# SCIENCE and IDEOLOGY

A COMPARATIVE HISTORY

EDITED by MARK WALKER

# SCIENCE AND IDEOLOGY

## A comparative history

*Edited by Mark Walker*

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

# CONTENTS

4

# FROM COMMUNICATIONS ENGINEERING TO COMMUNICATIONS SCIENCE

## Cybernetics and information theory in the United States, France, and the Soviet Union

*David Mindell*[1], *Jérôme Segal*[2], *and Slava Gerovitch*[3]

### Technical content and national context

When it appeared in 1953, the Russian translation of the "Mathematical Theory of Communication" hardly read like the same text written in English by Claude Shannon a few years before.[4] Purged of any trace of man-machine analogies, the translation portrayed communications engineering as an ideologically neutral technical field. The Russian editor replaced Shannon's original title with the Russian, "The Statistical Theory of Electrical Signal Transmission," and he rid the work of the words "information," "communication," and "mathematical" entirely, put "entropy" in quotation marks, and substituted "data" for "information" throughout the text. The editor assured the reader (and the censor) that Shannon's concept of "entropy" had nothing to do with physical entropy and was called such only on the basis of "purely superficial similarity of mathematical formulae."[5] Thus the editor carefully avoided the anthropomorphic connotations of the words "information" and "communication" and at the same time distanced the use of the term "entropy" in the text from its controversial discussions in physics and biology. Trying to avoid any reference to the links between information theory and linguistics, the cautious editor even removed the entire third section of Shannon's paper, the one dealing with the statistical analysis of natural language. The editor drew a sharp line between what he called ideologically deficient, pseudo-scientific attempts to "transfer the rules of radio communication to biological and psychological phenomena" and the practically useful, firmly scientific statistical theory of electrical signal transmission.[6] His discursive strategy was simple: to portray information theory as a purely technical tool with no connection to the ideology-laden biological and social sciences. The translation typified Soviet communications engineers' attempts to remove ideology from their work to place emphasis on technical applications of information theory rather than its potential conceptual innovations.

This translation of Shannon's work occurred at the time of the Soviet anti-cybernetics campaign, about which more will be said later in this paper. Taken on its own, however, the episode points to the charged relationship of information theory, and its Cold War cousin, cybernetics, to ideology and the social sciences in the cultural and political worlds of the 1940s and 1950s. In both cases, highly technical theories put forward by mathematicians acquired ideological baggage which some took up with enthusiasm and others vehemently rejected. In both cases, claims were made for the broader significance of the work outside the technical realms in which they originated, although the authors participated in this process to differing degrees. Norbert Wiener explicitly expanded his theory of prediction and smoothing to a universal science, an extrapolation Claude Shannon always resisted for his information theory. French scientists took up cybernetics and information theory, at least in part, because of their perceived ideological implications. In contrast, Shannon's Russian editors clearly thought they could distinguish between the political and cultural implications of information theory and the raw, technical content which concerned transmission of signals through noisy channels.

A cross-national comparison of the generation and reception of the two new sciences reveals how they acquired, shaped, and were formed by the cultures in which they were embedded. In the United States, information theory and cybernetics emerged out of highly technical, but also irreducibly social, military problems presented by the Second World War. In his post-war *Cybernetics*, Norbert Wiener attempted to abstract his mathematics out of the technical culture which gave birth to it and simultaneously to extend its reach beyond technology into biology, economics, and social systems. Claude Shannon, with a less ambitious but more analytically specific theory, made more modest claims but with equally broad implications: his theory of entropy and channel capacity could model not only technical communications but also human language, and hence a broad array of human activities. In France, commentators and scientists variously saw these new American sciences as bourgeois conjecture, full of mythology and mystification, or as exciting meta-theories capable of uniting diverse disciplines. Similarly, in Russia, an early anti-cybernetics campaign saw Shannon and Wiener's work as embodiments of idealist, reactionary, American pseudoscience. After Stalin's death, however, Russian scientists made a complete reversal of their attitude toward the two new sciences. They extracted from information theory "natural laws" of information processing and made cybernetic feedback the foundation of a dialectical description of language and society. Following initial skepticism and discussion, cybernetics was institutionalized in Europe in a way it never was in the United States.

In the pages that follow, we examine the conception of information theory and cybernetics in the United States and their relationship to the technical cultures within which Shannon and Wiener worked. Then we move on to their reception in France, and how ensuing debates shaped significant French contributions to the information sciences. Similarly, in Russia we trace how an initial ideological hostility transformed into grudging acceptance and then total embrace. As with any such story, the choice of origins is somewhat arbitrary, as both Shannon and Wiener had important influences from France, Russia, and elsewhere, but the two formed significant nodes in ongoing international networks of mathematics. In the interests of analytical simplicity and brevity, we do allow some slippage between information theory and cybernetics, as did the actors under study, though the relationship between them is worthy of a study in its own right.

In all these debates, and indeed in the subsequent history, the essence of cybernetics and information theory prove hard to pin down. Were they embodiments of an American, overarching military-industrial mindset, or new sciences of everything? The intellectual equivalents of the Marshall Plan, or useful new descriptions of electrical signals? Did Shannon and Wiener represent the antecedents of computer science, or an updated expression of Taylorist industrial rationality? Information theory and cybernetics were, perhaps, all of these things and none of them. Their very malleability makes a cross-national comparison worthwhile, as it highlights the difficulty of culling discrete political messages from mathematics, and also the difficulty of harvesting a pure, apolitical mathematics from its historical soil.

## The origins of cybernetics: expanding control

Norbert Wiener, in his 1948 book *Cybernetics: or Control and Communication in the Animal and the Machine*, articulated the marriage of communication and control for a generation of engineers, systems theorists, and technical enthusiasts of varied stripes. Wiener declared the merger occurred instantly, obviously and completely in the course of his work on anti-aircraft prediction devices. "I think that I can claim credit," Wiener wrote in his memoir, "...for transferring the whole theory of the servomechanism bodily to communication engineering."[7] Recently, historians have revisited this account, exploring the genesis of Wiener's project, its roots in his earlier work, and its short-term failure and profound long-term effects. But these views center on Wiener: the academic, the intellectual, and the mathematician; they tend not to address his connection to a broader technical culture.[8]

Indeed we have little historical understanding of cybernetics in relation to engineering practice in control, computing, electronics, and communications. Some things were genuinely new about the human/machine relationship articulated by cybernetics, others were derived from existing ideas in engineering. Wiener's cybernetics emerged from the world of automation, military command, and computing during and after the Second World War. Wiener's own work on control systems during the war existed within a set of projects and a technical agenda which aimed to automate human performance in battle through a tight coupling of people and machines. Indeed before Wiener's cybernetics, American technology was already suffused with what would later be called "cybernetic" ideas. Several strong pre-war traditions of feedback mechanisms – including regulators and governors, industrial process controls, military control systems, feedback electronics, and a nascent academic discipline of control theory – suggests a broader and more gradual convergence of communications and control than the strict "Wienerian" account.[9] Servo engineers turned to techniques common in the telephone network to characterize the behavior of powerful feedback devices. Radar engineers adapted communications theory to deal with noise in tracking. Human operators were always necessary but problematic components of automatic control systems. Military technologists had wrestled with the notion of prediction since at least the turn of the century. These were but a few of the features of the technological terrain onto which Norbert Wiener stepped in 1940 when he began working on control systems. Yet Wiener eventually presented cybernetics as a specifically *scientific* discourse of communication and control, distinct from its practitioners. Like Shannon's Russian translator, Wiener attempted to divorce the content of his work from its social soil, and to embed it in a different tradition.

## The NDRC and the fire control problem

In 1940 Vannevar Bush formed the National Defense Research Committee (or NDRC), to bring university and industrial research to bear on military problems. Led by Warren Weaver, then also head of the Natural Sciences Division of the Rockefeller Foundation, the NDRC established a committee, called section D-2, responsible for control systems. Under this committee, control engineers developed the technology, indeed the practical philosophy, that Wiener would articulate so effectively in his postwar writing on cybernetics. During the war, much of that philosophy coalesced around difficult problems of antiaircraft fire control. Using artillery to hit fast-moving airplanes pressed to the limits the engineering knowledge of dynamic performance, mathematical precision, corrupted data, and the human operator. Research in data smoothing and prediction – two key elements of fire control – began to formalize an engineering approach based on abstracting the physical world and manipulating it as electrical signals, the basis of later strategies of computing and information processing. Engineering practice evolved in parallel with this theoretical work, and sometimes preceded it.

Weaver's control systems committee brought institutional pressure to bear on communications and control; it placed dual emphasis on Bell Labs, temple of communications, and MIT, which had a strong program in feedback control and servomechanisms (a servomechanism, or servo, is an electric or hydraulic motor that, with the addition of a feedback loop, is able to precisely hold and control its position). During the war, the NDRC control systems committee funded eighty research contracts in feedback theory, devices, and computing, totaling about $10 million at Bell Labs, MIT, and a number of other academic and industrial laboratories. Nearly every American computer pioneer (Atanasoff, Eckert & Mauchly, Shannon, Stibitz) of the time worked on at least one of these contracts during the war. Two of the eighty projects funded Norbert Wiener at MIT.[10]

Wiener had studied electrical networks during the 1930s, and in 1940 he proposed to apply network theory to servo engineering. This work had already been done by Henrik Bode at Bell Labs, however, so in late 1940 the NDRC asked Wiener to bring his knowledge of networks to prediction in fire control. This tricky problem required anticipating the future position of a target aircraft so an antiaircraft gun could lead the target and hit it with a shell, after some finite delay of the shell's time of flight (as much as one minute for high-flying aircraft). Wiener simulated a prediction network on MIT's calculating machine, the Differential Analyzer, and showed encouraging results. On December 1, 1940 the NDRC let a contract to MIT for "General Mathematical Theory of Prediction and Applications." For the contract, Wiener and his assistant, engineer Julian Bigelow, would devise a theory to follow a given curve, chosen to represent the path of an airplane, and estimate the value of that curve at some time in the future. During early 1941 the two designed and built a machine to simulate their ideas on prediction.[11]

Wiener and Bigelow quickly ran into a stability problem. Wiener's network was highly sensitive, even unstable, in the presence of high frequency noise.[12] This was a cousin of the stability problem facing other engineering disciplines which dealt with feedback loops – transient inputs caused oscillations. Wiener quickly realized the problem was fundamental, "in the order of things," (he compared it to Heisenberg's uncertainty principle) and that he would need a new approach. He and Bigelow now turned to statistics, designing a new predictor based on "a statistical analysis of the correlation between the past performance of a function of time and its present and future performance." The new network continually updated its own prediction as time passed and it compared the target's flight path with previous guesses. A feedback network converged on guesses which minimized this error.[13] In modern terms, this device might be described as a one-dimensional neural network, which learned about the world as it gathered new data.

