketry, nuclear research, and air defense, systems analysis and decision research became a fifth direction of cybernetics' growth. A collective of authors has recently outlined the development of a "Cold War rationality" in the United States, in which rationality becomes reduced to rule; they claim that there was no Soviet analogue, but if there was, it is to be sought here.[62]

These systems, created for real-time control of spatially distributed man-machine complexes, were conceptually very different from the purely calculative vision of early computing, and more properly cybernetic in its original inspiration. It was by analogy with this evolving vision of cybernetic control of large-scale systems that the military cyberneticians would hope to radically reform the planned economy.

CYBERNETIC SCIENCE

From the Big Seminar to the Scientific Council

In 1955, with Lyapunov's and Sobolev's revision, assistance, and signatures, the overview of cybernetics that Kitov had been presenting at various institutes was

60. David Holloway, "Technology, Management and the Soviet Military Establishment," *Adelphi Papers* 11, no. 76 (1971): 1–15; Vitalii Tsygichko, *Modeli v Sisteme Priniatiia Voenno-Strategicheskikh Reshenii v SSSR* (Moscow: Imperium Press, 2005); Elliot R. Lieberman, "Soviet Multi-Objective Mathematical Programming Methods: An Overview," *Management Science* 37, no. 9 (1991): 1147–65.

61. First translations that had a determining impact were Philip M. Morse and George E. Kimball, *Methods of Operations Research* (Cambridge, MA: The Technology Press, 1946) as A. F. Gorokhova, ed., *Metody Issledovaniia Operatsii*, trans. Igor A. Poletaev and Konstantin A. Trofimov (Cambridge, MA: Sovetskoe Radio, 1956); and Harry H. Goode and Robert E. Machol, *System Engineering* (New York: McGraw-Hill, 1957) as *Sistemotekhnika: Vvedenie v Proektirovanie Bol'shikh Sistem* (Mosow: Sovetskoe Radio, 1962).

62. Paul Erickson et al., *How Reason Almost Lost Its Mind* (Chicago: University of Chicago Press, 2013). For a sense of the range of research, and the blurriness of the boundary with economics, see Yu. G. Evtushenko and S. L. Skorokhodov, eds., *50 Let VTs RAN: Istoriia, Liudi, Dostizheniia* (Moscow: Vychislitel'nyi Tsentr Rossiiskoi Akademii Nauk, 2005).

finally published in the arbiter of orthodoxy, *Voprosy Filosofii*.[63] Its publication was an unmistakable sign that the campaign against cybernetics had to abruptly stop and be quickly forgotten.[64] Lyapunov and his collaborators could now proselytize through the infrastructure of Moscow civilian mathematics: the seminars.

Lyapunov's seminar at the Artillery Academy had been paralleled by one at his home. It became what is remembered as "the Big Seminar," which met 121 times at Moscow State University between 1954 and 1964. The military connection remained important: one participant remembered that at the first meeting, the known informers (*stukachi*) stiffened upon the entrance, in full uniform, of the cybernetic colonels.[65] At this seminar all of the disciplines that were to receive cybernetic reframing—from computer engineering to biology, from economics to linguistics—met and mingled. Lyapunov's seminar begat numerous others.[66] Through the seminars, Luzin's genres of interaction and forms of pedagogy, the uninterrupted forms of pre-Soviet intelligentsia sociality, became thoroughly enmeshed with cybernetics. With the prodigious production of mathematicians and physicists trained therein and then moving into more applied fields—including economics—cybernetic *intelligentnost'* would permeate the late Soviet military-scientific complex.[67]

63. S. L. Sobolev, A. I. Kitov, and A. A. Lyapunov, "Osnovnye Cherty Kibernetiki," *Voprosy Filosofii* 4 (1955): 136–48. With some historical irony, it was followed by a defense of cybernetics by the very Ernst Kolman who had in 1930 so viciously attacked Luzin, Egorov, and the economic planners. Ernest Kolman, "Chto Takoe Kibernetika?," *Voprosy Filosofii* 4 (1955): 148–59.

64. Gerovitch, *From Newspeak* (ref. 7), 118–31.

65. Y. I. Fet, *Rasskazy o Kibernetike* (Novosibirsk: Izdatel'stvo CO RAN, 2007), on 34.

66. Counting just the interdisciplinary seminars attended by scientists from across Moscow: Programming, game theory, and mathematical biology, also directed by Lyapunov (1955–1961); biological cybernetics, by Leonid V. Krushinskii; mathematical cybernetics, by Sergei V. Yablonsky; programming, by Mikhail R. Shura-Bura; automation and image recognition (at IPU), by Mark A. Aizerman, L. I. Rozonoer, and Emmanuel M. Braverman; biology and mathematics, by Gelfand. The last spawned three others, on game theory in biology, higher nervous activity, and artificial intelligence ("psychonics" [*psikhonika*], on analogy with bionics). In Leningrad, Kantorovich founded a similar, though smaller, cybernetics seminar in 1956 at the House of Scientists. Modest Georgievich Gaaze-Rappoport, "Pervyi Neformalnyi Etap Razvitiia Otechestvennoi Kibenetiki," *Filosophskie Issledovaniia* 4 (1993): 439–50; Gaaze-Rappoport, "O Stanovlenii Kibernetiki" (ref. 6).

