Engineering Behavior: Project Pigeon, World War II, and the Conditioning of B. F. Skinner

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During the Second World War the scientific outlook and professional goals of American psychologist B. F. Skinner underwent a remarkable metamorphosis. Wartime contingencies reshaped his research agenda and converted him to the cause of behavioral engineering. Before the war, Skinner was reluctant to venture very far outside the academic laboratory. He was a scientific purist who resisted extrapolating the results of his animal experimentation to the realm of human behavior. After the war, he attempted to make such connections boldly explicit, arguing that the scientific principles of behaviorism had widespread applicability to human affairs. By the 1950s Skinner had emerged as an advocate of the use of operant conditioning techniques for the control of individual and group behavior in a variety of settings and promoted applications ranging from teaching machines to the design of entire societies.

Skinner's transition from inventive scientist to social inventor can be traced to the circumstances of World War II, which provided him with opportunities to explore the technological ramifications of operant psychology. Years later he noted that three wartime projects had dramatically broadened his intellectual horizons by offering the first evidence that his system of behavioral science could engender a system of behavioral engineering.[1] The first was known as Project

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[1]B. F. Skinner, "My Years at Indiana" (paper prepared March 31, 1988, for Indiana University Department of Psychology Centennial Celebration, Bloomington, April 1988), p. 5; a copy is in the personal collection of the author.

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Pigeon—an attempt to construct a missile guidance system utilizing the conditioned pecking behavior of pigeons. Project Pigeon consumed much of Skinner's energy during the war, and, even though it was never brought to fruition, it played a pivotal role in reorienting his thinking toward the possibilities of behavioral engineering.[2] The second project was closer to home. Faced with the challenges of raising a second baby daughter, Skinner drew on his manual skills and invented the "baby-tender," a futuristic climate-controlled crib designed to promote the physical and psychological health of infants.[3] Featured in the *Ladies' Home Journal* shortly following the war, the device was later marketed commercially with little success as the "Aircrib."[4] Skinner's third novel project was precisely that—a novel. During the summer of 1945 he drafted the manuscript that would be published three years later as *Walden Two*.[5] The book was Skinner's attempt to conceive a utopian human society based on the principles of reinforcement that he had gleaned from his laboratory research on animal behavior.

Taken together, these efforts represent Skinner's initial forays into the realm of behavioral engineering, and they clearly demonstrate how the technocratic ideals embedded in his research practices found expression in the wartime context. Although Skinner's work was undeniably idiosyncratic, it reflected broader trends in American psychology that reached their fullest expression during the Second World War, with its overriding emphasis on military utility and the virtues of order, control, and effectiveness.[6]

Of the three projects, *Walden Two* became the most famous. It was the first step in Skinner's public transformation from experimental psychologist to social philosopher, and its description of an entire culture molded along behaviorist lines suggested the scope of Skinner's ambitions. As important as the novel was, it was only the most visible manifestation of a more fundamental change that had begun during Project Pigeon, when Skinner first confronted the difficulties associated with conducting research outside the laboratory environment. The history of this unusual project is essential to understanding Skinner's profound intellectual shift from the development of a natural science of behavior in the laboratory toward its technological

[2]B. F. Skinner, "Pigeons in a Pelican," *American Psychologist* 15 (1960): 28–37.

[3]B. F. Skinner, *The Shaping of a Behaviorist* (New York, 1979), pp. 275 ff.

[4]B. F. Skinner, "Baby in a Box," *Ladies' Home Journal* (October 1945), pp. 30–31, 135–36, 138.

[5]B. F. Skinner, *Walden Two* (New York, 1948).

[6]See James H. Capshew, "Psychology on the March: American Psychologists and World War II" (Ph.D. diss., University of Pennsylvania, 1986).

applications in a variety of real-life contexts. Project Pigeon encouraged Skinner to think about his research in new ways and reinforced his belief in the underlying orderliness of behavior. Skinner's behavioral engineering was characterized by the same kind of inventive activity he had engaged in as a professional psychologist, except that it took place beyond the confines of the laboratory.

From the start of his career, Skinner had been an inventor. His experimental work depended significantly on his ability to design, build, and repair laboratory apparatus. Devices such as the Skinner box were essential in providing the proper conditions for the manipulation of operant behavior; in fact, they can be regarded as machines for the production of behavior. When integrated with other elements of Skinner's research method, such as conditioning techniques, data recording, and interpretive schemes, such devices constituted part of a technological system for scientific research.[7] What was notable about Skinner's wartime projects was their common focus on controlling behavior in nonlaboratory settings. Because it was his first serious effort to construct a technological system to address a practical problem, Project Pigeon is worth examining in detail.

The Control of Behavior

In 1938, a year before the war began in Europe, Skinner published his first book, *The Behavior of Organisms: An Experimental Analysis*.[8] The monograph synthesized nearly a decade of laboratory research on the conditioning of white rats and contained Skinner's program for establishing psychology as a natural science alongside biology, chemistry, and physics. The young psychologist was after nothing less than the foundations for a true science of behavior, one that treated behavior as a scientific datum in its own right. He was equally critical of both mentalistic theorizing and neurological reductionism. In his view, the goal of a naturalistic science of behavior was within reach, thanks largely to the legacy of Charles Darwin, Lloyd Morgan, and John B. Watson.

Skinner's scientific ambitions had been shaped by a long apprenticeship in the Laboratory of General Physiology at Harvard University. Arriving at the university as a graduate student in the mid-1920s, Skinner earned his Ph.D. in 1931. Although his degree was in psychology, he did the bulk of his work in physiology, where his primary mentor was W. J. Crozier, the architect of the Harvard

[7]On the notion that technological systems include people and organizations as well as artifacts and processes, see Thomas P. Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm, 1870–1970* (New York, 1989), pp. 184 ff.

[8]B. F. Skinner, *The Behavior of Organisms: An Experimental Analysis* (New York, 1938).

laboratory's program. Under the influence of Crozier and other members of the laboratory, Skinner became an adherent of the engineering ideal in biology championed by Jacques Loeb and sought to extend similar principles and techniques to the control of behavior.[9] Following an intellectual agenda outlined in his doctoral dissertation, Skinner virtually lived in the laboratory for five years of postdoctoral research, first as a National Research Council fellow and then as a member of Harvard's Society of Fellows.

Skinner modeled his approach on Ernst Mach's philosophy of science, emphasizing the functional description of observed behavior and rejecting causal explanations as unnecessary. His laboratory practices followed the pattern laid down by Loeb and his disciples, with their characteristic accent on the manipulation of biological organisms, and Skinner adopted "prediction" and "control" as his watchwords.

