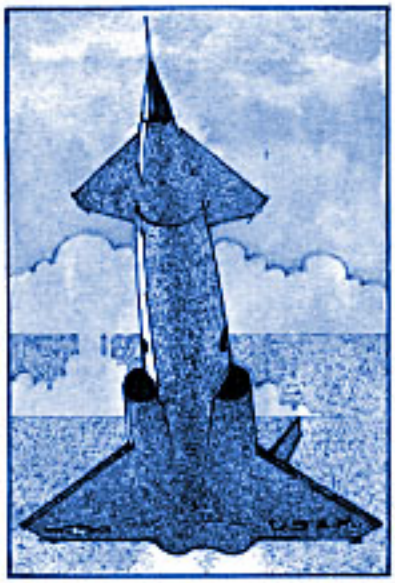
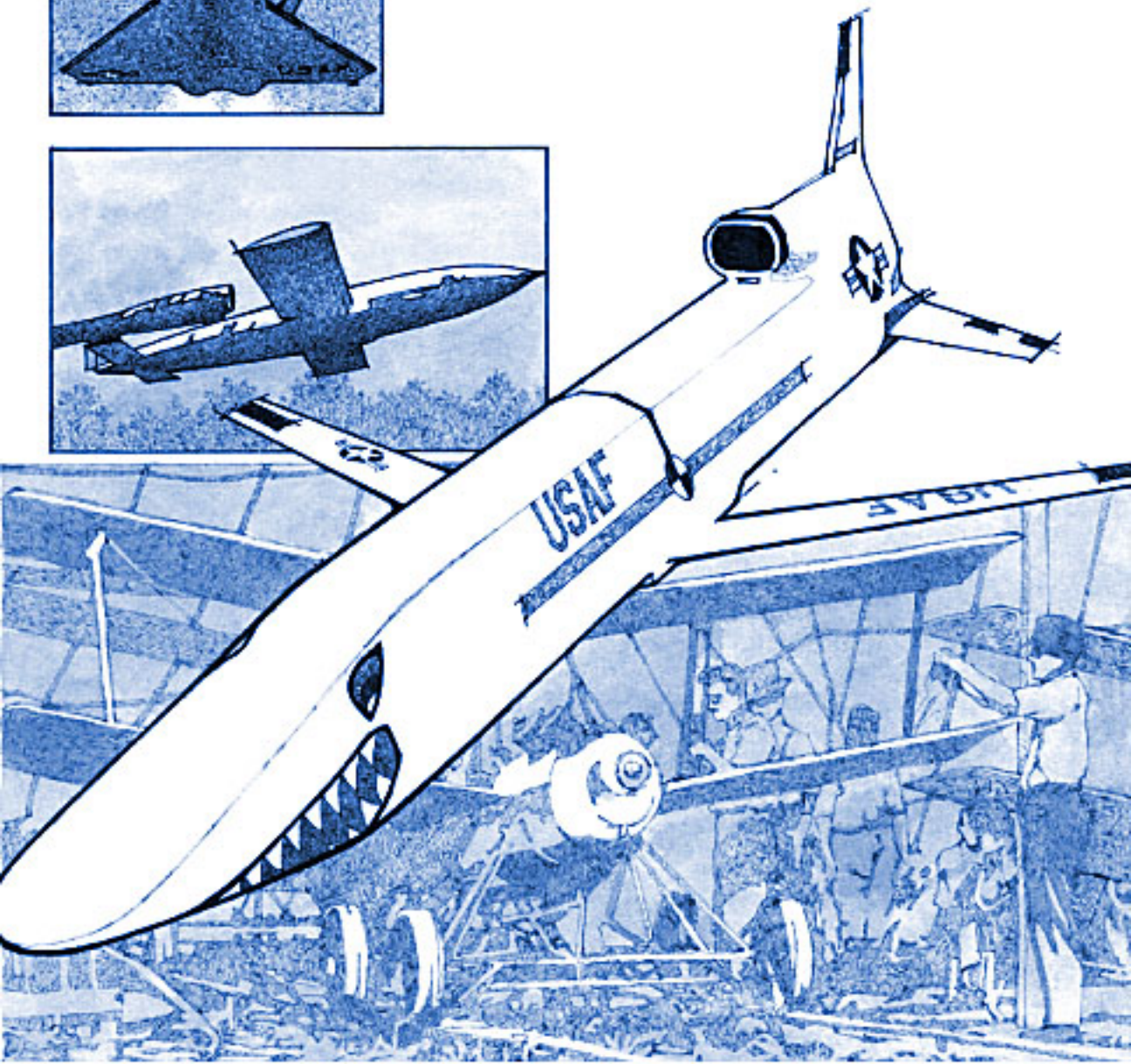


THE EVOLUTION OF THE CRUISE MISSILE



The Evolution of the Cruise Missile

by

KENNETH P. WERRELL

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To those Americans who have served, are serving, or will serve with the cruise missile.

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FOREWORD

The penchant of the American military to be on the leading edge of technology could destroy our perspective of new weapon systems and distort our perceptions of their most effective use in modern warfare. So it is with cruise missiles, one of technology's newest and most sophisticated developments. Dr Werrell's book provides the perspective and insight we would otherwise lack.

Although cruise missiles are among the newest and most sophisticated weapons fielded by the United States, they possess a rich conceptual and technological heritage. It is important that we understand this heritage as we consider deployment and employment options. It is also important that we understand the developmental process illustrated by the history of the cruise missile. Without the perspective provided by this history, our perceptions of their purpose and use lack depth and insight.

Many significant events have intervened between the completion of Dr Werrell's manuscript in 1982 and its publication. The manuscript has not been updated because rapid developments make such updating an endless task. In fact, the rapid pace of continued development serves to reinforce the need to reflect on the development of these systems and to place their purpose in perspective.

Donald D. Stevens

DONALD D. STEVENS, Colonel, USAF
Commander
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A frequent participant in military history workshops and conferences, Dr Werrell has authored several articles and papers on military history. Among these is *Eighth Air Force Bibliography* (MA/AH Publishing, 1981).

Dr Werrell was commissioned upon graduation from the United States Air Force Academy in 1960, and received his pilot wings in 1961. Assigned to the 56th Weather Reconnaissance Squadron in Yokota, Japan, from 1962 until 1965, Dr Werrell served first as pilot and later as aircraft commander for the WB-50. He resigned his commission with the rank of captain in 1965.

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Kenneth P. Werrell

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CHAPTER I

INTRODUCTION

The outcome of war is determined by a complex combination of factors that include numbers, politics, strategy, tactics, training, morale, leadership, organization, logistics, weapons, and luck. A slight superiority in most of these categories, or a great superiority in one, can account for victory. Without attempting to rank order these factors, it is obvious that the country possessing better weapons increases its chances of victory.

Consequently, the United States must come to grips with changing technology if the country is to remain militarily strong. A leading student of military technology has put it this way:

> . . . new and more effective weapons have generally been adopted only slowly in spite of their obvious advantages. Since the character of contemporary weapons is such that their production as well as their use can dislocate whole economies, it is probably not too much to suggest that the survival of entire cultures may hinge upon an ability to perfect superior weapons and exploit them fully. Survival itself, then, appears to depend on speed in both the development and the optimum utilization of weapons.[1]

Given this premise, the US military must not become part of the problem, but rather must make the best use of the country's economic, scientific, and manufacturing resources. The services must look to the future. In 1945, the top American airman wrote that:

> National safety would be endangered by an Air Force whose doctrines and techniques are tied solely on the equipment and process of the moment. Present equipment is but a step in progress, and any Air Force which does not keep its doctrines ahead of its equipment, and its vision far into the future, can only delude the nation into a false sense of security.[2]

While weapons come and go in the military, history provides examples of classes of weapons having both a dramatic and a lasting impact upon the conduct of warfare. These examples involve weapons which were, at their inception, revolutionary since they were not merely new but clearly superior to equipment already in use on the battlefield. Because they dominated warfare they were crucial to battlefield success; and nations possessing and using such weapons effectively were, more often than not, victorious. Examples include the long bow, gunpowder,

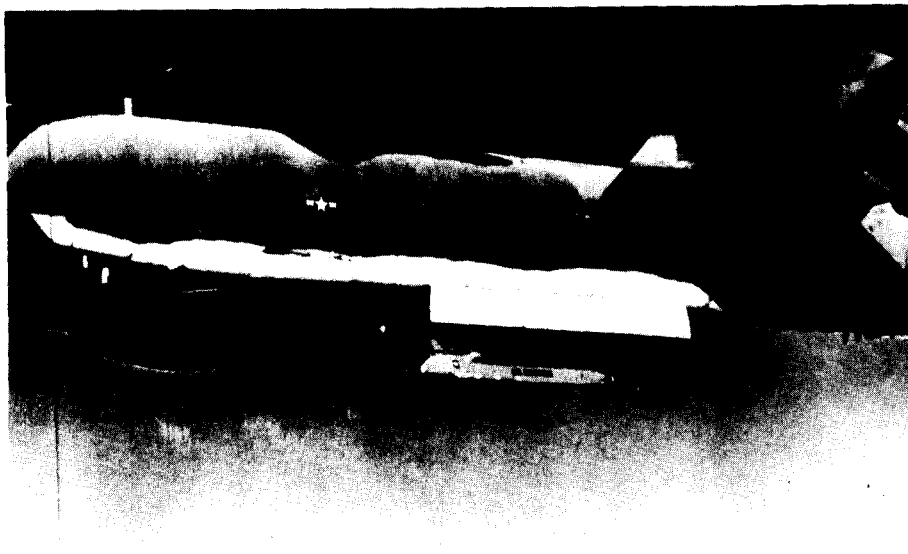
iron-clad steamships, tanks, and airplanes. These weapons not only displaced existing armaments, they also forced widescale changes in military training, organization, tactics, strategy, and thought. For example, the airplane has come to dominate land and sea warfare in addition to introducing a new form of warfare, direct bombardment of the enemy's homeland. A number of technological developments have fundamentally changed the course of airpower during its short history. Some of the more salient examples are jet engines, nuclear warheads, radio, radar, and missiles (ballistic and cruise: surface-to-surface, air-to-air, air-to-ground, and surface-to-air).

A class of missile of particular interest, now entering the US inventory, is the cruise missile. The purpose of this study is to evaluate the cruise missile against the criteria suggested above, seeking answers to two basic questions: Is the current cruise missile simply another weapon in the now familiar class of aerial munitions? Or does it represent a potentially revolutionary class of weapons in its own right? These questions, and the answers to them, may well have far-reaching implications, for if the current version of the cruise missile represents not an evolutionary development but a quantum leap forward in weaponry, then US development and employment strategies require significant adjustment.

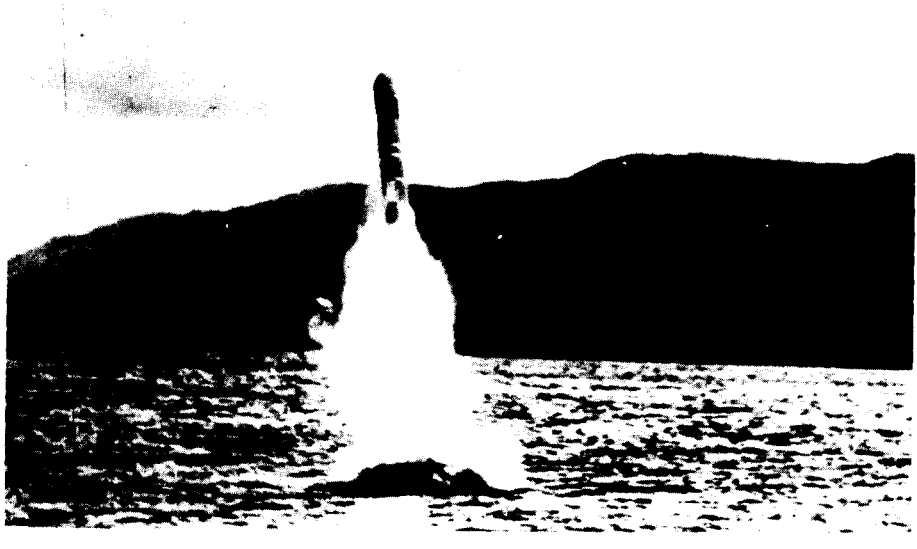
In actuality, the cruise missile, as an operational concept and system, has been around for some time; and very early on inspired rather far-reaching claims. A newspaper account in 1915 called it: "A device . . . likely to revolutionize modern warfare."[3] Before World War I was over, the cruise missile, or the aerial torpedo, as it was then called, was touted as "the gun of the future"[4] and compared in importance with the invention of gunpowder.[5] Billy Mitchell saw it as: "A weapon of tremendous value and terrific force to airpower."[6] The passing of years has not dimmed enthusiasm for the device, a newspaperman in 1977 writing that: "Except for gunpowder and atomic bomb, no weapon has threatened a greater effect on war and peace than the cruise missile."[7] More temperate comments also emphasize its importance. "The advent of the long-range highly accurate cruise missiles," one high official told Congress, "is perhaps the most significant weapon development of the decade."[8] According to Leslie Gelb, a noted defense analyst: "The cruise missile could be an invaluable addition to our security or a dangerous complication."[9]

Indeed, there is little doubt that the cruise missile today is important to the overall US defense effort. At this writing (June 1983), US defense planners are calling for a large buy of cruise missiles in a variety of forms: 3,000 ALCMs (Air-Launched Cruise Missiles), 3,994 SLCMs (Sea-Launched Cruise Missiles), 560 GLCMs (Ground-Launched Cruise Missiles), and perhaps 3,000 to 5,000 MRASMs (Medium-Range Air-to-Surface Missiles) with a total estimated price tag of almost $30 billion.[10] This willingness by DOD officials to spend large sums on various versions of the cruise missile indicates that DOD believes the weapon is crucial to a successful future defense posture. Such an investment of confidence and dollars merits serious attention by military professionals and lay persons alike.

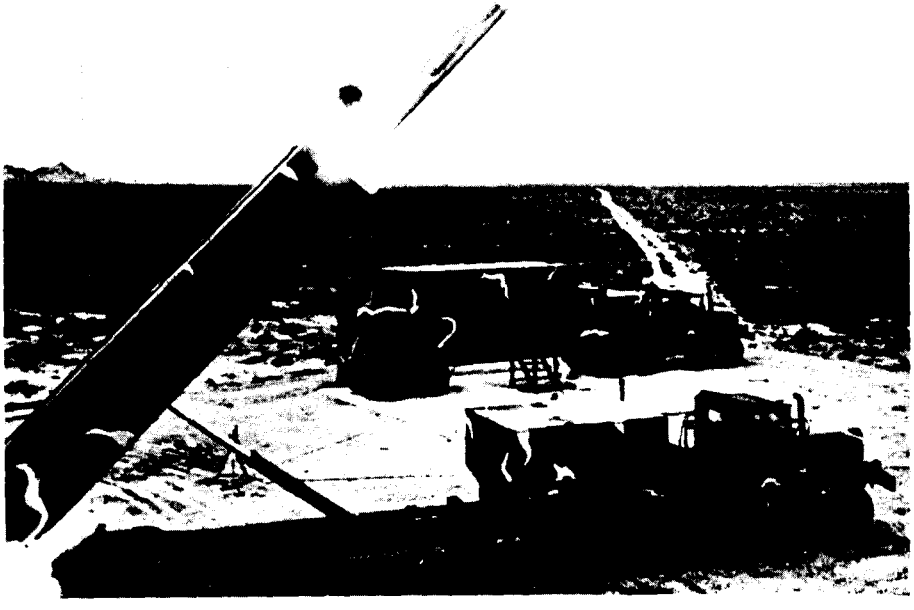
Certainly, the public needs to know more about this weapon in order to follow its



The Boeing AGM-86B, ALCM (Air Launched Cruise Missile). (USN)



The General Dynamics BGM-109, SLCM (Sea Launched Cruise Missile). (USN)



The General Dynamics BGM-109, GLCM (Ground Launched Cruise Missile). (General Dynamics)

progress, to understand its importance, and to bear its costs. This point is fundamental because public knowledge represents the only viable mechanism in a democracy for generating support for defense projects. For its part, the military establishment at all levels* needs to know more about the cruise missile for even more fundamental reasons. Those operating it will be effective only to the extent that they comprehend the weapon's capabilities and limitations. But even those military members not directly involved with the cruise missile need to be well informed to appreciate its importance and to know why it receives so much funding and attention. At the higher levels, planners and decisionmakers need to understand cruise missiles as much as possible in order to make the best decisions and plans.

Students of the cruise missile should focus on the basic characteristics of the weapon. Consequently, this study addresses these characteristics as well as questions derived from and inherent in them. Such an approach can put the story into a more meaningful context and suggest follow-on questions and hypotheses for further evaluation. A review of the cruise missile's long historical record can illuminate not only where it has been, but suggest where it may be going. This is admittedly an ambitious goal. But to be more than "just an interesting" study, more than "just history for history's sake," this study must raise and satisfactorily answer a number of specific questions.

*See Appendix B for a survey of the Air War College class of 1982, including a rough test of the knowledge level of Air Force officers on the cruise missile.

For instance, what has changed and what has remained constant between the earlier and current versions of the cruise missile? What advantages and disadvantages are inherent to cruise missiles as a class of weapons? Why were cruise missiles not successfully introduced on a large scale into military inventories before? What obstacles has the weapon encountered? Overall, what lessons can be gleaned from the historical record of the cruise missile? What are the useful parallels? Finally, how important is the cruise missile? Is the cruise missile just another weapon like so many others, or does it represent a revolutionary class of weapon?

NOTES

CHAPTER I

1. I. B. Holley, Jr., *Ideas and Weapons* (New Haven, Conn.: Yale University, 1953), 175.

2. Henry H. Arnold quoted in Air Force Manual 1-1, *Functions and Basic Doctrine of the United States Air Force*, February 1979, 4–11.

3. "Aerial Torpedo is Guided 100 miles by Gyroscope," *New York Tribune* (21 October 1915), 1.

4. Elmer Sperry to Admiral Earle, 25 October 1918, quoted in Delmar S. Fahrney, "The History of Pilotless Aircraft and Guided Missiles," manuscript, Naval Historical Center, c. 1958, 112, 113.

5. George O. Squier to Chief of Staff, 5 October 1918, Subject: "An Automatic Carrier for the Signal Corps (Liberty Eagle),"; Bion J. Arnold to the Secretary of War, "Secret Report on Automatic Carriers, Flying Bombs (FB), Aerial Torpedoes (AT)" 31 January 1919, Exhibit F, Air University Library Film 623.451 W253B.

6. William Mitchell, "Lawrence Sperry and the Aerial Torpedo," *U.S. Air Services* (January 1926), 16.

7. Howard Silber, *Omaha World-Herald* (17 April 1977), 11.

8. Malcolm R. Currie quoted in John H. Douglas, "A Technology Revolution in Weaponry," *Science News* (23 July 1977), 60.

9. Leslie H. Gelb, "Nuclear Bargaining: The President's Options," *New York Times Magazine* (27 June 1982), 61.

10. The price tag on the GLCMs is $3.7 billion, on the MRASM $3 to $6 billion, and on the SLCMs $11.8 billion. The ALCM buy of 4,348 missiles at $8.5 billion was cut to 3,000 missiles and unspecified cost in February 1983. "Tomahawk Numbers," *Aerospace Daily* (5 April 1982), 201; "Pentagon, Announcing SARs, Indicates F-15, F-16 Derivatives," *Aerospace Daily* (23 March 1982), 129, 130; "JCMPO Seeks Potential Competition for GLCM TEL, LCCs," *Aerospace Daily* (23 December 1981), 275; "SAR Programs Summarized as of September 30," *Aerospace Daily* (18 November 1982), 101; "Pentagon Puts Cruise Missile Through Extensive Review," *Aerospace Daily* (20 May 1981), 106; David R. Griffiths, "Proposal Set on Air-to-Surface Missile," *Aviation Week* (29 December 1980), 24, 25; Harriet S. Hughes, "Competition Options for the Medium Range Air-to-Surface Missile Program," unpublished MA Thesis, American University, 1981, 23, 24; "Navy Sees MRASM as Money Problem," *Aerospace Daily* (24 August 1982), 297; "Air Force Cuts ALCM Total; Navy Retains Tomahawk Plans," *Aerospace Daily* (3 February 1983), 193.

CHAPTER II

THE EARLY YEARS: TO 1941

Even before World War I, during the first decade of powered flight, the idea of an unmanned, automatically controlled "flying bomb" or "aerial torpedo" circulated in a number of countries.[1] The technology making such a device possible consisted of gyroscopes mounted in contemporary airframes. The first practical efforts on record began when Peter C. Hewitt, inventor of the mercury vapor lamp, approached Elmer A. Sperry of Sperry Gyroscope Company in April 1915 with the idea of a "flying bomb."[2] Together they developed and tested an automatic control system on both a Curtiss flying boat and a twin-engine aircraft.[3] This particular system showed enough promise by the summer of 1916 to merit a test with an official observer. In August, Elmer Sperry wrote to Lieutenant Colonel George O. Squier of the Signal Corps, but the Army did not answer.[4] Consequently, the two inventors arranged an official trial with the Navy. On 12 September 1916, Lieutenant T. W. Wilkinson, Jr. (USN), with Sperry's son Lawrence as pilot, took off aboard a specially equipped seaplane. Under automatic control, the aircraft climbed to a predetermined altitude, held a satisfactory compass course, flew a set distance, dove, and would have impacted as planned had Sperry not intervened.[5]

Elmer Sperry's developments with gyroscopes made unpiloted missiles possible. In addition, he was directly involved in both of America's World War I missiles. (Sperry Corp.)

Wilkinson wrote what appears, in retrospect, as a realistic appraisal of the missile's assets and liabilities. He noted that compared with guns the device had the advantage of longer range. Further, Wilkinson acknowledged, "The moral effect of such devices may be great. They are practically indestructible, unless a well-aimed shot disables [the] engine or control devices, and they cannot be driven off."[6] But the device was expensive, required complicated launching facilities, and its "use in long range attacks against forts and cities is of doubtful military value on account of [the] difficulty of striking at any desired point rather than at random within the limits of the city or fortress."[7]

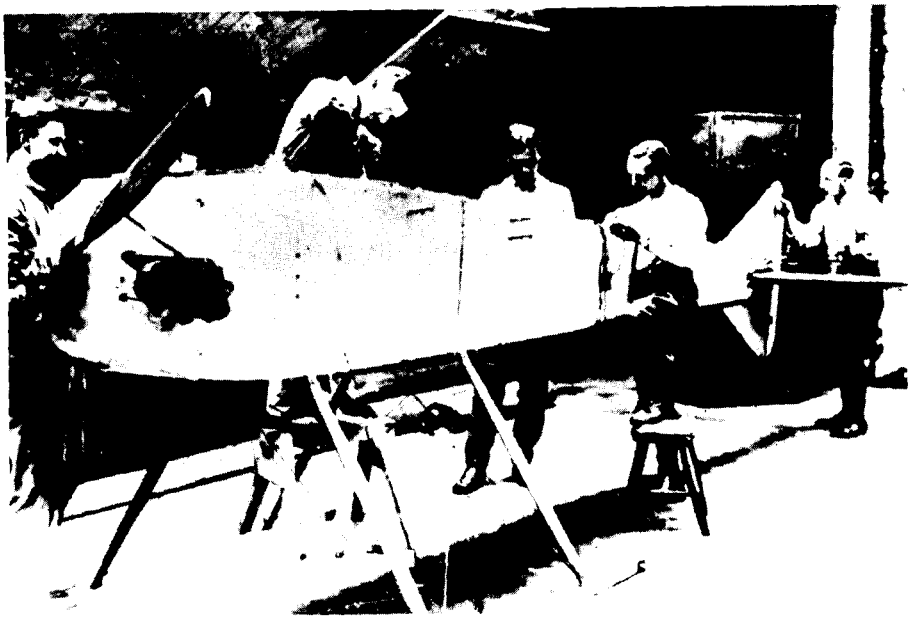
Foreign Efforts

In the same general time frame, Europeans also worked on "flying bombs." The principal efforts abroad were made by the British.[8] Shortly after World War I began, the British War Office asked Professor A. M. Low to work on a rangefinder for coast artillery, apparently because he demonstrated in London in 1914 the principles now used in television. But the project soon changed to a radio-controlled "flying bomb" to intercept zeppelins and attack ground targets. On 21 March 1917, Low demonstrated the device to Britain's top brass. The first vehicle immediately crashed. One observer, Major Gordon Bell, fittingly called the "Mad Major" because he terrified passengers with loops inches off the ground, flights under bridges, and in one case a flight through a hangar, exclaimed "I could throw my bloody umbrella that far!"[9] The second bird got off the ground and flew satisfactorily—for a while. But it then dove toward the assembled spectators, scattering them before crashing about three yards from Low and the radio controls.[10]

H. P. Folland, designer of the famous SE-5 pursuit plane, designed another missile for the project. Built by the Royal Aircraft Factory, it measured 20 to 22 feet in span, weighed 500 pounds, and used the same 35 hp engine as its predecessor. But the Folland missile proved equally unsuccessful, failing to get airborne on three attempted launchings in July 1917. Little wonder the British ended the project.[11]

The Navy-Sperry Flying Bomb

Meanwhile, America's declaration of war on 6 April 1917 changed everything in the United States. Eight days later, the Naval Consulting Board recommended that $50,000 be allotted to Sperry's "flying bomb" project.[12] Subsequently, Secretary



The British Royal Aircraft Establishment (RAE) Aerial Target under construction, 1917. The device was unsuccessfully tested in July 1917. (RAE, Farnborough)

of the Navy Josephus Daniels formed a five-man committee to investigate the idea; it recommended support for the project, and Daniels approved $200,000 for the "flying bomb" in late May.[13]

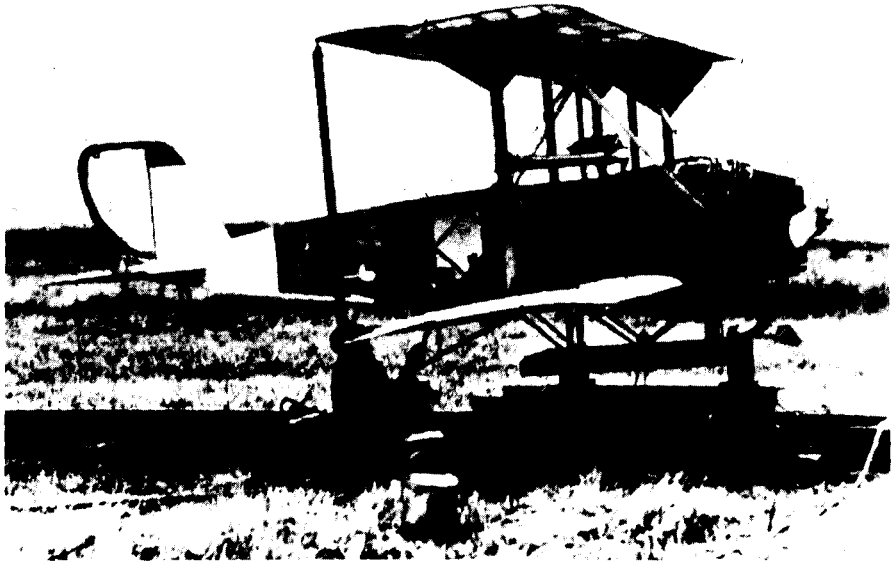
Experiments began in June at Amityville, Long Island. The Navy supplied five Curtiss N-9 seaplanes and purchased six sets of Sperry controls. During over 100 flight tests, which began in September, pilots got the Curtiss N-9s off the water, monitored the automatic function and, after the mechanism indicated its descent to the target, flew home.[14]

The next step came in mid-October when the Navy ordered five special aircraft ("flying bombs") from Glenn Curtiss because Sperry wanted a faster aircraft than the N-9. Remarkedly, Curtiss delivered the device* six days ahead of the 30 day schedule![15]

But after the success of the manned N-9, failure dominated the new phase with the unmanned vehicle. Major problems emerged, the first of which was literally getting the machine off the ground. Because takeoffs upset the azimuth control, the experimenters used catapult launchings. The first attempted launching on 24 November 1917 ended in disaster, as did a second on 7 December.[16] The third attempted launching on 21 December, with a different catapult system, failed because of engine problems. Crashes on 14 and 17 January, when "flying bombs" got briefly airborne, cast doubt on both the catapult system and the device's flying ability.[17]

*See Appendix A for missile characteristics.

Therefore to improve and hence to prove the airworthiness of the "flying bomb," man again took the controls. On 6 February, Lawrence Sperry successfully flew the machine, fitted with skis, off the ice of Great South Bay, Long Island. The next day, the missile crashed at lift-off, leaving Sperry unhurt but the machine demolished.[18] Further manned tests disclosed a third problem, a mismatch of control system and missile. Controls adequate for the N-9 proved inadequate for the more responsive "flying bomb." Finding that the machine lacked longitudinal stability, the testers lengthened the fuselage two feet and made other suitable modifications.[19]

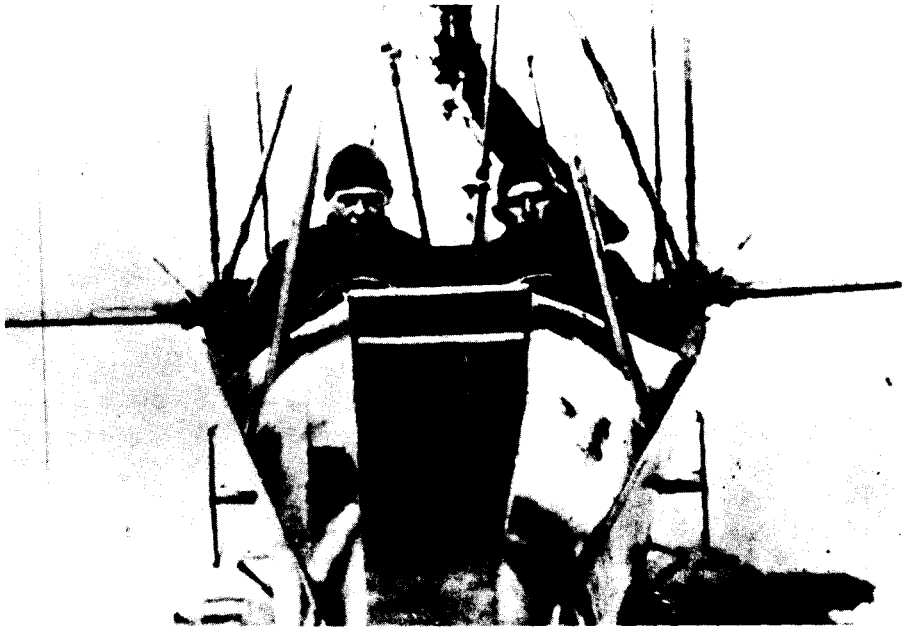


The Navy's World War I "flying bomb," associated with Elmer Sperry and Glenn Curtiss. A device of this type performed successfully for the first time on 6 March 1918. (General Motors Institute)

The first successful flight occurred on 6 March 1918, when the "flying bomb" flew 1,000 yards as planned. One month later, however, a similar attempt failed.[20]

Although the catapult functioned well, Sperry wanted a new launching device. Consequently, Sperry hired a consulting engineer, Carl L. Norden (later known for his World War II bombsight), to design a third type of catapult.[21] The Chief of Naval Ordnance, Rear Admiral Ralph Earle, reported that the catapult was worth all the time and effort spent on the "flying bomb."[22] In retrospect, we can only speculate as to whether Earle's appraisal was realism or rationalization. For while catapults were to prove important to the Navy in subsequent years, later models relied upon a much different technology.

Meanwhile, Sperry further tested the "flying bomb." The test bed consisted of a



Lawrence Sperry, the inventor's son, was very active in the development of the "flying bomb." Sperry (left) with Lieutenant Bellinger in a Curtiss flying boat in 1913. (National Archives)

Marmon car fitted with an OX-5 aircraft engine and an overhead frame for the "flying bomb." The auto-missile combination reached speeds of 75 to 80 mph on the Long Island Parkway, becoming in essence a moving, open-air wind tunnel. Sperry considered using the combination as a launcher but could not find a straight road of adequate length. The experimenters did try a straight section of the Long Island Railroad, but flanged wheels could not keep the Marmon on the tracks.[23]

In any event, while the Norden catapult proved satisfactory, the "flying bomb" did not. On 13 August, a "flying bomb" moving down the Norden device lifted the front wheel of the dolly off the track and wrecked the missile. In early September, another crash occurred because of an electrical power failure in the "flying bomb." On the 23d, the device flew about 300 feet before it went out of control and crashed. Another did little better three days later, flying only 500 feet before crashing.[24]

Meantime, tests continued with the N-9. On 17 October, the experimenters launched one with the distance device set at 14,000 yards. But because of a shortage of ground crew members, the pilot of the N-9 chase plane had to assist in the launching of the "flying bomb" and when he got aloft, he was unable to close on the lighter, pilotless N-9. The distance mechanism on the pilotless N-9 malfunctioned and the device was last seen flying straight and level eastward over the ocean. This was the longest flight in the Navy-Sperry tests.[25]

On 29 October, the Navy launched a modified "flying bomb" with a larger tail and aileron. The Navy officer in charge, recalling the missile's last performance,

ordered that only two gallons of fuel be put in the fuel tank (to ensure the machine's recovery). This proved catastrophic. As the catapult accelerated the aircraft, the gas shifted to the rear of the fuel tank, stalling the engine and destroying the last Curtiss "flying bomb."[26]

These failures discouraged neither the Navy nor Sperry; both parties insisted that the experiments should continue because the device still had a promising future. "I believe," Sperry wrote Admiral Earle, "that the time has practically arrived when we have on hand *the gun of the future*" [original emphasis].[27] Hence, on 1 November 1918, Admiral Earle reported to the Chief of Naval Operations (CNO) that, before spring 1919, the "flying bomb" could probably be developed to carry a 1,000-pound bombload up to 75 miles with an accuracy of about 1.5 miles. Earle wrote that such a device could be mass produced for $2,500. The "flying bomb," he continued: "Should have a strong moral effect, and should prove very valuable in bombarding cities. . . . [But it] will prove of little value against isolated forts or against ships."[28] Once the Navy found a satisfactory airframe, a production decision could then occur.[29]

Although the war ended, the Navy continued the program with the help of two former Sperry employees, Carl Norden and Hannibal Ford, after Elmer Sperry bowed out of the project. In September 1918, the Navy supervisor of the project, Commander B. B. McCormick, pushed for a new "flying bomb" design and improved autopilot. McCormick asked Norden to study the Sperry controls and report back, which he did on 30 October. A day later, McCormick recommended that the Navy purchase six aircraft from Wittenman-Lewis; on 2 November, the Bureau of Ordnance ordered five "flying bombs" from that company. The Navy fitted two of these aircraft with Sperry controls from the Amityville project, and the remaining three with controls redesigned by Norden. The Navy successfully flew the Wittenman-Lewis aircraft in March 1919.

The program continued as McCormick requested a shift of the testing site from Amityville, New York, to Dahlgren, Virginia, a move completed by May 1919. In addition to the N-9 and Wittenman-Lewis aircraft, the Naval Aircraft Factory at Philadelphia built ten "flying bombs." The latter were very tail-heavy, and apparently flew only with safety pilots aboard; a wise move in view of their unmanned flight performance. On the first attempted unmanned "flying bomb" launching on 18 August 1920, the machine crashed after 150 yards. The Navy did not attempt the next launch until November. This flight lasted twenty minutes, and the machine flew in circles. The third "flying bomb," launched on 25 April 1921, flew less than two minutes. The missile's lack of progress, coupled with declining funds, led the Navy to cancel the effort in 1922. Meanwhile, the Army had developed a somewhat more successful "flying bomb."[30]

The Army-Kettering Bug

There is a direct connection between the Army and Navy "flying bomb" programs. While Sperry failed to interest the Army in the idea before the war, a

flying demonstration in late 1917 did the trick. On 21 November, Glenn Curtiss, Elmer Sperry, Rear Admiral Ralph A. Earle, and Major General George O. Squier, now Chief Signal Officer, watched as an N-9 flew over seven miles under automatic control.[31] The flight impressed Squier who, five days later, wrote the Chairman of the Aircraft Board that immediate and energetic efforts should be made with the "flying bomb" project. He concluded:

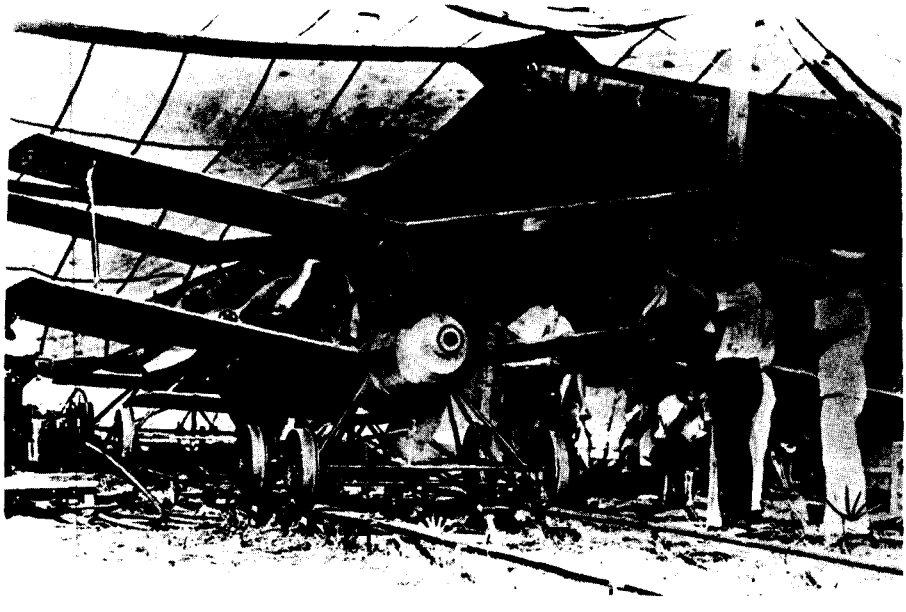
> The time has come, in the opinion of the writer, when this fundamental question should be pressed with all possible vigor, with a view to taking to Europe something new in war rather than contenting ourselves as in the past with following the innovations that have been offered from time to time since the beginning of the war by the enemy. Wars are won largely by new instrumentalities, and this Board should be a leader and not follower in the development of aircraft for war.[32]

The Board approved Squier's recommendations and, with the Secretary of War's verbal instructions, experimental work began.[33]

In December, Squier appointed a four-man board to investigate the possibilities of the weapon. While three members reported negatively, Charles F. Kettering, inventor of the automobile self-starter and later vice president of General Motors, filed a favorable minority report. Not surprisingly, he received a cost plus contract to develop the device.[34]

Parallel to the Navy-Sperry program was an Army program associated with Charles Kettering. Kettering (right) examines a model of his World War I missile in 1946. (General Motors Institute)

Kettering formed a team at Dayton, Ohio, consisting of his company, Dayton Metal Products (control systems); Elmer Sperry (gyroscopes); S. E. Votey of Aeolian Player Piano (pneumatic controls); Orville Wright of Dayton Wright Airplane (airframe); and C. H. Willis, Henry Ford's Chief Engineer (engine). The "flying bomb" that emerged was a biplane smaller than the Navy-Sperry device and designed to be less complex and cheaper.* Muslin and brown wrapping paper, doped with glycerine and creosote, covered the machine. Similar to the Sperry "flying bomb," an air log impeller actuated a standard National Cash Register counter which "measured" the distance and, after a designated number of turns, cut the ignition and folded the wings. There were no ailerons. Wright recommended a 10 degree positive dihedral for stability, which gave the aircraft its characteristic look. The device came to be called the Kettering "Bug," perhaps from the way it flew or looked, although its official name was the "Liberty Eagle."[35]



Army-Kettering missile shown on its launch dolly. Note the missile's small size and pronounced wing dihedral. (National Air and Space Museum)

The Army ordered 25 Bugs on 25 January 1918. But in contrast to Curtiss's astonishing performance with the Navy machine, the Army's first piloted flight, lasting six minutes, did not occur until 19 July. Two other piloted flights followed this initial flight. For the unmanned missile, the Army used a four wheel dolly and track that, unlike the Navy, did not employ a catapult. Following a launch test crash on 13 September, unsuccessful unmanned launches took place on 14 September and again on 1 October. On 2 October, the missile flew, if only for nine seconds. Two

*See Appendix A for missile specifications.

Kettering (left) examines wreckage of missile, location and date unknown. (National Air and Space Museum)

days later, the machine flew 45 minutes in wide circles covering a distance of over 60 miles, but crashed at Xenia, Ohio, only 20 to 25 air miles from its launch point. Kettering, Lieutenant Colonel Bion J. Arnold, the Army officer in charge and a member of the Naval Consulting Board, and a young airman, Henry H. Arnold, were watching. To conceal the device's purpose, Bion Arnold told a curious farmer that Hap Arnold was the pilot of the downed aircraft.[36] Test problems continued, culminating in crashes on 16 and 17 October, but another successful flight of 500 yards occurred on 22 October.[37]

Overall, the missile impressed the enthusiastic Army officers. B. J. Arnold, convinced of the "flying bomb's" potential, ordered 75 more devices and foresaw building 10,000 to 100,000 missiles at a unit cost of about $400 to $500.[38] Not one to understate, Squier wrote the Chief of Staff that:

> . . . this new weapon, which has now demonstrated its practicability, marks an epoch in the evolution of artillery for war purposes, of the first magnitude, and comparable, for instance, with the invention of gunpowder in the Fourteenth Century.[39]

He recommended that the General Staff immediately investigate quantity production, establish a suitable testing area, and inform American and Allied forces of the "flying bomb." Subsequently, H. H. Arnold went to France to disseminate

the results of the "flying bomb" tests to the Allies.[40] The Armistice, of course, overtook everything. When the Dayton project closed down on 27 November 1918, 20 Bugs were completed along with 5 airframes, and 11 partially built Bugs. But tests continued after the war.[41]

In December 1918, the Army sent six Bugs to Amityville for tests. But only one of four launches of the Long Island tests proved successful.

A three-officer board, in January 1919, recommended further development of the "flying bomb" by the Air Service, prompting the last phase of the project, tests in the fall of 1919. B. J. Arnold selected Carlstrom Field, near Arcadia, Florida, as a good place for further tests in his 1918 search. In mid-1919, Lieutenant Colonel Guy L. Gearhart, a 40-year old former coast artillery officer, took over the project and received authorization on 29 August to ship 12 Bugs to Carlstrom.[42]

Between 26 September and 28 October 1919, the Army attempted 14 test flights. Although five Bugs crashed on or immediately after launching, the sixth attempt (on 13 October) was successful; the "flying bomb" covered 1¾ miles. Other successful flights of 1¾ miles and 2 miles occurred before the final shot, on 28 October. On this particular test, the Bug flew 16 miles before crashing because of engine problems. But the 16-mile flight could not conceal the fact that 10 of 14 attempts had ended in failure. Gearhart's report avoided that point and recommended only matters of a technical nature: development of a catapult, improved engines, and experiments with larger gyros. So ended the Kettering Bug project, at a cost to the American taxpayer of about $275,000 for the period April 1917 to March 1920.[43]

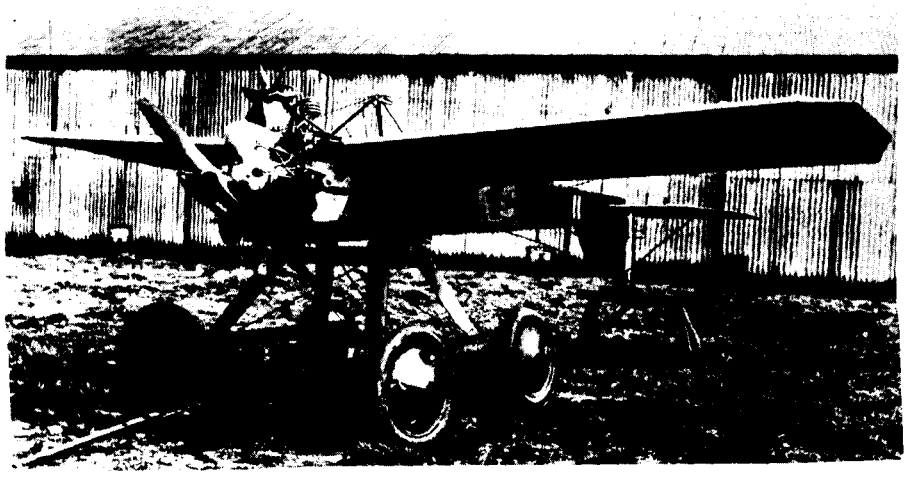
Besides an interesting and often overlooked episode, what did these World War I flying bomb projects reveal? First, the experimenters experienced difficulties just getting unmanned aircraft into the air. Launch problems caused a number of crashes, complicating development of the "flying bombs." Second, the manufacturers found that building a stable aircraft that flew well without pilots was not easy. Limited knowledge of aerodynamics, lack of testing, and haste in building the machines guaranteed problems. Little wonder, then, that the "flying bombs" had basic aerodynamic faults. The developmental method of the day, trial and error, did not work well with unmanned aircraft. Manned tests partially solved these aerodynamic problems; modifications and flight experience led to later, although somewhat limited, successes. Third, other technical problems hindered the programs. In particular, neither guidance systems nor engines performed as designed. Fourth, destruction of the "flying bombs" on most of the tests restricted the programs. This fragileness was due, in large measure, to the fact that these machines were designed to be cheap and fly short one-way missions. The Army was unable to recover many for subsequent testing, thereby rapidly exhausting the number of available vehicles. Further exacerbating this problem was that these wrecks yielded little positive data on why the crashes occurred. Finally, despite all the fanfare, expense, and effort, the experimenters achieved minimal success. Only 1 of the 12 Sperry-Navy tests functioned properly; and on this particular test, the "flying bomb" flew a mere 1,000 yards. The Kettering Bug had 2 successes on 6

attempts at Dayton, 1 of 4 at Amityville, and 4 of 14 at Carlstrom. Taken together then, there were only 8 successes on 36 attempts.

In brief, a few mechanically-gifted visionaries, equipped with limited knowledge and resources, were unable to transform the "flying bomb" idea into reality. Despite their best efforts and a few successes, the theory remained more advanced than the technology of the day. Nevertheless, the idea persisted in the years that followed.

Foreign Developments

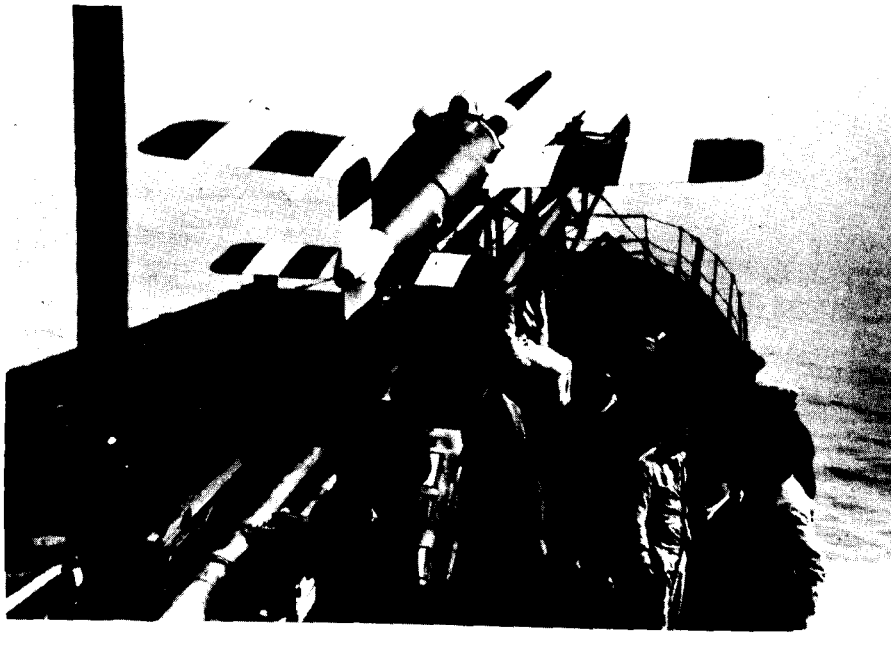
Work on the pilotless bomber continued not only in the United States but in Great Britain.[44] As early as May 1919, the Royal Naval Antiaircraft Gunnery Committee requested a radio-controlled target aircraft. In response, the Air Ministry attempted to develop such a vehicle in England and, at the same time, buy one from the United States; but British Secretary of State, Winston Churchill, vetoed the latter initiative. By 1920, the RAF perceived that three lines of potential development existed: a gyro-guided "flying bomb," a target missile, and a radio-controlled, air-launched missile. In short order, the RAF dropped the third and merged the first two categories. The British flew a number of radio-controlled aircraft (with pilot monitors) in the early and mid-1920s, including a Bristol fighter, a Sperry Avio, a D.H.9A, and a Wolf.



After the war, RAE built this radio-controlled missile, shown in 1920–22. (RAE, Farnborough)

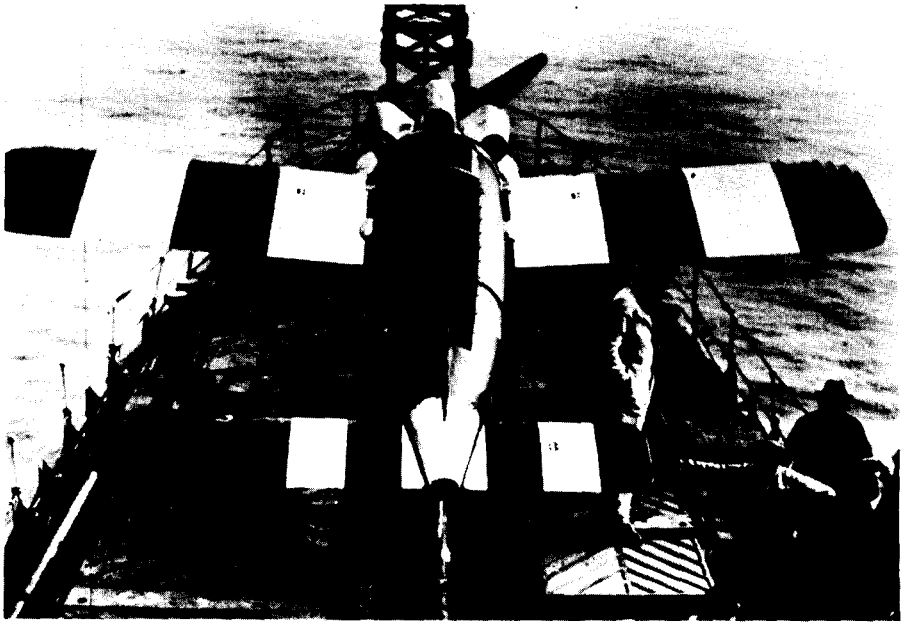
But perhaps equally pertinent to this particular story is the Royal Aircraft Establishment (RAE) 1921 Target aircraft.* Beginning in July 1922, the British conducted tests over water for both safety and security reasons. The seventh test, on 3 September 1924, was a partial success; the device, after its catapult launch, flew for 12 minutes before its engine stopped. On the tenth and final test on 2 March 1925, the missile flew 39 minutes.[45]

The RAF began work on a true "flying bomb" in September 1925. Compared with the RAE 1921 Target missile, the Larynx (Long Range Gun with Lynx Engine) was smaller, heavier, and faster.* In fact, a 200 hp Lynx IV engine gave the device a top speed of about 200 mph, making it faster than contemporary fighters. The first Larynx crashed into Bristol Channel shortly after a catapult launch from the HMS *Stronghold* on 20 July 1927. The RAF believed that the second missile completed its 100 mile course on 1 September 1927, although it was lost. On 15 October 1927, the third Larynx flew 112 miles at 193 mph, impacting five miles off target.[46] In September and October of the next year, HMS *Thanet* launched two missiles that flew approximately 50 miles each, one landing within 1.6 miles of its target while the other impacted 4.5 miles from its target. In May 1929, the RAF land-launched two missiles from Portland: the first flew beyond its target into the unknown, while the second performed as programmed.



The RAE Larynx missile on cordite-fired catapult of destroyer HMS *Stronghold*, July 1927. The man on the box is Dr. George Gardner, later Director of RAE. (RAE, Farnborough)

*See Appendix A for missile specifications.