Through the remainder of 1941, Wiener worked out in detail the theory behind his statistical approach, scribbling on a blackboard as Bigelow took notes. Warren Weaver agreed that Wiener's theory could produce an optimal predictor, and let another NDRC contract for Wiener to write up his theoretical results.[14] The product of that contract, Wiener's report, *Extrapolation, Interpolation, and Smoothing of Stationary Time Series*, was published by the NDRC for restricted circulation in early 1942. Here Wiener explicitly brought together statistics and communications theory with engineering of high-power systems:

> In that moment in which circuits of large power are used to transmit a pattern or to control the time behavior of a machine, power engineering differs from communication engineering only in the energy levels involved and in the particular apparatus used suitable for such energy levels, but is not in fact a separate branch of engineering from communications.[15]

Building on his own work in harmonic analysis and operational calculus, Wiener constructed a general theory of smoothing and predicting "time series": any problem (including economic and policy questions) expressed as a discrete series of data. While he gestured at electric power and servo design as well as communications, Wiener did not explicitly address any previous work in feedback theory.

Yet Wiener's work, however theoretically important, did not have immediate applications. In late 1942, Weaver reported that for predicting actual recorded target tracks, Wiener's "optimal" method proved only marginally more effective than a far, far simpler design of Henrik Bode's. At its next meeting, the NDRC decided to terminate Wiener's work; the project ended in January, 1943 (Bigelow left to join a statistical fire control group at Columbia).[16]

## Wiener's civilian elaboration

Disappointed by his failure to produce a practical device for the war effort, Wiener plunged into elaborating on his work in a context separate from the NDRC's concrete demands. Wiener had a long time interest in physiology, and the previous spring he and collaborators physician Arturo Rosenblueth and neurologist Walter Cannon had begun addressing physiological and neurological feedback. In the spring of 1942 Wiener's papers first mention the idea of the human operator as a feedback element, an integral part of the system. He discussed the "behaviorist" implications of his work in control, "the problem of examining the behavior of an instrument from this [behaviorist] point of view is fundamental in communication engineering."[17] This period, the last few months of Wiener's NDRC program, marked the conception of his "cybernetic vision," which would make him famous after the war. Wiener placed his understanding of the servomechanical nature of the mechanisms of control and communication in both humans and machines at the core of cybernetics, and his program sought to extend that understanding to biological, physiological, and social systems.

For Norbert Wiener, in the midst of the technological war, cybernetics became a civilian enterprise. The cancellation of his NDRC contracts in 1943 put him outside the massive wartime research effort, with access to only civilian resources. His 1943 paper, "Behavior, Purpose, and Teleology," written with Rosenblueth and Bigelow, allied servomechanisms with the "behavioristic approach" to organisms and classified behavior by level of prediction.[18] The paper's philosophical tone and biological metaphors reflected the strictures of secrecy surrounding Wiener's prior work and his new alliance with the life sciences: topics and researchers which, like Wiener, were comparatively free of the war effort. Later Wiener acknowledged the role fire control and prediction played in his thinking, but beginning with "Behavior, Purpose, and Teleology," cybernetics recast military control in a civilian mold.

Most indicative of this alienation and reconstruction is Wiener's consistent hesitation to acknowledge any of the multiple traditions of feedback in engineering which preceded him. In all his writing on cybernetics, he *never* cited Elmer Sperry, Nicholas Minorsky, Harold Black, Harry Nyquist, Hendrik Bode, or Harold Hazen: all published on the theory of feedback before 1940 (their publications became standard citations); all were recognized as important to the field; all speculated on the human role in automatic control; some even wrote on the merger of communications and control and the epistemology of feedback. But Wiener only rarely cited *any* servo theory later than Maxwell's 1867 paper "On Governors."[19] The omissions are striking. Wiener must have been aware of the work: he was closely involved in Vannevar Bush's research program in the 1930s including Hazen's work on servos; he worked with MIT's Servomechanisms Lab and its Radiation Laboratory during the war, and was in touch with Hendrik Bode during the wartime work on predictors. Still he wrote, "I think that I can claim credit for transferring the whole theory of the servomechanism bodily to communication engineering." Wiener placed cybernetics at the end of an intellectual, scientific trajectory, separate from the traditions of technical practice from which it sprang. Wiener's chapter on "Cybernetics in history," from *The Human Use of Human Beings*, refers only to Leibniz, Pascal, Maxwell, and Gibbs as "ancestors" of the new discipline.

Wiener reacted to and built on an evolving understanding, pervasive among engineers and psychologists involved with fire control in the 1940s, that the boundary between humans and machines affected the performance of dynamic systems and was a fruitful area of research. Unlike Wiener, however, NDRC researchers remained bound by military secrecy at least until 1945 and busy with contractual obligations (many remained so after the war). With no publication restrictions and no time obligations to wartime research contracts, Wiener could do and say as he pleased.

Wiener's reformulation had ideological implications, especially in light of his own estrangement from military research. After Hiroshima and Nagasaki, Wiener became critical of the American military's dominance of the country's engineering efforts. In the early forties, he had been anything but a pacifist: he suggested to the army filling antiaircraft shells with flammable gasses to burn enemy planes from the sky; he pondered what types of forested areas and grain crops were most susceptible to fire bombing.[20] Still, the atomic bombs, and perhaps his disappointing NDRC project, changed Wiener's attitude toward military research. His primary substantive contact with what he later called "the tragic insolence of the military mind," occurred under NDRC auspices and ended in January, 1943.[21] Though the "Interpolation, Extrapolation..." paper had significant military applications, Wiener's *Cybernetics* sought primarily to elaborate it as civilian philosophy, rather than military engineering.

Wiener's efforts to bring his model to broad communities of physiologists, physicians, and social scientists are well documented.[22] Through the informal "Teleological Society," the series of Macy Conferences, and a growing identity as a public intellectual, Wiener elevated his thinking on control and communication to a moral philosophy of technology, and enjoyed enthusiastic response. Of this elevation of the A.A. Predictor to the "symbol for the new age of man," Galison argues that Wiener enshrined an oppositional military metaphor into the civilian science of cybernetics and its descendents.[23] In light of Wiener's wartime work, however, the survival of the oppositional model was also ironic, as Wiener's wartime experience suggests he formulated cybernetics also as a specifically non-military, scientific endeavor.

Nor was Wiener's formulation the only one to emerge from the War with broad implications. In 1945, as the NDRC closed down, it issued a series of Summary Technical Reports. The volume on fire control contained a special essay, "Data Smoothing and Prediction in Fire-Control Systems," by Richard B. Blackman, Hendrik Bode, and Claude Shannon, which formally integrated communications and control and pointed toward generality in signal processing. The authors treated fire control as "a special case of the transmission, manipulation, and utilization of intelligence." They assessed control as a problem in electrical communications, developing analogs to the prediction problem, "couched entirely in electrical language." The authors, like Wiener, recognized the broad applicability of their study, "The input data...are thought of as constituting a series in time similar to weather records, stock market prices, production statistics, and the like." Acknowledging the importance of Wiener's work, Blackman, Bode, and Shannon devoted significant effort to summarizing his statistical approach. Ultimately they rejected it, however, due to problems applying the RMS error criterion to fire control, as well as its assumptions about statistical behavior of human pilots. Instead, the paper formulated the problem as one of communications engineering, drawing heavily on Bode's work in feedback control: "there is an obvious analogy between the problem of smoothing the data to eliminate or reduce the effect of tracking errors and the problem of separating a signal from interfering noise in communications systems."[24] While noting "this analogy...must of course not be carried too far," the paper considered inputs and disturbances in fire control systems as signals in the frequency domain, just like those in telephone communications.

At the same time that Wiener was working through his ideas on cybernetics, of course, Claude Shannon developed his own theory of communication, and the case forms something of a contrast to Wiener's expansive moves. Shannon built on his own experiences in fire control, computing, and cryptography as well as ideas from twenty years before at Bell Labs. In his famous 1948 paper, "A Mathematical Theory of Communication," Shannon provided a measure of channel capacity, in bits per second, which describes the maximum amount of information possible to send down a given channel. He added a serious consideration of noise and a statistical approach to the problem. "Communication theory is heavily indebted to Wiener for much of its basic philosophy and theory," Shannon wrote, citing Wiener's NDRC report.[25] Shannon's measure leads to a theory of efficient coding, how to optimally translate a series of "primary symbols," such as English text, into "secondary code" to be transmitted."[26] As if to solidify the connection between Shannon's theory and fire control, Warren Weaver wrote a popular introduction and explication of information theory, published with Shannon's paper in a small book, in which Weaver called for an expanded context for information theory in a hierarchy of human activity.[27] Yet while others built on Shannon's work and applied it to numerous other problems, including everything from biology to psychology and art, Shannon himself did not make the expansive leaps that Wiener did. In fact, Shannon mocked the "scientific bandwagon" which had grown up around information theory, and warned that "the basic results of the subject are aimed in a very specific direction, a direction that is not necessarily relevant to such fields as psychology, economics, and other social sciences."[28]

In light of the NDRC's research program in fire control, and, for that matter, of decades of pre-war control engineering, Wiener's syntheses of communications and control, human and machine, articulated broad converging patterns as much as created new ones. Cybernetic ideas had as much to do with established and evolving engineering traditions as with any radically new military mindset. *Cybernetics*, the book as well as the movement, articulated a vision of changing human/machine analogies which resonated with a broad audience. Its ramifications in the United States and abroad were significant, if as much for the overarching vision as for any concrete results. Its very malleability, however, of the human/machine analogy and its underlying mathematics, would both undermine cybernetics and be a source of its power, especially as it moved into international environments. Wiener's own postwar politics would not be enough to stabilize the ideology of his formulation, for others, as they took up cybernetics, had politics of their own.

## Cybernetics and information theory in France

How, then, was cybernetics received outside the United States, as a military tool, an analytical technique, and a philosophical program? While cybernetics is generally thought to have American origins, the book itself was actually published in France. In that country, information theory was hailed as a new general discipline which included cybernetics. Through the first two congresses dealing with cybernetics, held in Paris in 1950 and 1951, the French adopted and modified Wiener's work. Debates became acrimonious as the French Communist Party strongly engaged itself against cybernetics, which it saw as a "bourgeois" science. From the late 1950s onwards, a kind of normalization of the field took place, which correlated both with the promotion of cybernetics in popular science articles and books and with the institutionalization of cybernetics research in Western Europe. This development also relied on the contributions of a few scientists who took advantage of information theory to fill the existing gap between physics, mathematics and engineering science.

