

# A Brief History of Early Unmanned Aircraft

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**C**urrent developments in unmanned aerial vehicles (UAVs) trace their beginnings to World War I. Efforts during the Interwar Period, World War II, and afterward ultimately led to the development of cruise missiles such as Harpoon and Tomahawk, aerial targets, and the current family of UAVs. UAVs have the ability to transmit to the battlefield commander real-time intelligence, surveillance, and reconnaissance information from hostile areas. They can also act as communication relays, designate targets for neutralization by other assets, or attack the targets themselves with onboard munitions and then loiter while streaming real-time battle damage information back to friendly forces—all without risking the lives of an aircrew. This article provides a historical survey on the early development of select UAVs in the U.S. military and their military applications. The development of cruise missiles and UAVs is intertwined. As the reader will see, many of the technologies experimented with in cruise missiles made their way to UAVs, and vice versa. Although making mention occasionally of cruise missiles, this article will attempt to focus on selected UAV development and employment through the Persian Gulf War.

## **BACKGROUND**

Unmanned air systems trace their modern origins back to the development of aerial torpedoes almost 95 years ago. Efforts continued through the Korean War, during which the military services experimented with missions, sensors, and munitions in attempts to provide

strike and reconnaissance services to battlefield commanders. In the 1950s, both the Navy and Air Force bifurcated their efforts to concentrate on cruise missile and unmanned aerial vehicle (UAV) development via separate means. In this article, the term *cruise missile*

refers to a one-way lethal munition designed to strike specific targets, while UAV refers to a reusable aircraft that has the ability to perform a variety of missions. There are three classes of UAVs: (i) pilotless target aircraft that are used for training purposes (such as target drones); (ii) nonlethal aircraft designed to gather intelligence, surveillance, and reconnaissance (ISR) data; and (iii) unmanned combat air vehicles (UCAVs) that are designed to provide lethal ISR services.

UAVs have been around much longer than most people realize. During World War I (WWI), both the Navy and the Army experimented with aerial torpedoes and flying bombs. Some of the most brilliant minds of the day were called on to develop systems to be used against U-boat bases and to break the stalemate caused by nearly 4 years of trench warfare. Efforts consisted of combining wood and fabric airframes with either gyroscope or propeller revolution counters to carry payloads of almost 200 pounds of explosives a distance of approximately 40 miles. Hostilities ceased before either could be fielded.<sup>1</sup> These WWI UAVs highlighted two operational problems: crews had difficulty launching and recovering the UAVs, and they had difficulty stabilizing them during flight. During the Interwar Period, radio and improved aircraft engineering allowed UAV developers to enhance their technologies, but most efforts failed. Despite failures, limited development continued, and after UAVs successfully performed as target drones in naval exercises, efforts were renewed in radio-controlled weapons delivery platforms. World War II (WWII) saw the continued use of target drones for anti-air gunnery practice. Additionally, radio-controlled drones were used by both the Allied and Axis powers as weapons delivery platforms and radio-controlled flying/gliding bombs.

With the start of the Cold War, UAVs began to be used as ISR systems, with limited success as weapons delivery platforms. Development continued throughout the Vietnam War, but interest soon waned once hostilities ceased. The 1991 Gulf War renewed interest in UAVs, and by the time the Balkans Conflict began, military intelligence personnel were regularly incorporating UAV ISR information into their analyses. Currently, UAVs effectively provide users with real-time ISR information. Additionally, if the ISR information can be quickly understood and locations geo-registered, UCAVs can be used to strike time-sensitive targets with air-to-surface weapons.

Like many weapon systems, UAVs thrive when the need is apparent; when there is no need, they fall into disfavor. Numerous obstacles have hindered UAV development. Oftentimes, technologies simply were not mature enough for the UAVs to become operational. Other times, lack of service cooperation led to failure. For example, the U.S. Army Air Corps funded Project Aphrodite (using B-17s as flying bombs) in WWII,

while the Navy's WWII Project Anvil was very similar but used PB4Ys (the Navy's designation for the B-24). If the services had coordinated efforts, perhaps the overall effort would have been successful. Additionally, competing weapons systems made it difficult for UAVs to get funding. And of course, it was sometimes difficult to sell pilotless aircraft to senior service leaders, who were often pilots.

Many obstacles still stand in the way of continued UAV development. These include mostly nontechnical issues, such as lack of service enthusiasm, overall cost effectiveness, and competition with other weapons systems (e.g., manned aircraft, missiles, or space-based assets).

### WWI: Efforts in the Development of the Aerial Torpedo and Kettering Bug

In 1911, just 8 years after the advent of manned flight, Elmer Sperry, inventor of the gyroscope, became intrigued with the application of radio control to aircraft. Sperry succeeded in obtaining Navy financial support and assistance and, between 31 August and 4 October 1913, oversaw 58 flight tests conducted by Lieutenant P. N. L. Bellinger at Hammondsport, New York, in which the application of the gyroscope to stabilized flight proved successful.<sup>2</sup> In 1915, Sperry and Dr. Peter Cooper Hewitt (best known for his work in radio and contributions to the development of the vacuum tube) were appointed members to the Aeronautical Committee of the Naval Consulting Board, established by Secretary of the Navy Josephus Daniels on 7 October 1915 and led by Thomas A. Edison to advise Daniels on scientific and technical matters.<sup>3-5</sup>

By this time, Europe was embroiled in war, and the utility of unmanned aircraft was becoming apparent. Conditions on the European battlefields were ideal for such a system: enemy anti-aircraft weapons were heavily concentrated, Germany had air superiority in certain sectors, and there was an extremely static battlefield situation over 470 miles of front. Heavy British air losses led to a research program at the Ordnance College of Woolwich, United Kingdom, in remotely controlled pilotless aircraft designed to glide into the target and explode on impact. A parallel program was begun by the Royal Aircraft Factory that included aircraft manufacturers such as the Sopwith Aviation Company and de Havilland. None saw action during the war.<sup>6</sup>

By 1916, Carl Norden (developer of the famed Norden bombsight of WWII) joined the Sperry/Hewitt team and developed the concept of an aerial torpedo. After America's entry into WWI on 6 April 1917, they convinced the Navy to fund their research. Eight days later, the Naval Consulting Board recommended to Secretary Daniels that \$50,000 be granted to Sperry's team to carry out experimental work on aerial torpedoes.<sup>7</sup>

The fact that the Western Electric Company was working on radio devices encouraged Sperry to investigate the use of radio control in the aerial torpedo problem. However, after several tests, it was determined that the radio technology was too immature, and follow-on tests concentrated on maintaining course and measuring distance to the target.