Another view of the Larynx. Note the "3" on the missile's packing crates, wings, and tail. The missile's first launch on 20 July 1927 over the Bristol Channel failed. (RAE, Farnborough)

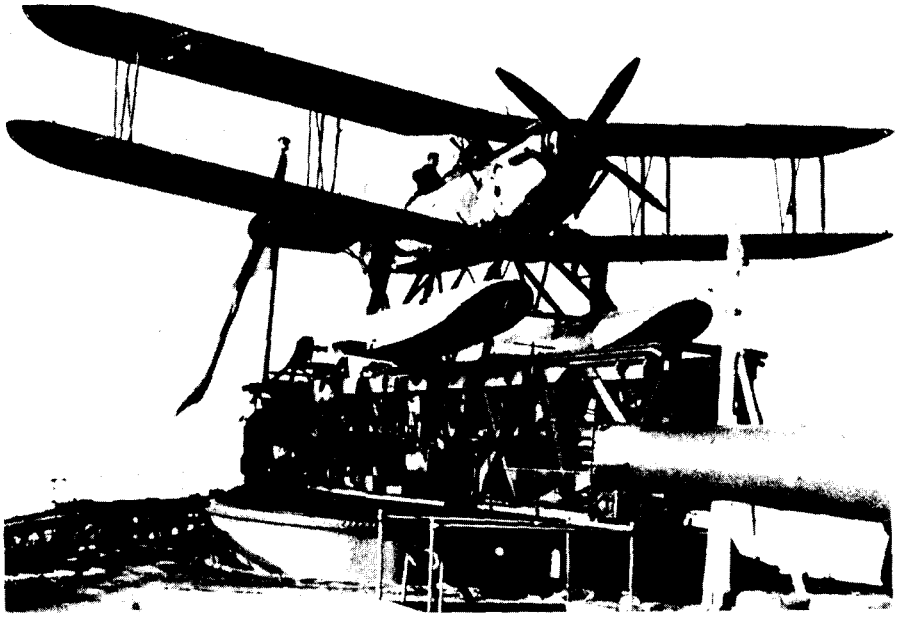
Because of safety and security considerations, the British shifted their tests to a 200-mile course in the desert wastes of Iraq. The results disappointed the RAF, however, as the three Larynxs launched in August and September 1929 flew only 27, 60, and 32 miles respectively. In October, one crashed on the launching platform while another was last seen as it passed the 22 mile mark. The airmen blamed vapor lock in the engine, rather than the control system, for the failures. They concluded from these tests that accuracy was equated with weather information, and targets beyond 100 mile ranges were therefore limited to area type targets.[47]

By 1927, the British were developing three types of missiles: a mechanically-controlled "flying bomb," a radio-controlled missile, and an air defense missile to break up enemy aircraft formations. In October 1930, the Chief of the RAF Air Staff eliminated the air defense missile, shelved the radio-controlled Larynx, continued the mechanically-controlled Larynx at a low priority, and emphasized instead a new target missile. Three years later, the Chief of the Air Staff established new priorities for the program. Defense against pilotless aircraft received top research priority, shepherd aircraft (manned mother ships guiding radio-controlled unmanned missiles) ranked second in priority (ahead of a new Larynx), with the lowest priority assigned to a missile that would home in on enemy radio stations. In 1934, the air defense missile regained its number one priority status; but because this air defense missile required two mother aircraft for guidance, cost as much as a

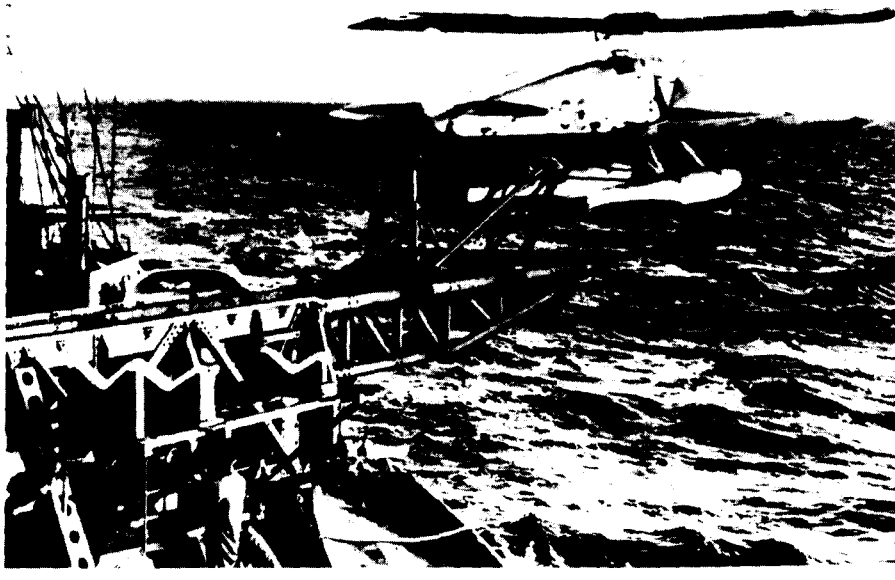
single engine fighter, could operate only in daylight, and required three to four years to develop, the RAF dropped it in 1936.[48]

Despite these stated priorities, the RAF really did nothing with the "flying bomb" until its final cancellation. The RAF's major concerns were high unit cost and low accuracy. The RAF estimated that a 300 mph, 250-mile-range missile would cost £ 500 each in a 5,000 unit run, while a 450 mph missile would cost £ 3,000 to £ 4,000 apiece. The British airmen estimated accuracy at 10 miles on a 200-mile flight in average weather conditions. During these studies, the Air Staff looked at rockets as a substitute for the "flying bomb" and considered jet-powered "flying bombs." Finally, in September 1936, the Air Staff reviewed both the air defense and Larynx missiles and decided that neither merited further development.[49]

The British, however, did have a successful interwar missile development program, the target missile. The RAF began this program by converting three Fairley IIIF float biplanes to meet the 1930 requirement for a radio-controlled target. Although the initial two, launched off the HMS *Valiant* in January and April 1932, crashed, the third, launched on 14 September 1932, flew for nine minutes. In January 1933, the converted aircraft, dubbed the Fairley Queen, survived two hours of Royal Navy antiaircraft bombardment. The next month, the Air Ministry let a contract for a cheaper target missile, a conversion of the Tiger Moth trainer. Called the Queen Bee, it first flew under radio control in 1934. In all, the Fairley Corporation built 420 such devices between 1934 and 1943.[50]



Fairley IIIF equipped with radio-control devices and known as the Fairley Queen. It also acted as a "shepherd" aircraft. (RAE, Farnborough)

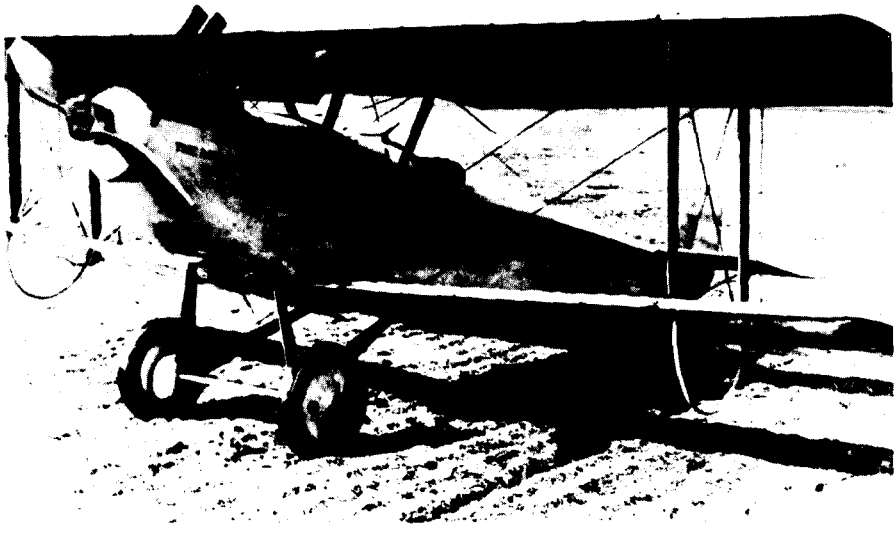


Launch of deHavilland Queen Bee. This target missile was a radio-controlled version of the deHavilland Tiger Moth. (RAE, Farnborough)

The Army-Sperry Experiments

US Army interest in "flying bombs" continued in post-war years. For example, in late 1919, one officer noted that the "flying bomb will be a great asset to the military forces of the country first perfecting it."[51] Consequently, the Army contracted with the Sperry Gyroscope Company in February 1920 to design and construct four gyro units, and then in April 1920 with the Lawrence Sperry Aircraft Company to perfect automatic control by installing equipment in three Standard E-1 aircraft and five Messenger aircraft. Mechanical problems, especially with gyroscopes, hindered several otherwise successful tests flown with pilot monitors in November and December 1920. Because Lawrence Sperry achieved even greater success in similar tests between March and May 1921 at Mitchell Field, he won a second contract in June to upgrade the guidance equipment and to construct six Messengers, three as aerial torpedoes. Further flights in late 1921 achieved good accuracy.[52]

The contract included one unusual feature, a provision providing $5,000 for hitting a target 1 out of 12 times at 30 miles, and a $5,000 bonus for 2 additional hits. The same bonus applied to trials at 60 and 90 miles.[53] Difficulties with the



Lawrence Sperry's Messenger aircraft. Sperry died in a crash of this type aircraft on 13 December 1923. (National Air and Space Museum)

automatic controls encouraged, if not forced, Sperry to use radio-control guidance. After gaining approval from the Army's contracting officer on 9 May, Sperry used radio-control equipment, developed at the Army Engineering Division by Lieutenant Redman, which allowed an aircraft about 1½ miles away to guide the simulated "flying bombs." Sperry obtained good results in May and June 1922—better than anything achieved thus far.[54]

In the tests at Mitchell Field one day before the expiration of the contract, the Army judged Sperry's devices to have twice hit a target at 30 miles, three times at 60 miles, and once at 90 miles.[55] The Chief of Engineering Division insisted, however, that Sperry had not earned the bonus since the contract did not specify radio control. This particular official noted that a system requiring a mother aircraft to fly a mile or so from the "flying bomb" all the way to the target offered little advantage. Regardless of the merits of the case, the Army paid Sperry a $20,000 bonus.[56]

Despite this negative reaction to a radio-control system, the Army proceeded to conduct its own radio-control tests. The Engineering Division developed a pilot-monitored system that guided a number of Sperry's Messenger aircraft between October 1923 and April 1925 at McCook and Langley Fields. Again, mechanical problems hampered the flights.[57]

In 1927, the war department pushed the radio-control idea. However, the two aircraft purchased in 1929 for these tests, a Curtiss Robin (XC-10) and a Stimson

Junior, proved unsatisfactory. More importantly, the country's economic depression constricted funds and delayed the project.[58]

Before leaving American Army developments temporarily, one keen proponent of "flying bombs" deserves mention. In July 1923, Billy Mitchell suggested using "flying bombs" in the famous battleship bombing tests. The Chief of Engineering Division recommended against Mitchell's proposal on the advice of Lieutenant Redman, who believed that the chances for failure were high because the system worked only against large targets and, moreover, because the Sperry test results were due largely to good luck. Therefore, on 18 August 1923, the Chief of the Air Service rejected the use of aerial torpedoes in the tests.[59]

US Navy Efforts

US Navy interest in cruise missiles reemerged in the mid-1930s from a somewhat different direction than might be expected, for the main impetus came by way of unmanned aerial target programs.

Like the Army, the Navy recognized the advantages of radio-controlled vehicles. The Navy discussed radio control not only in 1916 but also in the summer of 1917 in connection with the Sperry device. Radio control work commenced under the Bureau of Ordnance in January 1921, following an expression of interest by the Chief of Naval Operations in anti-aircraft targets. Flight tests began in 1921 with further experiments conducted in 1923 and 1924. The first successful unpiloted radio-controlled flight occurred in September 1924. Although this naval work continued, the Navy made little progress after 1925 because of insufficient funds. A Navy effort to reenergize the program in 1932 fell victim to a budget cut by President Roosevelt the following year.[60]

A second Navy effort beginning in 1935 did better. In April 1935, the Commander of Aircraft, Battle Fleet, requested that the CNO provide a high speed, radio-controlled aircraft for anti-aircraft target practice. In August, the Plans Division, Bureau of Aeronautics repeated this request. The CNO, Admiral William H. Stanley, who had seen the British aircraft target, the radio-controlled Queen Bee, supported the program. As the Bureau of Ordnance had little or no enthusiasm for such an aircraft, the CNO directed the Bureau of Engineering and the Bureau of Aeronautics to proceed with the project in May, 1936.

The Navy began flight tests in February 1937, and by the end of the year had achieved good results. The Navy first used the device as a target in operations with the carrier *Ranger* in August, 1938. These and subsequent practice sessions revealed shockingly poor US Navy anti-aircraft gunnery, considering the low performance of the target aircraft. Meanwhile, the Navy formulated more deadly plans for the radio-controlled aircraft.[61]

Lieutenant Commander Delmar Fahrney suggested combat uses for drones[62]

(termed "assault drones") as early as August 1936, a mere month after assuming command. Although one author asserts that in the late 1930s naval aviators prevented this concept from developing, the growth of technology and world events were certainly catalysts in accelerating the development of combat roles for drones. Two pieces of electronics equipment emerged at this point to foster the missile's progress: television and the radar altimeter. By 1937, RCA demonstrated airborne television in an air reconnaissance project for the Soviets. In August 1941, TV received its initial testing aboard an American drone. Intuitively obvious is TV's utility in extending the vision of the drone's operator, thereby increasing operational effectiveness. The concurrent use of radar altimeters made drone flight more practical, since they accurately measure altitude above the surface, an especially valuable capability when flying over varying terrain. (This is in contrast to the barometric altimeter, which measures a base pressure.) In January 1941, the Navy successfully tested radar altimeters in a drone.[63] A third factor, world events, was simply the growing tensions and conflict in the world.

Despite these technical advances, the drone program progressed relatively slowly. For instance, although the Navy tested target drones simulating assault drones in September 1940, it was not until November 1941 that the Chief of the Bureau of Aeronautics ordered 100 obsolescent torpedo bombers converted into assault drones and 100 missiles designed especially for the same purpose. The Navy deliberately gave the order to a company not associated with aircraft production so as not to interfere with the arming of US and Allied forces. While this idea had some merit, as we shall see, it hindered the missile program.[64]

The attack on Pearl Harbor changed the entire complexion of the program. The first impact was that the Navy reclaimed its 100 torpedo bombers for training purposes. Nevertheless, the Navy conducted two important demonstrations in April 1942. On 9 April, TV aboard a torpedo-carrying drone (TG-2) detected a US destroyer eight miles away from the drone, which in turn was 20 miles from its mother ship. The control plane guided the drone to intercept the destroyer and when the drone was 300 yards away from the ship, the drone released its torpedo which passed beneath the destroyer as planned. On 19 April, a raft towed at eight knots was the target of a BG-1 drone. After the drone's TV detected the raft at 4 miles, the control plane, situated 30 miles away, guided the drone into the raft.[65]

Early that same month, the Bureau of Aeronautics ordered 200 assault drones. The Naval Aircraft Factory would build 100 TDN-1s, and contracted with Interstate Aircraft and Engineering for the other 100, designated TDR-1. The contract scheduled deliveries to begin before 1 November 1942. The next month, the Vice Chief of Naval Operations expanded the program to 1,000 drones. But the Chief of the Bureau of Aeronautics, John H. Towers, the grand man of naval aviation, resisted the move. A "Catch 22" situation emerged: Ernest J. King, the CNO, wanted to avoid the piecemeal use of the weapon, as had been the case with the tank and poison gas in World War I, while Towers opposed production until the weapon proved to be superior to conventional weapons. But perhaps the single most convincing argument against the program was the tremendous commitment of

resources (10,000 men, of whom 1,300 were aviators, and $235 million) during the early dark days of the war. Towers recommended cutting the order to 500 machines (100 TDNs, 200 TDRs, 100 TD2Rs, and 100 TD3Rs), a recommendation approved by the CNO in August 1942. In March 1943, the Navy considered expanding the program to 3,000, but only added a 1,500 drone order to the existing order of 500.[66]

Admiral John H. Towers, considered the "father" of naval aviation, resisted the "flying bomb" idea. (USN)

Meanwhile, drone supporters attempted to get it into action; but timing and personalities prevented this. Unlike the situation in 1942, by early 1944 the US Navy was growing from strength to strength and defeating the Japanese Navy soundly. Also, the Commander of the Pacific Fleet, Admiral Chester W. Nimitz, did not want the device. Why deploy an untried weapon when carrier aviation seemed to do everything better? Further, the drones offered few advantages and were difficult to maintain in the field. There also were production problems: Interstate could not turn out the requisite number of machines as specified in its contract and, if that were not enough, there were technical difficulties that led to crashes. For example, investigation of one drone crash revealed a structural defect.

Therefore, in March 1944, the Navy cut the total program buy to 388 (100 TDNs already accepted, to be followed by 188 TDR-1s, 50 TD2Rs, and 50 TD3Rs).[67]

Despite such adversity, the Navy finally conducted combat tests in late 1944. After a demonstration against a beached Japanese merchant ship off of Cape Esperance on 30 July, during which drones scored two direct hits and two near misses, the real tests began. In operations from Sterling and Green Islands, between 27 September and 26 October 1944, the Navy expended 46 TDRs. Technically and militarily, the drone trials were less than a smashing success. Only 29 of 46 tested reached their target, mechanical problems accounting for 9 failures, TV problems for 5 more, and Japanese anti-aircraft fire for the remaining 3. And as this took place in a backwater of the war, these tests had minimal impact upon Japanese and US Navy operations.[68]

But even before the Navy launched its last TDR on 26 October 1944, the program was dead because on 8 September Admiral King cut it off. The Navy offered the AAF (Army Air Forces) the entire program, including control sets, drones, and personnel. On 25 October, General Arnold declined the offer.[69]

So in the end, the Navy gained little more than limited experience with its 200 pilotless aircraft. A number of factors account for this marked lack of success. First, the program encountered serious internal opposition from Naval aviators. In addition, a number of strong and influential personalities opposed the program; Admiral Towers because it was unproven, and Admiral Nimitz because it was not needed. On the latter point, timing was against the weapon. When the war was not going well and US carriers had not yet shown their potential, drones might have gotten enthusiastic support, but they were not ready. Later, when drones were ready, carrier aviation ruled the waves and there was no need for them. Problems with both technology and production also slowed the program. Finally, the drone program was very expensive in terms of men and money. Army airmen were to do little, if any, better.

The Kettering-General Motors A-1

In the late 1930s, two individuals connected with the World War I Kettering Bug reappeared in the cruise missile story. In mid-1936, Hap Arnold stated that "flying bomb" development should reopen.[70] But no action occurred until two years later, by which time overseas events and the improving domestic economic situation encouraged American rearmament. On 8 August 1938, the Chief of the Air Corps, Major General Oscar Westover, requested that the Chief of the Material Division begin immediate study of the aerial torpedo. Westover wanted a low cost ($300 to $800) weapon with a range of 20 to 30 miles, and he wanted it fast. "For your information," he concluded his letter, "the War Department insists upon some positive and practical results soon."[71]

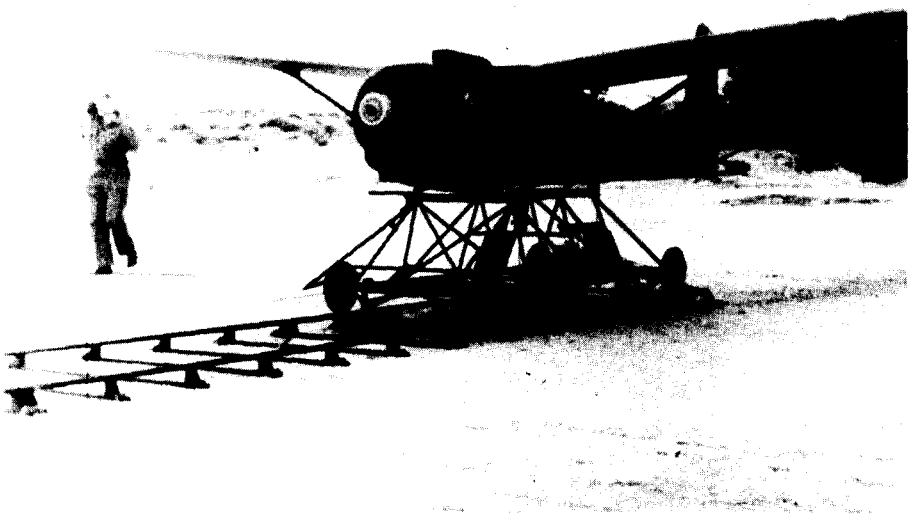
General Henry H. Arnold, wartime chief of the Army Air Forces, was a firm supporter of the "flying bomb." (USAF)

The specifications for the missile included a 200- to 300-pound warhead, 20-mile minimum range, and the ability to hit a 2 square mile target at 20 miles. These specifications went to the Adjutant General on 29 September 1938 over the signature block of the new Chief of the Air Corps who took command that day, Henry H. Arnold.[72] But industry could not meet the challenge. In April 1939, the airmen judged Vega, the only bidder, to be inadequate for the job.[73]

Enter, or reenter, Charles F. Kettering, now General Manager of Research at General Motors and a member of the National Research Council. He initiated correspondence with Arnold on 7 September 1939, writing: "I believe that a plane of 150 hp, complete with controls and radio . . . could be built in the neighborhood

of 12 to 15 hundred pounds and I don't believe should cost, in reasonable quantities more than that many dollars."[74] By this point, however, the airmen had upped their expectations from the September 1938 specifications to include a range of 100 miles and the ability to hit a 1/2 mile diameter target. On 15 January 1940, the Army formalized these specifications, stipulating a new minimum range of at least 20 miles with a maximum range of 100 miles. On 18 February 1941, the Army ordered ten "flying bombs" from General Motors for $250,000 and in July 1942 five more. To guide these aircraft, the Army decided to employ radio control.[75]

The General Motors (GM) A-1, a monoplane powered by a 200 hp engine, was designed to carry a 500-pound bomb load 400 miles at 200 mph.[76]* After some preliminary tests at Langley Field, Virginia, the Army flight-tested four machines at Lake Muroc, California (presently Edwards AFB) in November and December 1941. Consistent with the device's history, the tests harvested little success. The first GM A-1, launched on a carriage down a track on 15 November, immediately crashed. Bird number two flew two and one-half minutes on 5 December, bird number three for 10 minutes on 7 December, and bird number four 1 hour and 35 minutes on 8 December. The Army concluded that both the automatic (preset) and radio controls were unsatisfactory.[77] Suggested modifications included adding a power catapult and altitude control, modifying the airframe, and deleting the preset controls. The next group of vehicles, tested at Eglin Field, Florida, incorporated these changes. The first such device crashed on 10 March 1942, the second flew 1 hour and 57 minutes on 19 March, and the third for 1 hour and 40 minutes on 2 April. In this group of tests, the airmen noted particularly poor directional control.[78]



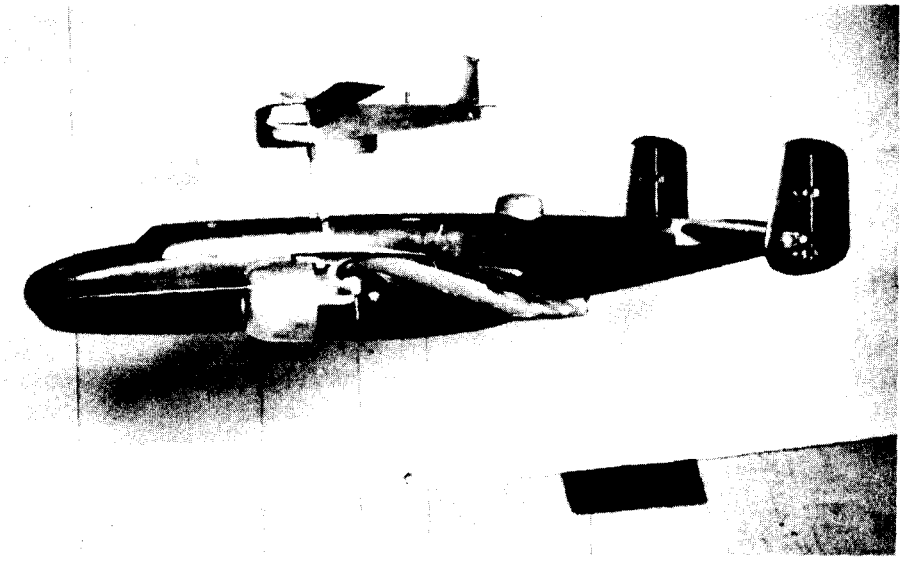
A General Motors A-1 about to undergo a captive launch test on 11 November 1941. Arnold and Kettering pushed the GM A-1, but it performed little better than Kettering's World War I "flying bomb." (USAF)

*See Appendix A for missile specifications.

Despite these aeronautical achievements, some Army aviators experienced doubts about the utility of the GM A-1, especially because of the small 500-pound bomb load and the need for a mother ship. General Motors suggested a twin-engine version which could carry a 1,000- to 2,000-pound bomb load 900 to 1,200 miles; but the engine production bottleneck made such a proposal impractical.[79]

Meanwhile, General Motors added landing gear, a monorail launcher, and a television sensor to the device. On 17 July 1942, the modified A-1 flew only two minutes, but this was better than the next two attempts: An accident during taxiing destroyed one device on 25 September; and five days later, another device crashed on takeoff.[80]

In October, a new idea emerged—air launching. Some believed only this technique, coupled with a TV sensor, would make the A-1 a useful military weapon. The North American B-25 emerged as the missile carrier, a bit of poetic justice since the nickname of the twin-engine bomber was "Mitchell." In 1943, the Army tested models of the missile mounted on the bomber in a wind tunnel at Wright Field.[81] Nothing else came of this effort.



These 1/22.2 wind tunnel models of GM A-1 atop a B-25 were tested at Wright-Patterson field, but the idea got no further. (USAF)

The last two A-1s flew in late May 1943 at Lake Muroc. On 24 May, the first remained aloft for 1 hour and 35 minutes, while the last on 27 May remained airborne for 1 hour and 20 minutes. Once again, the airmen noted ineffective control.[82]

A report in August 1943 spelled doom for this particular project, noting that

developing the device would cost $.7 million and 18 months development time. Even then, the report asserted, the small bomb load made the A-1 a questionable military weapon. Consequently, on 6 September 1943, Major General O. P. Echols, Assistant Chief Air Staff, Materiel, Maintenance, and Distribution, recommended cancellation of the project.[83] Following a demonstration of a parallel project on 10 October 1943 (see below), the Army cancelled the GM A-1 project. Arnold pulled the plug on 18 November, with General Motors receiving the formal word on 23 December 1943. The project had cost the Army about $350,000.[84]

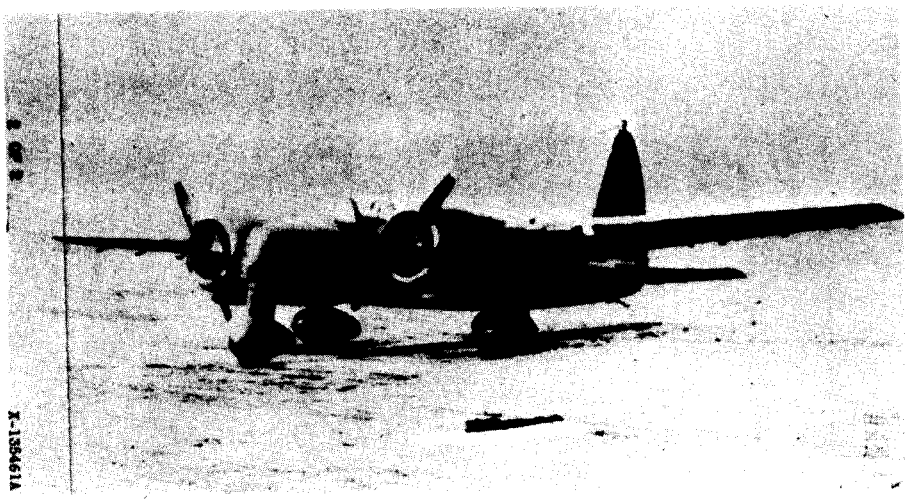
XBQ Aircraft as Aerial Torpedoes

Starting a bit later, but in progress at almost the same time as the GM A-1, was another American guided missile project. Following Pearl Harbor, some believed that the quickest way to get aerial torpedoes into action was to use radio-control target drones. But the Army considered the existing drones either too small or possessing unsatisfactory characteristics.[85] Nevertheless, the airmen tested target drones as facsimile aerial torpedoes. On the aforementioned tests on 10 October 1943, an airborne operator guided two PQ-12As fitted with TV and a 500-pound bomb load; one hit and destroyed another airborne drone (PQ-8), the other hit within 30 feet of a ground target. Despite these accomplishments, the Army considered such equipment inadequate in light of tactical requirements.[86]

In March 1942, the Army initiated projects involving two types of aerial torpedoes, one with a 2,000-pound bomb load, the other with a 4,000-pound bomb load. Fleetwings contracted on 10 July 1942 to build two aircraft of the first type (XBQ-1 and XBQ-2A), while Fairchild contracted on 1 October 1942 to construct two of the larger craft, designated XBQ-3. The Army Air Forces also requested US Navy aerial torpedoes for testing—the Interstate TDR-1, XTD2R-1, and XTD3R-1 which the Army redesignated respectively, XBQ-4, XBQ-5, and XBQ-6. The entire XBQ series consisted of twin-engine devices that looked like aircraft.[87]

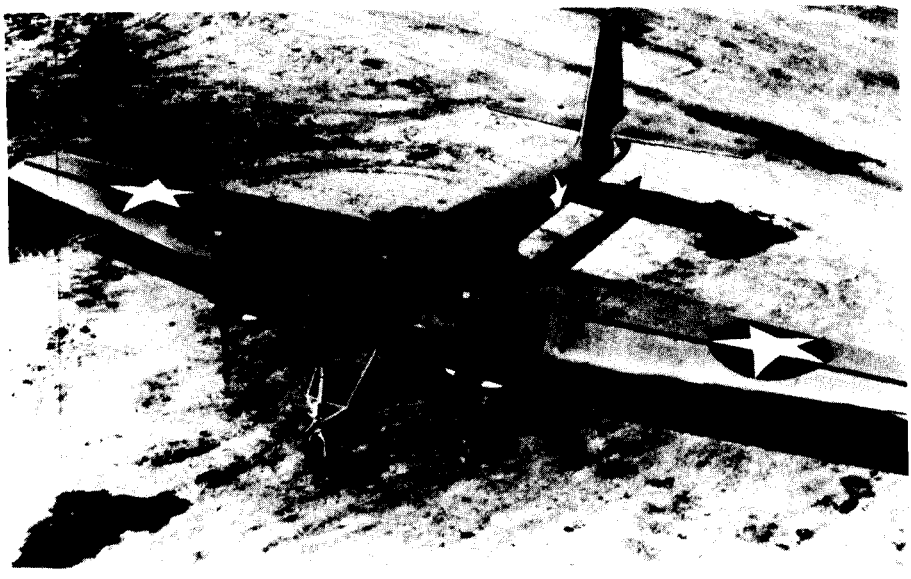
Although the Fleetwings XBQ-1 was designed to deliver its 2,000-pound warhead 1,717 miles at 225 mph,* a crash on the first flight ended the project in May 1944.[88] The next in the series, the XBQ-2A,* was essentially the same aircraft as the XBQ-1, but high cost led to its demise in December 1943.[89] In contrast, the Fairchild XBQ-3* was larger and heavier than either the XBQ-1 or XBQ-2A. Although one XBQ-3 received some structural damage in a forced landing in July 1944, XBQ-3 tests continued at a cost of $1.4 million.[90] The Army borrowed a fourth variant, the Interstate's XBQ-4* (TDR-1), from the Navy in April 1943 and, after completing tests, returned it in December of the same year. The last two prototypes, the XBQ-5 and XBQ-6, never got beyond the proposal stage.[91]

*See Appendix A for missile specifications.



The Fleetwings XBQ-2A was a radio-controlled missile capable of delivering a 2,000-pound warhead. Its larger engines and jettisonable landing gear made it different from the XBQ-1, but no more successful. (USAF)

The XBQ-3 was an unmanned version of Fairchild's AT-21 trainer designed to carry 4,000 pounds, 1,500 miles at 220 mph. (USAF)



The Interstate XBQ-4 possessed the most modest performance of the XBQ series. It was to carry 1,950 pounds, 400 to 750 miles, at 162 mph. (National Archives)

APHRODITE: The Aerial Torpedo In Action

The only AAF "flying bomb" used in combat during World War II had the code name APHRODITE. United States airmen stripped armament and nonessential flight equipment from worn out ("war weary") heavy bombers and crammed them with 18,500 pounds of explosive. A pilot got the modified bomber off the ground and up to cruising altitude, after which an electronic technician adjusted the radio control equipment and activated the fuze. Then the two men bailed out over England. A control ship, using radio control, guided the aircraft to its target.

APHRODITE's first mission, on 4 August 1944, failed. One modified B-17 crashed with the pilot aboard, the Germans shot down a second machine, a third overshot its target by 500 feet, and a fourth impacted 1,500 feet short of its target. Two further attempts on 6 August also failed, one missile crashing in England, the other into the North Sea.[92]

*See Appendix A for missile specifications.

Boeing APHRODITE, 11 September 1944. War weary B-17s, such as this one, were stripped of armor and armament, loaded with nine tons of explosive, and guided by radio control against German targets. (USAF)

On 15 October 1944 this APHRODITE missile exploded short of its target after being hit by flak. (USAF)

The white smoke trail was used by the controller to see the missile. The APHRODITE program was a failure. (USAF)

Concurrently, the US Navy engaged in a similar project, using B-24s, a different radio-control system, and a television sensor. On the first trial, on 12 August, the weapon blew up, killing Navy Lieutenants Wilford J. Willy and Joseph P. Kennedy, Jr. A second attempt that day demolished some German facilities at Heligoland but, because of a poor TV picture, not its target. There were no further Navy operations.[93]

The AAF persisted and received better equipment, including TV which permitted forward vision from the device and readout of the compass, an altimeter which allowed the aircraft to descend to and maintain a preset altitude, and a radio beacon. But the results were comparable to the Navy's test. The Germans shot down one missile 300 feet right of the target on 11 September 1944. Three days later, the AAF lost two more devices, the second missing its target by 200 feet. On 15 October, flak downed one missile while another hit a town one quarter mile from the target. Two more devices disappeared on 30 October, one over Germany and the other over the North Sea.[94]

On 27 October 1944, Headquarters US Strategic Air Forces (USSTAF) ordered that the remaining devices be used against German cities. The AAF added throttle controls to enable the device to fly a flight profile that included a 10,000-foot penetration altitude and a 300-foot approach altitude. The next mission on 5 December ended with one weapon destroyed by flak and a second downed by icing. The last mission, on 1 January 1945, proved equally unsuccessful with one device

hitting a residential area two miles beyond the target and a second crashing five miles short of the target. In the end, neither new targets nor new equipment made any appreciable difference. Fundamental mechanical problems persisted.[95]

But it was the USSTAF Commander, General Carl "Tooey" Spaatz, who in late January 1945 halted and later cancelled the launching of APHRODITEs against Germany. He did this not only because employment of such weapons ran counter to the American strategic bombing doctrine, but more importantly, the APHRODITE scheme did not work. The weapon proved highly susceptible to weather conditions, vulnerable to flak, and limited in accuracy. A report on the project concluded that the system needed more radio frequencies (to allow simultaneous launchings), more controls, and more instrumentation, as well as a remote detonator. The APHRODITE concept simply failed as a strategic precision weapon; it was instead a terror weapon, and not a very good one at that. As General "Jimmy" Doolittle, the Eighth Air Force commander, put it, the scheme was just a bad idea.[96] So ended APHRODITE.

In summation, American efforts with "flying bombs," before and during World War II, failed. Technical problems proved too great; and the results represented only a slight improvement over the World War I experiments. American "flying bomb" development shifted from pre-set guidance to radio-control from an accompanying aircraft. But, while radio-control efforts worked in theory and in tests, they did not work well in combat. Mechanical problems with missile, explosive, and guidance systems precluded adequate testing of both the equipment and the concept. A realistic appraisal of these piston-powered "flying bombs" during World War II must conclude that although they were comparable in cost to manned aircraft, they proved less reliable, less accurate, and more vulnerable than conventional aircraft. The Germans, however, came up with a breakthrough to make the "flying bomb" a marginal, if not truly practical, weapon.

NOTES

CHAPTER II

Data within the brackets indicate the location of source material: Public Record Office, London, United Kingdom (PRO); Air Force Museum, Dayton, Ohio (AFM); National Air and Space Museum, Washington, D.C. (NASM); Albert F. Simpson Historical Research Center, Montgomery, Ala. (AFSHRC); Air University Library, Montgomery, Ala. (AUL); Naval Historical Center, Washington D.C. (NHC). The numbers following the symbols for the Air University Library and Simpson Center are their call numbers.

1. *Notre Dame Scholastic* (5 November 1892); *Aeronautics* (October 1909) (October 1911) [AFSHRC-K110.70012-1]; House Committee on Military Affairs, 63rd Congress, 1st Session [AFSHRC-168.655-7]. Individuals associated with the idea included Elmer Berliner (1909), Paul E. Chamberlin (1911), and an unidentified Swede in 1913.

2. Bion J. Arnold to Secretary of War, "Secret Report on Automatic Carriers, Flying Bombs (FB), Aerial Torpedoes (AT)," 31 January 1919 [AUL-623.451 W253B]. Hereafter cited as Arnold Report. Lee Pearson, "Developing the Flying Bomb," *Naval Aviation News* (May 1968), 23.

3. Gordon Bruce, "Aerial Torpedo is Guided 100 miles by Gyroscope," *New York Tribune* (20 October 1915), 1; Delmar S. Fahrney and Robert Strobell, "America's First Pilotless Aircraft," *Aero Digest* (July 1954), 28; Charles Keller, "The First Guided Missile Program," *Journal of American Aviation Historical Society* (Winter 1975), 268. Hewitt and Sperry hoped to develop a weapon of war, as was dramatically made known to the world in a 1915 newspaper article based on information from Sperry's son, Lawrence, under the title "Aerial Torpedo is Guided 100 Miles by Gyroscope." The story's lead sentence read: "A device which is likely to revolutionize modern warfare has been invented and tested, and will be ready for the market within a very short time." The author speculated that the device could destroy an entire town as far as 100 miles away with no loss to the attacker, possibly with only one weapon. The story claimed that young Sperry told of tests indicating accuracies of 3 miles at a 10-mile range and 8 miles at a 100-mile range. The article concluded: "The new invention is a self-controlled aeroplane, flying without a pilot and loaded with death." Bruce, 1, 3.

4. Further efforts to stimulate Army interest in the project failed. Several Army officers invited to witness demonstrations found them cancelled because of mechanical problems. Hewitt and Sperry cancelled one demonstration scheduled for William "Billy" Mitchell in November 1916 because the soon to be famous aviator did not show up. Keller, 269.

5. Ralph Earle to Chief of Naval Operations, Subj: "The F. B., Development to Date," 1 November 1918, 1, [NHC] Hereafter cited as Earle Report; Fahrney and Strobell, 28; Keller, 268.

6. Quoted, Earle Report, 2; Keller, 269.

7. Quoted, Earle Report, 2.

8. In September 1914, an American attache reported an Italian aerial torpedo. While a successful French pilotless aircraft test of 36 miles was reported in 1917, it is unsubstantiated. The French did get a pilotless aircraft airborne for 51 minutes on 14 September 1918. House Committee on Military Affairs, 69th Congress, 1st Session, "Department of Defense and Unification of Air Service," hearing 19 January–9 March 1926, 377; A.Volmerange, "L'Avion Sans Pilote," *Aeronautique* (September 1921), 9; Henri Bergeron, "Les Avions Sans Pilote," *L'Air* (5 June 1921), 14.

9. A. M. Low, "The First Guided Missile," *Flight*, (3 October 1952), 438; Delmar S. Fahrney, "The History of Pilotless Aircraft and Guided Missiles," n.d., 103, 104, 998-1001 [NHC]. Hereafter cited as Fahrney manuscript. Grahame Felgate, "British Pilotless Aircraft," [W. R. Taylor (ed.), *Aircraft Annual 1960* (London: Ian Allan, 1960), 64, 65]; John W. R. Taylor, *Jane's Pocket Book of RPVs: Robot Aircraft Today* (New York, N.Y.: Macdonald and Jane's, 1977), 11, 13, 15.

10. Low, 436–438; Rhodi Williams, "The First Guided Missile," *Royal Air Force Flying Review* (May 1958), 26, 27.

11. *Jane's Pocket Book of RPVs*, 15; G. W. H. Gardner, "Automatic Flight: The British Story," *Journal of the Royal Aeronautical Society*, Vol. 62, (July 1958), 478.

12. Arnold Report, 2.

13. Ibid.; Earle Report, 2, 3; Fahrney and Strobell, 28.

14. Thomas P. Hughes, *Elmer Sperry* (Baltimore, Md.: John Hopkins, 1971), 265; Earle Report, 3; Fahrney and Strobell, 28; Keller, 269; Pearson, 23; Fahrney manuscript, 91, 92.

15. Specifications called for an empty weight of 500 pounds, a top speed of 90 mph, a 50-mile range, and a 1,000-pound payload. The machine was a biplane powered by the same 100 hp OX-5 engine used in the famous Jenny trainer. Gyroscopes held the machine to a set course and a small and simple propeller mechanism, after turning a preset number of revolutions, forced the missile to dive, presumably into its target. Exhibit J, Arnold Report; Fahrney and Strobell, 29; Keller, 270; Pearson, 24; Fahrney manuscript, 96-98.

16. Keller, 270, 271; Fahrney manuscript, 98, 99.

17. Keller, 271; Pearson, 24; Fahrney manuscript, 99.

18. Fahrney and Strobell, 29; Keller, 271; Fahrney manuscript, 100, 101.

19. Keller, 271.

20. Ibid., 272; Fahrney and Strobell, 29; Pearson, 25.

21. Keller, 272; Fahrney manuscript, 107.

22. Earle Report, 3.

23. Keller, 271; Pearson, 24; Fahrney manuscript, 106, 107.

24. Keller, 272; Pearson, 24, 25.

25. Fahrney and Strobell, 29; Keller, 273; Pearson, 25.

26. Keller, 273.

27. Fahrney manuscript, 112.

28. Earle Report, 4.

29. Ibid.

30. Hughes, 270–271; Fahrney manuscript, 113–117, 120–122.

31. Jones Collection [AFSHRC-168.655-7].

32. George O. Squier to Chairman, Aircraft Board, Subj: "F. B." 26 November 1917, Exhibit B, Arnold Report. When officers of a French mission were asked what was the best contribution the United States could make to the war, they answered, "new inventions." Guy L. Gearhart, "Resume of Aerial Torpedo Development," 7 July 1921 [AFM]. Hereafter cited as Gearhart, "Resume."

33. "Resume of Aerial Torpedo Development," 10 April 1926, 1 [AFM]. Hereafter cited as Resume, 1926.

34. Ibid.; Fahrney and Strobell, 29; Gearhart, "Resume."

35. "Brief History of Aerial Torpedo of 1918" [AFM]; Exhibit H, Arnold Report; Chief Signal Officer to the Chief of Staff, 5 October 1918 [AUL-623.451 W 253B]; Jones Collection; H. F. "Red" Smith, "The World's First Cruise Missile," *Air Force Magazine* (October 1977), 43; Fahrney and Strobell, 29, 32.

36. Data on the manned flights are unclear. My account follows data in the Jones Collection, while another claims the manned missile was larger than the Bug and was flown in September. Stuart Leslie, *Boss Kettering* (New York, N.Y.: Columbia University, 1983), 82. Arnold Report, 5, 6; Josephus Daniels to the Secretary of War, Exhibit C, Arnold Report; Thomas A. Boyd, *Professional Amateur* (New York, N.Y.: Dutton, 1957), 107; "Aerial Torpedo Development United States Air Service Contracts 2713-2714-229-242-379-387," 9, 10 [NASM]. DeWitt S. Copp's account of the Bug is

unsupported by the archival materials. He apparently confuses Bion J. Arnold, the commander of the project, with H. H. Arnold. See his *A Few Great Captains* (Garden City, N.Y.: Doubleday, 1980), 23, 118. On 23 April 1918 the Aircraft Production Board recommended $20,000 for an automatic airplane built by E. E. Winckley. There is no further mention of this machine. Another "flying bomb" may have been the Modisette aircraft, but there is no collaboration. Garther Littrell, "The First Robot Bomber," *Flying* (November 1944), 44, 45. B. J. Arnold, while looking for a better testing site, saw another "flying bomb" project, the Lloyd Giles machine in Los Angeles. It was smaller than the Bug, more costly, and not nearly so well developed. Bion J. Arnold to William C. Potter, 20 December 1918, Subj: "Giles Automatic Carrier," [AUL-623.451 W 253B]; Jones Collection.

37. Arnold Report, 7, appendices H and L.

38. Bion J. Arnold to Dayton Metal, Subj: "Ammunition Carrier," 10 October 1918, Exhibit M, Arnold Report; Arnold Report, 6.

39. George O. Squier to Chief of Staff, 5 October 1918, Subj: "Automatic Carrier for the Signal Corps (Liberty Eagle)," Exhibit F, Arnold Report.

40. Ibid.; Boyd, 107; Henry H. Arnold, *Global Mission* (New York, N.Y.: Harpers, 1949), 74–75.

41. Arnold Report, 14. On 22 December Major General George Squier, Lieutenant Colonel Bion J. Arnold, Orville Wright, and Charles F. Kettering briefed the Secretary of War, Newton Baker, on the "flying bomb" project. The Secretary in turn was to inform the President who might then decide to make a proposal at the upcoming Versailles Peace Conference to ban or limit the weapon. Other researchers will have to determine if this plan was carried out. Resume, 1926, 2, 3; Arnold Report, 13.

42. Dan I. Sultan, Board of Officers, 13 January 1919 [AUL-623.451 W 253B]; Resume, 1926, 7; 1916 Army Officer Register, 277.

43. Guy L. Gearhart, "Complete Data on Aerial Torpedo—1919" [AFM]; "Case History of Controlled Missiles—Aircraft," Part 1-GMA-1, 1 [AFSHRC-202.4-1 V]. Hereafter cited as Case History GMA-1.

44. In 1919 a French Artillery Officer, Rene Lorin, wrote a book which advocated long distance bombardment of distant objectives with jet-propelled pilotless aircraft guided from other aircraft. Basil Collier, *The Battle of the V-Weapons 1944-45* (London: Hodder and Stoughton, 1964), 12; Basil Collier, *The Defense of the United Kingdom* (London: Her Majesty's Stationery Office, 1957), 353.

45. *Jane's Pocket Book of RPVs*, 18, 21; Felgate, "British Pilotless Aircraft," 65–67; Gardner, "Automatic Flight," 479–481; "Statement of Pilotless Aircraft in Possession of A.M.S.R.," 22 May 1925 [PRO-AIR 5/506]; "Memorandum on Pilotless Aircraft," 3, 4 [PRO-AIR 20/382]; J. P. Hassell, "Larynx: Britain's Cruise Missile," student paper, RAE 1977, 2.

46. The Larynx carried a radio transmitter, but not radio control, in the 1927 Bristol Channel tests. Coupled with a chain of ground stations, the radio gave directional information as well as engine rpm, perhaps the first use of aircraft telemetry.

47. Gardner, "Automatic Flight," 482-484; Memorandum on Pilotless Aircraft, 2–6; "DRG No. A41762" [blueprint] [PRO-AIR 5/506]; Minutes of Pilotless Aircraft Committee of 23rd Meeting of 19 March 1930; "Report of the Pilotless Aircraft Committee on Trials of Larynx Aircraft in Iraq, 1929" [Both PRO-Minutes 78A, 76A; AIR 5/536]; Hassell, 3, 5, 6.

48. Memorandum on Pilotless Aircraft, 1; "Conference on Future Research Programme," [PRO-Minute 31A; AIR 2/1362]; "Record of Important Points Disclosed During the Conference on Pilotless Aircraft Held by CAS on 2 October 1930 and the Decisions Made," [PRO-Minute 2A; AIR 2/1313]; "Development of RAM and Larynx," November 1935; DSR to AMRD, 30 December 1935; DCAS to CAS, 20 January 1936; "Air Staff Note on the Wireless-Controlled 'Ram,'" 7 February 1936 [All 4 in PRO-Minutes 114B, 122, 123, 133A; AIR 2/1362]; Hassell, 7.

49. Wimperis (Director of Scientific Research), 28 September 1936; R. D. Inst. 2 to ADRD Inst, 21 September 1936; DSR to FOI, 26 March 1936; "Air Staff Note on the Mechanically Controlled Pilotless Aircraft (The Larynx)," 20 May 1936; DSR to AMSR, 15 December 1933; "Pilotless Aircraft Co-ordination Committee Minutes Meeting," 14 February 1934; [all 6 PRO-Minutes, unmarked, 158, 148, 156B, 22B, 20A; AIR 2/1362]; "Pilotless Aircraft Co-ordination Committee Meeting Minutes, 1 February 1935," [PRO-Minutes 22B; AIR 2/1313]; Gardner, "Automatic Flight," 484; Hassell, 8.

50. Felgate, "British Pilotless Aircraft," 68, 69; Gardner, "Automatic Flight," 484–488; *Jane's*

Pocket Book of RPVs, 22; Williams, "The First Guided Missile," 27; Peter G. Cooksley, *Flying Bomb* (New York, N.Y.: Scribner, 1979), 18; Fahrney manuscript, 1002, 1003, 1006, 1014, 1024.

51. Fahrney manuscript, 140.

52. Gearhart, "Resume," 1–3; Resume, 1926; Henry H. Arnold to Chief of Air Corps, Subject: "Aerial Torpedo," August 1930, 6 [AFSHRC-202.4-IV]; "Aerial Torpedo Development," 16, 17, 27A, 36A.

53. Gearheart, "Resume"; William W. Davenport, *Gyro* (New York, N.Y.: Scribner, 1978), 216.

54. Resume, 1926, 7.

55. Gearhart, "Resume," 2; Davenport, *Gyro*, 217; Resume, 1926, 8, 9.

56. Resume, 1926, 9.

57. Ibid., 9–11; Case History GMA-1; "Aerial Torpedo Development," 55.

58. "Summary of Power Driven Weapons Developed by Special Weapons Branch Equipment Laboratory," 20 November 1943, 2, 3 [AFSHRC-201-46 III]; Case History GMA-1.

59. Mitchell foresaw the use of the "flying bomb" against cities over 100 miles away. He insisted that: "The aerial torpedo is, and will be, a weapon of tremendous value and terrific force to airpower." Alfred Hurley, *Billy Mitchell* (Bloomington, Ind.: Indiana University, revised edition, 1975), 77, 88, 116, 121; William Mitchell, "Lawrence Sperry and the Aerial Torpedo," *U.S. Air Services* (January 1926),16; William Mitchell, *Winged Defense* (New York, N.Y.: Putnam's Sons, 1924),6. Concurrently, Mitchell observed that the device was languishing in the United States. Mitchell, "Lawrence Sperry," 16.

60. Fahrney manuscript, 92–94, 149–179; Berend D. Bruins, "U.S. Naval Bombardment Missiles, 1940–1958," unpublished Ph.D. dissertation, Columbia University, 1981, 67; L. S. Howeth, *History of Communications-Electronics in the United States Navy* (Washington, D.C.: Government Printing Office, 1963), 349–351.

61. Fahrney manuscript, 188–277; Howeth, 479–483.

62. Fahrney claims he coined the name "drone" for this type of craft in late 1936. The name follows the motif of the British Queen Bee, another radio controlled aircraft. D. S. Fahrney, "Guided Missiles U.S. Navy the Pioneer," *American Aviation Historical Society Journal* (Spring 1982), 17.

63. Bruins, 68, 69; Fahrney manuscript, 316–329; Howeth, 484–486.

64. Bruins, 70; Howeth, 486.

65. Delmar S. Fahrney, "The Birth of Guided Missiles," *United States Naval Institute Proceedings* (December 1980), 56, 57.

66. Bruins, 83–86; Fahrney manuscript, 372–375, 381; Howeth, 487, 489, 492. Although the TDN and TDR used different airframes, both used the same 200 hp Lycoming engine; the TD2R and TD3R were the same airframe with different engines. See below, "XBQ Aircraft as Aerial Torpedoes."

67. Bruins, 97–103; Fahrney, "The Birth," 58, 59; Fahrney manuscript, 394, 395, 398; Howeth, 493.

68. Fahrney, "The Birth," 59; Fahrney manuscript, 402, 403, 418, 419.

69. Bruins, 106; Fahrney manuscript, 417, 424. In 1939 the Army requested, and the Navy sent, the Air Corps a TG-2 control aircraft and a N2C-2 drone. Fahrney, "Guided Missiles USN the Pioneer," 21.

70. Routing and Record Sheet, handwritten comments 5/7/36 attached to Report of the Air Corps Board, No. 9 "Radio Controlled Aircraft," 25 October 1935 [AFSHRC-167.5-9].

71. Oscar Westover to Chief, Materiel Division, 8 August 1938 [AFSHRC-202.4-1 V].

72. "Report, Controllable Bomb, Power Driven, General Motors, Type A-1" 24 August 1943 [AFSHRC-Summary of Power Driven Weapons]. Westover died in an aircraft crash on 21 September 1938. Arnold, *Global Mission*, 169.

73. Engineering Section Memorandum Report, 26 April 1939 [AFSHRC-202.4-1 V].

74. Kettering to Arnold, 7 September 1939 [Summary of Power Driven Weapons, 2].

75. Summary of Power Driven Weapons, 3, 4; Case History GMA-1; Arnold to Kettering, 3 November 1939; Arnold to Adjutant General, Subj: "Military Characteristics of Aerial Torpedo" 15 January 1940; CG Materiel Center to Richards, G. M., 18 May 1942 [last 3 in AFSHRC-202.4-1 V].

76. Randolph P. Williams, Memorandum Report, Subj: "Controllable Bomb Project," 20 December 1941; H. A. Huebotter, Memorandum Report, Subj: "General Motors Corporation, Aerial Torpedo," 24 February 1942 [both AFSHRC-202.4-1 V].

77. Summary of Power Driven Weapons, 4, 5; Case History GMA-1; R. L. Mayrath, Memorandum Report, Subj: "Controllable Bomb, Power Driven," 24 January 1942 [AFSHRC-202.4-1 V].

78. Case History GMA-1; Summary Power Driven Weapons, 6, 7; Report, "Controllable Bomb, Power Driven, General Motors, Type A-1," 24 August 1943 [AFSHRC-202.4-1 V].

79. Case History GMA-1; Summary of Power Driven Weapons, 8; F. O. Carroll to Chief, Materiel Division, Subj: "Controllable Bomb Project," 17 January 1942 [AFSHRC-202.4-1 V].

80. Case History GMA-1; Summary of Power Driven Weapons, 9, 10; Report "Controllable Bomb, Power Driven, General Motors, Type A-1," 24 August 1943 [AFSHRC-202.4-1 V].

81. Case History GMA-1; R. L. Mayrath, Memorandum Report, "Controllable Bomb, Power Driven," 13 November 1942; O. E. Hunt to C.G., Materiel Center, 14 April 1943 [both AFSHRC-202.4-1 V]; AAF Technical Report, "Five Foot Wind Tunnel Test No. 396" [AFM].

82. R. L. Mayrath, Memorandum Report, "Controllable Bomb, Power Driven," 18 June 1943 [AFSHRC-202.4-1 V]; Summary of Power Driven Weapons, 12, 13.

83. Summary of Power Driven Weapons, 13, 14; Case History GMA-1.

84. Case History GMA-1; O. P. Echols memo to Chief of Air Staff, Subj: "Controllable Bomb, Power Driven, General Motors Type A-1," 6 September 1943 [AFSHRC-202.4-1 V].

85. Summary of Power Driven Weapons, 4.

86. Ibid., 5, 6.

87. Ibid., 4, 5.

88. "XBQ-1," 1 June 1943 [Pilotless Aircraft as Guided Missiles, AFSHRC-218.94-1].

89. "XBQ-2A," 1 August 1943 [Pilotless Aircraft].

90. "Details of AAF Guided Missile Programs," 9/2/44 [AFSHRC-201-46 III]; "XBQ-3," 1 January 1946 [Pilotless Aircraft].

91. "XBQ-4," 1 August 1945; "XBQ-5," 1 June 1945; "XBQ-6," 1 June 1945 [All in Pilotless Aircraft].

92. Case History GMA-1; 3rd Air Division Folders [AFSHRC-527.431A-21-2]; Paul A. Whelan, "History of the Third Air Division in World War II: 1943–1945," unpublished Ph.D. dissertation, St. Louis University, 1968, 249–62.

93. Third Air Division, "Final APHRODITE Project Report," [AFSHRC-527.431 A-1].

94. Ibid.; 3rd Air Division Folder; 3rd Air Division Tactical Mission Report [AFSHRC-519.431-1]; Pilotless Aircraft as Guided Missiles 1945-46 [AFSHRC-218.94-1].

95. E. E. Partridge to C. G., Eighth Air Force, Subj: "Report on APHRODITE Project," 20 January 1945, 1 [AFSHRC-527.431 A1]; Robert M. Lee to CG, USSTAF, 7 January 1945 [AFSHRC-519.311-1]; Captain R. S. Barnlard to CG, 8AF, 9AF, ASC, 17 January 1945; Msg Doolittle to 3AD, 11 December 1944 [both AFSHRC-527.431A-21-1]; 3rd Air Division Folder; Arnold to Spaatz, 23 November 1944, [Spaatz Collection, Library of Congress, Box 16]. Third Air Division Final APHRODITE Report; 3rd Air Division Tactical Mission Report.

96. Partridge Report, 3; Lieutenant Colonel R. B. Satterwhite to CG 3BD, 18 October 1944 [AFSHRC-519.311-1]. AAF Board Reports, 17 January 1945, 21 February 1945, 23 March 1945, 18 April 1945 [Pilotless Aircraft as Guided Missiles, 1945-46]. Interview James H. Doolittle, Columbia University, Oral History Collection, 17. Two further aspects require comment before closing this discussion of the APHRODITE project. In February 1945, the AAF began study of fighter aircraft as explosive drones, studies which never got beyond the preliminary stages. Finally, the AAF considered the system for use in the Pacific War. Insufficient radar to guide the machines and the emergence of a new weapon called the JB-2 (see Chapter III) killed that idea. "The Development of Guided Missiles," 1946 [AFSHRC-201-46 I].

CHAPTER III

WORLD WAR II

A number of spectacular technological developments emerged during the Second World War. The atomic bomb, jets, and medical advances come to mind, as do the German V weapons. The V-1 and V-2* ushered in a new type of warfare consisting of remote bombing of cities by pilotless weapons launched over a hundred miles away through all kinds of weather, day and night. Of the two, the V-2 impressed the layman more because of its thundering takeoff, its virtual in-flight inpregnability to conventional attack by defense forces, and its silent, faster-than-sound approach. Of all German secret weapons, it has commanded the most attention not only for its drama but also for its impact upon subsequent developments in rocketry. After all, German technicians, who developed the V-2 technology, subsequently provided much of the initial expertise for US space and ballistic missile programs. Hence, it is understandable that few lay people realize the V-1 caused greater damage and casualties than did the V-2.

