The A-1C(M) Gunsight: A Case Study of Technological Innovation in the United States Air Force

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(Overleaf) The F–86 Sabre was the U.S. Air Force's primary air superiority fighter in Korea. The E model shown here, entered service in May 1952 equipped with J-1 fire control system consisting of the A-1C(M) lead-computing gunsight and the AN/APG-30 ranging radar. (National Archives)

The A-1C(M) lead-computing sight was the first fighter gunsight to employ radar ranging. It was widely used in Korea where it received a mixed reception by the F–86 pilots who depended upon it. Many of the younger, less experienced pilots found it a godsend, while the veterans, particularly some aces of World War II, considered it unreliable and much too complicated—particularly its radar. Nevertheless, the introduction of the A-1C gunsight was an important milestone in the development of sophisticated fire control equipment for air-to-air combat.

The story of the A-1C provides evidence of the importance of the heterogeneous engineer in developing new technology and the impact of "innovative departure" on the users of a new weapons system. It also provides insight into the non-technical problems that often arise when a new weapons system is introduced.

EARLY BIRDMEN PREFERRED TO FLY "BY THE SEAT OF THEIR PANTS"

Ever since the early days of flight, seasoned pilots have often objected to the introduction of new flight instruments. The Wright brothers found it difficult to get their own student pilots to utilize such aids because of the negative connotation that the reliance on instruments elicited from the early birdmen who preferred to fly "by the seat of their pants."[1] Though the Sperry turn indicator had become standard equipment on most large aircraft by the mid-1920s, many pilots refused to rely on it.[2] Nor did most pilots trust the artificial horizon when it was first introduced a few years later. It took more than a decade before a majority of pilots had learned to trust these devices. The jet age brought new problems for pilots, especially with regard to air combat, which now took place at a pace much greater than ever. It also brought about a widespread reliance on radar and other electronic aids. As was the case in earlier years, the most experienced pilots proved to be the least receptive to the new technology.

THE MOST EXPERIENCED PILOTS PROVED TO BE THE LEAST RECEPTIVE TO THE NEW TECHNOLOGY

Genesis of the A-1C(M) Lead Computing Gunsight

Lt. Col. Leighton I. Davis was nearing the end of his second tour of duty at the U.S. Military Academy at West Point, New York, in April, 1943, when he received orders to command a fighter-bomber group composed of North American A–36s that was about to deploy overseas. He flew to Alabama in advance to meet his new boss and to look over the A–36—the ground attack version of the P–51 Mustang. "I was amazed to see that they still had ring and bead sights in the middle of the damn thing," exclaimed Leighton when he recalled the event in later years.[3] It was the same sight used in the P–12s that he had flown in 1936. Nothing new had been added to assist the pilot in his main mission: gunnery and dive bombing.

After returning to West Point, Davis journeyed to Norfolk to meet with Dr. Charles S. Draper of the Massachusetts Institute of Technology (MIT) to discuss the possibility of adapting the Navy's Mark-14 gyroscopically-controlled gunsight (developed by Draper) to dive bombing and aerial gunnery.[4] Davis knew about the work being done on gyroscopic sights having studied under Draper while completing his Master of Science degree in Aeronautical Engineering at MIT in 1940-1941. With input from Draper, Davis prepared a technical report on how a gyro computing gunsight could be used as a dive bombsight. His commanding officer, Col. John M. Weikert, who just happened to be a friend of Gen. Henry H. "Hap" Arnold, sent the report to Wright Field, Ohio, where it was analyzed by John E. Clemens. Davis's report must have been favorably endorsed by Wright Field, because Arnold, Commanding General of the U.S. Army Air Forces (AAF), had Davis's orders changed, sending him instead to the Armament Laboratory at Wright Field to work on a lead computing gunsight for dive bombers.[5]

The Education of an Engineering-Oriented Pilot

Leighton I. Davis was born in Sparta, Wisconsin, on February 20, 1910. He graduated from high school in Dawson County, Montana, in 1927 and entered the U. S. Military Academy in 1931. Davis graduated on June 12, 1935, and received a commission as a second lieutenant in the Corps of Engineers. Next, Lieutenant Davis was detailed to the Air Corps and sent to Randolph Field, Texas, for flight training. He proceeded to Kelly Field for advanced training in P–12s, earned his wings, and transferred to the Air Corps on October 1, 1936.[6]

Davis's first tactical assignment was as an engineering officer with the 6th Pursuit Squadron stationed in Hawaii. The squadron was equipped with the Boeing P–12, an open cockpit biplane with fixed landing gear that was the primary fighter in the Air Corps inventory in 1936. In addition to his flying and engineering duties, Davis was also assistant trial judge advocate, assistant athletic director, and assistant communications officer. The latter would later prove to have been a serendipitous assignment for the young officer, for it familiarized him with the cathode ray oscilloscope: a state-of-

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1st Lt. Leighton I. Davis taken at the U.S. Military Academy while he was an instructor there in 1940. *(U.S. Military Academy Archives)*

DRAPER FOUNDED THE INSTRUMENTATION LABORATORY, WHERE HE … EXTENDED THE LAB'S RESEARCH TO ALTIMETERS, AIRSPEED METERS, MAGNETIC COMPASSES, AND OTHER AIRCRAFT INSTRUMENTS

the-art electrical device that provided a picture of an electrical signal plotted against time. As assistant communications officer, Davis ran across a corporal who had brought his personal electrical equipment with him, including the oscilloscope. Davis doesn't tell us what the corporal had done as a civilian, but it is likely that the corporal had been involved in some sort of electronic endeavor before he was forced to join the Army to support himself. This situation was not uncommon during the Great Depression, when all sorts of people enlisted in the armed forces in search of a living.