On 10 November 1917, Glenn Curtiss, inventor of the flying boat, delivered an airframe designed to carry 1,000 pounds of ordnance a distance of 50 miles at 90 mph to the Sperry Flying Field at Copiague, Long Island, New York. A successful demonstration of the Navy's aerial torpedo was conducted 11 days later. Meanwhile, Rear admiral Ralph Earle, U.S. Navy Chief of the Bureau of Ordnance, had submitted his ideas on how the aerial torpedo might best be used to win the war and suggested that it might be most effective in defeating the U-boat menace. Earle suggested that aerial torpedoes could be carried on ships stationed off shore from the German submarine bases in Wilhelmshaven, Cuxhaven, and Flanders and used to destroy submarines, shipyard facilities, etc.<sup>3,4</sup> Earle directed Lieutenant T. S. Wilkinson, U.S. Navy, to proceed to the Sperry Flying Field to observe and report on tests being conducted

there. On 6 March 1918, the Curtiss-Sperry aerial torpedo made its longest successful flight, flying a distance of 1000 yards.<sup>1,7</sup> Experiments with pilotless flight continued, and on 17 October 1918, a pilotless N-9 aircraft was successfully launched; it flew its prescribed course but failed to land at a preset range of 14,500 yards and crashed at sea.<sup>4</sup> More than 100 tests were conducted by the Navy before the Armistice was signed on 11 November 1918 and, thus, like its British counterparts, the aerial torpedo never saw wartime service.

The Army was not to be left behind. After witnessing the Navy's aerial torpedo test on 21 November 1917, Major General George O. Squier, Chief Signal Officer of the Army, determined that a parallel effort by the Army should be undertaken at McCook Field, Dayton, Ohio.<sup>3,7,8</sup> The U.S. Army aircraft board asked Charles Kettering to design an unmanned "flying bomb" that could hit a target at a range of 50 miles. Kettering's design eventually acquired the name "Kettering Bug" and had Orville Wright as an airframe consultant and Childe H. Wills of the Ford Motor Company as engine consultant on the project.<sup>1,6,8</sup>

Launching the 530-pound "Bug" was accomplished using a dolly-and-track system, similar to the method



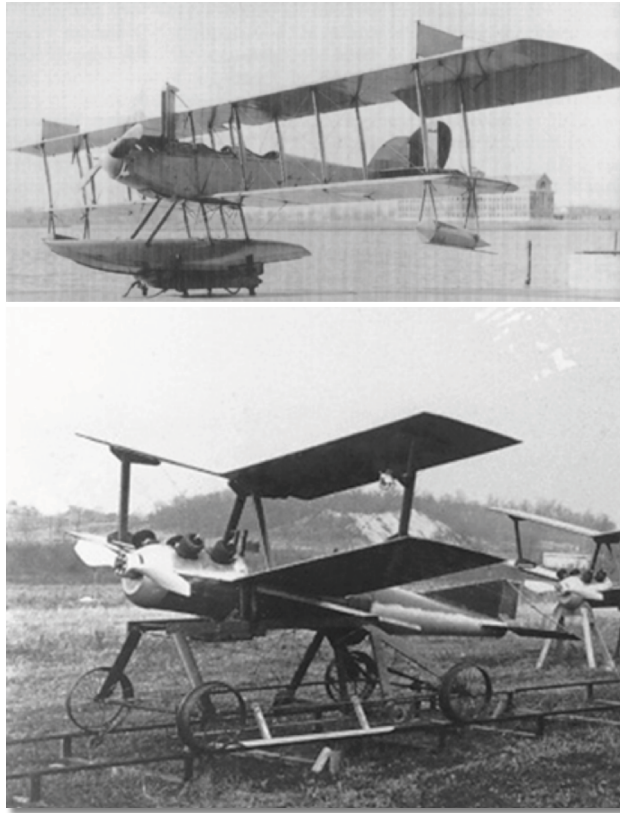
**Figure 1.** Elmer Sperry (top left), Peter Cooper Hewitt (top right), Josephus Daniels (bottom left), and Glenn Curtiss (bottom right) teamed to provide the Navy with its first unmanned aircraft, the aerial torpedo.



**Figure 2.** Charles F. Kettering (top left), Major General George Squier (top right), Orville Wright (bottom left), and Childe H. Wills (bottom right) teamed to provide the Army with the Kettering Bug.

used by the Wright Brothers when they made their first powered flights. Once launched, a small onboard gyroscope guided the aircraft to its destination at an airspeed of about 120 mph. Control was achieved through a pneumatic/vacuum system, electric system, and an aneroid barometer/altimeter.<sup>9</sup>

To ensure that the Bug hit its target, a mechanical system was devised that would track the distance the aircraft flew. Before takeoff, technicians plotted the plane's intended trajectory and forecasted the en route winds. Using this information, technicians also predicted the number of engine revolutions needed for the Bug to reach its destination. As the aircraft neared the end of its flight and the estimated number of revolutions had elapsed, the engine was mechanically turned off and the wings jettisoned. The Bug then began a ballistic trajectory into the target, with the impact detonating the explosive payload. The prototype Bug was completed near the end of WWI, and the Army ordered 25 Bugs on 25 January 1918.<sup>1,10</sup> Flight tests began in September 1918, with the first successful flight on 22 October 1918.<sup>6</sup> Unfortunately, the Bug failed in its testing, having made only eight successful test flights of 36, yielding a 22% success rate. In a fate like those of its Navy and British counterparts, the war ended before the "Bug"



**Figure 3.** A Curtiss N-9 (top), which was modified as the aerial torpedo and a Kettering Bug (bottom), neither of which saw wartime service.

could enter combat.<sup>1</sup> If the Army (Kettering Bug) and Navy (aerial torpedo) had worked jointly on these two concurrent efforts, perhaps an operational system could have been fielded before the Armistice.

### Interwar Years: Development of Target and Assault Drones

During the Interwar Period, the development of unmanned aircraft was impacted by several advancements in the aviation world. These advancements included the rapid growth of the aviation industry, specifically in the air transport sector. This growth hampered testing and operating unmanned systems and continues to do so today. Advancements in radio furthered development and fielding of radio-controlled aircraft. And, finally, the successful demonstrations of aircraft against capital ships off the Virginia Capes in June 1921 stressed the need for development of radio-controlled target drones for use in fleet training exercises.

Economic competition and necessity forced the American government to develop an air management system during the 1920s and 1930s, a period of rapid growth in the airline industry. This system of airways, navigation aids, airdromes, weather stations, and control centers was developed to make long-distance overland flight safer and more regular. Radios were used to simplify traffic deconfliction. Today, this system, administered by the Federal Aviation Administration (FAA), continues to provide for the safety of air travel, particularly through the enforcement of visual and instrument flight rules under which the pilot is to maintain safe separation from obstacles such as terrain, buildings, and other aircraft. Such rules remain obstacles to UAV use in the national airspace.