The Germans first considered "flying bombs" in the 1930s. While two German companies, Askania and Siemans, did some work in the field, an independent inventor, Paul Schmidt, achieved success. He began work in 1928 on a pulsejet, received a patent on the device in 1931 and, beginning in 1933, received modest government support. In 1934, along with G. Madelung, Schmidt proposed a "flying bomb" powered by a pulsejet. The next year, he received a contract; and four years later, he demonstrated a pulsejet-powered pilotless bomber. While the German Air Force (GAF) wanted such a device, it shelved the project because of range (a 350-mile range requirement exceeded the state of the art), accuracy, and cost problems. Nevertheless, the Argus Company began work on the pulsejet in 1938; two years later, the Air Ministry brought Schmidt to Argus.[3]

The German V-1

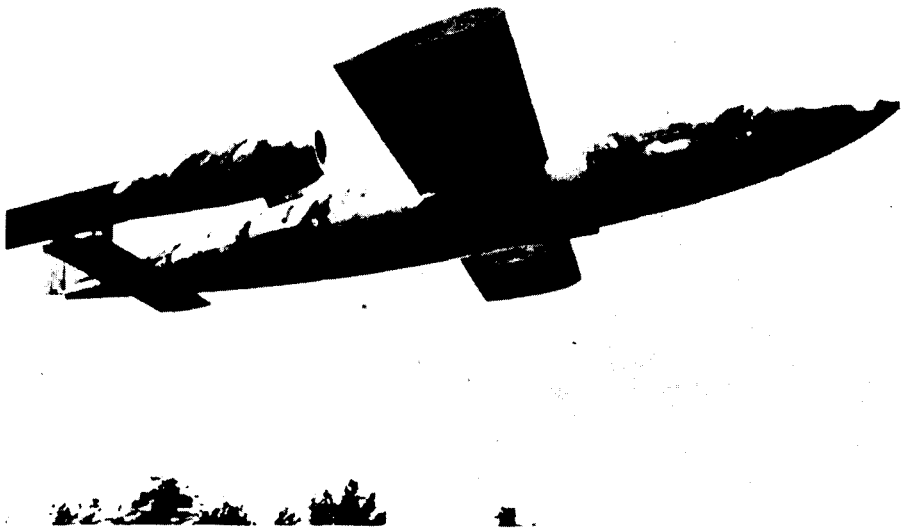
A number of factors encouraged development of what would become the V-1. First, the capture of France in 1940 reduced the distance to England, thereby ending the need for some form of radio control which experts thought to be necessary over

*While most authors assert that "V" stands for *vergeltungswaffe* (vengeance weapon), some claim it initially stood for *versuchmuster* (experimental).[1] The Germans also designated the V-1 the Fi (Fieseler) 103, *Kirschkern* (Cherry Stone), FZG-76 *(Flakzielgerat*, Flak Artillery Device, although some believe this stood for *Fernziel Gerat* long-distance target apparatus)[2]; for simplicity I shall use the less precise, but more common V-1.

the much longer distances between Germany and Britain. Second, the war depleted and dispersed the Luftwaffe's ranks by 1942, making the pilotless bombers more attractive. Third, the bombing of Germany infuriated Hitler. He demanded a terror weapon for retaliation against Britain. Finally, interservice rivalry entered in—the Air Force wanted a weapon to match the Army's V-2. Therefore in June 1942 Erhard Milch, GAF production chief, gave the highest priority to a proposal by three German companies to produce a pilotless bomber constructed from cheap materials: Argus the engine, Fiesler the airframe, and Askania the guidance system.

The V-1 flew in December 1942, first in a glide test after release from an FW 200, then on Christmas Eve in a 1,000-yard powered flight after a ground launch. In July 1943, a V-1 impacted 1/2 mile from the target after flying 152 miles.[4] By this time, the Germans had decided to build both the V-1 and the V-2.

On 26 May 1943, some of the Third Reich's top leaders visited the German test facility at Peenemunde and decided to put both weapons into full production. The V-1's considerable advantages (low cost, simplicity, ease of transportation, and low fuel consumption) convinced the German leadership of the efficacy of the system.[5]



The German V-1 was a cheaply built and cost effective "flying bomb." The pulse jet powerplant was inexpensive, yet gave the missile a top speed close to that of piston-powered fighters. (Imperial War Museum)

The V-1 was a small missile powered by a pulsejet.[6]* The cheap and effective engine operated a venetian blind-type device which opened to admit air and then closed to fire at 50 cycles per second. This propulsion system gave the V-1 its characteristic sound, however as the pulsejet could not operate at speeds of less than 150 mph, it required a boosted launch. A catapult accelerated the V-1 up a 180-foot ramp to a launch speed of 200 mph. The weapon's average range was about 150 miles, although some got as far as 175 miles. The missile crossed the

*See Appendix A for missile specifications.

British coast at about 340 mph, but as the 150-gallon fuel load burned off, its airspeed increased to about 400 mph by the time it reached London.[7] But problems associated with mass production adversely affected the missile's speed, accuracy, and operational altitude. The Germans used a gyro autopilot, powered by compressed air, to hold a course determined by a magnetic compass and a barometric device to regulate altitude. These devices sent signals to the craft's rudder and elevators on the tail surfaces. A small propeller device armed the warhead after the V-1 flew about 38 miles and then, after a preset number of turns, fired two detonators which locked the elevators and rudder in the neutral position and deployed hinged spoilers on the tail, presumably over the target. The downward attitude of the V-1 usually cut the fuel flow to the engine, causing it to stop and thereby warning those nearby of the impending explosion.[8]

The Allies early on knew of German efforts involving secret weapons. Not only was Germany known for her scientific and technological feats but, in November 1939, the British received the still mysterious "Oslo Report," which mentioned certain unspecified long-range weapons. The British, not knowing about GAF's V-1 program, at first focused their efforts on what turned out to be the German Army's V-2 program.[9] Increasing information came into the Allies' hands in June 1943 about an "aerial mine with wings." By August, the British knew of a ballistic missile and a pilotless bomber. Further confirmation of German progress occurred when some Danes smuggled out photographs of a V-1 that crashed on the island of Bornholm in August 1943.[10] The French underground also sent word of construction of launching sites in the fall. ULTRA, the decoding of German radio messages, provided more information. In November 1943, the British identified the V-1 in reconnaissance photographs of Peenemunde and then, in May 1944, examined a V-1 which had crashed in Sweden.[11] Meanwhile, the Allies took more active measures to counter this growing German threat.

In January 1943, the British began flying aerial reconnaissance over the German test facility at Peenemunde. In June, the British considered bombing the installation but deferred the attack until the longer hours of darkness in August. On the night of 17–18 August (the night following the Army Air Forces' (AAF) famous Regensburg-Schweinfurt mission), RAF bombers hit the east end of the research base and set back the V-2 project two to eight weeks. But British bombs left untouched V-1 operations on the west side of the base.[12]

The Allies also noted the construction of launch sites 10 to 35 miles inland from the French coast. Massive structures at seven locations, intended to house various German secret weapons (two for the V-1s), became increasingly visible to Allied photo-intelligence specialists. Allied bombing of these targets began with a US attack on 27 August 1943. In addition, the Allies discovered a large number of smaller complexes designed strictly for the V-1, which the Allies called ski sites because of the appearance of their storage buildings from the air.[13] Extensive aerial reconnaissance in October, combined with pictures already in hand, revealed 29 ski sites. In addition, 40,000 workers involved in the construction of these sites gave the French underground abundant information that helped pinpoint the location of

70 to 80 ski sites. A second series of photos in December uncovered 88 confirmed and 50 suspected sites.[14]

Although the Allies did not begin their bombing attacks in earnest until December 1943, by 10 June 1944 the Allies estimated that they had knocked out 82 of 96 sites attacked. Between 1 December 1943 and 12 June 1944, the Anglo-American Air Forces, flying 25,150 attack sorties, dropped a total of 36,200 tons of bombs on the sites. This bombing effort cost the Allies 154 aircraft and 771 crew members.[15]

The Germans, recognizing the vulnerability of these launching platforms to both Allied intelligence and bombing, in 1944 built smaller, more easily constructed and concealed launching platforms that the Allies called modified sites. By June 1944, the Germans had about half of their 150 sites ready for action. The Allies detected these modified sites in February, with positive identification occurring by late April. But, because of inhibiting operational factors, they attacked only one site.[16]

The Allied bombing of the sites was expensive and, as it turned out, ineffective. Intense political pressure, however, forced the airmen to pulverize the sites. While none of the bombed sites went into action, the bombing diverted vast amounts of Allied bombs from other targets and did not prevent the Germans from building alternate launching sites.[17]

The British also prepared defenses closer to home based upon the initial assumptions that the pilotless bomber would fly at about 400 mph (which proved correct) and at 7,500 feet (which did not). Later, the British revised these assumptions to 350 mph at 7,000 feet, and finally to 330 mph at 6,000 feet. The British completed a detailed plan in January 1944 which would establish fighter patrol lines (consisting of eight single-engine and two intruder squadrons) and an artillery line of 400 heavy and 346 light pieces south of London.[18] (See figure 1. They would later move the guns to the coast, ranging form Dover to Eastbourne, as indicated in figure 2.) But the demands of supporting the D-Day invasion and excessively optimistic bomb damage assessment reports of the ski sites led the British to revise the plan in March, reducing the number of guns defending London to 192 heavy and 246 light pieces.[19] The defense commander, Air Chief Marshall Roderic Hill, pointed out that the antiaircraft artillery would have difficulties if the V-1s operated at 2,000 to 3,000 feet, not the predicted 6,000 feet.[20] Subsequent events proved Hill's warning prophetic.

Meanwhile, on the other side of the Channel, German plans called for a V-1 production rate of up to 8,000 per month by September 1944, with operations starting from 64 sites on 15 December 1943. One source indicates that the Germans wanted to launch 5,000 V-1s per day against England, clearly an unrealistic goal even within the unrealistic government of Germany. Numerous technical problems hindered the program, as did Anglo-American air attacks which some believe delayed the start of the V-weapon campaign by a minimum of three months.[21]

Although Flakregiment 155 (W)* began training in the summer of 1943, this training included only limited firing of the missile at Peenemunde. The Germans organized this regiment into 64 launch crews.[22]

*"W" for the unit's commander, Colonel Max Wachtel.

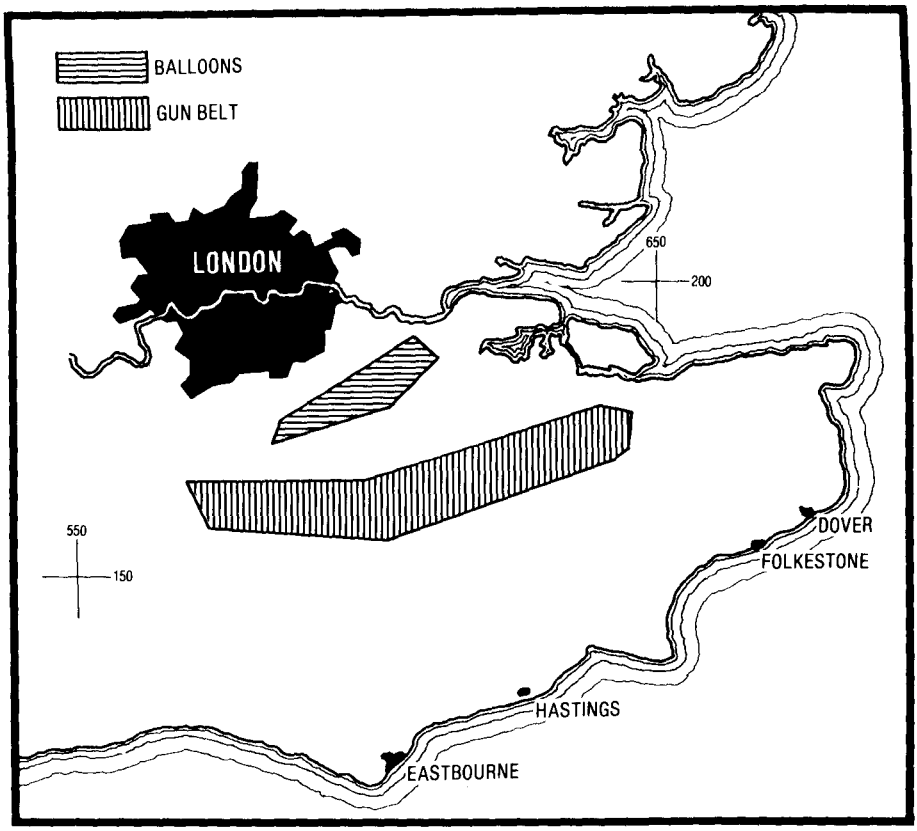


Figure 1. Initial British defensive deployment.

Following the cross-channel invasion of 6 June 1944, Hitler pushed for the start of the V-1 campaign as one way to relieve his troops. The Germans hoped to begin operations on 11 June, but circumstances forced a postponement until the next night. They planned to begin with a combined bomber and V-1 attack on London with a salvo of V-1s 20 minutes before midnight, harassing fire until 4:45, followed by a second salvo of 500 V-1s. But because of the disruption of the invasion and because the crews at 36 to 37 of the sites employed ramps and catapults for the first time and without safety equipment, the German plan failed. Flakregiment 155 did fire two small salvoes; none of the first salvo of nine missiles reached Britain, and the second salvo of 10 V-1s did little better. Five of the second salvo crashed soon after launch and a sixth disappeared, thereby leaving only four to hit England. The first impacted at 4:18 AM on 13 June. Seven minutes later, the third exploded at Bethnal Green, killing six, the only casualties from the four V-1s.[23] A lull followed, as the Germans worked out their equipment and supply problems. The V-weapons campaign resumed at 10:30 PM on 15 June; during the next 24 hours, the Germans

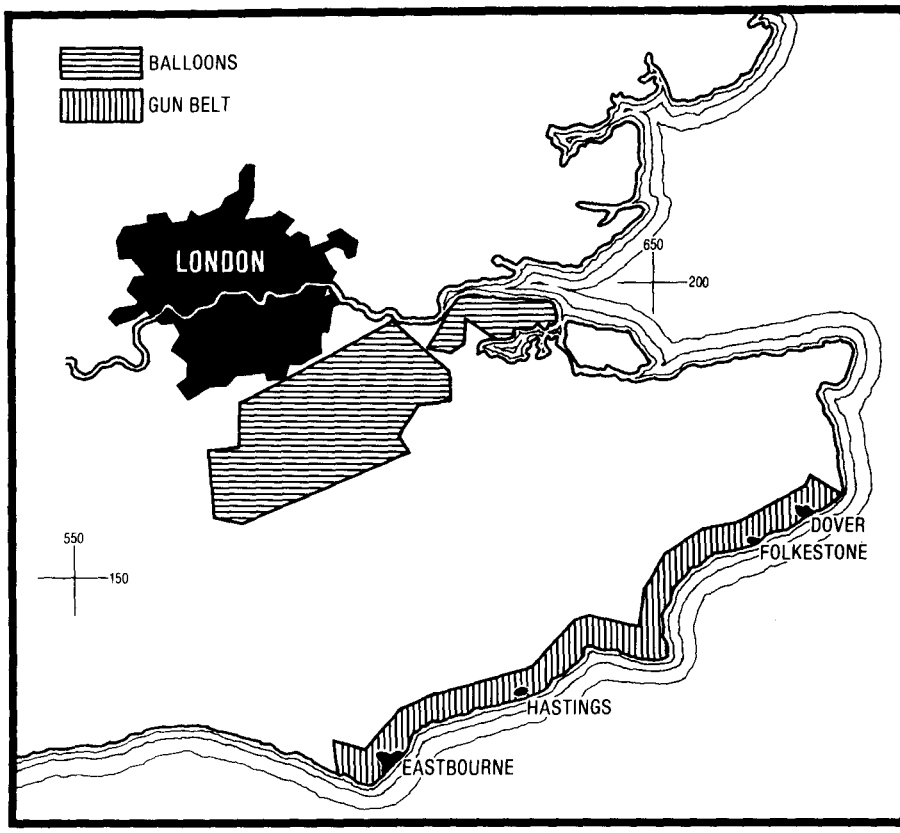


Figure 2. Final British defensive deployment.

launched 244 V-1s against London and 50 against Southampton. People came to recognize the eerie "putt, putt" of the pulsejets as they streaked across the English countryside towards London. Britons quickly learned that as long as the missile "putted" along they had nothing to fear, but once the noise stopped an explosion soon followed.[24]

By 18 June, the Germans had launched their 500th V-1; by 21 June, their 1,000th; by the 29th, their 2,000th; and by 22 July, their 5,000th.[25] The V-1 attacks continued until 1 September when Flakregiment 155 withdrew before the Allied ground advance.

The number of V-1s that approached London varied with the day (over 100 were observed crossing the coast on about 18 days) and by the hour.[26] The average V-1 explosion inflicted few casualties; however, some hit crowded areas with devastating effect. For example, at 11:20 AM on Sunday, 18 June, one impacted on

the Royal Military (Guard's) Chapel at Wellington Barracks, one-quarter mile from Buckingham Palace, killing 121 worshippers. The top echelons of the Allied leadership quickly learned of this disaster and the V-1's potential as a killer weapon. Moreover, the V-weapons' attacks forced the evacuation of 800,000 to one and one-half million Londoners.[27] All of this created intense political pressures. For these reasons, Eisenhower, in the midst of making the invasion work, on 18 June gave the V-1 countermeasures' campaign priority over all other requirements except the urgent needs of the ground war.[28]

The most dramatic single V-1 hit destroyed the Guard's Chapel at Wellington Barracks on Sunday, 18 June 1944, killing 121. (Imperial War Museum)

The British cabinet discussed deception measures to shift the mean impact point of the weapons because statisticians calculated that moving it six miles to the southeast would reduce casualties by 12,000 per month. Because such an action by the British had deep moral and political overtones, the Minister of Home Security, Herbert Morrison, argued against it, convincing the cabinet but not Prime Minister Winston Churchill. The British reported to Germany through captured German agents in the "Double Cross System," that their weapons fell beyond the target, thereby encouraging their foes to shorten the missile's range.[29] In fact the V-1s' mean point of impact until 21 July was about four and one-half miles south of its aiming point, the Tower Bridge. (See figure 3.) The weekly mean impact points wandered from there, but always remained south of the Thames, with the overall mean impact point (12 June–1 October) four miles south southeast. (See figure 4.) German plots, based on agents' reports, put the mean impact point 4 miles north northwest of the actual one—right on target.[30]

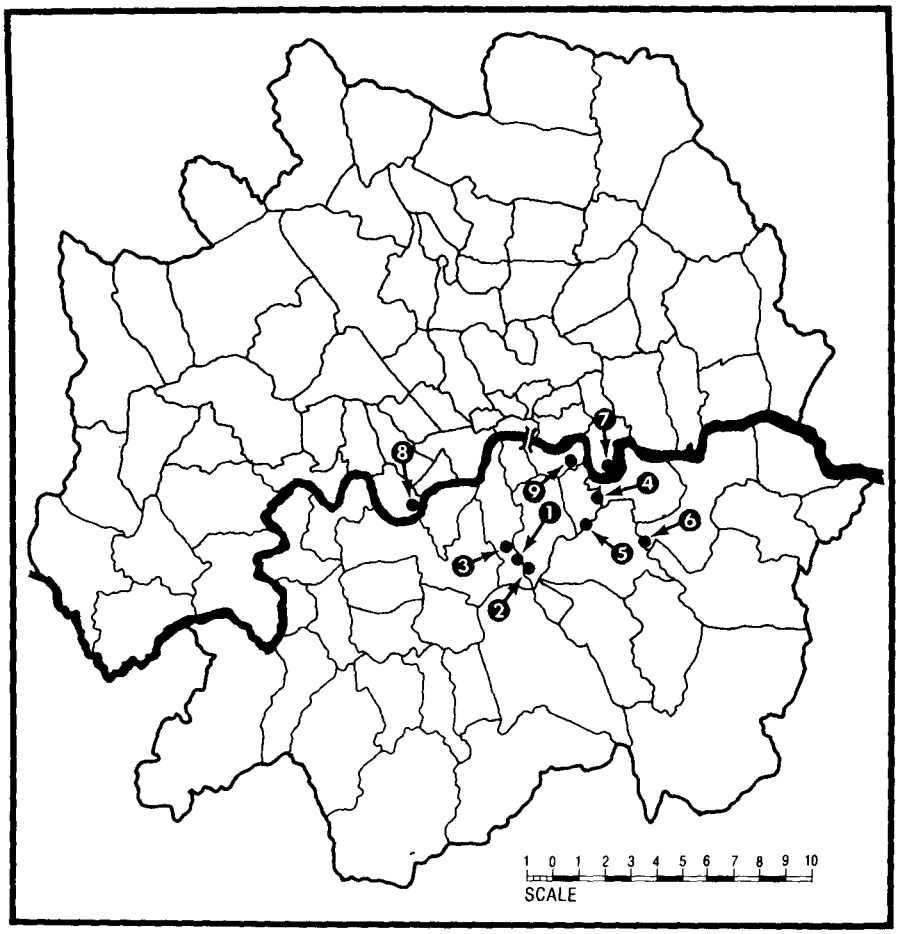


Figure 3. Median points of V-1 impacts for one-week periods. The bridge symbol locates the Tower Bridge, the principal German aiming point.

(1) 30 June to 7 July
(2) 7 July to 14 July
(3) 14 July to 21 July
(4) 21 July to 28 July
(5) 28 July to 4 August
(6) 4 August to 11 August
(7) 11 August to 18 August
(8) 18 August to 25 August
(9) 25 August to 1 September

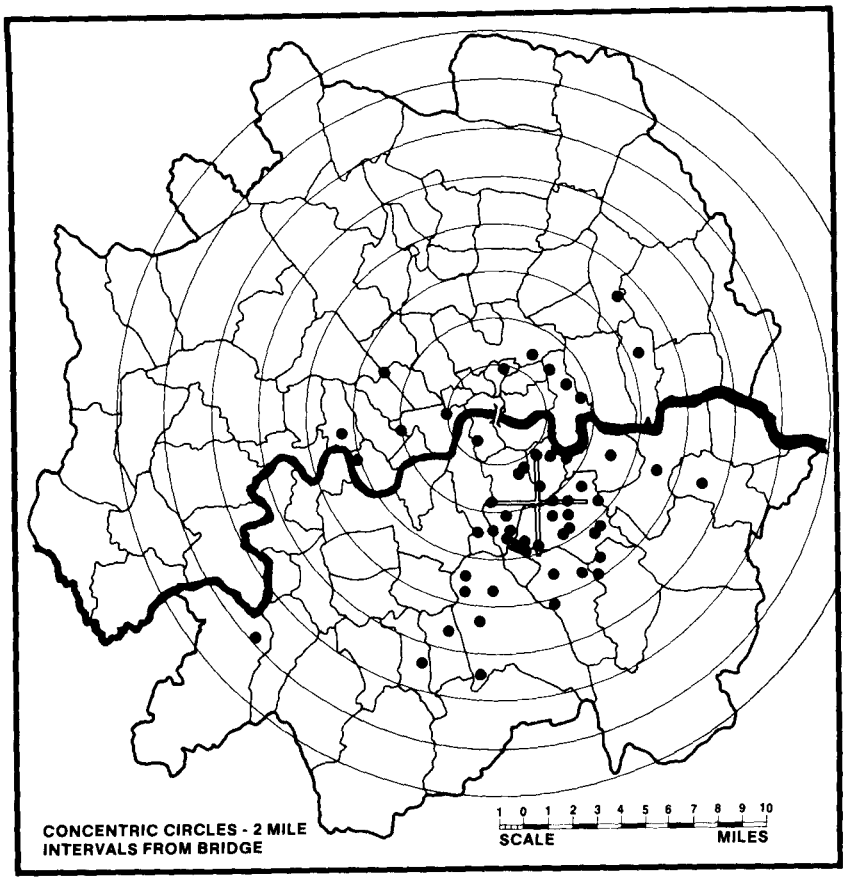


Figure 4. Centers of impact of 20 or more V-1s for 12 hour periods, 25 June to 29 August. Circles are 2 miles in radius from the main German aiming point, the Tower Bridge. The cross indicates the median point of impact.

The Germans also used obituary notices in the London newspapers as another source of target intelligence. In July the authorities plugged this source, a wise move as a German plot based upon this data put the mean point of impact one and one-half miles west of the actual impact point, certainly much closer to the truth than other information available to the Germans. The lack of German aerial reconnaissance permitted these deceptions to work.[31]

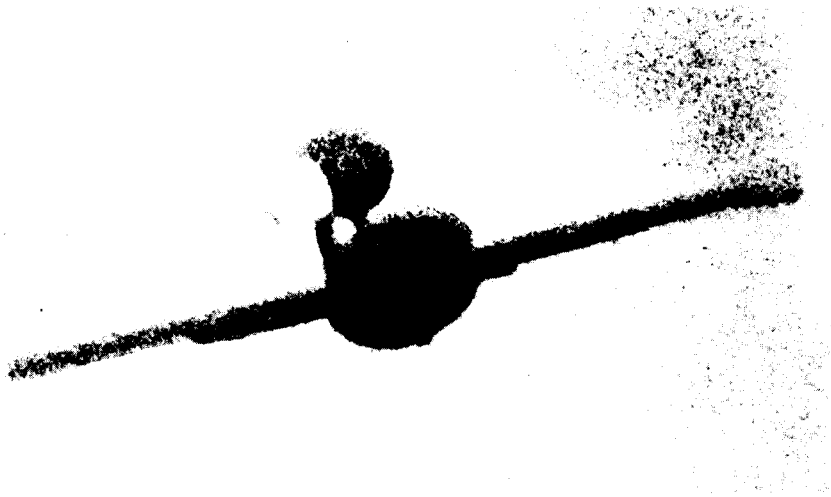
Throughout this missile bombardment, Anglo-American airmen continued bombing targets related to the V-1s. Between 12 June and 3 September, Allied Air Forces flew 26,000 sorties, dropping 73,000 tons of bombs on a variety of V-weapons' targets. The two bomber commanders, Arthur Harris of the RAF's Bomber Command and Jimmy Doolittle of the AAF's Eighth Air Force, opposed

bombing the launching sites from the start, wanting instead to hit V-1 factories. Despite their objections and intensified German flak (between December 1943 and May 1944, the Germans increased the number of heavy flak guns in France from 520 to 730), Anglo-American airmen bombed the launch sites. The ski sites remained on the target list until 27 June, after which only the large sites continued to be hit. By 15 July 1944, the Allies had hit 68 of the 88 identified modified sites, with 24 considered to have been knocked out. The Anglo-American airmen also attacked supply sites until mid-July, when they realized that storage sites were the main source of supply. The Joint Crossbow Committee decided at its first meeting on 21 July to assign storage depots and seven German factories top target priority, with 57 modified sites receiving second priority, and recommended that attacks on large sites stop. Consequently, the Allied Air Forces attacked these priority targets between 2 and 9 August with 15,000 tons of bombs, of which three quarters were targeted against storage sites. Following this massive assault, the scale of V-1 launchings fell by half. Concomitantly, the bombers also pounded factories involved in V-1 production: the Volkswagen plant at Fallersleben four times, the gyro factory at Weimar once, hydrogen peroxide facilities (used in the V-1's booster) at Peenemunde, Hollriegelshreuth, and Ober Raderach a total of seven times, and the Askania factory in Berlin (which manufactured missile controls) once. It cost the Allies 197 aircraft and 1,412 aircrew.[32]

Yet accidents hurt the German effort almost as much as the Allied bombing. About 20 percent of the V-1s proved defective, exploding on the ramp, crashing shortly after takeoff, or wandering well off course. In German tests between 18 August and 26 November 1944, only 31.4 percent of 258 V-1s impacted within either 30 km of the aiming point at 225 km range or 15 km at 100 km range, the GAF definitions of success. The Germans attributed at least 35 percent of the failures to premature crashes.[33] The V-1's accident rate of 9 percent with its early 138 foot ramp declined to 2 percent with its later 170 foot ramp. Accidents probably killed more Germans than the 185 killed by Allied bombs.[34]

The second line of Allied defense was the fighters. At first, the Allies committed eight single-engine and four twin-engine fighter squadrons consisting of the fastest types available—Spitfire XIV, Tempest V, Mustang III, and Mosquito—to the defensive effort. The AAF and RAF stripped armor, rear view mirrors, and paint from their fighters, and polished their surface skin. The Allies used higher test gasoline (150 octane) and greater engine boost to wring every possible bit of speed out of their aircraft. These measures added 13 to 30 mph to the fighters' top speed. The Anglo-Americans also employed their first operational jet, the Meteor, against the V weapons. The Meteor became operational on 27 July and claimed its first V-1 on 4 August.[35]

Fast for their day, the V-1s crossed the English coast at an average airspeed of 340 mph, building up their eventual speed to about 400 mph. This allowed Allied fighters about six minutes to catch and down the missiles before they reached their target. The missiles' small size made them difficult to spot, a problem exacerbated by their low penetration altitude which usually averaged between 2,100 and 2,500

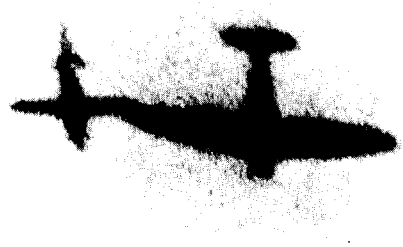


Aircraft could intercept and down the V-1, but not without difficulty. An aircraft closing within 200 yards of the missile risked damage or destruction from the V-1's jet exhaust or its explosion. (Imperial War Museum)

feet. Therefore conventional tail pursuit tactics proved unsatisfactory. The tactic finally adopted allowed the V-1 to overtake the fighter, which then closed to attack.[36] Allied pilots quickly learned that closing to ranges of less than 150 yards could result in the loss or damage of their fighter. V-1 explosions or jet exhaust damaged 37 aircraft and downed 4 or 5 aircraft, killing 5 pilots and a navigator in the first 6 weeks of the campaign.[37] Allied airmen used other tactics as well. On 23 June, a Spitfire pilot, Flying Officer K. Collis, flipped a V-1 over with his wing, upsetting the missile's gyro controls, causing it to crash. Four days later, a Tempest pilot achieved the same result with his aircraft's slipstream.[38] Nevertheless, Allied pilots found the V-1s not only tough to spot and intercept, but tough to down. One British estimate asserted that the V-1s were eight times as difficult to attack as a manned aircraft, even though they flew straight and level.[39] While that estimate may be somewhat exaggerated, the V-1s undoubtedly were a difficult target to destroy.

By 12 July, the Allies increased fighter interceptor units to 13 single-engine and 9 twin-engine squadrons (6 of the latter were part-time) and 1 month later to 15 day and 8 night fighter squadrons (2 of the latter were part-time).[40] The defenders worked out rules of engagement which gave the fighter pilots full rein in good weather and antiaircraft artillery gunners complete freedom in bad weather. For in-between atmospheric conditions, the most likely situation, the British allowed their antiaircraft artillery complete freedom up to 8,000 feet with fighter interceptors operating above that altitude. On 10 July, the British modified a 26 June order allowing fighters to enter the gun belt in hot pursuit of V-1s. After that, fighter pilots who entered areas where guns were firing did so at their own risk.[41]

A less orthodox method of destroying a V-1 was to fly alongside . . . (Imperial War Museum)



. . . slip a wing under the missile's wing, and then flip the device over, tumbling its gyro, causing it to crash. (Imperial War Museum)

England's third line of defense was antiaircraft artillery. (See figure 1.) When the campaign began, the Allies rapidly got 192 heavy guns and 200 light guns into position; by the end of June 376 heavy guns, 594 light guns, and 362 rocket launchers were operational.[42] But a number of problems became apparent as considerable numbers of V-1s still got through the defenses. The 2,000- to 3,000-foot operating altitude of the V-1s was the worst possible for the guns: too high for the light guns to be effective and too low for the heavy guns to traverse well. (Manually controlled mobile heavy pieces proved unsatisfactory as they could not smoothly and rapidly traverse.) Radar, sited in hollows and folds in the terrain to protect it from German countermeasures which did not materialize, operated at a disadvantage because such siting limited effective range and coverage. The proximity of the gun belt to London created another problem—a number of damaged V-1s crashed into London, even though the defenses had done their job. Finally, the guns and the fighters interfered with each other. The fast, low-altitude trajectory of the missiles meant that fighters strayed into the gun belt, thus inhibiting the gunners who, for their part, sometimes fired on fighters as well as the missiles. But ultimate success did occur because the defenders proved adept at generating rapid, flexible, and effective defensive adjustments.[43]

The defenders solved some of their problems more easily than others. For example, on 18 June, the British resited their radar on higher ground and ordered guns within London silent. The defenders built permanent structures, consisting of 28 railway sleepers and 12 ties, for the mobile guns. Devised by Brigadier J. K. C. Burls, these were first called "Pile Portable Platforms," for the AA Chief, Frederick Pile; they quickly became known as "Pile Mattresses." Beginning in late June, static guns with power controls and automatic fuze setters replaced mobile guns. Better gun predictors got into action in early July.[44]

But the most intractable problem remained the interference between fighters and guns. The overall defensive commander, Air Chief Marshall Roderic H. Hill, and the antiaircraft commander, General Frederick Pile, decided to designate an all-gun belt from which all aircraft would be excluded. As this idea emerged, two officers,

Air Commodore G. H. Amber and Lieutenant Colonel H. J. R. J. Radcliffe, simultaneously suggested moving the guns and radar to the coast, which would eliminate the problem of damaged missiles falling into London and would provide the radar with optimum range. Such a scheme would also give the fighter pilots a clear demarcation boundary (the coastline) between the gun and aircraft zones. About the same time, the eminent British scientist and developer of radar, Robert Watson-Watt, independently came up with the same concept, giving it even more force and credibility.[45]

Certainly such a scheme was risky. First, would the new concept actually improve the defenses? The most potent defensive weapon, the fighter, which by 13 July 1944 claimed credit for 883 of the 1,192 kills, would be inhibited by a split zone. Second, how long would such a redeployment, entailing hundreds of heavy guns, thousands of personnel, and tens of thousands of tons of supplies and equipment take? What would happen to the defenses in the meantime? A third problem involved interservice relations. Such a change might improve the effectiveness of the guns, but the fighters would be restricted. How would the RAF take such a proposal? Finally, how long would it take to get a clear decision on this proposal? As each day passed, it became increasingly difficult to redeploy because the defenders fitted more and more of the mobile guns with the "Pile Mattresses," and added more and more guns to the gun belt.[46]

On 13 July, the overall commander, Hill, made the decision to create an all-gun belt on the coast. (See figure 2.) His bold and quick exercise of authority is remarkable, as is the speed with which the British implemented Hill's decision: the defenders had the heavy guns, radar, and supporting equipment and supplies in place by 17 July, the light guns two days later. The move was no small feat, since it involved the movement of 23,000 people and about 60,000 tons of ammunition, equipment, and supplies.[47] The British placed the guns on the coast between Dover and Beachy Head, the killing zone extending 10,000 yards over water and 5,000 yards inland. They restricted aircraft to altitudes above 8,000 feet in this area, but allowed them to roam free over the Channel and over England between the gun belt and the balloon line.[48]

The defenders made other changes as well. The number of heavy guns in the coastal belt increased from 376 on 1 July, to 416 on 23 July, 512 on 30 July, and finally to 592 on 7 August. In addition, they emplaced 892 40mm guns, 504 20mm guns, and 254 rocket tubes.

The British found a new American radar set, S.C.R. 584, especially useful. Early on, General Pile sent Major P. Blair to Washington with pieces of a crashed V-1 and an urgent request for more equipment as soon as possible. Blair spoke to US Army Chief of Staff, George C. Marshall, who immediately allocated 165 S.C.R. 584s for shipment on the next boat to Britain.

Other factors also aided the defenders. No. 10 (BTC) predictor for the British 3.7 inch guns and the No. 9 (BTC) predictor for the American 90 mm guns increased kills,[49] as did another technical improvement, the proximity fuze. This type of fuze detonated at a preset distance from the target and proved about five

Antiaircraft artillery proved very effective against the "flying bomb," downing almost half the V-1s destroyed in the London campaign and almost all those destroyed in the continental campaign. Here Winston Churchill (right) inspects a gun battery with his antiaircraft commander, General Frederick Pile (left). (Imperial War Museum)

times as effective as either a time or contact fuze.[50] In addition, the gunners got better with increasing practice.

These measures enabled the defenders to improve dramatically their effectiveness. Prior to the redeployment, allied defenses downed 42.3 percent of the V-1s observed; after the redeployment, that figure rose to 58.6 percent.[51] Another set of data, similar but not exactly coinciding, indicates that the defense downed 48.4 percent of those missiles spotted over land in the first period, 84.1 percent in the second period.[52] The high point for the defense came on the night of 27/28 August when the defenses destroyed 90 of 97 missiles reported; only 4 impacted on London.[53]

This dramatic increase in destructiveness resulted largely from the tremendous improvement in the effectiveness of antiaircraft artillery. While the guns got only 21.5 percent of the destroyed credits in the first period, they got 53.9 percent in the

second.[54] In the first week after the move, the guns downed only 17 percent of their targets, but this figure rose to 74 percent in the last period (29 August through 1 September).[55]

Some of this increased success of the guns came at the expense of the fighters. Although by mid-August the Allies deployed 15 day and 6 night fighter squadrons, the fighters' scores declined from 74.5 percent to 38 percent of the V-1s downed.[56] The highest claims went to No. 3 Squadron (Tempest V) with 257½, No. 91 Squadron (Spitfire XIV) with 185, and No. 96 Squadron (Mosquito XIII) with 174. Thirty-four pilots received credit for downing 10 or more missiles, with top honors going to Squadron Leader J. Berry (61⅓–V-1 credits).[57]

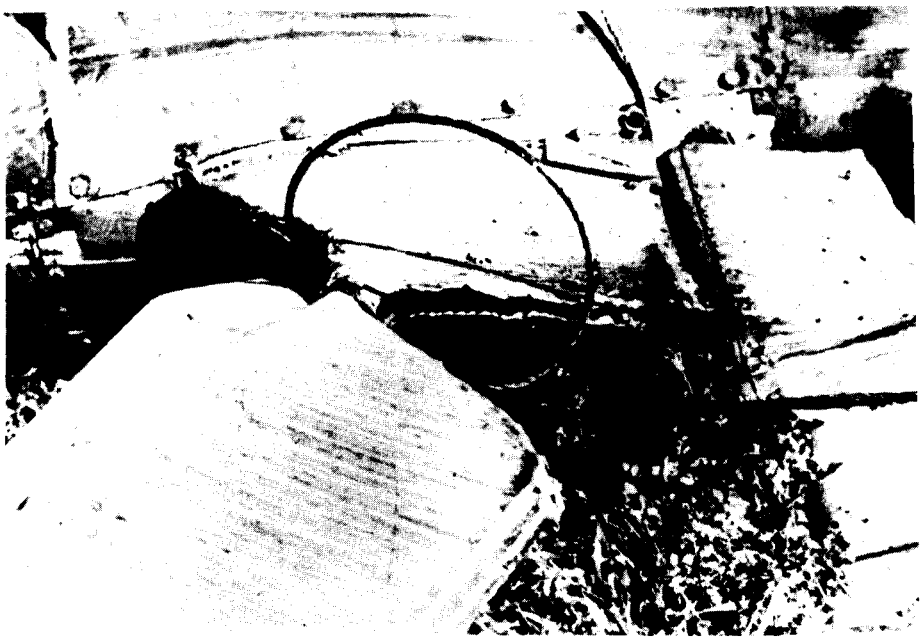
Squadron Leader Joseph Berry claimed the destruction of the most V-1s, 61⅓. On two occasions he destroyed seven in one day, on two occasions five in one day, and on four occasions four in a day. He was killed by flak on 1 October 1944. (Imperial War Museum)

In addition to the bombers, fighters, and guns, the British employed a fourth defensive agent, barrage balloons. The number of balloons increased from the initial 500 to 1,000 by 1 July, to 1,700 by 9 July, and to 2,015 by mid-August. Moreover, by 21 June the British had equipped all their balloons with a double link system that released the balloon cable at both ends when hit while simultaneously deploying parachutes at each end. But problems resulted because the British designed the device to ensnare an aircraft flying at 250 to 300 mph, not at the V-1's 300 to 400 mph speed. The defenders also used additional wires, nets between adjacent balloons, and kites, but none of these measures met with great success. Other factors curtailed the balloon barrage. Although the defenders desired to keep the barrage flying all the time, in all kinds of weather, this proved impossible. A shortage of hydrogen, coupled with balloon losses in bad weather, grounded the entire barrage one-fifth of the time.[58] The British lost about 630 balloons during the campaign.

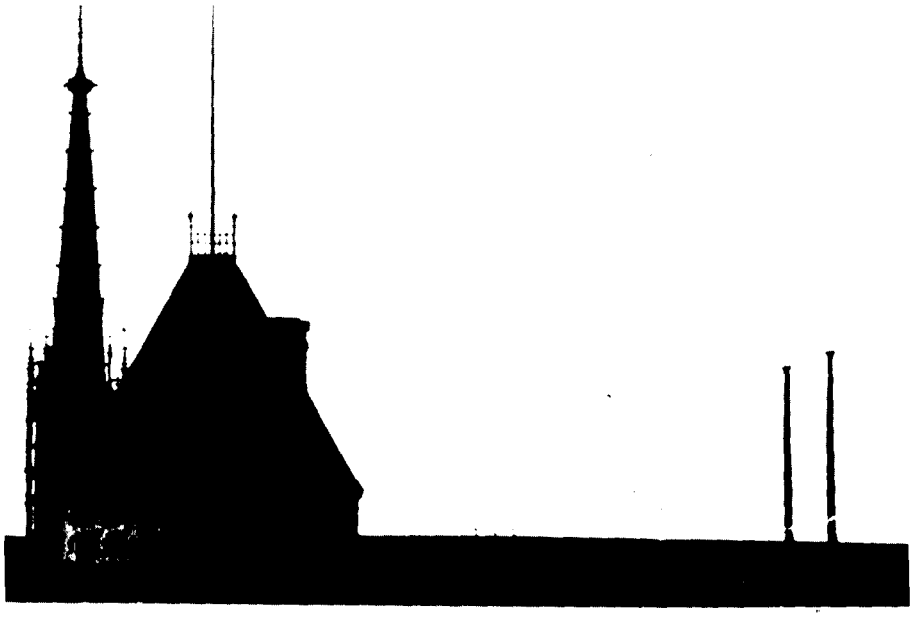
The fourth line of British defense was an armada of barrage balloons. (Imperial War Museum)

On 28 June, the British discovered missiles fitted with a metal attachment on the wings for cutting the balloon cables. Nevertheless, the evidence indicates that the effectiveness of the balloons increased; that is, the proportion of V-1s credited to the balloons rose from about 4.4 percent in the period prior to the redeployment to 7.8 percent afterwards.[59]

During the course of the summer campaign, the Germans introduced a new launching method. The first air launch known to the British occurred on 6 April



The balloon's cable could destroy a V-1. Balloons accounted for almost six percent of the V-1s destroyed by the defenders of London. (Imperial War Museum)



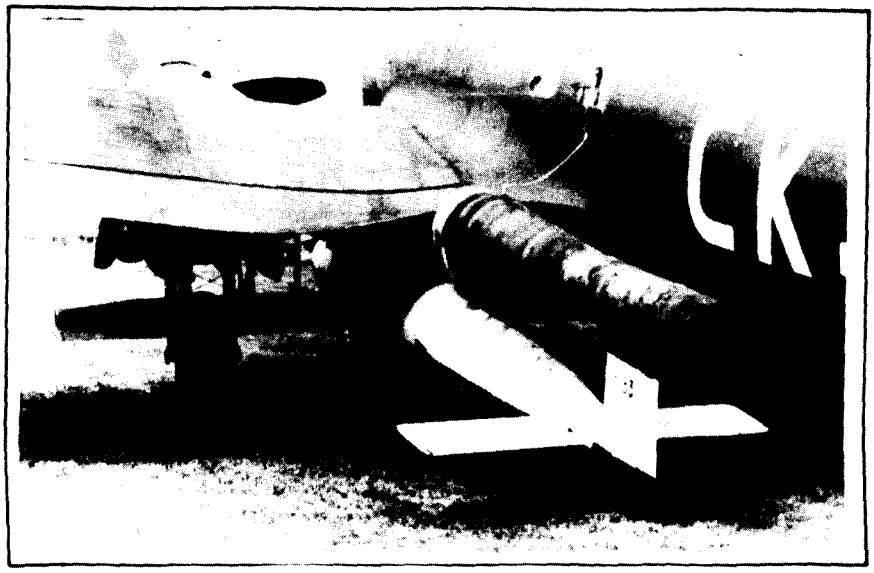
Nevertheless, many V-1s got through. This photo taken from a Fleet Street rooftop shows a V-1 about to impact near Drury Lane. (Imperial War Museum)

Almost 6,200 Britons died from the V-1 assault. This elderly man and his dog (right) survived the blast but the man's wife died. Note rescue workers in the background. (Imperial War Museum)

1944 at Peenemunde, with the first recognizable air launch against England on 9 July 1944. A bomber carrying one missile flew towards England at about 300 feet altitude and 160–170 mph until, about 60 miles off the coast, it climbed to several thousand feet and launched the V-1. The GAF air-launched about 90 V-1s prior to the defensive redeployment, and a further 310 between then and 5 September. With the withdrawal of German forces from French launching sites, these air-launched weapons became the chief air threat to Britain in the closing months of the war.[60]

Between 5 September and the last air launching on 14 January 1945, the Germans hurled about 1,200 V-1s against Britain. Of these, only 66 reached London. During this entire operation, the Germans lost a total of 77 missile-carrying aircraft,[61] including 16 to Allied fighters. Significantly, most of the weapons reaching London achieved very poor accuracy. Compared with the ground-launched missiles, which fell on the average within 7.9 miles of their aiming point in July and 11.4 miles in August, in September half of the air-launched weapons impacted within 24 miles of the aiming point, a full 29 miles north northeast of the ground-launched V-1's impact point.[62]

The Germans did not take advantage of the air-launched missile's ability to outflank the defenses except for one attack on Manchester on 24 December and, although the Germans that night launched 50 V-1s, only one of the weapons



While most of the V-1s were ground launched, about 1,600 were air-launched against Britain. (USAF)

impacted within the city. Clearly, the Germans by late 1944 lacked all forms of airpower and could not afford to risk their relatively few remaining aircraft in this kind of operation. Weather and British defenses restricted the obsolete He 111s. Finally, the poor accuracy of the air-launched missile did not recommend its use to the Germans.[63]

The final act in the V-weapon campaign against Britain came in March 1945 when the Germans introduced a long-range version of the V-1. Fitted with a wooden wing (which weighed 395 pounds compared with 445 to 480 pounds of the metal wing) and a reduced warhead, it could fly 220 miles as compared with the standard range of about 150 to 160 miles.[64] The Germans launched 275 modified V-1s from Dutch ramps between 3 March and 29 March against Britain, but only 13 reached London. Because photoreconnaissance and intelligence reports tipped the Allies off to this new weapon, they ordered the northern defenses reinforced on 27 February. This reinforcement consisted of six Mustang and one Meteor squadron for day defense, and two Mosquito and one Tempest squadron for night defense. But the guns worked so well that the British relieved the jets and five of the Mustang squadrons. The defenders downed 72.8 percent of the 125 missiles observed. Nevertheless, one flying bomb hit Smithfield Market on 8 March, causing 233 casualties.[65]

In all, the Germans fired 10,492 V-1s against Britain, all but 1,600 launched from ramps. About 2,000 of them crashed shortly after takeoff. The defenders observed 7,488 missiles, and downed 3,957 (52.8 percent).[66] The fighters received credit for 1,846 ⅚ kills, the guns for 1,878⅓, and the balloons for 231⅚.[67] The defenses downed 69 percent of the V-1s launched during daylight, compared with 65 percent at night. The defenses improved their overall kill effectiveness, downing 42.3 percent of the V-1s observed before the redeployment (12 June to 15 July), 58.6 percent after the redeployment (16 July to 5 September), 63.2 percent of the air-launched missiles after this period (16 September to 14 January 1945), and 33.1 percent of the ground-launched long-range V-1s from Holland, for an overall kill percentage of 52.8. Conversely, the percentage of V-1s that reached London, relative to those launched, declined in these same periods (29.1, 23, 5.5, 4.7) for an overall figure of 23.1 percent. Nevertheless, about 2,419 V-1s reached the London Civil Defense Region, killing 6,184 civilians and seriously injuring 17,981. Additional casualties included approximately another 5 percent consisting of service personnel. In all, about 92 percent of the casualties were in the London area.[68]

To put the lethality of the V-1s into perspective requires comparison with other German weapons that killed and maimed British civilians during World War II. German bombing killed 51,509, V-2s killed 2,754 and long-range guns killed 148.[69]

There is one more aspect of the V-1 operational story, an aspect frequently overlooked by authors. The Germans also launched anywhere from 7,400 to 9,000 V-1s against targets on the continent, with about 4,900 aimed at the key port of Antwerp. For their part, the Allies deployed 18,000 troops to man 208 90mm, 128

3.7-inch, and 188 40mm guns. In addition, the defenders initially used 280 balloons which, in time, grew to 1,400. The Allies did not employ any fighters in the defense of Antwerp.[70] This was a political decision, as a SHAEF document stated: "The problem of [continental] defense will not be approached from the same political viewpoint as was the case in the U.K."[71]

Despite the non-use of fighter-interceptors, the Allies successfully defended Antwerp. The German missiles first came from the southeast, then in mid-December shifted direction to the northeast, and finally by the end of January to the north. The defenders designated a 7,000-yard radius circle around the dock area as the vital area. About 2,759 of the V-1s detected threatened this crucial port facility; the Allies destroyed 1,766 (64 percent), so that only 211 missiles fell within the port complex.[72]

The Germans also attacked Liege with about 3,000 V-1s. The Allies defended this city from 23 November to 11 December when the German offensive in the Battle of the Bulge pulled the defenders out.

V-1s killed a total of 947 military and 3,736 civilians on the continent, and wounded an additional 1,909 military and 8,166 civilians. Antwerp suffered 10,145 (1,812 military, 8,333 civilian) of the total 14,758 V-1 casualties on the continent.[73]

The single best study estimates that the Germans built 30,000 V-1s, half the 60,000 planned.[74] They made a considerable investment in resources for both the V-1 and V-2, although the exact cost is difficult to estimate.[75] In any event, the Germans could ill-afford to put their precious resources into the wonder weapons. For although a technological accomplishment, the V-weapons certainly helped little in advancing the strategic interests of Germany. The Germans needed more effective weapons, superior in quality and in considerable quantity, to meet the overwhelming numbers of Allied weapons. Consequently, they could have gained much more militarily by putting these resources into jet aircraft, proximity fuzes, or flak rockets. As one author has so well put it: "Germany preferred the spectacular to the strategic; she preferred rockets to radar, and it was this that cost her the war."[76] To be precise, the Germans had more pressing needs that could not be met by either of the V-weapons.

But the introduction of the V-1 did impose some considerable cost on the Allies. From a strictly dollar point of view, the V-1 cost the Germans less to build and to operate than it cost the Allies in damage and defense. A wartime British study went into great detail analyzing the costs of the Allied campaign to counter the V-1. Using the German costs as unity (based upon an estimate of 8,000 launched), the study concluded it cost the defenders 1.46 for damage and loss of production, 1.88 for the bombing, .30 for fighter interception, and .16 for static defenses, for a total ratio of 3.80:1. Adjusting these figures for the continental defensive effort and the total German costs would lower this ratio only to about 3:1. Economically then, the V-1 more than paid for itself.[77] But it must be emphasized that the Allies could afford the cost, the Germans could not. This proved especially true in the last two years of the war.

The V-1 certainly had a number of advantages. It was a cheap weapon that did not use critical materials; therefore, the missile could be employed in mass. The V-1 could be easily launched regardless of weather conditions or time of day. It proved difficult to spot and to attack because of its relatively high speed and low altitude approach, and it was durable as a target since it had few vulnerable parts and no aircrew that could be killed or injured. Because it could not be turned back, it had to be either destroyed or allowed to crash.

Conversely, the weapon had a number of limitations. While the remarkable and cheap pulsejet engine did the job, the ground-launched version required a booster and a long ramp which, in turn, meant a fixed and vulnerable launch site. It is both ironic and illogical that the much larger and more complex V-2 had mobility, while the smaller and simpler V-1 did not. Fixed V-1 launch sites, along with fixed targets, meant that the missile's flight path was predictable. This, in turn, meant that defenders could mass their forces in a relatively concentrated and narrow zone. The missile flew a constant course, altitude, and speed which meant that, once located, the missile was easy to engage. The V-1's poor accuracy limited it to use against the largest of targets (cities). Therefore, the Germans employed the V-1 as a psychological weapon, despite the inability of bombing to break civilian morale in previous bombing campaigns. Moreover, poor German intelligence shielded the large city of London from an accurate bombardment. The GAF's inability to use aerial reconnaissance, in turn, permitted British deceptions to work. Finally, the V-1's small warhead restricted the impact of those missiles that penetrated the defense and hit their targets.

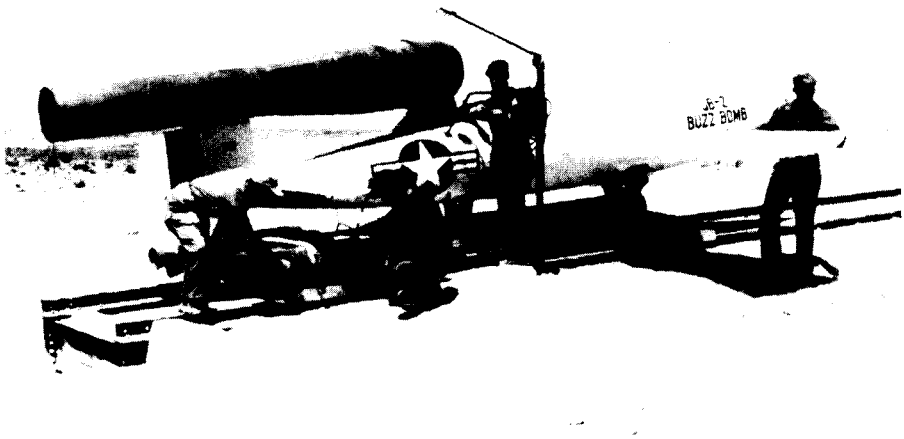
Because of the success of Allied defenses against the "flying bomb," postwar opinion downgraded the device. Observers doubted its future utility: "The V-1 is not worthy of further development, as it is too vulnerable to countermeasures. . . ."[78]

In short, the V-1 proved to be a remarkable technical achievement that was somewhat cost effective. But, on balance, it proved doubtful as a weapon of war. Although advanced technically, tactically, and economically, it was just too far ahead of its time. Fortunately for the Allies, the Germans did not possess the technologies during World War II to make the V-1 the potent winged weapon it foreshadowed.

For the German V weapons did serve as a primary catalyst in rejuvenating a dormant US missile program. The new US effort was to take two different routes—an American designed missile, the JB-1, and a copy of the V-1, the JB-2.

