TWENTY-FIVE YEARS AHEAD OF ITS TIME: THE AMERICAN AERIAL TORPEDO IN WORLD WAR I

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To the modern-day public, no weapon system is more evocative of American high technology than the "drone" or, more formally, the "Unmanned Aerial System" (UAS) or "Remotely Piloted Aircraft" (RPA). UASs in the last two decades have been deployed extensively through southwest Asia and appear almost daily in news reports. Few realize they were pioneered a century ago and nearly took their place alongside the tank, submarine, chemical weapons and fighter aircraft as an important technological breakthrough of World War I.

This paper explores the development and testing of the first American drone. Developed in Dayton, Ohio, this "aerial torpedo" (also called an "automatic carrier" or "flying bomb") was created by automotive innovator Charles F. "Boss" Kettering and nicknamed, in his honor, the "Kettering Bug." Along with Kettering, important future actors in American military airpower such as General of the Air Force Henry "Hap" Arnold and James Doolittle of "Doolittle's Raiders" were also involved in this secret development project, probably the first of its kind in Air Force history. Like most projects pushing the limits of the state of the art, the Kettering Bug was hampered by technical challenges; however, the project showed how breakthroughs can be achieved when a small group of accomplished technical experts are brought together on a complex task and allowed to seek creative solutions. Theirs was no small accomplishment. Looking back on the project, General "Hap" Arnold's assessment was:

> The Bug was twenty five years ahead of its time. For all practical purposes….It compared very favorably with the German V-1... Considering the trends in air weapons today, and that the German V-1 was not launched against Britain until the fifth year of WW II, it is interesting to think how this little Bug might have changed the whole face of history if it had been allowed to develop without interruption between the two world wars.[1]

The Navy's New Aerial Torpedo Inspires the Army's George Owen Squier.

In November 1917 the Naval Consulting Board took the highly unusual step of inviting the Army to observe a test of an "automatic" (i.e., pilotless) airplane at their Amityville, Long Island, test site, a system under evaluation as a possible countermeasure to the German submarine threat. The Army accepted and sent the best possible candidate as their observer, Lieutenant Colonel George Owen Squier.[2] Squier, a much underappreciated figure in the history of the U.S. Army and Air Force, was an archetype of the modern military technocrat—an officer as familiar with advanced technology as with strategy and tactics. After commissioning at West Point in 1883 and after an assignment at a Coast Artillery unit at famed Fort McHenry in Baltimore, he enrolled in a graduate program at Johns Hopkins University and was awarded the PhD in electrical engineering in 1893,[3] becoming the very first Army officer to earn a doctorate. Though not an aviator himself (he was Orville Wright's second military passenger during acceptance testing of the first American military aircraft in 1908), Squier could readily see the potential of this nascent technology, and he vigorously promoted it within and outside the Army. [4] His first significant accomplishment in military aviation was his U.S. *Signal Corps Specification 486, Heavier-Than-Air-Flying-Machine* (December 23, 1907), used to procure the first Army aircraft from the Wrights and still used as a model for a "performance based" technical specification with monetary incentives and penalties for exceeding or missing key requirements (in this case, ground speed).[5] Well before Billy Mitchell, Squier enthusiastically promoted the possibilities of airpower to the general public.[6]

Figure 1 Major General George Owen Squier
Source: Wikipedia Commons

Squier's time was only partly spent in aviation. The Signal Corps was about communications and Squier would be spending the bulk of his active duty time there, not only attending to military duties but astonishingly developing more than forty patents, primarily in telegraphy but oddly in aeronautics not a single patent.[7] In 1916, the National Defense Act had begun to finally pour money into the nation's defenses, allocating $17M to build 375 new army aircraft, and formally creating a distinct Aviation Division within the Signal Corps.[8] That year, Squier was recalled to the U.S. from an assignment as the British military attaché by "urgent request" of the Chief Signal Officer to jumpstart the branch's aviation activities.

Once back in America Squier found himself cursed with getting precisely what he had been advocating for years—funding for a large combat air fleet. He would be the one expected to turn this money into an actual aircraft production program to turn the tide of the European war. Americans may have invented the airplane but at the start of the war they had spent precious little money on it for military purposes. In 1913, for example, France spent $7 million on military aviation and had 250 aircraft, while the U.S. spent a mere $125,000 and had only 6.[9] Even worse, America had only a few aircraft manufacturers such as the ones led by Glen Curtiss and Orville Wright, and neither had anything remotely like the industrial capacity needed to design and produce the thousands of sophisticated aircraft the Allies and American public expected, expectations set by the booming automobile industry (Ford alone built about 750,000 cars in 1916). The great Arsenal of Democracy would be realized in the next war but not this one. American aircraft production in 1916-18 has been judged at best a disappointment, if not an outright failure and Squier's reputation would be severely tarnished because of it.[10] Squier was in the throes of these production issues when—now a Brigadier General—he saw the Navy's pilotless aircraft in November 1917. Perhaps it offered an alternative path for American airpower to win the war.