67. On Moscow informal mathematics, Slava Gerovitch, "Parallel Worlds: Formal Structures and Informal Mechanisms of Postwar Soviet Mathematics," *Historia Scientiarum* 22, no. 3 (2013): 181–200. Masha Gessen evokes the atmosphere in *Perfect Rigor: A Genius and the Mathematical Breakthrough of a Century* (New York: Houghton Mifflin Harcourt Publishing Company, 2009). The new "fizmat" schools, organized in 1958–1963 and championed by Lavrentiev, Kolmogorov,

The cyberneticians were not shy in proclaiming their new science. In 1958, Poletaev's popularization of cybernetics, *Signal*, made the subject accessible and exciting to a wider reading public.[68] In 1959, his letter published in *Komsomolskaia pravda* in response to an article by Ilya Ehrenburg ignited one of the most memorable debates of the Thaw, "the discussion of physicists and poets," in which the physicists in question were in fact cyberneticians. Often read as a "two cultures" quarrel, the debate reflected both exhaustion and disgust with the humanist intelligentsia so complicit in the culture of high Stalinism and a new self-consciousness among the "scientific-technical intelligentsia," who were coming to see themselves as not mere technicians but rather as both truer heirs to the intelligentsia tradition and the first flowering of the culture of the future.[69]

Key members of the mathematical community rose to leadership of the Academy on the wings of their atomic successes and the public campaign for cybernetics: Keldysh became President of the Academy of Sciences in 1961, and Lavrentiev led the new Siberian Division from 1957.[70] In 1961, Berg became the director of the Scientific Council on the Complex Problem of Cybernetics under the Academy Presidium, with Lyapunov as his deputy. This body aspired to coordinate cybernetics across all the disciplines. The cybermathematicians ascendent, they became a "universal passage point," their institutional power an organizational realization of the imperial ambitions of mathematics.[71] The two together—institutional power and claims to epistemological universality—constituted the ground for the rapid diffusion of cybernetics as discourse in the Academy throughout the 1960s.

Kronrod, and Lyapunov, not only secured the supply of cadres, but also propagated these cultural norms through yet wider social domains. Cf. Ilya Kukulin and Maria Mayofis, "Matematicheskie Shkoly v SSSR: Genesis Institutsii i Tipologiia Utopii," in *Ostrova Utopii: Pedagogicheskoe i Sotsial'noe Proektirovanie Poslevoennoi Shkoly (1940–1980-e)*, ed. Ilya Kukulin and Maria Mayofis (Moscow: Novoe literaturnoe obozrenie, 2015), 241–312.

68. Igor A. Poletaev, *Signal: O Nekotorikh Poniatiiakh Kibernetiki* (Moscow: Sovetskoe Radio, 1958).

69. Konstantin A. Bogdanov, "Fiziki vs. Liriki: K Istorii Odnoi 'Pridurkovatoi' Diskussii," *Novoe Literaturnoe Obozrenie* 11 (2011): 48–66.

70. On Lavrentiev's career and the founding of the Siberian Division, see Ksenia Tatarchenko, "Calculating a Showcase," in this issue.

71. Geof Bowker, "How to Be Universal: Some Cybernetic Strategies, 1943–70," *Social Studies of Science* 23, no. 1 (1993): 107–27. However, in a telling limit to the ambitions of cybernetics, the Council sought, without success, consensus around a vision for a new Institute of Cybernetics, until the founding of the Siberian Division of the Academy diverted much of its key members' energies.

The Post-Stalinist Order of Knowledge

It may seem paradoxical that, even as mathematicians reached the apogee of their involvement in applied research via cybernetics, they preached theoreticism. Yet it must be understood as a strategy to ensure the autonomy of science from political control while nevertheless retaining the levels of funding enjoyed in military research. Such a strategy involved a complicated re-articulation of the relationship between the scientific, the technical, and the political. With their newfound power—and Stalin safely buried while Khrushchev declined the title of "coryphaeus of science"—physicists and mathematicians challenged the reign of the philosophers and other guardians of orthodoxy. The battle was waged on two fronts: the normative status of Marxist-Leninist philosophy of science with respect to scientific practice, and the subordination of theory to technology and thence to the needs of economic development.[72] The direction of struggle was promulgated at the close of the war, but only at the end of the 1950s could victory be achieved.[73]

Stalinist Marxism had struggled over the relationship between politics and science: were there socialist and capitalist, proletarian and bourgeois sciences? From the 1930s, such a class theory of science reigned. Party philosophers exercised normative power over science, and the language of "dialectical materialism" ("diamat") entered into scientific disputes. But beginning around 1954—on the eve of the explosion of the hydrogen bomb—mathematicians and physicists confronted the philosophers, using the latter's recent opposition to quantum mechanics, relativity, and cybernetics as evidence of their wrongheadedness.

