The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision

Peter Galison

1. The Enemy

"I . . . hope you can find some corner of activity in which I may be of use during the emergency," the mathematician and physicist Norbert Wiener wrote the czar of American war research, Vannevar Bush, on 20 September 1940. Britain was under unrelenting aerial attack, and a Nazi invasion seemed imminent. Wiener scrambled across the disciplinary map to throw his weight behind a technological defense. He suggested procedures to improve Bush's computational device, the so-called differential analyzer, in ways that would facilitate faster design of war materiel from airplane wings to ballistic shells. More concretely, he reiterated a previous proposal that the Allies loft air-bursting containers of liquified ethylene, propane, or acetylene gases to engulf a wide volume of the sky in a pro-

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longed detonation.[1] That repelling the onslaught of bombers had pushed all scientific questions aside is hardly surprising. For the German Air Force had dubbed 13 August 1940 "The Day of the Eagle," and with it the Battle of Britain had begun with an assault of almost 1500 aircraft flown against British air stations and aircraft factories. During the following two weeks over a thousand Londoners had died under the rain of bombs, and September was worse. On 7 September alone, 448 civilians perished; on 15 September the Germans pitched 230 bombers and 700 fighters against London, Southampton, Bristol, Cardiff, Liverpool, and Manchester.[2]

Over the next few years, Wiener's attention focused increasingly on the problem of destroying enemy airplanes. His early efforts at computation and antiaircraft fire coalesced in a remarkably ambitious calculating device that he called the "antiaircraft (AA) predictor," designed to characterize an enemy pilot's zigzagging flight, anticipate his future position, and launch an antiaircraft shell to down his plane. But Wiener's electronic manipulation did not stop with halting Nazi air attacks. In the course of characterizing the enemy pilot's actions and designing a machine to forecast his future moves, Wiener's ambitions rose beyond the pilot, even beyond the World War. Step by step, Wiener came to see the predictor as a prototype not only of the mind of an inaccessible Axis opponent but of the Allied antiaircraft gunner as well, and then even more widely to include the vast array of human proprioceptive and electrophysiological feedback systems. The model then expanded to become a new science known after the war as "cybernetics," a science that would embrace intentionality, learning, and much else within the human mind. Finally, the AA predictor, along with its associated engineering notions of feedback systems and black boxes, became, for Wiener, the model for a cybernetic understanding of the universe itself. This paper is an exploration of that expansion. In it, I will be backtracking from the widest ontologi-

1. Norbert Wiener, letter to Vannevar Bush, 20 Sep. 1940, box 2, folder 58, Norbert Wiener Papers, collection MC-22, Institute Archives and Special Collections, Massachusetts Institute of Technology Archives, Cambridge, Mass. (hereafter abbreviated NWP).

2. Martin Gilbert, *The Second World War: A Complete History* (New York, 1989), pp. 117–25.

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cal claims of cybernetics into a collocation of vacuum tubes, resistors, and condensers designed to replicate the intentions of a hidden enemy pilot.

Enemies were not all alike. In the killing frenzy of World War II, one version of the Enemy Other (not Wiener's) was barely human; to the Americans, British, and Australians, the Japanese soldiers were often thought of as lice, ants, or vermin to be eradicated. As General Sir Thomas Blamey told a unit in Port Moresby in 1942: "Beneath the thin veneer of a few generations of civilization [the Japanese soldier] is a subhuman beast, who has brought warfare back to the primeval, who fights by the jungle rule of tooth and claw, who must be beaten by the jungle rule of tooth and claw. . . . Kill him or he will kill you." A year later, Blamey insisted on the Buna battlefield that "fighting Japs is not like fighting normal human beings. . . . The Jap is a little barbarian. . . . We are not dealing with humans as we know them. We are dealing with something primitive. Our troops have the right view of the Japs. They regard them as vermin."[3] These monstrous, racialized images of hate certainly presented one version of the World War II enemy, but it was by no means the only one.

Another and distinct Allied vision held the enemy to be not the racialized version of a dreaded opponent but rather the more anonymous target of air raids. This enemy's humanity was compromised not by being subhuman, vicious, abnormal, or primitive but by occupying physical and moral distance. Viewed from afar, from the icy heights of thirty thousand feet, a city in Germany looked small, and individual people appeared to be invisible, partially shorn of their likeness to the bomber. After opening a spate of airmen's letters, one British censor from the Air Ministry reported on 21 June 1942: "[The letters] illustrate the effect of airmen's remoteness from their attacks on human beings. Expressions of satisfaction that the Germans are having to undergo the punishment they have hitherto meted out to others are found in almost all letters, but there is an absence of vindictiveness or fanaticism in the phrases used."[4]

3. Quoted in John W. Dower, *War without Mercy: Race and Power in the Pacific War* (New York, 1986), pp. 53 and 71.

4. Quoted in Max Hastings, *Bomber Command* (New York, 1979), p. 146. Other recent literature on the moral, political, and military aspects of bombing civilians includes Michael Sherry, *The Rise of American Air Power: The Creation of Armageddon* (New Haven, Conn., 1987), which argues that the slide towards civilian bombing led inexorably to the use of atomic weapons against civilian targets, and Conrad C. Crane, *Bombs, Cities, and Civilians: American Airpower Strategy in World War II* (Lawrence, Kan., 1993), especially pp. 53–59, which tracks aviators' attitudes in the field as differing according to their specific tasks: piloting, navigating, or bombing. Distancing, however, had to be maintained, often under immense stress. One pilot (who was killed in November 1944) wrote shortly before his death: "The whole idea was to blow up just as much Germany tomorrow as possible. From way up high, it wouldn't mean a thing to me. I wouldn't know if any women or little kids got in the way." Such remarks were followed in the very next sentence by doubts: "I'd thought about it before, but that night it was close. The more I thought of it, the uglier it seemed" (Bert Stiles, *Serenade to the Big Bird* [1947; New York, 1952], p. 21).

But there is yet another picture of the enemy that emerged during World War II, less well known but in many ways more powerful and enduring than either the racialized or the anonymous enemy. More active than the targeted, invisible inhabitants of a distant city and more rational than the hoardelike race enemy, this third version emerged as a cold-blooded, machinelike opponent. This was the enemy, not of bayonet struggles in the trenches, nor of architectural targets fixed through the prisms of a Norden gunsight. Rather, it was a mechanized Enemy Other, generated in the laboratory-based science wars of MIT and a myriad of universities around the United States and Britain, not to speak of the tens of laboratories in the countries of the Axis.

On the Allied side, three closely related sciences engaged this calculating Enemy Other: operations research, game theory, and cybernetics. Each had its own prototypical war problem. Operations research focused, for example, on maximizing efficiency in locating and destroying German U-boats in the North Atlantic and along the coast of the Americas.[5] Game theory, though it had mathematical roots in the interwar years, exploded into view with John von Neumann and Oscar Morgenstern's masterwork of 1944, *Theory of Games and Economic Behavior*;[6] strategists picked up the technique as a way of analyzing what two opposing forces ought to do when each expected the other to act in a maximally rational way but were ignorant both of the opponent's specific intentions and of the enemy's choice of where to bluff. Wiener, the spokesman and advocate of cybernetics, in a distinction of great importance to him, divided the devils facing us in two sorts. One was the "Manichean devil" "who is determined on victory and will use any trick of craftiness or dissimulation to obtain this victory." Wiener's rational Manichean devil could, for example, change strategy to outwit us. By contrast, the other, the "Augustinian devil" (and Wiener counted the forces of nature as such) was characterized by the "evil" of chance and disorder but could not change the rules.[7] Exemplary of the Manichean enemy, von Neumann's

5. On the origins of operations analysis, see M. Fortun and S. S. Schweber, "Scientists and the Legacy of World War II: The Case of Operations Research (OR)," *Social Studies of Science* 23 (Nov. 1993): 595–642; and Robin E. Rider, "Early Development of Operations Research: British and American Contexts," paper presented at the Joint Meeting of the British Society for History of Science and the History of Science Society, Manchester, 11–14 July 1988, "Operations Research and Game Theory: Early Connections," in *Toward a History of Game Theory*, ed. E. R. Weintraub (Durham, N. C., 1992), pp. 225–39, and "Capsule History of Operations Research," in *Encyclopaedia of the History and Philosophy of Mathematical Sciences*, ed. Ivor Grattan-Guinness (forthcoming).

6. See John von Neumann and Oscar Morgenstern, *Theory of Games and Economic Behavior* (Princeton, N. J., 1944).

7. Wiener, *The Human Use of Human Beings* (New York, 1954), pp. 34–35; hereafter abbreviated *HU*. Elsewhere in the book Wiener writes that irrationality in human behavior (Freud) is of a piece with the chance element in the physical world (Willard Gibbs) and with the statistical system of reasoning itself (Henri Lebesgue): "This random element, this organic incompleteness, is one which without too violent a figure of speech we may consider

game theory postulated a logical but cunning opponent; it was designed precisely to analyze an antagonist who played against us and would bluff to win.

Building on Wiener's own usage of the term *Manichean* to designate the continuing struggle against an active oppositional intelligence, I will call this triad of wartime enterprises—operations research, cybernetics, and game theory—the Manichean sciences.[8] I choose the third war science, cybernetics, as an entry point to these machine-human systems.[9] Working with the Greek word for steersman, Wiener coined the term *cybernetics* in the summer of 1947 to designate what he hoped would be a new science of control mechanisms in which the exchange of information would play a central role.[10] If antisubmarine warfare was the formative problem for operations research, antiaircraft fire control was the key to cybernetics.[11] Faced with the problem of hitting fast maneuverable bombers with ground-based artillery, Wiener brought to bear his own established interest in feedback mechanisms, communication technology, and nonlinear processes.

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evil; the negative evil which St. Augustine characterizes as incompleteness, rather than the positive malicious evil of the Manicheans" (*HU,* p. 11). Wiener emphasizes over and again that the evil opposition of nature is not active: "I have already pointed out that the devil whom the scientist is fighting is the devil of confusion, not of willful malice. The view that nature reveals an entropic tendency is Augustinian, not Manichean" (*HU,* p. 190).

8. It is part of my argument that the division between active and passive antagonists is not sustained in the cybernetic view of the world. In particular, within Wiener's vision of the world there is great continuity between the antientropic self-regulating strategy for controlling (or destroying) an enemy and controlling the built and found world around us. Indeed, Wiener himself contends that the Augustinian position easily breaks down into Manicheanism. See *HU,* p. 191.

9. On earlier human-machine links, see, for example, Anson Rabinbach, *The Human Motor: Energy, Fatigue, and the Origins of Modernity* (New York, 1990).

10. See Wiener, *Cybernetics; or Control and Communication in the Animal and the Machine* (1948; Cambridge, Mass., 1961), pp. 11–12; hereafter abbreviated *C.*

11. On Wiener, see the rich and provocative book by Steve J. Heims, *John von Neumann and Norbert Wiener: From Mathematics to the Technologies of Life and Death* (Cambridge, Mass., 1980). An extraordinary source for original writings by Wiener is the four-volume set of his collected works; there one finds the best technical summary and analysis of Wiener's antiaircraft predictor. See P. Masani and R. S. Phillips, "Antiaircraft Fire-Control and the Emergence of Cybernetics," in *Norbert Wiener: Collected Works with Commentaries,* ed. Masani, 4 vols. (Cambridge, Mass., 1985), 4:141–79. I have also found very valuable the mathematically sophisticated treatment of Wiener's work on the AA predictor in Masani, *Norbert Wiener, 1894–1964* (Basel, 1990), esp. pp. 184–93.

Three authors writing recently on the links between cybernetics and the biological and psychological domains include Lily E. Kay, "Who Wrote the Book of Life? Information and the Transformation of Molecular Biology, 1944–55," in *Experimentalsysteme in den Biologische–Medizinischen Wissenschaften: Objekt, Differenze, Konjunkturen,* ed. Michael Hagner and Hans-Jörg Rheinberger (Berlin, 1994); E. F. Keller, "The Body of New Machine: Situating the Organism between Telegraphs and Computers," *Representing Life: Changing Metaphors of Twentieth-Century Biology* (forthcoming); and Paul Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (forthcoming).