The American V-1 (JB-2)

On 12 July 1944, 2,500 pounds of salvaged V-1 parts left Great Britain and arrived the next night at Wright-Patterson Field.[79] The AAF ordered the staff there



The AAF quickly copied the V-1 which it designated the JB-2. (National Air and Space Museum)

to build 13 copies of the "flying bomb"; and within three weeks, the AAF had completed its first JB-2.* Concurrently, a memo recommending US production of the weapon went to General Arnold.[80]

But the War Department realized some of the missile's inherent drawbacks. A December War Department message to the European forces noted the JB-2's inaccuracy and plainly called it a "terror weapon." In addition, the message mentioned the opportunity costs in terms of armaments not produced and delivered. Nevertheless, the War Department believed that if the weapon's accuracy could be improved, the JB-2 might prove valuable. The message ended with the observation that the main problem area was logistical, not tactical.[81]

Despite these reservations, before the end of July, General B. E. Meyers ordered 1,000 JB-2s. In August, the AAF contracted with Republic (airframe, later subcontracted to Willys-Overland), Ford (engine), Jack and Heintz (controls), and Alloy Products (pressure vessels). Contracts for launch rockets went to Monsanto, for launch sleds to Northrop.[82]

But the 1,000 JB-2 order marked only the beginning. Before September ended, the AAF wanted production raised to 1,000 a month, a rate which the AAF expected to reach by April 1945, with an increase to 5,000 a month by September.[83] AAF enthusiasm for the weapon grew rapidly, despite the fact that it failed in initial tests. In December 1944, the airmen ordered a second 1,000 and expected not only to reach the 1,000 per month production rate by April, but 5,000 a month by June; and they studied the feasibility of a rate of 1,000 a day![84] Some civilian leaders

*See Appendix A for missile specifications.

supported the AAF. Assistant Secretary of War (Air), Robert Lovett, for example, wanted a production rate of 3,000 a month.[85] On 14 January 1945, Arnold ordered a further 75,000 JB-2s; he wanted the ability to launch 100 a day by September and 500 a day by January 1946. The next day the project received an AA-1 priority, the same as that enjoyed by the B-29.[86]

Airmen in the field gave the weapon a guarded reaction. Leigh Mallory, commander of the Allied Expeditionary Air Force, endorsed use of the weapon as one way to help overcome poor weather and stiffening defenses.[87] Spaatz, who stated in July that there was no requirement for a pilotless aircraft in the ETO (European Theater of Operations), also noted the device's usefulness during bad weather when he wanted to use it to harass and demoralize the Germans. He believed it could be used perhaps ten days a month with the firing of about 300 weapons per day of operation. But these same AAF airmen put very specific conditions on their support of the project: they wanted the missile program if, and this was the big if, there would be no significant curtailment of bombs, artillery shells, or personnel. Most importantly, these officers insisted that the JB-2 production effort not disrupt the supply of bombs, as it just barely kept up with operational requirements.[88] Spaatz wrote Arnold of the need for a standoff weapon, but believed that current pilotless aircraft and bombs cost too much. The senior American airman in Europe preferred a more traditional course:

> We have proven the precision bombing principle in this war. . . . Therefore, we must develop bombsights and bombardiers, which, under all weather conditions, cannot only literally drop bombs in "a pickle barrel" but in the correct barrel.[89]

Later, Spaatz's Headquarters argued that it did not have time for testing these devices in the ETO. Other reasons advanced against premature use of the "flying bombs" by airmen in actual combat included inaccuracy and losing the element of surprise if used in a piecemeal fashion against enemy targets.[90]

The program met criticism stateside as well. In September, some expressed concern that the missile program would adversly affect the production of artillery shells and heavy artillery pieces. A report in late 1944 concluded that the program would cut field artillery production by 25 percent and bomb production by 17 percent.[91] In January 1945, General Myers learned that the proposed missile program would not only cost $1½ billion but would require one-fourth of Allies' ETO shipping assets. To circumvent the shipping problem, the planners considered building the device in Europe; but they quickly dropped this idea because of the limited capacity of continental industry and the requirement for raw materials from the United States.[92] These factors motivated the War Department's late January decision not to mass produce the JB-2. Consequently, on the last day of January, General Wolfe halted production until a further investigation could be concluded.[93] The Air Materiel Command study that emerged in February affirmed the earlier dire projections. Nevertheless, it did recommend a production rate of 1,000 per month beginning in November 1945 with a total production run of 10,000.[94] In fact, the

AAF ordered 10,000 more JB-2s in February, in addition to the 2,000 ordered in 1944. The new plan called for a launch rate of 1,000 per month by January 1946. The end of the war resolved the numbers game. When production terminated in September 1945, US industry had delivered about 1,385 JB-2s to the War Department.[95]

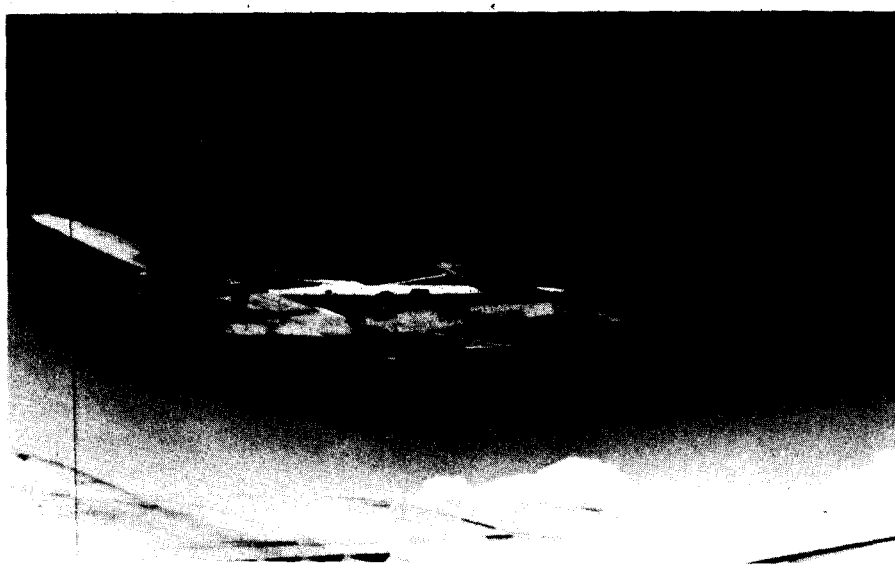
The US version of the V-1 differed little from the German original, except for two features: launching and guidance.[96] The danger of the German catapult propellant (hydrogen peroxide and potassium permanganate) and production problems encouraged US airmen to use something else to get the missile airborne and attain the minimum speed required for pulsejet operation. The AAF considered a number of alternative launch technologies: a flywheel, a cart powered by an aircraft engine, and powder. They adopted the latter, but a shortage of powder in December led to consideration, and testing, of air launch.[97] The AAF concentrated its efforts on ground launch, first from a 400-foot inclined (6 degrees) ramp, then a level ramp, and finally from a 50-foot ramp mounted atop a trailer.[98]

Early American efforts with the JB-2 were unsuccessful, as this one demonstrated on 21 November 1944. (USAF)

The first attempted flight on 12 October failed, as did many others that followed. By 3 December, the AAF record stood at 2 successes in 10 attempts. The AAF persisted—and did better: by June 1945, it had achieved 128 successes in 164 attempts.[99]

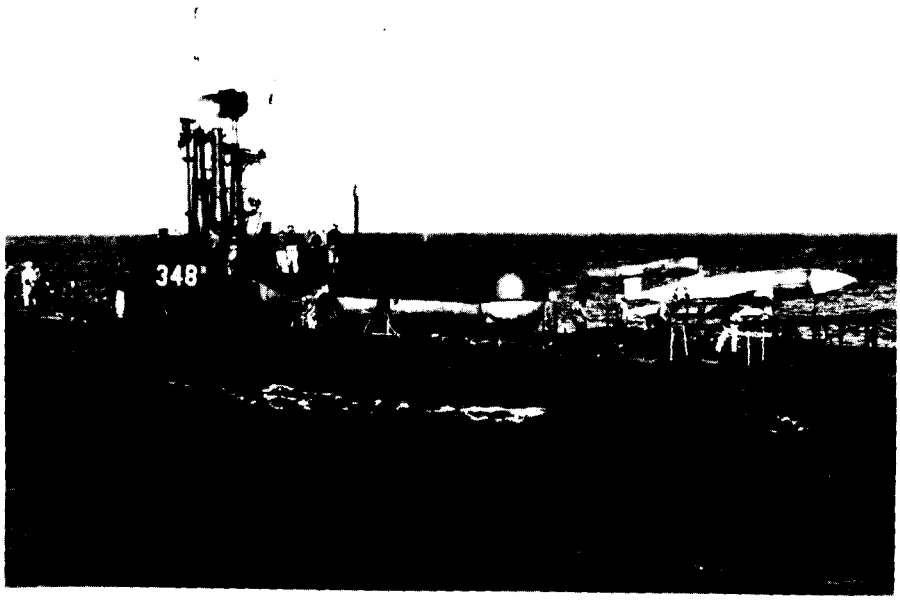
Because the AAF's major concern centered on accuracy, it worked on an improved guidance system. Tests with preset controls, the German method, achieved results similar to the Germans; the Americans experienced an average error of over eight miles at a range of 127 miles. Therefore, the airmen installed radio-control guidance in the missile. The AAF equipped the JB-2 with a radar beacon, which assisted tracking by a ground radar unit (SCR 584) up to the radar's

But AAF persistence led to success. On 5 June 1945 a JB-2 at Eglin releases its booster as a P-38 chase plane observes. (USAF)



The AAF also air-launched the JB-2 from B-17s. This Flying Fortress, complete with gun turrets, is flying over Holloman Field, New Mexico. (USAF)

maximum range of about 100 miles, and remote control equipment. One observer forecast in February 1945 that this system could achieve accuracies of 500 yards at 50 miles and 1,000 yards at 100 miles, which would put the "JB-2 into the class of very flexible, extremely long range artillery."[100] But the tests disappointed the weapon's enthusiasts with an average error of about 6 miles at 80 miles on 14 tests and almost twice that at 127 miles on 20 tests. Clearly these results fell below expectations and equaled the accuracy (or inaccuracy) of the preset system. But, in the end, accuracy did improve; postwar tests indicated an average accuracy of 5 miles at 150 miles for preset and one-fourth mile at 100 miles for the radar-controlled system.[101]



The Navy first launched its V-1, designated Loon, in January 1946, and first from the deck of the surfaced submarine *Cusk* on 18 February 1947. This Loon is aboard USS *Cusk* on 12 November 1948. (National Archives)

The US Navy also involved itself with the V-1. In September 1944, the Bureau of Aeronautics suggested firing the JB-2 from an escort carrier. The next month, the Chief of Naval Operations endorsed the idea and requested 51 of the flying bombs from the AAF for carrier trials. By April 1945, the Navy had named their version of the V-1 "Loon," and extended their study of launch platforms to include landing craft (LSTs), PB4Y-1s (the Navy's B-24), and off the beach. But a May 1945 study indicated that a reasonable date to expect operations from either ship or shore was not until August or September 1946.[102]

The Navy launched their first Loon on 7 January 1946; it glided to its destruction as the engine died. In March 1946, the Secretary of the Navy approved the

conversion of two submarines for Loon operations. The Navy also considered converting other vessels in June and July of 1946, specifically one *Essex* class aircraft carrier and one battle cruiser; but by the next year, it had dropped the idea. In January 1947, the submarine *Cusk* entered the Mare Island naval facility for conversion. On 18 February, it fired its first Loon, which flew a little over 6,000 yards before crashing. After a number of other failures, the Navy achieved success on its fifth try on 7 March. The submariners fired more Loons from the surfaced submarines and, on 26 January 1949, launched one from a surface ship, the converted seaplane tender *Norton Sound*. In March 1950, the Navy terminated the Loon program to make way for the more advanced and promising Regulus.[103]

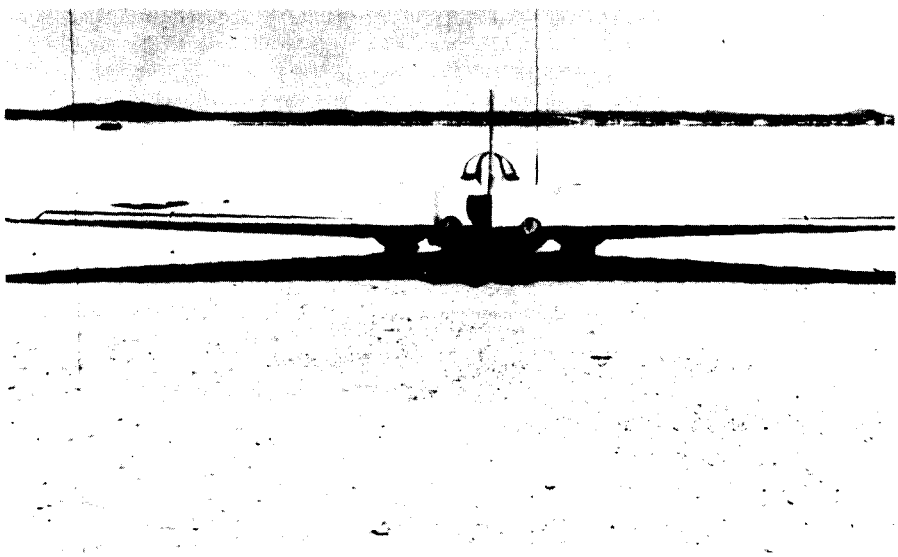
The Navy also had difficulties with the missile. This Loon exploded in July 1948 but did not seriously damage the submarine. (National Archives)

The Northrop JB-1/JB-10

The same month the JB-2 program began, so did another pilotless bomber program: on 1 July 1944, the AAF initiated a US-designed missile designated the JB-1. To expedite the design process, the Northrop Corporation, the primary contractor for the JB-1, used photos of the tooling templates from its MX-324, a

rocket-powered mockup of its equally obscure XP-79 rocket-powered interceptor.[104]

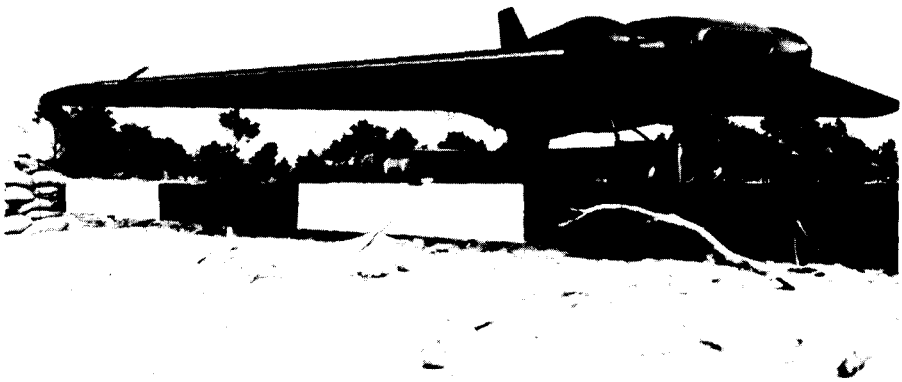
Northrop powered the JB-1A* with two General Electric B1 turbojets and designed it to carry two 2,000-pound bombs, 200 miles at 427 mph. On its first powered launch on 7 December 1944, the JB-1A climbed rapidly, stalled, and then crashed 400 yards from the launch point. Problems with the device included leaking tanks, inaccessible engines (each wing panel was secured by 270 screws), low thrust (each turbojet produced only half of the expected 400 pounds), as well as obtaining sufficient test engines.



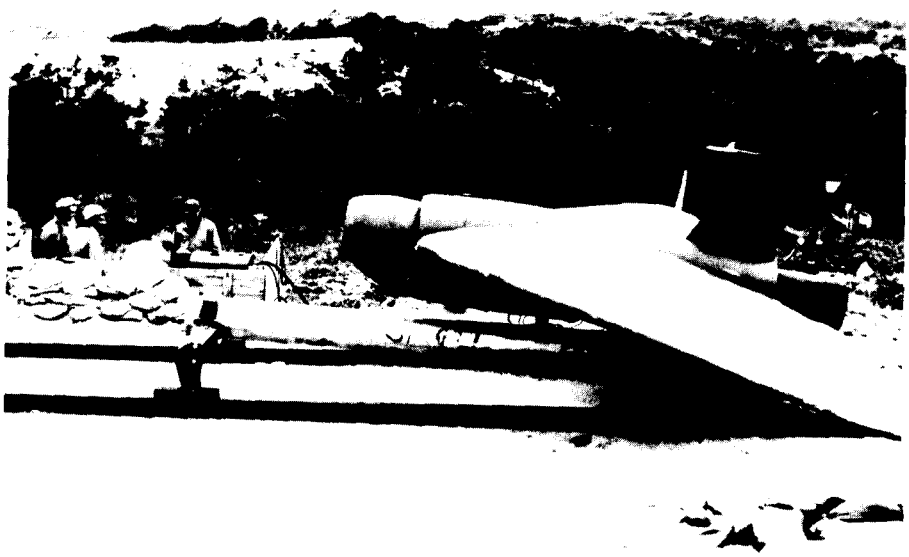
Prior to building its "flying bomb," Northrop built a manned tailless glider, which it flew in 1944 over Muroc Dry Lake. Due to longitudinal instability, these tests almost ended in disaster. (USAF)

Therefore, Northrop fitted a pulsejet pirated from the JB-2 program to the Northrop airframe. On 19 February 1945, the AAF redesignated the re-engined and slightly larger device, JB-10.*[105] But the JB-10's tests at Eglin Field disappointed the AAF, which considered only 2 of the 10 flights even a partial success. On its longest flight (13 April 1945), the missile covered only 26 miles due to longitudinal instability. This particular problem highlighted the need for extensive development. Most significantly, each JB-10 cost approximately $55,425 compared with $8,620 for each JB-2. Northrop built a missile just too elegant and expensive for its mission; in essence, Northrop built a missile to aircraft specifications. The AAF realized this pronounced tendency to overbuild the JB-10. This contributed to the AAF's November 1944 decision to lower the missile's priority. Finally, in March 1946, the AAF cancelled the project.[106]

*See Appendix A for missile specifications.



Northrop developed the glider into a "flying bomb," the JB-1A, which crashed on its first launching on 7 December 1944. It carried two 2,000-pound bombs on either side of the fuselage which housed twin General Electric jet engines. (USAF)



Problems with the JB-1A's power plant forced the AAF to install a Ford copy of the V-1's pulse jet. The missile, with the new engine and carrying two 1,825-pound warheads within the wing, was designated JB-10. Here the Northrop missile is readied for test at Eglin on 6 April 1945. (USAF)

NOTES

CHAPTER III

Data within the brackets indicate where the material is located: Public Record Office, London, United Kingdom (PRO); Royal Artillery Institution, Woolwich, United Kingdom (W); National Air and Space Museum, Washington, D.C. (NASM); Albert F. Simpson Historical Research Center, Montgomery, Ala. (AFSHRC); Air University Library, Montgomery, Ala. (AUL); Naval Historical Center, Washington, D.C. (NHC). The numbers following the symbols for the Air University Library, Simpson Center, and Public Record Office are their call numbers.

1. Wesley Craven and James Cate (eds.), *The Army Air Forces in World War II*, Vol. II: *Europe: Argument to VE Day (January 1944 to May 1945)* (Chicago, Ill.: University of Chicago, 1951), 85. Hereafter cited as Craven and Cate. "German Guided Missile Development," 4 October 1945, 3 [AFSHRC-203.1 Vol. 12].

2. Basil Collier, *The Battle of the V-Weapons, 1944–1945* (London: Hodder and Stoughton, 1964), 18. Hereafter cited as Collier, *V-Weapons*.

3. German Guided Missile Development, 2–3; Basil Collier, *The Defence of the United Kingdom* (London: Her Majesty's Stationery Office, 1957), 354–55. Hereafter cited as Collier, *UK*. Rowland F. Pocock, *German Guided Missiles of the Second World War* (New York, N.Y.: Arco, 1967), 21; Collier, *V-Weapons*, 15–17. The Germans also built a piloted, suicide version of the V-1 which need only be mentioned here as it did not see action, although American forces captured 175 copies. See Peter G. Cooksley, *Flying Bomb* (New York, N.Y.: Scribner, 1979), 133, 135; Pocock, 27; Antony L. Kay, *Buzz Bombs* (Boylston, Mass.: Monogram Aurron, 1977), 20, 24, 27; Hanna Reitsch, *Flying is My Life* (New York, N.Y.: Putnam, 1954), 208–219; William Green, *The Warplanes of the Third Reich* (Garden City, N.Y.: Doubleday, 1970), 170, 171.

4. Collier, *V-Weapons*, 18; Kay, 5.

5. Ironically, that same day the V-1 failed in the flying demonstration. Milch took the whole matter rather lightheartedly, slapping Walter Dornberger, the Army officer in charge of the V-2, on the back, and with a wry grin remarking: "Congratulations! Two-nothing in your favor!" Walter Dornberger, *V-2* (New York, N.Y.: Hurst and Blackett, 1955), 95.

6. The following mention a span of about 17½ feet: Alfred Price, *Luftwaffe Handbook, 1939–1945* (New York, N.Y.: Scribner and Sons, 1977), 85; Karlhenz Kens and Heinz J. Nowarra, *Die deutschen Flugzeuge* (Munchen: Lehmanns, 1968), 575; Leonard Bridgman (ed.), *Jane's All the World's Aircraft: 1945/46* (London: David and Charles, 1946), 148c; Michael J. H. Taylor and John W. R. Taylor (eds.), *Encyclopedia of Aircraft* (New York, N.Y.: Putnam's Sons, 1978), 237; British Air Ministry, "Vulnerability and Armament Diagram," [AFSHRC-Film #119, Frame 9058]; "British Air Ministry Technical Note 1464," June, 1944 [AFSHRC-142.0423-8]; US Forces European Theater, Report of the General Board, "Tactical Employment of Antiaircraft Units, including Defense Against Pilotless Aircraft," #38, 39 [AFSHRC-502.101-38]. Hereafter cited as USFET, #38. Other sources note a span of 16 feet: British Air Ministry, report 2242 "German Expendable Pilotless Aircraft," 13 June 1944 [AFSHRC-142.0423-9]; British Air Ministry, diagram "filed 18 July 1944" [AFSHRC-142.0423-8]; Office of Statistical Services, 19 June 1944 [AFSHRC-142.0423-9]. Finally some sources list both figures for the span: Collier, *UK*, 97; British Air Ministry, "German Expendable Pilotless Aircraft,"

report 2245, 13 June 1945 [AFSHRC-Film #228]; Elke C. Weal, *(et al), Combat Aircraft of World War Two* (New York, N.Y.: Macmillan, 1977), 106. Apparently most, if not all, V-1s had a span of 16½ feet. The confusion stems from the examination of a V-1 which landed in Sweden in early 1944 with a tapered wing which spanned 16 feet. War Cabinet Crossbow Committee, 18th Report, Assistant Chief of Air Staff, Intelligence, 22 July 1944 [AFSHRC-Film #154, Frame 9456]; Richard A. Young, *The Flying Bomb* (London: I. Allan, 1978), 135, 136.

7. Price claims in *Luftwaffe Handbook*, 189, that the V-1 flew at a constant speed even though the weight decreased, because the performance of the engine also decreased as the inlet shutter vanes gradually burned away. This information apparently is from Military Intelligence Division, "Handbook on Guided Missiles: Germany and Japan," MID 461, February 1946.

8. Air Intelligence Report No. 2258, 5 August 1944; Air Intelligence Report 2261, 17 August 1944 [Both PRO-AIR 40/2166]; *Jane's All the World's Aircraft: 1945/46*, 147c, 148c; Collier, *V-Weapons*, 66, 87; Weal, 106; Pocock, 23, 24, 103; Young, 132, 140, 141. A survey of 205 V-1 terminal dives by one British observation unit showed that 44 percent cut off their engines at the beginning of their dive and glided more than 10 seconds, 52 percent cut off their engines shortly before impact, and 4 to 5 percent impacted with the engines running. D.D. Science, "Behavior of Flying Bombs at End of Flight," 19 August 1944 [PRO-AIR 20/4262].

9. British Air Ministry, Air Defence of Great Britain, draft chapter, Vol. VII: The Flying Bomb and Rocket Campaign: 1944 to 1945, 15, 17, 23-25 [AFSHRC-512.431A]. Hereafter cited as Air Defence GB. J. C. Masterman, *The Double Cross System* (New Haven, Ct.: Yale University, 1972), 251; Ewen Montagu, *Beyond Top Secret* (London: Coward, McCann, and Geoghegan, 1977), 158; British Information Services, "Flying Bombs," December, 1944, 4 [AFSHRC-512.6522-10]; Hillery St. G. Saunders, *Royal Air Force, 1939–1945*, Vol. III: *The Fight is Won* (London: Her Majesty's Stationery Office, 1954), 142; Jozef Garlinski, *Hitler's Last Weapons* (London: Times Books, 1978), 53–54; Collier, *V-Weapons*, 24; Air Scientific Intelligence Report No. 5, "German Pilotless Aircraft," 23 December 1943 [PRO-AIR 20/1667].

10. Philip Joubert de la Ferte, *Rocket* (London: Hutchinson, 1957), 48; Saunders, 145; Collier, *V-Weapons*, 32; Air Defence GB, 15; Young, 17, 19; Kay, 6; ASI Report No. 5.

11. The British correctly assumed that the Germans would employ a crack radar unit during the testing of the weapon. Their patient monitoring of such units paid off in October 1943 when intercepted messages confirmed the basic performance characteristics of the V-1. Air Defence GB, 17, 23–25; David Irving, *The Mare's Nest* (London: Kimber, 1964), 126, 185; Collier, *UK*, 358; Joubert, 48; Saunders, 146; Collier, *V-Weapons*, 40; ASI Report No. 5.

12. Air Defence GB, 11, 12; Saunders, 144, 145; Joubert, 174, 176; Irving, 97-119; Collier, *V-Weapons*, 33, 34.

13. M. C. Helfers, "The Employment of V-Weapons by the Germans During World War II," Washington, 1954, 21 [AFSHRC-Film #31,731; Frame 323]; Joubert, 85; "The V-Weapons," *After the Battle* (No. 6, 1979), 3.

14. Craven and Cate, III, 91-93; Air Defence GB, 22; Joubert, 174–180.

15. Craven and Cate, III, 95, 105, 106; Saunders, 150; Collier, *V-Weapons*, 46; Collier, *UK*, 359, 360; Assistant Chief, Air Staff, Intelligence, "Flying Bomb and V-2 Rocket," 8 January 1945, 6 [AFSHRC-142.0423-4].

16. Saunders, 152; Helfers, 17, 20; Craven and Cate, III, 102; British Information Service, "Flying Bomb," 6; SHAEF, "Report of 'V' Section on Continental Crossbow (September 1944 to March 1945)," 23 [AFSHRC-505.42-13]; Collier, *UK*, 360. The AAF built a replica of the modified sites at Eglin AAF Base, experimented with tactics, and recommended low level fighter-bomber attacks against the sites. The RAF disagreed, claiming that the AAF constructed the Eglin replica to the wrong specifications. Craven and Cate, III, 98–100, 104; Air Defense GB, 59 fn. These sites consisted of 5 or 6 buildings and took 6 to 8 weeks to construct, compared with the ski sites' 12 buildings which required 2 to 3 months to build. By May 1944, the Germans had cut the time to 8 to 10 days, and finally to 18 hours. Once the firing began, a number of clues aided Allied intelligence officers to identify the sites: skid marks of the booster pistons which began 200 to 300 yards in front of the launcher, a pattern of scorch marks on the ground and foliage, and in the fall and winter, the fact that the Germans located the sites in deciduous

woods. The Germans learned their lesson and built their last sites (in Holland and western Germany) very simply in coniferous woods with a second wood a few hundred yards away. SHAEF, "Interim Report of 'V' Section on Crossbow, 24 October 1944–5 May 1945," 9, 10 [AFSHRC-Film #118]; SHAEF, Report of 'V' Section, September 1944–March 1945, 25; Young, 125.

17. Joubert, 96; Collier, *V-Weapons*, 148; Craven and Cate, III, 102, 531, 532; Irving, 224.

18. Collier, *V-Weapons*, 56–59; AC/AS, Intelligence, Flying Bomb, 7; Air Defence, GB, 42, 43; Roderic Hill, "Air Operations by Air Defence of Great Britain and Fighter Command in Connection with the German Flying Bomb and Rocket Offensives, 1944–45," Supplement to the *London Gazette* (19 October 1948), 5587.

19. This was part of a total reduction from 528 heavy pieces to 288 and from 804 light pieces to 282. In addition, the British planned to use 480 balloons. Collier, *V-Weapons*, 58; Collier, *UK*, 361, 363, 364; Hill, 5588, 5589.

20. Collier, *V-Weapons*, 59; Collier, *UK*, 361, 365; Hill, 5588, 5589.

21. Joubert, 84, 110; Irving, 193, 199; Interrogation Karl Thalen, Kassel, 10 and 21 July 1945, "V-1 Development and Test Programs," 10 August 1945, 2 [AFSHRC-519.619-20]; Kay, 6. Another figure is a planned rate of 6,000 to 9,000 per month. United States Strategic Bombing Survey, *V-Weapons (Crossbow) Campaign*, January 1947, 2nd edition, 214.

22. Helfers, 7-9; Headquarters, United States Strategic Air Forces, Technical Intelligence Report #31, "Report on V-1 Weapon by Colonel Eberhardt," 29 June 1945 [AUL-M28357, Vol. 11]; Price, 87; Collier, *V-Weapons*, 20.

23. Air Defence GB, 83; Helfers, 28-30; Collier, *V-Weapons*, 69, 71–75; Hill, 5591; Irving, 233; Pocock, 48.

24. Hill, 5591, 5592; Pocock, 48; Collier, *V-Weapons*, 79.

25. Irving, 236, 240; Garlinski, 168.

26. Pocock, 49.

27. Actually, other single V-1 explosions killed more: 30 June, 198; 3 July, 124; and 23 August, 211. Air Defence GB, 210; Collier, *V-Weapons*, 12; British Information System, "Flying Bomb," 15.

28. Air Defence GB, 92 fn; Collier, *V-Weapons*, 83; Collier, *UK*, 377, 378; Irving, 242.

29. Irving, 250, 257; Masterman, 253; Montague, 159, 160.

30. USSTAF, Armament and Ordnance Memo #5-7B, "An Analysis of the Accuracy of the German Flying Bomb (V-1) 12 June to 5 October 1944," 1, 9, 25, 39 [AFSHRC-519.6522-1]; Air Defence GB, 113, 127 fn.

31. Air Defence, GB, 127 fn; Rear Admiral G. P. Thomson, 25 July 1944 [PRO-AIR 20/6016]. Half the V-1s fell within 7½ miles of the mean impact point. J. B. Gordon to CG, AAF, 14 July 1944, 3 [AFSHRC-519.161-7]; British Air Ministry, "Points of Impact of Flying Bombs, 22 June–31 August" [PRO-AIR 20/4262]; AC/AS, Intelligence "Flying Bomb," 3.

32. Air Defence, GB, 55, 59, 116 fn, 117–122, 140, 147, 149; USSBS, *V-Weapons*, 19, 20; AC/AS Intelligence, "Flying Bomb," 8; Collier, *UK*, 522. The Anglo-American airmen dropped between 50,000 and 57,000 tons of bombs on the V-1 launching sites, 38,000 tons on supply sites, 8,000 tons on factories, another 8,000 tons on air-launched V-1 carrier bases, and 4,000 tons on Peenemunde. In all the allies dropped a total of 115,400 tons of bombs on 42,612 sorties, or about 2.4 percent of the bombs dropped in Europe by the AAF and RAF during World War II. One Allied airman asserts that the bombing of the V-1s distracted strategic bombing for three and one-half months. Arthur Tedder, *With Prejudice* (Boston, Mass.: Little, Brown, 1966), 584. United States Strategic Bombing Survey, *Over-all Report, (European War)* 1, 8, 89; United States Strategic Bombing Survey, Statistical Appendix to Over-all Report (European War), 11; The Contribution of Air Power to the Defeat of Germany: Appendix J, Long Range Weapons [AFSHRC-519.601C, 7].

33. Karlshagen E. T., "Erprobungsbericht FZG 76 Fur die ziet vom 18.8-26.11.1944," 1 [NASM, Reel 3585, Frame 650].

34. The British calculated the V-1 failure rate at Peenemunde between 16 and 33 percent. Air Scientific Intelligence Report No. 151, "Trials and Operation of Airborne Flying Bombs," [PRO-AIR 20/1661]; ASI Report No. 5; AC/AS, Intelligence, "Flying Bomb," 6; SHAEF Interim Report; Joubert, 97, 114. The French put the launch failure rate at 33 percent, while the British believed an additional 20 percent to 30 percent crashed before reaching the English coast. Young, 89; Kay, 9; "History of Antiaircraft Command," Plate 22 a [W-C3/53].

35. Hill, 5593 fn, 5594; Air Defence GB, 125, 126; Collier, *UK*, 374; Saunders, 165; Young, 70, 114; "Flying Bomb-Scientific Sub-Committee Report," 4 August 1944, 8[AFSHRC-Film #153, Frame 8758]. Experiments using methanol and nitrous oxide boosted engines added about 20 mph to the speed of Mustangs, 16 mph to the Spitfire XIVs, and 6 mph to the Tempest Vs. 10th War Cabinet Committee Report, 28 July 1944, Annex IV [AFSHRC-Film #154, Frame 9399].

36. Hill, 5594; Collier, *UK*, 374; Mary C. Welborn, "V-1 and V-2 Attacks Against the United Kingdom During World War II," 1950, 9 [AFSHRC-170.81-45]; Operations Research Section (ADGB) Report No. 88 [AFSHRC-142.0423-9]; British Air Ministry, "Points of Impact and Accuracy of Flying Bombs: 22 June–28 July" [AFSHRC-512.6522-9]; "The Speed of Air-Launched Divers" [AFSHRC-Film #155, Frame 12613].

37. Hill, 5594; S. B. 60093, 8/7/44, 5 August 1944 [AFSHRC-142.0423-9]; Air Defence Great Britain Tactical Memo-Day #3/1944 "Destruction of Pilotless Aircraft" [AFSHRC-512.6522-9].

38. Air Defence GB, 126; Saunders, 165; Young, 70.

39. ADGB Tac. Memo #3/1944; USFET, #38, 39 fn. Analysis of gun camera film showed that it took a 7.36 second burst to down a V-1 versus 6.06 seconds to down a German fighter. A.F.C. 166, "Flying Bomb Type FZG.76: Tactical Notes for Attacks" [PRO-AIR 20/3431].

40. Hill, 5594; Air Defence GB, 121, 179; Saunders, 165; Collier, *UK*, 380.

41. Hill, 5592; Air Defence GB, 131.

42. AC/AS, Intelligence, "Flying Bomb," 8; Mary C. Welborn, "Over-all Effectiveness of First U.S. Army Antiaircraft Guns Against Tactical Aircraft," 6 [AUL-M35044-2#42]; SHAEF/1029/4/ADD, "Notes on German Flying Bomb," 15 August 1944 [AFSHRC-506.6522C].

43. Frederick Pile, *Ack Ack* (London: Harrap, 1949), 330–333.

44. Ibid., 332; Hill, 5592, 5594; SHAEF/1029/4/ADD Notes, 26 July 1944; Collier, *UK*, 375; "History of Antiaircraft Command," 60.

45. Hill, 5596, 5597; Air Defence GB, 133-135; Frederick A. Pile, "The Anti-Aircraft Defence of the United Kingdom from 28 July 1939, to 15 April 1945," supplement to the *London Gazette* (18 December 1947), 5990. For another suggestion for a coastal belt see Spaatz to SHAEF, 11 July 1944 [AFSHRC-519.161-7]

46. Collier, *UK*, 381–383; Collier, *V-Weapons*, 91–95.

47. Pile, 335; Hill, 5597; Collier, *UK*, 523.

48. Pile, 334.

49. Ibid., 339; Air Defence GB, 130; AC/AS, Intelligence, "Flying Bomb," 8; SHAEF/1029/4/ADD, 15 August 1944.

50. Air Defence GB, 106; Ralph B. Baldwin, *The Deadly Fuze* (San Rafael, Calif.: Presido, 1980), 261–266. The Navy first tested the proximity fuze in August 1942 against target drones (destroying all three available with four bursts), getting it into combat by January 1943. Buford Rowland and William Boyd, *U.S. Navy Bureau of Ordnance in World War II* (Washington, D.C.: Government Printing Office, n. d.), 283.

51. Collier, *UK*, 523.

52. Welborn, V-1 and V-2 Attacks, Table 2.

53. Hill, 5599. The fighters downed 23, the guns 65, and the balloons 2; 3 overflew the city. Chaz Bowyer, *Air War Over Europe, 1939–1945* (London: Kimber, 1981), 171.

54. Collier, *UK*, 523.

55. Welborn, V-1 and V-2 Attacks, 10.

56. Collier, *UK*, 523.

57. Cooksley, 186; Saunders, 169; Hill, 5601. Some earlier figures indicate that the Tempests downed about 1/3 of the V-1s claimed by the fighters, while the Spitfires and Mosquitoes each downed about 1/4. "Squadron Claims for Divers Destroyed" [AFSHRC-Film #153, Frame 8536].

58. Hill, 5595 fn; Air Defence GB, 107, 108, 127, 128, 160, 167, 168. On one occasion, probably before the V-1 campaign, the British lost 80 balloons within a few moments and on 27 June 1944, 35 in about that time. War Cabinet Committee, "Anti-Diver Balloon Barrage-Lightning Risks," 24 July 1944 [AFSHRC-Film #154, Frames 9449, 9451].

59. In a study of the results of impacts of V-1s with 55 balloons, covering the period between 12 July

and 11 August, 19 parted the cables, 23 crashed immediately after the collision, and 4 exploded. Estimates of how many V-1s the Germans equipped with this cable cutting device range from 10 percent in the first month of the campaign to as high as 50 percent. Irving, 252; ORS Technical Report #3, B.D.E. SB 90/5/1 "Impact of Flying Bomb With Barrage Cables," 28 August 1944 [AFSHRC-142.423-9]; A.I.2 (g), Report #2251, 10 July 1944 [AFSHRC-142.0423-9]; Collier, *UK*, 523; British Air Ministry, "The Economic Balance of the Flying Bomb Campaign," 4 November 1944 [AFSHRC-512.675-3]; Young, 93. The Allies considered and rejected a number of other measures to help counter the V-1s. The British formed a committee to investigate how electronic jamming could disrupt radio control of missiles. (The V-1s were not radio guided, but the Germans simulated radio traffic to fool the British. Actually the Germans installed radio devices for tracking purposes on about four percent of the V-1s reaching England.) Allied bombing of the German radio facilities and the overrunning of the stations also helped nullify the German control infrastructure. Another British committee investigated electromagnetic methods of fouling up the V-1's compass. Other measures discussed included smoke and flash deception, commando attacks, and kidnapping of German technicians. Some rather outlandish ideas also emerged. An American officer proposed that heavy bombers pull metal cables and sweep the skies in a manner similar to ocean mine sweepers. A British civilian suggested that aircraft drop cables with weights, bolo fashion around the missile. The Allies also considered, and rejected, terror attacks on Berlin and poison gas attacks on the V-1 launch crews. Irving, 242 fn, 243; LTC, QMC to Commander SHAEF, 14 July 1944 [AFSHRC-512.662-1]; Air Defence GB, 37, 40, 93; Helfers, 28, 29; Hill, 5588; Young, 73; Eugene Walter, "V-Weapons," 16 May 1947, 30 [AFSHRC-171.3-11]; "Radio Transmitters in Flying Bombs, Revised Note, (22 June–22 July 1944)" [PRO-AIR 20/4262]; F.A.A. to Winston Churchill, 3 July 1944 [PRO-AIR 20/6016].

60. Hill, 5599; "Air Launched 'Divers' September and October 1944" [AFSHRC-Film #119]; Air Defence GB, 113; Collier, *UK*, 389; Saunders, 167, 168; 19th Report by Assistant Chief Air Staff (Intelligence), 22 July 1944 [AFSHRC-142.0423-32]; Kay, 9; Young, 119; ASI Report No. 151.

61. Hill, 5601; Collier, *V-Weapons*, 119, 131; Collier, *UK*, 390, 391, 522.

62. USSTAF, Armament and Ordnance Memo #5-7B, 9; AC/AS, Intelligence, "Flying Bomb," 3.

63. USSTAF, Armament and Ordnance Memo #5-7B, 9; Hill, 5602; Saunders, 168.

64. Air Ministry Weekly Intelligence Summary #289 [AFSHRC-142.423-15]; Air Intelligence Report No. 2321, 8 March 1945 [PRO-AIR 40/2167].

65. Hill, 5602, 5603; Collier, *V-Weapons*, 134, 135; Collier, *UK*, 523.

66. Collier, *UK*, 523.

67. Ibid.; Hill, 5603. The fighters got 48 percent of those downed during the day and 53 percent of those during the night, while the guns got 49 percent during the day and 43 percent during the night. Balloons got the remainder. USSTAF, Armament and Ordnance Memo #5-7B, 144.

68. Air Defence GB, 123; Collier, *UK*, 523. The Germans expected the overwhelming bulk of their missiles to get through the British defenses. Two sources relate that in the early summer, presumably 1943, the Germans ran tests at Vicenza in northern Italy matching V-1s against 20 fighters, including a captured Spitfire. These tests led the Germans to believe that the losses would be in the range of 10 percent. Nigel Tangye, "Flying Bombs and Rockets," *Foreign Affairs* (October 1945), 41; Bruce Robertson, *Spitfire: The Story of a Famous Fighter* (Letchworth, Herts: Garden City, 1960), 190.

69. Of the 146,777 British civilian casualties in World War II, 112,932 were due to bombing, 24,165 to the V-1s, 9,277 to the V-2s, and 403 to the long-range guns. Collier, *UK*, Appendix L.

70. USFET, #38, 40, 41, 45; Headquarters Antwerp X Forward Operations Report #2J, 1 May 1945, Annex A [AFSHRC-539.667-12]; SHAEF, Report of 'V' Section, September 1944-March 1945, 28; USSBS, V-Weapons, 15.

71. SHAEF, "Air Defence of Targets in Belgium Against Flying Bombs," 14 October 1944 [AFSHRC-Film #117, Frame 42948].

72. Headquarters Antwerp, X Forward, Report #2H, 4 March 1945 [AFSHRC-539.667-12]; Report #2J, Annex A; USFET, #38, 40–45; Young, 129; IX Air Defense Command, "Historical and Statistical Summary: 1 January 1944–1 June 1945," 32 [AFSHRC-539.04].

73. Cooksley, 185. For a good secondary account see R. J. Backus, "The Defense of Antwerp Against the V-1 Missile," MMAS Thesis, US Army Command and General Staff College, 1971.

74. USSBS, Aircraft Factory Division Industry Report, 115 [AFSHRC-137.302-3].

75. A number of secondary sources use a figure of 280 man-hours to build the V-1, which appears to

be rather low. Brian Ford, *German Secret Weapons* (London: Ballantine, 1969), 60; Rudolf Lusar, *German Secret Weapons of the 2nd World War* (London: Spearman, 1959), 132; H. W. Koch, "Science at War: Germany's Wartime Technology," 136. A very early intelligence report put the figure at 257 man-hours; S. B. 60093, 8/7/44, 5 August 1944 [AFSHRC-142.0423-9]. The United States version of V-1 (designated JB-2) cost about $8,080 each (less warhead) and about 1,047 man-hours, see below. Air Technical Service Command, "Progress Report" [AFSHRC-218.94-1]; John S. Vaugh, Jr. to B. D. Meyers, 16 January 1945 [AFSHRC-201-46 V]; Mitchell to CG AAF, 6 September 1945 [AFSHRC-201-46 VIII]. Three wartime reports put the figure between 800 and 1,150 man-hours. The post war United States Strategic Bombing Survey (USSBS) study, estimated that the 100th V-1 cost 17,000 man-hours, the 1,000th 7,500 man-hours, and the 10,000th 3,500 man-hours. USSBS, Aircraft Factory, 115; Intelligence Report SD 375-1, 17 July 1944 [AFSHRC-170.2271-5]; BAM, "The Economic Balance"; Air Intelligence, 2 (a) report No. V.1/44, "Production of Flying Bomb," 26 July 1944 [PRO-AIR 20/3398]. To translate this man hour figure into money is even more difficult. Some secondary sources use a figure of 125 pounds or $500, while others cite other amounts; Wernher von Braun, for example, states $4,000. All authoritative sources agree, however, that the V-2 cost more, but exactly how much more is again subject to a wide variety of opinions, ranging from a low of 3 times to a high of 96 times. Garlinski, 10, 70; Irving, 24, 25, 314, 24, 25; Dornberger, 94.

76. Irving, 313.

77. BAM, "The Economic Balance."

78. John R. Propst, "Development of the German V-1 and V-2, 1936–1945," Air Command and Staff School Thesis, 1948, 46 [AUL-239.04348 Propst]; *Aeroplane Spotter* (6 March 1948), 55.

79. Memo: Director of Technical Service, ASC, USSTAF, 15 January 1944 [AFSHRC-142.0423-9]; Robert A. Lovett memo for H. H. Arnold, 2 August 1944 Subj: Pilotless Aircraft and Guided Missiles, 2 August 1944 [AFSHRC-201-46 II]; Air Materiel Command, "The Development of Guided Missiles," June 1946, 35 [AFSHRC-201-46 I]; Delmar S. Fahrney manuscript, "The History of Pilotless Aircraft and Guided Missiles," n.d., 800 [NHC].

80. J. B. Gordon to CG, AAF, 14 July 1944, 4 [AFSHRC-519.161-7]; A.M.C., "Development Guided Missiles," 35 [AFSHRC-201-46 I]. For a general, undocumented account of the American V-1, see Richard Hallion's, "The American Buzz Bombs," *Aeroplane Monthly* (November 1976).

81. AGWAR to SHAEF W-78828, 18 December 1944 [AFSHRC-Film #127, Frame N3168].

82. K. B. Wolfe to O. P. Nichols, 31 July 1944; J. M. Gillespie to Deputy Director Air Technical Service Command, 7 September 1944 [both AFSHRC-201-46 IV]; A.M.C., "Development Guided Missiles," 35 [AFSHRC-201-46 I].

83. Arnold to Spaatz, 10 October 1944 [AFSHRC-519.8671-8'44]; James A. Burden to Chief of Engineering and Procurement, Air Technical Service Command, 23 September 1944 [AFSHRC-201-46 IV].

84. Memo for General Bull, Subj: Status of JB-2 (Chinese copy of German Flying Bomb), 3 December 1944 [AFSHRC-Film #127]; T. I. 2003 Addendum No. 14, 18 January 1945 [AFSHRC-201-46 V].

85. David T. Griggs, "The Role of Controlled Buzz Bombs in the German War," 5 February 1945 [AFSHRC-519.311-1].

86. E. M. Powers to Director Air Technical Service Command, Subj: Launching and Procurement Program JB-2, 14 January 1945; K. B. Wolfe to B. E. Meyers, Subj: JB-2 Large Scale Procurement Program, 15 January 1945 [both AFSHRC-201-46 V].

87. SHAEF, Leigh Mallory, 5 October 1944 [AFSHRC-Film #127, Frames N3198, N3199].

88. SHAEF, Minutes of Meeting 29 December 1944 [AFSHRC-Film #127, Frame N3177]; A.M.C., "Development Guided Missiles," 35 [AFSHRC-201-46 I].

89. Spaatz to Arnold, 3 December 1944 [AFSHRC-519.311-1].

90. David T. Griggs to Edward L. Bowles, 14 March 1945 [AFSHRC-519.161-7]; letter 5 March 1945 [AFSHRC-Film #127]; C. P. Kane to Office Liaison Officer, USSTAF, 3 March 1945 [AFSHRC-519.8671-8].

91. G. M. Barnes to Office, Assistant Chief Air Staff, Material and Supply, 30 September 1944

[AFSHRC-201-46 IV]; Wesley Craven and James L. Cate, (eds.), *The Army Air Forces In World War II*, Vol. VI: *Men and Planes* (Chicago, Ill.: University of Chicago, 1955), 256.

92. John S. Vaugh, Jr. to B. E. Meyers, 16 January 1945 [AFSHRC-201-46 V]; A.M.C., "Development Guided Missiles," 40 [AFSHRC-201-46 I]; USSTAF to War Department, 101342A, n.d. [AFSHRC-Film #127, Frame N3156]; Craven and Cate, VI, 256; Fahrney manuscript, 807.

93. AGWAR to SHAEF, W-25880, 24 January 1945 [AFSHRC-Film #172, Frame 1904]; Griggs, "The Role of Controlled Buzz Bombs in the German War" [AFSHRC-519.311-1]; A.M.C., "Development Guided Missiles," 41 [AFSHRC-201-46 I].

94. A. M. C., "Development Guided Missiles," 41 [AFSHRC-201-46 I].

95. Air Technical Service Command, "Program Report of Army Air Forces Pilotless Aircraft as Guided Missiles" rev. 1 January 1946 [AFSHRC-218.94-1]; A. M. C., "Development Guided Missiles" [AFSHRC-201-46 I]; Memo to Chief of Staff, 26 November 1946; Guided Missile Committee, Joint New Weapons Committee, Subj: Correction and Addition; Summary Handbook of Guided Missiles, 13 February 1946 [both AFSHRC-201-46 III].

96. The JB-2 cost about $8,620 (about twice the AAF's original estimate). The weapon required about 1,047 man-hours (excluding warhead) to produce, a man-hour figure remarkably close to that estimated for German production (above) which, in view of the relative condition of US and German industry in 1944 and 1945 suggests that the figure for German production is low. A.T.S.C., "Progress Report" [AFSHRC-218.94-1]; John S. Vaugh, Jr. to B. E. Meyers, 16 January 1945 [AFSHRC-201-465]; Mitchell to C.G.A.A.F., 6 September 1945 [AFSHRC-201-46 VIII]; Berend D. Bruins, "U.S. Naval Bombardment Missiles, 1940–1958," unpublished Ph.D. dissertation, Columbia University, 1981, 105; Hallion, 571.

97. By the spring of 1945, 6 of 10 attempted launches from B-17s failed. The B-17 could carry two JB-2s, but the additional drag and weight decreased the B-17's range by 500 miles. A one-fourth to one-half reduction in range for the B-17, depending of course, upon a host of variables.

98. A. M. C., "Development Guided Missiles," 38, 42 [AFSHRC-201-46 I]; A.T.S.C., "Program Report" [AFSHRC-218.94-1]; "American Buzz Bomb Now Gets in Air from 50-Foot Launching Ramp," *Impact* (August 1945), 64; Memo to Chief of Staff, 26 November 1946 [AFSHRC-201-46 III]; Cooksley, 143; Guided Missile Committee, "Summary Handbook of Guided Missiles," 1 July 1945 [AFSHRC-145.96-195]; Joint Committee on New Weapons and Equipment, Guided Missiles Committee, Evaluation Form No. 6, JB-2, 3 April 1945, 5 [NASM]; *Jane's All the World's Aircraft: 1945/46*, 213C; Gordon Swanborough and Peter Bowers, *U.S. Military Aircraft Since 1908* (London: Putnam, rev. 1971), 96; William Green, *Famous Bombers of the Second World War*, [Vol. I] (Garden City, N.Y.: Hanover, 1959), 36.

99. Memo for General Bull, 3 December 1944 [AFSHRC-Film #127, Frame N3159]; A.T.S.C., "Progress Report" [AFSHRC-218.94-1]; Guided Missile Committee," Abstract Report and Supplement," 26 April 1946, 31 [AFSHRC-178.2810]; Fahrney manuscript, 805, 806.

100. Griggs, "The Role of Controlled Buzz Bombs in the German War" [AFSHRC-519.311-1].

101. A.T.S.C., "Progress Report," [AFSHRC-218.94-1]; Memo to Chief of Staff, 26 November 1946, [AFSHRC-201-46 III]; G.M.C., "Summary Handbook" [AFSHRC-145.96-195]; A.T.S.C. Report on "JB-2 Pilotless Aircraft," 1 March 1946 [NASM].

102. In September 1945, submariners recommended study of submerged torpedo tube firing of V-1s, and also considered launching V-2s from their boats. Chief Bureau Aeronautics to Commander, Naval Air Material Center, Philadelphia, 26 December 1944 [AFSHRC-201-46 IV]; Joint Committee on New Weapons and Equipment, Guided Missiles Committee, Subcommittee No. 3, Special Weapons for Operations Against Japan, 1 May 1945 [AFSHRC-201-46 III]; Bruins, 122, 128-129; Fahrney manuscript, 539, 544, 813. Norwegian sources reported seeing two German submarines in December 1944 fitted with V-1s. While this report circulated through American intelligence channels, no confirmation exists. Colonel D. C. Doubleday to Director, ATSC, Subject: Transmittal of Paraphrased Message, 6 February 1945 [NASM].

103. Bruins, 129–131, 141–145; Fahrney manuscript, 546–565.

104. Gerald Bolger, "The Aircraft of Jack Northrop," *Journal of the American Historical Society* (Spring 1981), 86.

105. A.T.S.C., "Progress Report" [AFSHRC-218.94-1]; A.M.C., "Development Guided Missiles," 43 [AFSHRC-201-46 I]; Mervin E. Gross, "Guided Missiles," 8 November 1944 [AFSHRC-201-46 IV]; P. F. Helmick to Director, Air Technical Service Command, 9 December 1944 [AFSHRC-201-46 V].

106. Northrop built 10 of these pulse-jet versions in addition to the 1 glider and 2 turbo-jet versions. When the final cancellation occurred, only the 1 glider model and 1 JB-10 remained intact. A.T.S.C., "Progress Report" [AFSHRC-218.94-1]; A.M.C., "Development Guided Missiles," 35, 44 [AFSHRC-201-46 I]; G.M.C., "Summary Handbook" [AFSHRC-145.96-195]; G.M.C., "Abstract Report and Supplement," April 1946, 49, 52 [AFSHRC-178.281D]; Gross, "Guided Missiles"; W. M. Darling memo report, "Pilotless Aircraft, Type JB-10, Expenditure Order 448-18," 8 March 1946; Edward W. Moore, memo report, "Pilotless Aircraft Type JB-10, Project MX-543," 28 November 1945 [both AFSHRC-201-46 V].

CHAPTER IV

POSTWAR DEVELOPMENTS

Thus far, this narrative has centered on the technical development of the cruise missile; rightly so, for this was the focus of the story until 1945. But political considerations and intraservice and interservice rivalry emerged even before the last shot sounded in World War II. This competition occurred mostly between members of the Army and members of the soon-to-be independent air arm.

The intraservice disputes arose as the airmen used the war to advance their move towards independence. This is not to say that they put their interests above that of the nation; rather, they saw the two as intertwined since in using airpower to win the war, they could also advance the cause of air autonomy.[1] Senior airmen included the guided missile in this effort. For example, Arnold wrote Assistant Secretary of War Lovett in August 1944 that he wanted to get the JB-2 into action as soon as possible to stake out another role for the AAF (Army Air Forces).[2] A more charitable view can be seen in a letter written by Arnold's right-hand man in February 1945 that:

> We [in the AAF] believe the JB-2 to be representative of a new family of very long range weapons whose capabilities will profoundly affect future warfare and especially aerial warfare. We want now to explore the possibilities of very long range missiles to the utmost extent which will not involve a serious diversion of effort from the essential business of prosecuting this war.[3]

But as Chapter III indicated, the closest the airmen came to getting such a missile into combat during the war involved the less-than-successful APHRODITE project.

The AAF also made considerable efforts towards winning autonomy at home. The Air Staff produced a memo in September 1944 that, if approved, would place missiles that were essentially aircraft, launched or controlled from aircraft, directed against aircraft, or were alternatives or additions to bombers or fighters, under the AAF.[4] Such a position surely did not leave much for anyone else!

A meeting between representatives of the Joint Chiefs of Staff, the Army's three forces (air, ground, and service), and the War Department's General Staff on 14 September 1944 framed the basic Army missile policy.[5] On 2 October, Lieutenant General Joseph T. McNarney approved the document that served as a cornerstone in the evolution of future Army-Air Force missile roles and responsibilities.