This was of a piece with a reappraisal of "fundamental" science. Post–Great Break philosophical dogma stated that the productive forces drive technological development, and that science is an abstraction from or reflection upon this; scientists were thus enjoined not to stray too far from technological practice lest they be seduced by "idealism." Egorov and Luzin had been accused of just that, and the Moscow mathematical school was thus very sensitive to the charge.[74] But mathematicians and physicists now argued that

72. Loren R. Graham, Peter H. Juviler, and Henry W. Morton, "Reorganization of the USSR Academy of Sciences," in *Soviet Policy-Making: Studies of Communism in Transition* (New York: Frederick A. Praeger, 1967), 133–59; Konstantin Ivanov, "Science after Stalin: Forging a New Image of Soviet Science," *Science in Context* 15, no. 2 (2002): 317–38; Gerovitch, *From Newspeak* (ref. 7), 163–66, 189–92, 199–207.

73. Vucinich, *Empire of Knowledge* (ref. 14), 205–10.

74. Alexander Vucinich, "Soviet Mathematics and Dialectics in the Stalin Era," *Historia Mathematica* 27 (2000): 54–76.

the new mathematics seemingly so far from practice—set theory, mathematical logic, algebraic topology, probability theory, et cetera—had been revealed by nuclear physics and computing as a crucial driver of economic progress in the era of the "Scientific-Technological Revolution" that the advanced countries of the world were then understood to be entering.[75]

On both fronts a turning point was the 1958 All-Union Conference on Philosophical Problems of Natural Science, at which the philosophers were routed.[76] The new settlement proposed, first, that philosophers must now study science and philosophize on that basis rather than prescribe to it. Second, science was given an equal status to technology, which was enshrined in the 1961 Party Program that stated that "science will become, in the full sense of the word, a direct productive force" rather than part of the superstructure. Keldysh, upon becoming Academy President in 1961, swiftly enacted reforms under discussion since the early 1950s. On April 12, 1961, as Yurii Gagarin was launched into space in the machine he had helped design, Keldysh dissolved the Division of Technological Sciences of the Academy, its largest division, ejecting over fifty institutes.

With the Academy renouncing its claim to be the supreme coordinator of all research, a newly empowered and renamed State Committee for the Coordination of Scientific Research Work was to become the hinge between the realms of fundamental and applied science, and coordinate the latter. The Academy retained only the heart of cybernetics in a new Division of Automation, Remote Control, and Radioelectronics.

Lyapunov, Sobolev, and Kitov had framed cybernetics as more than mere engineering by rephrasing Wiener's claims in the language of fundamental science.[77] They also claimed computers as their domain against the engineers by basing cybernetics around the computer as tool and metaphor, and conversely framing cybernetics as a general theory of computing. Computer science, probability, and other "applied" specialties banished to other disciplines in the United States accordingly remained within mathematical departments and institutions. The Hilbertian image of the role of formalization and axiomatization that dominated Soviet mathematics provided an additional

75. Paul R. Josephson, "Science and Ideology in the Soviet Union: The Transformation of Science into a Direct Productive Force," *Soviet Union/Union Sovietique* 8, no. 2 (1981): 159–85.

76. P. N. Fedoseev, ed., *Filosofskie Problemy Sovremennogo Estestvoznaniia: Trudy Vsesoyuznogo Soveshchaniia po Filosofskim Vorprosam Estestvoznaniia* (Moscow: Izdatel'stvo Akademii Nauk SSSR, 1959).

77. Gerovitch, *From Newspeak* (ref. 7), 177–79.

rationale. In contrast to the later Bourbakist image equating mathematics with *mere* formalism, for David Hilbert mathematics and the physical sciences were in dialectic: mathematics could axiomatize any already sufficiently mathematically sophisticated areas of physical science, and thereby provide a springboard for their further development.[78] Hilbert thought mechanics ripe for such treatment; John von Neumann axiomatized quantum mechanics; one of Kolmogorov's early feats was an axiomatization of probability. We can thus understand the simultaneous burgeoning of mathematized applied sciences and rejection of engineering from science proper: cybernetics, at least its theoretical, general, mathematical part, was the properly *scientific* complement to new engineering practices, with a home in the Academy. Cybernetics was on the way to becoming an alternative scientific metalanguage, and mathematicians universal scientists.[79]

Despite its importance to the bid for scientific autonomy, cybernetics was far from apolitical. As Rindzeviciute argues, cybernetics was a political project in two senses.[80] First, mathematics, largely preserving a position exterior to politics even under Stalin, was the lever by which science as a whole could be pried loose from the political. Mathematics, computing, and cybernetics are thus a privileged site to observe the changing relationship of science to politics—the political ontology of truth—in the late Soviet Union. In a second sense, cybernetics was a theory of government, a science of it, a toolbox for it. It gave tools, concepts, and apparatuses to those who governed, as well as an overarching conception of the nature of government. Scientists thereby asserted a claim to jurisdiction over political problems. Stalin had attempted to stamp out the technocratism of elite engineers and economists during the Great Break.[81] But under the new dispensation, politics and politicians were excluded from science, while scientists themselves demanded that they and their expertise be taken into account by politicians. Such a vision of science, one with its own legitimacy not founded in the political, suited the

78. Leo Corry, "David Hilbert and the Axiomatization of Physics (1894–1905)," *Archive for History of Exact Sciences* 51, no. 2 (1997): 83–198.

79. Alexander Vucinich, "Soviet Mathematics and Dialectics in the Post-Stalin Era: New Horizons," *Historia Mathematica* 29 (2002): 13–39, on 16–21.