I will argue that the system of weaponry and people that Wiener had in mind was predicated on a picture of a particular kind of enemy. On the mechanized battlefield, the enemy was neither invisible nor irrational; this was an enemy at home in the world of strategy, tactics, and maneuver, all the while thoroughly inaccessible to us, separated by a gulf of distance, speed, and metal. It was a vision in which the enemy pilot was so merged with machinery that (his) human-nonhuman status was blurred. In fighting this cybernetic enemy, Wiener and his team began to conceive of the Allied antiaircraft operators as resembling the foe, and it was a short step from this elision of the human and the nonhuman in the ally to a blurring of the human-machine boundary in general. The servomechanical enemy became, in the cybernetic vision of the 1940s, the prototype for human physiology and, ultimately, for all of human nature. Then, in a final move of totalization, Wiener vaulted cybernetics to a philosophy of nature, in which nature itself became an unknowable but passive opponent—the Augustinian devil.

Cybernetics no longer appears as a futuristic bandwagon or as a rising worldview that will leave mere mechanism in the dustbin of history, but it has much to tell us about the nature of the sciences in the mid–twentieth century and, as I will speculate, about postmodern theory in the late twentieth century.

2. *The Calculating Enemy*

Norbert Wiener's upbringing resembled none so much as John Stuart Mill's. His father, Leo Wiener, was an erudite and driven Harvard Slavicist who was determined that his son know languages, mathematics, and the sciences long before he was old enough to attend grade school. Graduated from Tufts University at the age of fourteen, and armed with a Harvard Ph.D. at eighteen, the younger Wiener found his own style of work in physics-based mathematics. By the late 1930s, Wiener was in his forties and a major figure at MIT, where he had contributed to quantum theory, ballistics, the theory of integration, and communication technology. Like so much else in his life, he came to war preparations early (for an American). Already in February of 1940, he joined a subcommittee under the direction of the Princeton mathematician Marston Morse to consider how the American Mathematical Society might contribute to a national emergency "which we hope will never arise."[12] Needless to say, it did. Beginning on 10 July, German bombing attacks on British convoys grew significantly in number, ushering in the Battle of Britain. From 10 to 20 July the *Kanalkampf,* as the Germans dubbed it, was prosecuted with

12. Dunham Jackson, letter to Harry Bateman, E. J. McShane, M. H. Stone, J. H. Van Vleck, Wiener, and S. S. Wilks, 14 Feb. 1940, box 1, folder 56, NWP.

the goal of depleting the British supply of fighters, to be followed by an all-out assault on the fighter bases in Britain itself. It was this spate of Nazi bombing that precipitated Wiener's primary war work. By 23 July, Wiener had received notice that the armed forces had in hand his suggestion about the use of incendiary bombs and his reiterated desire to participate in the war effort.[13] But the main line of Wiener's military work centered on a general theoretical and practical inquiry into the possibility of radically improving antiaircraft technology. At root, Wiener's idea was to use electrical networks to determine, several seconds in advance, where an attacking plane would be and to use that knowledge to direct artillery fire. In an early simulated run of the AA predictor (November 1940), Wiener wanted to see how his machine would fare in four cases: a straight-line bomber trajectory, another having twice the slope of the first, a third with a parabolic slope, and a fourth with a curve following the integrated area of a semicircle. Since the circuit itself did not exist in wire and tubes, Wiener concocted a virtual mechanical equivalent and "tested" all four cases in simulated form on Vannevar Bush's differential analyzer.[14]

Partly as a result of an extended exchange and collaboration with Bush and partly as a result of his own early circuit designs, Wiener over the next few months came to insist that the wartime mathematician had to stray far from the "purity" of the prewar years. In January 1941, Wiener hired Julian Bigelow, an MIT-trained electrical engineer, to work with him in circuits design.[15] As a result of his commitment to the nitty-gritty of weapons work, Wiener had left the etherial domain of Tauberian theorems of mathematical analysis for the breadboard wiring schemes of the engineer long before American troops were attacked at Pearl Harbor. Writing to Morse back in Princeton in March 1941, Wiener used Bush's partial differential equation machine as an example of just how far mathematics would have to go if it were to advance. It could not remain "exclusively in the hands of mathematicians." He would need someone already versed in computing technique, someone, say, from Remington-Rand or IBM. This man (his term) would have to be familiar with vacuum tube work, and he would without question have to know his way around communication engineering techniques such as telephone technology.

13. See C. Thomas-Stahle, letter to Wiener, 23 July 1940, box 1, folder 57, NWP.

14. See S. H. Caldwell, "Proposal to Section D-2, National Defense Research Committee," 22 Nov. 1940, introduction to Wiener, "Principles Governing the Construction of Prediction and Compensating Apparatus," Record Group 227, Office of Science and Research Development (hereafter abbreviated OSRD), Division 7, General Project Files, 1940–46, General Mathematical Theory of Prediction and Application, Massachusetts Institute of Technology (hereafter abbreviated MIT), Wiener, NDCrc-83, National Archives, Library of Congress, Washington, D. C. (hereafter abbreviated NA-LC).

15. See Wiener, report to D. I. C. 5980 A. A. Directors, "Summary Report for Demonstration," 10 June 1942, Record Group 227, OSRD, National Defense Research Committee

> If I could not find these talents joined together in a single man, I would be forced to assemble a team of people each with particular talents in one field and a general knowledge of the others. In this team I would probably be the only mathematician thus the project as a whole would concern other engineering groups as much as the American Mathematical Society and it would be necessary for me to cross ordinary professional lines.[16]

No one who did not already have a feeling for engineering, at least by taking on the construction of radio sets as a hobby, could even hope to participate. "There is nothing in a drawing in abstract algebra or topology . . . which would prepare one in any way to cooperate in engineering design."[17] Though Wiener worked his illustrative example from the Bush differential analyzer, he assured Morse that the same was true for projects from cryptography to ballistics. To be useful to the war effort, it was science itself that would have to change, becoming both materially grounded and squarely directed into the world of weapons. For Wiener, Morse, and their colleagues, science was at war, even if the country was not.

The scale of Wiener's work was not large. It was, in fact, infinitesimal compared with the scope of work getting underway at the Radiation Laboratory or at Los Alamos. Wiener's little group had, as its first 1941 budget (submitted in 1940), a paltry request for $2325, with $1200 devoted to circuit building, three man-months for differential analyzer studies at $450, and the remainder going to labor overhead.[18] Scale, however, can be measured in other ways. As the AA predictor came to fruition, Wiener came to see it as the articulated prototype for a new understanding of the human-machine relation, one that made soldier, calculator, and firepower into a single integrated system. His two thousand-odd dollars would be conceptually stretched to blanket the earth.

Preliminary circuit diagrams indicated that the AA predictor would be vulnerable to two kinds of sudden movements: irregularities introduced as the operator of the crosshair telescope cranked his gun to follow the plane and irregularities injected as the pilot zigzagged to escape. Both would have to be filtered to gain a smoother curve that the predicting circuit could handle. In the design of the filters, as in many aspects of the project, the underlying mathematical or calculational methods Wiener wanted to use for the AA predictor carried over from earlier studies of servomechanisms, that is, of feedback devices such as thermostats or self-guided torpedoes. Indeed, the only real difference between the two types of feedback problems was that in the AA predictor there was a longer

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(hereafter abbreviated NDRC) Contractors' Technical Reports, Division 7, MIT, NDCrc-83, NA-LC.

16. Wiener, letter to Marston Morse, 12 Mar. 1941, box 2, folder 59, NWP.

17. Ibid.

18. See Caldwell, "Proposal to Section D-2, National Research Committee."

time lag between action and effect: the shell took several seconds to reach its target. One striking indicator of the congruence of technological practice is that Wiener specifically asked for an enforcement of the same patent clause for the AA predictor as was used in the earlier servomechanism program (figs. 1 and 2).[19]

As Wiener and Bigelow gave form to the hardware in the summer of 1941 (figs. 3 and 4), they desperately needed realistic information on the character of input data:

> We realized that the "randomness" or irregularity of an airplane's path is introduced by the pilot; that in attempting to force his dynamic craft to execute a useful manoeuver, such as straight-line flight or 180 degree turn, the pilot *behaves like a servo-mechanism,* attempting to overcome the intrinsic lag due to the dynamics of his plane as a physical system, in response to a stimulus which increases in intensity with the degree to which he has failed to accomplish his task. A further factor of importance was that the pilot's kinaesthetic reaction to the motion of the plane is quite different from that which his other senses would normally lead him to expect, so that for precision flying, he must disassociate his kinaesthetic from his visual sense.[20]

Here was a problem simultaneously physical and physiological: the pilot, flying amidst the explosion of flak, the turbulence of air, and the sweep of searchlights, trying to guide an airplane to a target. As Wiener saw it, humans acting under stress tend to perform repetitively and therefore predictably.

To recreate this tense concatenation of human and machine, Wiener, Bigelow, and Paul Mooney, an accomplished technician, began a series of experiments before the end of 1941 to simulate the data input of an enemy plane that would enter the AA predictor. Bigelow, who was an active pilot, took special responsibility for creating a mechanical apparatus "designed to have the 'feel' of an actual [airplane] control."[21] On a laboratory wall, a light-spot projector shot an intense white spot that followed a smooth but irregular back-and-forth motion, careening its way from wall to wall every fifteen seconds. At the same time, an operator—simulating the pilot—was given a deliberately sluggish control stick that guided the position and motion of a second colored light spot. The "pilot's" task was to guide the colored spot onto the "target," mimicking (as one contempo-

19. See ibid. A standard text on servomechanisms that Wiener approved of (and cited frequently) was Le Roy A. MacColl, *Fundamental Theory of Servomechanisms* (New York, 1945). MacColl clearly identified servomechanisms with slaved systems that used feedback; see pp. 1–9.

20. Wiener, "Summary Report for Demonstration," p. 6 (emphasis added).

21. George R. Stibitz, "Report on Visit to Prof. Norbert Wiener," 28 Oct. 1941, Record Group 227, OSRD, Division 7, Records of Chiefs and Members of Sections, 1940–46, George R. Stibitz, Section 7.1, Land-Based Fire Control Problems, "Predictions I," MIT, NDCrc-83, NA-LC.

rary witness put it) "a plane which is dodging, but flying a mission, i.e. the pilot is holding a general course, but with large swings away from the course."[22] Quite deliberately, the experimenters made the task exceedingly difficult by racing the target across the wall at high speed and by inserting a mechanical lag into the control stick. This, they hoped, would create precisely the disassociation between kinaesthetic sense and visual information that the pilot had to face in the theater of war and would therefore lead to the same sort of feedback difficulties. Meanwhile, the position of the operator's light signal went down on tape alongside the position of the guiding light spot. The fluctuating difference between the "intended" position and the actual position of the operator's light dot provided "a way to duplicate . . . the properties of the type of irregular motion of an airplane in flight."[23] These data would program the AA predictor.[24]

In particular, the pseudo pilots' "nervous reactions" exhibited two crucial features. First, there was no particular correlation among the recorded fluctuations of different operators; second, there was a high degree of autocorrelation between an operator's earlier and subsequent performances. More specifically, Wiener chose the following definition of prediction. Imagine a number of flight paths (ten, for example) that all coincide for a given segment of their trajectory but may differ after a given time, t. Now pick a point in space where we expect a plane to be at, say, $t + 2$ seconds. For any such predicted point we can calculate the square of the difference between the predicted point and the actual position of the first plane at $t + 2$ seconds, and we can do the same for the other nine planes. The point for which the sum of squared errors is minimized is what Wiener calls the best prediction.[25] It turned out that prediction worked rather badly for one operator based on another operator's data, but any given operator was enormously self-consistent. "This suggests the use of such apparatus in the diagnosis of individual differences in reflex behavior, and of pathological conditions affecting the reflex arc.

22. Stibitz, Section 2 of Division D, Diary of Chairman, 1 July 1942, Boston, Project no. 6, Record Group 227, OSRD, Division 7, General Project Files, 1940–46, General Mathematical Theory of Prediction and Application, MIT, Wiener, NDCrc-83, NA-LC; hereafter abbreviated "D."

