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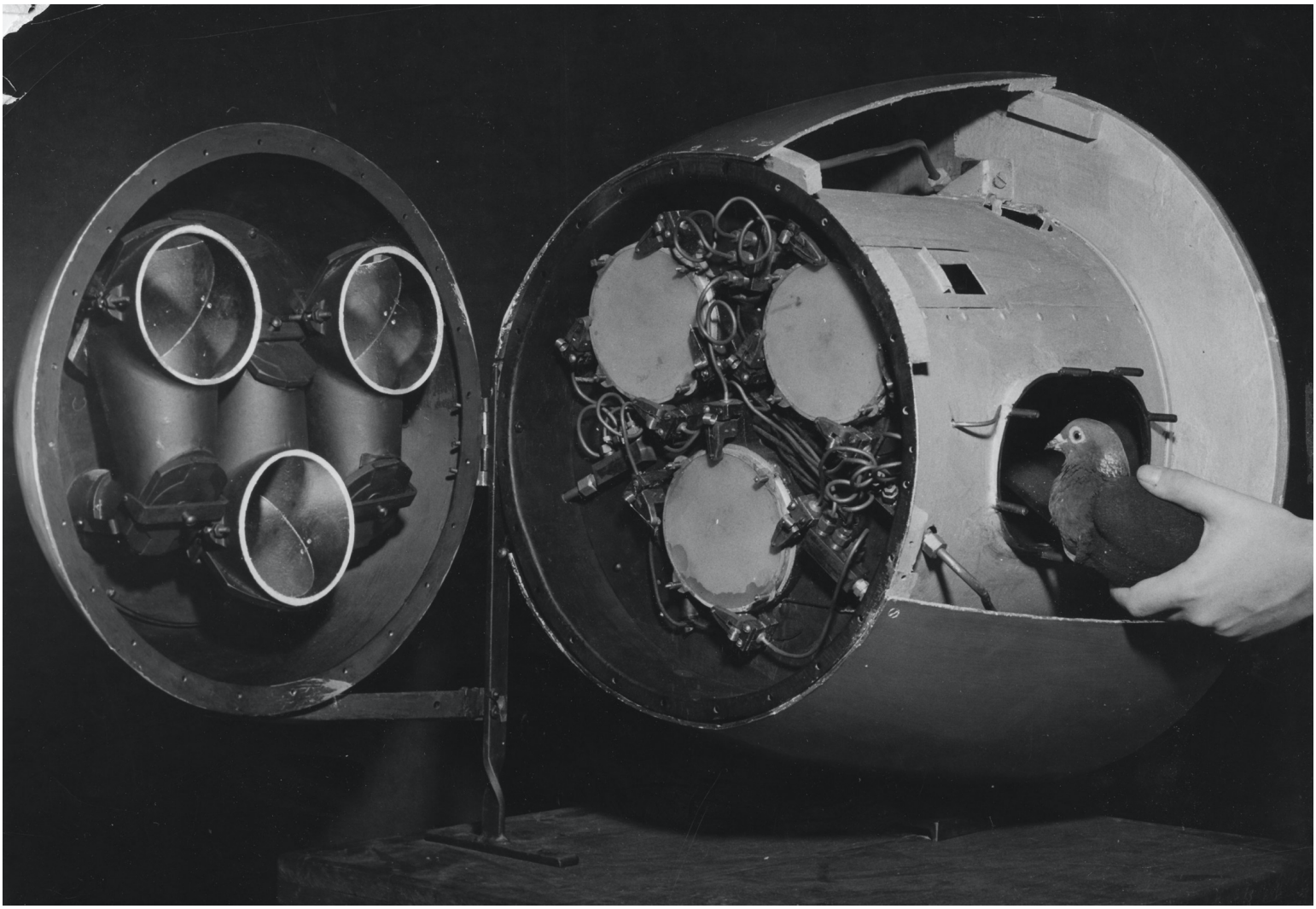

B.F. Skinner gave a demo of his prototype three-pigeon guidance system at MIT in 1944. Three specially trained birds were inserted into the nose cone of a glide bomb, where they pecked on targets projected onto screens. Two of the three birds had to agree on a course correction before pneumatic controls would adjust the bomb's steering mechanism.