Because the McNarney memo recognized that missile development was in its

early stages, it maintained that exclusive assignment of missiles to one arm or service was unwarranted. Further, the memo divided research and development responsibility on technological, not tactical, grounds. The memo assigned all responsibility for research and development of air-launched missiles and those ground-launched missiles depending primarily on aerodynamic lift to the AAF. The Army Service Forces (ASF) received responsibility for ballistic missiles launched exclusively from the ground.[6] In short, the McNarney memo divided responsibility on an evolutionary basis: winged missiles looked and performed like aircraft and therefore went to the AAF, wingless missiles looked and performed like artillery and, hence, went to the ASF. Although this solution appeared reasonable and tactful, it sought to avoid the key issue: operational control. In view of the accelerated JB-2 program, the issue could not be avoided. Consequently, in January 1945, Marshall assigned operational control of the JB-2 to the AAF. But as subsequent events revealed, this neither settled the matter nor stilled the airmen.[7]

In February, the airmen proposed a change to the McNarney memo which would give them both planning and operational responsibility for all missiles, except those replacing artillery, close support aircraft, and antiaircraft artillery. In short, the AAF wanted control of those missiles that supplemented or complemented aircraft. In contrast, the War Department's G-3 wanted to retain the McNarney memo guidelines for research and development, but proposed an operational division which would give the airmen control over air-launched missiles and those missiles used in missions of strategic bombardment, fighter escort, and distant interception. At the same time, responsibility for missiles used for supporting artillery, tactical bombardment, and antiaircraft guns would be split between the AAF and Army Ground Forces (AGF). The AGF, supported by the War Department General Staff Operations Plans Division, opposed this scheme, thereby forcing G-3 to revise slightly its proposal which the airmen supported for political reasons.[8] Marshall, however, maintained his position that the McNarney memo would guide research and development and that operational assignments would be made only after missiles developed sufficiently to be compared to mission requirements.[9]

Despite Marshall's position, the jockeying continued. Spaatz proposed assigning unguided missiles to the ASF, and controllable ones to the AAF, since the airmen did not like the line drawn in the McNarney memo between winged and non-winged missiles. Numerous meetings in 1946 failed to produce a solution.[10] The participants realized the importance of the issue; for example, in September 1946, Major General Curtis LeMay, the first Deputy Chief of Air Staff for Research and Development, argued that "the long-range future of the AAF lies in the field of guided missiles" and therefore the AAF "must 'stick to its guns'."[11] In October 1946, The Army resolved the issue momentarily by placing responsibility for all Army guided missile research and development under the AAF.[12]

When the airmen achieved independence in the fall of 1947, the issue of guided missiles remained unsettled. The 15 September 1947 document creating a separate air force gave the fledgling USAF responsibility for pilotless aircraft, strategic missiles, and area air defense; it gave the Army responsibility for airfield air

defense. The separation agreement left unstated responsibility for point air defense.[13]

The issue of responsibility for specific weapons has since been reopened on several occasions but never settled to the satisfaction of all concerned. Most of the participants viewed missiles as evolutionary weapons, devices to supplement or replace existing equipment. To the Army, missiles were a way to extend the range of the artillery; to the Air Force, missiles were a way to enhance aircraft. The problem is, of course, that these activities take place in the same geographic area. In summary, this digression points out that the issues of roles and responsibilities for missiles were raised at an early date (1944), argued forcefully, but never satisfactorily resolved.

Postwar Adjustment

One result of the massive war effort and service competition was that when the war ended, the United States had 19 different guided missile projects in progress, including both powered and unpowered missiles.[14] By January 1946, that number rose to 21 and continued to climb. Although the military revised the program in 1946, dropping many of the World War II projects (mostly the unpowered air-to-surface types), they added new ones; by mid-year, they carried 47 projects on the books. The inevitable came in December 1946 when the Administration slashed the fiscal 1947 missile budget from $29 to $13 million.[15]

Such a massive cut forced the military to make hard decisions about their future missile programs.[16] The airmen cancelled 11 of their 28 guided missile projects, but even more reductions were necessary. A study by Air Materiel Command recommended that AAF axe the so-called "insurance missiles," thereby cutting the number of funded projects to 12.[17] Thus, USAF cut the number of surface-to-surface missiles from 12 to 7: one 150-mile, two 500-mile, one 1,500-mile, two 5,000-mile, and the BANSHEE missile. But in March 1948, the total shrank to four: the Air Materiel Command BANSHEE, the Northrop Snark, the North American Navaho, and the Martin Matador.[18]

Air Materiel Command BANSHEE

In January 1946, Lieutenant General Ira C. Eaker suggested that the best way for the Air Force to press its case for guided missiles was to impress the American public by demonstrating a missile having at least a 1,000 mile range. USAF selected the BANSHEE for this task because it seemed best able to succeed.

Unfortunately for USAF, BANSHEE might be known as the son of APHRODITE, for the device (a modified B-29) failed in its mission as had APHRODITE (a modified B-17). Because BANSHEE encountered considerable problems, USAF terminated it in April 1949.[19] The other three surface-to-surface missiles did somewhat better.

Northrop Snark

In August 1945, the AAF established a requirement for a 600 mph, 5,000-mile-range missile with a 2,000-pound warhead. In response to an Air Force solicitation for such a device, Northrop presented a proposal in January 1946 for a subsonic, turbojet-powered, 3,000-mile range missile. That March, the company received one-year research and study contracts for a subsonic and a supersonic missile with a range of 1,500 to 5,000 statute miles, and a 5,000-pound payload. Jack Northrop, the company president, nicknamed the former (MX-775A) Snark, and the latter (MX-775B) Boojum, both names from the pages of Lewis Carroll.[20]

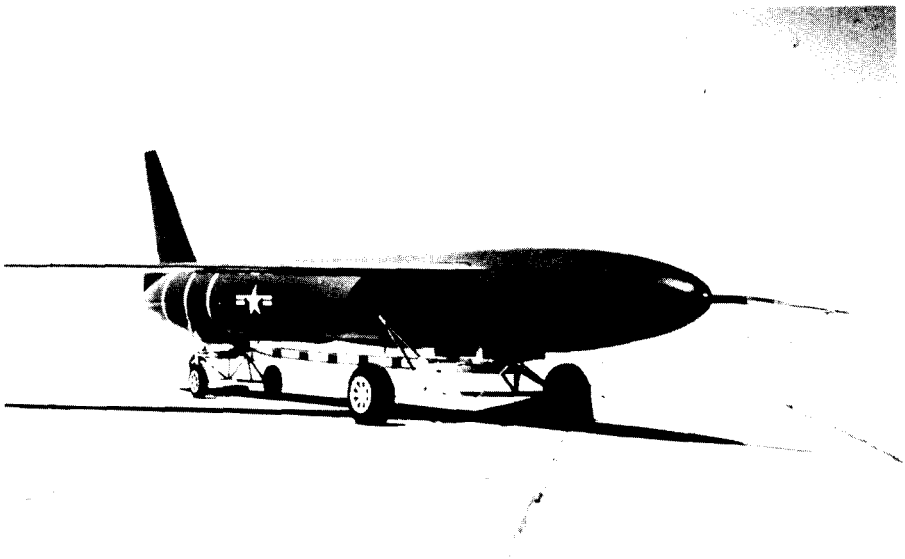
The 1946 Christmas budget reduction deleted the subsonic Snark from the AAF missile program, but retained the supersonic Boojum. But the matter did not end there. Jack Northrop personally contacted Carl Spaatz, Chief of the Air Arm, and others, to save the Snark. He promised development in two and one-half years, at an average cost of $80,000 for each of the 5,000-mile missiles in a 5,000-unit production run. The noted aircraft designer and manufacturer contended that it would take several years to develop the turbojet-powered missile, with 60 percent of the effort going into the guidance system. Before 1947 passed into history, USAF reconstituted the Snark program, slightly modified from the August 1945 specifications, at the same time relegating the Boojum to a follow-on status.[21]

Air Materiel Command authorized 10 flight tests of the Snark, the first by March 1949. In July, General Joseph McNarney called the Snark America's most promising missile project. But the Army and the Navy criticized both the Snark and Navaho for their high cost relative to their overall priority and unproven concept. Even Air Force enthusiasm for the Snark cooled; in March 1950, the airmen reduced the program to the development of only its guidance system.[22]

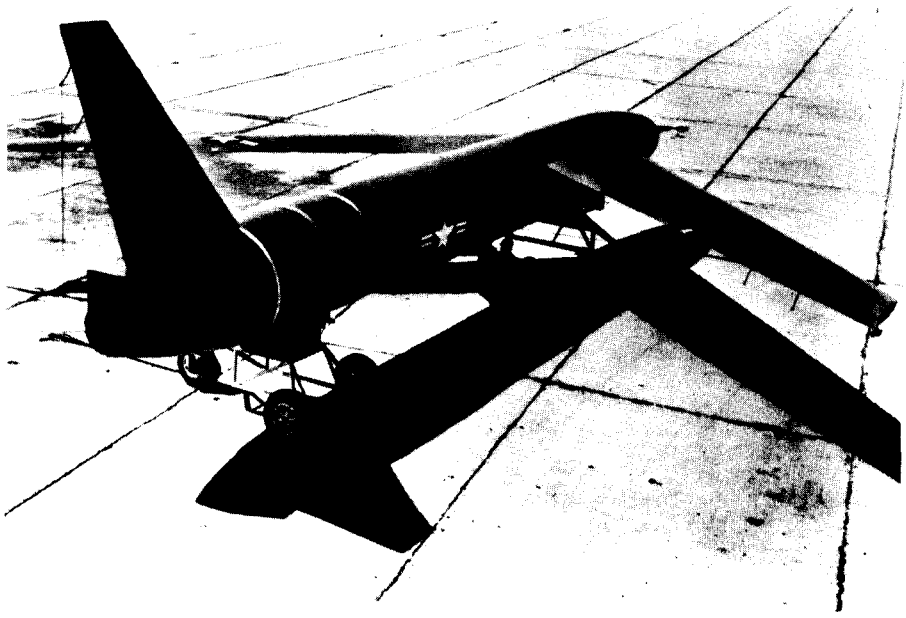
The company designated the initial version N-25. Larger and heavier than previous "flying bombs," Snark also possessed much greater performance; its J33 engine pushed it at a cruising speed of Mach .85 (with a maximum level speed of Mach .9) to a range of 1,550 statute miles.* A B-45 mother ship controlled the N-25, which Northrop designed to be recovered by means of skids and a drag chute. The designers expected that recovering the test vehicles would cut the time and money required to develop the missile.

Numerous problems became apparent in testing the N-25 at Holloman Air Force Base. Despite a schedule calling for flight tests in 1949, the experimenters did not

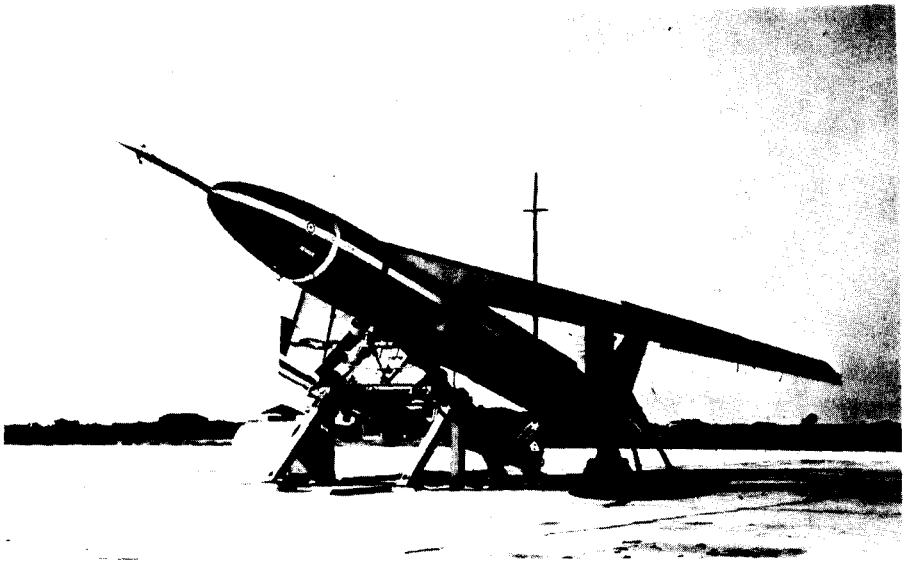
*See Appendix A for missile specifications.



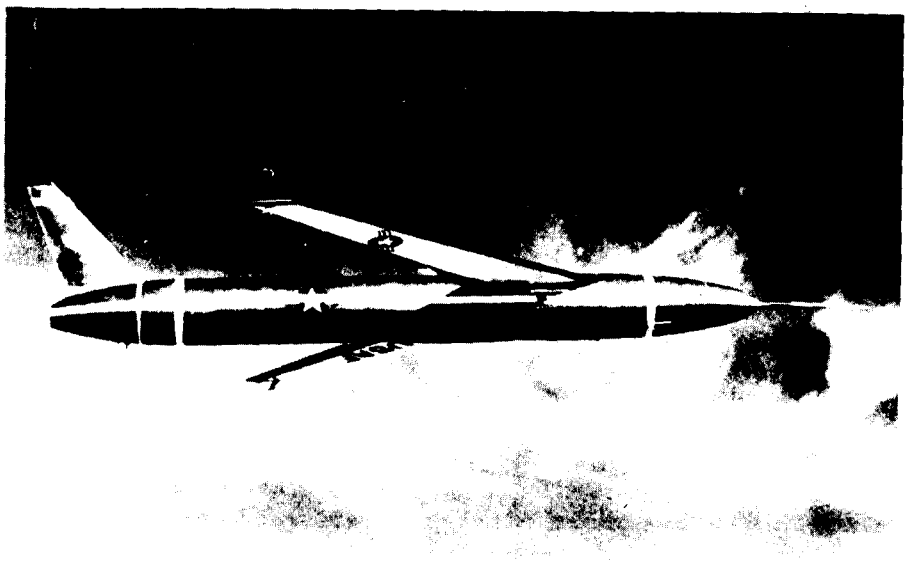
The first version of the Snark (MX-775) was designated N-25 by Northrop. The sleek, tailless missile successfully flew for the first time on 16 April 1951. (USAF)



N-25 at Holloman, 15 April 1950. (USAF)



This photograph of a N-25 (#972) on 11 December 1952 clearly shows the "saw tooth" leading edge on the wing. (USAF)



N-25 in flight. Although the first two N-25s crashed, the missile's overall flight record was very good. (Northrop)

make the first attempted launch until December 1950. It failed. After another failure, the first successful flight took place in April 1951 when the missile flew 38 minutes before recovery. During this series of tests, the 16 sled-launched missiles flew 21 times, achieving a maximum speed of Mach .9 and a maximum endurance of 2 hours, 46 minutes. With the conclusion of these tests in March 1952, 5 of the 16 N-25s remained.[23]

The prose description and a quick glance at a photograph of a Snark fails to highlight the uniqueness of the missile. The Snark flew in a nose-high flying altitude because it lacked a horizontal tail surface as did so many of Northrop's machines. Instead of conventional control surfaces (ailerons, elevation), the Snark used elevons. A profile view reveals that the missile also had a disproportionally small vertical tail.

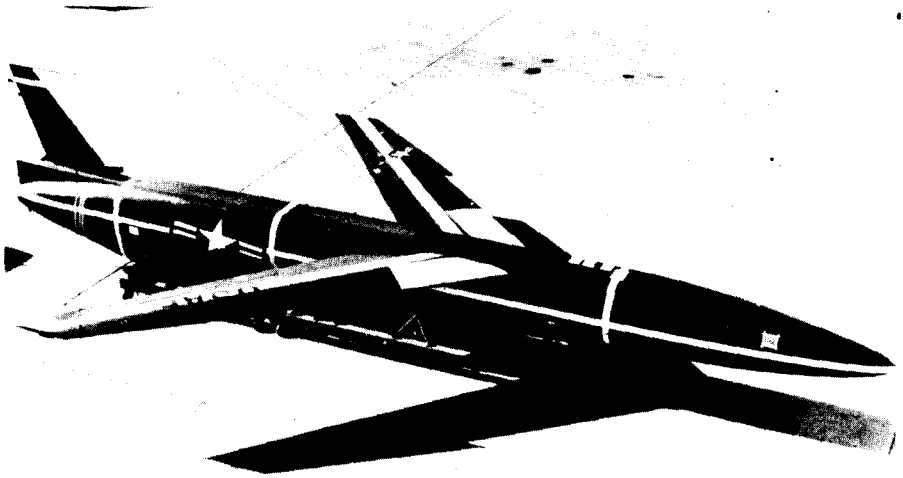
The sixth N-25 (#972) flew 81 minutes before it was recovered at Holloman on 26 June 1951. On 21 attempted N-25 flights between 21 December 1950 and 28 March 1952, 10 missiles were recovered. (USAF)

To meet the toughest challenge for the program, guidance over the proposed intercontinental distances, Northrop proposed an inertial navigation system monitored by stellar navigation. Northrop accomplished the first daylight (ground) test of this stellar device in January 1948. This was followed by flight tests aboard B-29s in 1951–52. Between 1953 and 1958, 196 flight tests aboard B-45 aircraft provided about 450 hours of guidance experience. The large and heavy (almost one ton) guidance system worked, but not for very long. The company claimed that the Snark could achieve a CEP* of 1.4 nm.[24]

In June 1950, the Air Force increased Snark requirements to include a supersonic dash at the end of the 5,500 nm mission (6,350 statute miles), a payload of 7,000 pounds (later reduced to 6,250 pounds), and a CEP of 1,500 feet. This key decision, increasing performance requirements, invalidated the N-25.

*Circular Error Probable (CEP) is the measure of average accuracy, that is, one-half the weapons will fall within that radius.

Northrop therefore produced a new design. Basically a scaled-up N-25, the N-69 was initially called "Super Snark."* The company lengthened the fuselage, sharpened the nose shape, replaced the external scoop with a flush scoop, and increased the launch weight. More noticeably, Northrop added a larger wing. Although Northrop slightly shortened the wing span, it broadened the wing by extending it further aft, thus increasing the wing area from 280 to 326 square feet. In addition, because wind tunnel and N-25 tests showed some instability in pitch (pitch-up), Northrop redesigned the wing with a leading edge extension, thereby giving the Snark wing its "saw tooth" shape.[25] A J71 engine powered the "A," "B," and "C" models before USAF adopted the J57 in December 1953 for the "D" models.

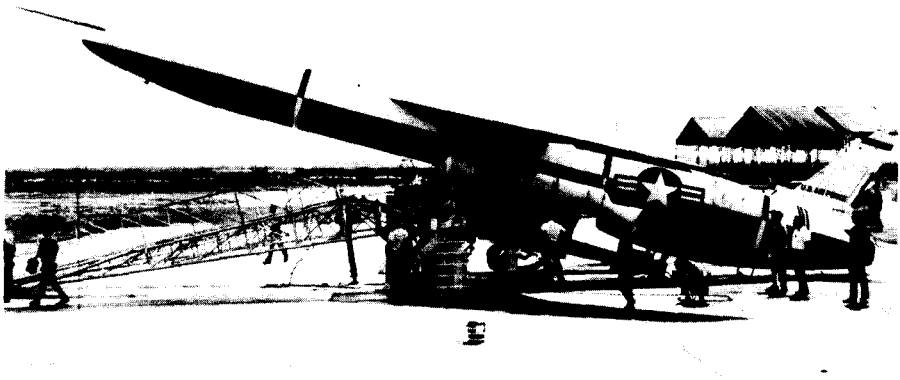


Northrop designated the enlarged Snark, N-69. Note the "saw tooth" leading edge and straight trailing edge on both the wing and shadow of missile N-3268. (USAF)

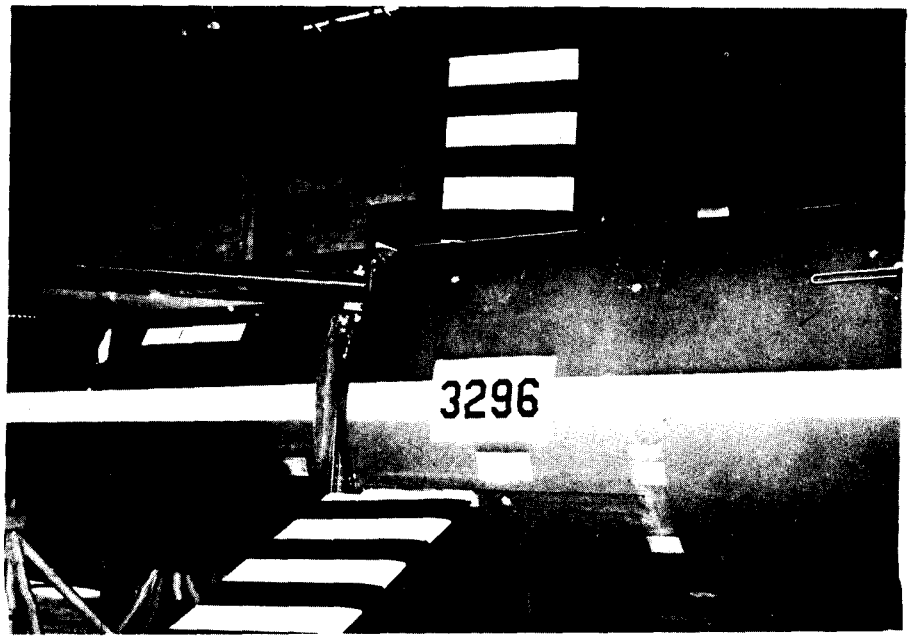
But testing was necessary before this could occur. First, the experimentors tested three unpowered dummy missiles with ballast to simulate the N-69. Then between November 1952 and March 1953, they flew four modified N-25s fitted with two 47,000-pound-thrust boosters. In contrast, the N-69A used twin, four-second duration, 105,000-pound-thrust boosters, while N-69C and later models relied on twin, four-second duration, 130,000-pound-thrust rockets.[26]

But numerous problems beset the Northrop missile during testing. The Snark proved unstable in all but straight and level flight. Northrop compounded these difficulties when it took engineers off the Snark project to help the company's ailing, but priority, F-89 all-weather interceptor program. Despite the reduction of test vehicles to 13 (as of February 1953), the program exceeded its budget by $18.3 million. The movement of testing from Holloman to the Atlantic Missile Range in

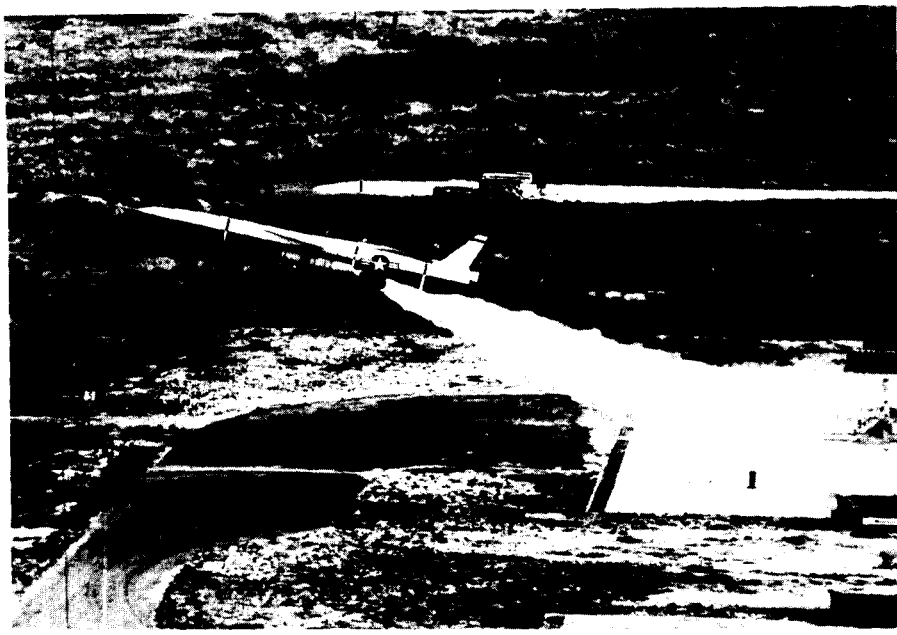
*See Appendix A for missile specifications.



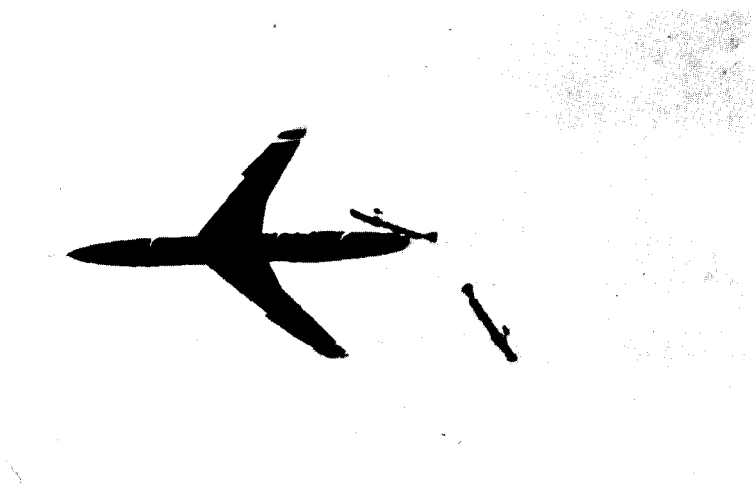
Side view of N-69C (GM-13107) showing the proportionally small rudder. This missile broke up in the first terminal dive test on 6 April 1955. (USAF)



The failure of the Snark in terminal dives forced a change in concept and design to a detachable ballistic nose with fin stabilizers. The new nose was fitted to a modified N-69D (N-3296) and first flown on 26 October 1955. (USAF)



This rare aerial picture shows the launch of GM-11111 on 26 April 1954. (USAF)



As GM-11111 drops its boosters it shows the profile of the new Snark wing with the extended trailing edge. (USAF)

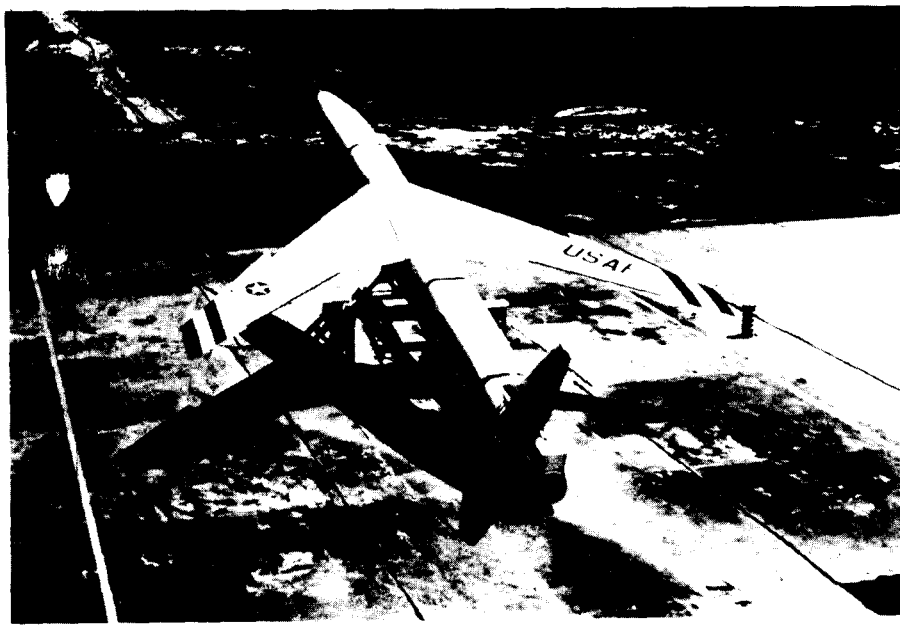
1952, a move opposed by Northrop, also hindered the program. In fact, the slow construction of test facilities in Florida restricted testing between 1953 and 1957. There were also powerplant problems because the J71 engine exceeded its fuel consumption specifications, necessitating a number of engine changes. If these problems were not enough, the first missile delivered for flight tests was in serious disrepair.

GM-11111 crashed, 3,000 feet from the launcher, due to electrical failure. The falling boosters can be seen in center and right of the picture. (USAF)

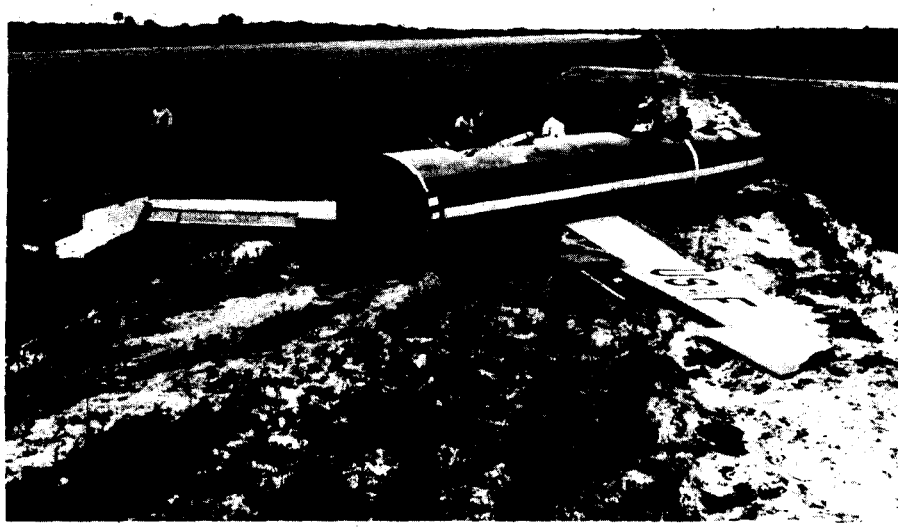
The program also suffered numerous test failures. The initial launch attempt on 6 August 1953 failed, as did the next four. On 3 June 1954, the missile flew three and one-half hours but exploded on landing. While USAF recovered 10 N-25s on its 21 flights, the first successful N-69 recovery occurred on the 31st flight on 2 October 1956. The lack of recoveries retarded the testing of the N-69. Northrop completed these tests by May 1955, well after the Snark's tentative activation date of April 1953 and operational date of October 1953.[27]

The problems grew worse. By May 1955, wind tunnel and flight tests indicated that Northrop's operational concept, terminal dive of the missile into the target, would not work because of inadequate elevon control. Five flight tests of the N-69C, a nonrecoverable radio-controlled missile with fuselage speed brakes (designed to test the Snark from launch into the target) confirmed these findings. In July 1955, the Air Force accepted the company's proposal for a different delivery concept involving a nose which detached from the airframe near the target and then followed a ballistic trajectory. The redesigned missile (N-69C, modified) first flew on 26 September 1955.[28]

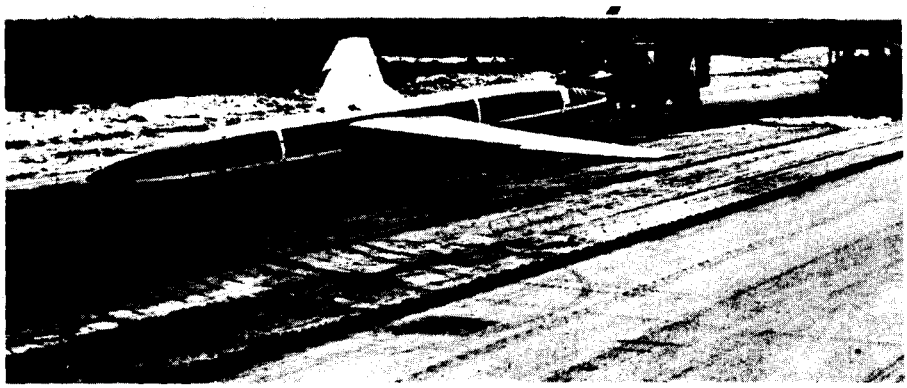
These aerodynamic, cost, and scheduling problems brought the missile under fire and generated unfavorable publicity. One bit of ridicule which outlived the program



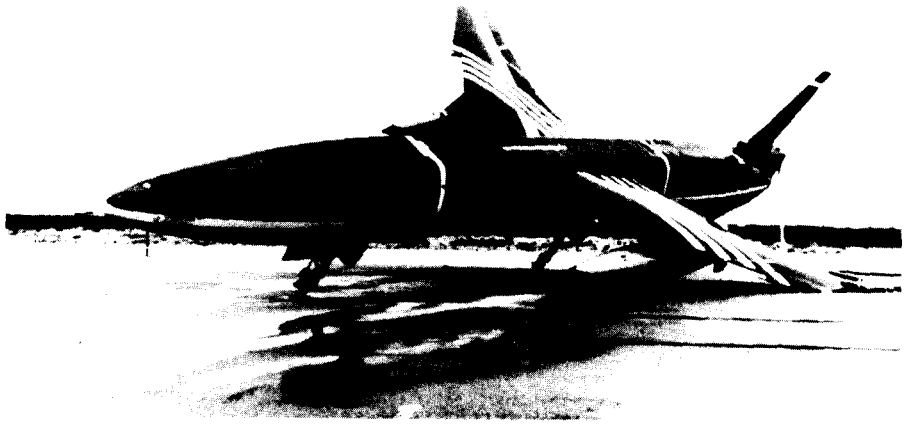
Another view of the modified Snark wing, circa 1955. (Northrop)



Initial attempts to recover the N-69 failed because the skid system created adverse aerodynamics. This N-69A (GM-3394) got to the skid strip but, because the rear skid was not locked, crashed and exploded on 3 June 1954. (USAF)



The first successful recovery of the N-69 (N-3303) did not occur until 2 October 1956. (USAF)



Even with wing damage, this recovery of N-3313 on 16 April 1957 was considered successful. Note the two landing struts and pylon wing tanks. (USAF)

dubbed the waters off Canaveral "Snark infested waters" because of the numerous crashes. (In fact, to some, this may well be the most memorable aspect of the entire program.) At the other extreme, a Snark in December 1956 flew too far; that is, it failed to respond to control and was last seen heading toward the jungles of Brazil. As one Miami paper put it, with apologies to Henry Wadsworth Longfellow: "They shot a Snark into the air, it fell to the earth they know not where."[29] In 1982, a Brazilian farmer found the errant missile.

Snark (N-3303) in flight with skids extended accompanied by a Northrop F-89 director aircraft, 2 October 1956. (Northrop)

Snark in flight. The missile flew in a nose high attitude. (USAF)

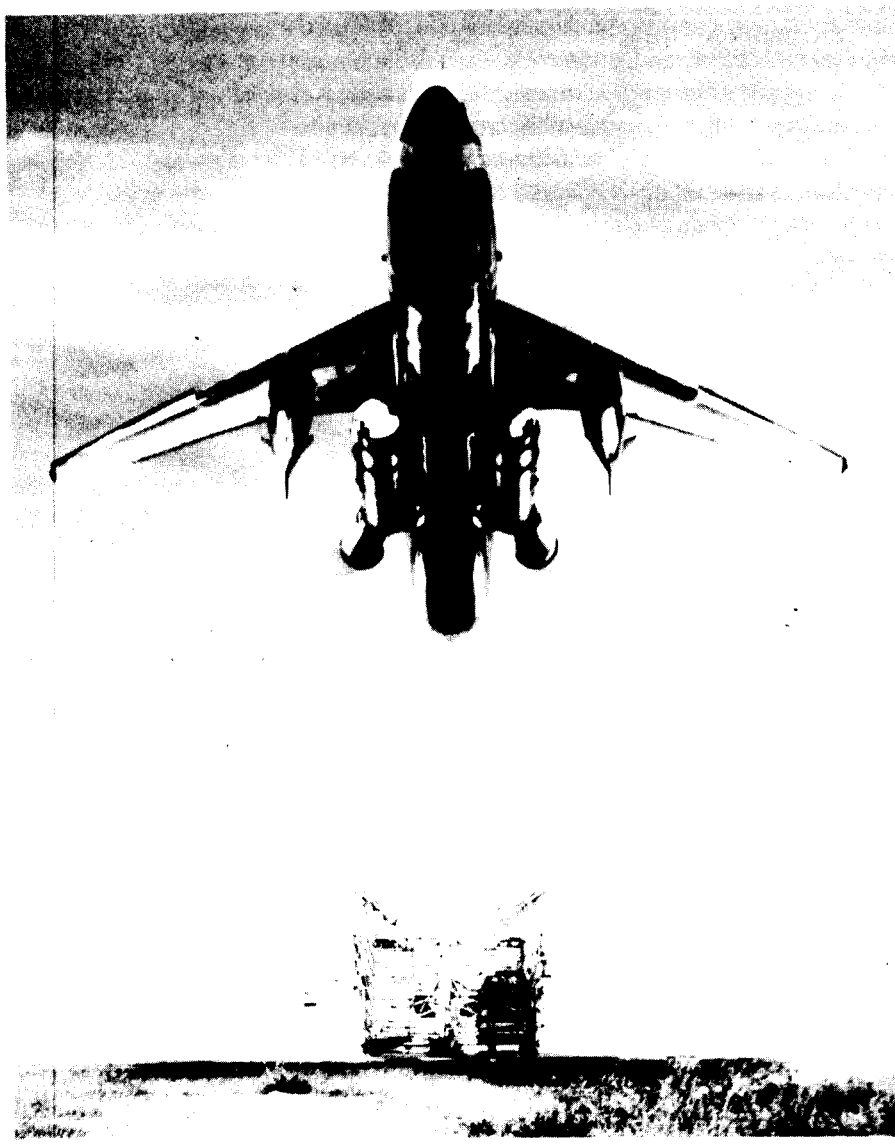
More importantly, Strategic Air Command (SAC), the intended user of the missile, began to express doubts about the Snark by late 1951. Although some may suspect the motives of a unit dominated by bomber pilots regarding a pilotless bomber that would take the man out of the machine, valid questions concerning the weapon's reliability and vulnerability emerged at this point. As early as 1951, SAC decried Snark's vulnerability both on the ground and in the air. On the ground, the missile would be based at unhardened fixed sites. In the air, the subsonic (Mach .9) Snark lacked both defensive armament and the ability for evasive maneuver.[30] Indeed, it is difficult to quarrel with the 1954 SAC command position, which was "conservative concerning the integration of pilotless aircraft into the active inventory in order to insure that reliance is not placed on a capability which does not in fact exist."[31] But some SAC officers in 1951 saw value in the Snark program as a way to get the command into the missile business. Or perhaps they just wished to make the most of a bad situation.[32]

Criticism of the Snark came from other quarters as well. In early 1954, a blue ribbon panel, The Strategic Missile Evaluation Committee,[33] found important aspects of all three American long-range missile programs (Snark, Navaho, and Atlas) unsatisfactory. The committee concluded that, in general, the missiles' CEPs were outdated and their bases were vulnerable. The panel assessed the Snark as an "overly complex" missile which would not become operational until "substantially later" than scheduled.

The panel went on to make three recommendations. First, it recommended that USAF employ a variety of means to assist heavy bombers: area decoys, local decoys, and ECM (electronics countermeasures). Second, it suggested that USAF extend missile CEP requirements from one quarter nm to three-to-five nm. Clearly, this relaxation made sense in view of the much greater warhead capability soon to be available with the evolution from atomic to hydrogen explosives, and the accuracy limitations of the existing guidance systems. (By mid-1954, USAF had loosened Snark's CEP requirement from 1,500 to 8,000 feet.) Third, the panel recommended simplification of the Northrop vehicle, entailing cancellation of both the Northrop and North American celestial navigation systems. The committee estimated that Northrop could produce a simplified Snark by 1957 with quantity production in 1958-59.[34]

But the Snark program did not appreciably improve. In fact, test problems demonstrated serious deficiencies in the weapon. In 1958, General Irvine of Air Research and Development Command (ARDC) cited the Snark as an outstanding example of unwarranted funding; and General Power, Commander of SAC, noted that the missile added little to the command's strength. The latter wanted a reevaluation of Snark in order to either correct deficiencies or terminate the program.[35]

But despite Air Force reservations about the Snark, journalists presented the case for the Northrop missile in the aviation press in the period 1955–58. They emphasized the missile's major advantages, chiefly resulting from the fact that it was a one-way, unmanned weapon. Besides not requiring a tanker fleet, advantages



Launch of N-69D (N-3316) on 20 November 1957. Both the boosters and pylon tanks are clearly visible. Because of a ripped drag chute, N-3316 was destroyed in landing. (USAF)

included fewer requirements for ground handling, repair, and safety. Snark's advocates noted that it could fly as fast as contemporary bombers, could be programmed for evasive maneuvers (so they claimed), and could be adapted for low-level (500-foot) operations. Suggestions that would reduce prelaunch vulnerability included rotating the missiles between sites (more sites than missiles)

and deploying them on old aircraft carriers. But the crucial argument for Snark focused on low cost. About 1/8th to 1/10th the size of a B-52, the Snark cost as little as 1/20th as much as the Boeing bomber.[36] Simply put, the Snark was cost effective.

Meanwhile, the program lumbered along. Northrop designed the "D" model Snark as a recoverable vehicle equipped with a 24-hour stellar-inertial system. In the most visible change, Northrop added two pylon tanks carrying a total of 593 gallons of fuel to the wing. The overall result increased the Snark's empty weight from 16,616 pounds ("C") to 20,649 pounds ("D") and the gross flying weight from 36,074 pounds to 44,106 pounds. The N-69D first flew in November 1955, but did not accomplish its first successful stellar-guided flight until October 1956.

The "E" model followed shortly.* While Northrop cut 2,000 pounds from the "D's" empty weight, the "E" weighed 5,000 pounds more at gross flying weight. The company first launched the N-69E, the prototype vehicle for the SM-62 (the operational designation, "strategic missile"), in June 1957 (it crashed within seconds), initially with a workable rudder that it later deactivated. An Air Force crew launched its first Snark on 1 October 1957. These operations by SAC crews illustrated the Snark's severe problems. Of the first seven Air Force launches, only two reached the drop zone and only one of these impacted within four miles of the aiming point.[37]

The central problems remained guidance and reliability. While the first full-range test revealed that existing maps mislocated Ascension Island, this meant little to the Snark program because of the missile's gross inaccuracy. On flights out to 2,100 miles, the Northrop missile averaged a CEP of 20 miles. The most accurate of seven

Launch of SM-62A (N-3425) on 12 February 1960. (USAF)

*See Appendix A for missile specification.

Launch of SM-62A (N-3445) on 16 June 1960. Because of flight control failure, it stalled and crashed six minutes after launch. (USAF)

full-range flights between June 1958 and May 1959 impacted 4.2 nm left and .3 nm short of the target; in fact, it was the only one to reach the target area, and one of only two missiles to pass the 4,400 nm distance mark. Not until February 1960 did Snark successfully complete a guidance trial. Based upon the last ten launches in the program, the guidance system showed less than a 50 percent chance of performing to specifications. In addition, the guidance system, along with the control system, accounted for about half the test failures; the other half were attributed to random factors. Test results indicated that Snark had only a one in three chance of getting off the ground and only one of the last ten launches went the planned distance.[38]

Nevertheless, the Air Force began to incorporate the Snark into its inventory. In March 1957, Headquarters Air Force approved the selection of Presque Isle, Maine as the first operational Snark base; and that December, activated the 556th Strategic Missile Squadron at Patrick Air Force Base, Florida, the Snark's test site. The 556th Missile Squadron completed the first Air Force unit launch of a Snark in June 1958, shortly before USAF deactivated the unit. In January 1959, the Air Force activated the 702nd Strategic Missile Wing* at Presque Isle. It received its first Snark in May. But in November 1959, within a year of Power's request for a program evaluation, SAC recommended cancellation of Snark (the recommendation was endorsed by ARDC). Headquarters USAF, however, rejected that proposal. SAC put the first Snark on alert in March 1960, almost a year before the 702nd became operational in February 1961.[39]

But the Snark was living on borrowed time. Shortly after taking office in 1961, John F. Kennedy scrapped the project. Kennedy, in his budget message to Congress on 28 March 1961, requested the immediate phase-out of Snark,** calling the

*As the program shrank, the 702nd Strategic Missile Wing ended up operating the Snarks directly, without subordinate groups or squadrons.

**The President also drastically rearranged other defense programs. He stopped further deployment of the Titan ICBM (Interconti. ental Ballistic Missile), accelerated the phase out of B-47s, reduced the B-70 program from 12 to 4 bombers (effectively killing it), terminated the nuclear-powered aircraft, and cancelled the plan to place Polaris missiles on surface ships.

missile both obsolete and of marginal military value relative to ballistic missiles. The President cited the weapon's low reliability (a particularly sore point to his Secretary of Defense), inability to penetrate, lack of positive control, and vulnerable, unprotected launch sites. Thus, the Air Force deactivated the 702nd Strategic Missile Wing on 25 June 1961.[40] Surely the unit's and Snark's service must rank as one of the briefest in peacetime US military history.

The reasons for the demise of the Snark were linked with its air breathing companion, the Navaho. Therefore a fuller explanation and summary must await a discussion of that missile.

North American Navaho

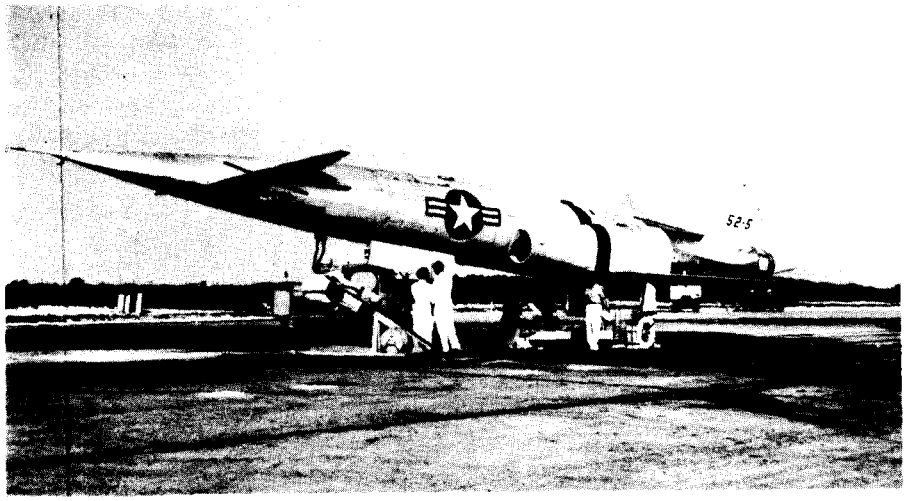
Concurrent with the Snark, another cruise missile had its brief moment in the sun. Compared to the Snark, the North American Navaho was much more dramatic and ambitious. Although the two air-breathing intercontinental missiles developed together, USAF planned to get the subsonic Snark into operations first, followed by the supersonic Navaho. Eventually, both would move aside for ballistic missiles.

In December 1945, the Technical Research Laboratory of North American Aviation submitted a proposal to the Air Force to continue German missile research, apparently in response to military requirements issued late that year. North American proposed a three stage effort: first add wings to a V-2, then substitute a turbojet-ramjet powerplant for the German rocket engine, and finally couple this missile with a booster rocket for intercontinental range. In April 1946, the Air Force bought the first part of this scheme under project MX-770, a 175- to 500-mile range surface-to-surface missile.[41] In July 1947, it added the 1,500-mile range, supersonic ramjet to the program. By March 1948, the program called for a 1,000-mile test vehicle, a 3,000-mile test vehicle, and a 5,000-mile operational missile. In 1950, the Air Force considered launching a Navaho from a B-36, an idea dropped the next year. Finally, in September, USAF firmed up the program, that is, not further changing it. The Navaho program called first for the design, construction, and test of a turbojet test vehicle, followed by a 3,600-mile-range interim missile, and culminating in a 5,500-mile-range operational weapon.[42]

USAF designated the first step, the turbojet test vehicle, the X-10. Two Westinghouse J40WE-1 turbojets powered the X-10, which first flew in October 1953. The missile was 70 feet long, configured with a canard, "V" tail, and 28-foot delta wing. Radio controls and landing gear permitted recovery. In all, 11 vehicles flew 27 flights. On the 19th test, the North American missile reached a maximum speed of Mach 2.05, establishing a speed record for turbojet-powered aircraft.[43]

Unfortunately, problems hindered the follow-on (interim) missile, the XSM-64,* and schedules slipped badly. In March 1952, USAF estimated that the first

*See Appendix A for missile specifications.



The North American X-10 was the test vehicle for the Navaho project. The missile's size, canards, and twin tail are visible in this picture of 52-5. (USAF)

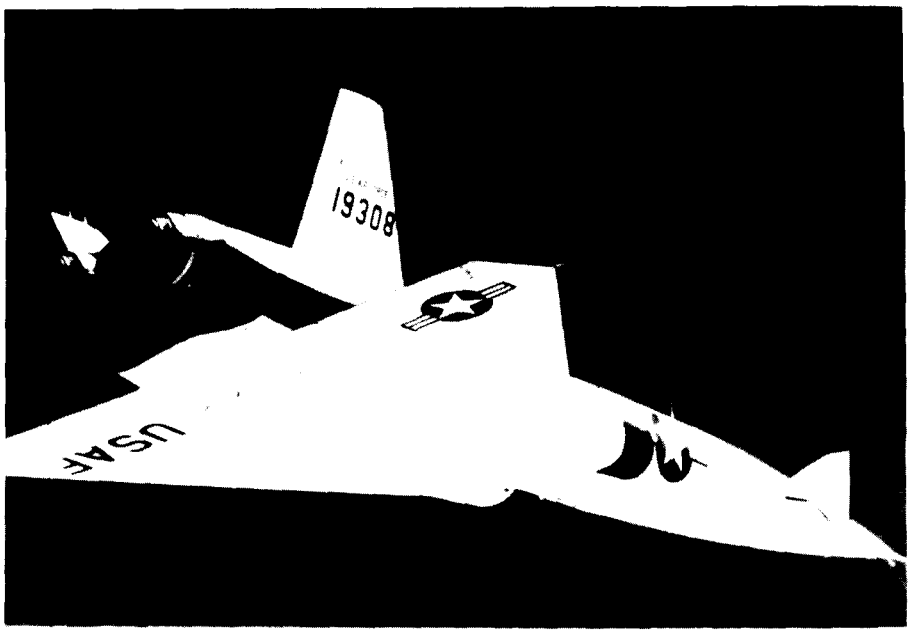
acceptance would occur in January 1954; it occurred in April 1956, 27 months late. Similarly, a January 1954 estimate expected the first flight in September 1954, a flight actually not attempted until November 1956. The first successful flight did not come until well into 1957. There was no single problem; difficulties seem to affect just about everything except the airframe. The most serious problems, however, centered on the ramjets and auxiliary power unit, the latter not operating successfully until February 1956.[44]

Between the summers of 1954 and 1955, USAF considered pushing the XSM-64 into operational service, but problems and delays in the basic program killed that idea. The Air Force did accelerate the Navaho program in late 1955, giving it a priority second only to that of the ICBMs (intercontinental ballistic missiles) and IRBMs (Intermediate Range Ballistic Missiles), aiming to get the intercontinental-range missile operational by October 1960.[45]

The XSM-64 resembled the X-10 in size and configuration. The big difference was a 76-foot, 3-inch long booster that was used piggy-back fashion with the XSM-64. Together, the two measured 82 feet 5 inches in length and were launched vertically.[46]

As impressive as the XSM-64 looked on paper and to the eye, in reality the system proved far different. The XSM-64 flight tests disappointed all, earning the project the uncomplimentary appellation, "Never go, Navaho." The first XSM-64 launch attempted in November 1956 ended in failure after a mere 26 seconds of flight. Ten unsuccessful launch attempts occurred before a second Navaho got airborne on 22 March 1957, for four minutes and 39 seconds. A 25 April attempt ended in an explosion seconds after liftoff, while a fourth flight on 26 June 1957 lasted a mere four minutes and 29 seconds.[47]

Takeoff of X-10 (GM 52-5) on 24 September 1958. This missile flew two successful tests in 1956; but on this test as a Bomarc target, it failed to engage the runway barrier, ran off the runway, and burned. (USAF)



X-10 (GM-19308) in flight. (USAF)

Little wonder then, with the lack of positive results, cost pressures, schedules slippages, and increasing competition from ballistic missiles, that USAF cancelled the program a few weeks later in early July 1957. The Air Force did authorize up to five more XSM-64 flights at a cost not to exceed $5 million. These tests, "Fly Five," occurred between 12 August 1957 and 25 February 1958. Although harassed by problems and failures, the vehicle exceeded Mach 3, with the longest flight lasting 42 minutes and 24 seconds. The final Navaho tests consisted of two launches in project RISE (Research in Supersonic Environment), which were equally unsuccessful. On the first flight on 11 September 1958, the ramjets did not start and on the second and last flight on 18 November 1958, the missile broke up at 77,000 feet. It cost the taxpayers over $700 million to gain less than 1½ hours of flight time. So ended the Navaho project.[48]

Nevertheless, USAF saw the Navaho project as a leap forward in the state of the art of missile technology. The Navaho required new technology that resulted in a complex missile. For example, aerodynamic heating (300° at Mach 2 and 660° at Mach 3) demanded new materials. North American used titanium alloys, much stronger than aluminum and yet 40 percent lighter than steel, as well as precious and rare metals at contact points on much of the electrical gear. Other untested technology and areas of risk included the canard configuration, ramjets, guidance, and the massive rocket booster. The situation required North American to develop and then manufacture these various pieces of new technology concurrently.[49]

On the positive side, although the Navaho did not get into service, some of its components did. Some went into other equally unsuccessful North American

The Navaho was larger than the X-10, and launched vertically. Here, it is lowered for mating to its booster on 5 March 1957. (USAF)

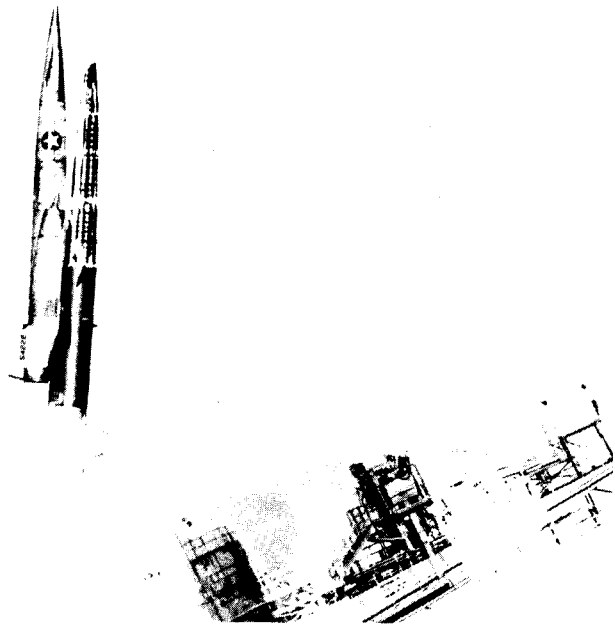
The next day, the pair were elevated to the vertical position. (USAF)

projects such as the F-108 and B-70. Others fared better. The Redstone used the rocket engine concept, and the Thor and the Atlas adapted the engine. The Hound Dog (see below), the nuclear submarine *Nautilus* for its epic under-the-ice passage of the North Pole, and the Navy's A3J-1 Vigilante bomber, all adapted the Navaho's inertial autonavigation system.[50] Therefore, while the Navaho proved costly, the program did have positive benefits.

But those successful adaptations cannot obscure the fact that Snark and Navaho failed to produce anywhere near the expected results. A number of reasons account for their demise. First and foremost, the technology of the day could not meet the ambitious requirements of accurately and reliably flying 5,000 miles over many hours without the intervention of pilot or navigator. Therefore, many of the missiles crashed or performed unreliably.

Second, the manufacturers failed to master the situation. Overly optimistic estimates and loose management led to cost overruns and schedule slippages. All-in-all, the record of American industry in these two programs is not a glorious one, for the private sector failed to produce a viable weapon despite promise, priority, and considerable money. One student of the US missile program sums up the dismal story: "At the end the Snark was a technological delinquent made up of indifferently compatible subsystems."[51] The same, of course, applies to the Navaho. The inability to recognize these technological defects early enough and appropriately respond, Robert Perry asserts, helps explain the fate of both. Significantly, he found no evidence that financial factors hurt either program. Crashes may be an unfortunate part of the process of gaining aeronautical knowledge and perfecting a new technology, but the chronic failures and crashes of

The third Navaho (AF 53-8272), "launched" on 25 April 1957, fell back on the pad and exploded. (USAF)



The last Navaho launch was in the RISE program on 18 November 1958. It broke up at 77,000 feet. (USAF)

the Snarks and Navahos revealed severe deficiencies of missile technology, design, and production.[52]

These problems* delayed the development of the cruise missile, thereby upsetting the sequence which planned for the cruise missile to precede, not coincide with the ballistic missiles. This coincidence in timing led to competition between the two types of missiles, the third factor in the demise of the Snark and Navaho. For the ballistic missile proved it could do the same job as the cruise missile, and do it better. In the final analysis, the cruise missile just could not successfully compete with either the old and proven technology (bomber) or the new and unproven one (ICBM).

At this time, the cruise missile seemed to offer only two advantages over the manned bomber. First, it appeared to be cheaper. "Appeared," because a lower percentage of cruise missiles launched would have penetrated to the target than bombers, and those that did would have impacted further from the aiming point than would bomber weapons. Second, man was not put at risk, a very important consideration in the American style of warfare that emphasized reliance on machines to minimize risk to men.