80. Egle Rindzeviciute, "Purification and Hybridisation of Soviet Cybernetics: The Politics of Scientific Governance in an Authoritarian Regime," *Archiv Für Sozialgeschichte* 50 (2010): 289–309.

81. Kendall E. Bailes, "The Politics of Technology: Stalin and Technocratic Thinking among Soviet Engineers," *The American Historical Review* 79, no. 2 (1974): 445–69.

Khrushchev government's need for noncharismatic sources of legitimation after the Secret Speech at the Twentieth Party Congress of 1956, "On the Cult of Personality and its Consequences," revealed and denounced (some of) the atrocities perpetrated under Stalin's rule.

By Stalin's death the Soviet order of knowledge was capped by three metadisciplines: *dialectical materialism*, general philosophy, including the philosophy of science; *historical materialism*, the philosophy of history; and *political economy*, which studied the "laws of motion" of different historical formations. Cybernetics' claim to apply indiscriminately to natural and social systems threatened this order from both ends, contesting the monopolies of both dialectical materialism and political economy. In his 1952 *Economic Problems of Socialism*, Stalin had excoriated a young economist for suggesting that economic science be involved in the "rationalization" of planning.[82] The political economy of socialism (*politekonomiia sotsializma*) had thus completed its transformation into an elaborate apologetics equating Soviet reality with socialist ideality by scholastic hermeneutics of the writings of Marx, Engels, Lenin, Stalin, and Party decisions. Economic cyberneticists refused the offered compromise—that their knowledge be understood as mere "method" subordinated political economy's orthodox "theory"—and asserted their expertise as a rival science under the umbrella of cybernetics.[83]

FROM THE HEAVENS DOWN TO EARTH: A REALISTIC UTOPIAN PROJECT

In the 1960s and 1970s, mathematical economists and cyberneticians proffered elaborate schemes of mathematical models and institutional reforms that would make use of them. They were the first real alternative visions to the Stalinist model, the first attempt to drive a wedge between Soviet reality and the ideal of socialism. It is easy to see them as quixotic. The literature is filled with reasons of institutions, interests, or ideology as to why the Soviet Union was unlikely and finally unable to address its institutional failures. But it is important to understand why would-be reformers did not anticipate failure at the time.

So great was the awareness of the need for change that reforms of economic administration began the very day Stalin died. Calls for more radical change

82. Iosif V. Stalin, *Ekonomicheskie Problemy Sotsializma v SSSR* (Moscow: Politizdat, 1952).

83. Pekka Sutela, *Socialism, Planning, and Optimality: A Study in Soviet Economic Thought* (Helsinki: Finnish Society of Sciences and Letters, 1984), 92–97, 111–20, 136–47.

came quickly.[84] Beginning in April 1954, a series of acts delegated rights from the union ministries to the republics and enterprises, increased the role of economic incentives, and repeatedly reorganized the economic bureaucracy.[85] Khrushchev's 1957 law drastically reorganized the sectoral planning apparatus to a territorial model, abolishing twenty-five ministries in the process.[86] These reforms occurred before and during the period of the Thaw, which combined relaxed ideological controls, sharply reduced state violence, and massive investment in both science and consumer goods and services. While Khrushchev's Secret Speech inaugurated the Thaw, at the same Party Congress the speeches of powerful Politburo members Mikhail Suslov and Anastas Mikoyan explicitly criticized the state of economic science.[87] To any economist of the period the possibility of change would have seemed very real.

In this context—of a decade of continual economic reform, Khrushchev's declaration at the 1961 Party Congress that "scientific calculations" showed that communism would be built by 1980, and the massive, lavishly funded projects in atomic weaponry and space exploration—the expansive vision of the May 31, 1963, joint decree of the Central Committee of the Communist Party and the Council of Ministers becomes both more intelligible and more remarkable.[88] It was the result of the machinations of Viktor M. Glushkov, a rapidly rising star of cybernetics, who had conspired to get a letter to Khrushchev warning of a catastrophic lag behind the United States in the computerization of economic management.[89] Glushkov freely admitted that this was a plan for

84. At the 1954 February–March Plenum of the Central Committee, the first session of the Supreme Soviet of 1954, and the 1955 July Plenum.

85. For a list and analysis, see Vladimir Aleksandrovich Mau, *V Poiskakh Planomernosti: Iz Istorii Razvitiia Sovetskoi Ekonomicheskoi Mysli Kontsa 30-x Nachala 60-x Godov* (Moscow: Nauka, 1990), 80–81; and Aleksei V. Kuteinikov, *Proekt Obshchegosudarstvennoi Avtomatizirovannoi Sistemy Upravleniia Sovetskoi Ekonomikoi (OGAS) i Problemy Ego Realizatsii v 1960-1980-X Gg* (Dissertation, Moscow State University, 2011), 127–29.

86. Nataliya Kibita, *Soviet Economic Management Under Khrushchev: The Sovnarkhoz Reform* (New York: Routledge, 2013).

87. *XX S'ezd Kommunistichoi Partii Sovetskogo Soiuza: Stenograficheskii otchet.* (Gospolitizdat: Moscow, 1966).