"Tell me how all those radios and things work," Davis asked the corporal.

"Well, the best way is [to] build one," he replied.

So, Davis scrounged up some parts from a local repair shop and built an RF-tuner, plus a hi-fi push-pull triode circuit. He had a lot of fun building the equipment, which was then hooked up to the oscilloscope in order to show Davis how the various circuits worked. [7]

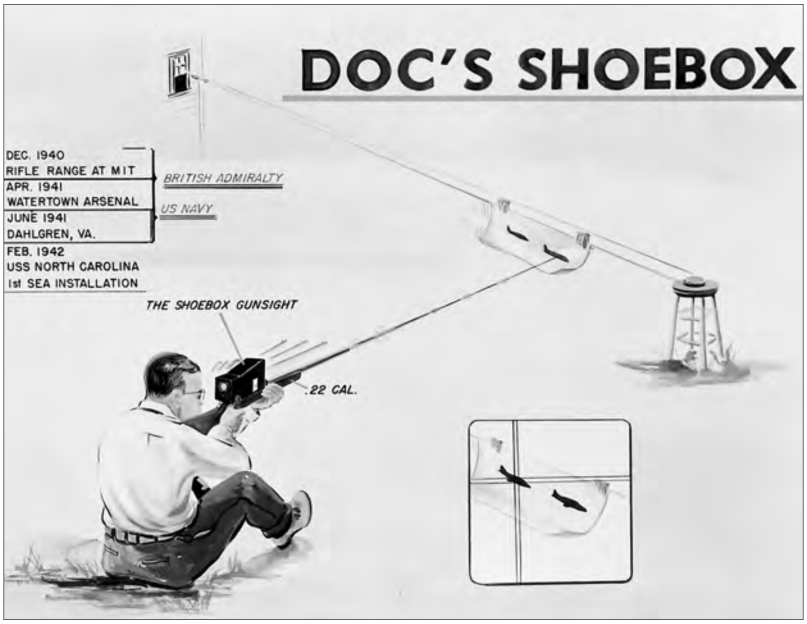
After two years in Hawaii, Davis received orders to attend the Air Corps Tactical School at Maxwell Field, Alabama. His orders were changed after someone in charge of assignments discovered that Davis had achieved good grades in the mechanics course at West Point, making him the ideal candidate to replace Maj. John Weikert, who had been teaching the course.[8] Air activities were on the rise at West Point and Weikert, the senior Air Corps officer at the Academy, was slated to take command of Steward Field where the cadets received training and indoctrination in aviation.[9] In January 1939, Davis returned to the U.S. Military Academy, as an instructor in the Department of Natural and Experimental Philosophy, which was then responsible for teaching such basic engineering subjects as statics, kinetics, kinematics, hydraulics, elementary thermodynamics, and aerodynamics.

Davis's teaching duties involved the thermodynamics laboratory where a variety of engines—diesel, gasoline, and steam—were used to demonstrate the fundamental principles of thermodynamics. The steam engines had engine indicator diagrams that could trace out the pressure-volume relationship occurring inside their steam cylinders. The indicator was a mechanical device that would not work in an internal combustion engine because of the faster moving pistons. From the experiments he had conducted in Hawaii, Davis knew that an oscilloscope could be used to plot the physical parameters taking place during high-speed phenomena such as occurred within the cylinder of an internal combustion engine. After talking it over with the other instructors, Davis decided to visit the Dumont Laboratories, one of the leading companies in the oscilloscope business.[10] Dumont, which was located in Passaic, New Jersey, was only a few hours drive from West Point.

Because Davis was on the staff at the U.S. Military Academy, he was able to get in and talk to Dumont's chief engineer. The engineer was not able to help with Davis's problem, but he knew about the work being done on a crystal pickup by the Radio Corporation of America (RCA). He suggested that Davis talk to them. So, Davis drove to Camden, New Jersey, where the RCA research and development laboratory was located. Once again he managed to wangle his way in and talk to the engineers. They had a pickup, but it was too sensitive and more of a vibration pickup than a pressure sensor. The RCA engineers suggested that Davis contact the Sperry Gyroscope Company, where a researcher—who worked under Dr. Draper—had developed an electromagnetic pickup.[11] The "pickup" they were referring to was part of the detonation indicator for internal combustion engines that Draper had developed at the MIT Instrumentation Laboratory.[12]

Draper, who was born in Missouri on October 2, 1901, first came to MIT as student in 1922. He graduated four years latter with a bachelor's degree in electrochemical engineering. Draper continued his studies at MIT, earning a Master of Science degree in 1928. He then began work as a research assistant in Charles F. Taylor's aeronautical engine lab and became involved in studies of the internal combustion engine that led to the development of the MIT "Knockmeter." In 1934, Draper founded the Instrumentation Laboratory, where he and a small team of graduate students and assistants, extended the lab's research to altimeters, airspeed meters, magnetic compasses, and other aircraft instruments, while continuing to work on the problem of measuring detonation or "knock." The latter led to a patent for a device called the detonation indicator that could be used with aircraft to prevent engine damage. The patent was signed over to the Sperry Gyroscope Company, which had put up money to develop it.[13]