23. Wiener, *I Am a Mathematician: The Later Life of a Prodigy* (Cambridge, Mass., 1956), p. 251.

24. See Wiener, "Summary Report for Demonstration."

25. This method of prediction (least squares) was mathematically felicitous but controversial. Stibitz, for example, argued that a pilot heading into a burst of AA fire would turn right or left, but the Wiener Predictor would lay the next burst dead ahead, and he argued, "is almost certain to miss." Duncan Stewart (for whom Stibitz worked at OSRD) was not at all confident that the enemy would behave in a consistent way. Would he see the burst? Would he fly on to complete a bomb run? "Present predictors, I fear, are useful largely because the psychological effect on the enemy serves to keep them far enough away to . . . reduce the damage" (Stibitz, "Report on Visit to Prof. Norbert Wiener").

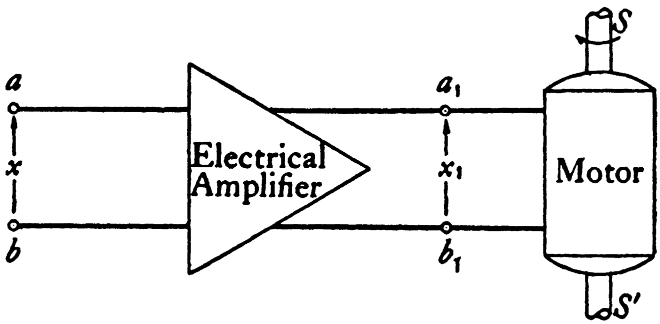

FIG. 1.—Sensor that actuates a motor. From Le Roy A. MacColl, *Fundamental Theory of Servomechanisms* (New York, 1945), p. 5.

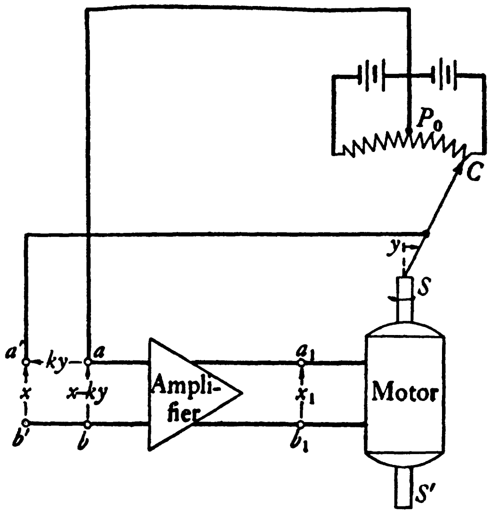

FIG. 2.—Sensor with feedback. According to most writers at the time, including MacColl and Wiener, a servomechanism was *defined* by the inclusion of feedback. From MacColl, *Fundamental Theory of Sevomechanisms,* p. 6.

Many other extensions of these ideas will suggest themselves to the physiologist, the neuropathologist, and the expert in aptitude tests."[26] More to the point, it suggested that a more refined AA predictor would use a pilot's own characteristic flight patterns to calculate his particular future moves and to kill him.[27]

The core lesson that Wiener drew from his antiaircraft work was that

26. Wiener, "Summary Report for Demonstration," p. 7.

27. Because Wiener's AA predictor based its algorithm for prediction on statistical input from the pilot's past performance, the device was a kind of learning machine. As such, it came to stand in for Wiener as the prototype of other game-playing and potentially war-fighting machines. See, for example, Wiener, *Cybernetics,* pp. xi–xii. The central idea in Wiener's statistical approach is the quantification and characterization of noise. His analysis

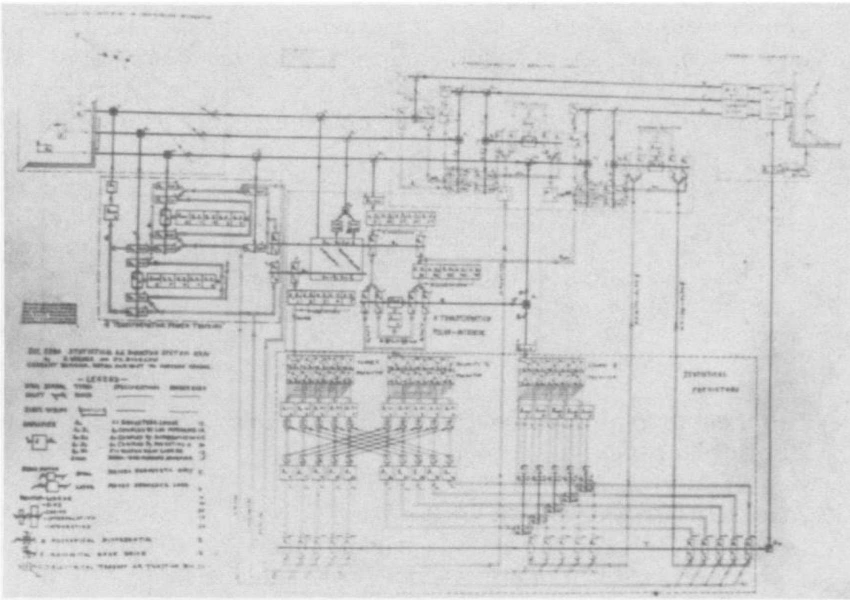

FIG. 3.—Wiring circuit for Wiener's antiaircraft predictor. From Norbert Wiener to D. I. C. 5980 A. A. Directors, "Summary Report for Demonstration," 10 June 1942, Record Group 227, Office of Science and Research Development, National Defense Research Committee Contractors' Technical Reports, Division 7, MIT, NDCrc-83, National Archives, Library of Congress, Washington, D. C..

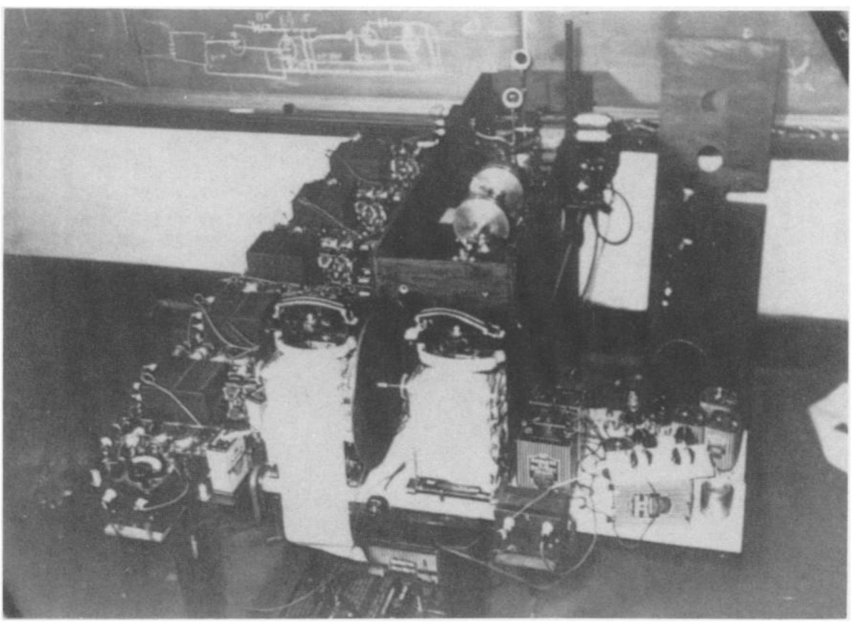

FIG. 4.—The antiaircraft predictor. From Wiener to D. I. C. 5980 A. A. Directors, "Summary Report for Demonstration."

the conceptualization of the pilot *and* gunner as servomechanisms within a single system was essential and irreducible. As Wiener put it a decade or so after the war, we might succeed in eliminating this or that human feature in a weapons system, but the enemy's human behavior would not go away:

> It does not seem even remotely possible to eliminate the human element as far as it shows itself in enemy behavior. Therefore, in order to obtain as complete a mathematical treatment as possible of the over-all control problem, it is necessary to assimilate the different parts of the system to a single basis, either human or mechanical. Since our understanding of the mechanical elements of gun pointing appeared to us to be far ahead of our psychological understanding, we chose to try to find a mechanical analogue of the gun pointer and the airplane pilot.[28]

Servomechanical theory would become the measure of man.

As the key discipline, servomechanical theory had a great deal to offer, and not just to laboratories devoted to enemy fire control. At MIT's huge and rapidly growing Radiation Laboratory, Wiener thought it obvious that suppressing noise and conveying information should be the central electronic mission. Here his views collided with those of an extraordinary collection of "fundamental" physicists—the likes of Lee DuBridge, M. G. White, N. F. Ramsey, I. I. Rabi, Julian Schwinger, Edward Purcell, and many others. On the evening of 21 March 1942, Wiener in frustration submitted his resignation from the laboratory, cut his relations with it, and handed in his identification badge. To E. L. Bowles, director of the Rad Lab, Wiener complained the next day:

> New members of the staff of your Laboratory are recruited from the theoretical physicists or mathematicians of the country, or indeed anywhere except from among the ranks of communication engineers in the strictest and narrowest sense of the term. . . . It [noise suppression, operational notation, and circuit theory] is not something which a quantum physicist has any reason to know the slightest thing about,

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begins with the determination of the autocorrelation coefficients and an associated spectrum. Given a sequence of numbers, $a(n)$, where $a(n)$ is the value of a at time $t = n$, the autocorrelation coefficients $\phi(m)$ for lag m are defined as the mean value, taken over all time, of the product of one of these numbers with its mth neighbor. The spectrum is then defined as the Fourier series where the $\phi(m)$ are the autocorrelation coefficients of the original series. Wiener characterizes what it means for stability to exist for these time series and therefore establishes conditions under which predictions can be made in his crucial work, "The Extrapolation, Interpolation and Smoothing of Stationary Time Series with Engineering Applications," DIC Contract 6037, MIT, 1 Feb. 1942, declassified, box 11, folder 561A, NWP.

28. Wiener, *I Am a Mathematician,* pp. 251–52.

> and to turn such an individual loose in your laboratory without special training, no matter what a big shot he may be in his own subject, is like ordering a corn-doctor to amputate a leg. Better three weeks delay while the big shot is learning his new trade than three months of puerilities and blunders.[29]

What the "big shots" lacked, Wiener contended, was a deep understanding of, for example, Brownian motion and generalized harmonic analysis. These were areas that Wiener had contributed to in fundamental ways; having found himself shunted off to trivial problem solving, he was furious. Without the requisite communications knowledge, Wiener prophesied, "the military efforts of the Laboratory will be about at a good boy-scout level."[30]

Pressure and frustration began to overcome Wiener. He was working frantically, often with the powerful stimulation of Benzedrine.[31] The day after his incensed letter of 22 March 1942 to Bowles, J. C. Boyce, professor of physics at MIT and technical aide to the National Defense Research Committee (NDRC), reported to Warren Weaver on Wiener's condition:

> He seems in an unusually bad nervous state the last few days, and I have been trying to get him to take a few days' rest. He had an unfortunate clash with the cleared patent attorney whom M.I.T. had asked to study some of his ideas on circuit theory, and at the same time he felt that the Radiation Laboratory was unappreciative of certain suggestions he had made to them on filter design. As a result of his state, Bigelow seems somewhat distracted, but I hope before very long this part of the zoo will be quiet again.[32]

Weaver replied the next day, after seeing Wiener pacing furiously up and down a room, "perspiring profusely," and apologizing for being unable to transform an integral into a more easily calculable, rapidly converging series that the great statistician Jerzy Neyman could use. "Upon inquiry," Weaver concluded, "it turned out that [Wiener] had not been doing any of the things we particularly wanted him to do and that his busyness consisted of 'holding myself in readiness in case other jobs turned up.'"[33]

If Wiener wasn't computing a faster-converging integral as quickly

29. Wiener, letter to E. L. Bowles, 22 Mar. 1942, box 2, folder 62, NWP.

30. Ibid.

31. See Wiener, *I Am a Mathematician*, p. 249.

32. J. C. Boyce, letter to Warren Weaver, 23 Mar. 1942, Record Group 227, OSRD, Division 7, General Project Files, 1940–46, General Mathematical Theory of Prediction and Application, MIT, Wiener, NDCrc-83, NA-LC.