88. Postanovlenie TsK KPSS, Sovmina SSSR ot 21.05.1963 N. 564, "Ob uluchshenii rukovodstva vnedreniem vychislitel'noi tekhniki i avtomatizirovannikh sistem upravleniia v narodnoe khoziaistvo."

89. This story is told in V. V. Shkurba, "V Komande Glushkova," in *Akademik V.M. Glushkov—Pioner Kibernetiki*, ed. V. P. Derkach (Kiev: Iunior, 2003), 351–56; Nikolai Prokofevich Fedorenko, *Bspominaia Proshloe, Zagliadivaiu v Budushchee* (Moscow: Nauka, 1999), on 147; Kuteinikov, *Proekt OGAS* (ref. 85) on 48–51.

a new megaproject, like the three Main Administrations, and would be more complicated than the rocketry and nuclear programs combined. The decree outlined an enormous coordinated program for the computerization and automation of economic accounting, planning, and management: the United State Network of Computer Centers (EGSVTs). Its immediate predecessor was Kitov's rejected 1959 proposal for a dual-use nationwide military and economic planning network.[90] The roots of these network visions were the anti-aircraft and antirocket real-time networks rationalized with the nascent techniques of systems analysis and operations research.

The centerpiece was to be a new organ under the State Committee for the Coordination of Scientific Research Work, the Main Administration for the Introduction of Computing Technology. This location, the institutional fulcrum between technology and science, mirrored the position of cybernetics in the order of knowledge. Its membership reads like a *Who's Who* of computing and military cybernetics.[91] The new Administration was to organize the production of computers, build a nationwide network of computing centers, and coordinate computerization and automatization at every level of economic hierarchy. Gosplan's Main Computing Center (founded in 1959) would be the heart of the new system; the Central Economic Mathematical Institute (CEMI)—very nearly named the Institute of Economic Cybernetics—would be its brain. Cybernetic inspiration shaped CEMI's very architecture: the building, designed by Leonid Pavlov, was itself a cyborg of two superimposed rectilinear forms, one for people, and the other (with double-height floors) for computers.[92] Considering CEMI in isolation from this larger project—as all of its previous historians have done, as though it were a Western economics

90. Poletaev, "'Voennaia' Kibernetika" (ref. 47), 523–24. A. I. Poletaev writes that Buslenko, Poletaev (his father), and Lyusternik were co-authors, but Isaev insists that, although they were important interlocutors, Kitov was the sole author. Vladimir P. Isaev, "Vspominaia A. I. Kitova—Nazad v Budushchee," in *Kitov Anatolii Ivanovich - Pioner Kibernetiki, Informatiki, I Avtomaticheskoi Sistemy Uprvaleniia: Nauchno-Bibliograficheskie Ocherk*, 2nd ed., ed. V. A. Dolgov (Moscow: KOS•INF, 2010), 122–45, on 139–41.

91. Kuteinikov, *Proekt OGAS* (ref. 85), on 65–66, 75.

92. By the time the building was erected, computers no longer required such spaces—and CEMI was no longer to be the head of the network. These rooms became the spaces of embodied sociality that Pavlov had thought obsolete, such as the library and auditoria. See Anna Bronovitskaya, "NII Perioda Stroitel'stva Kommunizma," *Proekt Rossiia* 4, no. 46 (2007): 145–52, on 50–52. Pavlov, fascinated by computing, also designed the computing centers for Gosplan and the Central Statistical Administration; Anna Bronovitskaya, ed., *Leonid Pavlov. 1909–1990: Vystavka K 100-Letiyu Arkhiteketora* (Moscow: Gosudarstvennyi nauchno-issledovatel'skii muzei arkhitektury im. A.V. Shchuseva (MUAR), 2010).

department or a Soviet version of the Cowles Commission—distorts beyond recognition its role as envisioned at the time of its founding.[93]

Economics and/or Cybernetics

Because of economics' origins in the human sciences, its mid-twentieth century American mathematicization and formalization has often been decried as a bout of "physics envy," scientism, or worse.[94] The more complex reality is that during the Second World War and afterward, physicists, some applied mathematicians, and engineers began to approach economic problems from new positions of institutional power. Philip Mirowski has recast the entire history of mathematical economics in the United States by examining its postwar encounters with operations research, cybernetics, and systems analysis; this work provides an entrée to the Soviet case.[95] Hitherto, the cybernetic language surrounding Soviet mathematical models, if noted at all, has been dismissed as ideological camouflage or mere fashion, obscuring mathematical economics' entangled histories.

Although it is beyond the scope of this article to explore its composition in any detail, there had been a loose community of individuals concerned with applying mathematical methods to the economy even under Stalin, though many of its members could not be called economists, and their methods may more properly be called numeric (or even just numerate) than mathematical. They included economic (originally agricultural) statisticians, engineers (especially in hydroelectrical and railroad engineering), and practical planning economists. They were distinguished more by their politics than by their methods: they were interested in reforming the institutions of Soviet socialism rather than celebrating their perfection. Such reformism had been nearly impossible before Stalin's death in 1953, by which time economics had become dominated by the sterile political economy of socialism, but afterward the limits to discussion quickly broadened. Eminent statistician Vassily Nemchinov functioned as a self-conscious organizer of this reformist network. Through

93. CEMI, IPU (mentioned above), and the Computer Center were among the principle civilian institutes of cybernetics within the Academy. On the activities and changing missions of CEMI and IPU in the 1960s, see Simon Kassel, *Soviet Cybernetics Research: A Preliminary Study of Organizations and Personalities* (Santa Monica, CA: The RAND Corporation, 1971).