During this period Skinner gradually refined his concept of the operant. In simple terms, operant behavior was emitted by the organism spontaneously, rather than being elicited by particular stimuli as in the classical conditioning demonstrated by Ivan Pavlov. In classical conditioning, if a neutral stimulus (such as a bell) is paired with an unconditioned stimulus (such as food), eventually the unconditioned response (salivation) will occur upon presentation of the previously neutral stimulus. Although classical conditioning had yielded useful quantitative analyses of some kinds of behavior, it seemed to be limited to simpler, reflexive behavior. Skinner was interested in exploring the more complex kinds of behavior that were maintained through operant reinforcement.

Skinner developed relatively simple yet powerful experimental procedures for operant conditioning. The basic setup involved a single rat in a standard apparatus (what became known as the Skinner box), in which the animal would press a bar in order to receive reinforcing stimuli in the form of food or water. Measurements of the rat's bar-pressing behavior were recorded mainly in the form of graphs plotting the cumulative number of responses over a given period of time.

Skinner discovered many regularities in the response rates of his subjects under various stimulus protocols and reinforcement schedules. As an example of how an animal's behavior could be radically shaped by operant methods, he trained one rat, named Pliny the

[9]Philip J. Pauly, *Controlling Life: Jacques Loeb and the Engineering Ideal in Biology* (New York, 1987), pp. 188–91. See also Laurence D. Smith, "On Prediction and Control: B. F. Skinner and the Technological Ideal of Science," *American Psychologist* 47 (1992): 216–23.

Elder, to perform a series of acrobatic tricks with a marble by reinforcing successive approximations of the desired responses. This provided a vivid demonstration of the power of operant conditioning to produce responses that were not in the original behavioral repertoire of the rat. Skinner was well aware that professional animal trainers relied on similar methods, which they had developed through trial and error rather than disciplined investigation. Skinner's work with Pliny came to the attention of the national media, and a story about it was published in *Life* magazine in 1937.[10]

By this time Skinner had left his monastic lab-centered existence at Harvard and was an assistant professor of psychology at the University of Minnesota. There he was exposed to the demands of teaching and to the array of scientific and professional concerns represented in a large midwestern psychology department. Although Minnesota was a noted center for applied psychology, Skinner hewed to his experimental program. In *The Behavior of Organisms,* he had studiously avoided commenting on the relevance of his work to human behavior until the last pages of the volume, where he admitted that "the importance of a science of behavior derives largely from the possibility of an eventual extension to human affairs. But it is a serious, though common, mistake to allow questions of ultimate application to influence the development of a systematic science at an early stage. I think it is true that the direction of the present inquiry has been determined solely by the exigencies of the system. . . . The book represents nothing more than an experimental analysis of a representative sample of behavior. Let him extrapolate who will."[11]

Not long afterward, the Second World War began, and Skinner himself was faced with the opportunity to extrapolate his system. Although a great number of other psychologists mobilized rapidly for the national emergency, nearly all, including those researchers in animal laboratories, addressed problems of human behavior. Skinner was unique, however, in that he found a way to continue working with animals in the unlikely field of guided missile technology.

The Genesis of Project Pigeon

Among the most disturbing aspects of the war in Europe was the emergence of aerial bombing as a terrible new weapon against which there was little reliable defense. Musing about the problem on a train bound for the Midwestern Psychological Association meeting in Chicago in 1940, Skinner was inspired with a solution: why not bomb

[10]"Working Rat," *Life* (May 31, 1937), pp. 80–81.
[11]Skinner, *Behavior of Organisms,* pp. 441–42.

the bombers with guided missiles dropped from planes flying at higher altitudes? The idea was hardly original—except for the guidance system, which would rely on the discriminative abilities of trained animals. As Skinner described his first thoughts: "I saw a flock of birds lifting and wheeling in formation as they flew alongside the train. Suddenly I saw them as 'devices' with excellent vision and extraordinary maneuverability. Could they not guide a missile? Was the answer to the problem waiting for me in my own backyard?"[12]

Fifty years later Skinner's idea may appear outlandish since guided missile technology has become highly sophisticated, relying on the latest advances in electromechanics and electronics. At the time, however, the United States possessed virtually no expertise in guided missiles. The development of propulsion systems and warheads was confined to a few experimental projects in mechanical and electrical engineering laboratories, and guidance techniques based on servomechanisms were in the early stages of theoretical exploration. Work soon accelerated, however, when U.S. government authorities, realizing that the Nazis were well ahead in the area, started to mobilize American scientists and engineers.[13]

Skinner continued to ponder the idea, and by the spring of 1941 he was actively exploring its feasibility. Deciding that birds would be the most appropriate research subjects, he bought several pigeons and trained them to peck at a bull's-eye target. The birds were harnessed to a movable hoist, and as they pecked their head movements operated electric motors that steered the hoist toward the target. Skinner demonstrated the experiment to John T. Tate, a well-known physicist and dean of the College of Science, Literature, and Art at Minnesota, who passed along the psychologist's "Description of a Plan for Directing a Bomb at a Target" to Richard C. Tolman, head of the physics department at the California Institute of Technology and vice chairman of the National Defense Research Committee (NDRC).[14]

[12]Skinner, *Shaping of a Behaviorist* (n. 3 above), p. 241. A similar account that is mistakenly dated 1939 is given in B. F. Skinner, "Autobiography," in *A History of Psychology in Autobiography*, ed. Edwin G. Boring and Gardner Lindzey (New York, 1967), 5:385–413, quote on 402.

[13]Leaders of the wartime research and development establishment considered guided missile work a top priority, second only to the atomic bomb project. See Vannevar Bush and James B. Conant, "Foreword," in *Guided Missiles and Techniques*, Summary Technical Report, Office of Scientific Research and Development (OSRD), Division 5 (Washington, D.C., 1946), p. v.