The Sperry engineer that the RCA folks had referred to was Joseph H. Lancor. Davis contacted Lancor through Frederick W. Castle, a former Air Corps pilot, who was employed at Sperry as assistant to the president.[14] The following is Davis's rec-



Davis arranged for Draper to use the Watertown arsenal that day and was present when Draper used the Shoebox against the moving target. ***(The Charles Stark Draper Laboratory, Inc. All rights reserved. Reprinted with permission.)***

ollection of what transpired when he finally met Lancor:

We sat down and talked about the problem [of plotting the cylinder parameters in real time]. He pulled out of the desk a little metal thing about the size of a spark plug, which was the pickup that you screw into the cylinder head if you have an extra spark plug hole like in aircraft engines where you have two spark plugs. Or otherwise you make an adapter, and then drill a hole and fit it in the place to get at the pressure inside the cylinder head. He says, "Well, this puts out a signal which is rate of change or pressure. You've got to integrate it, make an integrating circuit, in order to get what you want, which is pressure-time. Then you have to have a representation of volume, of course. Why don't you see what you can do with it." He handed the thing to me, and so I took it back up to West Point and talked with the electrical engineering instructors trying to figure out what an integrating circuit was.[15]

DRAPER'S DEVELOPMENT WORK ON THE ANTIAIRCRAFT GUNSIGHT, … NICKNAMED "DOC'S SHOEBOX," COINCIDED WITH DAVIS STUDIES AT MIT

Davis borrowed an amplifier and an oscilloscope from the electrical engineering department. He began fooling around with the equipment in the thermodynamics laboratory until he got it to work. Davis made photographs of the oscilloscope traces and sent them to Joe Lancor. Lancor forwarded them to Draper, at MIT, where they were enthusiastically received. In June, Draper came down from Boston to take a look at Davis's setup. He spent a week with Davis as his house guest, while they made changes to the circuits, took pictures, and worked on a joint paper that would later be published in the *Journal of the Institute of Aeronautical Sciences* titled, "Electromagnetic Engine Indicators." It was co-authored with Joe Lancor.[16]

This activity led to Davis's assignment to MIT for a year of graduate study in aeronautical engineering under Draper. It also brought him in contact with Draper's early work on a gyroscopic gunsight. Draper's involvement in the gyroscopic gunsight emerged from his interests in gyroscopic flight indicators and his long-term association with the Sperry Gyroscope Company. He had been consulting on aircraft instruments for Sperry for several years and had close contacts with Chief Engineer Preston Bassett, President Reginald Gillmor, and Director of Research Hugo Willis.[17] During this period, Sperry was actively involved in the development of fire control systems for the military. After war broke out in 1939, Draper began to build a device to compute lead angles for tank guns by adapting a gyroscopic turn indicator he had developed. In June 1940, Draper, with funding provided by the Sperry Gyroscope Company, turned his attention to antiaircraft fire control.[18]

Draper's development work on the antiaircraft gunsight, which lab personnel nicknamed "Doc's shoebox," coincided with Davis studies at MIT during the 1940-1941 academic year.[19] In April 1940, Davis arranged for "Doc" to make use of the facilities at the Watertown Arsenal in Massachusetts, to test the "little black box that "Doc" had mounted on a .22-caliber rifle.[20] Draper used this engineering model—it had mechanical indices directly coupled to the gyro gimbal frame—to shoot at a moving target traveling along a wire.[21] Davis, who was present that day, picked up the fundamentals that would later lead to the development of the A-1C.[22] The black box, with the moving cross hairs, evolved into the famous Mark 14 naval gunsight for 20mm antiaircraft guns and was later incorporated into the Mark 51 director for the 40mm Bofors gun.

Davis received his master's degree from MIT in the spring of 1941, and returned to West Point as a mathematics instructor. When the United States entered the war, he was director of the ground school and was kept on for another year. As described earlier, he was nearing the end of his second tour when he received orders to command the A–36 group, which ultimately led to the idea for a new gunsight.

Initial Development Work of the A-1 Gunsight

After getting his orders changed, Davis was assigned as Project Engineer, Bombing Branch, Engineering Division at Wright Field. That summer, a Mark 14 sight was modified and mounted on an A–24 dive bomber.[23] Good results were obtained and a contract was let with MIT to develop an experimental computing sight that could be used to direct gunfire, rockets and bombs from fighter aircraft.[24]

The first experimental model completed by the lab computed only the dive bomb solution.[25] Designated as the A-1 sight, it was installed in a P–38 and tested by Davis in early summer 1944, on the bombing range at Grenier Field, New Hampshire.[26] Davis dropped dozens of bombs as he struggled to overcome the problem of tracking stability and solution time. As Davis discovered, the sight was unable to provide a proper solution to the ballistic problem on steep dives, causing a condition that Draper had previously termed "tracking insta-

Cockpit photograph of North American F–86A Sabre taken on July 26, 1950, showing cockpit instruments and A-1C(M) gunsight. The A-1C(M) was added to the second production run of F–86s. ***(National Archives)***

THE TESTS CLEARLY DEMONSTRATED THAT THE A-1 WAS SUPERIOR TO THE FIGHTER SIGHTS THEN IN USE

bility." The phenomenon occurs whenever the rate of change of the lead angle changes faster than the motion of the sight line. At steep dive angles that Davis was attempting, the P–38 had minimal directional stability making it very difficult for the pilot to keep the sight's crosshairs on target long enough to establish an accurate bombing solution. The answer was to decrease the dive angle.