33. Weaver, letter to Boyce, 24 Mar. 1942, Record Group 227, OSRD, Division 7, General Project Files, 1940–46, General Mathematical Theory of Prediction and Application, MIT, Wiener, NDCrc-83, NA-LC.

as Weaver wanted, he was already beginning to explore how the feedback mechanisms of his servomechanical theory might reshape rather distant fields. To J. B. S. Haldane, on 22 June 1942, Wiener put it this way:

> Behaviorism as we all know is an established method of biological and psychological study but I have nowhere seen an adequate attempt to analyze the intrinsic possibilities of types of behavior. This has become necessary to me in connection with the design of apparatus to accomplish specific purposes in the way of the repetition and modification of time patterns.[34]

Unmentioned was the content of these behaviorist studies. For security reasons Wiener would not reveal that the time-pattern behaviors were the pilot's evasive maneuvers and the test procedures Wiener employed to reproduce these patterns from the responses of test-subjects in the safety of the laboratory.[35]

The examination of an apparatus "from this point of view" is, Wiener told Haldane, a fundamental component of communication engineering, where the *function* of an instrument between four terminals is specified before anyone takes up the actual constitution of the apparatus in the box. He reported that this "black-box" vision of the nervous system had already generated information on a priori types of behavior, and it was clear that up to that point "no behaviorist ha[d] ever really understood the possibilities of behavior."[36] Whether his remarks were a spontaneous expression of excitement over the new results or a cryptic declaration of a priority claim, Wiener clearly saw the AA predictor, even before it was ready to shoot down a plane, as the prototype of a new behaviorist understanding of the nervous system itself. By the time Wiener wrote Haldane, he was in the final stages of preparing the machine for its great unveiling.

For a brief and shining moment, it seemed that the AA predictor would, in fact, foretell the future like a crystal ball and down enemy planes with ruthless efficiency. On 1 July 1942, G. R. Stibitz, Wiener's NDRC section chairman, visited Wiener's laboratory and registered his

34. Wiener, letter to J. B. S. Haldane, 22 June 1942, box 2, folder 62, NWP.

35. As he made clear to a conference organizer shortly afterwards, even alluding to the connection between statistics and prediction could be disastrous. When a joint meeting was planned in 1942 between the American Mathematical Society and the Institute of Mathematical Statistics, several papers were slated to discuss statistical prediction; Wiener shot off an urgent note to one of the organizers, J. R. Kline, contending that even titles might be "a tip-off" to the enemy on subjects "vital and secret in more ways, and vastly more important ways, than I have been able to tell you" (Wiener to J. R. Kline, 20 Aug. 1942, box 2, folder 63, NWP).

36. Wiener, letter to Haldane.

astonishment in his working diary:

> Most of the day is spent with Wiener, Bigelow, and Mooney. It simply must be agreed that, taking into account the character of the input data, their statistical predictor accomplishes miracles. Whether this is a useful miracle or a useless miracle, W[arren] W[eaver] is not yet convinced. The fact that predictions can at present be made only for a maximum of 2 seconds is a very serious limitation. . . . For a 1-second lead the behavior of their instrument is positively uncanny.[37] WW threatens to bring along a hack saw on the next visit and cut through the legs of the table to see if they do not have some hidden wires somewhere. ["D"]

These numbers were more impressive than they might at first seem, since the Wiener-Bigelow scheme compressed time by a factor of four to five, making a two-second prediction the equivalent of ten seconds in the real world. Since an antiaircraft shell took about twenty seconds to reach a bomber at altitude, the predictor seemed well on its way to success.

Even in the midst of a war project that did not yet approach field capability, Wiener clearly had already begun to reflect on the broader ramifications of this species of machine. On the same day he saw the predictor demonstrated, 1 July 1942, Stibitz recorded Wiener's wider ambition for the device:

> W[iener] points out that their equipment is probably one of the closest mechanical approaches ever made to physiological behavior. Parenthetically, the Wiener predictor is based on good behavioristic ideas, since it tries to predict the future actions of an organism not by studying the structure of the organism but by studying the past behavior of the organism. ["D"][38]

37. Stibitz invokes the term *uncanny* at just the moment—1 July 1942—when Wiener's machine began predicting as if it were animated (whence Weaver's half-joking call for a saw). One is reminded here of Stanley Cavell's reflection that Freud, in his essay on the uncanny, may be protesting too much when he claims (no less than four times) that the animate/inanimate conflation does *not* lie behind the uncanny. For Cavell, the uncanny reflects precisely the philosophical anxiety exacerbated by the ambiguity created when it is unclear whether a mind or merely an inanimate object is at hand. The sentiment of uncanniness resulting from such an ambiguity is therefore tied to the philosophical problem of other minds. According to Cavell, this philosophical difficulty (surrounding the existence of other minds) is part of, not subordinate to, the psychology of uncanniness. See Stanley Cavell, "The Uncanniness of the Ordinary," *In Quest of the Ordinary: Lines of Skepticism and Belief* (Chicago, 1988), pp. 153–78. I would add this: each generation has its own conception of what constitutes a mind. Wiener's notion circulates around feedback, control, and the capacity to predict. Since characterizations of mind change, a philosophical-historical account of the uncanny would necessarily pass through many epochs.

38. *Behaviorism* as used by Wiener, Stibitz, Boring, and others encompassed a field and spirit of inquiry far wider than a behaviorism defined as a lineal descent from J. B. Watson to B. F. Skinner. For more on the scope of behaviorism, see Robert S. Woodworth, *Contemporary Schools of Psychology* (New York, 1931), pp. 43–92; Edna Heidbreder, *Seven Psychologies*

To get at the future behavior of the bomber-organism, Wiener and Bigelow made a tour that summer (1942) of the various installations charged with precisely measuring the flight of a plane. At Princeton and Tufts, they consulted on errors in tracking procedures; at Langley Field, experts offered them data on the regularities and irregularities of airplane motion; at the Aberdeen Proving Ground, at the Frankford Arsenal in Philadelphia, and at the Foxboro Instrument Company, additional information came pouring their way. But it was at the Anti-Aircraft Board at Camp Davis, North Carolina, that the two prognosticators received their most precious documents: tracking data on two test flights—the so-called flights 303 and 304—at one-second intervals.[39] These two trajectories through the sky were crucial because they gave, for the first time, realistic data that could be used as input to, and a test on the output of, the prognosticating machine.

Over the next five months, Wiener worked to reproduce these data—to little avail. By December 1942, it was all too clear that, however clever the general statistical analysis had been, it was barely able to compete with two simpler, geometrical prediction machines designed by Hendrik Bode. The first simply extrapolated the future from the derivative of the plane's trajectory, calculated at a fixed initial point. The second Bode method continuously recomputed its prediction on the basis of a trajectory derivative computed ten seconds back from the plane's current position. In December 1942 and January 1943, Wiener compiled the following chart for Weaver:[40]

Track	(1) Bode	(2) 10 Sec. Bode	(3) Statistical
303	6 hits	22 hits	23 hits
304	35 hits	55 hits	49 hits

Bode, from Bell Laboratories, had developed a geometrical fire-control predictor that had the virtue of being based on already-existing technology and the vice of not taking into account the random fluctuations and irregular trajectories of the bombers.

Quite clearly, Wiener's own method (statistical) was barely better than the ten-second Bode method for track 303 and inferior to the ten-second Bode for track 304. In light of this manifest inadequacy, Wiener

(1933; New York, 1961), pp. 234–86; and Woodworth and Mary R. Sheehan, *Contemporary Schools of Psychology*, 3rd ed. (New York, 1964), pp. 111–213.

39. See Wiener, "Statistical Method Of Prediction in Fire Control," Final Report on Section D-2, Project no. 6, submitted to Weaver, Section D-2 NDRC, 1 Dec. 1942, Record Group 227, OSRD, Contractors' Reports, Division 7, NDCrc-83, OSRD Report No. 1863, MIT, NA-LC.

40. See Wiener, letter to Weaver, 15 Jan. 1943, Record Group 227, OSRD, Contractors' Reports, Division 7, NDCrc-83, enclosure with OSRD Report No. 1863, MIT, NA-LOC. See also Wiener, "Final Report," 1 Dec. 1942, NA-LC.

judged the only hope for the method to lie in a vastly increased statistical base involving the calculation of tens, if not hundreds, of tracks. Since this would tie up the computing facilities of the country, and because the likelihood of improvement struck him as "too distant to be significant in the present war," Wiener hesitated to recommend further research until after the end of the war.[41] What went wrong? Wiener speculated:

> To what extent the negative result of this investigation is due to bad tracking, to what extent to the restriction of the useable past [flight path] to 10 seconds, and to what extent to the fact that the enemy plane has a very considerable chance to change its flight pattern, whether voluntary or involuntary, in the twenty seconds of projectile flight, is not yet fully clear.[42]

It may have been "not yet fully clear," but Wiener was "convinced" that it was the enemy's capacity to maneuver rather than anything else that would save him from inevitable destruction at the mechanical hands of the predictor. Failure came hard, for Wiener was frustrated by the predictor's weakness: "I still wish that I had been able to produce something to kill a few of the enemy instead merely of showing how not to try to kill them."[43]

3. *From AA Predictor to Human Nature*

What Wiener was willing to do, even in the worst days of war, was to turn to psychological and philosophical implications of the predictor. In their 1943 article "Behavior, Purpose and Teleology," Wiener and Bigelow collaborated with the cardiologist Arturo Rosenblueth, then visiting Harvard Medical School, to present a new, behaviorist description of the very concept of purpose. Aside from the pure satisfaction of classification, the authors were pleased to single out the class of predictive behavior because "it suggests the possibility of systematizing increasingly more complex tests of the behavior of organisms."[44] Of particular importance, they contended that their classification rehabilitated "purpose" and "teleology" by bringing them under the aegis of a "uniform behavioristic analysis" that was equally applicable to living organisms and machines.

Where Darwin had assiduously tracked the similarities between human and animal in order to blur the boundary between them, Wiener's

41. Wiener, letter to Weaver, 15 Jan. 1943.

42. Wiener, "Statistical Method of Prediction in Fire Control," p. 7.

43. Wiener, letter to Weaver, 28 Jan. 1943, box 2, folder 64, NWP.

44. Arturo Rosenblueth, Julian Bigelow, and Wiener, "Behavior, Purpose and Teleology," *Philosophy of Science* 10 (Jan. 1943): 22; rpt. *Norbert Wiener*, 4:184.

efforts were devoted to effacing the distinction between human and machine. Darwin's dog suffered remorse; Wiener's AA predictor had foresight. Indeed, over the course of the war, Wiener reported in 1945, men had grown ever more accustomed to attributing animation to servomechanical systems:

> The semi-humorous superstition of the gremlin among the aviators was probably due, as much as anything else, to the habit of dealing with a machine with a large number of built-in feedbacks which might be interpreted as friendly or hostile. For example the wings of an airplane are deliberately built in such a manner as to stabilize the plane, and this stabilization, which is of the nature of a feedback . . . may easily be felt as a personality to be antagonized when the plane is forced into unusual maneuvers.[45]

Our consciousness of will in another person, Wiener argued, is just that sense of encountering a self-maintaining mechanism aiding or opposing our actions. By providing such a self-stabilizing resistance, the airplane acts as if it had purpose, in short, as if it were inhabited by a gremlin.