Interest in unmanned flight waned with military budgets as hostilities ceased. However, this did not prevent enthusiasts from continuing to develop radio-controlled aircraft. A year after the war ended, the Army conducted 14 tests on the Bug, the most successful being a flight of 16 miles that ended in engine failure.<sup>7</sup> The Navy sponsored similar projects, primarily using radio-control technology developed at the Naval Research Laboratory and tested on aircraft at the Lower Station, Naval Proving Ground, Dahlgren, Virginia. The final aerial torpedo test flight was conducted on 25 April 1921 and ended in failure. Rear Admiral Earle's interest in aerial torpedo technology came to an end, and he recommended to Admiral Robert E. Coontz, the Chief of Naval Operations (CNO), that further tests be discontinued.<sup>4</sup>

On 11 May 1922, the Bureau of Ordnance directed that the Proving Ground at Dahlgren acquire one of the original N-9 aircraft used in the aerial torpedo experiments and fit it with a Norden radio-control system.<sup>4</sup> The Naval Research Laboratory, in April 1923, announced



**Figure 4.** On 15 September 1924, for the first time in history, a radio-controlled Curtiss F-5L was flown remotely through all phases of flight.

that equipment for radio control of an F-5L aircraft had been demonstrated up to a range of 10 miles and that it believed that radio control of an aircraft during landing and takeoff was feasible.<sup>7</sup> Tests continued, and on 15 September 1924, two test flights were made in which both the automatic stabilization and radio-control systems functioned flawlessly. A third flight was conducted that same day and, for the first time in history, a radio-

controlled aircraft was flown remotely through all phases of flight—takeoff, maneuver, and landing. Tests continued over the next 14 months, but after an unsuccessful test on 11 December 1925, interest once again waned and, although the project was not canceled, it remained dormant until 1936.<sup>4,8</sup>

After WWI, both the Army and the Navy began disputing the future use of aircraft against surface ships. In March 1919, while on the staff of General Charles T. Menoher, Chief of the Air Service, General Billy Mitchell, a self-proclaimed advocate of air power, proposed a test to determine the outcome. Mitchell hypothesized that the days of the battleship were over, and he wanted to prove it in an actual test. He aggravated his seniors in both services, most notably Rear Admiral William A. Moffett, the Navy's first Chief of the Bureau of Aeronautics.

Leveraging WWI technology used by the Germans in their unmanned torpedo boats, the U.S. Navy renamed the ex-USS *Iowa* (BB-4) to "Coast Battleship No. 4" and converted it to a radio-controlled target ship for gunnery training.<sup>5</sup> Controlled by the USS *Ohio* (BB-10), in June 1921 it was used as a target vessel during tests off the Virginia Capes during which



**Figure 5.** The sinking of the ex-USS *Alabama* (BB-8) (top left) and the ex-SMS *Ostfriesland* (top right) off the Virginia Capes in 1923 demonstrated the vulnerability of surface ships to aircraft. However, it contributed to friction between General Mitchell (bottom center) and senior officers in the Army and Navy, most notably General Menoher (bottom left) and Rear Admiral Moffett (bottom right) and ultimately led to Mitchell's court martial.



**Figure 6.** The de Havilland Tiger Moth was modified to provide radio-controlled aerial target services to the Royal Navy.

it sustained two hits on the forecastle, causing little damage.<sup>4</sup> *Ex-Iowa* would continue to serve the Navy as a radio-controlled target vessel, ultimately being sunk by the USS *Mississippi* (BB-41) in March 1923 in the Gulf of Panama. History was made that June when the German battleship ex-SMS *Ostfriesland* and the U.S. pre-Dreadnought battleship ex-USS *Alabama* (BB-8) were sunk by aircraft. Mitchell had ordered his pilots to avoid direct hits in favor of near misses in the hopes that the explosive forces and water pressure would weaken the hull, resulting in a catastrophic failure.<sup>11</sup> A board of naval officers who had observed the tests concluded that the “airplane is a powerful weapon of offense.”<sup>12</sup> Moffett was forced to admit that “the bombing experiments during June and July . . . demonstrate beyond question that unhampered aircraft suitably armed can sink any type of ship.”<sup>13</sup>

The results of the tests off the Virginia Capes sent virtually every maritime nation into crisis. Proponents of air power were convinced of the vulnerability of surface vessels of all types, while naval officers professed that the tests were unrealistic in that the ships were not shooting in self-defense. To that end, throughout the 1920s, the Royal Air Force worked on a dual-purpose, radio-controlled unmanned aircraft that would perform as an aerial target and as an aircraft capable of weapons delivery. Efforts led to tests of a radio-controlled version of the Fairey IIIIF reconnaissance float plane. Nicknamed the “Fairey Bee,” it was used successfully in exercises against the Home Fleet in the Mediterranean in January 1933. After these tests, the British went on to develop an all-wood version of the de Havilland Tiger Moth named the “Queen Bee,” which would see service through 1943.<sup>1, 4, 6, 8</sup>

In 1935, while attending the London Disarmament Conference, CNO Admiral William H. Standley, U.S. Navy, was provided with a demonstration of British aerial targets. On 1 May 1936, after conferring with Rear Admiral Ernest J. King, the Chief of the Bureau of Aeronautics, he directed the Bureaus of Aeronautics and Engineering, Rear Admiral Harold G. Bowen, to pro-

ceed with the development of radio-controlled targets. On 20 July 1936, Lieutenant Commander Delmar S. Fahrney was ordered as officer in charge of the Radio-Controlled Aircraft Project.<sup>4, 6, 14</sup> Work commenced on the airframe at the Naval Aircraft Factory in Philadelphia, while the radio equipment was developed by the Radio Division at the Naval Research Laboratory. In his semiannual report for the last half of 1936, Fahrney introduced the term *drone* for aerial targets, a designation that endures to this day.<sup>1, 4, 7, 8, 15</sup>

Tests continued through May 1938. On 1 June, all personnel and equipment were moved to San Diego and assigned to the Fleet Utility Wing. To remain clear of populated areas and the congested San Diego airspace, operations took place from Otay Mesa.<sup>14</sup> Drones were used as aerial targets for the first time in the United States on 24 August 1938, when gun crews aboard the USS *Ranger* (CV-4) destroyed the target drone. The second live-fire test was held on 14 September 1938, when gunners aboard the USS *Utah* (AG-16) successfully destroyed a drone simulating a dive-bombing attack. Use of such drones continued over the following year until their use became routine, revealing deficiencies in fleet air defenses against a maneuvering target and accelerating improvements in fire-control systems. The Navy was now committed to funding and developing assault drones.<sup>1, 4, 7, 8, 14, 15</sup>