B.F. SKINNER FOUNDATION

Pigeon pilots

B.F. Skinner trained birds to steer bombs. But his prototype was scrapped in favor of a bat-inspired missile guidance system developed at the Rad Lab.

by **Christina Couch, SM '15** Oct 24, 2019

As World War II raged in the 1940s, a showdown between missile guidance systems unfolded in Building 20, home of the recently established MIT Radiation Laboratory. The "Rad Lab" team was secretly building microwave radar technologies to support the Allied troops, focusing on detection: aircraft-locating technologies and target-finding explosives. But in the Midwest, the psychologist B. F. Skinner had been concocting an alternative plan: instead of building guidance technologies, why not let animals with innate homing abilities do the guiding? He began training pigeons to pilot bombs.

Skinner viewed the idea as a logical extension of years spent studying animal behavior. He had

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already conducted his now-famous rat experiments, which showed that behavior can be controlled by manipulating environmental conditions, and he knew that if complicated jobs were broken into simple components, animals given enough time (and treats) could master them piece by piece. The US Army already used trained pigeons for message delivery. Why not for bomb delivery, too?

In the months following Hitler's 1939 bombing of Warsaw, Skinner, who was then a professor at the University of Minnesota, wondered whether defensive missiles dropped from high altitudes could take out attack planes in midair. While on a train, he spotted birds flying in formation and thought the solution might be "waiting for me in my own backyard."

But first, he had to teach birds to recognize targets. Skinner cut the toe out of a sock and slipped a pigeon inside, head poking out the end. Wings restrained and legs tied with shoestring, the bird was strapped to a wooden block and placed in an apparatus attached to an electrical hoist that could

move up and down, and to a track that ran across the ceiling and down Skinner's wall. By nudging strategically placed lightweight rods, the pigeon could steer the contraption up or down, right or left.
Skinner set up a hanging bull's-eye that held a cup of grain and gradually moved the starting point of the pigeon's steering contraption away from it, eventually teaching the bird to align itself directly in front of the target as it was wheeled across the room.

Meanwhile, MIT researchers were making their own breakthroughs. Research on the microwave radar defense systems had begun at the Rad Lab shortly after the National Defense Research Committee had established it in early 1941. In 1942, NDRC's successor, the Office of Scientific Research and Development (OSRD)—which was directed by Vannevar Bush, EGD '16, a former dean of the MIT School of Engineering—launched its guided missile division at the Rad Lab.

The guided missile team focused on developing homing missiles that could be carried externally on high-flying planes.

"Project Pelican" was designed to guide a receiver in the bomb's nose cone to a

ground-based transmitter acting as a target. The Rad Lab was making radar breakthroughs in areas like navigation and air-to-surface vessel detection. But hundreds of (bomb-free) test flights later, guided missile systems were still unreliable.

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By late 1942, Skinner had requested OSRD funds for pigeon research twice, and twice had been rejected. A fellow researcher mentioned the work to executives at General Mills, and the company gave Skinner $5,000 and space in an old flour mill to develop the project so that its feasibility could be proved to the government. Skinner, several students, and a General Mills engineer began testing how restrained pigeons performed under extreme flight conditions. Upon finding that underfed birds stayed food-focused amid changes in temperature, pressure, acceleration, noise, and vibrations, they also began devising ways to turn precision pecking into precision bombing.