In the spring of 1947, Wiener was invited to a congress on harmonic analysis, held in Nancy, France and organized by the bourbakist mathematician, Szolem Mandelbrojt (1899–1983). During this stay in France, Wiener received the offer to write a manuscript on the unifying character of this part of applied mathematics, which is found in the study of Brownian motion and in telecommunication engineering. The following summer, back in the United States, Wiener decided to introduce the neologism "cybernetics" (from the Greek, meaning the man at the wheel or rudder) into his scientific theory. Though the word is found in the *Gorgias* by Plato, it also had a French usage, though Wiener did not know that the French physicist André-Marie Ampère (1775–1836) had already used it for his classification of the sciences to define "how the citizens can enjoy a peaceful time".[29]

Wiener's book was published in English by Hermann Editions in Paris and by M.I.T. Press, in collaboration with John Wiley & Sons in New York. In an introductory chapter about this "explosive science," Pierre De Latil reminds us that M.I.T. Press tried their best to prevent the publication of the book in France, since Wiener, then professor at M.I.T., was bound to them by contract. As a representative of Hermann Editions, M. Freymann managed to find a compromise and the French publisher won the rights to the book.[30] This became financially significant since after three reprints in six months, the book had sold 21,000 copies. A journalist at *Business Week* compared it with the Kinsey Report, also published in 1948, about the sexual behavior of American people: "In one respect Wiener's book resembles the Kinsey report; the publication reaction to it is at least as significant as the content of the book itself."[31]

The French press reacted enthusiastically. On December 28, 1948 in the newspaper *Le Monde*, a whole page was dedicated to "A new science: Cybernetics" with the subtitle "Towards a governing machine..." The author, Dominique Dubarle, stuck close to the myth of the robot, predicting that man would be replaced by machine even for the functions which require man's intelligence. Far from the technical questions linked to servomechanisms, this perspective was clearly driven by a kind of techno-optimism. New kinds of machines were mentioned: "prediction machines" (like air defense systems), "sensitive machines" (so the blind people could "see" again), and "sorting machines". It is noteworthy that Dubarle identified the key common point of these machines, the capacity to treat information, newly defined according to the scientific context introduced by Wiener and especially developed by Claude E. Shannon in his mathematical theory of communication. "Let's say that those machines are designed to collect and elaborate information in order to produce results which can lead to decisions as well as to knowledge." This was how

Dubarle ended his review, reflecting on "a unique government for the planet" which could as a new "political Leviathan," "supply the present obvious inadequacy of the brain when the latter is concerned with the customary machinery of politics."

This article in *Le Monde* was the impetus for a series of articles in the main intellectual journals like *Esprit* and *La Nouvelle revue française*. We again find Dubarle, in 1950, defending an indeterminist conception of science, necessary for him in order to introduce the scientific notion of information.[32] This philosophical debate turned out to be crucial in 1953, when the famous French physicist, Louis de Broglie, commenting on the theories of quantum physics adopted this same position (see below). During this lapse of two years, between 1948 and 1950, Louis de Broglie had already been confronted with cybernetics. A "Circle of Cybernetical Studies" (*Cercle d'Etudes Cybernétiques*) had been created and de Broglie was the Honorary President of this first association with the word "cybernetics" in its name.[33] Vallée, Scotto di Vettimo and Talbotier decided as early as 1949 to gather interested readers of Wiener's book.[34] Whereas many people read and discussed Wiener's book, few scientists were in touch with Americans involved in this field. For instance, the physicist Leon Brillouin (1889–1969), who had lived in New York since 1941, tried to organize visits from French officials to take advantage of the latest developments related to computers.[35] J. Pérès, director of the Institut Blaise Pascal in Paris (created in 1946), went with L. Couffignal to the United States, but Couffignal, then in charge of the construction of the first French computer, preferred advocating a different "French" conception and decided to ignore the American accomplishments related to the construction of the first computers. This turned out to be an important error and the notorious French delay in computing finds an explanation in the fact that so much credit had been accorded to Couffignal.

## French political context

Still, the fact that Couffignal decided to ignore U.S. research has to be understood in the French context of this time. In 1947, France was marked by political instability. In the November 1946 legislative election, the French Communist Party came first, with nearly a third of the votes, but in May 1947, the Communist ministers were dismissed by the President Ramadier who followed Truman's appeal from March 15th to all Western countries to exclude all communist forces from governments. French people still had to live with rationing, and by the end of August 1947, the daily bread value per inhabitant went under the 200g level. Strikes in October and November led to the resignation of the Ramadier cabinet.

These strikes affected the reception of cybernetics in France. At the Conservatoire Nationale des Arts et Métiers (C.N.A.M.), a series of five public lectures had been announced, dealing with servomechanisms. In his introductory remarks, Albert Métral (1902–62) advocated the "French technology" which could in his view could easily compete with the "science and techniques from abroad." The participants were mostly scientists who also worked with the military, especially from the engineering sciences or telecommunication research. Trained in mechanics, Métral praised the French "grey matter potential." This kind of scientific nationalism was indeed associated with a vague anti-Americanism, as in some of the public declarations made at this time by General de Gaulle.[36] One of the lectures organized in Paris in the last week of October 1947 had to be cancelled because of the strikes.[37] The general climate of opinion at this time was somewhat hostile to American culture and science, and this was only the beginning of the Cold War era. France was really "between the East and the West," which was made clear whenever the Marshall Plan or the status of Germany were discussed.[38]

This political context, then, set the stage for cybernetics, viewed as an American theory, to be introduced in France. In 1950, the French mathematician G.-Th. Guilbaud in his article entitled, "Cybernetical Divagations," criticized the use of a "fashionable name" and wondered if, in the development of cybernetics, there were not some "improper associations," "fuzzy meaning" and constitution of "myths." Nevertheless, he recalled that cybernetics was born out of a desire for unification and that, as such, it was worthy of consideration.[39] This idea of unification provided the impetus for the first scientific congresses on cybernetics.

## Discussions at the first French congresses

The first two congresses dealing with cybernetics or information theory gathered scientists from different backgrounds with different goals.[40] Mathematicians, for instance, were not much interested in the very general considerations contained in *Cybernetics*, while some engineers, who in France were somewhat despised by the intellectual elite, were intrigued by this book, in which they saw as a possibility of gaining social recognition. Generally, these congresses allowed a first timid institutionalization of cybernetics.

Instead of a congress, between April and May 1950 Louis de Broglie organized a series of lectures. The general title was "Cybernetics," with the subtitle, "Signal and Information Theory."[41] Dennis Gabor was the only scientist from abroad who insisted, like Louis de Broglie, on bringing cybernetics into the physical sciences to avoid it becoming a part of mathematics. Studies on Brownian motion, for instance, were considered helpful for telecommunication engineers. Engineers involved in this field generally accepted this suggestion, and Julien Loeb, from the National Center for the Study of Telecommunications (C.N.E.T.), who also had presented a paper at the C.N.A.M. in 1947, recalled that "If sciences like biology, sociology etc. should benefit from the theoretical works exposed in these series of lectures, the telecommunication techniques themselves should also profit."[42]

It was only after these lectures that information theory was progressively recognized as an autonomous scientific discipline. André Blanc-Lapierre, a trained physicist who decided to work on noise effects, remembers that prior to this lecture series, his colleagues found his work too impregnated with mathematics and that in the mathematics community, he was criticized for not having thoroughly studied probability theory.[43]

Cybernetics appeared again one year later in a congress titled "computing machines and human thought," held in Paris in January 1951. This congress was aimed at a larger public; as we can read in a report written by Paul Chauchard, it was "the first manifestation in France of the young cybernetics, with the participation of N. Wiener, the father of this science."[44] The anti-Americanism expressed at the end of the 1940s had almost vanished. The Marshall Plan had been accepted, two countries had been created in Germany and France was now clearly on the Western side.[45] For this congress, sponsored by the Rockefeller Foundation, a number of foreigners were invited, including Howard Aiken, Warren McCulloch, Maurice Wilkes, Grey Walter, Donald MacKay and Ross Ashby, along with Wiener who was staying in Paris for a couple of months at the Collège de France. It is no surprise that the two French scientists who organized the conference were the two who had visited the U.S. laboratories, Couffignal and Pérès.

Three hundred people attended the congress where fourteen machines from six different countries were demonstrated, including a mechanical chess player by Torres y Quevedo and the famous "Turtle" conceived by Grey Walter, two machines specially designed to imitate human behavior. Studying the thirty-eight presented papers and the script of the reported discussions, one can make two points. First, whereas in France the mathematicians seemed to dominate research related to computing machines, one finds physicists in the same position in the U.K. Secondly, information theory already played an important role in the development of the analogy between the human brain and computing machines. McCulloch for instance suggested that the nervous system makes use of "logarithmic processes," which are also utilized by telecommunications engineers. So, at the end of these two conferences, there was already a kind of "French cybernetics," which had been recognized in the scientific establishment. In 1952, a first assessment of American cybernetics was made by Louis de Broglie, who also attended this congress. He estimated that overall, cybernetics had not been as innovative as it could have been and that in fact, servomechanism theory had already been established as an independent discipline without it.[46] This was the time when cybernetics became the focal point of an important ideological debate.

## Ideological attack from the French Communist Party

Since the outbreak of the Cold War, philosophy of science had developed into a major ideological battlefield, and cybernetics quickly became the subject of several lively discussions. Already in May 1948, before the publication of *Cybernetics*, Jacques Bergier had written an article on "an ongoing new revolution even more important than that of the atomic age," the general theory of automata. His position was ambiguous: on the one hand he expressed his enthusiasm, and on the other, he feared that "robots will take the place of workers."[47] He referred mostly to Soviet science, and, as in the American case, his two reference fields which led to a general theory were automatic exchange systems and anti-aircraft technology.

One year later, in the same weekly, Jean Cabrerets attacked cybernetics.[48] Referring to the project of a French computing machine that Couffignal had begun to conceive, Cabrerets proudly announced that "the universal French machines have chosen intelligence" and will soon "eclipse those [American] electronic brains like the Eniac." His comments on the visit that Brillouin organized for Couffignal were typical of the period: "It is to us significant that these new 'electronic brains' were born after and not before the visit that Brillouin and Couffignal made last year to the universities of Harvard and Philadelphia."