The Genesis of Project Liberty Eagle: Creation of the Dayton Airplane Company

Seeing the Navy's pilotless aircraft immediately inspired Squier to develop a variation of it for the army—an unmanned flying bomb or aerial torpedo. Without a pilot, and designed only for one mission, it would be much smaller, simpler and cheaper than conventional airplanes, and therefore could be produced in numbers many times greater than the more complex and sophisticated aircraft now flying over France. It would even rival heavy artillery in cost. Urging the development of his aerial torpedo, he wrote two weeks after the declaration of war to the nation's Aircraft Production Board that "the time has come when this fundamental question should be pressed with all possible vigor, with a view to taking to Europe something new in war."[11] But to create this new weapon, a team was needed to design and build a prototype and solve some daunting technical challenges, most notably an automated flight control system that could successfully guide the torpedo to its target, *sans* pilot.

Figure 2 Charles F "Boss" Kettering Source: Wikipedia Commons

The man chosen to lead the design team was Charles F. "Boss" Kettering of Dayton, Ohio, inventor of the automobile electric starter and chief executive of the Dayton Electronics Company. At first glance this seems an odd choice. Why not Orville Wright, whom Squier knew personally, the most famous name in American aviation? Kettering was prominent, but only in the automotive industry. Why Kettering?

Figure 3 Colonel Edward Deeds. Courtesy of Special Collections and Archives, Wright State University

Part of the answer lies with General Squier's recently appointed head of Aircraft Production, Colonel Edward Deeds. Despite a complete lack of military training or experience, Deeds, a Dayton, Ohio engineer and industrialist, had been given given a direct commission in the Signal Corps Aviation section in the unusually high grade of full colonel in early 1918. Deeds was a longtime business partner with Charles Kettering, and together they had formed the core of a group of Dayton engineers known as the "Barn Gang," known for their love of tinkering with challenging technical problems. When General Squier and newly-minted Colonel Deeds discussed the idea for an aerial torpedo, Deeds must have immediately thought of Kettering and his ability to solve tough technical problems, something he had seen himself many times in their automotive ventures.

A more unsavory angle on the selection of Kettering also exists—a deliberate effort, spearheaded by Deeds, to direct as much army contract work as possible to his former business associates in Dayton. According to the memoirs of Mr. Grover Loening, a German-born American pilot and aircraft designer who worked for Orville Wright prior to and during the war, Deeds (still a civilian), Kettering, and several of their associates met at a private home in Dayton immediately after the declaration of war. Their aim was to set up a new aviation company to meet the huge demand for military aircraft that America's entry into the war would surely bring. The four would head a new company, the successor of the original Wright Company: the Dayton-Wright Airplane Company. Orville Wright would be involved, but as a "non-working" director (he was involved later with Squier's aerial torpedo as a working engineer). Loening himself was "astonished" by these plans and considered them somewhat "shady." Deeds (who divested his shares after accepting an army commission) thought all this new company would need were engines from the booming automotive industry in Detroit (using, of course, Kettering's electric ignition), prints from European aircraft designs and the war would be won, and at a considerable profit.[12]Another voice to promote Kettering to General Squier was Howard E. Coffin, a senior automotive executive and the chair of the Aircraft Production Board (Deeds and Squier were also members). Tasked with overseeing the Army's massive airplane production program, Coffin, who was not a government official but a "dollar a year man," was in the perfect position to influence the other key board member, General Squier, to direct all his aviation work

Figure 4 Aircraft Production Board, 1917. Chairman Howard Coffin at right, seated next to General Squier. Source: *MOTOR WEEK* magazine, 1917

to Dayton, including his idea for an aerial torpedo. And that is precisely what happened.

Work Formally Begins: Kettering Takes Charge

Squier, pointed in the right direction by Deeds and Coffin, approached Kettering about his idea for an aerial torpedo and Kettering agreed—after "considerable effort" by Squier—to take on the project in December 1917. Contracts were formally awarded January 25, 1918, and the secret project, code named "Liberty Eagle", had formally begun.[13] The contractual arrangements were a bit unusual, and highly favorable to the contractors. Two contracts were awarded, one to the Dayton-Wright Airplane Company and another to the Dayton Metal Products Company. Kettering was part owner of both, Wright only of the company that bore his name (Deeds' overly close association to both was eventually the cause for investigation for corruption after the war). Neither was designated as prime or lead contractor, so the army would have to ensure coordination and cooperation between the two (in practice, since Kettering was an owner of both, this was not an issue). Both received almost identical contracts with about as broad a scope of work as could be imagined, to "*proceed with and continue such experimental work in aeronautical development as the Government may from time to time direct.*" This ambiguity was to both keep the true purpose of the project hidden from the many contracting, financial and administrative personnel who might have reason to see the document as well as provide the contractor maximum flexibility to design a solution. There were no concrete deliverable items specified such as prototypes or fully functional test articles; everything depended on verbal direction from an "Accounting Officer" (in modern parlance, a military program manager) who would be allowed complete access to the contractors' workplaces and all technical and accounting data. The companies were more than happy to agree; these contracts were of the new "cost plus type," meaning that they would be reimbursed for all their expenses, plus receive a 12.5% profit, even if they failed to ever deliver anything that ever actually worked.[14] The Dayton Aircraft Company would even be reimbursed for work done prior to the contract award—a highly unusual feature, but a way for Kettering to be paid for a useful trip he took to visit the Navy's pilotless airplane at Amityville, NY, where he met their technical leader, Elmer Sperry, and learned more about the new and essential gyroscope. There was no planning or provisions made for the massive production effort that would be needed if the project was successful. An initial amount of $50,000 ($1.2M in 2018 USD) was allocated for the project, and like many R&D efforts the costs would eventually come out to about twice that original estimate.