94. E. Roy Weintraub, *How Economics Became a Mathematical Science* (Durham, NC: Duke University Press, 2002), tries to avoid these judgments.

95. Philip Mirowski, *Machine Dreams Economics Becomes a Cyborg Science* (New York: Cambridge University Press, 2001).

Leonid V. Kantorovich he became aware of cybernetics and in turn Nemchinov himself became known to the rest of the cybernetic network.

In 1957, with the support of Lavrentiev, Nemchinov organized the first Laboratory for Economico-Mathematical Methods (LEMM). Although located in Moscow, it was formally subordinated to Lavrentiev's newly founded Siberian Division of the Academy. By April 1960, a mere seven years after Stalin's death, Nemchinov hosted a large conference in Moscow on "the Application of Mathematical Methods in Economics and Planning," the proceedings of which filled seven volumes. Such an event, in the Soviet theater of signs, trumpeted political favor. We are now in a position to understand why nearly half of the members of the organizational committee were not economists at all, but superstars of mathematics and computer science (including ten full or corresponding members of the Academy) with no work before or since in economics.[96] Every one of them can be tightly linked to either Kantorovich, Kitov, or Bruk, the only three with any sustained interest in economics; there can be no doubt that these links account for their attendance. This was a simply unprecedented show of scientific and administrative force at an economics conference, the significance of which could not have been lost on any political economist in attendance.

After three years of politicking, and with the aid of Glushkov, as discussed above, Nemchinov managed to found his institute, CEMI. It gathered his network of numerically oriented reformist economists into one place. It was based on LEMM (54 researchers), but also absorbed a group devoted to the study of the effectiveness of capital investment from the Institute of Economics (11), the Department of Transportation Cybernetics from the Institute of Complex Transportation Problems (16), Nemchinov's former laboratory at the Council for the Study of the Productive Forces (SOPS), and the department of mathematical economics of Dorodnitsyn's Computer Center of the Academy of Sciences.[97] Most of these economists did not initially have a self-conscious identity as mathematical economists opposed to the "political

96. Among the non-economists were Aksel' I. Berg, Andrei N. Kolmogorov, Sergei L. Sobolev, Boris V. Gnedenko, Isaak S. Bruk, Leonid V. Kantorovich, Lazar A. Lyusternik, Andrei A. Markov Jr., Anatoly I. Kitov, Aleksei A. Lyapunov, Anatoly A. Dorodnitsyn, Vladimir S. Mikhalevich, Sergei V. Vallander, and Yurii V. Linnik. Vassily S. Nemchinov, ed., *Obshchie Voprosy Primeneniia Matematiki v Ekonomiki i Planirovanii*, vol. 1, Trudy Nauchnogo Soveshchaniia O Primenenii Matematicheskikh Metodov v Ekonomicheskikh Issledovaniiakh i Planirovanii (4–8 Aprelia 1960 Goda) (Moscow: Izdatel'stvo Akademii Nauk SSSR, 1961).

97. Fedorenko, *Bspominaia Proshloe* (ref. 89), 164.

economy of socialism." They acquired one only through their traffic with cybernetics.

Very quickly, CEMI recruited large numbers of newly graduated, Mekhmat-trained mathematicians, especially Jews barred from the anti-Semitic pure mathematics establishment, those with tarnished political records, and those looking to escape the strict environment of the military institutes. Two of my primary informants, Yurii Gavrilets and Viktor Volkonskii, for example, spent two years in NII-5 after graduating from Mekhmat with some political black marks, before Nemchinov poached them for LEMM in 1960. Volkonskii accordingly called CEMI a "Noah's Ark."[98] As Nemchinov remarked, he could freely discuss economics only with people over sixty-five or under thirty-five years of age.[99] The older cohort was the reform-minded economists, the younger the idealistic young mathematicians, engineers, and physicists.

Yet the alliance forged between nascent mathematical economics and military cybernetics at the end of the 1950s was very brief. The reform-oriented economists and the mathematicians and engineers who received a second education at CEMI had entirely different understandings of the task of CEMI, the EVGTs, and economic reform from the military cyberneticians.[100] (The economists' reform economics will be the subject of future publication.) In Kitov's and Glushkov's military cybernetic versions, the problem of planning became one of creating sufficiently pervasive, reticulated, and high-bandwidth information channels and sufficient computational capacity that the fused state-economy could essentially be a well-controlled dynamical man-machine system, akin to the antimissile systems.[101] Even insofar as it would have subsystems, and they have local criteria of optimality, the problem of

98. Viktor Volkonskii, interview by author, Moscow, 14 Oct 2011.

99. Vladimir G. Treml, "Interaction of Economic Thought and Economic Policy in the Soviet Union," *History of Political Economy* 1, no. 1 (1969): 187–216, on 209.