[14]Skinner, "Pigeons in a Pelican" (n. 2 above), pp. 28–29. Skinner recalled that psychological research using pigeons had hardly been attempted before and that he had bought the birds at a shop that sold them to Chinese restaurants (Skinner to J. H. Capshew, August 11, 1986; Skinner to Capshew, August 9, 1990; these letters are in the

Although Tolman called the plan "a new and unconventional approach to the problem," he rejected it, diplomatically claiming that the probable lack of interest by the armed services made it "hardly advisable" for the NDRC to develop it, even though the "suggestion may be perfectly feasible."[15] Skinner thanked Tolman for his interest and told him that he would continue to seek support for what was "admittedly a 'long shot.'"[16]

The entrance of the United States into the war after the attack on Pearl Harbor reactivated Skinner's interest, and on December 8, 1941, he began experiments on the guidance of offensive bombs directed toward stationary targets. With the help of a graduate student, Keller Breland, Skinner harnessed a pigeon in an apparatus that was guided by the bird's neck movements toward a target. After making a film demonstrating the device, he enlisted the aid of some of his colleagues in Washington and again approached the NDRC. Writing to Tolman once more, Skinner suggested that "if the United Nations could suddenly begin to sink ships with high altitude bombing, practically at the rate of one ship per bomb, the war would be won. And this is not a consequence to be sneezed at." He offered to send the demonstration film to the committee, joking that it would "at least . . . prove to be an entertaining 'short.' "[17] Tate also wrote to Tolman, avowing his "great confidence" in Skinner. In support of the unorthodox plan the physicist said, "If you have a steerable bomb, I feel fairly confident that a bird's vision and head movement constitute an instrument for guidance which is probably superior to anything which can be produced by the hand of man."[18]

In March 1942 Skinner traveled to New York to receive the prestigious Warren Medal of the Society of Experimental Psychologists. A chance encounter with a colleague led to a meeting between Skinner and the navy's chief of special devices in Washington. The official was supportive of Skinner's plan but was unable to provide financial backing.[19] Later the same month Tolman again rejected the proposal, in part because of the lack of suitable missiles. At that time

personal collection of the author). If Tolman was not particularly sympathetic toward psychology, he was certainly not ignorant of it since both his wife, Ruth S. Tolman, and his brother, Edward C. Tolman, were active professional psychologists in California.

15 Tolman to Skinner, June 9, 1941, Record Group 227, OSRD, National Defense Research Committee (NDRC), Records of Civilian Members, Tolman Files (hereafter cited as Tolman Files), Sk–Sm, National Archives, Washington, D.C.

16 Skinner to Tolman [June 1941], Tolman Files.

17 Skinner to Tolman, March 11, 1942, Tolman Files.

18 Tate to Tolman, March 19, 1942, Tolman Files.

19 Skinner, *Shaping of a Behaviorist* (n. 3 above), p. 257.

only rudimentary research had been conducted on guided missile technology, and the NDRC designated an entire division—Division 5—to foster its development.[20] Tolman encouraged Skinner to contact him if he performed more research and cautioned him against discussing the proposal in public.[21]

Skinner decided to continue on his own. Writing to Dean Tate about recent kamikaze attacks on Allied warships, he said it "looks as if the Japs were using men rather than birds. Perhaps we can get American morale that high, but if not, I can provide perfectly competent substitutes."[22] Through a fortuitous chain of circumstances, Skinner was able to obtain some research money from an unlikely source—the General Mills Company in Minneapolis. His work had come to the attention of the company's vice-president for research, Arthur D. Hyde, when it was mentioned by an inspired citizen in support of a scheme to use dogs to steer torpedoes by sound signals.[23] General Mills provided Skinner with a $5,000 grant to support his work during the summer of 1942.

General Mills also furnished the project with work space in an old flour mill, and another graduate student, Norman Guttman, volunteered to help. Skinner's group began working on an apparatus to translate a pigeon's pecking movements into a signal that could steer a gliding bomb. The pigeon's pecking behavior was shaped to the point where it would respond steadily and precisely to a sample visual target, which in this case was a particular street intersection in an aerial photograph of Stalingrad. At the same time Skinner worked with two more students, William K. Estes and Marian Breland, to carry out supplementary studies of possible environmental influences on the pigeon's behavior, including deprivation levels, reinforcement schedules, noise, and changes in temperature and pressure. The properly trained pigeon proved to be a stable performer under a wide range of conditions.[24]

Another demonstration film was sent to the NDRC, and the committee responded by dispatching an observer to Minnesota. Skinner was then invited to Washington to present his proposal in

[20]See *Guided Missiles and Techniques* (n. 13 above).

[21]Tolman to Skinner, March 31, 1942, Tolman Files.

[22]Quoted in Skinner, *Shaping of a Behaviorist*, pp. 256–57.

[23]Skinner remembered only the man's first name—Victor. See Skinner, "Pigeons in a Pelican" (n. 2 above), p. 29.

[24]For technical details, see Skinner, "Pigeons in a Pelican," p. 30. Skinner noted that the technique of "shaping" behavior (i.e., reinforcing successive approximations of the desired response) had its origins in the flour mill during an attempt to teach a pigeon to bowl. See B. F. Skinner, "Reinforcement Today," *American Psychologist* 13 (1958): 94–99.

February 1943. The plan for what Skinner termed the "Bird's-Eye Bomb" was based on principles of operant conditioning, which could easily be applied to pigeons. The birds also made good subjects because of their excellent vision and their imperturbability in the face of acceleration and noise. The steering mechanism was straightforward and fairly simple. A plastic screen was placed behind a lens in the nose cone of the missile. As the bomb pointed downward toward the target, an image of the field was projected upward onto the screen. The bird, trained on a chosen target, would peck at the image on the screen, which was mounted on gimbal bearings. Electrical contacts were activated when the bird pecked at the off-center target image, which then generated signals to operate steering controls.[25]

This method simplified the stimulus-response situation. The target pattern appeared directly in front of the bird in such a way as to readily control the desired pecking response. Extraneous stimulation was minimized, and the pigeon's instinctive flight habits were bypassed by the use of a harness that restrained wing movements. Training the bird to peck at a target image, such as a boat or a landscape feature, was easily accomplished by using aerial photographs. (The project was provided with photos of the New Jersey coastline for training purposes.) By using variable-ratio conditioning schedules, Skinner was able to train birds to peck continuously for a period of several minutes, which would be necessary in the actual use of the missile. One bird, for example, made over 10,000 pecks in forty-five minutes without stopping. Factors that might disturb the birds were systematically studied. The pigeons could readily be adapted to loud noises, vibration, and acceleration. Temperature and pressure changes could easily be accommodated in the design of the device. Possible disturbing effects of variations in the target such as brightness and size, as well as of atmospheric interference such as clouds, could be avoided by means of appropriate training procedures.[26]

The proposal and demonstration film favorably impressed NDRC officials, and in March 1943 the chief technical officer of Division 5, electrical engineer Hugh S. Spencer, visited Minneapolis along with an assistant for a firsthand look at the project. They were pleased with what they saw, commenting that "aside from the pigeon racket, the organization seems exceptionally able, well staffed, and well equipped."[27] By April, Spencer informed the group that a contract was likely to be approved if quantitative data on the accuracy of the pigeon pecking

[25]B. F. Skinner, K. B. Breland, and N. Guttman, "The Present Status of the 'Bird's-Eye Bomb,' " February 1, 1943, OSRD, NDRC Division 5, Spencer Files (hereafter cited as Spencer Files), 15, General Mills, Special Reports.