Flight testing of the second experimental sight, which could be used for both bombing and gunnery, was conducted that summer at Eglin Field, Florida. The tests clearly demonstrated that the A-1 was superior to the fighter sights then in use.[27] The A-1 could compute leads accurately at ranges up to 2,000 yards and solve bombing problems up to an altitude of 10,000 feet, at dive angles between 15 and 60 degrees.

Postwar Engineering and the Development of the A-1C(M)

World War II ended before the new sight could be placed into production. After the end of hostilities in August 1945, the AAF authorized the installation of A-1 sights in the Republic P–84 jet fighter then under development. Additional funds for the A-1 project were approved for test flights in P–80A aircraft. The purpose of the tests was to determine what modifications to the sight would be necessary and how well it would operate with a ranging radar.[28]

By then, Davis was no longer directly involved with the project, having been promoted to technical executive of the Armament Laboratory. He took over the lab in 1946. In the following year, he was awarded an oak leaf cluster to the Legion of Merit (which he had received for his work on the development of the electronic pressure sensor) for developing the A-1 gunsight. Davis spent the next twenty years in a variety of research and development positions within the Air Force. He retired in 1968, with the rank of major general and died in 1995.

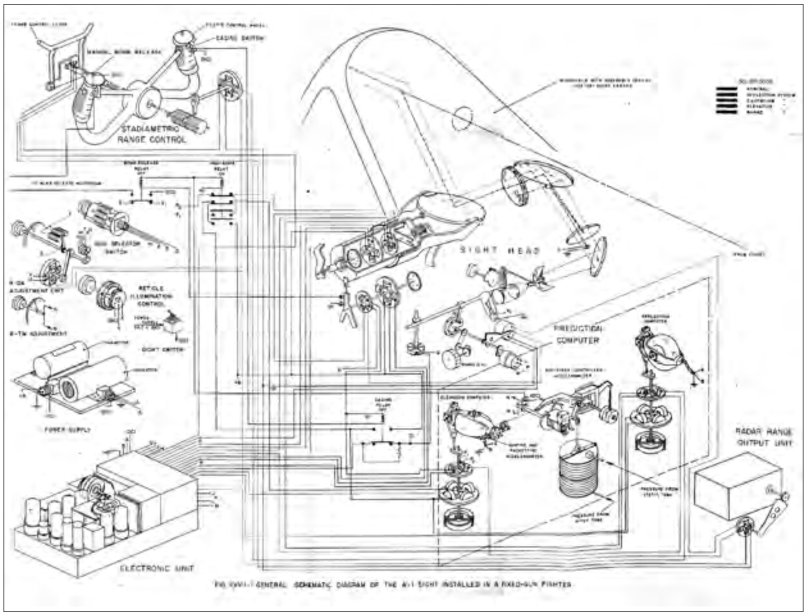
In March 1948, the Air Force decided that both the F–84 and F–86 would be equipped with the newest version of the A-1 sight, the B model, which was considered to be the most accurate lead computing sight available to the Air Force.[29] Its radar set could lock-on a target at 5,400 feet range. The pilot then checked visually to ensure that he was locked on to the proper target (if not, he pressed a target rejection switch and maneuvered until the radar locked onto the target desired) and "caged" the sight's gyros by pressing a button on the control stick grip. After placing the reticle dot on the target and releasing the caging button, the pilot had to keep the reticle on target for one-half to one second (the time needed by the sight to solve the ballistic problem) before opening fire in one-second bursts.[30]

Due to ground clutter, manual range was utilized when either the radar was inoperative or the aircraft was below 5,000 feet. Manual ranging was stadiametrically set by entering the target's wingspan on the sight head target span wheel and rotating the range control on the throttle grip until the reticle contracted to its minimum diameter. As in radar ranging, the pilot pressed the electrical caging button and maneuvered the aircraft so that the reticle dot—called the pipper—was on target. He established a smooth track and, when the target's wingspan filled the ranging circle, uncaged the gyros, waited a split second (one solution time), and began firing. If the computing or radar circuits of the sight were inoperative, the pilot could cage the sight mechanically with a lever on the sight head and use the fixed reticle for rule-of-thumb gunnery.[31]

During the fall of 1948, preliminary firing tests in F–84 and F–86 aircraft, revealed a problem that persisted throughout the life of the A-1 sight program—reticule jitter. Whenever the pilot pressed the firing button, the vibration of the guns either drove the sight reticle entirely from view or caused it to oscillate so rapidly that it became an orange blur.[32]

Flight tests to determine the best method of reducing reticle vibration to an acceptable level began at Muroc [later Edwards] AFB, California, in January 1949. The Sperry Gyroscope Company, which had been contracted to manufacture the first ninety-four A-1B sights, came up with a "fix" consisting of stainless steel stiffeners for the sight head mounting brackets. This reduced vibration considerably, but did not totally cure the problem.