Kettering immediately set to work. He had a number of things going for him besides a brilliant technical mind. Most importantly, he had complete control over all aspects of the project, including every design decision and trade off. His staff was small but comprised of very talented individuals whom he already knew and trusted, building on long term business relationships and mostly located in Dayton (except for the engine subcontractor), simplifying project communications enormously. And he had the complete confidence and support of his customer and sponsor, General Squier.

Even before the contract was awarded, Kettering called his core team together for their first meeting on Christmas Eve, 1917—a clear sign of the urgency to start as soon as possible. The attendees included several important local industrialists and leaders of Dayton Metal Products and Dayton Electronics Company, and Thomas Midgley, Jr. a mechanical engineer with Dayton Metal Products who would be assigned the most critical technical issue of the entire project.[15] Based on his conversations with Squier and visit to Amityville, Kettering laid out his vision. Though impressed with the technology in the Navy's flying torpedo, a truly pilotless airplane was not practical; the challenge of landing such a craft with the current technology was simply too great. What Kettering wanted instead, as Midgley later recalled, was "something to compete in price with a high explosive shell but could go further"—it would fly a one-way mission and simply crash into the desired target, detonating its bomb with the metal components of the airframe and engine serving as shrapnel during the explosion. Cost was a major design criteria—the target per aircraft was $575 each when produced in quantity. The payload would be a 200 lb. high explosive bomb, with a maximum range of 50 miles and an allowable target error of ¼% in degrees.[16] Though articulated by Kettering at the meeting as his own, it seems likely these requirements really originated with General Squier who had proven in the original Wright aircraft contract more than capable of writing such a specification.

After they departed the meeting for Christmas, this "aerial torpedo"–"flying bomb"–"automatic carrier"–became always and forever known within the team as the "Kettering Bug" because, as Midgley later recalled, "it was *his* baby".[17]

Designing "The Bug."

Kettering immediately split the "Bug" system design into three subsystems which could be designed and tested in parallel by teams of engineers. The first was the aircraft itself, referred to as the "kite," under the direction of Jay Schoonmaker Jr.; Orville Wright was involved as an occasional consultant and technical trouble-shooter.[18] The kite was an unremarkable design, just a miniature biplane similar to most WWI military aircraft, but much smaller in size, with a length of only 12' and wingspan of about 15'. To save money and reduce weight, unconventional aircraft materials were used, including scrap wood, cardboard and even paper mache. To simplify shipping, the kite was designed to be broken down into several modules easily assembled in the field with simple hand tools prior to flight.

Figure 5 Kettering Bug replica, National Museum of USAF (author photo)

The second subsystem was the only one that could not be reasonably designed or built in Dayton—the engine. Certainly engines and aircraft engine designs already existed, but these were too heavy and expensive for Kettering's purposes. A new simple, lightweight, and cheap engine was needed. Fortunately, Kettering had extensive contacts in the booming automotive industry, which included C. Harold Willis, a former chief engineer at Ford who, with American race car driver Ralph De Palma, had just founded the DePalma Manufacturing Company. They were subcontracted to build a low cost air cooled 2 stroke 4 cylinder engine which would propel the kite and its payload. When functioning properly, the engine did its job admirably, but manufacturing issues caused a constant stream of failures and it was not until the summer of 1918 that its performance was adequate for flight testing.[19]

Finally, the biggest technical challenge of the entire project, the flight control system, which would guide the Bug on a more or less level flight after launching (off a rail, much like the original Wright aircraft) until it reached its target. Two sensors made this possible : Sperry's gyroscope, a stable reference point to determine a level flight path, and a very sensitive aneroid barometer which could discriminate changes in altitude as small as a few feet. These sensors provided the necessary data but a unique new design was needed to transfer it into a mechanical system to operate the flight controls. Thomas Midgley, a mechanical engineering graduate of Cornell University, was chosen by Kettering for this task because he had previously proven an innovative problem solver before the war. Kettering was also personally involved in this part of the design, first attempting an electrical control system, then abandoning it after some experimentation in favor of a pneumatic (compressed air) solution, ingeniously using suction from the crankcase of the engine to activate the controls in a closed feedback loop. It is unclear if this idea originated with Midgley or Kettering. Kettering later recalled parts for the prototype were had by "pinching pieces out of my pipe organ and player piano."[20] Eventually he subcontracted with the Aeolian Company of New York (which manufactured keyboard instruments) to produce the bellows and other parts of the pneumatic control system.