To understand these vehement attacks against American science, one has to consider the action of the Kominform, created in September 1947, and the evolution of the Soviet positions (see the section on Soviet cybernetics below). The anti-cybernetics campaign in France culminated with an article by André Lentin, in the official monthly journal of the communist party, *La Pensée* (The Thought). Lentin wrote on "Cybernetics: Real Problems and Mystifications".[49]

In an interview, Lentin remembers that he was annoyed at the beginning of the 1950s because "bad scientists" used cybernetics' popularity to publish and Wiener's book was used in almost all disciplines as a kind of panacea.[50] In his article, he directed the reader to the proceedings of the 1947 conferences held at the C.N.A.M. to understand a real general theory of servomechanisms. He tried to show that what Wiener did was more or less merely commentary on James Watt's work on the governor of a steam engine (which is, of course, a ridiculous claim). Cybernetics was simply described as a "gigantic enterprise of mystification." The only interest Lentin saw in Wiener's theory was the description of negative feedback which showed for him a "clear and conscious expression of the dialectic laws." Apart from this point, he believed that cybernetics should be rejected because it is a legitimatization of three dangerous bourgeois ideologies: Taylorism, robots without class consciousness instead of workers; idealism, interpreting a formal analogy between information and entropy as an identity; and, above all, capitalist economy, if one thinks of such feedback laws as "offer and demand determine the market."[51]

## French contributions to information theory

Apart from these ideological critics, the mid-1950s were also marked by French contributions to the development of information theory. Brillouin, a central figure for the exchanges he organized between France and the United States, was also one of the first promoters of information theory in physics. His first publication on this theme, which emphasized the analogy between entropy and information as defined by Shannon in order to explain paradox like that of the Maxwell's Demon, dates from 1949.[52] A few years later he managed to rewrite most of the chapters of physics using information theory. The corresponding book became known worldwide as a milestone in the development of information theory.[53] With his involvement in information theory, Brillouin managed to fill the gap between his interests for engineering science (for instance, he contributed during the war to the development of magnetron) and his general conceptions of physics.

In mathematics, two names are particularly significant and information theory was again at the crossing between different interests. Benoît Mandelbrot (born in 1924), who proofread with Walter Pitts Wiener's manuscript for *Cybernetics*, made for his Ph.D. in mathematics a clear connection between game theory and information theory.[54] He showed, for instance, that both thermodynamics and statistical structures of language can be explained as results of minimax games between "nature" and "emitter." He also made the connection between the definitions of information given by the British statistician Ronald A. Fisher in the 1920s, by the physicist Dennis Gabor in 1946 (he was born in 1900 in Budapest but exiled in Great Britain since 1934) and the already well-known definition proposed by Shannon.

Beyond a mathematical generalization of all these definitions, one finds also an important development of the unifying character of information theory. This is a noteworthy aspect of another Ph.D. written by Marcel-Paul Schützenberger (1920–96) and also published in 1953.[55] As early as 1951, preparing this work, Schützenberger had showed that a generalized information theory could be used as well for the analysis of electrical circuits as for the determination of liminal sensibility values in drug design or for botanic taxonomy.[56]

These French contributions to information theory quickly found recognition in the United States more than in their own country. From 1952 to 1954, for instance, Mandelbrot was at M.I.T. and then at the Institute of Advanced Studies in Princeton, and it is emblematic that when a new journal was founded on information theory, *Information and Control*, in 1958, Brillouin was one the three editors (with the British Colin Cherry and the American Peter Elias), and among the scientists of editorial board, one finds L. Couffignal and B. Mandelbrot next to Shannon and Wiener.[57]

## A French consensus regarding the place of cybernetics

After Stalin's death in May 1953, the general strike that took place in France in August and the election of René Coty in December, a period of normalization set in. This was profoundly marked for the cybernetics field by the popularization of Wiener's theory with a European reappropriation and the beginning, even in the 1950s, of the institutionalization of cybernetics research.

A few journalists decided to write books recasting the work of Wiener and all the American scientists who had participated in the birth of cybernetics in a wider (French!) tradition beginning with Ampère and including for instance, the work of Lafitte presented in his *Thoughts on the Science of Machines*, published in 1932.[58] The main books, assuring a large audience for cybernetics, were written by the journalists Pierre de Latil, Albert Ducrocq in France and also by the mathematician Vitold Belevitch in Belgium.[59] With this new rebuilt history of cybernetics, the aim was to present an alternative to the Anglo-Saxon empiricism which gave significant importance to simulations. For the French, a few realizations are indeed shown as examples, but the "as if" does not become an "is" like in America. Presenting the latest work on machine languages, Belevitch showed the underestimated difficulties related to the understanding of language. General enthusiasm had given place to moderate assessment.

At the same time, the institutionalization of cybernetics took place along a French – Belgian axis.[60] The International Association for cybernetics was created in Namur, and it is in this Belgian city that international conferences are regularly held, the first one in 1956 and the most recent in 1998. In France, cybernetics helped to reshape the boundaries between mathematics, physics and engineering, making them more permeable. After identifying the ideological load of cybernetics and using it in the debates of the national context, cybernetics was regarded as a pool of new ideas to promote interdisciplinarity.

The Second International Congress on Cybernetics in Namur in September 1958 was attended by a small "reconnaissance mission" (three delegates) from the Soviet Academy of Sciences. Upon their return, the delegates complained in their report that "the small size of the Academy of Sciences delegation does not correspond to the scale of our country and to the tasks put before Soviet science in the field of cybernetics."[61] In subsequent years, however, Soviet delegations remained small and low-profile. In 1960, Communist Party bureaucrats rejected a proposal for the Soviet Academy Council on Cybernetics to join the International Association for Cybernetics.[62] As in the French case, the history of Soviet cybernetics was marred by a controversy.

## Cybernetics and information theory in the Soviet Union

The evolution of Soviet attitudes toward cybernetics and information theory in many ways paralleled the French story, but with stronger accents: the initial Soviet rejection of cybernetics was more decisive, while the later embrace of this field proved more wide-spread and profound. In 1954, the *Short Philosophical Dictionary* – a standard ideological reference – defined cybernetics as a "reactionary pseudo-science," "an ideological weapon of imperialist reaction."[63] By the mid-1950s, cybernetics was portrayed as an innocent victim of political oppression and "rehabilitated," along with political prisoners of the Stalinist regime. In the early 1960s, cybernetics was canonized in a new Party Program and hailed as a "science of communism." Soviet intellectuals of the Khrushchev era put cybernetics forward as a project for radical reform, challenging the Stalinist legacy in science and society. By the early 1970s, however, former cybernetics enthusiasts were left disillusioned, while cybernetic discourse was appropriated by the political establishment and cybernetics turned into a tool for maintaining the existing order rather than changing it.[64]

## The anti-cybernetics campaign in the USSR

The early 1950s – the time when cybernetics and information theory became known to the Soviet reader – was the wrong time to propagate in the Soviet Union ideas originated in the West. That applied not only to political doctrines, but to scientific theories and engineering approaches as well. In the Cold War wave of anti-American propaganda in the early 1950s, nearly a dozen sharply critical articles appeared in Soviet academic journals and popular periodicals, attacking cybernetics and information theory as products of American imperialist ideology and totally ignoring Russian traditions in these fields.[65]

Soviet critics charged that Shannon's theory of communication reduced the human being to a "talking machine"[66] and equated human speech with "just a "flow" of purely conditional, symbolic 'information,' which does not differ in principle from digital data fed into a calculating machine."[67] Wiener's formula, "information is information, not matter or energy," provoked a philosophical critique of the concept of information as a non-material entity.[68] Repeating Lenin's criticism of some philosophical interpretations of relativity physics in the early twentieth century, Soviet authors castigated cyberneticians for replacing material processes with "pure" mathematical formulae and equations, in which "matter itself disappears."[69] Cybernetics was labeled a "pseudo-science produced by science reactionaries and philosophizing ignoramuses, the prisoners of idealism and metaphysics."[70]

The anti-cybernetics campaign turned into a relentless war on words like "information" and "entropy," which crossed the boundaries between the animate and the inanimate. In his *Cybernetics*, Wiener attempted to bring together Shannon's concept of entropy as a measure of uncertainty in communication and Erwin Schrödinger's concept of negative entropy as a source of order in living organisms. Wiener identified information with negative entropy and aspired to create a common language for describing living organisms, self-regulating machines (for example, servomechanisms and computers), and human society. The critics argued that such crossing of disciplinary boundaries was illegitimate and accused cyberneticians of philosophical, ideological, and eventually political errors. As in the French case, the Soviet critique of cybernetics served a particular political agenda; it was inspired if not directly commissioned by the Communist Party and became part of a general wave of anti-American propaganda in the context of the Cold War.[71]

Schrödinger's analysis of life within the framework of the chromosome theory became a prominent target in Trofim Lysenko's crusade against genetics.

Lysenko, backed by high-ranking Soviet officials, attempted to discredit the use of physical methods and conceptual apparatus in biology.[72] In his 1940 dispute with the leading Soviet specialist on probability theory, Andrei Kolmogorov, Lysenko argued that "biological regularities do not resemble mathematical laws" and equated the use of statistics in support of genetics with the submission to "blind chance."[73] Trying to protect their political and institutional domination in Soviet biology, the Lysenkoites erected a philosophical Chinese wall between biology, on the one side, and physics and mathematics, on the other. This posed serious obstacles before information theory and cybernetics, which attempted to breach that wall.