Within the rubric of "purposeful behavior," then, Wiener and his collaborators Bigelow and Rosenblueth allowed for those acts that do not involve feedback while the process is underway (such as a frog that shoots its tongue out towards a fly) and those (such as a self-guided missile or torpedo) that gather information and use that information to correct themselves en route. But beyond any particular features of humans or machines lay Wiener's deep-seated commitment to a behaviorist vision of both. His was not a claim that no criteria differentiated humans and machines. Quite obviously there was no machine that could (as yet) write a Sanskrit-Mandarin dictionary; and, similarly, no living organism rolled on wheels. But it was the behaviorist impulse to focus on broad classes of actions, and to do so on the basis of the input and output he knew so well from communication technology, that led Wiener to his blurring of the man-machine boundary. *Black boxes,* as Wiener used the term, meant a unit designed to perform a function before one knew how it functioned; *white boxes* designated that one also specified the inner mechanism. In this

45. Wiener, "Operationalism—Old and New" (1945), box 11, folder 570, NWP, pp. 14–15. In particular, the wings of an airplane rise from the fuselage upward towards the wingtips (this rise is known as the dihedral). When the plane banks (while maintaining direction), the plane side-slips towards the lower wing. Since the lower wing is now positioned more nearly parallel to the ground, the lower wing encounters the relative wind strongly while the upper wing, now tilted more nearly perpendicular to the ground, encounters the relative wind more weakly. This raises the lower wing, righting the airplane. See, for example, the popular 1944 flight instruction book by Wolfgang Langewiesche, *Stick and Rudder: An Explanation of the Art of Flying* (1944; New York, 1972), especially the subsection "What the Airplane Wants to Do," pp. 125–27, which addresses the dihedral.

language, the more sophisticated feedback mechanism of the AA predictor opened a new universe of black boxes to the engineer—and to the philosopher.[46]

Behaviorists took note. The eminent Harvard psychologist and historian of psychology Edwin Boring found Wiener's suggestion that all functions of the brain might be duplicated by electrical systems "very attractive." Having had a chance to contemplate this circuit-reductionist program, Boring reckoned in a 13 November 1944 letter to Wiener that he could provide "a pretty complete list of psychological functions" in his spare time, all psychological facts being in principle expressible in terms of stimulus and response. "A symbolic process" would be "a delayed, adequately differential reaction"; "introspection" would be a reaction to a reaction, and Wiener's task, should he decide to accept Boring's challenge, would be to transfer these stimulus-response pairs and respond with his own matching catalogue that would give the "same specificity of 'output' to 'input.'" With fourteen psychological properties on the list already and others like "Generalization" and "Abstraction" to be added, Boring assured Wiener that a paper with these electrical designs would greatly benefit "us operationally-minded psychologists." "Is it a go?" Boring queried. "I do not know that you can [do it], but I should be betting on you."[47] Black-box engineering now had something more complex than electrical amplification as its functional goal: to re-create the mind itself.

Within a few weeks, Wiener's ambition left behind even the human mind. Collaborating with Howard Aiken, one of the pioneers in computer technology, and with von Neumann, the supremely versatile mathematician then at work on the computer, Wiener sent out a restricted letter on 4 December 1944 to a collection of seemingly unrelated experts:

> A group of people interested in communication engineering, the engineering of computing machines, the engineering of control devices, the mathematics of time series in statistics, and the communication and control aspects of the nervous system, has come to a tentative conclusion that the relations between these fields of re-

46. See Rosenblueth, Wiener, and Bigelow, "Behavior, Purpose, and Teleology," pp. 23–24. The term *black box,* commonly used at the MIT Radiation Laboratory during the war, became popular through the use of common black-speckled boxes to encase radar electrical equipment such as amplifiers, receivers, filters, and so on. Wiener himself referred during the war to "boxes" with unspecified interiors, as in his 1942 letter to Haldane, cited above. After the war, Wiener elaborated on the notion of a black box, contrasting it with a "white box" in the sense invoked here. See, for example, *C,* pp. xi and 180 and Wiener, "Über Informationstheorie," *Die Naturwissenschaften* 48 (Apr. 1961): 174–76. On the black box as part of "radar philosophy" at the Rad Lab, see Galison, *Image and Logic: The Material Culture of Modern Physics* (forthcoming).

47. Edwin G. Boring, letter to Wiener, 13 Nov. 1944, box 2, folder 66, NWP.

> search have developed to a degree of intimacy that makes a get-together meeting . . . highly desirable.[48]

Because many of the relevant developments were directly tied to the war effort, Wiener asserted, the assembly would necessarily be nonpublic. It was a new vision of the world that was to emerge from this secret confluence of war sciences, one that would embrace matters of "engineering, physical, and even economic and social interest."[49] Wiener, Aiken, and von Neumann named the group the "Teleological Society."[50]

The first meeting of the Teleological Society took place on 6–7 January 1945, and Wiener was delighted with its outcome. Rafael Lorente de Nó and Warren McCulloch, both physiologists specializing in the functional organization of the central nervous system, presented their work on the organization of the brain. "In the end," Wiener gushed to Rosenblueth, "we were all convinced that the subject embracing both the engineering and neurology aspects is essentially one."[51] It was time, Wiener contended, to turn separate avocations into an integrated, permanent research program, one that would be backed by many sources. These included the Rockefeller Foundation, with Weaver's support, along with "mysterious words from von Neumann concerning . . . some thirty megabucks" from which powerful resources could be "siphoned."[52]

For his part, von Neumann used the meeting to set up a division of labor: Wiener and Walter Pitts (a logic student of Rudolf Carnap who had used logic to analyze the switching properties of neurons) would cover filtering and prediction problems such as the prototypical AA predictor; the mathematical statistician W. Edwards Deming (who would become a principal advisor to Japan during its postwar economic miracle), von Neumann, and several others would cover the application of fast, mechanized computing methods to statistical problems; the application to differential equations (astronomy, hydrodynamics, ballistics, and so on) would come from Aiken, H. H. Goldstine, and von Neumann; and the

48. Howard Aiken, von Neumann, and Wiener, letter to E. H. Vestine, 4 Dec. 1944, box 2, folder 66, NWP.

49. Ibid. See also Wiener, letter to von Neumann, 17 Oct. 1944, box 2, folder 66, NWP.

50. Wiener, Aiken, and von Neumann identified the common center of their interests to revolve around intention: "Teleology is the study of purpose of conduct, and it seems that a large part of our interests are devoted on the one hand to the study of how purpose is realized in human and animal conduct and on the other hand how purpose can be imitated by mechanical and electrical means." Their intention was to found a society, a journal, a patent and support mechanism, a means of popularization, and, finally, a protective net to guard against "dangerous and sensational publicity" (Aiken, von Neumann, and Wiener, letter to H. H. Goldstine, 28 Dec. 1944, box 2, folder 66, NWP).

51. Wiener, letter to Rosenblueth, 24 Jan. 1945, box 2, folder 67, NWP.

52. Ibid.

neurological features would go to de Nó, McCulloch, and Pitts.[53] This was fine with Wiener, though he found von Neumann's sketch to lack the crucial transition from the computing machine to the control machine. "The issues that come up here are those of transfer from continued data to counted data; of the final transition from counted data to the motion of a shaft effector; and the sensing of the motion of the effector by feedback or other quasi-proprioceptor apparatus." Such a *feedback system,* which Wiener had stressed from his earliest work on servomechanisms, continued to occupy a central place in his thinking. For it was this same proprioceptive process that occurred in mechanical controls, organic controls, and in hybrid mechanico-organic systems. Von Neumann ceded the point.[54]

Despite the fantastic array of supporters that Wiener's approach elicited, there was resistance. In 1950 Richard Taylor, a young philosopher from Brown University, asked with incredulity if Wiener and his collaborators could seriously be proposing a definition of purposefulness that was built purely on the culmination of a sequence of events. Rosenblueth, Wiener, and Bigelow's definition was this:

> The term purposeful is meant to denote that the act or behavior may be interpreted as directed to the attainment of a goal—i.e., to a final condition in which the behaving object reaches a definite correlation in time or in space with respect to another object or event. Purposeless behavior then is that which is not interpreted as directed to a goal.[55]

To Taylor this definition was both so all-encompassing as to rule out nothing and so devoid of content that it had no overlap with any common meaning of the term. Let a clock run for many years only to break down at midnight on New Year's Eve. What rules this out as an instance of purposefulness? A brick tumbles off a building, killing a passer-by. Is this, too, to be considered as purposeful? For Taylor, the utter arbitrariness imposed by the clause "'may be interpreted'" makes it all too easy to allow these tumbling bricks and failing clocks to be counted as purposeful, voiding the term of any similarity with our usual understanding.[56]

Of course Taylor recognized that Wiener and Bigelow wanted to lay special stress on self-regulating machines. This did not move him. Could

53. See Von Neumann, memo to Aiken, Leland E. Cunningham, W. E. Deming, Goldstine, R. Lorente de Nó, W. S. McCulloch, Walter H. Pitts, Vestine, Wiener, and Wilks, 12 Jan. 1945, box 2, folder 67, NWP.

54. Wiener, letter to von Neumann, 24 Jan. 1945, box 2, folder 67, NWP; see von Neumann, letter to Wiener, 1 Feb. 1945, box 2, folder 67, NWP.

55. Rosenblueth, Wiener, and Bigelow, "Behavior, Purpose, and Teleology," p. 18.

56. Richard Taylor, "Comments on a Mechanistic Conception of Purposefulness," *Philosophy of Science* 17 (Oct. 1950): 311.

the authors really be claiming that a roulette wheel—by construction a purposeless device—could be rendered into a purposeful machine by the addition of a lead weight on its perimeter? Even the guided missile, that paragon of purpose, is hardly to be philosophically distinguished from non–self-regulating devices. Consider a missile following mechanically along a taut wire attached to a target. Such a mechanism might be less etherial than radar guidance but would hardly be distinct insofar as it could be considered self-regulating. "The expression 'target-seeking missile' is," Taylor concluded, "metaphorical." Wiener and Bigelow might choose to redefine the very concept of purpose, but their discovery would amount to no more than the redefinition of the plus sign with that of multiplication: "entirely correct, but scarcely significant."[57]

In a joint postwar response to Taylor, Wiener had no apologies for classifying a crooked roulette wheel as purposeful. But he and Rosenblueth (who collaborated on the riposte) reemphasized that the weighted wheel and the magnetic compass differ from the servomechanisms of guided missiles and AA predictors because the former are passive whereas the latter are active. In the laboratory, Wiener and Rosenblueth insisted, the physics and engineering practices behind self-regulating systems are utterly different from that of bricks and clocks; the former are governed by time-reversible causal stories whereas the latter are unidirectional in time. (The AA predictor, for example, makes its statistical forecast on the basis of the *history* of the pilot's past performance.)[58]

Offering a cornucopia of war-related electromechanical feedback systems—guided missiles, target-sensing torpedoes, and radar trackers among them—Wiener and Rosenblueth saw pragmatically defined novelty where Taylor saw none.[59] But beyond the issue of novelty, Taylor had emphasized what was fundamentally an objection to the behaviorist input-output analysis that underlay the Wiener program. And here the two sides found no meeting of minds. Explaining that they did not care whether, in the abstract, machines "are or can be like men," Rosenblueth and Wiener insisted that the question was "irrelevant" for scientific objectives:

> We believe that men and other animals are like machines from the scientific standpoint because we believe that the only fruitful methods for the study of human and animal behavior are the methods applicable to the behavior of mechanical objects as well. Thus, our

57. Ibid., pp. 316, 317.

58. See Rosenblueth and Wiener, "Purposeful and Non-purposeful Behavior," *Philosophy of Science* 17 (Oct. 1950): 328; rpt. *Norbert Wiener,* 4:188.

59. See Taylor, "Purposeful and Non-purposeful Behavior: A Rejoinder," *Philosophy of Science* 17 (Oct. 1950): 328. Taylor did concede to Wiener and Rosenblueth that his Newtonian scientific conception of causes and categories needed updating in light of recent developments in physics; see p. 332.

> main reason for selecting the terms in question was to emphasize that, *as objects of scientific enquiry, humans do not differ from machines* [emphasis added].[60]

We should read this last remark critically and historically. In 1941 and 1942, it had made sense to Wiener and his collaborators to view humans, qua pilots and gunners, as undifferentiated from the bombers and antiaircraft units in which they fought. Seen as man-machine *enemies*, from a military perspective "humans do not differ from machines." It was then a short step from viewing the enemy as a cybernetic entity to seeing the quasi-automated Allied aircraft gunner the same way. What had begun in the Manichean field of science-assisted warfare had now been decontextualized. By 1950, Wiener had globalized his claim: under the gaze of scientific inquiry, human intentionality did not differ from the self-regulation of machines, full stop.