Kettering's cannibalization of his home's musical instruments underlie a prosaic but significant schedule issue with the development of the Bug—obtaining the necessary hardware to build subsystem prototypes and the first complete flight test articles. As the Army itself admitted, work "progressed very slowly at first."[21] Competing with much larger orders in various machine shops for piece parts in very small quantities must have been extremely exasperating and time consuming, taking up valuable months. As the official report on the development of the Bug stated:

> as practically all parts of the torpedo had to be originated by Mr. Kettering and his associates … and detailed devices or mechanisms already in existence adapted to perform certain functions in controlling the torpedoes, much traveling and purchasing of various devices were necessary at the start.[22]

The Army Team.

Assisting in this procurement of hardware—"chasing parts"—was the task of the small Army Signal Corps team sent to Dayton to oversee the day-to-day effort. Squier, now a major general and Chief Signal Officer for the Army in the middle of a war, plus having aircraft production oversight responsibilities, could not possibly be involved in overseeing the details of his pet project. Major C.M. Hall, another civilian directly commissioned as an officer, was assigned that duty.

Hall is a curious character and there is little known about him. Recommended for this position by Aircraft Production Board chair Howard Coffin, he was ordered to report to Dayton on February 1, 1918. He immediately established offices in a commercial building away from the local military base (McCook Field) assisted by a small staff including a secretary, one officer, First Lieutenant Coffman (oddly, later transferred to the motor pool) and one enlisted man, Pvt. J.B. Book.[23] Unlike their commanding officer, Coffman and Book kept copious journal notes and were clearly involved on site every day with the project; Book was eventually rewarded with a commission as a second lieutenant in August. Hall's tenure as officer-in-charge was brief; an official program report made in September 1918 notes his successor "proceeded to hurry along development" and "straighten things out that not been done in proper form." Specifically,

> it was necessary to make arrangements for the refunding of moneys to the Dayton Metal Products Co. for purchases which had been made and bills they had paid under Major Hall's orders, [which] should have been made through proper military channels.

Apparently Hall gave verbal directions to purchase hardware beyond the amount available in his budget, violating a cardinal rule of military procurement.[24] Not for the only time in the Great War, a successful businessman learned the difference between conducting public and private business. And to be fair, Hall had been given virtually no training or guidance in taking on this formidable project.

Colonel Harris's assignment also lasted only a few months, and during that time the relationship between the Army and Kettering began to fray. The contractor team was beginning to feel pressure from above for an apparent lack of progress, and resented the assistance and opinions offered by their customer who was, after all, footing the entire development bill. In July, Harris had to send Squier a letter advising him that a consulting visit by Elmer Sperry, arranged by Squier to speed up the critical control system, had backfired; "but as Mr. Kettering resents any suggestions, we have found as yet no way to set our views before him."[25] Things got even edgier a bit later. Lt. Coffman recorded in his log on Tuesday, August 6, 1918, "Mr. Sheets [a Dayton Metal Products employee] resented a civil question put forth by Colonel Harris and completely lost his head, insulting the colonel and the entire United States Army."[26] The daily logs of that time reveal a constant stream of technical problems requiring design changes and hardware modifications: the springs holding regulator valves were too weak, engine pistons stuck, and missing parts and key personnel (particularly when Kettering was not on site). Colonel Harris probably invoked the ire of his contractor team by asking one time too many when the problems would end and the Bug would finally fly.

Apparently word filtered up to the Army hierarchy that Harris's working relationship with the Kettering team had irrevocably broken down. In the next month, September, the last officer in charge, Lieutenant Colonel Bion J. Arnold, was appointed by order of the Secretary of War after an unusual letter recommending him for the post from the Secretary of the Navy. [27] Arnold, an electrical engineer who had also displayed an early interest in the Wright Brother's flying machines, was nominated in 1916 to the prestigious Naval Consulting Board, in addition to already being on the Board of Directors for the American Society of Aeronautic Engineers which included among its leadership Orville Wright, Elmer Sperry, and Grover Loening. Regarded as "an engineer of the highest standing with broad experience in large and important matters," Arnold had impeccable technical credentials and was probably the only military officer other than Squier or Deeds capable of getting Kettering's respect and attention. [28]

Figure 6 Lt. Colonel Bion J Arnold
Source: Wikipedia Commons

And General Squier was convinced he needed to do just that. In a letter addressed to Kettering just before Arnold assumed the responsibility of managing the Bug, Squier put Kettering and his team on notice: "it now remains to push the actual assembly and testing of the apparatus with the utmost vigor whereby the success of the project may be practically demonstrated." Squier felt "it his duty to urge and insist that every step be taken forthwith looking to the completion and determination of this development at the earliest possible hour."[29] A core issue was Kettering's personal availability to the project. Like most great technical men, Kettering was pulled in many directions by many critical projects—not the least the floundering aircraft production program—but Squier was out of patience. The Bug design had to be completed and proved feasible, and soon, in order to go into production and be deployed in significant numbers for the anticipated spring 1919 offensive that would win the war at last. Squier wanted a "thoroughly competent engineer, satisfactory to the Signal Corps, secured whose sole and only duty will be to push this important work under the personal direction of Mr. Kettering."[30] Kettering got the message: the competent engineer ended up being Kettering himself.