[26]Ibid.

[27]Spencer, "Visit," March 16, 1943, Spencer Files, 15, General Mills Correspondence.

could be provided. Skinner supplied the data in the form of plaster casts taken from modeling clay used to record the birds' pecking. The pigeons' marksmanship was excellent. Spencer also inquired about the available supply of birds. Skinner replied that practically all varieties of the species were usable and that pigeons could be obtained easily on the commercial market.[28]

An additional visit to the project laboratory by another NDRC staff member, physicist Alan C. Bemis, clinched the case for support. After spending a couple of hours with Skinner, Bemis reported, "As seems to be the case with most visitors, I went as a scoffer and came away somewhat converted."[29] Skinner discussed his need for assistance on the mechanical and electrical engineering aspects of the device. The only other visual guidance system under development by Division 5 was one that utilized television, and in consideration of the money spent on it Bemis commented, "Pigeons don't look too bad, but I still wouldn't know whether to vote yes or no on a contract."[30] His ambivalent endorsement epitomized the general attitude toward the project within the National Defense Research Committee. Even though the animal homing device had some promise, especially given the state of guidance-system technology, the NDRC officials clearly had trouble accommodating a psychological approach to an engineering problem.

By the end of May, Spencer wrote to Vannevar Bush, president of the Carnegie Institution and director of the Office of Scientific Research and Development (OSRD), the NDRC's parent body, to recommend support for the project, citing computations indicating that the system could guide a missile to within 20 feet of its target if the original azimuth error was less than 2,000 feet. Bush thanked Spencer for the project summary, stating, "I have the feeling that this whole subject is now for the first time on a basis of sound scientific examination from the angle of the physical as well as the organic elements."[31] On June 1, the NDRC awarded a $25,000 contract for an "organic homing device" to General Mills for the period from February 1 to December 31, 1943.[32]

[28]Spencer to Hyde, April 10, 1943; Skinner to Spencer, April 12, 1943; Spencer to Skinner, April 30, 1943; Skinner to Spencer, May 6, 1943; all in Spencer Files.

[29]Bemis characterized Skinner as "scientifically sound, able in his field though not of great caliber, and certainly a very pleasant individual personally." See Alan Bemis, "Diary," May 1, 1943, OSRD, NDRC Division 5, Bemis Files (hereafter cited as Bemis Files), 91, Diary 1943.

[30]Ibid.

[31]Spencer to Bush, May 27, 1943; Bush to Spencer, May 28, 1943; both in Spencer Files, 15, General Mills Correspondence.

[32]Contract no. OEMsr-1068, Spencer Files, 15, General Mills Contracts and Vouchers.

Refining the Device

Neither Skinner nor the NDRC engineers made much effort to enlist advice about the project from other psychologists. On a programmatic level, Skinner and his group received the endorsement of Princeton psychologist Charles W. Bray, soon to become head of the OSRD Applied Psychology Panel.[33] The panel, however, was oriented toward manpower and training problems and was preoccupied with the administration of its own contracts. Skinner had mentioned a number of psychologists as potential advisors, but the suggestion was never followed up.[34] Project Pigeon remained isolated both intellectually and institutionally from the tight-knit wartime psychology community.

At General Mills, the project was supervised by Arthur Hyde, vice-president and director of research. Hyde, who wanted to channel the company's broad program of engineering research on food-processing machinery into federal contract research, became an enthusiastic supporter of Skinner's group. Bemis, the NDRC official assigned to oversee the project, was located at Division 5's headquarters at the Massachusetts Institute of Technology (MIT). Deeply involved in overseeing a number of contracts for servomechanism research and development, he was not particularly interested in the Minnesota project, and its distant location reinforced his laissez-faire attitude. It was clear from the start that General Mills and Project Pigeon were on their own.

Problems soon arose as it became apparent that the main technical obstacles were mechanical rather than psychological. The birds' pecking provided an adequate signal for the servomechanism, but the development of mechanical linkages for translating the signal into steering movements proved difficult. Skinner was disappointed with the slow pace of the mechanical research, saying, "I am not yet used to the low tempo of industry." Unfortunately, collaboration between the project's psychologists and engineers was hampered because the two groups were not under the same roof at General Mills, being housed in separate buildings nearly 4 miles apart. The NDRC's Spencer also expressed some reservations about the project's low-budget style, which he characterized privately as building on a "hay-wire-screen-door basis."[35]

[33]Joseph Boyce, chief of Section 5.5, solicited Bray for some advice on the project, which they had previously discussed at the Cosmos Club in Washington. Bray was glad to oblige but apparently never did. See Boyce to Bray, July 13, 1943; Bray to Boyce, July 17, 1943; Boyce to Bray, July 21, 1943; all in Bemis Files, 96, General Mills Correspondence.

[34]Spencer to Bemis, July 31, 1943, Bemis Files, 91, General Mills-Pigeons.

[35]Ibid.

Within a few months, however, the General Mills group constructed an improved signaling system that used pneumatic valves rather than electrical contacts. The target plate rested on four air valves at its edges. Depending on the location of the bird's pecking, the valves would allow air into the chamber and operate tambours that sent signals to the mechanism. As Skinner described it: "When the missile was on target, the pigeon pecked the center of the plate, all valves admitted equal amounts of air, and the tambours remained in neutral positions. But if the image moved as little as a quarter of an inch off-center, corresponding to a very small angular displacement of the target, more air was admitted by the valves on one side, and the resulting displacement of the tambours sent appropriate correcting orders directly to the servosystem."[36] By early September 1943 Project Pigeon had produced a workable model. At that time the project engineer at General Mills tried to get more information concerning the design and performance characteristics of the missile, which was under development at the MIT Servomechanisms Laboratory. The NDRC contract monitor was lackadaisical in responding to the queries, and, without proper specifications for their part of the servomechanism, Project Pigeon workers refined their system as best they could.[37]

The project was discussed at the next general meeting of NDRC Division 5. After hearing a report on its overall progress, the division chief could foresee eventual combat action, "not tomorrow, but in the not indefinite future."[38] This meeting was apparently the first time that many division officials had heard of the project, and Bemis told Hyde that there were favorable notices "in spite of the natural reaction which everyone has when learning about it for the first time to make light of it."[39]

By November contract funds were running out, and Skinner was anxious for NDRC officials to view his working model. In mid-December, shortly before the contract officially expired, Spencer and Bemis made another trip to Minnesota. They reviewed tracking data and observed the simulator—now with a three-bird control system to provide redundancy—following a target in the laboratory. Skinner

[36] Skinner, "Pigeons in a Pelican" (n. 2 above), p. 31.