As a result of his work, Fahrney recommended that the aerial torpedo project of WWI be revived and that the Chief of the Bureau of Aeronautics, Rear Admiral Arthur B. Cook, investigate the use of radio control for testing new aircraft. In early 1938, the Navy commenced discussions with the Radio Corporation of America (RCA) to investigate the possibility of using television equipment to provide an operator in a trailing aircraft with information pertaining to drone instrumentation, as well as to provide the controller with a view ahead of the assault drone during the attack run. Such tests provided the Navy with data to further develop both the assault drone and guided missiles.<sup>1, 4, 7, 8, 14, 15</sup>

In March 1939, tests continued with the USS *Utah* at Guantanamo Bay, Cuba, in which only two drones were lost to gunfire. In a 1980 article in the U.S. Naval Institute *Proceedings*, Fahrney wrote, “This precipitated an agonizing reappraisal of the effectiveness of fleet anti-aircraft defenses and resulted in redesign of both fire control and artillery systems.”<sup>14</sup> The Army sent Captain George Holloman and Lieutenant Rudolph Fink of the Army Air Corps to observe and report on the Guantanamo tests. In a report to the Chief of the Air Corps, Major General Henry “Hap” Arnold, they recommended that the Army initiate its own developmental programs for radio-controlled targets and weapons.

As a result of these tests, the Army contracted with British actor Reginald Denny who, after a move to Hollywood, had started his radio-controlled aircraft



**Figure 7.** In early 1942, Rear Admiral John Towers (left) convinced CNO Harold Stark (right) to pursue development of a radio-controlled aircraft capable of deploying ordnance.

company, Radioplane. In 1941, he began to supply the U.S. Army Air Corps with aerial targets, and over the course of WWII, he supplied them with more than 3,800 target drones. Eventually, Radioplane was acquired by what is now Northrop Grumman, which still produces unmanned aircraft.<sup>1, 8, 9, 15</sup>

## WWII

While the United States watched as war spread across the world, the services continued their efforts to perfect radio control of aircraft, primarily as weapons delivery and guided missile platforms. Upon entry into the war, naval forces in Europe submitted an urgent operational need for a weapon that could be flown into the reinforced U-boat pens along the coast of France. In the South Pacific, the Navy searched for a weapon that could be used to suppress the Japanese defenses of Rabaul.<sup>14</sup> Meanwhile, the Army's Eighth Air Force attempted to develop a similar weapon that could be used to strike heavily defended strategic targets in mainland Europe, specifically facilities supporting the testing and use of Germany's so-called "Vengeance Weapons"—the V-1 flying bomb, V-2 rocket, and V-3 cannon. However, as in WWI, these efforts were uncoordinated and mired in intra- and interservice politics, resulting in limited operational success.

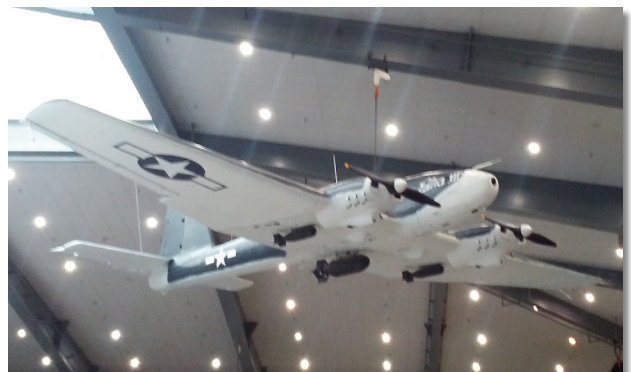
### Navy Efforts

The prewar target drone successes and the lack of sufficient aircraft carriers and their embarked air wings sparked a revival of the aerial torpedo concept. In January 1942, the Chief of the Bureau of Aeronautics, Rear Admiral John H. Towers, pushed to develop a radio-controlled aircraft capable of conducting offensive operations while carrying either a torpedo or depth charge (a forerunner of today's UCAV).<sup>16</sup> Within 3 months, he advised CNO Admiral Harold R. Stark that radar was being developed to replace television as the primary

guidance system to allow operations under all conditions of visibility. During that same month, March 1942, the Navy conducted the first successful live attack with a radio-controlled aircraft armed with a dummy torpedo set against a maneuvering destroyer, USS *Aaron Ward* (DD-483) in Narragansett Bay. Controlled by a "mother" aircraft 20 miles away, the radio-controlled aircraft scored a direct hit on the destroyer's target raft.<sup>1, 7</sup> Further tests against the *Ward* were equally successful when the torpedo was deployed 300 feet from the target and successfully passed directly under the full length of the ship.<sup>7, 14</sup>

Additional tests were conducted in April 1942 when Utility Squadron VJ-1 flew a BG-1 drone just beyond the wreck of the USS *San Marcos* in Tangier Sound in the Chesapeake Bay. A second test was conducted at Civil Aeronautics Administration Intermediate Field in Lively, Virginia. Using a BG-2 drone equipped with a television camera, the control plane, flying 11 miles in trail, successfully directed the drone's crash into a raft being towed at a speed of 8 knots.<sup>7</sup> Successful tests were conducted that summer during which depth charges and torpedoes were deployed from radio-controlled aircraft using television guidance systems. In all, 47 of 50 runs were satisfactorily completed with a maximum distance of 6 miles between the controlling aircraft and the drone in which a clear television picture was maintained. As a result, the Navy ordered 500 assault drones and 170 mother aircraft in preparation for WWII.<sup>1, 4, 7, 14</sup>

Rear Admiral Towers, impressed with the success of the tests, suggested that as many as 100 obsolete TBD Devastator aircraft be assigned to the program, and as SB2C Helldiver and SB2D Destroyer aircraft became obsolete, that they also be assigned. He was emphatic that special assault aircraft be developed in such a manner that they could be manufactured in quantities by industries not connected with the aircraft industry so that the industry would not be further burdened with a weapon unproven in combat.<sup>4, 14, 16</sup>



**Figure 8.** The only remaining TDR-1 on display at the National Museum of Naval Aviation in Pensacola, Florida.



**Figure 9.** USS Sable (IX-81), one of two side-wheel aircraft carriers used for training on the Great Lakes, was used in operational tests of the TDR-1.