Taylor rejoined: How could Wiener and Rosenblueth base a notion of purposefulness on *observable* behavior alone (Taylor's emphasis), ignoring the blatant distinction between the various intentions behind the observation that a car is following a man? Is the driver trying to run the man down? Making a joke? Trying to frighten him? Or simply veering to rid his car of a pesky bee? Taylor concedes that observation may well be our best or even only evidence, but surely we want to distinguish between the definition of purpose and the evidence we may or may not have to ascertain what that purpose is. Further complicating the purely behaviorist notion are cases in which the goal, as a distinct physical entity, does not even exist: knights seek the Holy Grail, alchemists pursue the philosopher's stone, and people stumble around in the dark looking for matches that are not there. Intention, like desire, is something that is just as real as more tangible acts. Taylor protested: We should not abandon concepts simply because they are not operationally useful to science.[61]

While Wiener let the debate end at this point, the fundamental conflict remained unresolved. With the mathematics of cybernetic feedback systems, the formalism of game theory, and the flow charts of operations analysis, the Manichean sciences had, in a sense, reached the apotheosis of behaviorism, as Boring had hoped. In fact, in February 1945, despite a recent and dramatic collapse due to an ulcer, Boring tried to deliver on the side of the bargain he had proposed to Wiener three months earlier. Riveted by the progress of Wiener's interdisciplinary research, Boring attested: "What I had done before [his collapse] is to make out a list of

60. Rosenblueth and Wiener, "Purposeful and Non-purposeful Behavior," p. 326, p. 195. The problem of integrating intentionality into the broad project of behaviorism had vexed psychologists for decades, and proffered solutions to the difficulty were numerous. One of the most famous of the attempts was by Edward C. Tolman, *Purposive Behavior in Animals and Men* (New York, 1932), but his approach was by no means universally accepted.

61. See Taylor, "Purposeful and Non-purposeful Behavior: A Rejoinder."

what I thought all the functions of the brain are, putting them in positivistic reaction terms of the organism, terms which could be translated into in-put, out-put and adjustment of a mysterious box with binding posts and knobs on it." His conclusion: "That's about what a person is, really."[62] W. Ross Ashby writing from England had similar panegyrics for Wiener's black-box program:

> When I consider how the psychologists have been trying to solve exactly this problem for decades (if not for centuries), the black box being the brain, and when I think how little attention they have given to the principles involved, my opinion of psychologists falls to a new low. The trouble with the psychologist is that he is too proud to learn to walk before he tries to run. So today he lies on his back, foolishly waving his legs, and pretending to be a ballet-dancer, when in reality he hasn't yet learned how to crawl.For this reason I regard it as highly complimentary when I say that your study of the "black box" problem is a first step towards a scientific psychology![63]

Wiener, unlike Boring, thought he could actually make the hardware that would put the specific black-speckled boxes on the table. Such a radical position necessarily left unsatisfied those like Taylor who could not abide the elimination of inner states of human intention, desire, pleasure, and pain in favor of purely observable manifestations. But with the power of wartime materiel and the glittering promise of future industrial riches, it was clearly not Taylor's view that prevailed.

4. *The Philosophy of Nature and the Delivery of Cannon Fire*

If humans do not differ from machines from the "scientific standpoint," it is because the scientific standpoint of the 1940s was one of men-machines at war. The man-airplane-radar-predictor-artillery system is a closed one in which it appeared possible to replace men by machines and machines by men. To an antiaircraft operator, the enemy really does act like an autocorrelated servomechanism. What is astonishing is the globalization of this technological *aperçu* into a new age for humanity and a general philosophy of human action. In 1947, as Wiener reflected on the events of the war, he divided the thoughts of the ages into three epochs. A first era was characterized by the clockmakers, surveyors, and planetary astronomers. Their science was one of prediction by laws and their economy that of the merchant. Boats sailed across seas based on the clocks and astronomical calculation of longitude; this was, as Wiener put it, the

62. Boring, letter to Wiener, 8 Feb. 1945, box 2, folder 67, NWP.

63. W. Ross Ashby, letter to Wiener, 6 Feb. 1951, box 3, folder 134, NWP. Ashby went on to write a well-known text, *An Introduction to Cybernetics* (London, 1956).

"engineering of the mercantilist" (*C*, p. 38). As the seventeenth and eighteenth centuries drew to a close, Wiener asserted, a new day dawned in which clocks gave way to the steam engine as the symbol and real center of technological work. Huygens and Newton ceded their place to Rumford, Carnot, and Joule, and it was the manufacturer not the trader who embodied the new culture. Finally, for Wiener, the present age, ushered in by the vast array of electromechanical devices of the war, was the age of information and control. If these developments reached back to Kelvin and Gauss, they found their real form (and interpreters) only in the laboratories and factories of radar and its associated systems. This age, our age, was that of the servomechanism.

As Wiener argued, each age engendered its own simulacrum of humanity—clockmakers of the eighteenth century made their pirouetting mechanical figures, steam engineers of the nineteenth glorified their engines as versions of the body. Our age? We make computers to calculate differential equations, open doors with photocells, and, not surprisingly, "the present automaton . . . points guns to the place at which a radar beam picks up an airplane" (*C*, p. 40). In a sweeping totalization Wiener had, within two years of the end of the war, elevated his AA predictor to the symbol for a new age of man. Whether or not we accept Wiener's techno-periodization of the history of humanity, there seems little doubt that he and many of his contemporaries saw themselves as standing at a historical and philosophical watershed in which the Manichean sciences would undergird the cybernetic age.

To a certain extent, Wiener's hopes and fears for cybernetic technologies were in place before Hiroshima and Nagasaki, but they were multiplied one hundredfold by the August 1945 nuclear bombing of Japan. In the weeks following the atomic blasts, Wiener was too distracted even to respond to a letter from his friend and collaborator, the philosopher Giorgio de Santillana. Finally, in October 1945, Wiener put pen to paper:

> Ever since the atomic bomb fell I have been recovering from an acute attack of conscience as one of the scientists who has been doing war work and who has seen his war work a[s] part of a larger body which is being used in a way of which I do not approve and over which I have absolutely no control. I think the omens for a third world war are black and I have no intention of letting my services be used in such a conflict. I have seriously considered the possibility of giving up my scientific productive effort because I know no way to publish without letting my inventions go to the wrong hands.[64]

In short, almost telegraphic prose, Wiener reported to de Santillana on the full range of his cybernetic work, ranging from wave filters and pre-

64. Wiener, letter to Giorgio de Santillana, 16 Oct. 1945, box 2, folder 69, NWP.

dictors, computing machines, automatic control of assembly lines, and control of chemical plants to random nets of switching devices, quantum theory, and cardiac fibrillations. But, agonizing over the possible uses of his research, he halted his letter with these "sketchy" descriptions in part because of a claimed modesty and in part because "in these troubled times I do not feel any too certain that I shall continue in science indefinitely. I do not know how to publish work without making it available for the strongest hands and I do not like the strongest hands of the present time. I feel it most intensely personally and in particular what I have seen in looking upon a world completely inadequate to receive the atomic bomb."[65] Two days later, he drafted a letter to the president of MIT, Karl T. Compton, in which he rehearsed his fears about the scientist's loss of "control" over the civil and military uses of science, concluding that he "intend[ed] to leave scientific work completely and finally. I shall try to find some way of living on my farm in the country. I am not too sanguine of success, but I see no other course which accords with my conscience."[66] In the years that followed, Wiener repeatedly stressed the power of cybernetics to save, enslave, or destroy humanity. Already built into the AA predictor and its progeny was a set of cultural meanings not easily shed.

Nineteen forty-seven closed with Wiener still at MIT, despite his moral discomfort with the technical possibilities of cybernetics. In handing over the technology to what he called "the world of Belsen and Hiroshima," he could only hope to "confine our personal efforts [in cybernetics] to those fields, such as physiology and psychology, most remote from war and exploitation" (*C*, p. 28). Paradoxically, during the war Wiener had extended the cybernetic vision beyond its narrow applications because of the weakness of the AA predictor; now that he associated cybernetics with the power of cataclysmic weapons, he tried to push cybernetics away from the military arena because of its deadly efficacy. Either way, for Wiener and many colleagues, the association of cybernetics with its wartime origin was forcefully and deeply inscribed in the cultural meaning of the new science and its machines.

The Josiah Macy, Jr. Foundation opened the cybernetic age for the social sciences. On 8 and 9 March 1946, the foundation gathered psychologists and anthropologists to meet with mathematicians and physicists on the general subject of circular causal systems. Gregory Bateson, already persuaded of the importance of the new ideas, led the contingent of nonphysical scientists and helped organize the second such meeting, "Teleological Mechanisms in Society," on 20 September 1946, and a third, "Feedback Mechanisms and Circular Causal Systems in Biology and the Social Sciences." Those invited included Paul Lazarsfeld, Margaret Mead, and F. S. C. Northrop, among many others. Backed strongly by Bateson

65. Ibid.

66. Wiener, letter to Karl T. Compton, 18 Oct. 1945, box 2, folder 69, NWP.

and enthusiastically led by Wiener, von Neumann, McCulloch, and de Nó, the group's intense discussions brought systems, information theory, and feedback mechanisms onto the center stage of sociology, psychology, and anthropology.[67] Northrop later acknowledged the impact of servomechanical theory as "of revolutionary significance for natural science, moral as well as natural philosophy, and for one's theory of the normative factor in law, politics, religion, and the social sciences."[68] To Bateson, the new vocabulary of communication theory and cybernetics presented a turning point in his work; his biographer David Lipset called it a "theoretical conversion" in which his older terms, such as *schismogenesis,* were reworked into the language of the purposeful machine: "regenerative feedback."[69]

While reaching out to the social sciences, Wiener also wanted to raise the Manichean sciences to a more abstract philosophy. At least since the early 1930s, Wiener had held a deep interest in Leibnizian philosophy. He extolled Leibniz's philosophically open mind (as opposed to the Newtonians' dogmatism), he celebrated Leibniz's commitment to relativity, to the quantum mechanical-like identity of indiscernibles, even to the idea of monadic self-containment (by analogy to certain higher-dimensional theories of the electron).[70] But in the years after the war, Wiener saw more in Leibniz. He extracted an overarching philosophical umbrella that covered and combined cybernetics *and* operations research.

Both cybernetics and operations research, he told the Operations Research Society in 1953, were grounded in a modern parallel to Leibnizian monads. Leibniz's own conception of monads are, Wiener assures us, far too anthropomorphic. It was a world picture in which "monads [were] quasi-souls whose activity was confined to the mirroring of the universe of the monads themselves." Cybernetics provided "a similar world-picture": nodes of communication interact by the exchange of orders or commands. According to the cyberneticist, the world is nothing

67. On the Macy meetings, see Gregory Bateson, memo to [invitees], 19 June 1946, box 2, folder 71, NWP; McCulloch, memo to the members of the "Macy Conference on Feedback Mechanisms, 17–19 Oct. 1946," n. d., box 2, folder 71, NWP; "Conference on Feedback Mechanisms and Circular Causal Systems in Biology and the Social Sciences," n. d., box 2, folder 71, NWP. Heims has a good discussion of the tenor of these meetings in *John von Neumann and Norbert Wiener,* pp. 201–7 and a wide-ranging study of the impact of cybernetics on the social sciences in *Constructing a Social Science for Postwar America: The Cybernetics Group, 1946–1953* (Cambridge, Mass., 1993).

68. F. S. C. Northrop, "Ideological Man in His Relation to Scientifically Known Natural Man," in *Ideological Differences and World Order: Studies in the Philosophy and Science of the World's Cultures,* ed. Northrop (New Haven, Conn., 1949), p. 414.

69. David Lipset, *Gregory Bateson: The Legacy of a Scientist* (Englewood Cliffs, N. J., 1980), p. 182. See also Heims, "Gregory Bateson and the Mathematicians: From Interdisciplinary Interaction to Societal Functions," *Journal of the History of the Behavioral Sciences* 13 (Apr. 1977): 141–59.