Figure 7 Flight testing the Bug, 1918 (Courtesy National Museum of USAF)

Testing the Bug.

At the end of August the Bug team went into high gear in a final push to get the Bug working, and the progress was remarkable. Lt. Colonel Arnold appeared on site for the first time on Monday, September 9, 1918, clearly determined to implement General Squier's direction to get the Bug out of design and into testing. The first test to actually launch a Bug was planned for that Thursday, only to be cancelled for "high and variable

Figure 8. Kettering Bug aircraft construction at Dayton-Wright Airplane. Courtesy of Special Collections and Archives, Wright State University

winds" as recorded by newly commissioned Lt. Book. The next day the Bug was actually launched down the track, but issues with its design—among other things, too short a length—caused the test to fail. Changes were immediately made, and some minor damage to the test article fixed, and on the next day, Saturday, September 14, 1918, at approximately 6:30 p.m., the first test flight actually occurred.[31]

It was not a success. After a great deal of adjusting both the carburetors and the spring suspension (designed to isolate the gyroscope from engine vibrations) the Bug left its newly lengthened launch track, flew approximately a hundred feet, and nosed down into a crash. The flimsy aircraft fuselage and propeller were badly damaged, but not the engine and control mechanism. The next day, a Sunday, the Army team appeared, hoping to conduct a post mortem, but Kettering never showed. On Monday, September 16, they all reconvened and Kettering and his team presented their findings—the failure was caused by faulty engine carburetion, causing both insufficient thrust to allow lift and excessive vibration which degraded the flight control system. Later analysis would show that the pneumatic system had accidentally ingested loose splinters of wood as well. But at least it had gotten into the air. Both Kettering and the Army (still officially led by Colonel Harris, despite Arnold's presence) decided to build 50 more test Bugs, a number reduced later that day to 25. Work commenced on those immediately.[32]

Within a few days another Bug test article was completed. The next major step forward came on the next Thursday, September 19, when C. Harold Wills of DePalma brought 4 new and improved engines with him. Though they produced 175 more RPM than any previous engine, the performance was still far below expectations; after some on-site testing Wills discovered workmanship issues were to blame.[33] Kettering returned with one of the engines and Wills in tow back to Detroit. The next week General Squier himself made a rare visit to the Dayton contractor site to see the progress, and Thomas Midgley continued to make modifications to the flight control system as well. October 2, 1918, saw another flight test. It only lasted 9 seconds, the Bug having wildly veered around after launch in a circular pattern before crashing and scattering the Army observers on the ground. Kettering made some further adjustments to the control system

Thursday evening, and on Friday, October 4, 1918, the first partially successful flight occurred, a flight that was almost too successful.

At 5:55 p.m. the Bug was launched. Rising slowly and then almost making an Immelman maneuver (a complete loop back on itself) it was supposed to level off at an altitude of 1000 feet and fly straight; instead it circled several times for 20 minutes at an altitude of approximately 10,000 feet before finally disappearing from sight in an easterly direction toward what is now Wright-Patterson Air Force Base Area "B." Kettering, disgusted, told the observing Army, "let the thing stay up there" and left.[34] Several officers—including Lt. Colonel Bion Arnold and Colonel (later General of the Air Force) "Hap" Arnold, General Squier's Executive Officer, got into an automobile and gave chase. Having lost sight of the Bug, they returned to base and discovered that Wright Field had received a telephone call from the Xenia police. A military airplane had crashed there (approximately 25 miles from the launch point), about 4 miles out of town and only 1000 feet from a farmhouse. Even worse, the pilot was still missing, though a number of local farmers were still searching for him, and the town newspaper, the Xenia *Gazette,* was also on the scene and preparing a story for publication. The officers immediately drove to the scene to put a halt to the search and attendant publicity. When they arrived Lt. Colonel Arnold pointed to Colonel Hap Arnold—who was wearing his flying jacket—and assured everyone that here was the pilot who had safely bailed out (though in fact parachutes were not then issued by the Air Service). The police and the newspaper were told this was a secret project, and all publicity on the incident was subsequently quashed. The crushed remains of the fuselage were burnt on the spot and the surviving pieces of the engine and control system collected and returned to Kettering. In the coming weeks both the tail and the wings (which had fallen off prior to crash as designed) were recovered as well. Analysis showed the flight stopped only because the engine was out of fuel.[35]

This particular Bug flight immediately became the stuff of legend. Wills of DePalma wrote in a rather catty letter to Elmer Sperry a few days later:

> I never saw anything that had so many tales and stories about it as that flight. Everybody had a different story about the

> capers it cut up. Some of the aces in France could have learned a few tricks.[36]

Wills also felt his engine, after many failures and several redesigns, had been completely vindicated. This conclusion would prove premature.