In May 1942, after viewing films of successful tests conducted in the Narragansett and Chesapeake Bays, CNO Admiral Ernest King directed that a program be initiated to expedite the development and use of target drones as guided missiles in combat. Dubbed “Project Option,” under the command of Commodore Oscar Smith, drones produced by the Interstate Aircraft and Engineering Corporation were designated TDR-1 and outfitted with television guidance systems and controlled from a trailing TBF Avenger. They could be armed with either a torpedo or a 2000-pound bomb.<sup>4, 14–18</sup>

Meanwhile, on 29 August 1943, the Navy established Special Air Task Groups (STAG) to operate the drones. Although experiments conducted from both the training carrier USS *Sable* (IX-81) (one of the Navy’s two side-wheel propulsion Great Lakes training carriers) and the escort carrier USS *Charger* (CVE-30) determined the feasibility of deploying the TDR-1s from fleet carriers, their only combat use was to be from land. Between July and October 1944, STAG-1 deployed to the Solomon Islands. During that time frame, squadrons VK-11 and VK-12 deployed to Sunlight Field on Banika Island and executed 46 TDR-1 missions against selected Japanese targets from Stirling and Green Islands. Of the 29 missions that reached the target area, 18 were considered successful. The first successful mission on 30 July 1944 was conducted by four drones against the beached Japanese merchantman *Yamazuki Maru* on which anti-aircraft batteries were mounted. Other targets included bypassed Japanese units such as anti-aircraft installations, supply caves, and radar sites. Because the major conflict had moved far to the north, these strikes had little effect on the South Pacific. Additionally, Navy leadership believed that the number of available carriers in the Pacific was sufficient now that the tide had turned and that the TDR, a one-way weapon, was of limited value to the carrier battle group. The unit was disestablished on 27 October 1944, the day after its last mission against a Japanese target.<sup>4, 14–19</sup>

Meanwhile, on the other side of the world, the U.S. Army Air Forces (USAAF) and the U.S. Navy were busy with separate, uncoordinated efforts to attack strategic sites critical to the German war effort. On 6 July 1944, Commander, Air Force Atlantic Fleet, formed a special air unit tasked with converting PB4Y-1 Liberator bombers to assault drones. Reporting directly to Commander, Fleet Air Wing 7 (FAW-7), in Dunkeswell, United Kingdom, the special air unit was tasked with sending explosive drones into the U-boat pens in Helgoland, Germany. Dubbed “Project Anvil,” the first such mission was flown unsuccessfully on 12 August 1944. Project Anvil is blamed for the death of Joseph P. Kennedy Jr., the oldest brother of John F. Kennedy. During an Anvil flight, Kennedy’s aircraft mysteriously exploded in midair, incinerating Kennedy and his crew.<sup>1, 20–22</sup>

### Army Efforts

Operation Aphrodite was the code name of a secret program initiated by the USAAF. The U.S. Eighth Air Force used Aphrodite both as an experimental method of destroying German V (“V” for “Vengeance”) weapon production and launch facilities and as a way to dispose of B-17 bombers that had outlived their operational usefulness—known as “war-weary” bombers.

The plan, first proposed by Major General James H. Doolittle in 1944, called for B-17 aircraft that had been taken out of operational service to be loaded to capacity with explosives and flown by remote control into bomb-resistant fortifications.<sup>20</sup> In preparation for their final mission, several old B-17 Flying Fortress bombers were stripped of all normal combat armament and all other nonessential gear (armor, guns, bomb racks, seats, etc.), reducing each plane’s weight by about 12,000 pounds. The stripped aircraft were then equipped with a radio remote-control system, including television cameras mounted in the cockpit and at the bombardier’s station in the plexiglass nose, and loaded with up to 18,000 pounds of Torpex explosives, more than twice the normal bomb payload.<sup>20, 21</sup> The cameras were used to provide views of both the ground and the main instrumentation panel. These views were transmitted back to an accompanying control aircraft, allowing the craft to be flown remotely on its one-way mission.<sup>1, 20, 21</sup>

Because the remote control did not allow for safe takeoff from a runway, each craft was taken aloft by a volunteer crew of two (a pilot and flight engineer), who were to fly the aircraft to an altitude of 2000 feet, at which point control would be transferred to the remote operators. Just before reaching the North Sea, the two-man crew would prime the explosive payload and parachute out of the cockpit. The “mothership” would then direct the pilotless aircraft to the target.

The first six Aphrodite flights, launched on 4 and 6 August 1944 against facilities for the V-1 flying bomb



at Siracourt, the V-2 rocket at Watten and Wizernes, and the V-3 cannon at Mimoyecques (all in northern France), were only moderately successful.<sup>23</sup> The first mission was flown on 4 August 1944 against a V-1 launch site. One plane lost control after the flight engineer bailed out, and it crashed near Oxford, United Kingdom, making a huge crater and destroying more than 2 acres of the surrounding countryside and killing the pilot. The view from the nose of the other drone was obscured as it came over the target, and it missed by several hundred feet. In the mission's next phase, one drone was shot down by flak and the other missed its target by 500 yards.<sup>20</sup> During the second mission, flown on 6 August, more problems occurred. Although both crews were able to successfully abandon their B-17s without complications, one of the armed B-17s lost control and fell into the sea. The second also lost control but turned inland and began to circle Ipswich, United Kingdom. After several minutes, it fortunately crashed harmlessly at sea.<sup>21</sup>

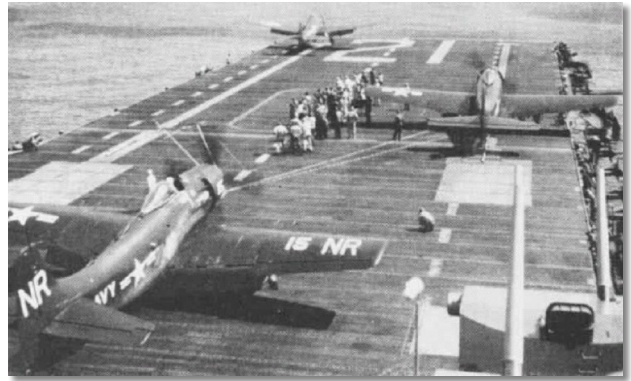
Follow-on flights were halted while Doolittle ordered a failure investigation. Concluding that Project Aphrodite was not successful against the "hard targets" for which it had been designed, U.S. Strategic Air Forces Headquarters ordered that aircraft be sent against industrial targets instead. Two more missions were flown against oil facilities in Heide, Germany, and both were failures. Bad weather and control problems caused misses. The only drone that actually hit the target did not explode, supplying the Germans with a completely intact B-17.<sup>1</sup>

The final Aphrodite mission was flown on 30 October 1944, when two drones were launched against the submarine pens on Helgoland, Germany. One drone landed close enough to the target to cause significant damage and casualties. The second B-17 failed to respond to control signals from the mothership and continued eastward until it eventually crashed and exploded in Sweden.<sup>1, 20, 21, 23</sup> The USAAF decided that the concept behind Project Aphrodite was unfeasible and scrapped the effort. In the course of the operation, only one drone caused any damage, and none hit its assigned targets.

Hence, Project Aphrodite, like the Navy's Anvil, consisted of just a few flights and was canceled for the same reasons. Perhaps if the USAAF and U.S. Navy had worked together as a joint team, an effective guided bomb could have been delivered to operational units.