70. See Wiener, "Back to Leibniz! Physics Reoccupies an Abandoned Position," *Technology Review* 34 (Feb. 1932): 201–3, 222, 224.

more than the mutual internal relations of these incoming and outgoing messages—ultimately cybernetics carries, on Wiener's own account, a "quasi-solipsistic" vision of the universe. Taken in its epistemological function, cybernetics can be either observational (purely incoming messages) or experimental (incoming and outgoing messages). At the same time, Wiener wanted to make plain that while epistemology may well capture the knowledge-gathering function of the science, cybernetics will not rest there: "messages may be sent for the purpose of exploring the universe, but they may also be sent with the intention of *controlling* the universe." Precisely because Wiener wanted to accentuate the dual aspect of information, he distinguished between messages that could be sent "in the indicative and the imperative mood."[71]

As the windowless monads suggest, and as Wiener's own proclamation of quasi-solipsism made explicit, the cybernetic philosophy was premised on the opacity of the Other. We are truly, in this view of the world, like black boxes with inputs and outputs and no access to our or anyone else's inner life. This same opacity prevails in von Neumann's game theory, where the opponent acts according to certain universal maximization principles but where the thought process that eventuates in any given move is hidden from us. Although in his later life Wiener came to reject von Neumann's game theory as containing an inadequate psychological basis,[72] in the years directly after the war, he sympathized with the project, even identifying it as being of the same "spirit" as cybernetics.[73]

The impact of the Manichean sciences not only on computation and automata theory but also on the social sciences should not be underestimated. For Mead, Northrop, and Bateson, the impact of Wiener's models of feedback and homeostasis became essential components of their analyses. Even *Time* saluted Wiener in 1950 as one of the leaders of the new "computermen" who were blurring the boundaries between the wet sciences of the brain, psychological properties, and the machine (caricatured in fig. 5). Given such adulation, it is perhaps not too surprising to find many social scientists identifying themselves with the new sciences emerging from the war. The social scientists' fascination with systems in the 1940s and 1950s may have roots in older turn-of-the-century networks of telephony and power. Recent fascination with information-based feedback systems, however, tracks its roots more proximately—to the radar and tracking systems of World War II.

71. Wiener, "Delivered to the Operations Research Society," 23 Nov. 1953, box 12, folder 738, NWP, pp. 2, 3.

72. See Heims, *John von Neumann and Norbert Wiener,* pp. 305–10.

73. "[Morgenstern's] very important joint book on games with Dr. von Neumann . . . represents a most interesting study of social organization from the point of view of methods closely related to, although distinct from, the subject matter of cybernetics" (*C,* pp. 18–19).

FIG. 5.—The cybernetic entity. *Time* featured this wonderfully literal representation of the ultimate cyborg. Note its three best features: military threads, feedback as it watches its output, and biomechanical form. Cover, *Time,* 23 Jan. 1950.

There is a more contemporary phase in this continuing history of the Manichean sciences. More startling than the continuity between wartime and postwar systems theory is the role Wiener's cybernetics played and continues to play in *post*modernist discourse. Beginning with Jean-François Lyotard, whose *The Postmodern Condition* (1979) is often counted among the founding documents of postmodernism, we can trace a continued role for cybernetic theories.[74] Lyotard himself rather nervously contended that his social analysis, produced for the government of Quebec, departed radically from cybernetics. On the contrary, I want to argue that the link between the two is profound and the continuity nearly complete.

First, Lyotard asserted that, contra cybernetics, "messages have quite different forms and effects depending on whether they are, for example, denotatives, prescriptives, evaluatives, performatives, etc." Here at least two of Lyotard's categories (denotative and prescriptive) directly parallel Wiener's distinction between the indicative and imperative moods of messages. Secondly, Lyotard contended that "a cybernetic machine does indeed run on information, but the goals programmed into it [leave no way] to correct in the course of its functioning . . . its own performance." Nothing could be further from the mark. This self-correction is *exactly* what Wiener's machines did. Indeed, in every piece of his writing on cybernetics, from the first technical exposition of the AA predictor before Pearl Harbor up through his essays of the 1960s on science and society, Wiener put feedback in the foreground, returning again and again to the torpedo, the guided missile, and his antiaircraft director. Moreover, even in the predictor *both* the performance *and* the rules governing performance were corrected "in the course of its functioning." Third, Lyotard found the "trivial cybernetic version of information" to miss the decisively important "agonistic aspect of society." On his postmodern vision of social relations, Lyotard saw each "player" as undergoing a "'displacement'" as he sent and received messages. "'Moves'" and "'countermoves'" characterize Lyotard's world, as he insisted that what we need for postmodern understanding is an "agonistic" theory of communication and a theory of games.[75]

But it was on the agonistic field that Wiener, von Neumann, and the operational analysts were most at home. Formally, militarily, and philosophically, theirs was a universe of confrontation between opponents: Allies to Axis, monad to monad, message to message, and mechanized "man" to servomechanical enemy. The opposition between Lyotardian

74. On the first page of *The Postmodern Condition,* Lyotard refers explicitly to Wiener's *Cybernetics* and *The Human Use of Human Beings;* Ashby's *Cybernetics;* and von Neumann's work in general. See Jean-François Lyotard, *The Postmodern Condition: A Report on Knowledge,* ed. Geoff Bennington and Brian Massumi (Minneapolis, 1984), p. 3.

75. Ibid., p. 16.

postmodernism and the "trivial" cybernetic vision (presumably of Wiener) is unsustainable.[76]

From this continuity between cybernetic and Lyotardian postmodernist social relations, two things might follow. We could conclude that Wiener and his allies were postmodernists *avant la lettre.* Or, as I incline to believe, it might be the other way around: we track Lyotard's postmodernist and game-theoretical worldview back deep into the heart of the Manichean sciences. As we study the development of postwar science, then, it seems to me of utmost importance not to seize uncritically the central metaphors of operational analysis, game theory, and cybernetics and make them our own while claiming all the while a new "postmodern" periodization.

Donna Haraway invoked cybernetics in a more subtle, yet still conflicted *post*modern way. In "The Biological Enterprise: Sex, Mind, and Profit from Human Engineering to Sociobiology" (1979), she used the term *cybernetics* to characterize post–World War II biological sciences in terms, and with a periodization, that Wiener would have recognized. Before the war (according to Haraway) biological discourse had been organized around the organism viewed through the categories of medicine and the clinic. These included intelligence testing, human relations, physiology, and racial hygiene. After the war, the new sciences of information- and control-dominated systems reshaped biology, including sociobiology. This new, more cybernetic biology emphasized communication and feedback. For Haraway, E. O. Wilson's work typified the latter set of developments with his stress on information transfer among insects, including efficiency, noise, and capacity.[77] In her view, cybernetics, although often used to sanction the status quo, is ultimately far more open to a new and more liberating vision of the biological sciences than the psychobiological and organic functionalist theories that preceded it. The cybernetic biological view (sociobiology) is, in Haraway's view, *less* open to racism or sexism because in cybernetics the organic body is depicted as an engineering entity, always modifiable, and never defined essentially.[78]

Haraway opened "A Cyborg Manifesto" (1985) with a partial, ambivalent continuation of these Wienerian themes: "A cyborg is a cybernetic organism, a hybrid of machine and organism, a creature of social reality as well as a creature of fiction."[79] I say the continuation is partial and

76. Ibid., p. 16.

77. See Donna J. Haraway, "The Biological Enterprise: Sex, Mind, and Profit from Human Engineering to Sociobiology," *Simians, Cyborgs, and Women: The Reinvention of Nature* (New York, 1991), pp. 44–45.

78. See ibid., p. 67.

79. Haraway, "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century," *Simians, Cyborgs, and Women,* p. 149.

ambivalent because the cultural meaning she struggled to ascribe to the communication and information technologies is utterly different from the cultural meanings that emerged from cybernetics.[80] Haraway alluded to the "cyborg orgy" that she saw "coded by C^3I, command-control-communication-intelligence, an $84 billion item in 1984's US defence budget." Just this cyborg root in military feedback systems is, she allowed, the "main trouble" with cyborgs: "But illegitimate offspring are often exceedingly unfaithful to their origins. Their fathers, after all, are inessential."[81] Can the cybernetic vision be so easily detached from its military historical origins and present location? After all, the very notion of a cyborg issued from an Air Force contractor's extension of Wiener's ideas.[82] I would argue that the associations of cybernetics (and the cyborg) with weapons, oppositional tactics, and the black-box conception of human nature do not so simply melt away.

For the classic cyberneticists (exemplified by Wiener, Rosenblueth, McCulloch, and their colleagues), the blurred boundary between human and machine opened an infinity of possibilities; Haraway, like Wiener, stressed the possibility that machines could be open-ended, nondedicated in their function, and able to reproduce, learn, and interconnect with the human. But Wiener, unlike Haraway, saw power and control as absolutely central to the very definition of cybernetics, for better or worse. Indeed, by the end of his life, as if to push this theme to its theological *Endstation*, Wiener had come to see the human-machine relation as a model, if not an incarnation of the bond between God and "man." The paradoxes of religion ("Can God create a rock too great for him to move?") reemerged as questions about the cyberneticist and his offspring ("Can a human create an entity that can beat him at chess?"). On the last lines of the last page of his last book, Wiener put it this way: "Since I have insisted upon discussing creative activity under one heading, and in not parceling it out into separate pieces belonging to God, to man, and to the machine, I do not consider that I have taken more than an author's normal liberty in

80. On "cultural meaning," see Peter Galison, "The Cultural Meaning of *Aufbau*," in *Scientific Philosophy: Origins and Developments*, ed. Friedrich Stadler (Dordrecht, 1993), pp. 75–93.

81. Haraway, "A Cyborg Manifesto," pp. 150–51.

82. The term *cyborg* itself was, as Matthew Price has shown, first used by Air Force contractors, in 1960, in the context of speculative research on biochemical means for extending the capability of astronauts. One line of inquiry was the search for drugs that would alter osmotic pressures within the body to allow unprotected "walks" in space. See Matthew Price, "'Man Must First Conceive'—A Critical Philology of the Cyborg," unpublished manuscript. This links rather closely on the one hand with Wiener (whom the Air Force contractors cite) and on the other with the bionic implants required by the space pilot in the science fiction representations of cyborgs cited by Haraway in "A Cyborg Manifesto," p. 179.

calling this book

GOD AND GOLEM, Inc."[83]

We who make cyborgs are, in the end, like gods.

Haraway, by contrast, took the variability, the unfixed nature, of the cyborg as grounds for the *partiality,* not the *omnipotence,* of what is human. As she put it, we are ourselves already in so many respects cyborgs—through our reproductive technologies, our psychopharmacologies, our prostheses (mechanical and computational)—that we can no longer put any stock in essentialist definitions of the classic dichotomies of mind and body, animal and human, organism and machine, public and private, nature and culture, men and women, primitive and civilized.[84] I understand her project to resonate with the more critical branch of postmodern theory: a refusal to espouse a nostalgia for a "natural" or "feminine" world that preexisted technology and a concomitant move to use (rather than simply shun) the built world of technology and science. Postmodernism holds cybernetics in an uneasy embrace. As a postmodernist challenge to a fixed human, racial, or gendered nature, the cyborg presents an alternative, a way out. But (as Wiener and Lyotard attest in different ways) the successes of cybernetics in blurring the human and nonhuman have been most striking in the agonistic field, if not the battlefield itself; the choice between fighting Augustinian and Manichean enemies, as Wiener pointed out, is merely one of tactics. In choosing the cyborg to lead the flight from modernism, one risks reducing the picture of human capacities to one of tactical moves and countermoves in a metaphorical extension of automatic airwar.

Whether we accept or reject the ontology of the Manichean sciences, in discussing the technologies of cybernetics we find ourselves in the grip of a powerful set of cultural meanings. By this, I do not mean that feedback systems were born (so to speak) with a full complement of symbolic associations. As with any set of artifacts, it is possible to trace back fragments of servomechanisms, game theory, and operational reasoning long before 1940. One can cite, as Wiener often did, fragments by James Clerk Maxwell, Leibniz, and many others who attended to issues of self-regulation, interconnection, and communication. Wiener, for example, knew perfectly well that the nineteenth century had a well-developed theory of the steam-engine governor, and by the 1920s electrical analogues in the form of voltage regulators were legion.