[37] Bemis, perhaps feeling some guilt over his lack of help, was reassured by a visit from Charles Bray and Walter Hunter of the Applied Psychology Panel, who had a "positive opinion" of the project. See Bemis to Hyde, September 10, 1943, Bemis Files, 91, General Mills-Pigeons; and Bemis, "Diary," October 15, 1943, Bemis Files, 91, Diary 1943.

[38] Meeting of Division 5, verbatim transcript, October 20, 1943, Richmond quoted on p. 46, OSRD, NDRC Division 5, Richmond Files (hereafter cited as Richmond Files), 62.

[39] Bemis to Hyde, October 22, 1943, Spencer Files (n. 25 above), 15, General Mills Correspondence.

later reported, "The only questions which arose were the inevitable consequence of our lack of information about the signal required to steer the [missile]."[40] The Minnesota group, without guidance from the NDRC or its vehicle contractors, had had to make arbitrary engineering decisions, such as compromising between smoothness and sensitivity in the vacuum-generated signal. Unfortunately, the chosen values had produced data that did not favorably impress the NDRC advisors. Bemis thought the birds' behavior looked erratic and was skeptical about the mechanics of the device. He favored extending the contract, "but," as he told Spencer, "let's can the thing in a hurry if they don't do a neat job on the oscillating target measurements."[41]

Project Pigeon came up for extended discussion at the next meeting of the NDRC, in January 1944. The MIT physicist Joseph C. Boyce, chief of the section, recommended the continuation of three projects, including the General Mills contract. The other two contracts—totaling $130,000—were quickly approved. Boyce began discussion of the third by saying, "I, having been previously skeptical, would now like to recommend an additional $25,000 for General Mills for the continuation of the studies on the organic homing project."[42] He noted that the latest version of the device used three pigeons rather than one for added efficiency and reliability. Boyce's positive opinion was undercut by Spencer, who told the group that he and Bemis were disappointed by their observations in Minnesota the month before. Concerned about the overextension of the project budget (it had run out of contract funds in November), Spencer had told Hyde then that the results were "not of sufficient promise to justify my asking him to go any farther or giving him any expectation of further support from NDRC."[43] Hyde had asked what kind of data the NDRC advisors would find conclusive; Spencer replied that they would like something quantitative that Albert C. Hall, a specialist at the Servomechanisms Lab, could analyze. General Mills complied, Spencer reported, but "unfortunately, the data shows just a little too much hope, so that you can't drop it out of hand. It is not quite good enough to be promising; it is not quite bad enough to throw away."[44]

[40]Bemis to Hyde, November 20, 1943, Bemis Files (n. 29 above), 91, General Mills-Pigeons; Bemis to Spencer, December 3, 1943, Spencer Files, 15, General Mills Correspondence; Skinner, "Pigeons in a Pelican," p. 33.

[41]Bemis to Spencer, December 13, 1943, Spencer Files, 15, General Mills Correspondence.

[42]Meeting of Division 5, verbatim transcript, January 12, 1944, Boyce quoted on p. 130, Richmond Files, 62.

[43]Ibid., p. 134.

[44]Ibid.

An official from another section who had originally supported the contract changed his mind, saying that "if it doesn't look pretty good by this time I'm inclined to be a little cool."[45] Another committee member, aeronautical scientist Hugh Dryden, who was engaged in missile development, criticized the control mechanism as a "player piano movement type of thing" of the sort expected in a psychologist's laboratory.[46] J. C. Hunsaker, the National Advisory Committee for Aeronautics representative, maintained his original opposition. Although his vote did not count, Bemis, the project's technical monitor, voiced his opposition to extending the contract. In the face of dwindling support, Boyce was ready to withdraw his motion for $25,000, but the group went ahead and voted, rejecting the request for more funds for Project Pigeon.[47]

Fighting for Continuation

Reacting to news of the termination, Skinner exploded with a long letter to Spencer. He began by saying that "the action of the Division regarding our project was very nearly a knockout blow" and that he found it "difficult to understand this decision." He went on to reiterate the rationale for the project and suggested that the device had not been "judged fully on its merits" because the division had not provided complete performance specifications. The signal system gave values within the verbal specifications supplied in November, but those had evidently changed. Skinner complained that "if more rigid specifications are now found to be necessary, we should at least have been given the chance to shoot for them." Responding to another question concerning the bird's accuracy at close range, Skinner told Spencer that the bird could be conditioned to focus on successively smaller details as the target approached. Furthermore, "the extraordinary possibilities of pattern selection could hardly have been correctly represented to the Division at the time action was taken,

[45]Ibid., p. 135.

[46]Ibid., p. 136.

[47]Ibid., p. 140. After the vote, Spencer raised the nagging issue of reimbursing General Mills for its good faith in continuing to fund the project. He thought the NDRC's "no loss/no gain" principle regarding contractors implied some moral commitment to the company and pointed out that most contractors did not know how much they had spent until well past budget. Furthermore, the contract had come up for consideration without a thorough report from the contractor. Skinner and General Mills had complied with requests for data and results from their NDRC advisors, but no summary report had been requested. Apparently the Project Pigeon researchers had not been warned that their funding was in such jeopardy. After discussion, however, the reimbursement issue was dropped without a vote.

since we have not reported on them."[48] Skinner provided his own analysis of the decision:

> My guess is that certain technicalities have been invoked to support an underlying doubt concerning the reliability of the birds. I am quite sure that a non-organismic device which gave the same kind of signal with respect to any visual pattern would not be dropped at this stage. As a psychologist I can understand this (I have certainly seen enough of it during the past four years!), but I hate to accept it as the final word of men well acquainted with the history and methods of science. Any valid judgment of reliability must be made on the facts, not on random personal experiences. As you yourself must be able to testify, every competent person who has familiarized himself with our work has passed from a stage of amused skepticism to a serious belief that the scheme deserves to be tried. It is unfortunate that the final decision always seems to rest with men who have not had the benefit of close contact with the project.[49]

Skinner wanted to present his case directly to NDRC officials, hoping to persuade them to reopen the contract "up to the point of a field test." But he left the decision to Spencer, saying to him, "If you feel that such a step is hopeless, that the action would not be reconsidered, please say so frankly. In that case we shall immediately close up shop."[50] Under Hyde's signature additional supporting materials, including new data on the signal characteristics, were sent to Spencer from General Mills. In that report Hyde estimated that the device could be ready for a drop test in one month, at an estimated cost of $6,000. He repeated the group's plea that their work be more closely coordinated with the vehicle development team at MIT, complaining that "so far we have been working in the dark . . . with rather nebulous guesses and assumptions for guidance." In summary, he listed fourteen distinct advantages of the device, including its resistance to jamming, automatic close-up targeting, wide field of vision and small dead spot, easy construction, and short preparation time.[51]

Hyde also appealed to Spencer's superiors at the National Defense Research Committee. He arranged for the president of General Mills

[48]Skinner to Spencer, January 31, 1944, Spencer Files, 15, General Mills Correspondence.