### The Cold War

The Cold War started immediately after WWII. America's concern was to suppress the spread of Communism by maintaining a nuclear weapons advantage and developing a significant intelligence database to support strategic planning. Manned reconnaissance



**Figure 10.** An F6F-5K of GMU-90 launches from USS *Boxer* (CV-21) off the coast of Korea.

missions were conducted by U.S. Air Force and Navy crews against the Soviet Union, Cuba, China, and North Korea. Aircrews conducted both intentional overflights of sovereign territory as well as Peacetime Aerial Reconnaissance Program flights along unfriendly borders and coastlines. Between April 1950 and April 1969, 16 such missions encountered hostile fire, with the loss of 163 lives.<sup>24, 25</sup>

### The Korean War and the 1960s

When North Korean forces launched a sudden all-out attack on the Republic of Korea on 25 June 1950, U.S. forces in the Pacific were unprepared. In fact, the U.S. Army had no troops on the peninsula, the Air Force had only a few air wings available in the region, and the Navy had just one cruiser, four destroyers, and a few minesweepers on station in the Sea of Japan. Within 36 hours, the United Nations called on its members to assist the South.<sup>23</sup> The next month, in a record Pacific transit, USS *Boxer* (CV-21) carried badly needed Air Force and Navy aircraft and personnel to the war zone. *Boxer* would make three more deployments to Korea. On 5 August 1952, while engaged in combat operations, it suffered a fire on its hangar deck. Two weeks later, after repairs, it was back on station with Guided Missile Unit 90 (GMU-90) and embarked with six F6F-5K Hellcat drones. Each Hellcat carried a 1000-pound bomb under the fuselage and a television and radio repeater pod mounted on the wing.

On 28 August, they took off under radio control from *Boxer* and, under the radio control of Douglas AD-4N Skyraiders from Composite Squadron 35 (VC-35), were guided against selected targets. In all, six such missions were conducted between 28 August and 2 September 1952 against power plants, rail tunnels, and bridges in North Korea, but with an operational success rate of less than 50 percent, the program was dropped. The Hellcats continued to be used by the Navy as targets at China Lake, California, into the 1960s.<sup>7, 26, 27</sup>

In the early 1950s, Ryan Aeronautical Company developed and built 32 jet-propelled, subsonic UAVs known as Ryan “Firebees.” The Firebee design lives to this day and has dominated UAV history. The Firebee UAV (originally designated Q-2A/B) dates to 1951 and was used initially as a target drone. The political fallout of Francis Gary Powers being shot down over the USSR in his U-2 in 1960 led many in the DoD to start thinking about unmanned reconnaissance of the USSR. Ryan Aeronautical modified some of its standard Firebee training targets into reconnaissance UAVs (recon-UAVs) and designated them the 147A “Firefly.” The Firefly, renamed the “Lightning Bug,” was modified considerably to change it from a target drone to a recon-UAV. In the early 1960s, Ryan Aeronautical Company designed and developed more than 20 versions of its famous Lightning Bug unmanned subsonic target drone.<sup>28</sup> One model, the AQM-34N, had wet wings, meaning that it carried fuel in its wings, giving it a range of approximately 2500 miles.

In the mid- to late 1950s, the United States needed a way to counter the threat of a rapidly growing Soviet submarine force. The Navy’s DASH (QH-50) was the first operational unmanned helicopter designed for a combat role. In 1960, a QH-50 (powered by a Gyrodyne-Porsche engine) made its maiden flight at Patuxent River Naval Air Station in Maryland. During the 1960s, almost 800 QH-50s were built.<sup>29</sup> The DASH unmanned helicopters were flown remotely from a destroyer’s deck and carried Mk-44 homing torpedoes or Mark 17 nuclear depth charges. They could also be controlled from manned aircraft or ground vehicles and could drop sonobuoys and flares, perform rescues, transport cargo, illuminate targets, deploy smoke screens, perform surveillance, and target spot for naval fire support. QH-50s subsequently carried a mini-gun and even



**Figure 11.** A QH-50C DASH drone is recovered aboard USS Hazelwood (DD-531).



**Figure 12.** Still used today, two Teledyne-Ryan AQM-34 drones are carried on the wings of a DC-130 Hercules aircraft.

dropped an assortment of bomblets in various covert missions over Vietnam in the late 1960s. In 1970, the DASH program was canceled, and remaining QH-50s were used as target drones.<sup>30</sup>

The Bikini program was a 7-year U.S. Marine Corps research and development program, beginning in 1959, that looked at methods of providing organic, real-time reconnaissance for a battalion commander. It was designed to consist of a two-man drone team with a jeep-mounted launcher and an airborne drone with a 70-mm camera. However, the U.S. Marine Corps determined that technology at that time was inadequate and the system was therefore not fielded. However, the 7-year program did lead to development and employment ideas for UAVs three decades later.

On 27 October 1962, President Kennedy demanded that the Soviet Union dismantle its missile bases and remove its nuclear warheads from Cuba. That same day, Soviet SA-2 missiles in Cuba shot down a U-2, killing its pilot Major Rudolph Anderson Jr. With the Cuban Missile Crisis at its peak, the United States needed photographic confirmation that the Soviets had either removed their missiles or refused to do so. Only two U-2s were immediately available to continue the Cuban overflights. Because only two of the Ryan Lightning Bugs had been built and their operational testing had not yet been completed, RF-8A Crusader aircraft were used to image Cuba. The Cuban Missile Crisis demonstrated a need for a concerted UAV development effort by the U.S. military. By the August 1964 Tonkin Gulf incident, UAVs were finally accepted for wartime service.<sup>31</sup>

In 1964, while deployed to Kadena Air Base, Okinawa, the Strategic Air Command’s 100th Strategic Reconnaissance Wing launched Teledyne-Ryan AQM-34 drones from DC-130 Hercules aircraft flying along the coast of mainland China. These UAVs penetrated Chinese airspace and obtained high-quality photographic imagery of military facilities and troop movements and



**Figure 13.** An H-53 helicopter performs a midair retrieval (MARS).

were later recovered on the surface of the South China Sea. In 1965, the Chinese held a news conference during which they displayed a downed U.S. pilotless reconnaissance aircraft. This was the first opportunity the American public had to observe a UAV performing missions too dangerous or politically sensitive to be undertaken by manned aircraft. UAV operations against mainland China were suspended by President Richard M. Nixon in the early 1970s as a result of improved relations between the two countries.<sup>6</sup>

### The Vietnam War

The Vietnam War was America's first "war" that saw extensive use of UAVs. A total of 3435 operational reconnaissance UAV missions were flown between 1964 and 1975.<sup>1</sup> Approximately one-third of these missions were various versions of the Lightning Bug, which was the workhorse of Vietnam-era UAVs. Between 1967 and 1971, 138 missions were launched from DC-130 aircraft and flown via remote control in hostile territory. Many were recovered via the MARS (midair retrieval system), which was a specially equipped H-53 helicopter that caught the drone while in its parachute descent.