Seeking to avoid political complications, Soviet mathematicians and engineers working in the field of control and communications kept their studies strictly technical and eschewed man/machine analogies. In the late 1930s and early 1940s, Kolmogorov developed a prediction theory of stationary processes similar to Wiener's, but did not make any attempt to extend its applications to the life sciences or social sciences.[74] Kolmogorov was also among the first mathematicians to appreciate the significance of Shannon's "Mathematical Theory of Communication."[75] Kolmogorov and his students developed a rigorous mathematical foundation of information theory, providing precise definitions and meticulous proofs of major theorems. The 1953 Russian translation of Shannon's work unfortunately transformed the original nearly beyond recognition; working under Soviet ideological censorship and self-censorship, a cautious editor removed not only ideologically suspicious passages, but also Appendix 7, which seemed too abstract for a technical paper. As Kolmogorov later discovered with great disappointment, some of his important theoretical results had already been published by Shannon in the cut-out fragments.[76]

## The rehabilitation of cybernetics and the new era

In March 1953, with the death of Stalin, the Soviet Union entered a new era. The political "thaw" brought significant changes to all spheres of Soviet life, including science and technology. The period of forced isolation of Soviet science and technology from its Western counterparts came to an end. The division into "socialist" and "capitalist" science no longer held; claims were made for the universality of science across political borders. The Soviet leadership embarked on a course of rapid assimilation of modern Western scientific and technological advances. In March 1955, a special governmental committee prepared a classified report, "On the State of Radioelectronics in the USSR and Abroad and Measures Necessary for Its Further Development in the USSR." This report emphasized the Soviet lag in communications engineering, control engineering, and computing and blamed it on the anti-cybernetics campaign: "As a result of irresponsible allegations by incompetent journalists, the word 'cybernetics' became odious and cybernetic literature was banned, even for specialists, and this has undoubtedly damaged the development of information theory, electronic calculating machines, and systems of automatic control."[77] In October 1955, the Academy of Sciences, the State Committee on New Technology, and the Ministry of Higher Education submitted to the Party Central Committee a top secret report, "The Most Important Tasks in the Development of Science in the Sixth Five-Year Plan," which, in particular, called for a significant expansion of studies in the theory of probabilities, including information theory. "It is imperative," the report stressed, "to achieve a radical improvement in the application of probability theory and mathematical statistics to various problems of biology, technology, and economics. The void existing here must be filled."[78]

As a sign of recognition of the importance of information theory for the national defense, the Soviet authorities became concerned with potential leaks of Soviet results in this field to the West. In August 1955, when Kolmogorov was invited to Stockholm to give a series of lectures on the theory of probabilities, the Party Central Committee allowed him to go only under the condition that he would not lecture on information theory. The head of the Science Department of the Central Committee argued that "certain aspects of information theory, if developed further, may become very important for secret work."[79] Ironically, as soon as ideological obstacles to the development of information theory were removed, the policy of military secrecy imposed new, even more severe restrictions on this field.

In August 1955, in a drastic reversal of the earlier philosophical critique, the journal *Problems of Philosophy* published the first Soviet article speaking positively about cybernetics and non-technical applications of information theory, authored by three specialists in military computing: Aleksei Liapunov, a noted mathematician and the creator of the first Soviet programming language; Anatolii Kitov, an organizer of the first military computing centers; and Sergei Sobolev, the deputy head of the Soviet nuclear weapons program in charge of the mathematical support. They presented cybernetics as a general "doctrine of information," of which Shannon's theory of communication was but one part. "Cybernetics," they wrote, "combines common elements from diverse fields of science: the theory of communication, the theory of filters and anticipation, the theory of tracking systems, the theory of automatic regulation with feedback, the theory of electronic calculating machines, physiology, and so on. Cybernetics treats various subjects of these sciences from a single point of view – as systems that are processing and transmitting information."[80] The three authors interpreted the notion of information very broadly, defining it as "all sorts of external data, which can be received and transmitted by a system, as well as the data that can be produced within the system."[81] Under the rubric of "information" fell any environmental influence on living organisms, any knowledge acquired by man in the process of learning, any signals received by a control device via feedback, and any data processed by a computer.

Treating information theory as an "exact science," Soviet specialists saw its mission in bringing rigor into disciplines deeply corrupted by ideological and political pressures. Kolmogorov insisted that now, with the advent of cybernetics and information theory, "it is impossible to use vague phrases and present them as being 'laws,' something that unfortunately people working in the humanities tend to do."[82] "The laws of existence and transformation of information are objective and accessible for study," wrote the mathematician Igor' Poletaev, the author of *Signal*, the first Soviet book on cybernetics. "The determination of these laws, their precise description, and the use of information-processing algorithms, especially control algorithms, together constitute the content of cybernetics."[83] Soviet cybernetics transcended the domain of engineering and fashioned itself as a *science*, a systematic study of the laws of nature. The "nature" that cybernetics studied, however, was of a special kind: it was an "objective" world constituted by information exchanges and control processes.

Liapunov and his colleagues soon put forward an ambitious project for the comprehensive "cybernetization" of Soviet science. Lecturing in diverse scientific, engineering, and public audiences, Liapunov carried with him a huge human-size table, whose rows represented twelve methods of cybernetic analysis (determining information exchanges, deciphering information code, determining the functions and elements of the control system, etc.) each of which was applied to eight fields of study (economics, computer science, hardware design, production control, linguistics, genetics, evolutionary biology, and neurophysiology), represented by columns.[84] Biologists and linguists, physiologists and economists, computer programmers and engineers all found a place for themselves in this grand design. In 1956–7, Liapunov and his associates delivered over one hundred lectures on cybernetics in various academic institutions. Soviet cybernetics spread over a wide range of disciplines and became a large-scale social movement among Soviet scientists and engineers.

In April 1959, the Academy of Sciences created the Council on Cybernetics to coordinate all Soviet cybernetic research, including mathematical and engineering aspects of information theory. The Academy also established the Laboratory for the Systems of Information Transmission, later transformed into the Institute for the Problems of Information Transmission, which became the leading Soviet research center in communications engineering.[85] Institutionally and conceptually, Soviet communications engineering was brought under the roof of cybernetics; the Laboratory director Aleksandr Kharkevich became deputy chairman of the Cybernetics Council.

## Soviet cybernetics as a trading zone

Soviet cybernetics served as a "trading zone," in which information theory concepts could transcend the boundaries of communications engineering and spread into the life sciences and the social sciences.[86] Bringing genetics under the cybernetic umbrella, in particular, served an important purpose: to protect Soviet geneticists from Lysenkoites' attacks. "A 'unit of hereditary information' sounded less anti-Lysenkoist than a 'gene,'" recalled geneticist Raisa Berg.[87]

Soviet genetics found an institutional niche among the communication sciences, the domain of mathematicians and engineers, where the Lysenkoites could not reach. Mathematicians Liapunov and Sobolev declared: "A living organism develops out of certain embryonic cells in which somewhere lies information received from the parental organisms. This is not physics; this is not physiology; this is the science of the transmission of information."[88] They argued that since Lysenko could not prove the flow of hereditary information from an organism as a whole to its embryonic cells, his claim of the inheritance of acquired traits must be false. On the other hand, they asserted the validity of classical genetics on the basis of its "full agreement with the ideas advanced in cybernetics."[89] The prominent evolutionary biologist Ivan Shmal'gausen, one of the main targets of Lysenko's 1948 speech, defended his theory of stabilizing selection by "translating Darwin's theory into the language of cybernetics."[90] The Council on Cybernetics provided support for persecuted biologists; the series *Problems of Cybernetics*, edited by Liapunov, regularly published articles on genetics, which could not appear in the biological journals, controlled by the Lysenkoites.

In the field of linguistics, a crucial mediating role was played by the prominent Russian émigré linguist Roman Jakobson, who since 1949 taught at Harvard University. Jakobson was fascinated by Shannon's work and applied Shannon's method of calculating the entropy of printed English in his analysis of spoken Russian.[91] Jakobson saw a deep similarity between Shannon's choice of binary digits (bits) as minimal units of information and his own earlier idea of using binary oppositions as the structural basis for organizing phonemic distinctive features into a phonological system. In Jakobson's view, Shannon's theory helped generalize Jakobson's insight about the underlying binary structure of spoken language to human communication in general.[92] In 1957, Jakobson became an Institute Professor at MIT, where he helped establish the Center for Communications Sciences; in 1958 he joined the editorial board of the journal *Information and Control*. Starting from the mid-1950s, Jakobson regularly visited the Soviet Union and actively propagated the innovations brought into linguistics by information theory.

## Models of communication as exchange of information

The model of human communication as information exchange became very popular among young linguists who challenged traditional Soviet linguistics, which relied on intuitive concepts and ideological declarations. Ironically, they elaborated a new concept of meaning based on Shannon's notion of information, even though Shannon himself had intentionally excluded any consideration of meaning from his communication theory. Linguists Igor' Melčuk and Alexander Zholkovsky developed a formal model of natural language, in which they turned Shannon's definition of information as "that which is invariant under all reversible encoding or translating operations"[93] into a definition of meaning as "what is common in all texts that are intuitively perceived as equivalent to the original text."[94] In a Soviet context, Shannon's model of communication crossed the boundaries between engineering and science to serve as a basis for an alternative to the dominant linguistic discourse.

Searching for rigorous laws in linguistics, Kolmogorov and his students conducted a series of experiments on measuring the entropy of printed texts, using a modified version of Shannon's letter-guessing method.[95] Kolmogorov was particularly pleased to remark (in private) that from the viewpoint of information theory (Soviet) newspapers were less informative than poetry since political discourse employed a large number of stock phrases and was highly predictable in its content.[96] On the other hand, brilliant poetry, despite the strict limitations imposed by the poetic form, carried more information, for original poetic expressions were much more difficult to guess.

Kolmogorov's poetic studies had a surprising outcome, leading to the elaboration of an original mathematical theory of complexity related to the concepts of information and entropy. While Shannon interpreted entropy as a measure of uncertainty, and Wiener as a measure of disorder, Kolmogorov viewed it as a measure of complexity. Kolmogorov put forward an algorithmic approach to the definition of information as an alternative to Shannon's probabilistic approach. In his view, the main problem with the probabilistic approach was that it precluded the possibility of calculating the amount of information in the case of a unique message, for example, Tolstoy's novel *War and Peace*. "Is it possible to include this novel in a reasonable way into the set of 'all possible novels,'" Kolmogorov asked sarcastically, "and further to postulate the existence of a certain probability distribution in this set?"[97] He proposed to measure the amount of information in an individual object with relation to another individual object, based on the notion of "relative complexity," or entropy, of those objects. He defined the relative complexity of an object (depending on the "method of programming") as the minimal length of a "program" that can produce that object.[98] "If some object has a 'simple' structure," he explained, "then for its description it suffices to have a small amount of information; but if it is 'complex,' then its description must contain a lot of information."[99] Kolmogorov argued that, within his algorithmic approach, the complexity of the novel *War and Peace* could be "uniquely determined," given certain *a priori* information about the language, style, and content of the text.[100] His reformulation of both information theory and probability theory in terms of complexity was perceived in the mathematics community as "almost a cultural revolution, turning both subjects inside out, and reversing the order in which they are normally considered."[101]

Paradoxically, cybernetics, which was supposed to bring formal rigor and exact reasoning to all disciplines, was itself conspicuously lacking a formal definition. Soviet cyberneticians often had very different notions about the content and boundaries of cybernetics. In his 1958 article in *The Great Soviet*

*Encyclopedia*, Kolmogorov defined cybernetics as a discipline studying "the methods of receiving, storing, processing, and using information in machines, living organisms, and their associations."[102] In the same volume, Kolmogorov also published an entry on information, which he introduced as the "main concept of cybernetics."[103] Mathematician Andrei Markov, Jr., ridiculed Kolmogorov's definitions, arguing that they produced a vicious circle. Kolmogorov responded by defining information as an "operator which changes the distribution of probabilities in a given set of events." Markov dismissed that definition too, mockingly describing how "a given computer would receive a given operator, which changes the distribution of its probabilities, and store this operator on its magnetic drum."[104] In cybernetic discourse, the word "information" had two very different meanings: in information theory, the "amount of information" characterized the uncertainty removed by the "information source"; in computing, on the other hand, the term "information" stood informally for any kind of data processed by a computer. The mechanical unification of information theory and computing in the Soviet Union under the rubric of cybernetics mixed the two uses of the term "information" together and produced the confusion pointed out by Markov. The insurmountable difficulty of forging a common language for all members of the diverse cybernetic community to a large extent undermined the entire project for the "cybernetization" of science. Soviet cybernetics, which at first had emerged as an alternative to official philosophy and a movement for radical reform, eventually lost its rebellious spirit and turned into a pliable philosophical doctrine of the "dialectical rotation of information and noise."[105]

## Conclusion

The main difference between Soviet cybernetics and its American and French counterparts is not to be found in the range of cybernetic applications or the types of mathematical models used. In this sense, there was a great similarity across the borders, due to the systematic Soviet efforts to appropriate the latest American and Western European techniques and technologies. The main difference lies in the political and cultural meanings attached to cybernetic ideas.