[49]Ibid.

[50]Ibid.

[51]Hyde to Spencer, January 31, 1944, OSRD, NDRC Division 5, Contractor's Reports (hereafter cited as Contractor's Reports), 648, General Mills Final Report, January 31, 1944.

to contact Frank B. Jewett, an NDRC member and president of Bell Laboratories, and sent him a copy of the report. Ten days after the termination Jewett put Spencer "on the griddle" at a general NDRC meeting. Under pressure to justify the decision, Spencer requested more information from General Mills and asked Hall of the MIT Servomechanisms Lab to prepare a statement concerning the proper testing procedures for the device.[52]

The General Mills researchers responded with a three-part plan, covering drop tests, combat tests, and regular field use. The drop tests would use six pigeon units, costing $1,000 apiece, and could be ready to go in one week. For combat testing an estimated 200 units—employing 1,000 birds and fifty training devices—would be required, taking about three months of preparation time. Some forty unskilled workers would be needed to condition the pigeons under the supervision of five psychologists. Finally, plans for a regular field program projected sixteen units per day. For the necessary output of fifty birds per day, some 3,000 pigeons would participate in a general training program. Upon selection for a mission, they would be conditioned to the specific target. The basic conditioning work could be performed by the elderly or physically unfit, who could learn the procedures in a month or less. Compared to other military logistical operations, personnel requirements would be relatively modest, consisting of four experts, nine skilled group trainers (e.g., graduate students), 100 unskilled trainers, twenty caretakers, two repairmen, one pigeon specialist, one records clerk, one secretary, and a part-time installation crew. The report ended with a rhetorical flourish aimed at the NDRC engineers: "We again wish to emphasize our belief that the pigeon—an organism—is essentially an extremely reliable instrument, rugged in construction, simple and economical to obtain, and easily conditioned to be entirely predictable in behavior."[53]

Spencer received a five-page memorandum in early March from Hall regarding the device's technical feasibility. The servomechanism expert seemed impressed with its possibilities and stated that "at the present time I can see nothing which would lead me to believe that such a system should be inoperative."[54] On the basis of the new

[52]Spencer to Boyce, "Memo," February 21, 1944, Bemis Files, 91, General Mills-Pigeons.

[53]B. Skinner, E. Kuphal, G. Long, P. Christopherson, I. Boekelheide, "Cost of Homing Units, Personnel and Organization Required, Discussion and Analysis," February 21, 1944, Contractor's Reports, 648, General Mills Final Report, February 21, 1944. Kuphal to Spencer, February 25, 1944, Bemis Files, 91, General Mills-Pigeons.

[54]Hall to Spencer, March 6, 1944, Spencer Files (n. 25 above), 15, General Mills Correspondence. Spencer thanked Hall for his reports, commenting that he was sorry

material Spencer pushed for reconsideration of the project. He wrote Hyde: "If the Division's action in terminating the project at its last meeting was premature, the fault was mine. I did not feel at that time assurance that the results obtainable by the system could be as substantially improved as your later work has shown possible."[55] Soon Spencer sent a memo to Division 5 members asking that the project be reconsidered. Citing the improved results reported by General Mills, Spencer apologized for "misleading" the group at the last meeting and admitted, "I am wholly candid in stating that the material furnished this office in these two reports is definitely more encouraging than anything that I expected to receive."[56] Skinner and his group were invited to present their case at the next meeting of Division 5, in March 1944.[57]

Spencer began the meeting's discussion by saying he would have supported extension of the contract in January had the improved data been available then. Hall, harboring some doubts about the device, strongly recommended that thorough laboratory testing be completed before field testing. His mathematical calculations of the signal characteristics were inconsistent with the empirical data the project researchers had obtained. Various explanations of the inconsistency were offered, but, whatever the reason for it, the signal seemed adequate for controlling the missile. Skinner thought the discrepancy had been satisfactorily resolved beforehand and was surprised when Hall told the group "that the signal we reported would cause the missile to 'hunt' wildly and lose the target."[58]

Skinner went on to enunciate the unique advantages of the organic device, pointing out the bird's ability to react to patterns rather than to the point sources or fields of force that radar and other systems relied on. Drawing on the language of engineering again, he said, "We have used pigeons, not because the pigeon is an intelligent bird, but because it is a practical one and can be made into a machine, from all practical points of view."[59]

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that a plan for using a mirror-centering system rather than the pneumatic signal was not picked up by the project. See Spencer to Hall, March 10, 1944, Bemis Files, 91, General Mills-Pigeons.

[55]Spencer to Hyde, March 10, 1944, Spencer Files, 15, General Mills, Special Reports.

[56]Spencer, "Memo to Division 5 Members," March 13, 1944, OSRD, NDRC Division 5, Dryden Files, 67, General Mills.

[57]"Minutes of Section 5.5 Meeting," March 21, 1944, Bemis Files (n. 29 above), 91, Minutes of Meetings.

[58]Skinner, "Pigeons in a Pelican" (n. 2 above), p. 33. Meeting of NDRC Division 5, verbatim transcript, March 30, 1944, Richmond Files (n. 38 above), 62.

[59]Meeting of NDRC Division 5, March 30, 1944, pp. 94–95, Richmond Files, 62.