100. Martin Cave, *Computers and Economic Planning: The Soviet Experience* (New York: Cambridge University Press, 1980); William J. Conyngham, "Technology and Decision Making: Some Aspects of the Development of OGAS," *Slavic Review* 39, no. 3 (1980): 426–45; Ivan Mikhailovich Siroyezhin, "Man-Machine Systems in the U.S.S.R.," *Management Science* 15, no. 2 (1968): 1–10. I have confirmed this interpretation with Eduard Baranov, a key principal of the SOFE project, interview, Moscow, 29 Jul 2013, and e-mail correspondence April 2014.

101. Compare the Soviet project to the Chilean experiment. Eden Medina, "Designing Freedom, Regulating a Nation: Socialist Cybernetics in Allende's Chile," *Journal of Latin American Studies* 38 (2006): 571–606; Eden Medina, *Cybernetic Revolutionaries: Technology and Politics in Allende's Chile* (Cambridge, MA: MIT Press, 2011).

divergent interests could not arise, as it does not in a military situation in which all agents have the global goal of preventing a nuclear missile from detonating.

The military cyberneticians were never able to realize this cybercratic utopian (or dystopian) dream. The EGCVTs, slowly dismembered by various bureaucracies, became "automated management systems" (*avtomatizirovanye sistemy upravleniia*, or ASU) in different enterprises and state organs. These statistical, communications, and database systems assisted management while leaving its structure entirely unchanged.[102] The mathematical economists became the voice for more radical reconfigurations. In the vision of Viktor V. Novozhilov and Kantorovich, the nationwide network would be a technical means to *calculate* an "optimal plan" from an enormous linear programming problem. Solving the linear programming problem would generate prices and assorted "normatives," which would be set into law. The administrative management system could then be dismantled. Enterprises would maximize their profits on their own, steered indirectly by these stable parameters toward fulfilling the optimal plan. In sum, whereas the cyberneticians imagined a single well-*controlled* goal-oriented system, the economists imagined *calculating* parameters to steer another system, one external to the controllers: an evolving economy of independent agents.

But the short-lived alliance allowed the network of mathematically oriented economists to coalesce as an institutionally powerful force. And the young mathematicians that crossed the cybernetic bridge into economics brought with them norms of behavior, metaphors, techniques, and problems, and those international standards of mathematical rigor and sophistication—the Hilbertian axiomatic formalism—that are the very conditions for misrecognizing Soviet mathematical economics as belated Western neoclassicism.[103] This economics, born in the encounter with cybernetics, remained deeply marked by the experience. Emil Ershov, a Mekhmat-trained mathematician who spent the formative years of his career focused on input-output modeling at the Research Institute of Gosplan, remembered cybernetics' impact on the economists thusly, running together its various problems and techniques:

102. On the fate of Soviet networking, see Kuteinikov, *Proekt OGAS* (ref. 85); and Benjamin Peters, *How Not to Network a Nation: The Uneasy History of the Soviet Internet* (Cambridge, MA: MIT Press, 2016).

103. In indirect evidence of cybernetics' imprint, three decades later American economists characterized Soviet mathematical economics as more akin to operations research. Stanley L. Brue and Craig R. MacPhee, "From Marx to Markets: Reform of the University Economics Curriculum in Russia," *Journal of Economic Education* 26, no. 2 (1995): 182–94, on 184.

> But then materials became available connected with optimization methods and their application. Not only from Kantorovich's work, but because the military paid attention, and interest rose, due to the position of Academic Aksel' Berg. In other words, the state recognized the danger of lagging behind not only in mathematical methods, but also in what is now called computer science [*informatika*]. Then arose the problem of pattern recognition. It was necessary to discover the position of enemy submarines in the ocean. To differentiate them from something else, like a whale. Not easy. At the same time mathematicians were working on similar questions. How to send a rocket somewhere. For example, a body with changing mass is flying to the moon and must gently set down upon it. They began to think that such equations could also be used to control the economy. This, I would say, was the mathematical optimization direction in combination with the theory of control, using differential equations.[104]

This younger generation brought with them a vision of their field as merely one application of cybernetics, of the economy as merely one system to be studied. As one of the founding members of CEMI, economist and cybernetic enthusiast Aron Katsenelinboigen reminisced,

> The basic subjects of my conversations with [physicist and co-author Yefim] Faerman were various problems in the general systems theory. We were both interested on the whole in questions of cognition and the creation of an artificial intelligence. However, we understood that this interest could be satisfied to a certain extent if the principles of the construction of any one complex system were understood. However the difficulties in receiving initial information interfered with applying this to natural systems, especially the biological system. From this point of view it seemed that the process of cognition in economics was simpler than in natural systems, because economics was a relatively recent artificial system with a short and visible history; the groundwork in many respects lay on the surface. All this predetermined our decision to attempt a mutual study of the economic system in order to branch out to the investigation of another system.[105]

This attitude—blithely ignoring disciplinary boundaries and with a technological optimism that would be unwarranted even today—appears repeatedly in the interviews and writings of mathematicians and physicists who, around the turn of the 1960s, refashioned themselves as economists. It would be easy to

104. Emil B. Ershov and Grigorii Sapov, "Tri Inter'viu S E.B. Ershovim, Fevral'-Mart 1999 g," http://www.sapov.ru/staroe/si06.html (accessed 29 Aug 2016), my translation.