That April, Sperry Gyroscope and the AC Spark Plug Company, which also built the A-1B sight, both agreed to produce 551 A-1C sights, with improved computing features, for the F–86A, F–86D, and F–94 aircraft. Full-scale production was scheduled to begin in August 1950, but the Air Force suspended deliveries of all A-1C sights until some method was found to make the sights more usable in the field. After a short period of review, the Air Materiel Command (AMC) authorized Sperry to modify thirty-five A-1C sights by provid-



Schematic diagram of the A-1C lead-computing gunsight. The sight computed kinematic lead based on the input from two internal gyroscopes based on range information supplied automatically by external radar, or manually via stadiametric control. ***(National Museum of Electronics)***

ing a more efficient sight head and computer heating system, a brighter reticle, and special stiffeners to reduce reticle vibrations. The result was designated as the A-1C(M). After the modifications proved successful, the Air Force ordered that all A-1 sights in the field be returned for conversion to the new configuration. By then, several different combinations of the gunsight and its radar had been installed in various versions of the F–86A Sabre coming off the production line at North American Aviation.[33]

The A-1B gunsights, with the AN/APG-5C radar, were provided as factory installed equipment beginning with the third production run of 333 F–86A's starting with aircraft serial number 49-007. All earlier production versions of the aircraft had been equipped with the K-18 sight. The last twenty-four aircraft of this production run were equipped with the A-1C(M) gunsight, coupled to an improved ranging radar, the General Electric built AN/APG-30 installed in the nose above the intake.[34] The A-1C(M) sight and the AN/APG-30 ranging radar were to be retrofitted to earlier models in field installations. Radar production of the APG-30 manufactured by General Electric was inadequate to meet all of the service needs, however. Thus by the end of the Korean conflict, a considerable number of F–86As still contained older fire control equipment; some had A-1B or A-1C sights plus APG-5C ranging radars or earlier versions of the APG-30.[35]

GEN. OTTO P. WEYLAND,… FELT THAT THE A-1C(M) HAD NOT RECEIVED A FAIR TRIAL

The A-1C(M) Takes on the MiG–15

The first Sabres to arrive in Korea were the F–86A models, equipped with K-18 sights. These sights were soon found to be unsuited for the high-speed combat that ensued when MiG–15s were engaged. The K-18 was a modified version of the K-14 gyro gunsight developed during World War II. Unlike the A-1C(M), it was dependent upon manual range control that was much too stiff and erratic.[36] Tracking at the high indicated air speeds encountered in Korea was difficult with the K-18: excessive movement of the reticle occurred when guns were fired, and a boresight speed of 357 knots made the sight useless when the enemy was pursued at indicated speeds of over 500 knots.

Most aviation historians of the air war in Korea agree that the A-1C sights were far superior to those on the MiG–15 and gave the American pilots a great advantage—when it worked. Although the A-1C and its radar differed radically from the gunsights it superseded, spare parts, spare components, and test equipment did not reach the Far East until mid-1951.[37] Both gunsight and radar were beset with a multitude of maintenance problems, some due to rough runways, which jarred delicate electronic components, but even more to a dearth of trained personnel and the necessary test equipment to keep the system operational. Keeping the radar operational proved particularly daunting. It did not take long for maintenance personnel to discover that once an electronic component failed the entire radar had to be replaced—not just the faulty module.[38] There were other problems with the radar too. It performed erratically in clouds (due to moisture), sometimes would break radar lock, and would not work below 6,000 feet due to ground clutter.[39] All of the above, combined with a general lack of pilot training in the proper use of the sight, soon led many of the Sabre pilots to become disenchanted with the A-1C sight. As a result, many of them favored the clearly inferior, but dependable, K-18 sight, which continued in general use until the arrival of the F–86E, beginning in June 1951.[40] Others caged the A-1C's gyro to eliminate radar and gyro inputs, turning it into a fixed gun sight.[41] The problems with the A-1C sight proliferated until the director of operations for the Fifth Air Force declared it was "too complicated to be maintained."[42]

Gen. Otto P. Weyland, commander of the Far East Air Forces (FEAF), felt that the A-1C(M) had not received a fair trial. At his request, AMC initiated an all-out remedial program (named Project Jaybird) to fix the problem. In April 1952, a team of personnel from the AMC and the Air Training Command (ATC), together with civilian technical representatives, arrived in Korea to resolve the supply and maintenance issues and to upgrade all A-1C sighting control systems (now designated as the J-1 fire control system) to the latest configuration. By the end of June 1952, the AMC team completed its work and ATC had begun to turn out the technicians needed to maintain the gunsight and its radar.[43]

The A-1C(M) sight had been designed to automatically compute lead at ranges up to 1,500 yards. The excessive "time of flight" required for the sight's computer to provide a ballistic solution at this relatively long range caused the sight to be more sensitive to aircraft motion at longer ranges. Because of this, inexperienced pilots found it difficult to keep the pipper on the target as they tried to maneuver closer to a highly evasive MiG–15. This led to the development of the Jenkins Range Limiter. The limiter consisted of a range selector switch and a sensing device that prevented the radar range signal from exceeding the value selected by the pilot. This selector switch allowed the pilot to select his maximum desirable firing range before initiating the attack. When the radar indicated a range in excess of the selected value, the selected value was fed to the computer limiting the time of flight input so that the sight was less sensitive. When the radar range equaled or was less than the selected range, the radar value was fed to the computer. A change in reticle configuration simultaneously occurred, indicating to the pilot that he had reached the range selected to begin firing.[44]