Hoping that a live demonstration would dispel any doubts about the feasibility of the project, Skinner set up a simple simulation. A target was projected on a window in a small black box in which the pigeon was harnessed. A small tube would allow individual observation, but, since time was short, the top was taken off the box. As Skinner described the scene:

> The translucent screen was flooded with so much light that the target was barely visible, and the peering scientists offered conditions much more unfamiliar and threatening than those likely to be encountered in a missile. In spite of this the pigeon behaved perfectly, pecking steadily and energetically at the image of the target as it moved about on the plate. . . . It was a perfect performance, but it had just the wrong effect. One can talk about phase lag in pursuit behavior and discuss mathematical predictions of hunting without reflecting too closely upon what is inside the black box. But the spectacle of a living pigeon carrying out its assignment, no matter how beautifully, simply reminded the committee of how utterly fantastic our proposal was. I will not say that the meeting was marked by unrestrained merriment, for the merriment was restrained. But it was there, and it was obvious that our case was lost.[60]

Literally and figuratively unable to keep the lid on the black box, Skinner left the group to its deliberations.[61] Spencer suggested an additional $50,000 for the project, including $20,000 to cover the General Mills deficit as well as a budget for six additional months. Much discussion focused on the logistics of field deployment until it was pointed out that the army already used pigeons, as carriers for messages. Pigeons would also be simple to transport compared to other things already routinely moved, such as bombs or electronic equipment. But the officials seemed more interested in laying the

[60]Skinner, "Pigeons in a Pelican," p. 34. In an earlier summary of the project, Skinner noted only that "the questions which were put to us were random and for the most part trivial. It was clear to us that most of the men present had only the vaguest notion of the proposed system, and we left the meeting with the feeling that any decision, favorable or unfavorable, would have little to do with the facts of the case." See [B. F. Skinner], "History of the 'Project Pigeon' Contract with NDRC," HUG 60.20, Box 8, Folder 2, Project Pigeon, p. 5, Skinner Papers, Harvard University Archives, Harvard University, Cambridge, Mass.

[61]On the notion of "black boxes" in the construction of knowledge claims, see Michel Callon and Bruno Latour, "Unscrewing the Big Leviathan: How Actors Macrostructure Reality and How Sociologists Help Them to Do So," in *Advances in Social Theory and Methodology: Toward an Integration of Micro- and Macro-Sociologies*, ed. Karin Knorr-Cetina and Aaron V. Cicourel (Boston, 1981), pp. 277–303.

matter to rest. It was clear that the project had not received good supervision or adequate technical support. Boyce, the section chief, admitted, "I am perfectly free to confess that I have not supervised the thing in detail." Another official noted that project members were "working in ignorance of what is involved in a guided missile. We have been so long finding out."[62] These statements seemed designed more to assuage possible guilt feelings regarding the project's administration than to promote serious reconsideration. Continued support was voted down, four to two, on the basis of the perceived lack of armed forces interest and the problems of coordination with the missile development team at MIT.[63]

The Demise of Project Pigeon

Project Pigeon was officially over. As Skinner wrote, "We had to show, for all our trouble, only a loftful [*sic*] of curiously useless equipment and a few dozen pigeons with a strange interest in a feature of the New Jersey coast."[64] In retrospect, it seems clear that the project failed, not for technical reasons, but because of fundamental differences in disciplinary outlook and research style between the Skinner team and the NDRC engineers. Coming from laboratory psychology, Skinner was at a disadvantage in trying to enter territory that was considered part of electrical and mechanical engineering. He lacked experience in dealing with extramural research funding agencies, even in his own field of psychology. Furthermore, he failed to mobilize the support of influential psychologists involved in government scientific circles. Instead, Project Pigeon members felt their way, eventually learning to articulate their work in engineering terms, as seen in the use of the metaphor of the bird as a machine. But that rhetorical ploy was tried only after NDRC officials had already begun to lose their initial enthusiasm for the novel guidance system. The contract administrators had tried to be open-minded about the project but proved unable to accommodate its unusual approach and eventually retreated behind traditional professional boundaries. In the official account of the project, NDRC staff members noted the prevailing mood: "Investigators in the physical sciences are inclined to discount unduly the findings of their colleagues in the field of psychological behavior. Such an attitude is far from scientific."[65]

The interests of the NDRC staff members were focused elsewhere, on the development of more conventional hardware, and they

[62]Meeting of Division 5, March 30, 1944, pp. 151–53, Richmond Files, 62.

[63]Ibid., pp. 154–55.

[64]Skinner, "Pigeons in a Pelican" (n. 2 above), p. 34.

[65]*Guided Missiles and Techniques* (n. 13 above), p. 201.

devoted a minimum of supervision to Project Pigeon. Although the General Mills contract generated much discussion, it was a marginal item in the budget, receiving only \$25,000 of the \$13,000,000 spent by the division over the course of the war.[66] Other speculative projects, such as television-guided missiles, received major funding despite little demonstrable utility. None of the officials assigned to oversee the project spent much time doing so; more significant, none of them emerged as advocates for it, which was crucial to continued funding. Finally, logistical problems deepened the gulf between the two groups. The division was headquartered at MIT, a key center of wartime technological innovation, whereas Project Pigeon was isolated in a more limited research environment in the Midwest. The development of the missile vehicle went ahead at MIT without real consideration of the organic guiding mechanism. Communication between the groups was poor, and the lack of information clearly hampered the General Mills engineers.

The physical scientists and engineers of the National Defense Research Committee succeeded in closing the issue, and their postwar accounts became the official word on Project Pigeon. In *Guided Missiles and Techniques,* the Summary Technical Report of Division 5, less than four pages were devoted to "Organic Target Seeking." Asserting that "recognition by intelligence" was the simplest method of targeting, the report mentioned the effectiveness of Japanese kamikaze attacks as a prime example.[67] The main components of the pigeon device were described, and the summary concluded that the project "was given up because the mechanical engineering problem of developing an appropriate servo link seemed too difficult," especially in light of advances made with other missile systems.[68]

In the official public history of wartime guided missile research and development, NDRC section chief Joseph Boyce gave a brief but balanced review of Project Pigeon.[69] Another Division 5 member, physicist Louis N. Ridenour, satirized the project in the pages of the *Atlantic Monthly* in 1947 as one of "the more bizarre problems of wartime research." In a short piece entitled "Doves in the Detonator," he caricatured Skinner (under the pseudonym Ramsay) as an impractical dreamer and misrepresented several key aspects of the project. Among other inaccuracies, Ridenour claimed that homing pigeons were used and placed together in ten-bird units. In dismissing the

[66] Irvin Stewart, *Organizing Scientific Research for War: The Administrative History of the Office of Scientific Research and Development* (Boston, 1948), pp. 86–87.

[67] *Guided Missiles and Techniques,* p. 198.

[68] Ibid., p. 201.