105. Aron Katsenelinboigen, *Soviet Economic Thought and Political Power in the U.S.S.R.* (New York: Pergamon Press, 1980), on 188.

adduce cultural antecedents in Russian history that exhibit a similar impulse toward holism; in a sense it was overdetermined. Searching for such antecedents is not irrelevant, but what forged them into something new and peculiar to the moment, so powerfully generative of new horizons of possibility, was the brief conjuncture of particular epistemic dispositions with institutional changes at different scales.

CONCLUSION: DREAM DYNAMICS

This story reframes our understanding of Soviet cybernetics in three ways. First, I argue that Soviet cybernetics was inextricable from the assembly of the postwar military research complex, and further that this underpins a new understanding of both its conditions and its effects. The unprecedented technological challenges of the Second World War and early Cold War military competition drew together the engineering cultures of communication, control, and computation with world-class applied mathematicians. It was this new, extradisciplinary milieu that would recognize itself in Wiener's cybernetics. While cybernetics was a response to these engineering challenges, it at the same time made sense of the institutional solutions improvised to their attendant organizational challenges. It thus began to affect the growth patterns of the expanding military-scientific complex. The ensemble of institutions, personnel, technology, and science that conditioned the reception of cybernetics in turn was reconfigured by it: the two grew together. The boundaries of this project were uncertain and expanding. Cybernetic concepts, tropes, and images rapidly spread into knowledges increasingly distant from military engineering. Cybernetics thus catalyzed the explosive reaction of the institutional growth of military technoscience and the sociodemographic growth of the scientific-technical intelligentsia that drove the propagation of its own shockwave front.

Second, cybernetics' ambition to embrace the natural and social worlds (indeed, by refusing any ontological difference between them) led it into confrontation with the Soviet Union's uniquely politically privileged social science: economics. Cyberneticians and reformist economists interacted through the image of a novel sociotechnical system: the computer network conceived as a control system, a servomechanism to govern the polity. Although their divergent understandings of the relationship of system and polity prevented this alliance from stabilizing, economics' encounter with cybernetics precipitated a properly Soviet mathematical economics. This was neither the merging of two disciplines, nor a straightforward mathematicization, nor an epistemic break finally setting economics on (or returning it to) the royal road of Science. Rather, cybernetic techniques, metaphors, and personnel complexly recombined with reformist economics to create a new form of knowledge.

Third, I claim that cybernetics was crucial to the post-Stalinist re-articulation of science and politics. Scientists' assertion of the autonomy of science *from* politics was at once one of the entitlement of scientists *to* politics. And the most explicit expression that scientists' politics then took was economic cybernetics. Immediately after the Twentieth Party Congress, the allied cyberneticians and economists proposed the first altogether different visions of socialism, sundering the Stalinist equation of socialist ideals with the Soviet polity. The end of the 1950s thus captures the moment in the growth of the late Soviet scientific technical intelligentsia when it began to dream alternative socialisms.

Past studies have explored in detail the contribution of the artistic and literary intelligentsia to late Soviet reformism, as well as that of the political dissidents, yet these were but tiny minorities. The numerically more massive, and I would argue, more consequential stratum, was the scientific-technical intelligentsia, which evolved distinct attitudes, modes of sociality, and political relationships to the Soviet regime.[106] Implicitly liberal historiography, always looking for prodemocracy or liberal forces "outside of" or "in opposition to" the state, founders on the thoroughly étaticized society of the Soviet Union. It tends to miss or misconceptualize emergent critiques from those, like military scientists or economists, located in the heart of the state.[107] During this period,

106. An important recent statement of this problem is found in Mark Lipovetsky, "The Poetics of ITR Discourse: In the 1960s and Today," *Ab Imperio*, no. 1 (2013): 109–39, and the symposium in the same issue. Ivan Szelényi and his collaborators have posed macrosociological versions of this hypothesis since the landmark publication of Ivan Szelényi and George Konrád, *The Intellectuals on the Road to Class Power* (New York: Harcourt Brace Jovanovich, 1979). Marc Garcelon has demonstrated that this strata provided mass behind the pro-democracy movement in "The Estate of Change: The Specialist Rebellion and the Democratic Movement in Moscow, 1989–1991," *Theory and Society* 26 (1997): 39–85.

107. Or it ascribes to these state actors the oppositional and autonomous stance of "civil society" (itself a term popularized by Eastern European dissidents), as David Holloway does to Soviet physicists in "Physics, the State, and Civil Society in the Soviet Union," *Historical Studies in the Physical and Biological Sciences* 30, no. 1 (1999): 173–92. Stephen Kotkin and Jan T. Gross, in *Uncivil Society: 1989 and the Implosion of the Communist Establishment* (New York: Random House, 2009), provide a thoroughgoing critique of the applicability of the "civil society" concept to the late decades of the Soviet Union.

the number of available positions that could be assumed with respect to the officially formulated goals of the state began to multiply.[108] In specific locales, an openness toward alternative futures, suffused with moral and political ideals but with concrete programs for institutional change, could be fashioned out of the available intellectual and cultural resources. Cybernetic mathematical economics was one critical such locale.

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108. Kevin M. F. Platt and Benjamin Nathans, “Socialist in Form, Indeterminate in Content: The Ins and Outs of Late Soviet Culture,” *Ab Imperio*, no. 2 (2011): 301–23.