GABRESKI DID NOT LIKE THE A-1C SIGHT. HE OFTEN CLAIMED THAT HE "COULD DO BETTER WITH A PIECE OF CHEWING GUM IN THE WINDSHIELD"

Despite these fixes, the Air Force debated whether or not to retain the J-1 fire control system, described by some as 200-pound "luxury gadgets."[45] There was a wide divergence of opinion within the fighter pilot community as to the value of such a complex system. In summer 1952, Gen. Hoyt Vandenberg, the Air Force Chief of Staff, queried a group of fourteen veteran Sabre pilots, whose combat tours had coincided with the first combat use of the A-1 sight, when its performance was marginal at best. (This was before Project Jaybird was implemented in April 1952, to rectify the sight's logistics problems.) The pilots recommended that the A-1C(M)s be replaced with a manual ranging gyro-computing sight similar to the K-14 or K-18. General Vandenberg directed both the Air Proving Ground Command and the FEAF to evaluate the two types of sights.[46]

Accordingly, the Fifth Air Force convened a seminar of aces from the 4th and 51st Wings on September 11, 1952. All of the current aces—mostly younger pilots who had arrived in Korea after the veterans had rotated home—agreed that the automatic features of the A-1 gunsight should be retained. They recognized that most MiG kills were obtained from low deflection shots, but all of the pilots attributed this to the short-range guns on the Sabre. With improved armament (the T-160 20mm cannon was about to be introduced) they predicted, deflection shots would become more usual. It was true, they said, that superior pilots would probably do well with a Mark 18 sight, but in any future conflict they foresaw that the burden of air combat would fall upon younger pilots who would have neither the experience nor the training that would make them superior gunners.

While the Fifth Air Force seminar was convened, the Air Proving Ground Command began to assemble a team of veteran pilots—six of whom were veteran aces who had flown in Korea—to conduct a comparison test of the two sights at Eglin AFB.[47] The effectiveness of the two sighting systems was to be determined, in part, by a series of camera gunnery passes using six F–86Es: three equipped with the K-14 sights and three with the new A-4 sight. The latter was substituted for the A-1C, which was no longer in production. The general procedure was for the target to maintain 0.8 Mach at 35,000 feet altitude and the attacking aircraft to make moderately high side approaches. The target would take moderate evasive action as the attacking aircraft neared the anticipated firing range.

Col. Francis S. "Gabby" Gabreski, considered by many to be a "fighter pilot's pilot," was the senior member of the team.[48] He was flamboyant, heroic, and had been the leading U.S. fighter ace in the European Theatre during World War II. In June 1951, Gabreski, then in command of the 56th Fighter Interceptor Wing, was posted to Korea. He flew 123 missions in the F–86E and was credited with an additional 6 1/2 MiGs, making him one of only six U.S. Air Force pilots to have achieved the distinction of becoming an ace in both conflicts.

But Gabreski has been chastised for ignoring his wingmen. He flew the fastest aircraft available and would not respond when wingmen could not keep up.[49] He was also criticized for a lack of discipline among his off-duty pilots, and for allegedly encouraging exaggerated kill claims.

Gabreski did not like the A-1C sight. He often claimed that he "could do better with a piece of chewing gum in the windshield," which he may have used in place of the A-1C on more than one occasion.[50] He came to Eglin to prove that the K-14 would show much better results.[51] During the flying portion of the project, Gabreski, using the K-14, was paired against Col. James K. Johnson, using the A-4. Johnson, called "Rabbit" because of his quickness as a pilot, was one of the test pilots chosen to replace two of the original test team selectees who had not arrived in time for the fly off. He had yet to fly in Korea where he would become a double ace, but he was an experienced combat veteran of World War II.

Before taking off, Johnson asked Gabreski where he wanted the pipper to be. He had to badger the unresponsive ace for an answer. Gabreski finally said, "Just put the pipper on the cockpit!"[52] Johnson was an extremely smooth pilot who made good use of the A-4. When the gun camera films came back, almost every frame showed Johnson's pipper right on Gabreski's cockpit.

When Gabreski's turn came to be the attacker he told Johnson to "hold it" so that he could bore sight the camera that was rigged through the K-14. As soon as he was lined up on Johnson's tail he triggered the gun camera and radioed "fights on." When Gabreski's film was developed Johnson's tail pipe was in the center of the first few frames, after that, all you saw was sky, because Gabreski was not able to get in another shot at Johnson once he started to maneuver defensively.[53]

After the tests were completed, Gabreski's team of veteran pilots still wanted to "do away with the radar ranging and the intricate, highly complicated electronic equipment."[54] The commander of the Air Proving Ground Command, Maj. Gen. Patrick W. Timberlake, was not persuaded by the team's recommendation to remove the APG-30 from the existing F–86Es. A second report based on a comprehensive analysis of in theater gun film showed otherwise.[55] "Extensive analysis of combat gun camera file," he wrote in his summarization of

The A–36 was a ground attack version of the North American P–51 Mustang fighter. It was armed with six .50-caliber machine guns and had racks on each wing for one 500-lb bomb. The A–36 was used during World War II in North Africa and Italy. *(National Archives)*

the two project reports, "establishes the fact that despite popular opinion to the contrary, the bulk of the firing in combat is conducted at ranges and angles off in excess of *1,500 feet* and 10°. Furthermore, pilots with two or more "kills" during their tour showed *no* firing under 1,200 feet in the film available for assessment."[56] Under these conditions, the Air Proving Ground Command's analysis showed that the kill probability using the A-4 sight with radar ranging was twice that attained with either the A-4 or K-14 with manual ranging.