But the list of disadvantages overwhelm these two advantages. The technology of the 1950s produced a cruise missile that looked like an aircraft, but which performed less well. Cruise missiles could fly as high and as fast as bombers, and far enough, but they lagged in a number of other areas. First, compared with the bomber, they were inflexible. A bomber can be recalled, rerouted in flight, used as a show of force, or used in a nonnuclear conflict. It can hit numerous targets, targets of opportunity, and report back its observations. The bomber is reusable. Second, cruise missiles were vulnerable. They could not defend themselves with either maneuver or active defenses, as they essentially fly straight and level at a constant speed. Third, cruise missile accuracy was much less than that of a bomber. Fourth, taking man out of the loop with this level of technology left serious reliability problems. In contrast, bombs and bombers were proven, reliable weapons. As General LeMay put it, missiles could not replace bombers because missiles could not think.

Moreover, the airmen's prejudice against the unmanned weapon cannot be overlooked. As one Air Force officer wrote in 1954:

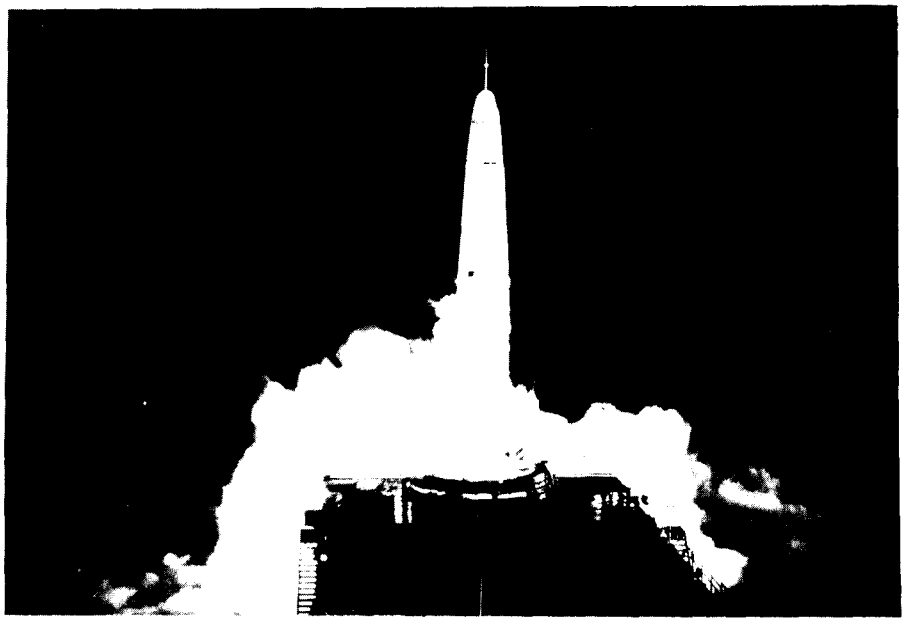
> Unfortunately, the actual reaction within the Air Force [to the guided missile] appears to be the exact opposite of that which might logically be expected. The attitude of Air Force personnel, individually throughout the Air Force and collectively in the major commands, seems to best be described as a combination of skepticism, indecision, and indifference. This is a sweeping statement, but it appears to be well supported by the facts.[53]

General Thomas D. White, Chief of Staff of the Air Force, agreed. In a commander's conference in 1957, he noted that some believed the airmen to be as wedded to the airplane as the cavalrymen was to the horse. "The senior Air Force

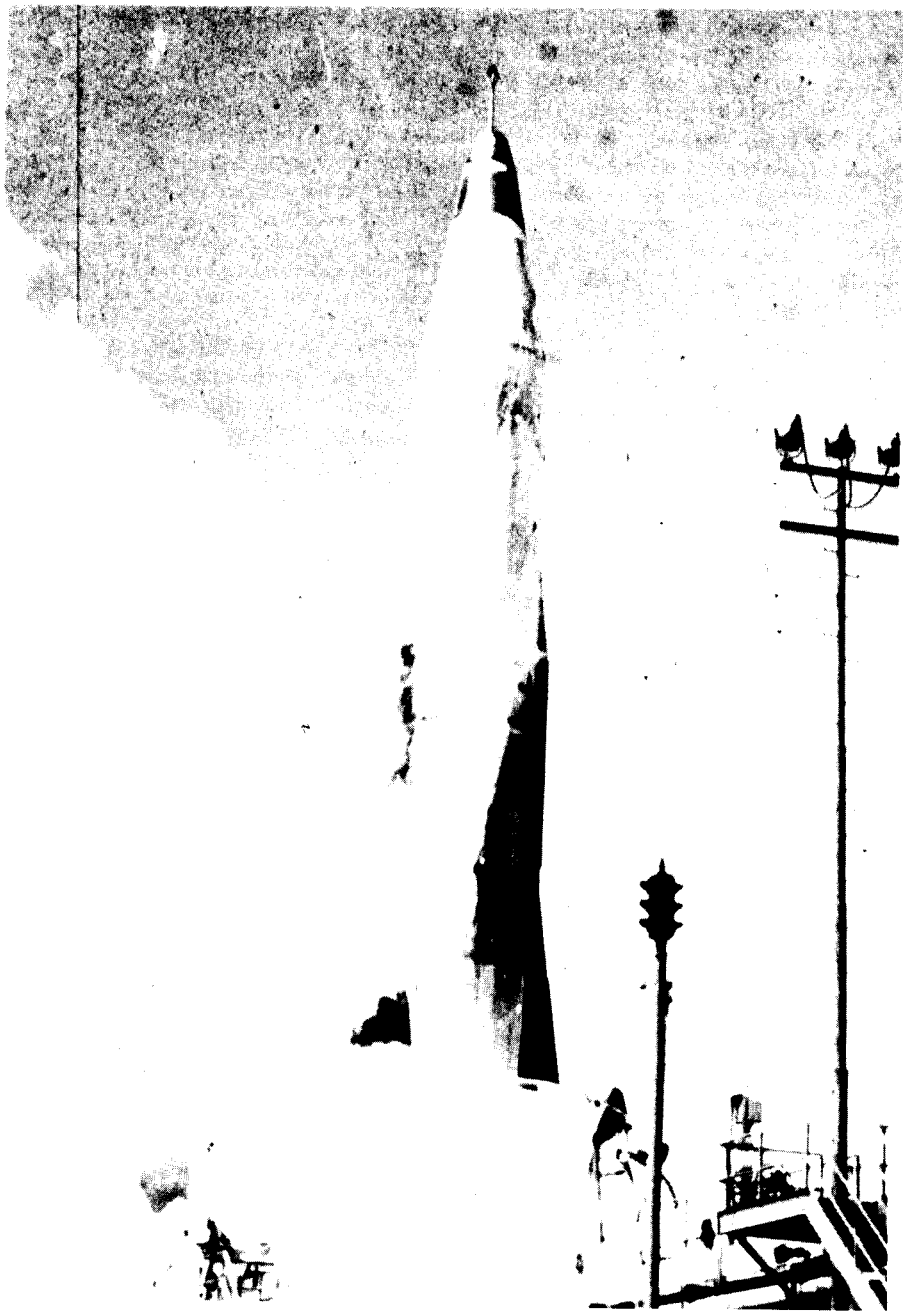
*The new requirements that swept the N-25 aside for the larger and more difficult N-69 also hurt the Snark program. As a result the program lost considerable time (38 months between the first flight of each). This overstates the impact somewhat, however, as difficulties with the guidance system as well as airframe sank the program.

officer's dedication to the airplane is deeply ingrained, and rightly so," White told the generals, "but we must never permit this to result in a battleship attitude. We cannot afford to ignore the basic precept that all truths change with time."[54] He admitted that USAF belatedly realized the potential of missiles and insisted that his top commanders remain flexible and ready to adopt superior technologies, once proved. White put forth a guide (namely, the USAF position) for top level thinking and activities regarding missiles. First, USAF must admit that the missile was here to stay since it should be a highly effective weapon. Second, USAF wants to get into the missile business as quickly as possible despite the constraints of money and technology. Third, once missiles proved themselves they would be quickly integrated into the Air Force.[55] Finally, White commented that cruise missiles were inferior to ballistic missiles; many missilemen saw the air breathers as nothing more than a stopgap weapon.[56]

Nevertheless, the intercontinental ballistic missile also got off to a slow start. The Convair Atlas began in 1945, but the program dried up in 1947 due to restricted funds and low priorities. Although subsequently revived, it was clearly secondary to USAF's two cruise missiles as made clear by missile funding. During fiscal years 1951 through 1954, the Atlas program received $26.2 million, while the Snark and Navaho got a total of $450 million. Prior to 1952 or 1953, the Air Force favored the winged cruise missile over the wingless ballistic missile despite quantitative studies indicating that the former would be less accurate and dependable, as well as more costly than the latter. The primary reasons for this situation seemed to be emotional and cultural resistance. As one student of the missile program of these years writes:



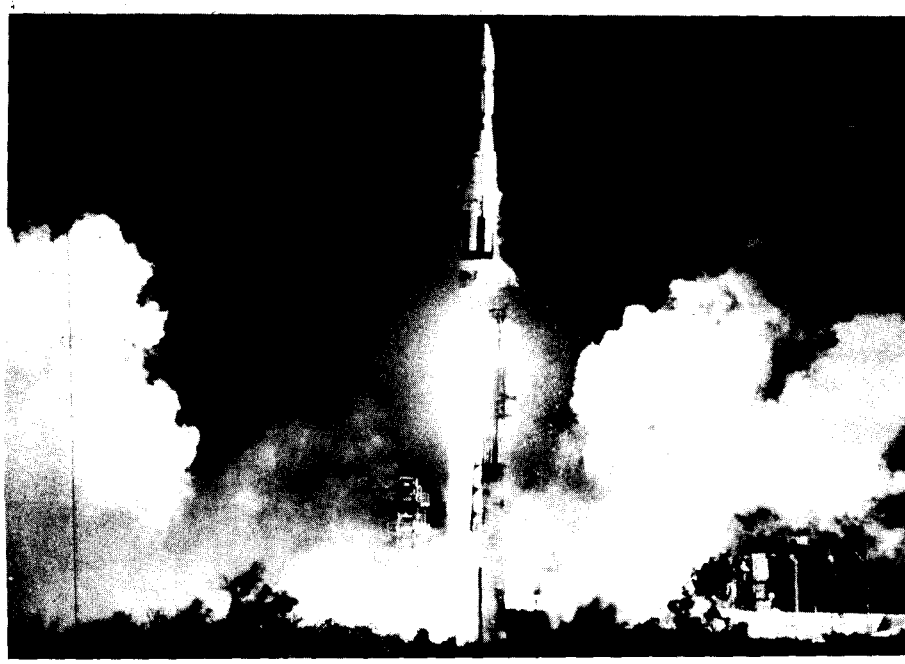
The ballistic missiles overcame the cruise missiles in the late 1950s. Here a Thor IRBM is prepared for its first flight on 23 January 1957. (USAF)



The first American ICBM to fly was this Atlas on 11 June 1957. (USAF)

> To people who had grown up with the manned bombers before and during World War II and who had mostly stayed with them through the early part of the next decade, a cruise missile was a less painful and certainly a less abrupt departure from what they were familiar with than would be a totally alien ballistic missile. Those who favored the evolutionary approach to the creation of a new generation of weapons, predominantly missiles, were people to whom aircraft had a meaning as a way of life, a symbol, a preferred means of performing a military assignment.[57]

Emotion did give way to reality. In October 1953, the Air Force learned that a megaton-class warhead weighing 1,500 to 3,000 pounds would become available shortly, making the ICBM much more feasible and encouraging its development. Studies conducted in December 1953 and February 1954 indicated that the Atlas could be operational by 1960. Probably as important, the decisionmakers learned of the energetic Soviet efforts in the ICBM field and thus, in July 1954, the Air Force assigned the highest priority to ballistic missiles. Despite the clamor over Sputnik, launched in October 1957, and fears of a missile gap, the Russian ICBM missile threat proved, in retrospect, to be overstated. Regardless, the American ICBM program got the top level support it required. As a result, the Americans launched their first medium-range ballistic missile (Thor) in January 1957, the first Atlas in June 1957, and the first Titan (another liquid-fueled ICBM) in February 1959. The Atlas became operational in September 1959 and went on alert in October, five months before the Snark.[58] The ballistic missile had passed the cruise missile. There were significant performance differences as well.



The first Titan ICBM flight was on 6 February 1959. (USAF)

Another important ballistic missile was the Navy's Polaris. (USAF)

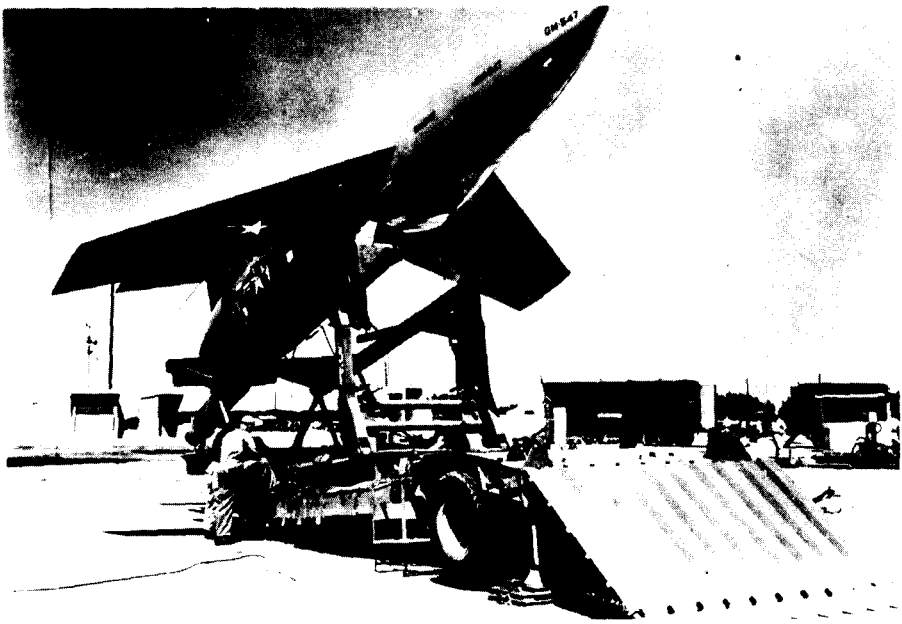
At first glance, the two appeared to have relatively comparable capabilities; that is, they both could deliver nuclear warheads over intercontinental distances. But closer examination of these weapons systems reveals something else. In the 1950s, the ICBMs had an edge in accuracy due primarily to their much shorter flight time. (Inertial guidance accuracy depends on flight time, the longer the flight the less accuracy.) Second, the Snark and Navaho test record indicates that their reliability was also substantially less than that of the ICBM's. Probably the only major advantage the cruise missile had over the ICBM was cost.

Three additional factors probably explain the triumph of the ICBM over the cruise missile. First, the ICBM got to the target much faster than did the cruise missile, in minutes as compared to hours. (A rough estimate for the time required to fly the 5,000 to 6,000-mile mission would be on the order of one-half hour for the ICBM, compared to the Snark's 10 to 11 hours.) Second, once launched the ICBM was invulnerable to countermeasures, while the cruise missile could be downed by fighters and, increasingly after 1960, by surface-to-air missiles. A third factor was political-psychological. While the ICBM was a new weapon, the cruise missile physically resembled the bomber. Perhaps the greatest impetus was psychological. The fact that the Soviets had made so much of the Sputnik forced the United States to counter with some sort of equally modern and impressive weapon. So, for domestic and foreign political/psychological reasons, the United States needed ballistic missiles.

In the end, American industry failed to produce a cost-effective cruise missile relative to either the bomber or ballistic missile. In contrast, industry successfully, if not brilliantly, managed the ballistic missile program—which accounts for much of the ICBM's success. As a consequence, the land- and sea-based ballistic missiles took over the field of strategic missile delivery, which they continue to dominate. Cruise missiles, however, served well in other roles.

The Martin Matador

The third important USAF cruise missile under development in the 1940s and 1950s was the Martin Matador. In August 1945, the AAF established a requirement for a 175- to 500-mile range 600 mph surface-to-surface missile. Martin received a one year contract in March 1946 to study both a subsonic and supersonic version, but the military deleted the latter in December. Despite its subsonic speed, the Martin missile survived the 1947 cut. In March 1949, however, the Guided Missile Committee of the Research and Development Board recommended its elimination. The Matador continued, although USAF cut it back in August 1949. The Air Force rescinded that decision in December 1949 and then in September 1950 gave the missile top priority, no doubt because of the Korean War.[59]



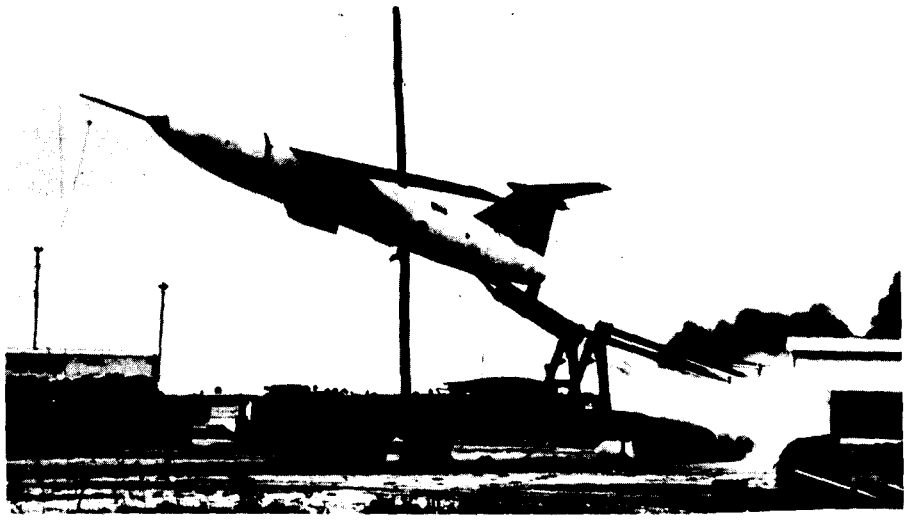
The Martin Matador was smaller than the Snark, and launched from a mobile launcher It flew successfully for the first time on 19 January 1949 at Holloman Air Force Base. (USAF)

The Matador possessed about the same size and looks as a contemporary jet fighter.* A booster generating 57,000 pounds of thrust for 2.4 seconds got the 12,000-pound missile airborne and up to a flying speed of 200 mph from a zero-length launcher.[60] Powered by a 4,600-pound-thrust J33-A-37 engine, the missile (designated TM-61A) carried a 3,000-pound warhead over 650 mph to a maximum range of 620 miles.[61]

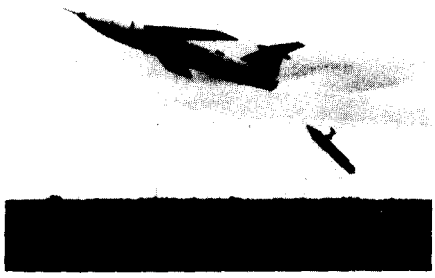
Testing of the Matador began at Holloman Air Force Base with the first flight on 19 January 1949. Like so many of the missiles, the initial flight ended in a crash. Testing continued with 46 prototype missiles until March 1954, then with 84 production models between December 1952 and spring 1954. Between August 1953 and February 1954, USAF tested a second series of missiles with strengthened tail and wings to alleviate structural problems.[62]

The Matador's guidance system presented another problem because the guidance radar's range proved less than the missile's flying range. This guidance system required a ground-based operator to track and guide the missile, which, with line-of-sight communications, limited guided range to 250 miles. In late 1954, USAF added a guidance system called Shanicle and redesignated the missile TM-61C. In this system, the missile automatically flew a hyperbolic grid.[63] Based upon results of 74 TM-61Cs launched on the Atlantic missile range between April 1957 and September 1960, USAF calculated the missile's overall reliability at 71 percent and CEP at 2,700 feet. However, these accuracy figures included student launches;

*See Appendix A for missile specifications



This Matador (#11042) launch on 17 November 1952 was the first for the B-61A. (USAF)

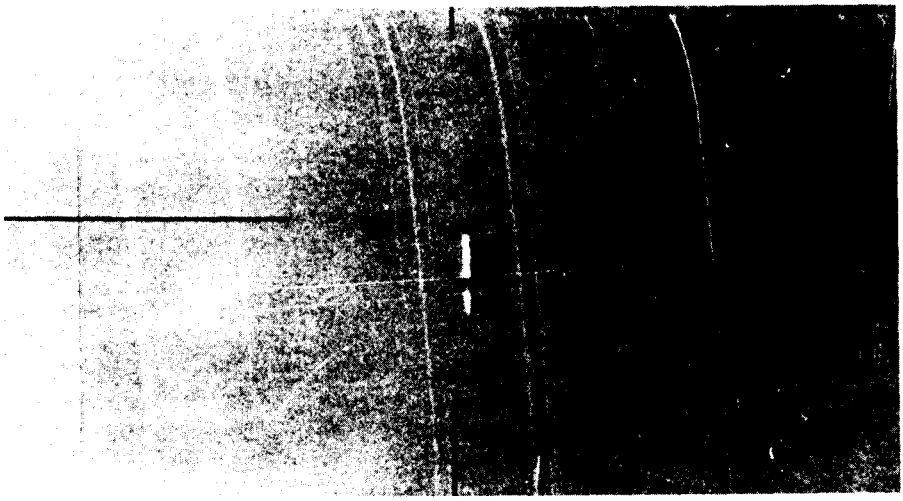


The missile's JATO unit malfunctioned, penetrating the missile . . . (USAF)

. . . causing the Matador to impact 400 feet from launch. (USAF)

instructors achieved CEPs of 1,600 feet.[64] But Shanicle still limited the range of TM-61C to that of line-of-sight transmissions; moreover, this guidance system could be jammed. To break this dependence, the Air Force installed a third guidance system.

The Goodyear Aircraft Corporation developed ATRAN (Automatic Terrain Recognition And Navigation), a radar map-matching system. The company began lab tests in March 1948, flight tests in October of that year. Martin showed little initial interest, but problems with the Matador's guidance necessitated a change. In



The Matador had difficulties with the terminal dive phase. Here, GM-11081 is 175 feet above impact at Grand Bahama on 4 August 1953. It was the first of the structurally reinforced B-61As. (USAF)

August 1952, Air Materiel Command initiated the mating of the Goodyear ATRAN with the Martin Matador. This mating resulted in a production contract in June 1954.[65] ATRAN could not be easily jammed and was not range-limited by line-of-sight, but its range was restricted by the availability of radar maps and missile range. Although in time it became possible to construct radar maps from topographical maps, ATRAN initially performed poorly.

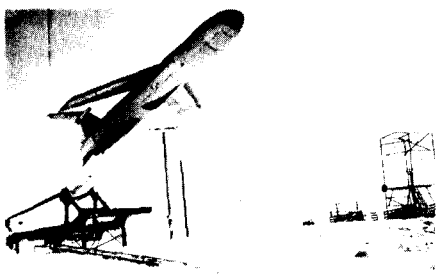
USAF installed ATRAN in the TM-61B variant, nicknamed Mace.* The missile differed from the "A" and "C" models in more ways than just designation and name. Mace had a longer fuselage, shorter wings, and more weight than the "A" and "C." The Mace also had more power, with its 5,200-pound-thrust J33-A-41 turbojet engine and a 97,000-pound-thrust booster. It first flew in 1956 and could reach Mach .7 to .85 over a 540-mile range at low level (as low as 750 feet), and 1,285 miles at high altitude. Because of these substantial differences of configuration and capability, the Air Force redesignated Mace TM-76A. But these improvements did not come cheaply; the TM-76A cost about $250,000, compared to $60,000 for the TM-61C. USAF installed a different navigation system, inertial guidance, aboard a Mace (designated TM-76B) which had a range exceeding 1,300 miles.[66]

Meanwhile, the Air Force took action to get the missile into the field by activating the 1st Pilotless Bomber Squadron in October 1951. This unit went to Germany with TM-61As (Matadors) in March 1954 and became operational in 1955. USAF deployed the Mace in Europe in 1959, and it served alongside the Matador before the latter phased out in 1962. Eventually, six missile squadrons (comprising the 38th Tactical Missile Wing) served in Europe with just under 200

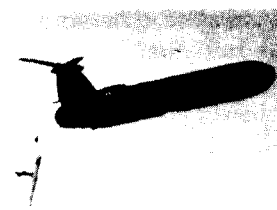
*See Appendix A for missile specifications.

TM-61s and TM-76s. But the missile proved less than satisfactory. Missile firings in Florida and Libya dramatically demonstrated low reliability and poor accuracy. Nevertheless, the Matador soldiered on. USAF deactivated the last unit, the 71st Tactical Missile Squadron, in April 1969 as the Army's Pershing missiles took over the Quick Reaction Alert Force role.[67]

In Korea, the 58th Tactical Missile Group became combat ready with 60 TM-61Cs in January 1959. It ceased operations in March 1962, only a few months after the 498th Tactical Missile Group in December 1961 took up positions in semi-hardened sites on Okinawa. These two squadrons of TM-76B/MGM-13C continued on active duty until December 1969.[68]



Mace launch on 11 February 1960. The B-61B Mace was larger and heavier than the B-61A Matador. (USAF)



Mace dropping booster on 11 February 1960. (USAF)

Like the other guided missile programs, numerous problems beset the Matador/Mace project. Production, engines, and most of all, guidance, were especially troublesome. The Martin Company must bear much of the responsibility for these difficulties. In 1953, the USAF Project officer wrote that the "Martin Matador program was delayed excessively because of [Martin's] poor design, inadequate testing, and difficulty in retaining qualified people."[69] Throughout its service, observers criticized the Matador for its low inflight reliability, high CEPs, and questionable control over long distances. A 1956 study noted that USAF did not develop Matador according to procedures and military requirements, but rather devised the missile around existing components and techniques. Further, at the time the Air Force initially deployed the Martin missile, the weapon had not demonstrated operationally acceptable performance and required major modifications.[70]

Moreover, the Matador's limited mobility concerned the Air Force. With the prodding of the Wright Air Development Center, Goodyear developed a combination transporter/launcher. The new equipment cut both launcher weight (from the original 40 tons to 17½), and the number of different type vehicles required to support the missile (from 28 with the Matador to 2 with the Mace). To enhance mobility, Martin designed the Mace's wings to fold for transport (the Matador's wings were transported separately and then bolted on for flight).[71]

Navy Programs

The Navy was, of course, also interested in missiles. As already described in Chapter III, the Navy was deeply involved with the American adaptation of the V-1, the JB-2, or as the Navy referred to it, the Loon. Even before this activity, in July 1943, the Navy designated the Navy Aircraft Factory at Philadelphia to handle a guided missile project code named Gorgon. In this effort, the Navy developed a bewildering number of missiles, some rocket-powered (Gorgon IIA, IIIA, IIIC), some turbojet-powered (Gorgon IIB and IIIB), some pulsejet-powered (Gorgon IIC and Pollux), and one ramjet-powered (Gorgon IV). While most of these need not detain us, as they are either rocket-powered or air-to-air missiles, three are of interest to this study.

At first, the Gorgon IIC (also known as JUN-1, CTV-3, KDN-1) received the most emphasis after the Bureau of Aeronautics (BuAer) initiated the ship-to-shore, pulsejet-powered device in May 1945. By the end of January 1946, the Navy planned to use the missile in combat from escort carriers and landing craft supported by a production rate rising from 200 a month in December 1945 to 500 a month by April 1946. Except for its canard configuration and guidance, Gorgon IIC resembled the V-1, with its 14-inch pulsejet mounted above an 18-foot fuselage and straight wing which spanned 11 feet. After a catapult launch got the 1,688- to 1,984-pound missile airborne, it flew about 400 to 450 mph under radio control approximately 60 to 90 miles to its target. The first successful flight occurred in September 1946. In the late 1940s, the Navy tested 35 to 100 of these missiles.[72]

Also during the 1940s, Martin built another surface-to-surface missile, the Gorgon IV (also known as the KUM-1). The company delivered eight of the conventionally configured and ramjet-powered missiles. It first successfully flew after an air launch in November 1947.

The last vehicle in the Gorgon program was named Pollux. It differed in two ways from the Gorgon IIC. First, the builders mounted the pulsejet underneath its 28-foot fuselage. Second, the missile's wings (spanning 10 feet) were swept back at a 35 degree angle. The 2,350-pound missile first flew in October 1948. But two months after its third and last free flight in December 1950, BuAer cancelled the entire Gorgon project.[73]

Regulus I, Rigel, Regulus II, Triton

In October 1943, Chance Vought signed a study contract for a 300-mile range pilotless missile that carried a 4,000-pound warhead. But little transpired until the soon-to-be-separated AAF provided the impetus for the Navy Program. In May

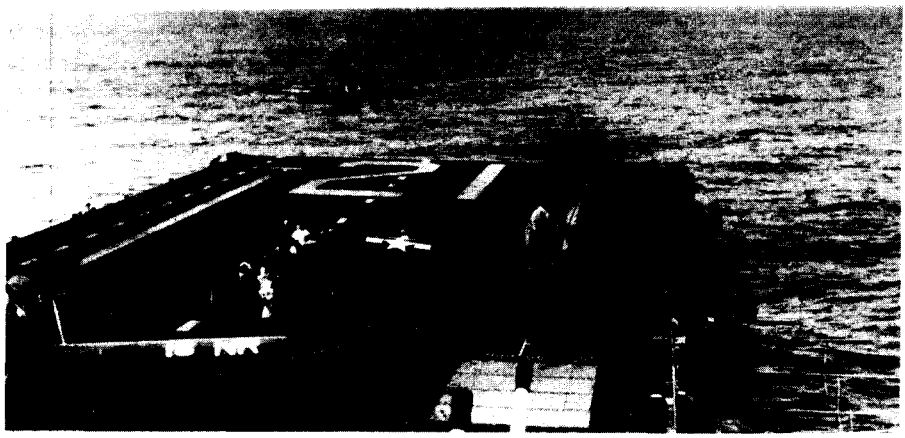
1947, the Army airmen awarded Martin a contract for a turbojet-powered subsonic missile which became the Matador. The Navy saw this as a threat to its role in guided missiles and, within days, ordered BuAer to start a similar Navy missile that could be launched from a submarine, using the same engine as the Matador (J33) and components on hand. By August 1947, the project had gained both a name (Regulus) and performance requirements. The Navy wanted the missile to carry a 3,000-pound warhead to a maximum range of 500 nm at Mach .85 with a CEP of .5 percent of the range. The vehicle would be 30 feet in length, 10 feet in span, 4 feet in diameter, and would weigh between 10,000 and 12,000 pounds.*[74]

Another factor fostering the development of the Regulus program, and which became increasingly important, was the Navy's desire to deliver a nuclear weapon. The Navy's problem centered on the heavy weight of atomic weapons in the late 1940s (about five tons), just too heavy for almost all carrier-launched aircraft. The Navy converted twelve P2Vs (twin-propeller-powered patrol bombers) for such a role, but while they could take off from carrier decks, they could not land on them. Only the AJ Savage could do both. The Navy converted the North American bombers for nuclear delivery, but they were limited in range to about 800 miles. Captain Fahrney, of World War II drone fame, proposed a pilotless version of the AJ with a range of about 1,400 nm. But the Navy cancelled this TAURUS project in 1948. So despite mechanical and tactical limitations, the AJ represented the only carrier aircraft capable of delivering a nuclear weapon in the early 1950s. New urgency to develop nuclear delivery systems followed the Soviet nuclear test in the summer of 1949. Therefore, the Military Liaison Committee to the Atomic Energy Commission recommended consideration of Regulus along with three other missiles for this role.[75]

Certainly interservice competition complicated the missile's development. Navy's Regulus and USAF's Matador not only looked alike; their performance, schedule, and costs were about the same, and they used the same engine. With pressure to reduce defense spending in 1949, the Department of Defense (DOD) impounded fiscal 1950 funds for both missiles. Because most observers considered Matador to be about a year ahead of the Regulus, DOD ordered the Air Force to determine if Matador would indeed work, and BuAer to slow development of Regulus and fund a study to determine if Matador could be adapted for Navy use. But the Navy successfully argued that Regulus could perform the Navy mission better than could Matador. Regulus advocates pointed to its simpler guidance system which required only two stations (submarines) while the Matador required three. Also, the Matador's single booster had to be fitted to the missile after it was on the launcher while, in contrast, the Regulus was stowed with its two boosters attached. This meant that in comparison to the Regulus, the Matador would require more men and machinery and that the submarine had to remain on the surface longer, thereby increasing its vulnerability to enemy action. In addition, Chance Vought built a recoverable version of the missile, which meant that while each Regulus test vehicle cost more than the Martin missile to build, Regulus was cheaper to use than Matador over the series of tests. While some of the Matador's

*See Appendix A for missile specifications.

problems would doubtlessly have been resolved, the Navy insisted on a separate program; and in June 1950, the joint service Research and Development Board concurred.[76] The Navy program continued.



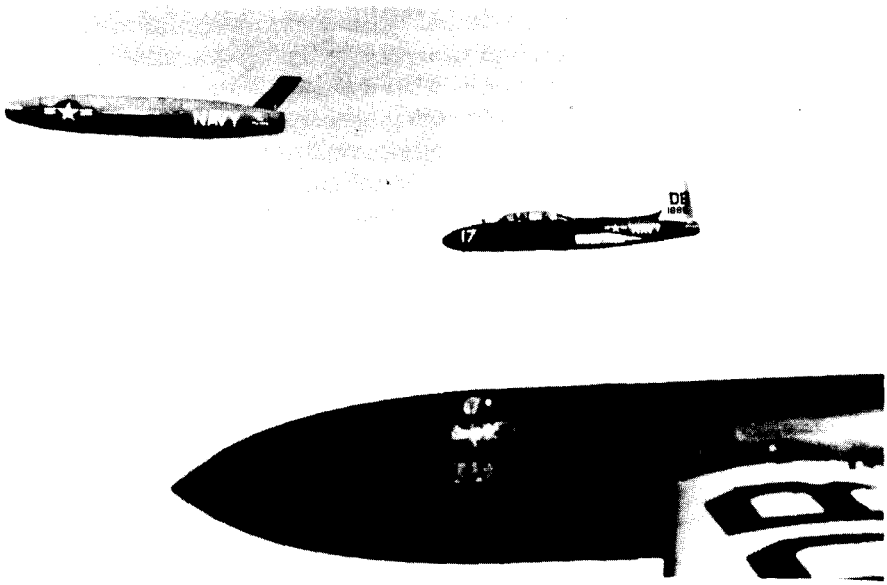
During the Korean War, the Navy employed F6F-5Ks as assault drones, but only one of six launched scored a hit. Here a drone clears the deck of the USS *Boxer* in August 1952 as its mother ship, an AD4-Q, prepares to launch from the right catapult. (National Archives)

The Navy's Chance Vought Regulus I missile, similar in many respects to the Matador, used the same (J33) engine. (USN)

Two 33,000-pound-thrust boosters launched Regulus, which first flew in March 1951. The first submarine launch of Regulus occurred in July 1953 from the deck of the USS *Tunny*. After such a launch, the Navy guided the Regulus toward its target by two other submarines and, later, with the Trounce system, one submarine. Regulus could also be launched from surface ships. Cruisermen were enthusiastic about this weapon which would extend both their offensive range and mission. The lack of a capability to pass control of the missile from the cruisers and submarines, however, limited the weapon. The Navy also launched the missile from carriers and guided it with a control aircraft. Problems included booster launch (the launcher weighed eleven tons and sometimes spectacularly malfunctioned), control aircraft (which lacked adequate speed and range to do the job), and the entire radio control system. Engineers resolved these problems but naval aviators, like their Air Force brethren, strongly preferred aircraft and this preference may well have undermined the Regulus program.[77]

Regulus I, launched from the USS *Halibut* (SSGN-587) on 31 March 1960. The Navy fired Regulus I from a variety of ships and it eventually served aboard aircraft carriers, cruisers, and submarines. (USN)

Nevertheless in 1955, Regulus became operational, eventually serving aboard diesel- and nuclear-powered submarines, cruisers, and aircraft carriers. The last versions of the missile could carry a 3.8 megaton warhead 575 miles at Mach .87. Regulus phased out of production in January 1959 with delivery of the 514th missile. The Navy launched perhaps 1,000, obviously including many of the recoverable versions, before it took Regulus out of service in August 1964.[78] Admiral Zumwalt calls that decision the "single worst decision about weapons [the Navy] made during my years of service."[79] But careful examination of Regulus reveals few advantages over the V-1. While the Chance Vought flew somewhat further and faster, American guidance was not much better than the earlier German



Regulus I in flight, 10 April 1956. (National Archives)

missile guidance system. The principal American missile improvements were the nuclear warhead and increased reliability.

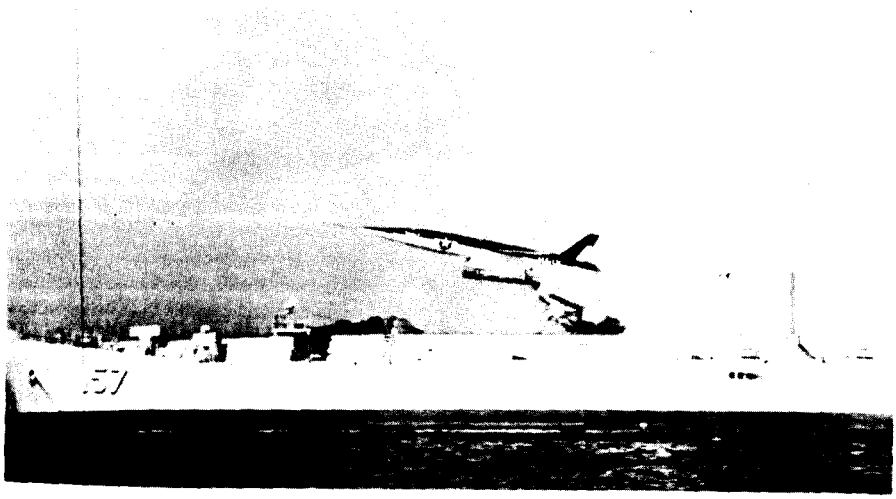
Another Navy cruise missile of this period was the Grumman Rigel. In May 1950, the Navy planned to get the Regulus operational in 1953, Rigel operational in 1955, and the "ultimate cruise missile," the Triton, operational in 1960. Plans called for a Marquardt ramjet to power Rigel, whose all-up weight was 19,000 pounds with booster. The missile was designed to fly 400 to 500 nm at Mach 2. However, because there were no facilities large enough to test the 48-inch ramjet, the testers used a 28-inch version. This powered a six-tenth's scale test model which first flew in March 1950. But the program encountered what proved to be insoluble problems. By October 1952, 11 of the flight tests had failed. Therefore, the Navy cancelled Rigel in August 1953.[80]

With the demise of Rigel, the Regulus successor became another Chance Vought product designated Regulus II*. In March 1954, the Navy planned to have Regulus II operational by 1957 and Triton operational in 1965. Vought began design of the supersonic winged missile in April 1952, receiving a development contract in June 1953. Thirty-six months later, the first Regulus II flew when a 115,000-pound-thrust booster launched the canard-configured missile. Regulus II could carry its 2,920-pound warhead 570 nm at Mach 2, and over 1,150 nm at reduced speeds.[81] One suggestion in 1957 was to fit wing tanks on the missile to extend its range.

The Navy successfully tested a recoverable Regulus II test vehicle in 30 of 48 tests, achieved partial success in 14, and failed in only 4. The government signed a production contract in January 1958. That September the Navy fired a Regulus II

*See Appendix A for missile specifications.

The Navy planned to replace the Regulus I with the Regulus II. A recoverable version of the latter was very successful, shown landing at Edwards AFB on 19 March 1958. (USN)



The Regulus II in its first launch from a surface ship, the USS *King County* (AG-157), on 10 December 1958. (USN)

This view of Regulus II clearly shows its long lines and its canard configuration. The Navy cancelled the missile in December 1958. (USAF)

from the submarine *Grayback,* the only such launching. The Navy scheduled one other snorkel submarine to be equipped with Regulus II, along with four cruisers, and planned in 1956 to eventually put Regulus on 23 submarines. But on 19 November 1958, the Office of the Secretary of Defense withdrew its support from the program; and on 18 December 1958, Secretary of the Navy Gates cancelled the project. At that point, Chance Vought had completed 20 of the missiles with 27 others still on the production line. The missile's cost (one million dollars each), budget pressures, and the greater attractiveness of alternative nuclear delivery systems doomed Regulus.[82]

Indeed, a number of technological developments in the 1950s helped push the cruise missile aside. The most important was a smaller and more powerful thermonuclear weapon. Another development was in naval aviation. The evolution of aircraft carriers, with such innovations as slanted deck, steam catapult, and nuclear propulsion, allowed the operation of heavier and higher performance jet-powered aircraft off carrier decks. The Navy also developed the nuclear-powered submarine and the Polaris ballistic missile.

Thus, the "ultimate cruise missile," the Triton, did not appear. It was to have a 12,000 nm range, fly at Mach 3.5 at 80,000 feet, be guided by radar map-matching, and deliver a 1,500-pound warhead within 600 yards of its aiming point. It entered full-scale development in 1955, but never got into production.[83]

The Crossbow

USAF developed two other categories of cruise missiles during the 1950s: air-to-surface and decoy. During World War II, the AAF had paid some attention to guided bombs but very little to powered air-launched missiles with the exception of the air-launched V-1/JB-2. As we have seen, the Navaho was briefly considered for this role; but there is little to refute the notion that in the minds of most Air Force officers during this period, strategic air campaigns would be waged by the tried and true: the manned penetrating bomber.

In the early 1950s, Radioplane responded to a USAF request for a missile to home in on and destroy enemy ground radar. The government awarded a contract (in March 1953) to Radioplane, despite the company's limited experience and personnel. The GAM-67* had a low and straight wing and twin tail, and carried a 1,000-pound warhead. SAC planned to load at least four GAM-67s on their bombers and launch the GAM-67s outside enemy radar range at about 34,000 feet. Then the Crossbow would climb to 40,000 feet and fly at 480 knots to about seven miles from the radar, where the missile would make a 30-degree power-on dive into its target. Specifications called for 75 percent of the devices to impact within 75 feet of the target. The weapon's estimated range was 247 nm.

The Radioplane Crossbow (GAM-67) was designed as an air-to-surface missile. It flew under its own power for the first time in March 1956, about the time of this photograph. (USAF)

*See Appendix A for missile specifications.

Crossbow tests began at Holloman in December 1955, with the first powered flight occurring in March 1956, the first successful flight (lasting 18 minutes) on 2 July 1956, and the first guided flight in May 1957. But because of financial pressure, Headquarters Air Force cut the program back in November 1956 to emphasize guidance. In addition to money problems, the Crossbow flew 50 mph slower than expected and had less range than Soviet radar. Thus, the Air Force Chief of Staff cancelled the project in June 1957. Ironically, the weapon had its greatest success about three weeks later (26 June 1957), flying through the target's radar antenna.[84]

The Hound Dog

In March 1956, Headquarters Air Force issued a General Operations Requirement (GOR 148) for an air-to-surface missile for the B-52. In August 1957, Secretary of the Air Force James H. Douglas telephoned J. H. Kindelberger of North American Aviation to tell him that his company had won the contract. In February 1958, growing concern about both the perceived unfavorable shift in the strategic balance and the increasing vulnerability of penetrating bombers prompted USAF to accelerate the weapon that came to be called the Hound Dog.* The missile, first designated GAM-77, then AGM-28, initially flew in April 1959.[86]

North American built the Hound Dog** with a canard, a delta wing configuration, and an underslung J52 engine. The design requirements called for a 350-mile range and Mach 2 speed at over 55,000 feet. The AGM-28B carried a 1,742-pound warhead (four megatons) 652 nm in a high-level profile, 340 nm in a low-level (1,000 feet at Mach .83) profile. A B-52 could carry two of the inertially-guided missiles.[87]

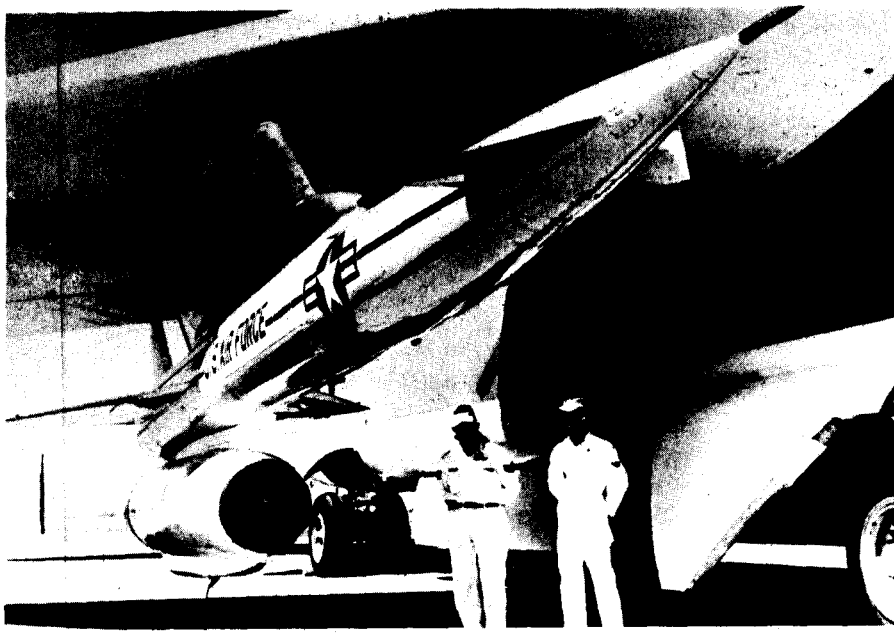
North American delivered the first production Hound Dog in December 1959. SAC launched its first AGM-28 in February 1960; by the following July, one wing was operational with the weapon, although the first airborne alert with it did not take place until January 1962. SAC crews soon found that they could shorten B-52 takeoff rolls by using the Hound Dog engines in addition to the bomber's eight engines. (Bomber fuel could later be transferred to the missile.)

Accuracy, while exceeding one nm at full range, was probably adequate considering the four megaton warhead. But two other problems hindered the missile. Reliability was a constant concern and in addition the two five-ton missiles, carried on pylons, degraded B-52 flight performance.[88]

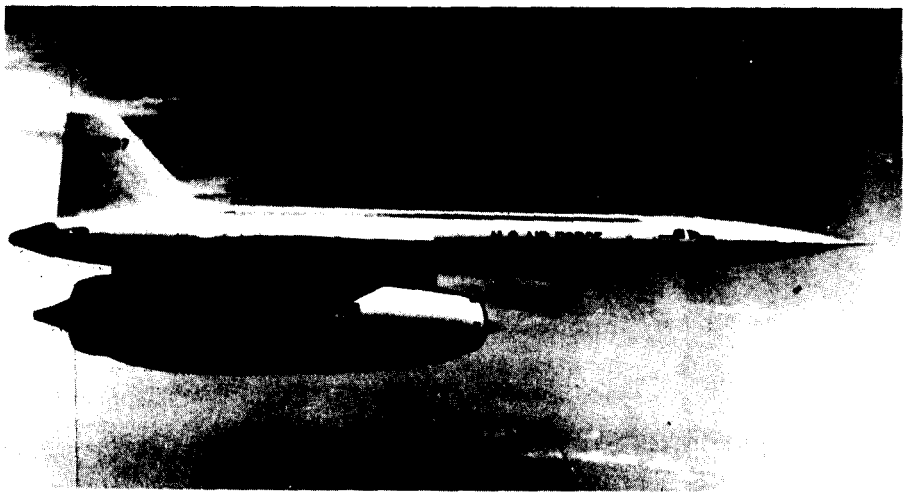
Nevertheless, the numbers of Hound Dogs in the B-52 fleet rapidly grew from 54 in 1960, rising to 230 the next year, 547 in 1962, and 593 in 1963. By August 1963, 29 SAC wings were operational with the AGM-28.

Hound Dog production ended in March 1963 and the number of operational missiles declined in the late 1960s and early 1970s to about 308 in 1976.[89] USAF

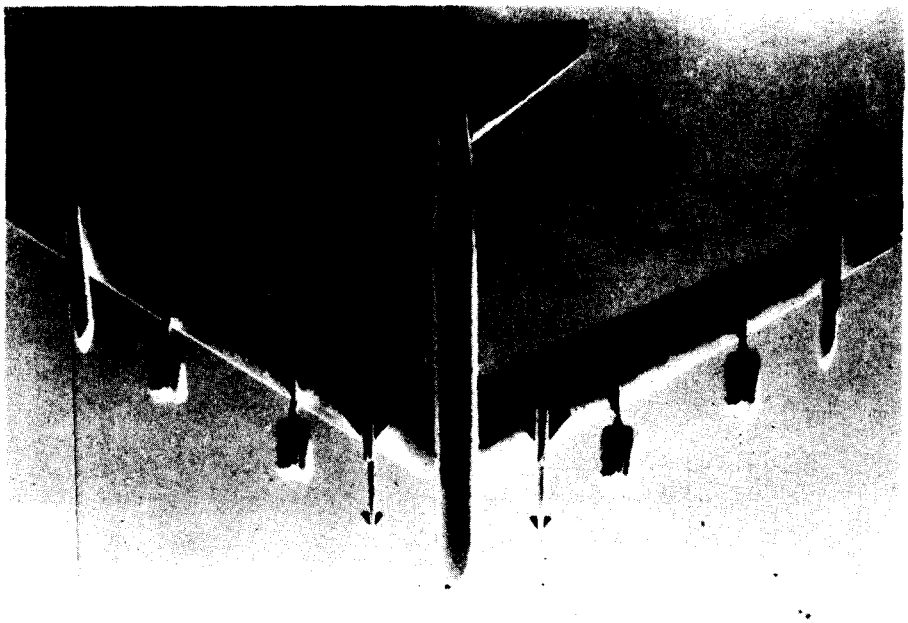
*USAF lifted the name from the title of an Elvis Presley hit song.[85]
**See Appendix A for specifications.



The North American Hound Dog (AGM-28) was a supersonic air-to-surface missile powered by an underslung ramjet: The company turned the first operational missile over to Strategic Air Command in 1961. (USAF)



AGM-28 in flight over the Atlantic Missile Range in 1962. By August 1963, SAC had almost 600 Hound Dogs operational with 29 SAC Wings. (USAF)



A B-52 could carry two Hound Dogs. But the unreliable missile reduced the bomber's performance, making it less than a success. (USAF)

phased out the Hound Dog in 1976, replacing it with the smaller (14 feet in length), faster (Mach 3), and lighter (2,230 pound) SRAM.* The cruise missile had lost out again to a ballistic missile.

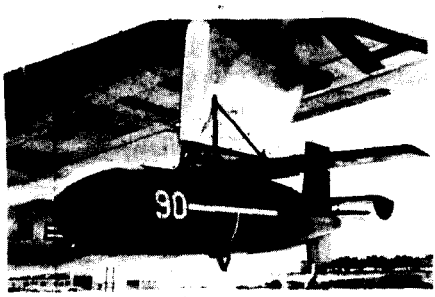
The Buck Duck

Decoy missiles were the other major subdivision of cruise missiles developed during the 1950s and 1960s. The decoys were designed to appear on enemy radar the same as the SAC bombers, and thus to confuse, dilute, and degrade enemy air defenses. Those responsible for the naming of the decoy missiles must have been hunters to have come up with the names they did: Buck Duck, Bull Goose, and Quail.

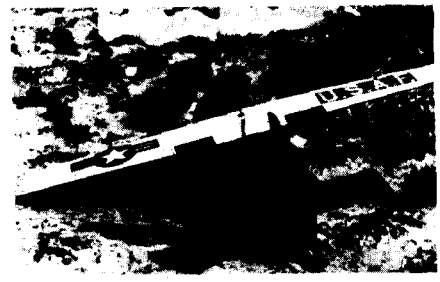
USAF planned to fit six Consolidated-Vultee Buck Ducks (GAM-71) on that company's giant B-36. Unlike the rather exotic-looking Navaho and Hound Dog, the Buck Duck was a conventional-looking missile, with a high straight wing measuring 14 feet in span (which folded to five feet).** While the Buck Duck underwent both glide and captive tests in February and March 1955, there is no record of any powered trials before USAF cancelled the project in January 1956.

*Headquarters Air Force sent out a Qualitative Operational Requirement (QOR 95) in November 1963 for a SRAM (Short Range Attack Missile) which first flew in July 1969. Boeing delivered the first production copy in March 1972; by 1974 over 1,100 were aboard B-52s.[90]

**See Appendix A for missile specifications.



Convair designed the Buck Duck as a B-36 decoy. Here, the missile is mounted on a B-29 pylon for captive tests on 16 February 1955. (USAF)



The Air Force conducted seven glide tests of the Buck Duck in March 1955. Shown here is the fourth, recovered with minor damage on 9 March. Note the missile's parachute in the background. (USAF)

Slippages in the decoy schedule and the impending replacement of the Convair bomber by the B-52 meant that the Buck Duck would have only about 12 months of useful life.[91]

The Bull Goose

The XSM-73 (WS-123A) Bull Goose was an intercontinental range surface-launched decoy missile. Work on the concept started in December 1952, although USAF did not release a request (GOR 16) until March 1953, and did not sign a contract with Fairchild until December 1955.

The Air Force planned to field 10 Bull Goose squadrons and buy 2,328 missiles in addition to 53 for research and development. The first squadron was to be operational in the first quarter of Fiscal Year 1961, the last at the end of Fiscal Year 1963. But problems with funding, the subcontractor's fiberglass-resin bonded wing, the booster, and the engine (J83-3) delayed the program.[92]

The delta-wing XSM-73 weighed 7,700 pounds at launch, including a 500-pound payload.* A J83 or J85 engine provided the Bull Goose with 2,450 pounds of thrust after a booster with a 50,000-pound thrust got it aloft. The specifications called for a 4,000-mile range at Mach .85 with an accuracy of plus or minus 100 nm.

Sled tests began at Holloman in February 1957, with the first of 15 flights taking place at the Atlantic Missile Range in June 1957. While five tests in 1957 were successful, those in 1958 were less so. Construction of the missile sites began in August 1958, a few months before the first Bull Goose flight with the YJ83 engine in November. USAF considered arming the Goose, but in early December cancelled the program because of budgetary pressures and because the Fairchild

*See Appendix A for missile specifications.