Also premature was the optimism of the senior Army members of the team supervising the Bug project. The day after this first partially successful flight, General Squier sent a mufti-page SECRET report to the Army Chief of Staff, who apparently was completely unaware of the Liberty Eagle project. After describing the Bug, relating the technical challenges encountered and overcome, he posited conclusions and recommendations that could hardly have been more sanguine[37]: the Bug as an innovation was “comparable, for instance, with the invention of gunpowder in the fourteenth century” and “a distinct product of American genius.” Not only should the General Staff promote this product for immediate quantity production, but the American military leadership in France and our Allies should be informed of its existence as well. Lt. Colonel Arnold thought that quantity production meant a range to 10,000 to 100,000 Bugs. How and who would deliver such an enormous quantity to the Western Front in less than six months’ time was apparently not thoroughly considered.

A second flight was conducted on October 22 and judged to be “perfectly successful” —the Bug took off, flew a straight course and crashed landed exactly as planned (it was set to fly a mere 520 yards). That same day Colonel Harris, still nominally in charge, requested 10 additional officers and 150 enlisted men be assigned the project to refine the system’s targeting capabilities. General Squier, with apparent agreement from the General Staff, dispatched his executive officer Colonel “Hap” Arnold to Europe to brief General Pershing on this development. Enroute Arnold contracted the notorious 1918-19 flu and was unable to see Pershing before the Armistice, but afterwards Pershing was impressed, telling Arnold (the Army’s youngest Colonel) “Young man, that is a very important development. I would keep at work on that, because you will need it in the next war.”[38] Apparently the Allies were also briefed on the Bug, as Great Britain requested the opportunity to evaluate a test article, a request denied because of intellectual property considerations.[39]

Meanwhile, the team remained busy throughout October until the November 11 Armistice. More engines arrived from DePalma, with still further improvements. More test articles were being built – at first 25, a number Lt. Colonel Arnold later raised to 100. Kettering and team continued to tweak the Bug design, conduct tests, particularly the control system, and Kettering even felt comfortable enough with the progress to take five days recuperative vacation on October 23. Lt. Colonel Arnold toured possible test sites in remote areas of the southern US, hoping to avoid another security compromise like the Xenia fiasco. Further flight tests were planned in early November, but with the announcement of an Armistice the entire project came to a sudden and complete stop on November 11. “The work has stopped on the birds and no more trial flights are to be made” recorded Lt. Book for that day. All that remained was the residual work of collecting drawings, test articles and other artifacts already paid for by the Government. In Dayton, Project Liberty Eagle was stopped, just as it was beginning to pay off.

Post Armistice Developments.

In Washington, however, the project was gathering interest at the highest level of the U.S. Government. In late November General Squier sent Lt. Colonel Arnold a telegram—could he bring Kettering and Orville Wright to Washington to meet Secretary of War Newton Baker on December 2? The purpose was to brief the Secretary on Project Liberty Eagle. As it turned out though, Secretary Baker was interested in the combat potential of the Bug with an eye toward something else altogether. Having witnessed the death and destruction caused by innovations such as chemical weapons and submarines, should President Wilson, about to depart for Paris Pace Conference, recommend restricting or even prohibiting “aerial torpedoes,” too? Baker was clearly concerned about such weapons. In a speech on March 24, 1919, in Fort Worth, he stated that one of the “most destructive weapons” devised during the war had been relegated to the Army’s secret archive.[40] But there is no evidence that President Wilson himself was ever briefed on the Bug, or considered the abolition of aerial torpedoes.

Despite the Secretary’s ethical concerns the Army project team decided that, though the Armistice had obviated the need for mass production, more testing was badly needed. After all, as even Lt. Colonel Arnold conceded, “there had been but one flight of the device where all the elements of the torpedo had apparently functioned perfectly.”[41] Setting up a new test facility would be expensive and time consuming—the Army would be better off using the existing Navy facility at Amityville, Long Island, where Sperry’s automatic airplane had been flown. Four of the Bug test articles (a full 20 were completed by Armistice Day, with a number of partially completed in-stock as well) were dispatched for testing. These tests at Amityville did not go particularly well, with 3 failures out of 4 test flights. Oddly, no written reports of these tests exist.