The history of cybernetics and information theory is one of crossing cultural, political, and disciplinary boundaries. Wiener abstracted a general scientific theory out of technical culture, and his theory was broadly interpreted by American political scientists, anthropologists, economists, and social scientists. Through Wiener's supple hands, what started out as an applied method of military computing transformed into a vision of the new bio-machine age. In the West, cybernetics contributed to the already strong contemporary traditions of mathematical reasoning in biology, physiology, linguistics, and economics by expanding the arsenal of mathematical and engineering tools used in those disciplines for modeling and implementation of control and communication mechanisms. In the United States, Wiener's formulation of cybernetics as civilian science of technology and society helped to legitimize ideas originally developed and continually applied to warlike purposes. Ironically, that vision's military roots, and many of its Cold War military applications, were at odds with Wiener's personal pacifist stand.

Crossing international borders placed cybernetics and information theory in completely different cultural contexts, in which the question of national origins of scientific ideas suddenly acquired great political significance. The Soviet ideological campaigns against Western influences condemned information theory and cybernetics as reactionary and idealistic. The Soviet position had great impact on French Communists and the subsequent controversy over these theories in France. In both France and the Soviet Union, cybernetics and information theory could be adopted only after their "domestication," i.e. adaptation to the specific cultural situations in the two countries.

In France, reactions of many scientists towards cybernetics were, from the beginning, marked by a kind of diffuse nationalism. The French attempted to appropriate cybernetics as their own by claiming Ampère's priority. Even if Wiener's work had to be mentioned, it was only to add immediately that the book was published in Paris and that Ampère had used the word 'cybernétique' as early as the 19th century. The communist party supported this campaign until it reversed its position following changes coming from Moscow.

Once cybernetics was sufficiently reinterpreted, France and the Soviet Union deployed its ideas differently. In France, from the mid-1950s onwards, cybernetics was used to promote interdisciplinary fields in which engineers as a group found public recognition. Soviet cybernetics, on the other hand, emerged during the post-Stalin era as a cross-disciplinary project and a social movement with a distinct mission – to reform Soviet science, both politically and intellectually – after the years of Stalinism. Western scientists viewed cybernetics as a useful method for solving a wide range of theoretical and practical problems. For Soviet scientists, cybernetics served a higher goal, breaking administrative and disciplinary barriers and liberating Soviet science from ideological and political pressures; they spoke the cybernetic language as a language of objectivity and truth.

Different national versions of cybernetics and information theory did not differ much in the range of cybernetic applications or the types of mathematical models used, considering the active exchange of latest techniques and technologies among the industrialized countries. The main difference lay in the political and cultural meanings attached to cybernetic ideas. Crossing boundaries often provoked attempts to separate the content of information theory and cybernetics from their initial ideological assumptions. Each time a significant cultural/political/disciplinary boundary is crossed, old ideological connotations are questioned and new ones attached. Trying to avoid political complications, Soviet scientists in the early 1950s tried hard to present the two new sciences as politically neutral, value-free technical tools for solving problems. Having failed to de-ideologize cybernetics and information theory, however, they instead re-ideologized these two sciences – but with different ideology. A cross-cultural analysis illuminates both the ideological malleability of cybernetics and information theory and the role of cultural context in shaping the fate of these ideas.

## Notes

1 MIT.
2 Institut Universitaire de Formation des Maîtres de Paris.
3 Dibner Institute for the History of Science and Technology and the Russian Academy of Sciences.
4 See Claude E. Shannon and Warren Weaver, *The Mathematical Theory of Communication* (Urbana, IL: The University of Illinois Press, 1949), 29–125, translated as Klod Shennon [Claude Shannon], "Statisticheskaia teoriia peredachi elektricheskikh signalov," in Nikolai A. Zheleznov (ed.), *Teoriia peredachi elektricheskikh signalov pri nalichii pomekh* (Moscow: Izdatel'stvo inostrannoi literatury, 1953).
5 Nikolai A. Zheleznov, "Predislovie," in Zheleznov, *Teoriia peredachi elektricheskikh signalov*, 5.
6 Zheleznov, *Teoriia peredachi elektricheskikh signalov*, 6.
7 Norbert Wiener, *I Am a Mathematician: The Later Life of a Prodigy* (Cambridge, MA: MIT Press, 1956), 265; Also see *Cybernetics: Or Control and Communication in the Animal and the Machine* (Cambridge, MA: MIT Press, 1948), 8 for a similar account and a similar claim.
8 Steve Joshua Heims, *John von Neumann and Norbert Wiener: From Mathematics to the Technologies of Life and Death* (Cambridge, MA: MIT Press, 1980); Peter Galison, "The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision," *Critical Inquiry*, 21 (Autumn, 1994): 228–66; Paul Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, MA: MIT Press, 1996); Lily Kay, "Cybernetics, Information, Life: The Emergence of Scriptural Representations of Heredity," *Configurations*, 5 (1997): 23–91.
9 David A. Mindell, "Beasts and Systems: Taming and Stability in the History of Control," in Miriam Levin (ed.), *Cultures of Control in the Machine Age* (London: Harwood Academic Publishers, 2000).
10 David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics* (Baltimore: Johns Hopkins, 2000)
11 Several published accounts narrate of Wiener's work in prediction: Wiener, *I Am a Mathematician*, 242–56; Stuart Bennett, *A History of Control Engineering, 1930–1960* (London: The Institution of Electrical Engineers, 1993), 170–9; Stuart Bennett, "Norbert Wiener and Control of Anti-Aircraft Guns," *IEEE Control Systems*, December (1994): 58–62; Galison, "The Ontology of the Enemy"; Pesi Rustom Masani and R.S. Phillips, "Antiaircraft Fire Control and the Emergence of Cybernetics," in Pesi Rustom Masani (ed.), *Norbert Wiener: Collected Works with Commentaries*, vol. 4 (Cambridge, MA: MIT Press, 1985), 141–79.
12 Norbert Wiener, Final Report on Section D2, Project #6, December 1, 1942, quoted in Masani and R. Phillips, "Antiaircraft Fire Control and the Emergence of Cybernetics," 152.
13 See Bennett, *A History of Control Engineering*, 174, and "Norbert Wiener and Control of Anti-Aircraft Guns," for a technical explanation of this approach; see also Thomas Kailath, "Norbert Wiener and the Development of Mathematical Engineering," (unpublished manuscript, Stanford University, 1996).

14 "Summary of Project #6: Section D-2, NDRC," October 1, 1941. OSRD E-151 Applied Mathematics Panel General Records, Box 24.
15 Norbert Wiener, *The Extrapolation, Interpolation, and Smoothing of Stationary Time Series*(Cambridge, MA: MIT Press, 1949), 3; This is the published version of Wiener's original "Yellow Peril," report (so named because of its yellow cover and difficult mathematics) "Extrapolation, Interpolation, and Smoothing of Stationary Time Series with Engineering Applications," NDRC Report to the Services 370, February 1, 1942.
16 Division 7 Meeting Minutes, January 7–8, 1943 and February 3, 1943. OSRD7 GP Box 72 Division 7 Meetings folder. See also Galison, "The Ontology of the Enemy," 244–5 and Bigelow interview, 8. NW to WW, January 15, 1943 and January 28, 1943 are Wiener's last words on the project to the NDRC. Wiener recognized his predictor barely exceeded the performance of competing smoothers, but he believed there was too little data (only two courses for comparison) and that further work should continue to compare ten or a hundred courses.
17 See, for example, Wiener to Haldane, June 22, 1942. Wiener Papers, Box 2 Folder 64. This letter is marked "NOT SENT"; That May, Rosenblueth mentioned his conversations with Wiener and Bigelow in a presentation at a meeting on the physiology of the conditioned reflex, sponsored by the Macy Foundation; see Steve J. Heims, *Constructing a Social Science for Postwar America: The Cybernetics Group: 1946–1953* (Cambridge, MA: MIT Press, 1993), 14–15.
18 Arturo Rosenblueth, Norbert Wiener, and Julian Bigelow, "Behavior, Purpose, and Teleology," *Philos. Sci.*, 10 (1943): 18–24, reprinted in Masani (ed.), *Collected Works*, vol. 4, 180–6.
19 In one of Wiener's rare references to servo theory, on page 7, *Cybernetics* cites Leroy A. MacColl, *Fundamental Theory of Servomechanisms* (New York: Van Nostrand, 1946). This book synthesizes the Bell Labs approach to servos as developed for the electrical gun director computer, T-10. While Wiener cited Maxwell's paper as fundamental, Otto Mayr has persuasively argued that it was incoherent in terminology and definition and lacked the idea of a closed feedback loop so central to later conceptions of control; Otto Mayr, "Maxwell and the Origins of Cybernetics" in *Philosophers and Machines* (New York: Science History Publications, 1976), 168–88.
20 Lt. Col. C. Thomas Sthole to NW, July 23, 1943. Wiener Papers, Box 1 Folder 57; NW to Bush, September 21, 1940. Box 2, Folder 58, Wiener Papers.
21 Norbert Wiener, "A Scientist Rebels," *Atlantic Monthly* (January, 1947), reprinted in Masani (ed.), *Collected Works* vol. 4, 748; note that in Masani, *Norbert Wiener*, the bibliography of Wiener's military work (391) lists no contributions after January 15, 1943.
22 Steve Joshua Heims, *The Cybernetics Group: Constructing a Social Science for Postwar America* (Cambridge, MA: MIT Press, 1993); Edwards, *The Closed World*, ch. 6, Kay, "Cybernetics, Information, Life," 47.
23 Galison, "The Ontology of the Enemy," 253.
24 R.B. Blackman, H.W. Bode, and C.E. Shannon, "Data Smoothing and Prediction in Fire-Control Systems," in Harold Hazen, *Summary Technical Report of Division 7, NDRC Volume I: Gunfire Control* (Washington, DC: Office of Scientific Research and Development, National Defense Research Committee, 1946); Also see H.W. Bode and C.E. Shannon, "A Simplified Derivation of Linear Least Square Smoothing and Prediction Theory," *Proc. I.R.E.*, 38, April (1950): 425, which addresses Wiener's prediction in more detail; Also see R.B. Blackman, *Linear Data-Smoothing and Prediction in Theory and Practice* (Reading, MA: Addison-Wesley, 1965), an extension of the 1948 work.