Operation Chicken was the operation in which the Lightning Bug UAV was introduced to many of the same tactics used by manned aircraft to escape MiG (Mikoyan and Gurevich—a former Soviet, and now Russian corporation) aircraft intercepts, air-to-air missile intercepts, and surface-to-air missile intercepts, thus introducing us to the age of artificial intelligence.

Because of the extent of enemy anti-aircraft fire in Vietnam, UAVs were often used as unmanned intelligence gathering platforms, taking photos from low and high altitude (IMINT, or imagery intelligence) that were used for strike planning and battle damage assessment. As the Vietnam War wore on, the Lightning Bugs were modified with larger engines that allowed them to carry heavier payloads. These UAVs could now perform sig-

nals intelligence missions in addition to their IMINT roles. Late in the Vietnam War, UAVs also performed psychological operations via leaflet drops.

In 1965, the U.S. Air Force established a requirement for a long-range recon-UAV. Ryan developed the model 154, Compass Arrow, designed to fly at 78,000 feet; it was also designed with minimal heat and radar signature, thus becoming the first UAV to use stealth technologies. Like its cousin the Lightning Bug, Compass Arrow was launched from a DC-130, was recovered via MARS, and had electronic countermeasures to improve its survivability. The program failed to move forward because of various political, financial, and technical problems. So while the Lightning Bug was an enormous success, both as a drone and a recon-UAV, Compass Arrow was a failure and possibly led to the lack of UAV acceptance at that time by many in the aviation business.

But with the success of the Lightning Bug, the modern UCAV was born. After 4 years of research and development, Ryan Aeronautical took its Lightning Bug design and showed that it could strike and destroy a ship from a distance of about 100 miles. In 1971, the Lightning Bug (model BQM/SSM) flew a perfect demonstration, slamming into the side of the ex-USS *John C. Butler* (DE-339). But the BQM/SSM was competing against the more versatile Harpoon weapon system, which was all-weather and could be employed from a variety of platforms. Hence, the Navy chose Harpoon and canceled the BQM/SSM effort.

Like the BQM/SSM, the BGM-34A was developed because of hostilities. Israel was concerned about Soviet-made anti-aircraft artillery emplacements along the Suez Canal. In 1971, Teledyne-Ryan Aeronautical (TRA) developed a UCAV that could deliver air-to-surface munitions.<sup>1</sup> TRA again used the Lightning Bug as the basic frame and then used pieces from other UAVs to develop the final BGM-34A product. In less than a year, TRA had developed a UCAV that was used to fire a powered, guided air-to-surface missile against a simulated target. American military thinkers had the idea of using these UCAVs on the first wave to soften a target then to finish off the target with manned aircraft. The Israelis agreed and used the BGM-34A against Egyptian missile sites and armored vehicles in the October 1973 Yom Kippur War and again in 1982 against Syrian missile emplacements in the Bekaa Valley.<sup>13</sup> These Israeli UCAVs certainly saved the lives of Israeli pilots. Americans never used this UCAV in Vietnam because it could not perform better than manned technology. After the Vietnam conflict, a few improvements were made to the BGM (such as models 34B and C), but generally speaking, interest in UAVs in general waned and further expenditures on recon-UAVs were put on hold. Additionally, UAVs had to compete with new high-speed missile systems, long-range bombers, and cruise missiles.



**Figure 14.** A Pioneer UAV is recovered aboard an *Iowa*-class battleship.

So, with drastic budget cuts, UAV development basically ceased for about a decade.

In the late 1970s, the U.S. Army began a major UAV acquisition effort known as Aquila. It was originally estimated to cost \$123 million for a 4-year development cycle, followed by \$440 million for the production of 780 vehicles.<sup>32</sup> Its original mission was to be a small propeller-driven, man-portable UAV that provided ground commanders with real-time battlefield intelligence. As development continued, requirements grew and the UAV's small size could no longer handle the avionics and payload items the Army wanted, such as autopilot, sensors to locate the enemy in all conditions, laser designators for artillery projectiles, and abilities to survive against Soviet anti-aircraft artillery. The Army abandoned the program in 1987 because of cost, schedule, and technical difficulties (and after \$1 billion in expenditures).

### The First Persian Gulf War

Israeli successes in 1973 and 1982 led the United States to finally procure a new UAV of its own, primarily to conduct battle damage assessment for the U.S. Navy. This Israeli Aircraft Industries UAV, Pioneer, has been used by U.S. forces since the late 1980s. Pioneer was procured starting in 1985 as an interim UAV capability to provide IMINT for tactical commanders on land and at sea. Pioneer skipped the traditional U.S. development phase of the acquisition process, and nine systems, each with eight air vehicles, were procured beginning in 1986, at an estimated cost of \$87.7 million. Similar to Aquila, Pioneer is a small propeller-driven aircraft. The Pioneer encountered unanticipated problems almost immediately after delivery. Recoveries aboard ship and electromagnetic interference from other ship systems were serious problems that led to a significant number of crashes. The Pioneer system also suffered from numerous other shortcomings. The Navy undertook a \$50-mil-

lion research and development effort to bring the nine Pioneer systems up to a level it described as a “minimum essential capability.”<sup>33</sup>

However, the Pioneer flew 300+ combat reconnaissance missions during Persian Gulf operations in 1990–1991. The system received extensive acclaim for outstanding performance in Operations Desert Shield and Desert Storm. Army, Navy, and Marine Corps commanders lauded the Pioneer for its effectiveness. During the Persian Gulf War, all the UAV units at various times had individuals or groups attempt to signal the Pioneer, indicating their willingness to surrender. The most famous incident occurred when the USS *Missouri* (BB-63), using its Pioneer to aim its accurate 16-inch gunfire, devastated the defenses of Faylaka Island off the coast near Kuwait City. Shortly thereafter, while still over the horizon and invisible to the defenders, the USS *Wisconsin* (BB-64) sent its Pioneer over Faylaka Island at low altitude. When the Pioneer came over the island, the defenders recognized that they were about to be targeted, so using handkerchiefs, undershirts, and bedsheets, they signaled their desire to surrender.<sup>1,34</sup> Since the Persian Gulf War, Pioneer has flown operationally in Bosnia, Haiti, and Somalia, and, of course, it has become one of the primary weapons of choice in the Second Persian Gulf War and the Global War on Terror.