The Air Proving Ground Command's conclusion was in keeping with the views espoused by the Fifth Air Force, whose commanders believed that the fourteen aces queried by General Vandenberg were probably not well-trained in the use of the radar ranging gunsight and had served in Korea when the gunsight reliability problem was at its worst. Those who had some training with the sight or familiarity with radar were less critical and saw its value.[57]

THE HETEROGENEOUS ENGINEER IS A VISIONARY; …WHO UNDERSTANDS THE TECHNOLOGY…AS WELL AS THE SOCIAL, POLITICAL, AND CULTURAL RAMIFICATIONS

Although AMC later concluded that the decision to introduce the A-1C had been somewhat premature, its use in Korea provided the U.S. Air Force with invaluable experience on the practical problems of radar based fire control systems for air-to-air combat.

The A-1C(M) as an Example of Technological Change within the Military

As a case study of a new weapons system, the development and introduction of the A-1C(M) gunsight supports two widely held theories about innovation that are often discussed in discourses on new technology and the military. The first, and perhaps the most obvious, is the concept of the "heterogeneous engineer." The heterogeneous engineer is a visionary; the sort of person who understands the technology of an innovation as well as the social, political, and cultural ramifications that go along with it.[58] He is usually the project champion, sometimes referred to as the innovation advocate.[59] In addition to technical acumen, the heterogeneous engineer must be capable of building social networks. To be successful he has to gain the support of his superiors and motivate them to provide the resources needed to fulfil the project's goals. General Davis clearly played this role in the case of the A-1C(M). A gifted engineer and an experienced fighter pilot, he had both the technical and cultural knowledge needed to develop a new gunsight. In addition, he had the respect and support within the Air Force and the scientific community enabling him to obtain the resources necessary for the A-1C development program.

The second theory supported by the case study of the A-1C(M) is what Ronald J. Kurth called innovative departure, which he describes as a "radical departure from the technology supporting existing weapons systems."[60] Innovative departures are of particular interest to those seeking to promote technological change because they threaten to replace or render obsolete the technology upon which a way of life has grown. Because they can alter the status quo between or within career groups, they can be quite disruptive. In the case of the A-1C, the older, more veteran air aces had the most to lose. As an elite fraternity within the Air Force, their status depended upon their skill in downing enemy aircraft—skills that took many missions and combat encounters with the enemy to perfect. In the hands of a pilot trained to use it, however, a properly functioning A-1C(M) with its radar ranging gunsight made it easier for a skillful pilot (a good stick) with less combat experience to make a "kill." This was exemplified by the experience of 2d Lt. Robert F. Low, who became the seventeenth and most junior air ace on June 15, 1952, just six months out of flight school. Low's success and the reasons behind it were chronicled by aviation historian Robert Dorr: "unlike older pilots, who had to change with the advent of new technologies, Low had no trouble learning how to use the A-4 automatic gunsight on the F–86E and later Sabres."[61]

As with all technologies, technical change, and social change are intertwined. It is hoped that the example of the A-1C provides the Air Force community with a better understanding of the problems and obstacles inherent in developing any new technology. ■