With the end of the war, personal and business agendas rapidly shifted. Kettering realized the lucrative financial payoff from the Bug project – a large production contract – was now gone, and almost as soon as the Armistice was announced he made it clear he wished to be freed from the time consuming Bug test effort to focus on other business. Knowing that without Kettering little progress would be made, and desirous himself to return to private life anyway, Lt. Colonel Bion J. Arnold requested release from active duty before Christmas 1918, returning to his highly productive life as an engineer developing sophisticated urban rail systems for Chicago, Cincinnati and a number of other cities.[42]

Despite the failures at Amityville, the Army eventually saw the need to complete a test program of its own and on September 4, 1919, 12 of the remaining Bugs were shipped to Carlstrom Field in remote Arcadia, Florida. Tests were conducted there from the end of September to nearly the end of October.[43] Films made by the Air Service of these tests show a civilian test team of about a half dozen men (almost certainly the same Dayton men who flew the Bug a year before), supervised by a few army officers. Kettering himself did not take part, but it seems very likely that Thomas Midgley did, because during testing frequent adjustments were made (again) to the temperamental flight control system, and only Midgley would have possessed this expertise. It had been almost a year since the Bug last flew, and not surprisingly the early flight attempts did not go well.

Old and familiar problems reappeared. The launching track once again had to be adjusted to get the Bug airborne, multiple issues with the engine were noted and the flight control system was troublesome as well. Finally, on October 28, 1919, after adjustments to the altitude control on a test article that had been built up from cannibalized parts surviving previous failures, came a flight of some 16 miles. It would be the last and best flight of the Kettering Bug.[44]

The final test report, written by a promising young pilot and officer recently awarded the first PhD in aeronautical engineering in America, Lt. James Doolittle, contained a number of specific observations and recommendations, the most critical of which was the final observation "it appears, further, that the ideal aerial torpedo must be radio controlled."[45] Air Service interest in this innovation, plus the meager peacetime defense budget, put an end to Kettering's Bug once and for all. Almost.

Conclusion – The Untapped Potential.

The Liberty Eagle Project almost made it to WWII. Colonel Hap Arnold, the alleged Bug "pilot" in the Xenia test debacle, rose to lead the Army Air Forces in the Second World War, and when faced with the prospect of high bomber crew losses in the upcoming air war against Germany, seriously considered the use of an unmanned aircraft in its stead. A new and improved Bug, the A-1, was a General Motors product proposed by Charles Kettering in 1939, taking advantage of improvements in gyroscope and other aviation technologies since the last development stopped in 1919. With a 400 mile range, a 500lb bomb payload and controlled by radio, it can fairly be called a next generation Bug.[46] Once again a small number of test articles were built and once again a number of flight control issues surfaced. Without the time to fully wring out the technical problems and with a range insufficient to strike much of Germany, Arnold, after

Figure 9. General Motors A-1 aerial torpedo. (Courtesy U.S. Air Force)

consulting Kettering in early 1942, abandoned the idea, though he noted that such a weapon in German hands could have been very effective against Britain from bases in Holland and Belgium.[47] Arnold was not alone among the early leaders of the Air Force in his enthusiasm for aerial torpedoes. The most famous advocate of American airpower, Billy Mitchell, saw great value in the aerial torpedo as a first strike weapon, calling it "a weapon of tremendous value and a terrific force to air power."[48] Unfortunately, post-WWII Air Force leadership would not be so interested in these possibilities.

Cultural imperatives in the U.S. Air Force in the decades following the Second World War show strong preference for manned over unmanned systems. This is not surprising, since during the service's most critical and formative years no viable unmanned aerial platform existed. Consequently there was little chance that the Bug's descendants — today's drones—would receive the resources necessary to create a truly effective weapon system for most of the twentieth century. Even after Israel successfully showed the value of unmanned systems in the Beqaa Valley in the late 1970s, the U.S. Air Force failed to field any such capability until almost two decades later. To be sure, the technical limitations on unmanned systems before the advent of GPS and digital avionics processors running sophisticated software meant these early "aerial torpedoes" could never provide the military capabilities we take for granted today, but they could have provided at least a partially effective close air support and interdiction capability, even as early as 1919. By the late 1970s, their utility in these and other missions could have been considerable.

The Bug is noteworthy for other reasons as well. It was one of the first "black" (i.e., highly classified) research and development projects in American history, having the hallmarks of future such projects—brilliant technical leadership, a small development team, senior level military sponsorship, and potential for high operational payoff. It also highlighted the need for a new kind of military officer like General George Squier, one trained in military organization and strategy and also able to work with an emerging defense industry to develop and field large numbers of sophisticated new weapon systems. More than a mere WW I curiosity, the Bug can reasonably be seen as one of the forerunners of the modern American military-industrial complex.