### CONCLUSIONS

In this review article, we have presented the reader with a brief history of early unmanned aircraft, focusing on WWI through the First Persian Gulf War. Nowadays, unmanned aircraft such as the Predator are armed with laser designators and Hellfire missiles so they can perform attack orchestration and target termination, not just ISR. Other unmanned aircraft, such as Global Hawk, operate almost completely autonomously, remotely piloted by operators thousands of miles away—this type of vehicle uses GPS and transmits a live video feed back to its operations center. In addition, other unmanned aircraft are so small that they can be hand launched and have become useful in street fighting or other types of close-in engagements, where they can assist the operator in discovering imminent ambushes.

Unmanned aircraft have come a long way over the past century. Just as Brigadier General Billy Mitchell crusaded against traditional military thinking when it came to the use of airpower, current UAV crews are striving for greater recognition of their aircraft and the operations they perform, from ISR to force protection to precision strike.

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## REFERENCES

- Clark, Richard M., *Uninhabited Combat Aerial Vehicles: Airpower by the People, for the People, But Not with the People*, CADRE Paper No. 8, Air University Press, Maxwell Air Force Base, Montgomery, AL (2000).
- Coletta, Paolo E., *Patrick N. L. Bellinger and U.S. Naval Aviation*, University Press of America, Inc., Lanham, MD (1987).
- Van Wyen, Adrian O., *Naval Aviation in World War I*, Chief of Naval Operations, Washington, DC (1969).
- Howeth, Linwood S., *History of Communications—Electronics in the United States Navy*, Bureau of Ships and Office of Naval History, Washington, DC (1963).
- Scott, Lloyd N., *Naval Consulting Board of the United States*, Government Printing Office, Washington, DC (1920).
- Shaker, Steven M., and Wise, Alan R., *War Without Men: Robots on the Future Battlefield*, Pergamon-Brassey's International Defense Publications, Inc., Washington, DC (1988).
- Grossnick, Roy A., *United States Naval Aviation, 1910–1995*, Naval Historical Center, Department of the Navy, Washington, DC (1997).
- Erhard, Thomas P., *Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation*, PhD thesis, Johns Hopkins University, Baltimore (2000).
- O'Reilly, Thomas G., *Uninhabited Air Vehicle Critical Leverage System for Our Nation's Defense in 2025*, Air University Press, Maxwell Air Force Base, Montgomery, AL (1999).
- Nalty, Bernard C. (ed.), *Winged Shield, Winged Sword: A History of the USAF*, Air Force History and Museums Program, United States Air Force, Washington, DC (1997).
- Doolittle, James H., *I Could Never Be So Lucky Again*, Bantam Books, New York (1991).
- Waller, Douglas, *A Question of Loyalty: Gen. Billy Mitchell and the Court-Martial That Gripped a Nation*, Harper-Collins Publishers, New York (2004).
- Trimble, William F., *Admiral William A. Moffett: Architect of Naval Aviation*, Smithsonian Institution Press, Washington, DC (1994).
- Fahrney, Delmar S., "The Birth of Guided Missiles," *Proceedings* (December 1980), 54–60.
- McDaid, Hugh, and Oliver, David, *Robot Warriors: The Top Secret History of the Pilotless Plane*, Orion Media, London (1997).
- Reynolds, Clark G., and Towers, John H., *The Struggle for Naval Air Supremacy*, Naval Institute Press, Annapolis (1991).
- Hall, James J., *American Kamikaze*, J. Bryant, Ltd., Titusville, FL (1984).
- Special Task Air Group One (STAG-1) website, [www.stagone.org](http://www.stagone.org).
- Cressman, Robert J., *The Official Chronology of the U.S. Navy in World War II*, U.S. Naval Institute, Annapolis (2000).
- "Operation Aphrodite," *Wikipedia*, [http://en.wikipedia.org/wiki/Operation\\_Aphrodite](http://en.wikipedia.org/wiki/Operation_Aphrodite) (last modified 11 Aug 2013).
- Olsen, Jack, *Aphrodite: Desperate Mission*, Pyramid Books, New York (1972).
- Jermy, Trevor, and Curtis, Lester (ed.), "Lt. Joe Kennedy," *Norfolk and Suffolk Aviation Museum*, [www.aviationmuseum.net/Joe\\_Kennedy.htm](http://www.aviationmuseum.net/Joe_Kennedy.htm).
- Price, Alfred, *The History of US Electronic Warfare: The Years of Innovation—Beginnings to 1946*, The Association of Old Crows, Alexandria, VA (1984).

- <sup>24</sup>Tart, Larry, and Keefe, Robert, *The Price of Vigilance: Attacks on American Surveillance Flights*, Ballantine Books, New York (2001).
- <sup>25</sup>Burrows, William E., *By Any Means Necessary: America's Secret Air War in the Cold War*, Farrar, Straus and Giroux, New York (2001).
- <sup>26</sup>Cagle, Malcolm W., and Manson, Frank A., *The Sea War in Korea*, Naval Institute Press, Annapolis (1957).
- <sup>27</sup>Memorandum from Commanding Officer, USS Boxer (CV-12), to Chief of Naval Operations, 8 Sep 1952 (in possession of authors).
- <sup>28</sup>Parsch, A., "Teledyne Ryan Q-2/KDA/xQM-34/BGM-34 Firebee," *Directory of U.S. Military Rockets and Missiles: AQM/BQM/MQM/BGM-34*, Designation-Systems.Net, <http://www.designation-systems.net/dusrm/m-34.html> (last updated 18 Oct 2012).
- <sup>29</sup>"DASH Weapon System," *DASH History*, Gyrodyne Helicopter Historical Foundation, [www.gyrodynehelicopters.com/dash\\_history.htm](http://www.gyrodynehelicopters.com/dash_history.htm).
- <sup>30</sup>"QH-50A Drone," White Sands Missile Range Historical Foundation website, [www.wsmr-history.org/QH-50A.htm](http://www.wsmr-history.org/QH-50A.htm).
- <sup>31</sup>Fleishood, Dennis G., *Employment of RPVs in Support of Naval Operations*, Naval War College Press, Newport, RI (1988).
- <sup>32</sup>Federation of American Scientists website, Aquila search results, <http://www.fas.org/search/index.html?cx=011272476961064978591%3A1x1cammk60s&cof=FORID%3A11&q=aquila&siteurl=www.fas.org%2Fprogram%2Fcollect%2Faquila.htm&ref=&ss=1553j628831j6>.
- <sup>33</sup>Pike, John, "Pioneer Short Range (SR) UAV," Federation of American Scientists website, <https://www.fas.org/irp/program/collect/pioneer.htm> (updated 5 Mar 2009).
- <sup>34</sup>"Growing World of Unmanned Airborne Spies," *Armada International* 28(3), 55–56 (2004).

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