The Fairchild Bull Goose (XSM-73) was a ground-launched decoy missile with intercontinental range. (USAF)

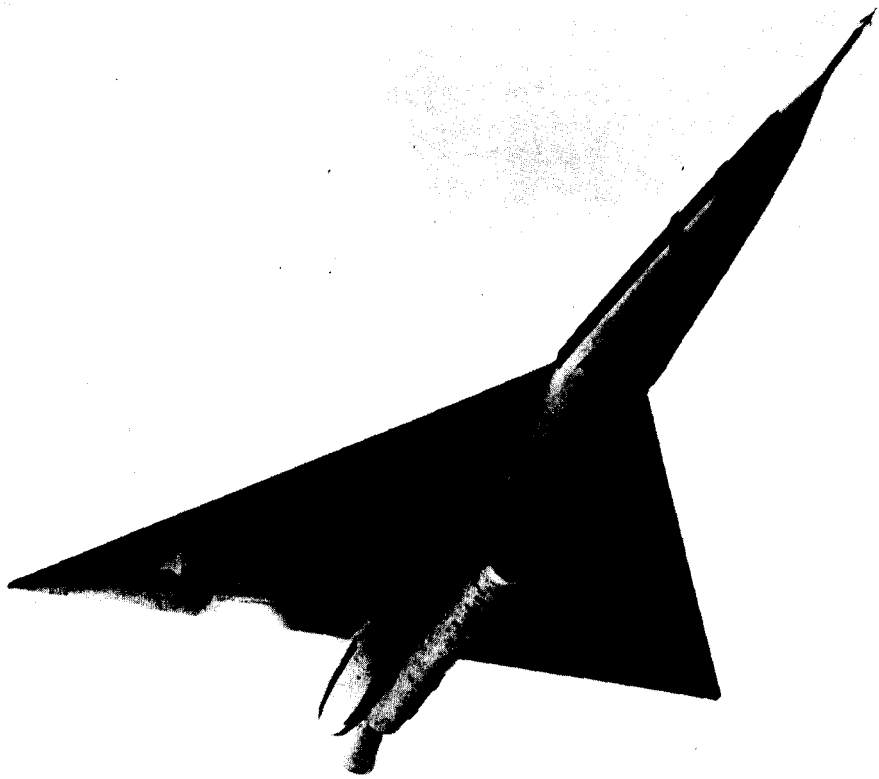
missile could not simulate a B-52 on enemy radar. The Goose program amassed a total of 28½ flying hours at a cost of $70 million.[93]

The Quail

The most successful of the decoy missiles proved to be the McDonnell Quail—most successful because it not only became operational, but it served SAC for more than ten years. USAF first discussed the requirement for such a device in October 1952, but did not initiate the missile until April 1955 and did not establish a formal requirement (GOR 139) until January 1956. The next month, USAF selected McDonnell as the contractor. Flight tests began in July 1957, with the first glide test in November 1957 and the first successful powered flight, which lasted 14 minutes and covered 103 miles, in August 1958. The progress of the tests enabled McDonnell to gain a production contract in December 1958, about the same time the Air Force terminated so many other projects.[94]

The GAM-72 (ADM-20A) was a tailless high-wing delta with four vertical fins.* McDonnell designed the missile to operate at 35,000 to 50,000 feet, at Mach .75 to .9, with a range (depending on altitude) of 357 to 445 nm. While eight could be carried on the B-52 and four on the B-47, the normal loading was, respectively, four and two.[95]

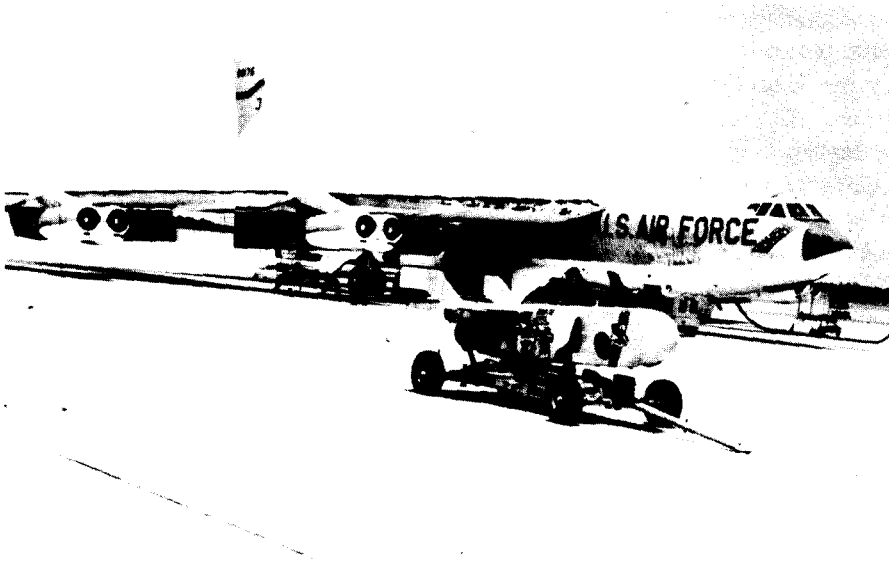
*See Appendix A for missile specifications.



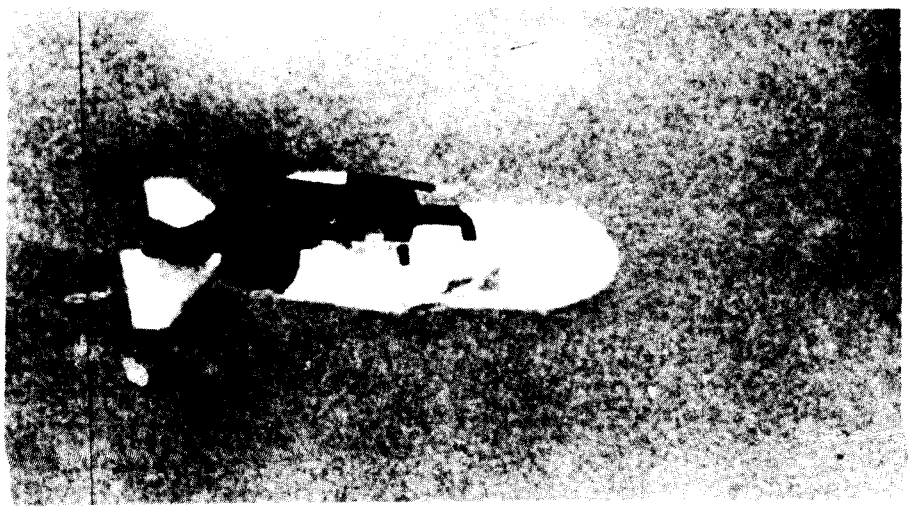
Bull Goose launch, 28 August 1958. (USAF)

The Quail simulated the bomber in a number of ways. First, its operational performance was comparable to the B-52; and it could be programmed (on the ground) to make at least two changes in direction and one in speed during its 46- to 55-minute flight. Second, its slab sides and twin vertical ventral and twin vertical dorsal fins produced a radar image similar to the bomber. In addition, the GAM-72 carried a 100-pound ECM payload consisting initially of a responder, later of both chaff and a heat source.

A General Electric J85 powered the decoy and caused most of the problems on the project, even though the same engine also powered the Northrop T-38. These problems led to modification of the engine, one of the major differences between the original GAM-72 (AGM-20A) and its successor, the GAM-72A (AGM-20B). The latter used the J85-GE-7, which had eight compressor stages instead of the seven stages in the J85-GE-3. The GAM-72A weighed almost 200 pounds more than the GAM-72, but had the same engine power and less wing area. Hence, it carried less payload a shorter time and distance at the same speed. The GAM-72A first flew in March 1960.[96]



The McDonnell Quail (GAM-72) was an air-launched decoy missile carried by the B-52 (background). (McDonnell-Douglas)



Quail in flight. It carried a 100-pound electronics countermeasures package over 300 miles. (USAF)

SAC received its first GAM-72 in September 1960. By February 1961, one Quail-equipped B-52 squadron was operational. USAF declared operational the last of 14 B-52 squadrons with the device in April 1962, the same year it accepted the GAM-72A. SAC had 492 Quails at its peak inventory in 1963. In all, McDonnell produced 616 of the missiles.[97]

But while the Quail served on, there were major problems. Reliability declined. Improvements in enemy radar rendered the Quail less effective. In a 1972 test, radar controllers correctly identified the B-52s 21 out of 23 times. By then, USAF recognized that the Quail was no longer a credible decoy. In 1971, the commander of SAC wrote the Air Force Chief of Staff that the Quail was only slightly better than nothing.[98] The General's candor may have reflected the fact that the Air Force was already taking action to provide a more effective decoy.

Before turning to these programs, two important points require emphasis. First, America's experience with cruise missiles in the 1950s and 1960s was largely unsuccessful. Not only did the devices prove costly and unreliable, but they offered few advantages over competing systems. Based upon this record, the US military establishment's skepticism of cruise missiles is both understandable and well founded. Second, those cruise missiles and their records were based on the outdated technology of the 1940s and 1950s. Dramatic technical changes in the 1960s produced a more technologically advanced weapon.

NOTES

CHAPTER IV

Data within the brackets indicate where the material is located. The following abbreviations are used: Aeronautical Systems Division, Dayton, Ohio [ASD]; Air Force Museum, Dayton, Ohio [AFM]; Air University Library, Montgomery, Ala. [AUL]; Albert F. Simpson Historical Research Center, Montgomery, Ala. [AFSHRC]; National Air and Space Museum, Washington, D.C. [NASM]; Northrop Corporation, Hawthorne, Calif. [N]; Naval Historical Center, Washington, D.C. [NHC]; Naval Air Systems Command, Washington, D.C. [NAVAIR]. The numbers following the symbols for the Air University Library and Simpson Center are their call numbers.

1. Both Arnold's impatience for action and his desire to have the AAF drop an ever greater tonnage of bombs on the enemy, even if not in accordance with the prewar bombing doctrine, is evident throughout his correspondence with his subordinates. Spaatz wanted the top American fighter ace to be from the AAF. Spaatz's Daily Diary, 1 December 1944, Box 16, Spaatz Collection, Library of Congress.

2. Max Rosenberg, "The Air Force and the National Guided Missile Program, 1944–50," June 1964, 18 [AFSHRC-K239.046-15]. Hereafter cited as Rosenberg, Air Force.

3. Giles to Bush, 20 February 1945, quoted in Delmar S. Fahrney, "The History of Pilotless Aircraft and Guided Missiles," c 1958, 811 [NHC]. Hereafter cited as Fahrney manuscript.

4. Proposed Memo, 5 September 1944 [A.M.C., The Development of Guided Missiles, June 1946, AFSHRC-201-46 II].

5. Rosenberg, Air Force, 21.

6. Memorandum for the Commanding General, AAF, Subject: "Guided Missiles," 2 October 1944 [AFSHRC-519.861-8].

7. Rosenberg, Air Force, 23–24.

8. Ibid., 25-27; Memo, 1 June 1945 [AFSHRC-201-46 II].

9. Memo for the Commanding Generals AAF, AGF, ASF, 19 March 1945 [AFSHRC-201-46 II]; William F. McKee, Deputy Chief Air Staff, Operations, Commitments, Requirements to CG USSTAF, Subject: "Responsibilities in Guided Missile Program," 14 May 1945 [AFSHRC-519.8671-8 45].

10. Rosenberg, Air Force, 30–32; Mary R. Self, "The History of The Development of Guided Missiles, 1946-50," December 1951, 15 [AFSHRC-K201-78]; Memorandum for Deputy Chief of Staff, 21 February 1946; Minutes of Staff Meeting, 3 January 1946 [both AFSHRC-201-46 II].

11. Rosenberg, Air Force, 36.

12. Ibid., 36–38; Self, 14–15.

13. Rosenberg, Air Force, 97, 103–04.

14. Guided Missile Committee, Guided Missile Current Status, 1 March 1946 [AFSHRC-178.281A].

15. Rosenberg, Air Force, 78; Self, 42.

16. E. M. Powers to CG, ATSC, 26 June, 29 June, 16 July, 21 August, 10 September 1945 [AFSHRC-201-46 II]; Supplement to Project B-7 Postwar Research and Development Program, Five Year Period 25 June 1945 Issue, 18 September 1945 [AFSHRC-201-46 VIII]; E. Michael Del Pappa and Sheldon A. Goldberg, *Strategic Air Command Chronology, 1939–1973* (Offutt AFB, Neb.: Headquarters Strategic Air Command, 1975).

17. Rosenberg, Air Force, 75, 78, 79; Self, 42–44. Headquarters Air Force reviewed this AMC study and missile requirements and decided on a program with the following priorities: (1) bomber-launched air-to-surface and air-to-air missiles; (2) surface-to-surface (150-mile range missiles); (3) surface-to-air and fighter-launched air-to-air missiles; (4) long-range, surface-to-surface missiles; and (5) an interim air-to-surface missile. On 18 June 1947, the Vice Chief of Staff of the USAF, General Hoyt Vandenberg, approved the priority list. Rosenberg, Air Force, 117; Self, 45–46.

18. Rosenberg, Air Force, 76, 79, 117.

19. Self, 11, 25–26.

20. Del Pappa and Goldberg; Rosenberg, Air Force, 76; Robert L. Perry, "System Development Strategies: A Comparative Study of Doctrine, Technology, and Organization in the USAF Ballistic and Cruise Missile Programs, 1950–1960," Rand RM-4853 PR, 1966, 30. Hereafter cited as Perry, RM 4853. Fred Anderson, *Northrop* (Los Angeles, Calif.: Northrop, 1976), 132; History and Development of SM-62 (WS-103-A) Weapon System, Northrop Report NOR 61-103, 1961, 1 [N].

21. Northrop designed the supersonic MX-775B Boojum to have a maximum gross weight of 112,131 pounds, fly 4,410 nm into the target at Mach 1.8 (or 4,325 nm at Mach 2). Powered by two J47 turbojets with afterburners almost at the wing tips, the vehicle was to be a two-stage affair. After about 1,300 nm, a slipper shaped fuel tank would be dropped from the tailless delta-winged aircraft measuring 85.3 feet in length (104.8 feet with the tank) and 50.9 feet in span. Other proposed versions of the Snark included the N-112 (QB-62) target drone, the N-124 (RSM-62) reconnaissance version, and the N-134 high altitude model. Neither the Boojum nor these other versions were built. "The Northrop MX-775B Supersonic Missile," June 1950 [N]; NORAIR Project Designations, 16 February 1956, 11–13 [N].

22. Rosenberg, Air Force, 113, 114, 117, 140, 149; Self, 86–89; Perry, RM 4853, 30, 31.

23. Perry, RM 4853, 33, 35; Anderson, 134, 135; "Standard Missile Characteristics, SM-62A Snark," June 1960, 3 [AFM]; History Air Research and Development Command, January 1950–June 1951, 506 [AFSHRC-K243.01 January 1950–June 1951]. Hereafter cited as ARDC History. Northrop, Project Snark: XB-62 Pilotless Bomber, 3 [N-TL 55,235]; NORAIR, "Snark Weapon System Program: Historical Summary," February 1959, 6 [N-NAI 59-47].

24. Anderson, 133, 134, 142; Robert B. Whitman, "Astronautical Navigation for Cruise Application," Northrop, 1980; Snark Weapon System Program, NAI 59-47, 6; Northrop, Weapon System Program Summary, GM 958, 46, 47 [N].

25. The leading edge extensions boosted the wing area to 336 square feet. A trailing edge extension, increasing total wing area to 366.4 square feet, appeared on the "A" model in 1953.

26. Anderson, 135, 142, 143; Perry, RM 4853, 33, 34, 37; History and Development SM-62, NOR 61-103, 21; Snark Weapon System Program, NAI 59-47, 7; Project Snark, 1, 5, 9; "Standard Missile Characteristics: SM-62A," June 1960 and March 1954; GM 958.

27. Strategic Air Command History, July–December 1951, 20 [AFSHRC-K416.01 II July–December 51]. Hereafter cited as SAC History. Perry, 35, 36; Anderson, 136; ARDC History, I, January–June 1954, 199; History and Development SM-62, NOR 61-103, 8; GM 958, 27; Chronology of the Atlantic Missile Range and Air Force Missile Test Center: 1938–1959, 86, 100 [ASD].

28. Perry, RM 4853, 37; Project Snark, 7, 8; Anderson, 136, 138; Snark Weapon System Program, NAI 59-47, 8; GM 958, 27, 44.

29. History Atlantic Missile Range, July–December 1956, Vol. I, 164–167 [AFSHRC-K241.01 I July–December 1956]; Perry, RM 4853, 38.

30. SAC History, July–December 1951, 2, 18, 21; E. Michael Del Pappa, *Snark to SRAM* (Offutt AFB, Nebr.: Headquarters Strategic Air Command, 1976), 3.

31. SAC History, January–June 1954, I, 46.

32. SAC History, July–December 1951, II, 21.

33. Members included such notables as J.B. Wiesner (M.I.T.), Clark B. Milliken (Cal. Tech), John von Neumann, Simon Ramo, and Dean Wooldridge.

34. ARDC History, January-June 1954, I, 198; Recommendations of the Strategic Missile Evaluation Committee, February 1954, 2–6, 10 [AFSHRC-K168.15-75].

35. ARDC History, 1958, II, 325; Del Pappa, 33.

36. "Guided Missiles, 1956," *Flight* (7 December 1956), 907; Raymond M. Nolan, "Snark

Disclosures Fit With Carrier-base Plan," *Missile and Rockets* (March 1958), 42; Curtis L. Bates, "Pilotless Aircraft: A Statement of the Problems," *Aeronautical Engineering Review* (April 1955), 56; Russell Hawkes, "Subsonic Snark Adds Effectiveness to SAC Forces," *Aviation Week* (15 September 1958), 17, 19; David A. Anderton, "Snark Design Stresses Range, Simplicity," *Aviation Week* (26 March 1956), 46, 48.

37. Del Pappa and Goldberg; Perry, RM 4853, 41, 42, 48; GM 958, 27, 54, 58, 59; History and Development SM-62, NOR 61-103, 45; Chronology Atlantic Missile Range, 108.

38. Headquarters 6555 Test Wing, AFBM Division, "SM-62 Weapons System Evaluation Category II Final Engineering Evaluation," 23 December 1959, 9, 15 [AUL-M40716-U#60-1]; Perry, RM 4853, 40, 42; Anderson, 132; Ronald Huisken, *The Origin of the Strategic Cruise Missile* (New York, N.Y.: Praeger, 1981), 17.

39. John Bohn, *The Development of Strategic Air Command, 1946–1976* (Offutt AFB, Nebr.: Headquarters Strategic Air Command, 1974), 72, 79, 86; History, Assistant Chief of Staff for Guided Missiles, January 1957–January 1958, 25, 26 [AFSHRC-K168.0321 January 1957–January 1958]; 702nd Strategic Missile Wing History, January–July 1959, 1, 15 [AFSHRC-K-Wg-702-HI January-July 1959].

40. 702nd SM Wg History, May–June 1961, 29, 31; "Text of Kennedy's Special Message to Congress on Defense Spending," *New York Times* (29 March 1961), 16, 17; Huisken, 17.

41. Guided Missile Committee, Guided Missile Current Status; Goldberg, Air Force, 76; Russ Murray, "The Navaho Inheritance," *Journal American Aviation Historical Society* (Spring 1974), 18.

42. Goldberg, Air Force, 83, 117; Perry, RM 4853, 32; SAC History, July–December 1951, 24–26 [AFSHRC-K416.01 July–December 1951]; Self, 91, 92.

43. Murray, 19, 20; Dale D. Myers (et al.), "Propulsion Systems for the Navaho Missiles," NAA Report AC-2463, March 1957, 2 [NASM].

44. Perry, RM 4853, 43, 45.

45. Ibid., 42–45, 49; Del Pappa and Goldberg.

46. Lloyd S. Jones, *U.S. Bombers B-1—B-70* (Los Angeles, Calif.: Aero, 1962), 214.

47. Murray, 18; Perry, RM 4853, 45–47.

48. Murray, 20; Perry, RM 4853, 47, 48; Assistant Chief of Staff for Guided Missiles, History January 1957-January 1958, 24 [AFSHRC-K168.0321 January 1957–January 1958]; Historical Office, "Index of Missile Launchings By Missile Program, July 1950–June 1960," 8–3, 8–4 [AFSHRC-K241.04-1 July 1950–June 1960]. The proposed intercontinental XSM-64A was to measure 87.3 feet in length and have a wing span of 40.2 feet. The vehicle had a canard configuration with a diamond-shaped wing and a single vertical tail. Weighing 120,000 pounds at launch, the missile was to be powered by two XRJ47-W-7 ramjets with a total thrust of 40,140 pounds. A booster weighing 169,500 pounds and measuring 91.5 feet in length would produce 415,000 pounds of thrust for 110 seconds to launch the 290,000 pound Navaho vertically in a piggyback fashion. North American designed the XSM-64A to reach Mach 3.25 at 45,000 feet, travel 5,500 miles, and impact within two nm of the aiming point. It never flew. "Strategic Missile Characteristics: SM-64A Navaho," May 1957 [AFM].

49. James F. Scheer, "Project Fantastic," *Skyline* (August 1956), 33, 37; Henry T. Simmons, "The Navaho Challenge," *Missiles and Rockets* (December 1956), 77, 78; Perry, RM 4853, 50.

50. Murray, 20; Perry, RM 4853, 50.

51. Perry, RM 4853, 48, 49.

52. Ibid.

53. Richard P. Klocko, "The Impact of Guided Missiles Upon the USAF," Air War College Thesis, 1954, 9 [AFSHRC-K239.0421-4]. For comments on similar attitudes towards RPVs see William Wagner, *Lightning Bugs and Other Reconnaissance Drones* (Fallbrook, Calif.: Aero, 1982), [iii, iv].

54. General Thomas S. Power, Memorandum for General Knapp, Subject: "Commander's Conference, Patrick Air Force Base, 30 September to 1 October," 4 October 1957. [Document No. 5, Strategic Air Command's Participation in the Missile Program from March 1957 through December 1957, Historical Study No. 70, Vol. II, AFSHRC-K416.01-70 II M-D '57.]

55. Ibid.

56. S. L. A. Marshall, "Have We Been 'Oversold On Missiles'?," *Army Navy Register* (28

September 1957), 24; Michael Yaffee, "Missile Spending Spurred by Soviets," *Aviation Week* (3 March 1958), 93; *Aeroplane Spotter* (6 March 1948), 55; Propst, 47.

57. Robert L. Perry, "Appendix," 120, 119–121 [Monte Wright and Lawrence Paszek, (eds.), *Science, Technology, and Warfare: The Proceedings of the 3rd Military History Symposium*, United States Air Force Academy, 1969].

58. Perry, RM 4853, 8, 9, 56–61, 92; Del Pappa and Goldberg.

59. Self, 78, 82-84; Bernard J. Termena, "History of the Matador and Mace Guided Missiles, 1951–1957," Vol. I, 6, 7 [AFSHRC-K201-94 I].

60. Martin rejected a catapult launcher and both a long and short rail launcher because of the constraints they would put on the missile's mobility. C. J. Libby, "Zero Length Launcher," paper, Institute of Aeronautical Sciences, 27 January 1955, 2, 4. [NASM].

61. Termena, 2; "Matador," *Missile and Rockets* (July 1958), 114; *Jane's All the World's Aircraft: 1955–56* (New York, N.Y.: McGraw-Hill, 1956), 292; *Jane's All The World's Aircraft: 1956–57*, 361.

62. Termena, 7–9; History ARDC, January 1950–June 1951, Vol. I, 507 [AFSHRC-K243.01 January 1950-June 1951 I].

63. "Matador," *Missiles and Rockets* (July 1958), 114; Edwin B. Miller, Jr., "Guided Missiles and Pilotless Aircraft in Theater Operations," Air War College Thesis, 1953, 63 [AFSHRC-K239.0421-1 May 1957]; Major Anderson, "USAF Guided Missile Program," Air War College Thesis, 1951, 2, 3 [AFSHRC-K239.716251-10].

64. Headquarters Tactical Air Command, TM-61C Operational Summary, October 1960 [AFSHRC-K417.304-61]. On these launches, NATO crews firing before June 1960 achieved an average CEP of 1,700 feet, while those firing after that date achieved 4,150 feet. Nevertheless, Tactical Air Command used a planning figure of 1,700 feet for experienced crews and 3,200 for new crews. History of 1st Tactical Missile Squadron, January 1955-June 1955, 13 [AFSHRC-K-Sq-MI-1-HI January–June 1955].

65. Termena, 25, 31, 41.

66. Ibid., 3, 4; "Mace," *Missiles and Rockets* (July 1958); *Jane's All The World's Aircraft: 1958–59*, 419, 420; *Jane's All The World's Aircraft: 1959–60*, 444; *Jane's All The World's Aircraft: 1960–61*, 461; Miller, 70; Huisken, 23.

67. *Jane's All The World's Aircraft: 1963–64*, 408; *Jane's All The World's Aircraft: 1964–65*, 431; History, Headquarters USAF Europe, 8 July–December 1959, 21 [AFSHRC-K570.01 July–December 1959]; History of 1st Pilotless Bomber Squadron (L), January 1954, ii, 3 [AFSHRC-K-Sq-MI-1-HI January–June 1954]; History 36th Tactical Fighter Wing, July–December 1967, B-IV-3 [AFSHRC-K-Wg-36-HI July–December 1967]; History 36th TFWg, January–June 1969, A-3 [AFSHRC-K-Wg-36-HI July–December 1967]; History 38th Tactical Missile Wing, July–December 1965, 2 [AFSHRC-K-Wg-38-HI July–December 1965].

68. History of the 58th Tactical Missile Group, January–March 1962, 6 [AFSHRC-K-Gp-M-58-HI January–March 1962]; History USAF Korea, 314th Air Division, January–June 1959, Tab 7 [AFSHRC-K-Div-314-HI January–June 1959]; History 498th Tactical Missile Group, October–December 1969, vi, 1, 8 [AFSHRC-K-Gp-MI-498-HI October–December 1969].

69. Quoted in Termena, 38; also see 14, 16, 31, 35, 36.

70. "Operations Analysis—Report No. 17," May 1956 [XO Concept Paper, AUL-M42107-34].

71. Libby, 8; Termena, 48, 49, 57-60; *Jane's All The World's Aircraft: 1958–59*, 420.

72. "Gorgon IIC," Assistant Chief of Staff, Plans, Guided Missiles Committee, Summary Handbook for Guided Missiles, 1 January 1945 [AFSHRC-145.96-195]; Fahrney manuscript, 501–506; Delmar S. Fahrney, "The Genesis of the Cruise Missile," *AIAA Journal* (January 1982), 39.

73. Fahrney, "Genesis," 39, 53; Fahrney manuscript, 506–509.

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75. Bruins, 154, 155, 165, 200, 421.

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78. William B. Hendrickson, Jr., "The Cruise Missile Returns," *National Defense* (September 1981), 38; Bruins, 212, 306, 332, 346; *Jane's All The World's Aircraft: 1958–59*, 411; *Jane's All The World's Aircraft: 1959–60*, 430; *Jane's All The World's Aircraft: 1960–61*, 448.

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80. Fahrney manuscript, 1114, 1194, 1205, 1209; Admiral J. H. Sides, "US Navy Guided Missile Program," lecture Air War College, 9 December 1952, 10 [AFSHRC-K239.16252-65]; Bruins, 236–339, 415.

81. Characteristics Summary, "Chance Vought 'Regulus II,' " 28 February 1958 [NAVAIR]; "Regulus II—An Appraisal," 3, 8 [NASM]; Chance Vought, "Regulus II: The Mobile Supersonic Long Range Surface to Surface Missile and Producibility," August 1958, 3; *Jane's All The World's Aircraft: 1958–59*, 411, 412; RDB Project Card Continuation Sheet, "Regulus II, XSSM-N-9," 1 July 1954 [NAVAIR]; Bruins, 319, 416.

82. "Regulus II—An Appraisal," 1, 5, 8; "Brief History of Program," n.d. [NAVAIR]; Bruins, 303, 328, 331, 501. Regulus was also considered for a ground launch role. In May 1953 the Army expressed interest but was thwarted by the USAF. Four years later, Regulus II was considered for the same role by some of the NATO Allies. Bruins, 204, 205, 211, 328, 329.

83. Bruins, 517.

84. "Standard Missile Characteristics: XGAM-67 Crossbow," April 1956 [AFM]; Aircraft and Aircraft Missile Testing, June 1963 [AFSHRC-Film #32,235, Frame 250]; Historical Data, GAM-67 [AFSHRC-Film #31,754, Frame 856]; Test Report on GAM-67, March 1956 [AFSHRC-Film #31,754, Frame 856]; Test Report on GAM-67, March 1956 [AFSHRC-Film #31,794]; History of Holloman Air Development Center, January–June 1955, 126–128 [AFSHRC-K280.10-52 January–June 1955]; ARDC History, July–December 1956, 333, 336; ARDC History, January–June 1957, 227; ARDC History, July–December 1957, II, 198, 199.

85. Tulsa Division, North American Rockwell, untitled, re Hound Dog [NASM].

86. Ibid.; North American Aviation, News Release, Hound Dog background [NASM].

87. North American Aviation, News Release; *Jane's All The World's Aircraft: 1961–62*, 406; "Standard Missile Characteristics, AGM-28B Hound Dog," January 1977 [AFM].

88. Tulsa Division, untitled; North American Aviation, News Release; History of Air Force Missile Center, January–June 1962, I, 89 and January–June 1963, I, 56 [AFSHRC-K280.10-60 January-June 1963]; *Jane's All The World's Aircraft: 1960–65*, 464; Del Pappa and Goldberg; Huisken, 19.

89. Del Pappa and Goldberg; *Jane's All The World's Aircraft: 1963–64*, 411; Bohn, 81, 88, 97, 106, 113, 119, 126, 132, 138, 142, 148, 155, 160, 167, 172, 177, 184.

90. Bohn, 172; Del Pappa and Goldberg; *The U.S. War Machine* (New York, N.Y.: Crown, 1978), 219; Huisken, 18. The British put a similar weapon into operation in the 1960s, the Hawker Siddeley Dynamic Blue Steel measuring 36 feet in length with a 13 foot wing span. A rocket engine propelled the 11,000-pound canard-configured missile 200 to 400 miles at Mach 1.6. *Jane's All The World's Aircraft: 1961–62*, 395; *Jane's All The World's Aircraft: 1963–64*, 388–89; *Jane's All The World's Aircraft: 1969–70*, 580; Derek H. Wood, "Sky Bolt, Blue Steel and the 'V' Bombers," *Interavia*, #7, 1960, 814.

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92. ARDC History, July–December 1957, 221; History ARDC, January–June 1956, 174; Directorate of Management Analysis, Weapon System Summary SM-73 (Goose), August 1958, 3, 13 [AUL-M40074-10-C].

93. *Jane's All The World's Aircraft: 1959–60*, 438; "Standard Missile Characteristics XSM-73 Bull Goose," July 1958 [AFM]; G. C. White "WS 123A Program History," December 1958 [NASM]; Fairchild, "Weapon System No. 123A," September 1956 [NASM]; "Goose Missile Engine Contract is Cancelled," *Washington Evening Star* (3 January 1959); ARDC History, July–December 1957, II, 223.

94. Del Pappa, 49; Del Pappa and Goldberg; "Standard Missile Characteristics: ADM-20B Quail," February 1965.

95. "Standard Missile Characteristics, ADM-20B"; "Standard Missile Characteristics, XGAM-72"; Del Pappa, 48; McDonnell Aircraft Co., "GAM-72 Effectiveness Report," March 1958 [AUL-M-30737 #5996].

96. "Standard Missile Characteristics, ADM-20B"; "Standard Missile Characteristics, XGAM-72"; History Air Force Missile Development Center, July–December 1960, I, 128, 129 [AFSHRC-K280.10-57 July–December 1960, I].

97. Bohn, 106; Del Pappa, 49; Del Pappa and Goldberg; GAM-72 Quail [NASM].

98. McDonnell, GAM Effectiveness; B. K. Holloway to John D. Ryan, 6 October 1971 [AFSHRC-168.7085-106 1971].

CHAPTER V

US CRUISE MISSILES REVITALIZED

The connection between the Hound Dog and Quail of the 1960s and 1970s and the cruise missile of today remains vague and complex to the uninitiated. Superficially, there appears to be little direct connection since the present cruise missile is a new and substantially different weapon system. Yet, the present cruise missile does have certain historical and intellectual antecedents. The transition from past to present is through evolving technology, Remotely Piloted Vehicle (RPV) successes in Southeast Asia, USAF's decoy (SCAD), and the Navy's antiship (Harpoon) program.

Advancing Technology

Advancing technology transformed the large, unreliable, inaccurate cruise missile of the 1950s and 1960s into the much different cruise missile of the 1970s and 1980s. Improvements in engines, fuels, materials, and guidance account for this change. With the possible exception of guidance, all were evolutionary developments; that is, the technology grew slowly and in predictable steps.

Of all the technologies associated with the cruise missile, the most crucial is, and has always been, guidance. As has been amply demonstrated, one of the constant problems throughout the cruise missile program has been its inaccurate and unreliable, large and heavy guidance systems. But significant incremental improvements in inertial systems and computers, and the development of terrain contour matching (TERCOM), yielded radically new capabilities.

In 1958, inertial systems had an inherent inaccuracy (drift) of about .03 degrees per hour. By 1970, this had been cut to about .005 degrees or one-third nm per hour. Concurrently, the size, weight, and power requirements of inertial systems shrank, decreasing weight from about 300 pounds in 1960 to 29 pounds a decade later.[1] The total cruise missile guidance package, including computer, radar

altimeter, and inertial systems, now measures one and one-third cubic feet and weighs 115 pounds. Therefore by 1970, a smaller inertial guidance system had achieved much better accuracy, on the order of one-third nm per hour (about one nm for a 550-knot vehicle traveling 1,650 nm).

Perhaps even more amazing than the remarkable size/weight/power reduction of inertial guidance systems was the even greater impact of the computer. Engineers in the 1950s measured computer size by the number of rooms its components occupied; within a quarter century, the computer had shrunk to the size of a loaf of bread. Accounting for this improvement were the transistor and magnetic disc in the mid-1950s, followed in the mid-1960s by microcircuits with solid state memories. In the early 1970s, microprocessors and semiconductor memories on chips became available. Thus, computers became much smaller with greatly increased capabilities.[2]

Along with these advances, a new type of navigation system emerged. The early, mostly unsuccessful, attempts with radar matching systems in the Mace and Triton in the mid-1950s have already been described. In 1958, the LTV-Electro Systems Company patented a system called TERCOM* as part of the "fingerprint" guidance for Chance Vought's strategic attack missile called SLAM (Supersonic Low Altitude Missile), a system cancelled the following year. Efforts in the 1960s to put TERCOM into Hound Dog missiles also failed.[3]

In the TERCOM system, engineers divided a terrain map into a matrix of cells which have ranged in size from 100 feet to 3,200 feet on a side. Thus, each map measures a number of miles. (See figure 5.) The E-Systems matrix consists of 64 cells, each 400-feet on a side, yielding a 4.9 nm strip map. Engineers assign each cell an average elevation derived from a contour map or satellite reconnaissance map, and this information is stored in the system's computer. In flight, a radar altimeter measures the actual elevations and then at checkpoints matches that sequence with the digital map stored in the computer. (See figure 6.) Here, "voting" takes place; that is, the system checks three maps and if one is found to disagree with the other two, the odd reading is disregarded. To date, no false update has resulted from three TERCOM fixes. The system is based on assumptions that the mapping information is available and accurate, unique land contours can be used, and the radar altimeter and computer can do their jobs.[4]

TERCOM is mated with an inertial system—the two sometimes known as TAINS (TERCOM Aided Inertial System), which describes the system, but more commonly and simply, just TERCOM. The inertial guidance system navigates the missile to the first TERCOM checkpoint and between subsequent checkpoints en route to the target. At each checkpoint, the computer updates the inertial guidance system and corrects the missile's course. Theoretical accuracy of TERCOM is .4 times the size of the cells, which are progressively reduced in size the closer the map set is to the target. The overall accuracy of the system depends upon the distance between the target and the last TERCOM fix and the size of the cell: the less distance and smaller cell size, the greater the accuracy. The open literature states that the system's accuracy is normally between 100 and 600 feet, with a

*Other names associated with the system included LACOM (Low Altitude Contour Matching) and RACOM (first Rapid Contour Matching, later labeled Recursive All Weather Contour Matching).

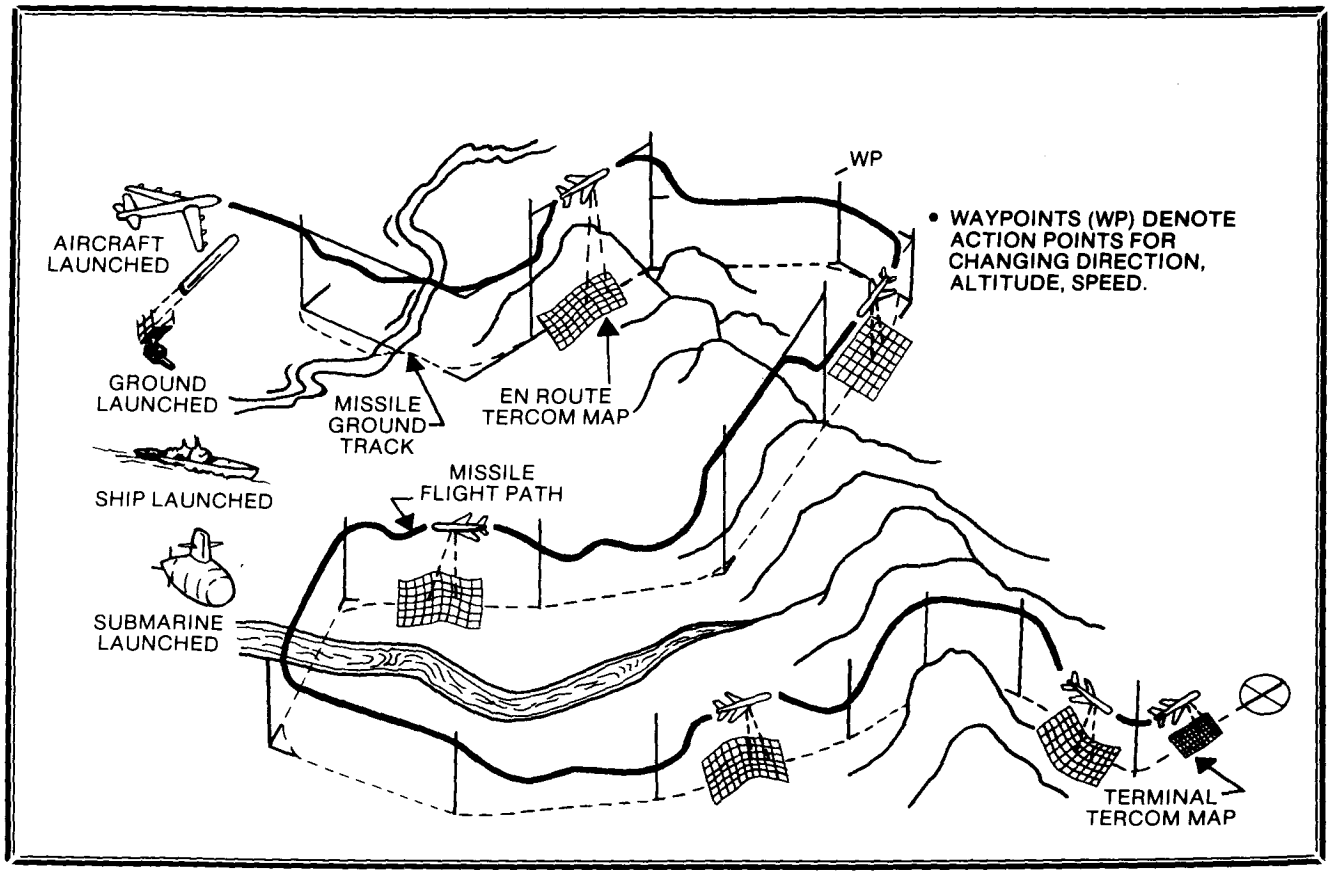


Figure 5. Cruise missile operational concept. After launch, the missile's inertial navigation system is corrected (updated) by numerous en route TERCOM fixes. The last (terminal) TERCOM fix is a short distance from the target.

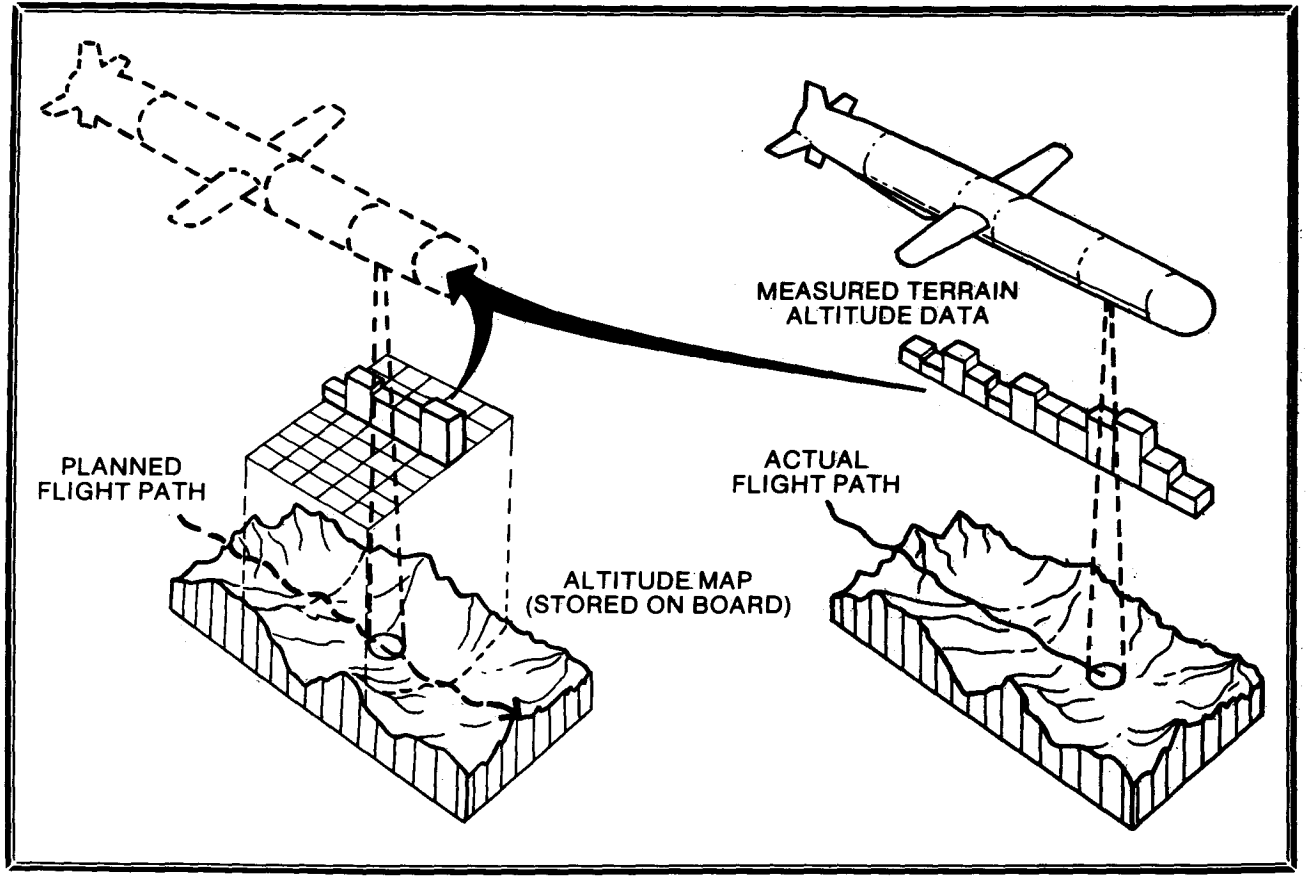


Figure 6. Terrain correlation (TERCOM) process. The missile's computer compares the altitudes observed by its radar altimeter (right) with the altitudes of the desired flight (left).

165-foot accuracy supposedly demonstrated in 1960. Whatever the precise figure, it is significantly more accurate than existing inertial systems.[5]

Some claim that difficulties with mapmaking, and problems caused by seasonal changes (snow and foliage) and flatlands, invalidate the system. Others assert that these problems have been surmounted and that the present system can operate successfully, regardless of weather or season. Despite patent problems, TERCOM has been extensively tested beginning with Beech tests in 1959, and further tests on T-29s, Pipers, C-141s, A-7s, B-52s, drones, and the cruise missiles themselves. As of February 1982, the TERCOM system had logged over 2,300 test hours on a total of 946 test flights, involving over 4,800 fixes. These tests used at least 212 maps in 16 states and 2 Canadian provinces.[6]

Another important feature of the cruise missile, indirectly linked with guidance, is its ability to fly at extremely low altitudes. USAF first employed terrain-following devices, using radar altimeters and forward looking radar, in FB-111s and B-52s. These devices permit very low flight that follows the contour of the ground, making detection and interception extremely difficult. The offensive-defensive cycle has seen radar and surface-to-air missiles force aircraft from high speed, high altitude operations to low altitude, high subsonic speed operations. Here, limited radar range, ground clutter, and terrain-masking greatly complicate the defender's task by curtailing both range of detection and tracking, and, thus, reaction time. The next defensive move was toward an airborne warning and control system (AWACS) for detection and interceptors with a look down/shoot down capability. At this point, the cruise missile enters.

The cruise missile can make even better use of low flying than can a manned aircraft. First, it flies a known track, presumably over known obstacles and elevations. Second, lacking a pilot, the cruise missile can withstand more Gs and thus maneuver better than a manned aircraft. Finally, since man is not at risk, more chances can be taken.

The terrain-following system on the cruise missile consists of a downward looking radar altimeter (also used by the TERCOM) linked to the missile's controls. The planners set a preplanned separation altitude that is a tradeoff between flying very low (making detection and tracking more difficult) and flying at a higher altitude (with less risk of hitting the ground).[7] The addition of forward looking radar (such as fitted on the B-52 and FB-111) could further lower these altitudes, but would also add weight, increase complexity, and radiate a signal that defenders could detect.

Advances in guidance technology were the most important developments in the evolution of the cruise missile. New manufacturing processes and materials did reduce weights and costs, but neither was a major factor in the overall success of the missile. There was another major technological development, however: the evolution of a small fuel-efficient jet engine.

Design of small jet engines began with the Navy's Gorgon IIB and IIIB projects in 1945. Their designers planned to power these air-to-surface surface missiles with a 9-inch diameter Westinghouse engine. By 1960, the French had developed the

Not quite James Bond! In the late 1960s, the Williams Company built the engine for this "jet belt." This engine was the predecessor of a family of small efficient engines that power current American cruise missiles. (Williams International)

Microturbo series with engines as small as 12½ inches in diameter, producing 175 pounds of thrust.[8]

In the United States, small engines for the cruise missiles can be traced back to Sam Williams, who worked on Navy turbojets and gas turbines for Chrysler and, in 1954, organized the Williams Research Company. His first engine, the WR-2, ran in 1962 with 70 pounds of thrust and powered the Canadian AN-USD-501 reconnaissance drone and the US MQM-74 target drone. Williams' work led to a significant step, the development of a small fanjet.* In 1964, the Williams Company proposed a turbofan engine for ARPA's (Advanced Research Projects Agency) "flying belt," a device strapped on a man's back, propelling him up to 10 miles at 60 mph. The initial tests of the WR-19, completed in 1967, demonstrated that a 12-inch diameter (24-inch length) engine, weighing 68 pounds, could produce 430 pounds of thrust at a fuel consumption rate of .7 pounds of fuel per hour per pound of thrust. So an engine with very good performance and about one-tenth the size of the next largest available engine existed. By late November, the WR-19 had successfully met 36 hours of hot testing to the almost complete satisfaction of the military.[10]

At this same time, USAF was considering a 2,000 nm Mach .85 SCUD (Subsonic Cruise Unarmed Decoy), or SCAM (Subsonic Cruise Attack Missile), but responses from major engine manufacturers as to the feasibility of these missiles ranged from skeptical to pessimistic. A 1968 Williams report also concluded that such ambitious performance could not be met by using conventional fuels. But, with high energy fuels under development, it would be possible. Shelldyne seemed the best bet, promising an increase of up to 30 percent in range.[11]

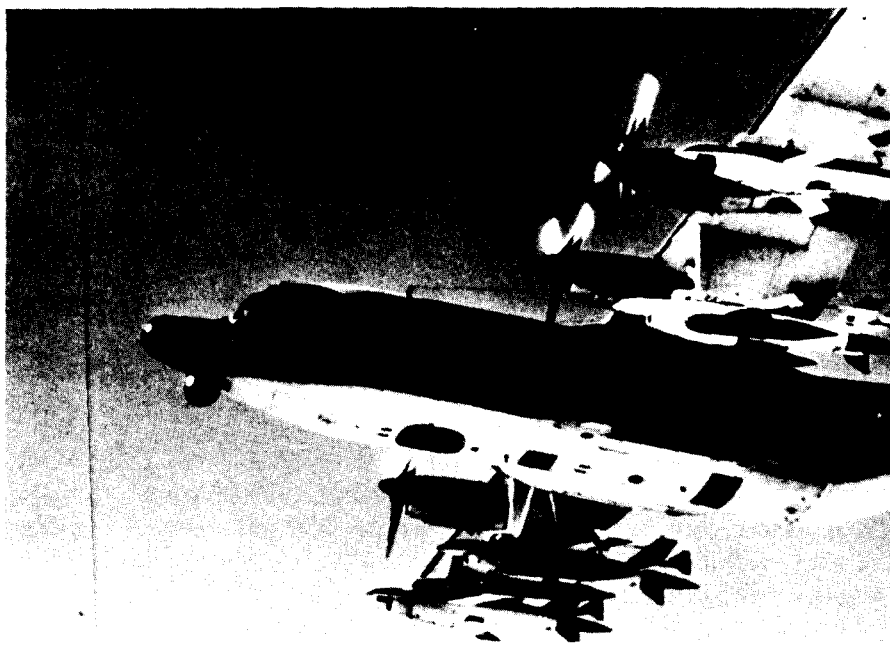
In April 1969, USAF awarded Williams a contract for preliminary design and preparation of engine specifications for a version of the WR19 engine. A second contract followed, in November 1969, for component development of the engine, and for design, construction, and testing of these engines. Thus, as the 1960s closed, Williams had a lead in the field and the Air Force potentially had a small, high performance, turbofan engine.[12] Therefore, the development of a number of different technologies at about the same time made a small, very accurate, low-flying, long-range missile possible. Decreases in the size and weight of both guidance and engines, along with markedly enhanced capabilities, were key developments. Finally, the miniaturization of nuclear warheads made the cruise missile a very potent war machine.

*Air enters and is compressed in both the turbojet and turbofan engine. But while all air passes through the combustion process in the former, part is diverted and bypasses combustion in the latter. A turbojet is simpler, less expensive (1/3 to 1/4), and has a relatively smaller diameter (therefore, less frontal area and drag) than a turbofan. The turbofan, however, is more efficient (15 to 20 percent less fuel consumption at subsonic speed), and leaves a smaller acoustical and infrared signature than does the turbojet.[9]

Remotely Piloted Vehicles (RPVs)

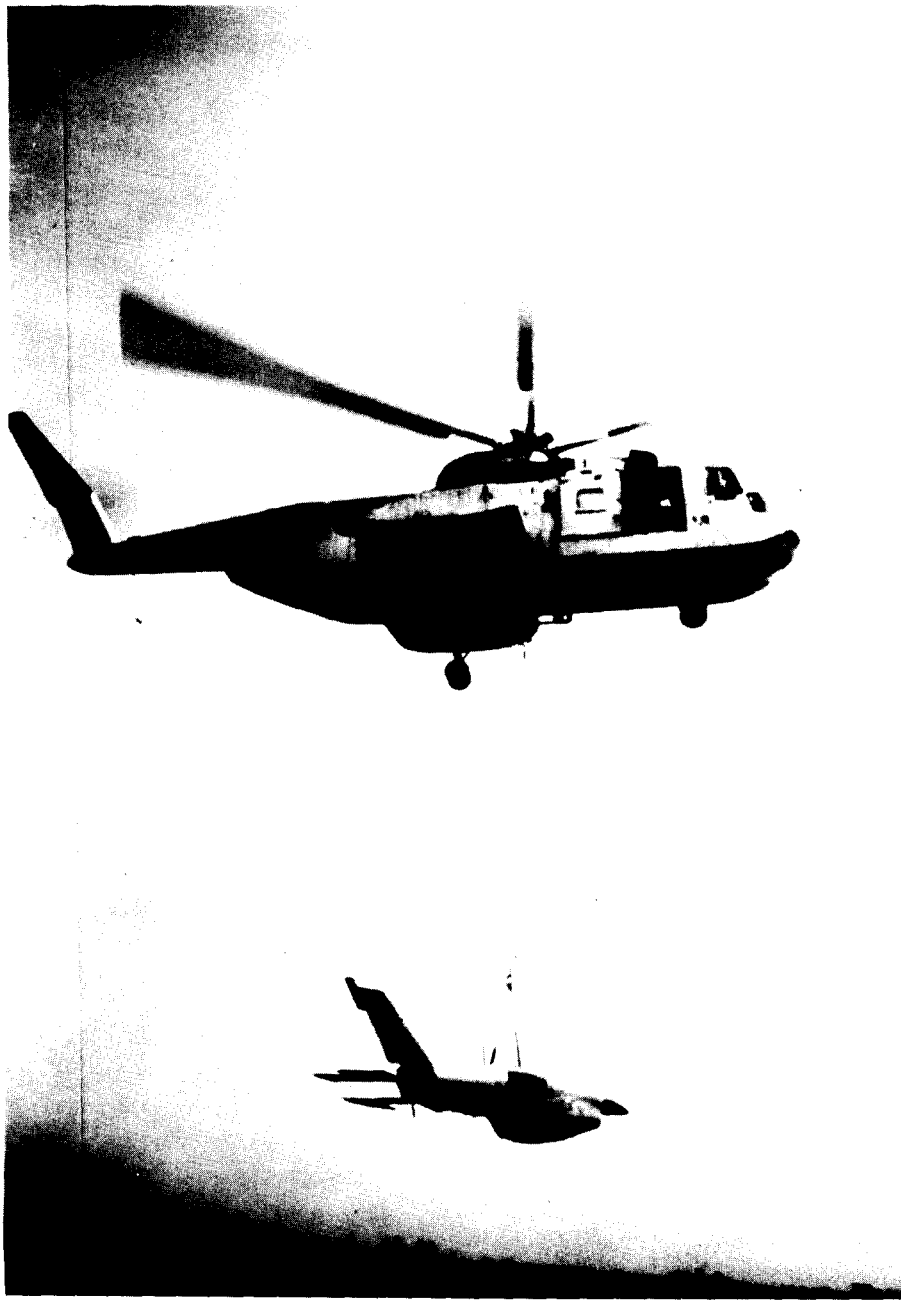
Another line of the current cruise missile's genealogy extends through RPVs.* As already described, the first practical unmanned missiles served as radio-controlled anti-aircraft targets prior to World War II. More diverse uses emerged with the appearance of the Ryan Firebee (BQM-34A). This drone sprang from a joint Army, Navy, Air Force project which began with vehicle glide tests in March 1951. The first BQM-34A flew in December 1958. Powered by a 1,700-pound-thrust engine, it was 22.9 feet long and had a 12.9-foot span. Weighing 2,500 pounds, the BQM-34A could fly up to 600 knots with an endurance of one hour at altitudes between 300 and 50,000 feet. It was about one-third the size and one-twentieth the weight of the standard fighter of the day (the F-4).[13]

Development of the Firebee accelerated during the 1962 Cuban Missile crisis when Ryan produced 147 within 3 months of receiving an Air Force request; but although ready, the Firebee was not used. The weapon flew its first operational



The USAF flew over 3,400 RPV sorties over Vietnam. C-130s carried, launched, and directed the drones. This DC-130A carries AQM-34H and AQM-34J drones over Nellis AFB in November 1971. (USAF)

*RPVs differ from cruise missiles in that they are designed to be recovered and some are controlled in flight by outside (real time) direction. Otherwise, the vehicles themselves are very similar, and could be the same. See the discussion in SALT, below.



Recovery of a Firebee II target drone by a H-53 in September 1972. A variety of Firebees flew as reconnaissance RPVs in the Vietnam war. (USAF)

sortie as a reconnaissance vehicle over Red China in August 1964. Some were lost over China, presumably to mechanical failures as well as to hostile actions. By May 1965, the Chinese Communists claimed to have downed eight—and they displayed three American drones. In tests against US air defenses, the missiles proved undetectable at low altitude.[14]

The BQM-34's extensive use in Vietnam revealed not only the RPV's promise, but its overall operational reliability and low-vulnerability in combat. The most used version was the AQM-34L ("SC"), which measured 29 feet in length and 13 feet in span. Of the 1,651 SCs launched in Southeast Asia, 87.2 percent returned. The drones flew more than 3,400 sorties in Southeast Asia, the majority over North Vietnam. Unclassified sources state that in 1971 and 1972, the Communists downed 81 drones on 743 sorties.[15] The low loss rate was due in part to the fact that Soviet radar in North Vietnam could not detect drones flying below 300 feet. One AQM-34L, "Tom Cat," flew 68 missions before being downed on its 69th on 25 September 1974. Considering the dense antiaircraft defenses in North Vietnam, and that the drones flew in the most dangerous areas, this record is outstanding. Also, the Israelis used Model 124I Firebees as decoys in the 1973 Mid-East War and at least two types of drones in their 1982 invasion of Lebanon.[16]

If new technology pushed the development of the cruise missile, then the combat performance of RPVs indicated some of the potential of low-flying, unmanned vehicles in combat. Concurrently, new requirements evolved, producing a feasible and visible, but not, as we shall see, viable program.