[69] Joseph C. Boyce, ed., *New Weapons for Air Warfare: Fire-control Equipment, Proximity Fuzes, and Guided Missiles* (Boston, 1947), pp. 247–48.

work, he invoked the ultimate wartime fruit of physical science and engineering by concluding that perhaps "operational problems loomed so large that the Air Forces decided they'd rather wait for the atomic bomb, which you don't have to be very accurate with."[70]

Beyond the Laboratory

With Project Pigeon over, Skinner returned to scholarly pursuits and took up a Guggenheim Fellowship to prepare a monograph dealing with verbal behavior. As he worked on the book during the 1944–45 academic year, Skinner explored other forms of behavioral technology. He built the baby-tender for his second daughter, and described it to the NDRC's Hugh Spencer as "a very different and more peaceful sort of behavioral engineering."[71] Extending his concerns to the rational management of society, Skinner drafted the manuscript for *Walden Two* during the summer of 1945, shortly before the end of the war. He later noted the connection between Project Pigeon and the book, saying "that piece of science fiction was a declaration of confidence in a technology of behavior."[72]

The details of Project Pigeon remained classified for more than a decade following the war. Unable to comment directly on this research, Skinner continued to elaborate on the insights gained from his wartime experiences. In 1947, at a symposium on current trends in psychology, he punctuated his discussion of experimental psychology by stating, "It is not a matter of bringing the world into the laboratory, but of extending the practices of an experimental science to the world at large. We can do this as soon as we wish to do it."[73] Although Skinner resumed his research program in the experimental analysis of behavior, he devoted increasing amounts of time to applied projects, most notably teaching machines.[74] In *Science and Human*

[70]Louis N. Ridenour, "Doves in the Detonator," *Atlantic Monthly* 179 (January 1947): 93–94.

[71]Skinner to Spencer, August 23, 1945, Spencer Files (n. 25 above), 15, General Mills Correspondence. In an earlier letter Skinner had thanked Spencer for recommending James Burnham's recent book *The Managerial Revolution* (New York, 1941) and commented, "My faith in the success of a managerial society will not, however, reach a maximum until scientists become better managers." Skinner to Spencer, January 31, 1944, Spencer Files, 15, General Mills Correspondence.

[72]Skinner, "Pigeons in a Pelican" (n. 2 above), p. 37.

[73]B. F. Skinner, "Experimental Psychology," in *Current Trends in Psychology* (Pittsburgh, 1947), pp. 16–49, quote on p. 24.

[74]B. F. Skinner, "The Science of Learning and the Art of Teaching," *Harvard Educational Review* 24 (1954): 86–97, and "Teaching Machines," *Science* 128 (1958): 969–77. Skinner noted "a direct genetic connection between teaching machines and Project Pigeon." See Skinner, "Pigeons in a Pelican," pp. 36–37.

Behavior, published in 1953, he took a unified approach to behavioral science and engineering. Arguing that "the methods of science have been enormously successful wherever they have been tried," Skinner proposed to "apply them to human affairs" in the form of operant conditioning techniques.[75]

In 1958, after Project Pigeon was finally declassified, Skinner chose to discuss it in a highly visible forum when he accepted the Distinguished Scientific Contribution Award from the American Psychological Association. Instead of talking about his laboratory research, Skinner presented a history of Project Pigeon, characterizing it as "a crackpot idea, born on the wrong side of the tracks intellectually speaking, but eventually vindicated in a sort of middle class respectability."[76] He claimed that his efforts to develop a pigeon-guided missile generated techniques for shaping behavior that provided the foundation for a "technology of behavior."[77]

Over the course of two decades Skinner's perspective on the relation between his scientific research and its applications had changed considerably. In the 1930s he had drawn a sharp distinction between the pursuit of scientific discovery in the laboratory and any potential practical consequences. During World War II Skinner began to link his experimental research to various technical and social problems encountered in the wartime context. By the 1950s, he had integrated the scientific and technological elements in his system and used them to advance a behavioristic view of the world.

Skinner dramatized the consequences of his wartime research in his autobiography, published thirty-five years after the event: "Project Pigeon was discouraging. Our work with pigeons was beautifully reinforced, but all our efforts with the scientists came to nothing. . . . [However,] the research that I described in *The Behavior of Organisms* appeared in a new light. It was no longer merely an experimental analysis. It had given rise to a technology."[78] Project Pigeon became

[75]B. F. Skinner, *Science and Human Behavior* (New York, 1953), p. 5.

[76]Skinner, "Pigeons in a Pelican," p. 28.

[77]Ibid., p. 37.

[78]Skinner, *Shaping of a Behaviorist* (n. 3 above), p. 274. His students Marian Breland and Keller Breland also profited from their experience and in 1947 opened Animal Behavior Enterprises, a business based on the "mass production of conditioned operant behavior in animals" for circuses and other clients. See Keller Breland and Marian Breland, "A Field of Applied Animal Psychology," *American Psychologist* 6 (1951): 202–4, quote on 202. See also Keller Breland and Marian Breland, *Animal Behavior* (New York, 1966). For a brief account of postwar research on organic control at the Naval Research Laboratory, see U.S. Naval Research Laboratory, "Project ORCON: The Use of Pigeons to Guide Missiles," in *Report of NRL Progress, August 1959* (Washington, D.C.: U.S. Naval Research Laboratory, 1959); and Skinner, "Pigeons in a

the opening wedge in what evolved into a campaign for behavioral engineering. The war provided Skinner with an opportunity to redefine the disparate problems associated with guiding a missile, raising a baby, and managing a society in terms of a common behavioral framework and to propose solutions based on techniques derived from the psychological laboratory. His wartime mechanical devices and literary constructions were designed with the same goals as his experimental apparatus: to control behavior predictably. Although Skinner's inventions received mixed reviews, he became convinced that behaviorism offered scientific methods equally applicable outside as well as inside the experimental workplace. Faced with new contingencies, Skinner changed his behavior as a scientist during the war and began to discover how the laboratory could provide significant leverage in the wider realm of human affairs.[79]

Pelican" (n. 2 above), pp. 34–36. For a review of the military uses of animals, see Robert E. Lubow, *The War Animals* (Garden City, N.Y., 1977).

[79]See Bruno Latour, "Give Me a Laboratory and I Will Raise the World," in *Science Observed: Perspectives on the Social Study of Science*, ed. Karin Knorr-Cetina and Michael Mulkay (London, 1983), pp. 141–70. In the apt phrase of one historian, Skinner remained "above all a scientific preacher," preferring to proselytize from his university post rather than become a full-time behavioral engineer. See Pauly (n. 9 above), p. 196.