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The team built an apparatus to train four birds simultaneously. Each pigeon was harnessed and placed in a tight enclosure with a four-inch opening near the bird's beak. The opening contained a translucent plate with an image of a target projected from a lens outside the enclosure. Light beams formed an X where the pigeon was to strike, and as it pecked, grain dropped onto the plate. As the target moved across the field of view, pigeons moved their heads to keep pecking directly on the center of the target—and keep the food coming. (Skinner would later realize that cannabis made pigeons "almost fearless," and replaced the grain with hemp seed.) The OSRD awarded General Mills $25,000 to develop "Project Pigeon" for the Pelican, which had been designed to fly without radically changing direction. If a pigeon guidance system could move the bomb just a few degrees toward the target as it dropped, that would increase accuracy.

Skinner's team built a "multiple bird unit" with three lenses, three screens, and pressurized chambers for three restrained birds who'd been trained to recognize aerial footage of a target. Conditioned to expect that grain would eventually drop, the birds diligently pecked at targets projected onto the screens. Each screen had air valves positioned on the north, south, east, and west edges. When the target image moved

away from center (and pecking did, too), air on the opposite side of the plate was released, triggering pneumatic sensors and sending directional signals to move the glide bomb's fins. To prevent errors, two of the three birds had to agree before the system changed direction. The team built a simulator that mimicked Pelican's steering.

In early 1944, after learning that OSRD had not renewed his contract, Skinner headed to MIT to show the researchers in Building 20 what they were missing. In a live demonstration, the birds successfully followed the target, pecking fast and hard enough to keep the image within 3 degrees of the center of the screen. Reactions were mixed. While servomechanisms engineer (and future MIT Graduate School dean) Harold Hazen '24, SM '29, SCD '31, said the pigeons were "better than radar," others doubted that Skinner's test conditions accurately simulated a glide bomb in flight and said it would be too difficult to fine-tune the servomechanism linking the pecking to the steering. Instead of convincing OSRD to renew Project Pigeon's funding, the demo proved what Skinner himself had once observed: "A pigeon was more easily controlled than a physical scientist serving on a committee."

Project Pigeon was shelved in favor of another promising animal-inspired bomb. In

May 1944 a team led by the National Bureau of Standards, including a Rad Lab research group headed by Ralph Lamm and Perry Stout, began testing the "Bat" bomb—a missile that emitted electrical radiation and used echolocation to estimate distance from a target. It went on to become the first fully automatic guided missile deployed in combat.

Experimental psychologist Franklin V. Taylor, who was then running the Naval Research Lab in Washington, DC, briefly rebooted Project Pigeon in 1948 after seeing a film of Skinner's bird pilots. His team attached gold electrodes to the pigeons' beaks and projected the target images onto conductive screens that transferred their pecks into electronic signals, replacing the pneumatic controls. But the project was canceled in 1953 as other electronic guidance systems became more reliable.

Although pigeon-guided bombs never took flight, Skinner stood by the research. "Call it a crackpot idea if you will," he wrote in a summary of the project published in 1960. "It is one in which I have never lost faith."

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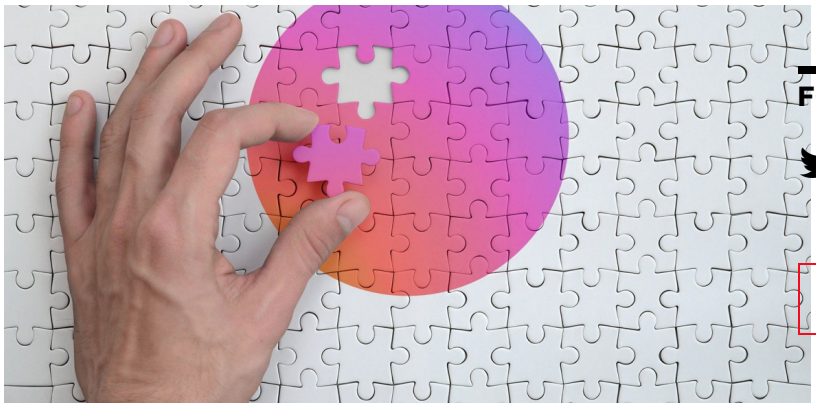

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