NOTES

1. Scott McCreddie, "Balance, When Pilots Lose Their Sense in The Air," *Lost Magazine*, No. 24, May 2008, http://www.lostmag.com/issue24/balance.plp.
2. *Ibid*.
3. Leighton I. Davis, "Interview Conducted by Maj. Lyn R. Officer and Hugh Ahmann," Burbank California, Apr. 26, 1973, U.S. Air Force Oral History Program, IRIS No. 00904753, [hereafter Davis Interview], p. 13.
4. Leighton I. Davis, "Military Significance of Draper's Work for the Air Force," *Air Space and Instruments*, edited by Sidney Lees (McGraw-Hill, 1963), p. 7.
5. Davis Interview, p. 14; Davis, "Military Significance of Draper's Work," p. 7.
6. Sources of biographical and service data: "Lieutenant General Leighton I. Davis," *U.S. Air Force Military Biographies Annual, 2004*; Davis, Leighton Ira, Biographical Study of General Officers, 1917-1952, Air Force Historical Studies Office, Bolling AFB, Washington, D.C.
7. Davis Interview, p. 6.
8. *Ibid*., p. 4.
9. Major General John Mauurice Weikert, Air Force Link Biographies, www.af.mil/bios/bio.asp?bioID=7539
10. Davis Interview, p. 6.
11. *Ibid*., p. 7.
12. William G. Denhard, "The Start of the Laboratory: The Beginnings of the MIT Instrument Laboratory," *IEEE AES Systems Magazine*, Oct., 1992, pp. 8-9; Stuart Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (Columbia University Press, 1993), p. 80
13. *Ibid*.
14. Davis Interview, p. 7. Note: Frederick W. Castle re-entered the armed forces in World War II, achieved the rank of Brigadier General, and was posthumously awarded the Medal of Honor.
15. *Ibid*., p. 8.
16. *Ibid*., pp. 8-9; Davis, "Military Significance of Draper's Work," p. 6.
17. David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing Before Cybernetics* (Johns Hopkins University Press, 2002), p. 178.
18. *Ibid*., p. 177.
19. *Ibid*., p. 179.
20. Davis interview, p. 12.
21. Robert C. Seamans, Jr., "Past, Present, and Future," *Air and Space Instruments*, edited by Sidney Lees (McGraw-Hill, 1963), p. 11.
22. Davis, "Military Significance of Draper's Work," p. 6.
23. *Ibid*., p. 7.
24. "Air Force Systems Command, Aeronautical Systems Division, "Development of Airborne Armament 1910-1961," Vol. III Fighter Fire Control, (hereafter Airborne Armament Vol. III), p. 387, Historian's Office, AFMC.
25. Air Technical Service Command, U.S. Army Air Forces, *Research and Development Projects of the Engineering Division* [hereafter R&D Projects], Sixth Edition, Jan. 1, 1945, "A-1 Combination Gun-Bombing Sight," Classified Project No. MX-402, Historian's Office, AFMC.
26. Davis, "Military Significance of Draper's Work," p. 7.
27. R&D Projects, Seventh Edition, July 1, 1945, "Type A-1 Sight Installation," Classified Project No. MX-402, Historian's Office, AFMC.
28. Airborne Armament Vol. III, p. 388.
29. The K-14, the Air Force's first lead computing sight, was a U.S. Navy sight developed from the British Mk-IIc. It was briefly employed in combat during the last stages of World War II
30. Airborne Armament Vol. III, pp. 389, 394-95.
31. *Ibid*., p. 395-96.
32. *Ibid*., p. 396.
33. *Ibid*., p. 397.
34. The antenna horn was placed in the upper lip of the nose intake, underneath a dark-colored dielectric covering.
35. Airborne Armament Vol. III, p. 399.
36. "United States Air Force Operations in the Korean Conflict 1 November 1950-30 June 1952," USAF Historical Study No. 72, Historical Division, Air University, 1953, p. 119.
37. "United States Air Force Operations in the Korean Conflict 1 July 1952-27 July 1953," USAF Historical Study No. 127, Historical Division, Air University, 1956, p. 65.
38. Frank P. Robison, Jr., telephone interview conducted by the author, Oct. 10, 2008. Robison flew 13 missions as Gabreski's wingman in Korea and was the armament officer for the 336th Fighter Squadron.
39. Kenneth P. Werrel, *Sabres over MiG Alley: The F–86 and the Battle for Air Superiority in Korea* (Naval Institute Press, 2005), p. 28.
40. The F–86E was equipped with the J-1 fire control system consisting of the A-1C(M) sight and the improved AN/APG-30A ranging radar.
41. USAF Historical Study No. 72, p 119; Frank P. Robison, Jr. interview.
42. USAF Historical Study No. 72, p 119.
43. USAF Historical Study No. 127, p. 66.
44. Jack L. Jenkins, "Some Notes on the Behavior of Computing Gunsights," *Fighter Weapons Newsletter* 61, No. 1 (Feb. 1958), p.51.
45. USAF Historical Study No. 127, p. 66.
46. *Ibid*.
47. "Report on evaluation of K-14 and J-2 Sighting Systems by the Project Test Team," p. 1 and "Relative Combat Effectiveness of J-2 and K-14 Fire Control Systems," p. 2, " both in *Final Report, Project no. APG/ADB/59A,* Headquarters, Air Proving Ground Command" Sep. 26, 1952, DTIC No. AD004359. Col. Francis S. Gabreski (6.5 Korea, and 28 World War II credits), Col. John Meyer (2 and 24), Maj. William T. Whisner, Jr. (5.5 and 15.5), Maj. James Jabara (15 and 1.5) were the aces. Col. James K. Johnson and Capt. Jesse E. Green flew for the APGC. Lts. Ivan C. Kincheloe and James H. Kasler were other members of the test team, but did not arrive in time to participate in the flying portion of the test.
48. Werrel, *Sabres Over MiG Alley*, p. 188.
49. Robison interview; Werrel, *Sabres Over MiG Alley*, p. 188.
50. Davis Interview, p. 26; "I just stick a piece of chewing gum on my windscreen and use that as a sight," Werrel, *Sabres Over MiG Alley*, p. 30. [Note: The K-14 had a fixed pipper on the gun line in addition to the disturbed reticule showing lead. If you ignored the disturbed reticule, it was just a typical reflecting sight.]
51. Robison Interview.
52. *Ibid*.
53. *Ibid*.
54. "Report on evaluation of K-14 and J-2 Sighting Systems by the Project Test Team," p. 5.
55. "Relative Combat Effectiveness of J-2 and K-14 Fire Control Systems," pp. 1-17.
56. Patrick W. Timberlake, Accelerated Comparison Test of the K-14 Sight and J-2 fire Control System in the F–86E Fighter to Fighter Combat," in Air Proving Ground Final Report.
57. Werrel, *Sabres over MiG Alley*, p. 188.
58. Walter E. Hammond, *Space Transportation: A Systems Approach to Analysis and Design* (AIAA, 1999), p. 548.
59. Vincent Davis, *The Politics of Innovations: Patterns in Navy Cases* (University of Denver, 1967), p. 33.
60. Ronald J. Kurth, "The Politics of Technological Innovation in the United States Navy," Doctoral thesis, Harvard University, 1970, p. 2.
61. Robert F. Dorr, Jon Lake, Warren Thompson, *Korean War Aces: Aircraft of the Aces* (Osprey Publishing, 1995), p. 61.