25 Claude Shannon, "A Mathematical Theory of Communication," *BSTJ*, 27, July–October (1948): 379–423, 623–56, reprinted in N.J.A. Sloane and Aaron D. Wyner (eds), *Claude Elwood Shannon: Collected Papers* (New York: IEEE Press, 1993), 5–83; Claude Shannon and Warren Weaver, *The Mathematical Theory of Communication* (Urbana, IL: University of Illinois Press, 1949). The relationship between Shannon and Wiener's work is more complex than outlined here. In a later interview, Shannon related "I don't think Wiener had much to do with information theory. He wasn't a big influence on my ideas there [at MIT], though I once took a course from him." Shannon, *Collected Papers*, xix. Semantic confusion sometimes exists over the "Weaver-Shannon" or the "Wiener-Shannon," theory of communication. The former derives from the book listed in the previous note, and is inaccurate because Weaver served only to translate Shannon's work to make it more accessible (Weaver claimed no more).

26 Shannon, "A Mathematical Theory of Communication," 36.

27 Shannon and Weaver.

28 Claude Shannon, "The Bandwagon," *IEEE Transactions on Information Theory*, vol. 2, March, 1956; reprinted in Sloane and Wyner (eds), *Collected Works*, 462.

29 André-Marie Ampère, *Essai sur la philosophie des sciences ou exposition naturelle de toutes les connaissances humaines* (Paris: Mallet-Bachelier: 1834).

30 Pierre de Latil, *La Pensée artificielle* (Paris: Gallimard, 1953); Having lived together in Mexico, Freymann and Wiener were friends and it is Freymann who is supposed to have suggested that Wiener write this book. Wiener thought at first that he would need at least twenty years to produce something on this subject and finally went back to Mexico to write the manuscript.

31 (Anonymous article), "Machines that think," *Business Week* (19 February 1949), 38–42.

32 Dominique Dubarle, "Idées scientifiques actuelles et domination des faits humains," *Esprit*, 18, 9 (1950): 296–317; Emphasis is laid on Shannon's work and information is defined as "what the signal brings to the receptor, not in terms of supports necessary to exist physically, but regards to the different configuration which are going to be identified."

33 Robert Vallée, "The 'Cercle d'Etudes Cybernétiques,'" *Systems Research*, 7 (1990): 205. More directly on the role of de Broglie, see Robert Vallée, "Louis de Broglie and Cybernetics," *Kybernetes*, 19, 2, (1990): 32–3.

34 Among the forty members, one finds Couffignal, Dubarle, Ducrocq, Latil, Lafitte and Mandelbrot, all scientists who played an important role in the introduction of cybernetics in France.

35 Léon Brillouin, "Les machines américaines," *Annales des Télécommunications*, 2 (1947): 331–46, and "Les grandes machines mathématiques américaines," *Atomes*, 2, 21 (1947): 400–04.

36 Métral does not mention the contacts that some of the participants had with American researchers, nor the existence of a similar congress, "on automatic regulator and servo-mechanisms," held in London in May 1947.

37 Archives of the C.N.A.M., folder "Conférences d'actualité scientifique," 1947.

38 Pierre Grosser, *Les temps de la guerre froide* (Bruxelles: Complexe, 1995) or for a rapid overview Pierre Grosser, "Entre l'Est et l'Ouest, la France," *L'Histoire*, 209 (1997): 28. As far as instability is concerned, it is worth mentioning that on November 30th, 1947, 80,000 reservists had to be called up to face the crisis. For the period from the mid-1950s to the beginning of the 1960s, see Kristin Ross, *Fast Cars, Clean Bodies: Decolonization and the Reordering of French Culture* (Cambridge, MA: MIT Press, 1995).

39 G.-T. Guilbaud, "Divagations cybernétiques," *Esprit*, 18, 9 (1950): 281–95.

40 In Europe, information theory usually means cybernetics and communication theory (see F. Stumpers and H.M. Louis "A Bibliography on Information Theory (Communication Theory – Cybernetics)," *I.R.E. Transactions on Information Theory*, 1 (1955): 31–47.
41 Louis de Broglie, *La Cybernétique: Théorie du Signal et de l'Information* (Paris: Edition de la Revue d'Optique Théorique et Instrumentale, 1951). The choice of this subtitle has been very controversial, depending on the definition given to cybernetics (this became evident during interviews with four of the participants).
42 Broglie, *La Cybernétique*, 4.
43 Interview conducted on March 19th, 1997. For a general background, see Michel Atten (ed.), *Histoire, Recherche, Télcommunication, des Recherches au CNET 1940–1965* (Paris: Dif'pop, 1996).
44 Paul Chauchard, "Les machines à calculer et la pensée humaine," *Revue Générale des Sciences Pures et Appliquées*, 58 (1951): 5–7; The proceedings of the congress appeared in 1953 as number 47 of the series *Colloques Internationaux du Centre National de la Recherche Scientifique* (no editors named).
45 The Communist Party was still the first party at the legislative elections from June 17th 1951 (with 26.5 percent) but its influence in the intellectual world was not so decisive.
46 Louis de Broglie, "Sens philosophique et portée pratique de la cybernétique," *Atomes*, 7 (1952): 3–9.
47 Jacques Bergier, "Un plan général d'automatisation des industries," *Les Lettres françaises* (15 April 1948), 7.
48 Jean Cabrerets, "Intelligence et mémoire des Cerveaux éléctroniques," *Les Lettres françaises*, (13, 20, 27 October 1949).
49 André Lentin, "La cybernétique: problèmes réels et mystifications," *La Pensée*, 47, March–April (1953), 47–61.
50 Interview with André Lentin conducted on June 20th, 1997.
51 Incidentally, on the subject of idealism, one should keep in mind this sentence written by Wiener: "Information is information, not matter or energy. No materialism which does not admit this can survive at the present day." Norbert Wiener, *Cybernetics, or Control and Communication in the Animal and the Machine* (Paris: Hermann et Cie/The Technology Press, 1948).
52 Léon Brillouin, "Life, Thermodynamics, and Cybernetics," *American Scientist*, 37 (1949), 554–68. On the history of the Maxwell's Demon with a particular attention to the use of information theory, see H.S. Leff and A. F. Rex (eds), *Maxwell's Demon: Entropy, Information, Computing* (Bristol: Adam Hilger, 1990).
53 Léon Brillouin, *Science and Information Theory* (New York: Academic Press. Inc., 1956); the book was edited again in 1962 and translated into Russian and French.
54 Benoît Mandelbrot, "Contributions à la théorie mathématique des jeux de communications," *Publication de l'Institut de Statistiques de l'Université de Paris*, 2, fasc. 1 and 2 (1953): 3–124.
55 Marcel-Paul Schützenberger, "Contributions aux applications statistiques de la théorie de l'information," *Publications de l'Institut de Statistique de l'Université de Paris*, 3 (1953), 3–117.
56 Jean Ville and Marcel-Paul Schützenberger, "Les opérations des mathématiques pures sont toutes des fonctions logiques," *Comptes rendus de l'Académie des Sciences*, 232 (1951): 206–07 and Marcel-Paul Schützenberger, "Sur les rapports entre la quantité d'information au sens de Fisher et au sens de Wiener," *Comptes-Rendus de l'Académie des Sciences*, 232 (1951): 925–7.
57 See the first volume of *Information and Control*, published 1958.
58 Jacques Lafitte, *Réflexions sur la Science des Machines* (Paris: Librairie Bloud & Gay, 1932).

59 Pierre de Latil, *La Pensée artificielle* (Paris: Gallimard, 1953); Albert Ducrocq, *Découverte de la cybernétique* (Paris: Julliard, 1955); and Vitold Belevitch, *Langage des machines et langage humain* (Bruxelles: Office de publicité, 1956).

60 For a brief account of this French-Belgian connection, see Brigitte Chamak, *Le groupe des dix ou les avatars des rapports entre science et politique* (Paris: Editions du Rocher, 1997), 104–22.

61 Ivan Ia. Aksenov, Iurii Ia. Bazilevskii, and R.R. Vasil'ev, "Otchet ob itogakh II Mezhdunarodnogo kongressa po kibernetike," Russian Academy of Sciences Archive, Moscow (Arkhiv Rossiiskoi Akademii Nauk), f. 395, op. 17, d. 47, l. 43.

62 Kirillin and Monin to the Central Committee, July 13, 1960; Russian State Archive of Contemporary History, Moscow (Rossiiskii gosudarstvennyi arkhiv noveishei istorii [hereafter RGANI]), f. 5, op. 35, d. 134, ll. 55–56.

63 "Kibernetika," in Mark Rozental' and Pavel Iudin (eds), *Kratkii filosofskii slovar'* (Moscow: Gospolitizdat, 1954), 236–37.

64 On the history of Soviet cybernetics, see Boris V. Biriukov (ed.), *Kibernetika: proshloe dlia budushchego. Etiudy po istorii otechestvennoi kibernetiki* (Moscow: Nauka, 1989); Slava Gerovitch, *From Newspeak to Cyberspeak: A History of Soviet Cybernetics* (Cambridge, MA: MIT Press, 2002); Richard D. Gillespie, "The Politics of Cybernetics in the Soviet Union," in Albert H. Teich (ed.), *Scientists and Public Affairs* (Cambridge, MA: MIT Press, 1974), 239–98; Loren R. Graham, *Science, Philosophy, and Human Behavior in the Soviet Union* (New York: Columbia University Press, 1987), ch. 8; David Holloway, "Innovation in Science: the Case of Cybernetics in the Soviet Union," *Science Studies* 4 (1974): 299–337; Alexander Y. Nitussor, Wolfgang Ernst and Georg Trogeman (eds.), *Computing in Russia: The History of Computer Devices and Information Technology Revealed* (Braunschweig: Vieweg, 2001); Dmitrii A. Pospelov and Iakov I. Fet (ed. and comp.), *Ocherki istorii informatiki v Rossii* (Novosibirsk: OIGGM SO RAN, 1998).