[1] (H. H. Arnold 1972), p. 76
[2] (B. J. Arnold 1918)
[3] (Gross 1990) p. 283
[4] (Kennelly 1938) p. 152.
[5] Author's personal recollection as a Defense Systems Management College student, 1985. (Allen 1907)
[6] (Kennelly 1938) p. 158
[7] (Kennelly 1938), pp 156-58
[8] (Williams 2016)
[9] (The Signal Corps and Air Service A Study of Their Expansion in the United States 1917-1918 1922) p. 31
[10] (Gross 1990) p. 302
[11] (B. J. Arnold 1918) Nov 27, 1917 letter to Aircraft Production Board
[12] (Laidlaw n.d.) Notes on Loening manuscript cited
[13] (B. J. Arnold 1918) p.3, formal report. Multiple sources confirm Squier approached only Kettering on this task
[14] (B. J. Arnold 1918) Annex – Contracts Projects 2713 and 2714
[15] (Laidlaw n.d.) Manuscript notes on Midgely's recollection of the project
[16] Ibid
[17] (Laidlaw n.d.)
[18] (Boyd 1957) pp. 106-07
[19] (B. J. Arnold 1918) Logs of Government witnessed testing make frequent comments on engine issues
[20] (Boyd 1957) p. 107
[21] (B. J. Arnold 1918)
[22] Ibid. p. 3 of the fifteen page formal report at the beginning of the file
[23] Ibid. See Lt. Col Arnold's formal history
[24] Ibid. See the Annexes in the report entitled "Research Department, Signal Corps, Sept 18, 1918"
[25] Ibid. July 17, 1918 letter from Colonel Harris to General Squier
[26] Ibid. See daily activity logs by Lt.s. Coffman and Book that begin in July 1918
[27] Not to be confused with then Colonel Henry "Hap" Arnold, later General of the Air Force
[28] (News 1916) p. 168-69
[29] (B. J. Arnold 1918)SECRET (now declassified) August 25, 1918 letter "Experimental Work for Signal Corps"
[30] (B. J. Arnold 1918) Annex, August 25, 1918 letter from General Squier
[31] (B. J. Arnold 1918). Lt. Book's journal of test activities, an annex
[32] Ibid.
[33] Ibid.
[34] Ibid, C . Harold Wills letter to Elmer Sperry, Oct 7, 1918
[35] Ibid, Lt. Book's journal entry Oct 4 1918. Also (H. H. Arnold 1972) p. 75-76
[36] Ibid, Oct 7, 1918 letter from Wills to Elmer Sperry
[37] Ibid, Oct 5, 1918 letter from Chief Signal Officer to Chief of Staff
[38] (Boyd 1957) p. 109. Arnold's memoirs make no mention of this quote.
[39] (Doolittle 1927) p. 3
[40] (Paul W. Clark 2014) p. 251 (cited in chapter endnote)

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[41] (B. J. Arnold 1918) p.14 of the formal report
[42] Ibid
[43] (Doolittle 1927) p. 3-4. These tests were filmed by the Air Service and can be viewed at https://www.youtube.com/watch?v=Nd8lLykmbJk
[44] Ibid.
[45] (Doolittle 1927) p. 4
[46] (Everett 2015) p. 319-20
[47] (H. H. Arnold 1972) p. 260
[48] (Mishra 2009) p. 116

Annotated Bibliography

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> The original specification for the first military aircraft procured by the US Army from the Wrights. Still used as a model for "performance based" specification. Authored by then Major George Squier.

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> The contracts file for the Liberty Eagle project from January to December 1918. The first 15 pages consist of a formal report/chronology of events by Lt. Colonel Bion J. Arnold, followed by a wide array of other documents including letters from General Squier to Kettering and the Army General Staff, the actual contracts with Dayton Wright Airplane and Dayton Metal Companies, daily journals of officers observing work in progress, invoices, test results and many others. Indispensable source of data on the project, save for the technical details of the Kettering "Bug" system itself.

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> General of the Air Force "Hap" Arnold's personal memoirs of his military career, written well into retirement with the aid of Lt Colonel W.R. Laidlaw (see below). Though not directly involved with the development or management of the Kettering "Bug" project, Arnold was an enthusiastic advocate for it.

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Several pages in this sympathetic biography are dedicated the Bug project in WW I.

Doolittle, 1LT James. *The Kettering Aerial Torpedo.* Military test report on Carlstrom Field tests conducted in 1919, Dayton, OH: US Army Air Service Experimental Engineering Section, 1927, 4.

Lt. Doolittle, future hero of the WWII Tokyo Raid, wrote this brief 4 page report in 1927, eight years after the actual "Bug" flight tests were conducted. There is no documentation that Doolittle himself actually witnessed the tests, though other historians have asserted this. This is a highly unusual situation, and the author can only surmise that Doolittle was directed to publish an official unclassified test report from existing test notes in conjunction with Kettering's 1927 release of a patent for the system.

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> A series of letters from Laidlaw, who assisted "Hap" Arnold in his autobiography, to Kettering and his associates inquiring about the "Bug" project, concerned largely with Arnold's role in it. The responses confirm the narrative in Lt Colonel Bion Arnold's official report.

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> The only complete biography of a military leader who might reasonably be called "the father of modern military research and development". Squier, who made critical contributions in both communications and aviation, also decided after his army career that office background music was conducive to efficiency, and so indeed was the creator of "wired radio", later "Muzak".

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