As Otto Mayr has so exhaustively demonstrated, pre–twentieth century feedback devices were culturally located quite differently from sys-

83. Wiener, *God and Golem, Inc.: A Comment on Certain Points where Cybernetics Impinges on Religion* (Cambridge, Mass., 1964), p. 95.

84. See Haraway, "A Cyborg Manifesto," p. 163.

tems discussed here. Known in the golden age of Islam, feedback mechanisms—especially liquid-level regulators—flourished in antiquity. Then, from the Middle Ages through the baroque period, the technology vanished almost completely in Europe. Clocks, not self-regulating machines, held pride of place. Timekeeping machines served as a cultural symbol of authority; these were the mechanisms that appeared everywhere, celebrated from literature and poetry to philosophy and political theory. According to Mayr, "the authoritarian conception of order was directly and patently shaped by society's experience with the mechanical clock."[85] When the feedback device came back into European favor in the seventeenth and especially in the eighteenth century, it did so not on the Continent but in the British Isles, a manifestation, in Mayr's view, of the "liberal attitude" that at one and the same time shaped the "socio-intellectual" and the "technological" sides of culture. Regulating devices, especially as popularized by Watt's incorporation of the governor into the steam engine in the 1780s, were celebrated alongside political rhetoric of "dynamic equilibrium," "self-regulation," "'checks and balances,'" and "'supply and demand'" (*A*, p. xviii).

But there are differences, crucial differences, between these devices and the wartime work at MIT or Los Alamos. First, as Mayr points out, there was no early modern entity coextensive with the abstraction *feedback systems*. There were fluid regulators, steam-engine regulators, and windmill governors aplenty—but no notion of these constituting a collocation defined by an abstract causal loop.[86] Second, neither the political theorists nor the inventors of the seventeenth and eighteenth centuries made explicit any link between the two domains of self-regulation rhetoric. Consequently, while Mayr conclusively demonstrates the coperiodization of feedback talk in technology and politics, historiographically the bond between them remains that of an acausal zeitgeist, albeit one located (spatially and temporally) with the onset of "liberal attitudes" and a "liberal conception of order." He concludes: "About the details of the causal nexus between the advent of the liberal conception of order and the rise of self-regulating mechanisms in technology we are reduced, at this point,

85. Otto Mayr, *Authority, Liberty and Automatic Machinery in Early Modern Europe* (Baltimore, 1986), p. 197; hereafter abbreviated *A*. See also Mayr, *The Origins of Feedback Control* (Cambridge, Mass., 1970).

86. "The abstract concept of the closed causal loop which provides the common basis for all the regulating mechanisms discussed in this study, and which is expressed most compellingly by the graphic symbols of the block diagram, is an achievement of the 20th century" (Mayr, *The Origins of Feedback Control,* p. 129). While the nineteenth century was rife with studies of speed regulation and its theoretical representation in terms of differential equations, the general feedback problem was posed only with developments in electrical self-regulation, especially through the work of K. Küpfmüller (1928), H. Nyquist (1932), H. L. Hazen, and H. S. Black (1934), and assembled into treatise form by R. C. Oldenbourg and H. Sartorius (1944) and Le Roy MacColl (1945). See Mayr, *The Origins of Feedback Control,* p. 132.

to speculation" (*A*, p.199). The links holding the disciplines of cybernetics together need not be so speculative.

What we have seen in Wiener's cybernetics is the establishment of a field of meanings grounded not through zeitgeist but explicitly in the experiences of war. For however far telephone relaying technology or A. N. Kolmogoroff's statistics had come before the war, it was the mass development and deployment of guided missiles, torpedoes, and antiaircraft fire that centralized the technology to scientists and engineers. To the thousands of servicemen who used and faced this new generation of weapons, the "human" character of self-regulating machines seemed all too human. After all, trying to shoot down a Junkers JU 88 heading for London or a V-1 buzz bomb doing the same thing was not all that different. A skipper trying to dodge a self-guided torpedo could be excused for referring to the device as "trying" to kill him, as could the pilot ascribing airfoil self-adjustment to the work of "gremlins." And in the specific case of Wiener, Bigelow, Weaver, and their colleagues, it is perhaps understandable that the pilot of an enemy plane could be said to "behave like a servo-mechanism." While prewar behaviorists might have cautioned against the ascription of internal states, war made it impossible; reading the hidden enemy meant reading his actions. In the mechanized battlefield, in those life-and-death confrontations with an enshrouded enemy, the identity of intention and self-correction was sustainable, reasonable, even "obvious."

Face to face with another person, with no way to avoid the full depth and ambivalence of human interaction, feedback may seem (as it did to Taylor) to be a ludicrously simplistic representation of intentionality. But to Stibitz and Weaver, as they stood in Wiener's MIT laboratory that July day in 1942, the system of simulated pilot and AA predictor was positively "uncanny" in its capacity to predict a pilot's next move. World War II elevated the stakes of understanding the enemy's intention to survival itself; it stripped human behavior to moves of pursuit, escape, and deception; and it introduced a new class of self-regulating weapons. It is in this specific context that the identity of intention and self-correction was forged.

Symbols matter: it counted for a great deal in the reception of cybernetics that its war applications were lethal, or potentially so. After all, as Wiener himself recognized, much of the theory of servomechanisms (time series autocorrelation, for example) had been developed before the war in nonmilitary contexts, and a great deal more had come from the "pure" statistical investigations of Kolmogoroff. Would cybernetics, information theory, and "systems thinking" have proved such a central and enduring metaphor without combat? Would the pervasive postwar ontology of the enemy have had such a runaway success without the seduction of victorious military power? I doubt it. Without the specific lived horror of V-2s raining down on London, the air-dropped torpedoes ruthlessly diving for Japanese warships in the South Pacific, or the fire-controlling AA predictor that promised to stem the enemy barrage, it is hard to imagine the new technologies appearing so much *like* human pilots and gunners that the two could be conflated. In World War II, the mechanized soldier faced his opponent as a machine, and machines manifested themselves as people. After the AA predictor but before Nagasaki, Wiener responded to the newfound moral, political, and industrial power of automatic control like this: "It . . . occurred to me that we were here [with self-regulating machines] in the presence of another social potentiality of unheard-of importance for good and for evil" (*C,* p. 27). After the bomb, as we have seen, Wiener's association of danger and moral weight with cybernetics grew even stronger. War gave the new cybernetic technologies a role to play in the Manichean drama of the world. Mere governors, thermostats, and voltage regulators could not usher in a cybernetic age—weapons could.

In general, the cultural meaning of concepts or practices, I would argue, is indissolubly tied to their genealogy. To understand the specific cultural meaning of the cybernetic devices is necessarily to track them back to the wartime vision of the pilot-as-servomechanism. In the air-ground battle, it was a short step for Wiener and Bigelow to take the pilot-as-servomechanism directly over into the AA gunner-as-servomechanism and thence to the operation of the heart and proprioceptive senses. From the body, it was us more generally—we humans—whose intentions could be seen as none other than self-correcting black-boxed entities and finally nature itself that came to be seen as a correlated and characteristic set of input and output signals.

If this cybernetic conception seems to differ from more familiar conceptions of the Other, it should. The cybernetic Enemy Other has little to do with the racialized Other so horrifyingly invoked by Blamey, and examined, for example, by Edward Said in *Orientalism.*[87] There is no sense in which Wiener sees the German bomber pilot as a racially lesser being. Nor is the German pilot an Other in being simply invisible. Finally, I take it to go without need of much elaboration that the servomechanical pilot is not Emmanuel Levinas's Other, where the recognition of the ineradicable humanity outside of oneself is the fundamental move in the establishment of an ethical philosophy.[88] No, Wiener's conception of the Enemy Other is more like his depiction of the game players in von Neumann's theory: "perfectly intelligent, perfectly ruthless operators" (*C,* p. 159). This is a theoretical representation in which information, statistics, and strategies are applied to moves and countermoves in a world of opposing but fundamentally *like* forces.

Surprisingly, the cybernetic Other is not negatively contrasted with

87. See Edward W. Said, *Orientalism* (New York, 1978).

88. See *The Levinas Reader,* ed. Séan Hand (New York, 1989).

us, nor are we the model upon which the Other is empathetically formed; our understanding of the cybernetic Enemy Other becomes the basis on which we understand ourselves. Wiener's image of the human and natural world is, in the end, a globalized, even metaphysical, extension of the epochal struggle between the implacable enemy from the sky and the Allies' calculating AA predictor that did battle from the ground. It is an image of human relations thoroughly grounded in the design and manufacture of wartime servomechanisms and extended, in the ultimate generalization, to a universe of black-box monads.

In principle, can the cultural meanings of feedback systems be disassociated from the origins of the technology? Of course. After all, early modern "self-regulation" rhetoric spanned steam-engine governors and liberal political economy; feedback rhetoric in 1946 bound together very different meanings. Another instance of shifting cultural meanings comes from flying itself. During the 1920s, the airplane and "airmindedness" came, in America, to stand for a concatenation of individual freedom, religious renewal, and the inauguration of a new, modern, international era. In Germany, at nearly the same time, opposite associations prevailed: gliding and then powered flight carried with them an inextricably nationalist association; airmindedness meant a self-conscious revolt against Versailles and a constant reassertion of community over individualism.[89] Of interest is not the mere identification of associations, but the cultural historical account of their assembly, persistence, and deconstruction.

Cultural meaning is neither aleatory nor eternal. We are not free by fiat alone to dismiss the chain of associations that was forged over decades in the laboratory, on the battlefield, in the social sciences, and in the philosophy of cybernetics. At the same time, it would clearly be erroneous to view cybernetics as a logically impelled set of beliefs. Nothing in the feedback device implies a representation of human beings as behavioristic black boxes; nothing in the mathematics entails by deduction alone a universe reducible to Wiener's monadic input-output analysis. What we *do* have to acknowledge is the power of a half-century in which these and other associations have been reinstantiated at every turn, in which opposition is seen to lie at the core of every human contact with the outside world.

As a twenty-year old, Wiener published his first philosophical paper opposing the notion of a "highest good" and underlining the irreducible internal and external conflicts that fixed our notion of morality. When disputes could not be settled by reason, young Wiener wrote, "*the conflict can be settled, if at all, only by the suppression by brute force of the disputant or*

89. For the American history of the popular culture of flying, see Joseph J. Corn, *The Winged Gospel: America's Romance with Aviation, 1900–1950* (New York, 1983); on the German cultural history of aviation, see Peter Fritzsche, *A Nation of Fliers: German Aviation and the Popular Imagination* (Cambridge, Mass., 1992).

disputants on one side."[90] Differing from Hobbes (Wiener did not believe that people were fundamentally selfish), he nonetheless saw morality as a conflict not resolved in the distant past but as continuing into the here and now. Such a relentless struggle continued in the cybernetic weltanschauung, though it took a new, scientific, and more subtle form, embracing not only morality but our relation with the world itself. Wiener queries whether the world is an active (Manichean) opponent or merely a passive (Augustinian) antagonist, the only difference being that the "Manichean devil" used tricks, craftiness, and dissimulation against us, while the "Augustinian devil" did not change methods: "The difference between these two sorts of demons will make itself apparent in the tactics to be used against them" (*HU*, p. 35). To Wiener, the essential and unrelieved reality of the world was that the individual lived in isolation, struggling (searching for tactics) to create order out of chaos. Science itself, as it faced nature, was such a battle: "The scientist," he declared late in life, "is always working to discover the order and organization of the universe, and is thus playing a game against the arch enemy, disorganization. Is this devil Manichean or Augustinian? Is it a contrary force opposed to order or is it the very absence of order itself?" (*HU*, p. 35). Cybernetics, that science-as-steersman, made an angel of control and a devil of disorder.

But perhaps disorganization, noise, and uncontrollability are not the greatest disasters to befall us. Perhaps our calamities are built largely from our efforts at superorganization, silence, and control.

90. Wiener, "The Highest Good," *The Journal of Philosophy, Psychology, and Social Methods* 11 (Sep. 1914); rpt. *Norbert Wiener*, 4:49.