65 Both Wiener and Shannon were indebted to Russian scientists for important insights. Wiener was influenced by the works of the Russian mathematicians Nikolai Bogoliubov, Andrei Kolmogorov, and Nikolai Krylov, physiologist Ivan Pavlov, and linguist Roman Jakobson; see Wiener's acknowledgement of Russian contributions in Wiener, *Cybernetics*, 11, 59, 127, and Wiener, *The Human Use of Human Beings: Cybernetics and Society* (New York: Avon Books, 1954), 255. Shannon employed the apparatus of "Markov processes," developed by the Russian mathematician Andrei Markov, Sr., in the early twentieth century for the same problem of stochastic description of natural language texts; see Shannon and Weaver, 45; Andrei A. Markov, "Primer statisticheskogo issledovaniia nad tekstom 'Evgeniia Onegina', illiustriruiushchii sviaz' ispytanii v tsep'," *Izvestiia Imperatorskoi Akademii Nauk* (1913): 153–62.

66 Bernard E. Bykhovskii, "Nauka sovremennykh rabovladel'tsev," *Nauka i zhizn'*, 6 (1953): 44.

67 Teodor K. Gladkov, "Kibernetika–psevdonauka o mashinax, zhivotnykh, cheloveke i obshchestve," *Vestnik Moskovskogo universiteta*, 1 (1955): 61.

68 Wiener, *Cybernetics*, 132.

69 Bykhovskii, "Nauka sovremennykh rabovladel'tsev," 44.

70 Zheleznov, "Predislovie," 6.

71 One Soviet author cited André Lentin's critique of cybernetics with strong approval; see Materialist [pseudonym], "Whom Does Cybernetics Serve?" (1953), trans. Alexander D. Paul, *Soviet Cybernetics Review*, 4, 2 (1974): 41.

72 In his anti-genetics speech at the July–August 1948 session of the Lenin All-Union Academy of Agricultural Sciences, personally edited and approved by Stalin, Lysenko attacked Schrödinger's book, *What Is Life?*, for bringing physical methods

into biology. See Kirill Rossianov, "Editing Nature: Joseph Stalin and the 'New' Soviet Biology," *Isis*, 84, 4 (December 1993): 728–45.

73 Trofim D. Lysenko, "In Response to an Article by A.N. Kolmogoroff," *Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS*, 28, 9 (1940): 833.

74 See André N. Kolmogoroff, "Sur l'interpolation et extrapolation des suites stationnaires," *Comptes Rendus de l'Académie des Sciences de Paris*, 208 (1939): 2043–5; Andrei N. Kolmogorov, "Statsionarnye posledovatel'nosti v gil'bertovom prostranstve," *Biulleten' MGU. Matematika*, 2, 6 (1941): 1–40; Andrei N. Kolmogorov, "Interpolirovanie i ekstrapolirovanie statsionarnykh sluchainykh posledovatel'nostei," *Izvestiia AN SSSR. Matematika*, 5 (1941): 3–14. Referring to the 1949 publication of Wiener's book, *Extrapolation, Interpolation, and Smoothing of Stationary Time Series*, Peter Whittle has concluded: "Kolmogorov and Wiener are generally given joint credit for the development of the prediction theory of stationary processes. This surely constitutes insufficient recognition of Kolmogorov's clear ten-year priority," (Peter Whittle, "Kolmogorov's Contributions to the Theory of Stationary Processes," *The Bulletin of the London Mathematical Society*, 22 (1990): 84; cf. Pesi R. Masani, *Norbert Wiener, 1894–1964* (Basel: Birkhäuser Verlag, 1990), 193–95. As stated above, Wiener's report was already in restricted circulation in 1942, which still gives Kolmogorov a lead.

75 Kolmogorov recalled that at the International Mathematical Congress in Amsterdam in 1954 he, a Russian, had to argue the importance of Shannon's information theory before American mathematicians, who were skeptical about the mathematical value of this engineer's work; see Andrei N. Kolmogorov, "Predislovie," in Klod Shennon [Claude Shannon], *Paboty po teorii informatsii i kibernetike*, trans. from English (Moscow: Izdatel'stvo inostrannoi literatury, 1963), 5.

76 See Andrei N. Kolmogorov, Izrail' M. Gelfand, and Akiva M. Yaglom, "Amount of Information and Entropy for Continuous Distributions," 1958, in Al'bert N. Shiryayev (ed.), *Selected Works of A.N. Kolmogorov, vol. III: Information Theory and the Theory of Algorithms* (Dordrecht: Kluwer Academic Publishers, 1993), 33, fn. 1.

77 Nikolai S. Simonov, *Voenno-promyshlennyi kompleks SSSR v 1920–1950-e gody: tempy ekonomicheskogo rosta, struktura, organizatsiia proizvodstva i upravleniie* (Moscow: ROSSPEN, 1996), 259–60.

78 "Vazhneishie zadachi razvitiia nauki v shestoi piatiletke," October 1955; RGANI, f. 5, op. 35, d. 3, l. 6.

79 Rumiantsev to the Central Committee, August 9, 1955; RGANI, f. 5, op. 17, d. 509, l. 214.

80 Sergei L. Sobolev, Anatolii I. Kitov, and Aleksei A. Liapunov, "Osnovnye cherty kibernetiki," *Voprosy filosofii*, 4 (1955): 140.

81 Sobolev, Kitov, and Liapunov, "Osnovnye," 136.

82 Andrei N. Kolmogorov, "Intervention at the Session," 1956, in Shiryayev (ed.), *Selected Works of A.N. Kolmogorov*, vol. III, 32.

83 Igor' A. Poletaev, *Signal: O nekotorykh poniatiiakh kibernetiki* (Moscow: Sovetskoe radio, 1958), 23.

84 See Aleksei A. Liapunov and Sergei V. Iablonskii, "Teoreticheskie problemy kibernetiki," 1963, in Aleksei A. Liapunov, *Problemy teoreticheskoi i prikladnoi kibernetiki* (Moscow: Nauka, 1980), 71–88.

85 In 1959, the Laboratory began publishing the journal *Problemy peredachi informatsii*, which since 1965 has been also published in the Engish translation as *Problems of Information Transmission*.

86 In his recent study of the subcultures of instrumentation, experiment, and theory within the larger culture of microphysics, Peter Galison calls a "trading zone" the area where, despite the vast differences in their symbolic and cultural systems,

different groups can collaborate. See Peter L. Galison, *Image and Logic: A Material Culture of Microphysics*(Chicago: University of Chicago Press, 1997), especially ch. 9.
87 Raisa L. Berg, *Acquired Traits: Memoirs of a Geneticist from the Soviet Union* (New York: Viking, 1988), 220.
88 Sergei L. Sobolev, "Vystuplenie na soveshchanii," in Petr N. Fedoseev (ed.), *Filosofskie problemy sovremennogo estestvoznaniia* (Moscow: AN SSSR, 1959), 266.
89 Sergei L. Sobolev and Aleksei A. Liapunov, "Kibernetika i estestvoznanie," in Fedoseev (ed.), *Filosofskie problemy*, 252.
90 Raisa L. Berg and Aleksei A. Liapunov, "Predislovie," in Ivan I. Shmal'gausen, *Kiberneticheskie voprosy biologii* (Novosibirsk: Nauka, 1968), 13.
91 Jakobson to Shannon (24 April 1951) MC 72, box 45.21, Jakobson papers, MIT.
92 See Roman Jakobson, "Linguistics and Communication Theory," 1960, in Roman Jakobson, *Selected Writings, vol. II: Word and Language* (The Hague and Paris: Mouton, 1971), 570–9.
93 Claude E. Shannon, "The Redundancy of English," in *Cybernetics: Transactions of the Seventh Macy Conference* (New York: Josiah Macy, Jr. Foundation, 1951), 157. See also Roman Jakobson, "Linguistics and Communication Theory," 578.
94 Igor' A. Melčuk, *Cybernetics and Linguistics: Some Reasons for as Well as Some Consequences of Bringing Them Together* (Vienna: Osterr. Studienges. f. Kybernetik, 1977), 15.
95 Akiva M. Iaglom and Isaak M. Iaglom, *Probability and Information*, trans. V.K. Jain (Dordrecht: Reidel, 1983), 198–201.
96 Andrei S. Monin, "Dorogi v Komarovku," in Al'bert N. Shiriaev (ed.), *Kolmogorov v vospominaniiakh* (Moscow: Nauka, 1993), 484.
97 Andrei N. Kolmogorov, "Three Approaches to the Definition of the Notion of Amount of Information," 1965, in Shiryayev (ed.), *Selected Works of A.N. Kolmogorov*, vol. III, 188.
98 Kolmogorov, "Three Approaches," 190.
99 Andrei N. Kolmogorov, "The Combinatorial Foundations of Information Theory and the Probability Calculus," 1983, in Shiryayev (ed.), *Selected Works of A.N. Kolmogorov*, vol. III, 210.
100 Kolmogorov, "Three Approaches," 192.
101 David G. Kendall, "Kolmogorov: The Man and His Work," *The Bulletin of the London Mathematical Society*, 22 (1990): 40.
102 Andrei N. Kolmogorov, "Kibernetika," in *Bol'shaia Sovetskaia entsiklopediia*, 2nd ed., vol. 51 (1958): 149.
103 Andrei N. Kolmogorov, "Informatsiia," in *Bol'shaia Sovetskaia entsiklopediia*, 2nd ed., vol. 51 (1958): 129.
104 Andrei A. Markov, "Chto takoe kibernetika?" in Aksel' I. Berg *et al.* (eds), *Kibernetika. Myshlenie. Zhizn'* (Moscow: Mysl', 1964), 41. Andrei Markov, Jr., was the son of the author of "Markov processes."
105 Il'ia B. Novik, *Kibernetika: filosofskie i sotsiologicheskie problemy* (Moscow: Gospolitizdat, 1963), 80. On Soviet philosophical discussions of the concept of information, see Graham, *Science, Philosophy, and Human Behavior in the Soviet Union*, 281–93.