SCAD,* SCAM, SCUD

In the 1960s, the major powers showed little interest in the cruise missile. Rather, these nations rapidly added ballistic missiles to their inventories; and these weapons dominated strategic thinking. Meanwhile, cruise missiles served as weapons on both American and Soviet bombers, and as decoys on American bombers. In the early 1960s, USAF believed that successful bomber operations entailed the use of low-level tactics, ECM (Electronic Countermeasures), defense suppression, and decoys. Toward the end of the decade, the Air Force sought a replacement for the Quail, which a 1967 Strategic Air Command (SAC) study considered obsolete because it had limited range at low altitudes and because of its size could be carried only in limited numbers. Improvements in Soviet radar, the impending Soviet deployment of AWACS and advanced interceptors, the cancellation of the B-70, the Vietnam experience, and the appearance of new technology were also factors in the Air Force push for a new decoy.[17] In 1966 and 1967, Air Force contractors (The Institute for Defense Analysis and RAND) and the Defense Science Board Task Force studied the situation and suggested possible successors to the Quail. Two concepts put forth were a more advanced decoy (SCUD) and an armed version (SCAM).[18]

*Subsonic Cruise Armed Decoy.

RAND suggested a lower speed, longer-range missile that could be used in the B-52's rotary SRAM (Short Range Attack Missile) launcher. The basic concept was no longer to evade, confuse, and dilute enemy defenses, but to overwhelm the defense with great numbers of SCAMs which would "MIRV the bomber." The Defense Science Board Task Force report recommended a missile (dubbed MILAM, for Multiple Independently Aimed Low Altitude Missile) with an effective range of 2,000 nm. Also in 1967, a report by the West Coast Study Facility foresaw the possibility of a decoy with the same volume as the Quail flying ten times as far. It recommended a supersonic missile (ASALM, Advanced Supersonic Air-Launched Missile), the same size as the Quail, as an air-to-air missile, but conceded that a subsonic decoy missile would be a much lower risk.[19] The Air Force wanted a longer-range decoy missile, but considered arming some of the new missiles, apparently between one-tenth and one-third, to enhance their credibility.[20] The air arm has identified with the bomber for the majority of its history, from the B-17 through the B-29, B-36, B-47, and B-52 up to today's B-1B and tomorrow's stealth bomber. In SAC, many believe that future wars will be fought and won by men flying bombers into the enemy's airspace and destroying the enemy's homeland. In the minds of cruise missile advocates, this viewpoint has had a negative and important influence on USAF's treatment of the cruise missile. In the minds of cruise missile critics, however, such a position is unfounded.[21] In fairness to the Air Force flyers, it should be noted that naval aviators were also leery of cruise missiles, which they feared threatened carrier aviation, prompting Admiral Zumwalt to suspect the opposition of an "aviator's union" when he was Chief of Naval Operations.[22]

Nevertheless, General Glenn Kent, Commander of Air Force Systems Command (AFSC), initially proposed putting a warhead and a 20-pound ECM package on a missile called SCAD, but later suggested two missile programs, one armed and the other not. The issue of arming or not arming the new missile remained unresolved for the next number of years, and proved critical to the SCAD's ultimate fate.[23]

On 12 January 1968, Headquarters Air Force issued a Requirements Action Directive to Air Force Systems Command for a subsonic, armed cruise missile, superseding a document issued only three weeks earlier that called for a pure decoy. Strategic Air Command issued a Required Operational Capability (SAC ROC 68-1) for an improved unarmed decoy on 19 January.[24]

As a consequence, the Air Force initiated in-house studies of SCAD and contractor studies of SCAM. The contractor studies (awarded to Beech, Boeing, and Lockheed) concluded that the SCAM was technically feasible, requiring no technological breakthroughs. In addition, these studies found that SCAM could not only be made compatible with the SRAM launcher, but that it would provide increased flexibility to the bomber force in three roles: decoy, armed decoy, or attack missile. These studies identified propulsion, guidance, and possibly the ECM decoy payload, as critical areas in any such missile program. They recommended inertial navigation with TERCOM as the guidance system. Finally, the three contractors noted that for ranges of 1,500 to 2,000 nm, the missile would probably

be restricted to external carriage. USAF could not resolve the basic question, however, "Should the missile be a SCAD, SCAM, or SCUD?" Nevertheless, the Air Force established a SCAD (not SCAM or SCUD) project office headed by Lieutenant Colonel Robert B. Shaw in October 1968.[25]

The Air Force also debated the question internally. SAC pushed for short-range decoy missiles, while AFSC advocated a long-range armed missile. In early 1969, Secretary of the Air Force Robert C. Seamans, Jr., set out the official USAF position in testimony before the Senate Armed Services Committee. He supported the SCAD primarily as a decoy, with an arming option, although personally the Secretary was not enthusiastic about the cruise missile. The battle lines were drawn between the Air Force and the Office of the Secretary of Defense (OSD) at these hearings as Dr. John S. Foster (Director of Defense Research and Engineering) pushed for an armed SCAD. In short, SAC wanted the cruise missile to assist the bomber's penetration while OSD saw the missile as a standoff weapon, reducing if not eliminating the need for penetration. OSD cut the Air Force fiscal 1970 SCAD budget from the $30 million requested to $17.1 million.[26]

The government contracted for two additional sets of studies. Completed in 1969, the studies by Beech, Boeing, and Lockheed confirmed the findings of their 1968 studies that a SCAD was technologically practical, while those by Raytheon and Philco-Ford concluded that a credible decoy was possible. In response to an Air Force request on how an austere decoy could be built, Beech, Boeing, and Lockheed proposed a new airframe, McDonnell proposed a modification of the Quail, while Northrop, North American, and Ryan proposed a modification of their drones.[27]

Meanwhile, in September 1969, SAC affirmed its position in SAC ROC 20-69 that it wanted a decoy. But the missile had already outgrown the low cost decoy with which SAC had begun. Probably because of the pressures of SAC, Congress, and OSD, the Chief of Staff of the Air Force divided the program into two distinct parts: a low-cost, low-risk decoy for the B-52, with an early service date and warhead option; and a modular missile that could be either decoy, armed decoy, or attack missile for the B-1. In December, the Air Force established a Special Projects Office.[28]

1970s

In June 1970, General Ryan approved the austere, modular, low-cost SCAD, primarily as a decoy for internal carriage for the B-52[29] (with a later arming option). This was the weapon that SAC wanted, although OSD continued to see three options: pure decoy, armed decoy, and attack missile. In July 1970 the Deputy Secretary of Defense, David Packard, approved the USAF concept—an unarmed decoy.

Congress, however, evidenced less enthusiasm for the program, cutting fiscal year 1970 funds from $17.1 million to $9.1 million, and cutting out all fiscal year 1971 funds. The congressmen also picked up on the standoff concept; Senator Thomas McIntyre of the Committee on Armed Services repeatedly raised this point. At a hearing in March 1971, McIntyre suggested improving the accuracy of the SCAD, arming it, and using it as a standoff weapon, thereby possibly eliminating the B-1.

USAF responded unfavorably to the committee recommendations. First, the airmen emphasized the failings of the cruise missile. They argued that the cruise missile was inaccurate, could carry only a small warhead, and could be stopped by terminal defenses, a SAM barrier (a line of surface-to-air missiles), or AWACS. Second, the airmen advocated the advantages of a mixed (cruise missile and manned penetrator) force. The mixed force would cost Soviet defenders more than would a defense against either a standoff or penetrating force. The Air Force insisted that penetration was better than standoff tactics and that man must be kept in the loop. Meanwhile, OSD cut the fiscal 1972 request for SCAD from USAF's original $45 million to $10 million.[30]

Some advocates of the cruise missile suspected that the Air Force was dragging its feet on the guidance system. For decoy purposes, simple guidance would be adequate, which is exactly what USAF wanted. OSD pushed for more precise guidance, as did Congress. The Senate Committee on Armed Services advocated that USAF give the highest priority to increased accuracy and a dual role for the missile. Despite these prods, the Air Force spent little on guidance as compared to much more spent on decoy equipment.[31]

Adding to the impression that USAF was ignoring the weapon's potential (perhaps in this case unfairly) was that service's insistence that the SCAD fit the B-52's rotary SRAM launcher. This insistence would have far-reaching consequences because the dimensions of the B-52 SRAM rotary launcher constrained the design of the SCAD and, as we shall see, its descendant, the ALCM (Air-Launched Cruise Missile). The rotary SRAM launcher not only determined the size (length and diameter) of the SCAD but also fostered its triangular or trapezoidal cross section (for greater volume in the pie-shaped compartment of the launcher) and the initial "duck bill" nose shape on the Boeing SCAD (to clear the launcher's rotary mechanism).

Substantial arguments existed for continued use of the rotary launcher. (1) The B-1's planned offensive armament consisted of three SRAM launchers; changing it would upset the entire design.[32] (2) The penetrating bombers needed SRAMs (for defense suppression), which could best be carried in the rotary launcher. (3) Interchangeable SCADs and SRAMs gave SAC planners maximum flexibility. (4) Both the SRAM and SCAD require a launcher. Neither can be just dropped from the bomber; both must be ejected within certain limitations of velocity and attitude, otherwise they will not function properly. (5) Costs preclude a new launcher. (6) SAC had a considerable investment in its inventory of both SRAMs and SRAM launchers.

Therefore, in July 1971, the SCAD Project Office released letters to potential contractors, but it was not until February 1972 that Dr. Foster approved release of the RFP (Request For Proposal) for the various components (airframe, engine, decoy, and navigation-guidance) to 64 companies. Congressional insistence (also recommended by the comptroller general) on competitive prototypes, "fly-before-you-buy," presented one complication.[33] The Air Force argued that such action would increase the missile's costs and the time to initial service, and that much had already been accomplished. The airmen's view essentially prevailed, but there would be parallel development of two engines.[34]

In May 1972, USAF gave Teledyne and Williams a total of $7.4 million in contracts for engine development; and in June, awarded Boeing a $43.4 million contract for engineering the interface between the SCAD and the B-52. In July, the government announced the other contracts: $66.6 million to Boeing for the airframe, $5.2 million to Litton for navigation-guidance, and $14.2 million to Philco-Ford for a decoy package. The next month, the Deputy Secretary of Defense approved full-scale development engineering of the SCAD.[35]

But basic problems did not go away magically with the award of contracts. *Air Force Magazine* wrote in 1972 that USAF leaders "categorically deny" the claim of foot-dragging on the project.[36] The article went on to quote these leaders (partially from congressional testimony) that it "makes no sense to substitute a small, subsonic, relatively inaccurate missile for the ballistic missile" and that SCAD was too small to be a standoff missile.[37] Conveniently, the article failed to mention that USAF was responsible for the SCAD being small and inaccurate. The article ended: "The Air Force is determined to make SCAD meet these [decoy] goals, but SCAD is not, and never was meant to be, a new strategic weapons family."[38] In short, USAF meant it only to be an adjunct to the bomber, not a replacement.

Senator Proxmire, in June 1971, was the first publicly to make the charge of Air Force obstruction to protect the B-1. Cancellation of a number of DSARC (Defense Systems Acquisition Review Council) meetings and the feeble effort to extend SCAD range did not help the USAF case. (The Air Force insisted that it did not need extended range for a decoy—that extended range was needed only for the armed version.) The engineers took two approaches to extend the missile's range: lengthening the missile's fuselage, and adding a belly tank. But as neither of these missiles would fit the SRAM launcher, both had to be carried externally. The Air Force opted for the less aesthetic belly tank arrangement, which they claimed offered longer range than the extended fuselage version, because six could be carried externally on pylons versus only three of the extended fuselage types and because the SRAM launcher could still be used with the standard missiles.[39] The specifics of SCAD range are still shrouded by classification but we know that the belly tank SCAD would degrade bomber performance more than the extended fuselage version, and today's pylons carry six extended-range missiles each.

Even more damaging to the Air Force position were two studies released in early 1973. A Government Accounting Office study criticized the SCAD program for a

number of reasons, but its most telling point dealt with schedule slippages. It noted that the SCAD would not be operational until two years after the threat it was designed to counter. Even more damning and embarrassing was an Air Force study. After requests from the Director of Defense Research and Engineering (DDRE) on 12 January, Headquarters Air Force ordered an examination of both bomber tactics and the role of SCAD in the 1980s. A little over one month later, USAF briefed the study, Saber Penetrator V. It concluded that while SCAD was vital to the B-52, increasing the Boeing bomber's probability of penetration by 50 percent, SCAD was not vital to the B-1, whose probability of penetration increased only one percent.[40]

It soon became evident that the Air Force had been less than candid with Congress concerning the SCAD and the aircraft that would employ it. Since 1971, Air Force spokesmen had insisted that the missile would be used to aid both the B-52 and the B-1, and that the missiles carried on the two bombers differed only in their electronic decoy package. Later testimony indicated that in fact the two versions would also have different airframes. In May 1973, an Air Force General admitted to a Senate Committee that: "SCAD would exactly be the wrong shape, size, and [too] sharp cornered . . . to provide a standoff vehicle."[41]

At a DSARC meeting on 13 April 1973, Dr. Foster found the Air Force plan unsatisfactory because it did not call for simultaneous fielding of the decoy and the armed, extended-range versions of SCAD. In addition, the DSARC participants were not convinced of the absolute value and urgency of a B-52 SCAD. Foster requested that USAF return within two weeks with additional rationale for the device and a plan for simultaneous IOCs (Initial Operational Capability). The Air Force insisted that it wanted a minimum cost decoy and did not comply. The inevitable came in short order. On 20 June, Foster directed USAF to submit a plan for simultaneous IOCs for the armed and unarmed versions. The resulting plan of 28 June left Deputy Secretary of Defense Packard unimpressed, as he ordered cancellation of full-scale engineering development of the SCAD on 30 June. The cancellation orders went out in July. Thus the Air Force did not get its decoy missile replacement.

A number of factors killed the SCAD project. First, costs appeared to exceed benefits. Development costs skyrocketed, more than doubling in six months, from $285 million to $700 million. Procurement costs of $604.7 million must be added, pushing total costs to $1.3 billion.[42] Second, the failure of the Soviets to deploy AWACS and look-down/shoot-down fighters (the antidote to low-flying aircraft) as rapidly as feared represented another factor in SCAD's demise because the existing defensive threat did not justify SCAD. Other factors involved late availability, marginal capacity to penetrate, and ineffective ECM.

Air Force reluctance to support the armed version of the missile, however, was probably the key. The airmen simply did not want SCAD; at the very best, they appeared to be lukewarm. Insistence on the decoy version, simple guidance, and restrictions on SCAD's dimensions, and hence range, indicated the Air Force's position. This position ran directly counter to that of both OSD and Congress. A congressional report sharply concluded:

> The Air Force has proceeded with this program solely as a decoy, not withstanding the direction of the Congress. It is generally recognized that the Air Force has resisted pursuing SCAD with an armed warhead because of its possible use as a standoff launch missile. This application could jeopardize the B-1 program because it would not be necessary to have bomber penetration if a standoff missile were available as a cheaper and more viable alternative.[43]

The final question concerned mission: Why build SCAD to help the soon-to-be retired B-52, a device not needed by its successor, the B-1?[44]

SCAD was finished. But the decisionmakers continued development of its technology to keep the SCAD option open if the Soviet threat materialized. Congress directed that the two similar cruise missile programs, Air Force and Navy, be merged.[45]

Harpoon

The US Navy never put a high priority on the cruise missile either. One reason was that naval aviators had dominated the sea service since their glory days in World War II. They championed their weapon, and saw little need for cruise missiles. In contrast, the Soviets compensated for their lack of carrier aviation by developing a large family of cruise missiles. Another factor accounting for this imbalance was the difference in the size of the two fleets; the Soviets had many more ship targets than did the US Navy. Although the American Navy knew of Russian cruise missiles and the potential and feasibility of cruise missiles, it was not until the sinking of the Israeli destroyer *Elath* in October 1967 by Soviet Styx antiship missiles that the US Navy moved purposefully into this area.

Fortunately for the Navy, McDonnell-Douglas had already initiated antiship missile studies in 1965 so that the company was ready in late 1967 for a Navy study contract for ship- and air-launched antiship missiles. The Navy wanted a 40-nm-range missile to carry a 250-pound conventional warhead that could use existing naval missile (Talos, Tartar, and Terrier) magazines, hoists, and launchers.[46]

To meet this objective, the US Navy established the Harpoon program in 1969. In November 1970, DSARC approved the development of two versions of the missile, AGM-84A air-launched and RGM-84A-1 ship-launched. In June 1971, McDonnell-Douglas won the airframe contract and the next year Teledyne beat out Garrett for the turbojet contract.[47] In January 1972, the Navy added submarines to the two other launch platforms.

Powered tests began in July 1972, the first flight occurring in December of that year.[48] The basic missile can carry a 500-pound warhead 60 nm. In June 1974, the DSARC authorized pilot production of 150 missiles and in July 1975 the Harpoon received production go-ahead. Two years later, the Navy approved a deployment

decision. McDonnell-Douglas delivered the 1,000th missile in late 1979, and by early 1980 had a further 1,735 on order.[49] The Harpoon's importance to this study is that it provided the basis for bigger and better things. But the transition between Harpoon and follow-on cruise missiles went through a number of confusing naval programs in the early 1970s.

STAWS and SCM to SLCM

The concept of an underwater-launched cruise missile did not receive serious consideration until 1970, when a study by the Center for Naval Analysis concluded that such a missile was indeed feasible. The Systems and Analyses Section within OSD initiated discussions of fitting cruise missiles into ten old Polaris boats with three missiles in each ballistic missile tube. Meanwhile, the CNO (Chief of Naval Operations) established a panel with an unwieldy title, Submarine-Launched Anti-Surface Ship Interim Missile Ad Hoc Panel, which recommended an encapsulated Harpoon* as the quickest way to achieve a submarine-launched cruise missile capability. In April 1971, Naval Air Systems Command took a different tack when it proposed a new class of nuclear-powered submarines armed with 20 vertical tubes to launch 30-inch diameter, 300- to 500-mile-range cruise missiles, a concept referred to as the Submarine Tactical Antiship Weapons System (STAWS).[50]

Thus, by late 1971, the Navy had two parallel cruise missile programs going: the encapsulated Harpoon short-range missile, and STAWS, sometimes known as ACM (Advanced Cruise Missile), a somewhat longer-range missile. At this point, intraservice politics entered in the person of the hard-driving maverick, Admiral Hyman Rickover, who saw the latter concept as a way to advance nuclear-powered submarines. In 1971 and 1972 he repeatedly told the congressmen of the system's great value, testifying that it was the "single most important tactical development effort the Navy must undertake."[51] In essence, Admiral Rickover, never popular with the Navy brass, proposed to siphon off Navy money for nuclear submarines. The negative reaction to Rickover's initiative is evident in the Navy's fiscal year 1973 budget request: only $4 million for ACM/STAWS but $16 million for the encapsulated Harpoon.

The Navy's revived strategic cruise missile program really begins in January 1972 with a memo from the Secretary of Defense to the DDRE to start a Strategic Cruise Missile (SCM) with Fiscal Year 1972 supplemental funds. The CNO ordered that priority be given the encapsulated Harpoon.[52]

It was an outside event, however, that pushed the strategic cruise missile program forcefully forward. The May 1972 signing of the SALT (Strategic Arms Limitations Treaty) agreement (see below), instead of limiting the cruise missile, nurtured it. For within a few weeks of the signing, in a move that seemed to contradict the spirit

*The missile is encased in a metal capsule for protection and ease of handling. The firing sequence is described in Figure 7.

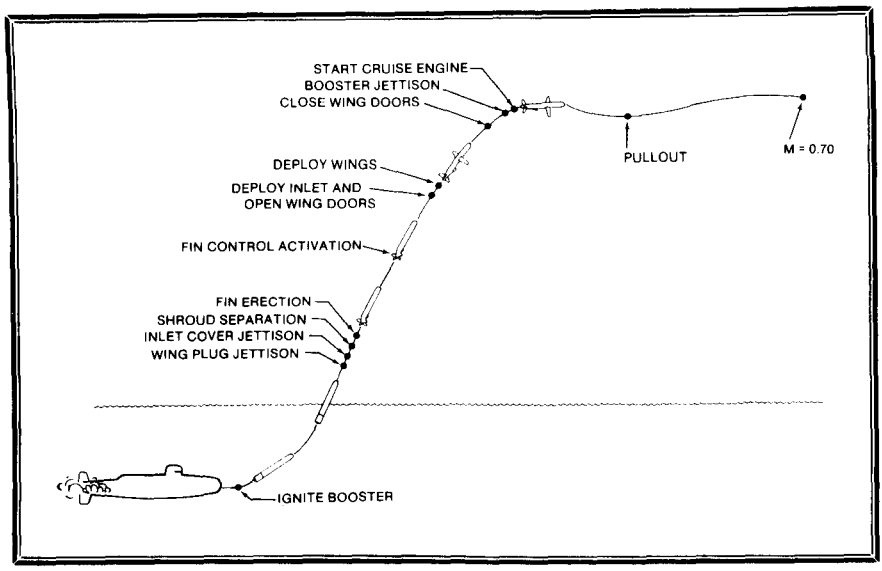


Figure 7. Submarine launch sequence. The SLCM launch procedure requires approximately 20 minutes to align the missile's guidance, and check out the missile's system. Then the submarine's torpedo tube is flooded, the internal missile's pressure equalized with the tube, and the outside torpedo tube door opened. When fired, a hydraulic device propels the missile inside the capsule and the torpedo tube. (The capsule is later ejected.) Thirty feet from the submarine, a lanyard ignites the booster which pushes the missile toward the surface, guided by four jet vanes around the booster's nozzle. The Tomahawk emerges from the water with an escape velocity of about 75 fps. Once clear of the water, covers from the wing slots and the booster-missile junction fly off, permitting springs to deploy and lock the four cruciform configured (+ shaped) tail fins into position. These fins roll the missile 180 degrees. When the booster burns out after 12 seconds, it is jettisoned and the wings deploy. At this point the missile is 1,100 to 1,300 feet over the water and above flying speed. Meanwhile, the air intake beneath the fuselage extends, and a gas cartridge fires to start the turbofan engine which powers the missile in the cruise phase.

and promise of the newly concluded treaty, Secretary of Defense Melvin Laird requested an additional $1.3 billion from Congress for strategic weapons. He reasoned that the United States needed the increase in defense spending as both a hedge against a breakdown of detente and as a bargaining chip for future discussions with the Soviets. (Some insist that Laird used the move to win the support, or at least acceptance, of both the Joint Chiefs of Staff (JCS) and conservative politicians for SALT in the critical senate ratification hearings.) The request provided primarily for the bomber (B-1) and Trident SLBM (Submarine-Launched Ballistic Missile) programs, but included $20 million for SCM. Apparently Laird had not intended to push the cruise missile, but the Navy convinced him that the United States could get both strategic and tactical weapons at a relatively low cost.[53]

SALT I introduced another twist into the cruise missile's story due to the agreed limits on SLBMs. The overall ceiling on nuclear weapons meant that as the newer Poseidon-armed nuclear submarines became operational the older Polaris-armed boats would have to be retired. But the Americans saw an opportunity in this situation, for the treaty did not mention cruise missiles. (The Soviets would not seriously discuss them, as only they had the weapon.) Therefore, putting cruise missiles aboard these older subs had considerable appeal by keeping these boats operational, increasing the number of strategic weapons, and, incidentally, closing out Admiral Rickover's bid for a new submarine. In addition, administration officials noted that the Russians had cruise missiles aboard their submarines, neglecting to mention that these missiles were large, short-range weapons, vintage early 1950 technology, mostly on diesel-powered boats. Finally, the proponents asserted that the new weapon, called yet another name, SLCM (Sea-Launched Cruise Missile)* by Laird, would stress Soviet air defenses.[54]

But up to this point, SLCM was just a vague idea; the Navy did not know precisely what it wanted. They considered four launch options: vertical from converted SSBNs (nuclear-powered ballistic submarines), horizontal from SSNs (nuclear-powered attack submarines), horizontal from SSBNs, and vertical from a new SSN. Laird and OSD liked the first option, the CNO the second, and Admiral Rickover and his submariners the fourth.

The missiles for these platforms were as varied as the options and their advocates.[55] In mid-1972, the Navy considered five different cruise missiles, at least three vertically launched, ranging in diameter from 19 inches to 36 inches, and in weight from 1,850 pounds to 8,350 pounds, and two 19-inch diameter encapsulated missiles. The variety of missiles expanded by January 1973. By then, the Navy considered five SCM contractor proposals, each designed to fit three missiles in a Poseidon tube.[56] In addition, there were five contractor proposals for encapsulated vertical-launched missiles.[57]

During 1972 the choices narrowed as the Navy dropped STAWS, merged the strategic and tactical cruise missile programs, and scuttled the proposed new cruise missile submarine. In November, the Navy rejected the four options under consideration in favor of a new option, a SLCM launched from a torpedo tube. This mode of operation, however, restricted the missile to the 21-inch diameter and 246-inch length of the torpedo tube, and the 4,200-pound weight of the handling equipment. This new missile would have both strategic and tactical versions, although the Navy emphasized the former. The Navy insisted that these two versions would be about 85 percent common. The proposed missile ensured maximum versatility of launchers by retaining submarines as a platform. In fact the new missile would not be tied to a particular launch platform, but would be suitable for air, surface, and subsurface launch. It would employ existing technology: boosters from the SUBROC program (a submarine-launched antisubmarine weapon) and engines from SCAD, for example. Therefore the Navy assessed the

*The acronym SLCM originally stood for "Submarine Launched Cruise Missile," but currently translates as "Sea Launched Cruise Missile" to include both ship and submarine launchers.

program as a medium risk. After soliciting 12 companies, the Navy awarded design contracts to five in December 1972.[58]

The Navy and Air Force programs, already linked in some minds, officially converged in the summer of 1973. The Department of Defense (DOD) was in the process of cancelling SCAD when SALT intervened again. On 11 June 1973, Kissinger wrote Clements of the utility of the strategic cruise missile as a bargaining chip in the SALT negotiations. He repeated this view a week after SCAD's cancellation on 13 July. Secretary Clements responded to the Secretary of State that there were two cruise missile programs, one Navy and one Air Force. So there were. As we shall see shortly, the USAF Program received new life and a new name on 20 July when it was reconstituted as ALCM. A memorandum from the Deputy Secretary of Defense on 14 August 1973 set out in general terms the two separate programs. The Navy would conduct competitive flights in 1973 to demonstrate underwater, air, and surface launches. While DOD emphasized the strategic missile, it also wanted to demonstrate the tactical missile.[59]

DOD ordered the Air Force and the Navy to cooperate with each other in developing the key components of cruise missile technology; Air Force shared its turbofan engine and high energy fuel, Navy shared its TERCOM guidance system. DOD put this rather loose arrangement into a formal program decision paper on 19 December 1973, and DSARC approved it in February 1974.

Secretary Clements stressed missile commonality and interservice cooperation. He believed deployment would be possible for the ALCM in late 1978, and for the SLCM in 1980.[60]

The Navy Effort: General Dynamics Wins the SLCM Contract

In December 1973, the Deputy Secretary of Defense ordered the Navy to conduct a flyoff to choose its SLCM contractor. The next month, Naval Air Systems Command selected Convair (General Dynamics) and Chance Vought (LTV) as the two finalists. These two companies proposed quite different designs to meet the Navy's goals, which included a 1,300- to 1,400-nm range.[61]

The Vought missile's stainless steel fuselage measured 214 inches in length (plus 32 inches for the booster). The missile carried two unusual features: a three-piece curved wraparound tail that extended in flight, and a one-piece fiberglass wing which spanned 126 inches. From its stowed position atop the fuselage, the wing pivoted 90 degrees around its center through narrow slots to the extended position. Panels then closed over the slots (a modification to the original flyoff covers), permitting both surface and air launching. A Teledyne CAE 471-11DX turbofan engine powered the Vought missile.[62]

Convair took a different approach to the problem. A 1¼-inch steel capsule, weighing about 1,000 pounds, enclosed the missile until it fired from the torpedo

tube. (See figure 7.) The missile's welded aluminum fuselage measured 18 feet in length, its wings 8½ feet in span. Like the Vought missile's wings, the wings of the Convair entry were also unconventional; they were stored scissor-like, that is, one above the other, which means that, deployed, one wing is higher than the other. A Williams F-107-WR-100 turbofan engine powers the General Dynamics (GD) missile.[63]

The flyoff* competition required each contractor to qualify its missile with one successful transition from underwater launch to inflight glide on two launches. GD achieved success on both 13 and 15 February 1976. Vought did not do as well. On the Vought missile's first test, the hydraulically actuated torpedo tube failed, a failure correctly charged to the Navy. On the second attempt on 24 February, the missile broached the surface but the wing did not deploy. The Navy scheduled another test for 24 March, but on 8 March cancelled the program. Vought's cost overruns and test failure, as well as GD's successes, were factors in the Navy's decision. After rejecting a Vought proposal to finance a second test, on 17 March the Navy awarded the missile contract to General Dynamics. Two months later, the Navy named Williams as the winner of the engine contract.[64]

Between 1973 and 1977, the Air Force and Navy cruise missile programs continued to converge. A memorandum from DDRE in January 1975 ordered the two programs restructured so that they would share common milestones as mandated in December 1973. The services complied and presented their revised program to a DSARC 1A review on 18 March 1975, a program approved by the Deputy Secretary of Defense in May. The DDRE memo instructed the Navy to select a guidance contractor by October 1975, and scheduled the first ALCM flight in February 1976, the first SLCM flight in May, and fully guided flights in September and October, respectively. The memo urged maximum commonality for the ALCM and SLCM with the goal of a common warhead, navigation-guidance system, and powerplant. By April 1976, the Air Force would help the Navy begin work to launch an SLCM from a B-52.[65]

The Navy selected the guidance contractor in October 1975. E Systems, the originator of TERCOM, designed a new system for the competition while its rival, McDonnell-Douglas, used off-the-shelf components. The Navy aimed for an average accuracy of .1 nm for its strategic missile. In the flyoff competition flown in an Air Force C-141 over a 1,500-nm course, McDonnell-Douglas recorded five successful flights, E Systems none. Therefore, the choice was not difficult. The Navy awarded McDonnell-Douglas a $12.8 million SLCM guidance contract and a $1.4 million ALCM contract.[66]

In February 1976, the Navy began its study of air launching an SLCM from a B-52 and established a January 1980 IOC for ALCM. But in August 1976, this date slipped to July 1981. The Navy set July 1980 IOCs for the conventional land attack and antiship Tomahawk, January 1981 for a surface-launched conventional variant, and July 1981 for a land-launched nuclear missile.[67]

*Even before the Navy conducted the flyoff in September 1975, the CNO approved the name Tomahawk for the SLCM.

ALCM

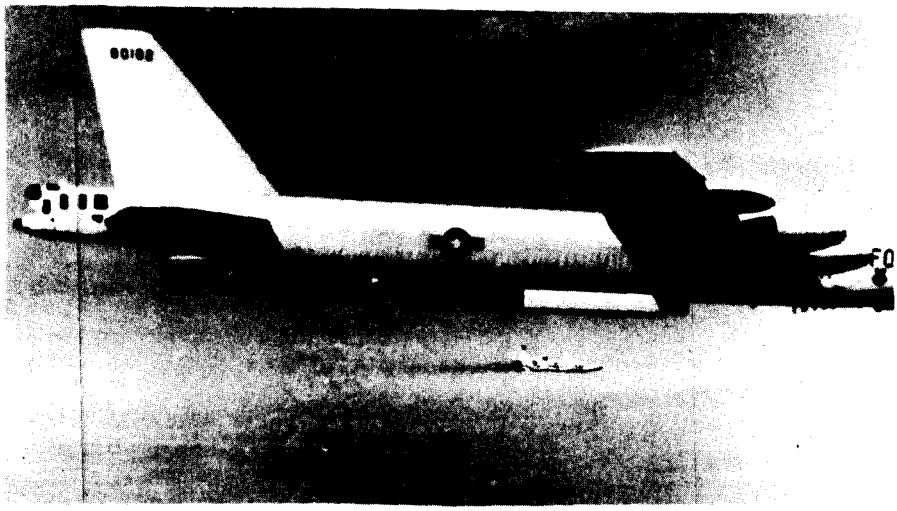
On 19 December 1973, Secretary Clements established the ALCM program from the SCAD program: "The ALCM will make maximum utilization of the terminated SCAD engineering development program for a vehicle design and small turbofan engine development."[68] USAF went ahead with the existing weapon rather than start over again with just the SCAD technology. After DSARC endorsed this move in a February 1974 meeting, a change order went out to Boeing and Williams, cancelling the stop order of the previous summer.[69]

But it was not long until some questioned the necessity of two cruise missile programs. In 1974, DDRE (Malcolm Currie) favored the SLCM over the ALCM to the extent of standardizing on the Tomahawk, even though the naval missile was thought to be two years behind the Air Force one. An important factor against the ALCM was the Air Force's lack of enthusiasm for it. USAF clearly maintained its position that the ALCM was useful to assist the bomber (B-52) but, in the words of the Chief of Staff, the ALCM ranked in importance behind the new Air Force bomber (B-1) and the new Air Force ICBM (MX).[70] The Air Force attitude toward ALCM changed, however, as the naval cruise missile program began to pick up technical momentum and, even more important, political momentum.

Congress also entered the fray. In late 1975, the House of Representatives deleted all money from the ALCM program while retaining financing for the SLCM program. Congress was aware of the Tomahawk's progress as well as the Air Force's reluctance to support the ALCM program. Congress, however, overestimated the similarity between the two missiles and considered the two seemingly parallel programs unnecessary. In early 1977, the estimated saving by using the Tomahawk as both ALCM and SLCM was thought to be about $300 million. While the Senate restored the ALCM funding, the trend was clear. USAF reluctantly and, almost, belatedly hurried to "get on board" to avoid getting "a torpedo rammed up its bomb bay."[71] For a very real and growing possibility existed that if the Air Force did not produce a suitable cruise missile, DOD and Congress would see that the Navy did. (This is an excellent example of how civilian leaders exploit interservice rivalry.) Little wonder then that the ALCM program took a different turn in the mid to late 1970s. As a SAC internal document put it in early 1976, "SAC's position . . . has mellowed, because of the political atmosphere, and is [now] in line with higher echelon thinking."[72]

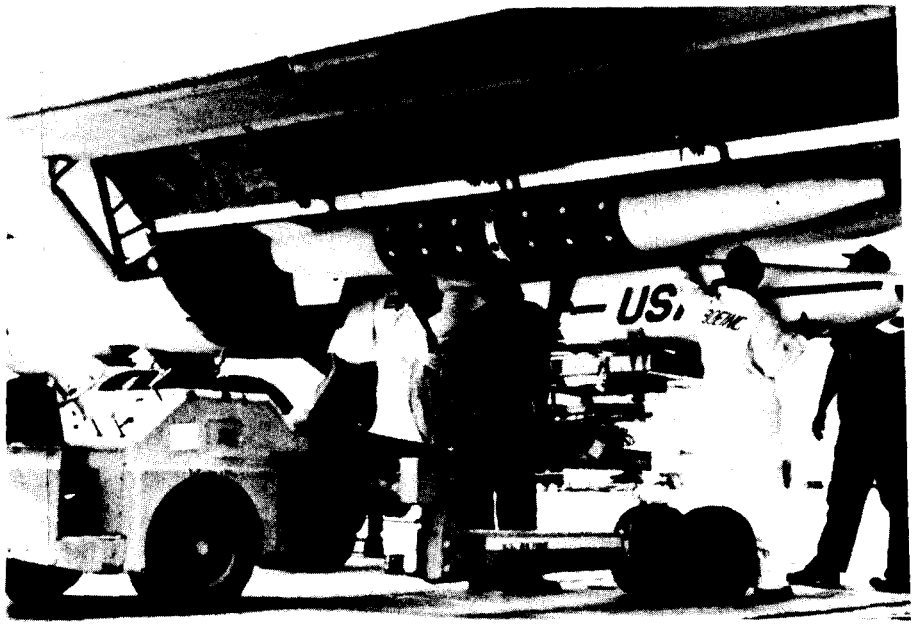
The ease of adapting the Boeing SCAD simplified that weapon's transformation into ALCM. The two missiles looked the same, differing only in payload (nuclear warhead substituting for the ECM package), removal of 21 antennas, and wing construction (metal replacing fiber-glass). It is most important to remember that Boeing designed ALCM to fit the B-52's SRAM launcher, just as GD designed its SLCM to fit a submarine torpedo tube. These factors constrained both missiles' length and shape, thus their performance.[73]

The Boeing AGM-86A had a trapezoidal cross section, elevon controls, and duck

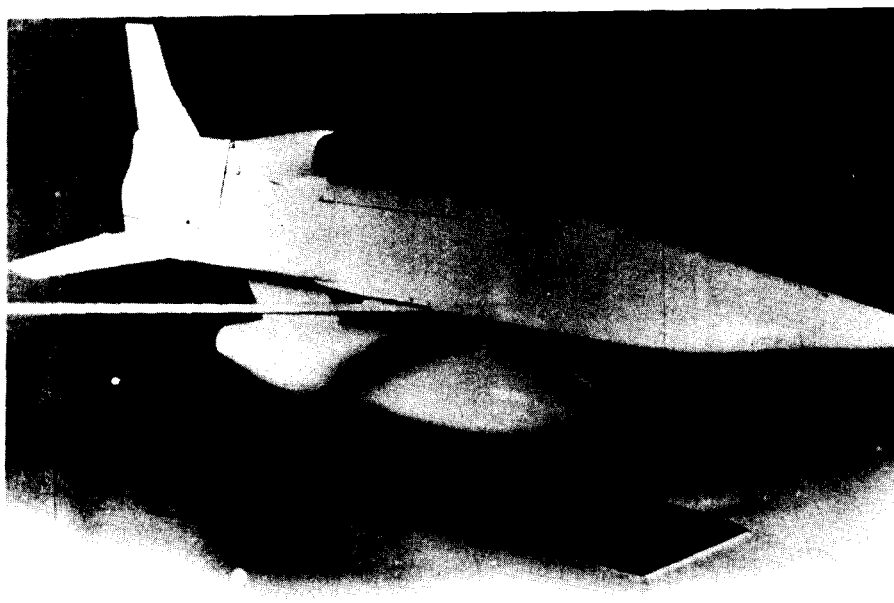


The launch of the Boeing AGM-86A on its first powered flight on 5 March 1976. Dropped from the weapon's bay at 10,000 feet, it flew 10 minutes and reached Mach .65. (USAF)

This view of the AGM-86A reveals the inlet above the fuselage and the "duck bill" nose. (Boeing)



AGM-86A being uploaded into SRAM Rotary Launcher alongside SRAMs. Note the cruise missile's size, nose, and folded tail fins. (Boeing)



One way to extend the range of the AGM-86 was to attach a belly tank. No such missile was built; shown here is a 3/4 scale model. (USAF)

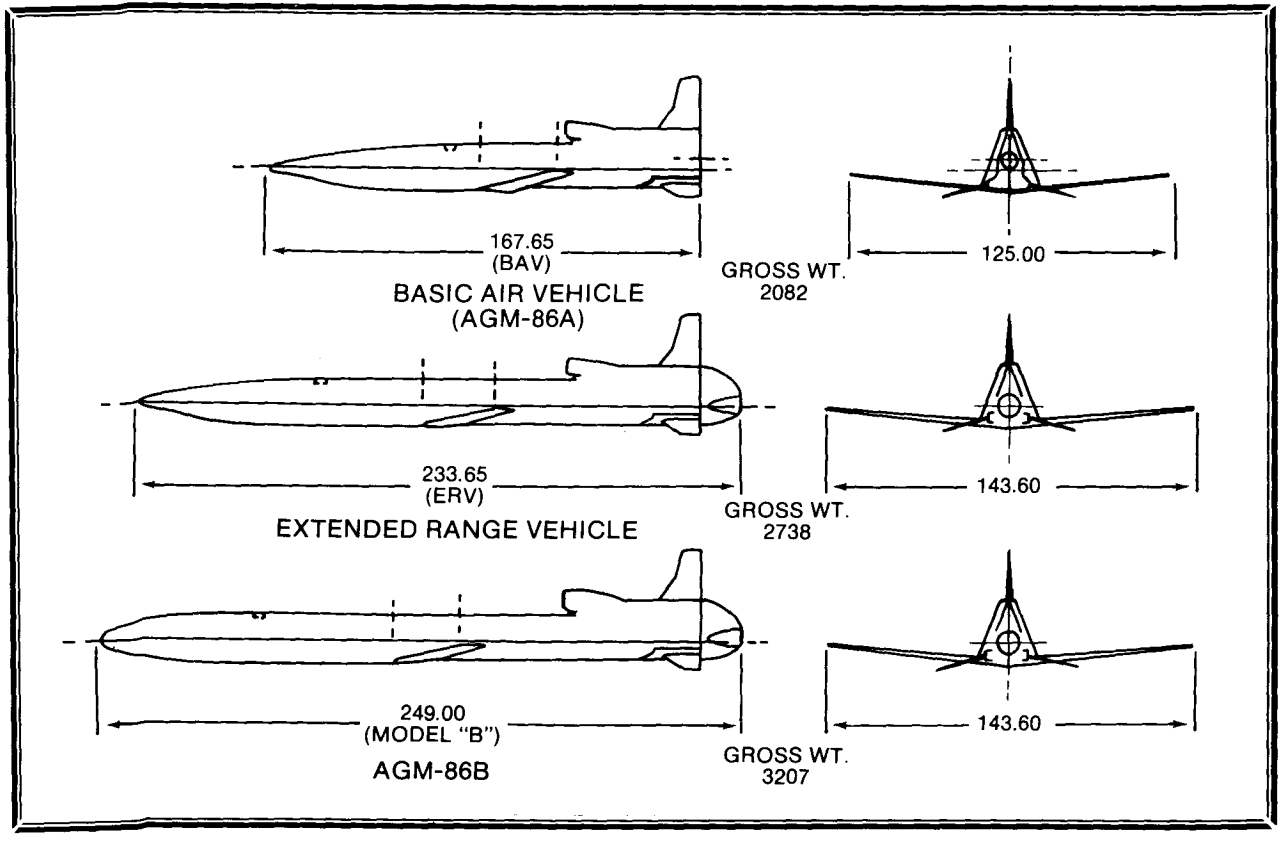
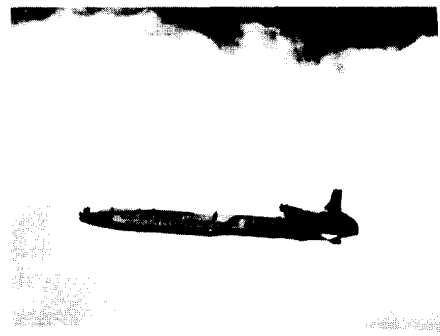


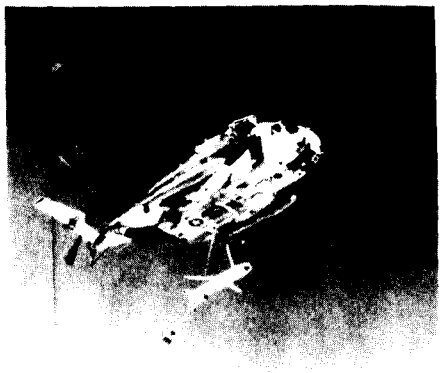
Figure 8. The Boeing cruise missile family. The Boeing's basic air vehicle (top) was the SCAD which became the AGM-86A. The requirement for longer range led to the extended range vehicle (middle) and eventually to the AGM-86B (bottom).

A second way to extend the range was to extend the body of the missile. The difference in size can be seen in this picture of mockups of the AGM-86B (left) and the AGM-86A (right). Also note the small swept back wings and negative dihedral tail. (Boeing)

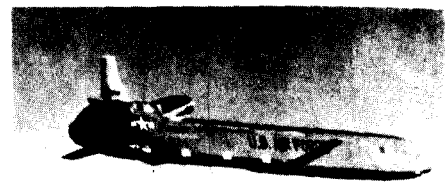
AGM-86B (FTM-2) being launched from the left pylon of a B-52 on 6 September 1979 during the flyoff competition. (Boeing)



This 6 September 1979 flight was the AGM-86B's second powered flight. (Boeing)



FTM-2 flew 249 minutes and was successfully recovered, even if in this rather undignified position. (Boeing)



FTM-10 over Utah. After this first low altitude launch from the SRAM rotary launcher on 29 November 1979, the Boeing missile flew 265 minutes. (Boeing)

Four key individuals involved in the ALCM program at the roll-out of the first AGM-86B on 20 March 1979. From left to right are: LTC Gene P. Burbey, Offensive Avionics Program Manager, Mr. Ray Utterstrom, Boeing Program Manager, Rear Admiral Walter Locke, Director of the Joint Cruise Missiles Project Office, and Colonel Alan Chase, ALCM Program Manager. (Boeing)

There were of course others involved in the development of the cruise missile. Shown taking the oath of office from Secretary of Defense Robert McNamara (right) on 1 October 1965 are (left to right) Norman S. Paul, Undersecretary of the Air Force, Thomas D. Morris, Assistant Secretary of Defense (Manpower), Dr. John S. Foster, Jr. Director, Defense Research and Engineering, and Dr. Harold Brown, Secretary of the Air Force (and later Secretary of Defense). The last two were directly involved with the cruise missile. (USAF)

bill nose. (See figure 8.) The wings were stored switch blade fashion and, when extended, were swept back 35 degrees, spanning 115 inches. The subsonic (Mach .65 to .85) missile could fly 650 nm. The Air Force conducted the first jettison test from a SRAM launcher in June 1975. Flight testing began in March 1976.[74]

The Boeing AGM-86A flew its first powered flight on 5 March 1976. AGM-86A flew successfully on its next two attempts, and on 9 September successfully completed its first fully guided flight. The missile negotiated four TERCOM map sets, demonstrating its terrain avoidance ability by flying at 180 feet above ground level and as low as 30 feet above the ground during its 31-minute flight. But due to an error in filling the fuel tank, the missile ran out of gas and crashed one mile short of its target. That may have been an ill omen for the next two tests. On test number five, 14 October, the gyros tumbled after eight minutes of flight, resulting in a crash. The last test of the series, on 30 November, also failed—this time because the engine refused to run, flaming out three times. But the missile, released at 7,000 feet, glided for 75 seconds, climbed 1,000 feet to clear a mountain, and landed 10 miles from its release point. Because Boeing did not fit the missiles with recovery equipment, only missile number seven remained.[75]

Another key individual was William P. Clements, Jr. then Deputy Secretary of Defense, later Governor of Texas. (USAF)

Meanwhile, the Tomahawk program caught and passed the Boeing ALCM. The GD missile's first flight on 28 March took place only three weeks after Boeing's first free flight. But the Navy conducted its first fully guided test (lasting 61 minutes) in June, three months ahead of USAF. In 1976, the Navy flew 16 flights, amassing about 13 hours of flying time compared with the Air Force's six flights and 1¼ hours of flying time.

Two aspects help explain the Tomahawk's surge. First, the GD missile had fewer failures, apparently only one. Second, the Tomahawk was reusable. Fitted with a parachute and flotation gear, 80 percent of these first GD birds were recovered and reused.[76] Hence, the Air Force and Boeing saw what many had thought in 1974 was a two-year developmental lead disappear during 1976 as the Tomahawk swept on by.

NOTES

CHAPTER V

Data within the brackets indicate the location of the material and, in the case of the Air University Library and Albert F. Simpson Historical Research Center, their call numbers. Joint Cruise Missiles Project Office, Washington, D.C. [JCMPO]; Naval Historical Center, Washington, D.C. [NHC]; Strategic Air Command, Offutt AFB, Nebr. [SAC]; Aeronautical Systems Division, Wright-Patterson AFB, Ohio [ASD]; National Air and Space Museum, Washington, D.C. [NASM]; Albert F. Simpson Historical Research Center, Montgomery, Ala. [AFSHRC]; Air University Library, Montgomery, Ala. [AUL].

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10. Tatum, 15; Wainstein, 15, 16; History, Directorate of Research and Development, July to December 1970, II, 221 [AFSHRC-K140.01 II Jan–Dec '70].

11. Shelldyne H has 33 percent more energy per unit volume than standard JP-4 fuel. While the fuel initially promised an increase of 15 to 30 percent in range, later testing forced a 30 percent downward revision of these estimates. Two problems with high energy fuels are their high viscosity at low temperatures, which hampers starting at high altitudes, and higher costs. JP-9 costs from $35 to $105 a gallon, in 1982 around $50 a gallon. Wainstein, 17, 22; Michael L. Yaffee, "High Density Missile Fuel Research Grows," *Aviation Week* (7 May 1973), 67; Interview, Colonel Joseph Rutter, 29 March 1982; Aeronautical Systems Division, Historical Report, ASD/YM 86, January–December 1976, Sect. 4, 9–15 October [ASD]; ASD Historical Report, ASD/YM, January–June 1977, Sect. 2, 28 May–3 June and 2–16 June [ASD].

12. Wainstein, 17, 18; AGM 86A Program Office, "AGM-86A (SCAD) Final Report," Vol. II, Chapter 14, Engineering, SCAD Document No. 141, 9 July 1973, 12 [ASD].

13. *Jane's All the World's Aircraft: 1981–82* (London: Jane's, 1982), 669, 670; Government Accounting Office (GAO), "Department of Defense Use of Remotely Piloted Vehicle Technology Offers Opportunities for Saving Lives and Dollars," April 1981, 1; William E. Krebs, "Did We Err in the Development of Remotely Piloted Vehicles?" Air War College thesis, 1979, 14 [AUL-MU43117 K92d].

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15. Wagner, 199, 200, 213.

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19. Wainstein, 52–55; Linee, 62.

20. Wainstein, 54; Senate Armed Services Subcommittee, Air Force FY 1972 Authorization, 3102.

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23. Wainstein, 55.

24. Ibid., 56; Jerry V. Poncar, "The Subsonic Cruise Decoy (SCAD) Program: An Analysis of Systems Requirements and Program Direction," Air War College thesis, 1974, 16 [AUL-MS32983 P792s].

25. Poncar, 17; History of Aeronautical Systems Division, July 1968–June 1969, Vol. I, 5 [AFSHRC-K243.011, I, FY69]; United States Senate, Committee on Armed Services, Research and Development Subcommittee, "SCAD," 16 May 1973, 3326; ASD, SCAD Final Report, Vol. II, Chapter 14, 10, 11.

26. "SCAD Seen in Danger of Cancellation," *Aerospace Daily* (5 April 1973), 201; "High Level Activity on SCAD Prompts New Hope for Program," *Aerospace Daily* (13 August 1970), 241; Poncar, 18–20, 27, 28; Huisken, 65, 66; USAF Oral History Interview, Robert C. Seaman, Jr., 1973–74, 64 [AFSHRC-K239.0512-687A]; "The Trouble With SCAD: Nobody is Sure What It Is," *Aerospace Daily* (21 May 1970), 113; ASD History, Fiscal Year 1972, I, 109.

27. History of Directorate of Operational Requirements, Research and Development, July-December 1969, Vol. II, 78, 79 [AFSHRC-K140.01 II Jul–Dec '69]. Hereafter cited as DOR History, although Directorate renamed Development and Acquisition in 1972.

28. Poncar, 20, 23; DOR History, July–December 1969, II, 80–81; Wainstein, 56, 57; ASD History Fiscal 1972, 109, 113.

29. The Air Force spokesman testified in congressional hearings in 1969 and 1970 that SCAD would help both the B-52 and FB-111. In 1971, the USAF no longer mentioned the FB-111 but did link SCAD with both the B-52 and B-1. DOR History, January–June 1970, II, 258–259; DOR History, July–December 1970, II, 212, 213; US House of Representatives, Appropriations Committee, "Department of Defense Appropriations Fiscal Year 1972," part 6, 27 May 1971, 293, 362; Senate, Armed Services Subcommittee, "Air Force Fiscal Year 1972 Authorization," 3094; US Senate, Armed Services Committee, "Authorization for Military Procurement, Research and Development Fiscal Year 1971 and Reserve Strength," part 1, 26 February 1970, 325; US Senate, Armed Services Committee, "Authorization for Military Procurement, Research and Development, Fiscal Year 1970 and Reserve Strength," part 1, 15 January 1969, 30, 31; ASD Historical Report, AGM-86 SCAD, July–December 1970 I [ASD].

30. DOR History, January-June 1970, II, 257, 259; DOR History, July–December 1970, II, 216, 217; DOR History, January–June 1972, II, 197; Canfield and Kellett; Huisken, 66, 68; Wainstein, 58, 59; "Urging Stand-Off," *Aerospace Daily* (10 August 1970), 217; US Senate, Armed Services Committee, Ad Hoc Research and Development Subcommittee, "Fiscal 1973 Authorization for Military Procurement. . . .", part 4, 18 February 1972, 2370; US Senate, Armed Services Committee, "Military Authorization, Fiscal Year 1972," 18 March 1971, 490; House Appropriations Committee, DOD Appropriations Fiscal Year 1972, 360.

31. DOR History, January–June 1970, 257, 259; DOR History, July–December 1970, 213; ASD Historical Report, AGM-86 SCAD, RW 86, January–June 1971, 2, 3 [ASD].

32. Wainstein, 57.

33. This concept had been with the air arm even before it was the Air Force, and had caused the airmen numerous difficulties in the past.

34. DOR History, January–June 1971, II, 209; DOR History, July–December 1971, II, 183, 186; DOR History, January–June 1972, II, 192, 194, 198; DOR History, January–June 1972, IV, 41, 42; Poncar, 33–36; "New SCAD Contracts Awarded by USAF," *Aviation Week* (17 July 1972), 15; "Staats Urges Competitive Prototyping for F-15, SCAD and A-X," *Aerospace Daily* (15 July 1969), 63; ASD Historical Report V, SCAD Document 107, AGM 86A, SCAD, January–June 1972, 1, 4 [ASD]. A unique aspect of the SCAD program was overall Air Force management as compared with the standard selection of a prime contractor. The SCAD Project Office would retain all these functions, acting as a "systems integrator," the first such use by Air Force Systems Command. Poncar, 39–41; DOR History, January–June 1971, II, 209; "New SCAD Contracts Awarded," 15; Michael L. Yaffee, "USAF Seeks Intergrator Role," *Aviation Week* (10 May 1971), 14.

35. Poncar, 35, 36; DOR History, January–June 1972, II, 194, 198; ASD Historical Report V, SCAD Document 107, January–June 1972, 1. On 23 April 1973, Williams won the SCAD engine competition. "Williams Research Beats Teledyne CAE for SCAD Engine Award," *Aerospace Daily* (24 April 1973), 307.

36. Ulsamer, "SCAD," 47.

37. Ibid.; US House of Representatives, Appropriations Committee, "Department of Defense Appropriations Fiscal Year 1973," part 4, 22 March 1972, 360; House Appropriations Committee, DOD Appropriations, Fiscal 1972, 361.

38. Ulsamer, "SCAD," 47; "SCAD is Only a Decoy, Not a Standoff Missile, AF Contends," *Aerospace Daily* (8 June 1971), 201.

39. Poncar, 44; DOR History, July–December 1972, III, 10–11; DOR History, January–June, 1973, II, 9; "SCAD is Only a Decoy," 201; Senate R and D Subcommittee, "SCAD," 3336, 3413.

40. History DOR, January–June 1973, II, 9–11; Huisken, 70, 71; Senate R and D Subcommittee, "SCAD," 3405, 3411; US Senate, Armed Services Committee, Military Procurement Fiscal Year 1974, 26 April 1973, 1139.

41. Senate R and D Subcommittee, "SCAD," 3392, 3383.

42. US Senate, Armed Services Committee, Research and Development Subcommittee, "Department of Air Force," 21 May 1973, 3463; Levine, 126; DOR History, January–June 1973, II, 11; Poncar, 56; US Senate, Armed Services Committee, "Report Together With Separate and Individual Views. . . ," Report 93-385, 6 September 1973, 28.

43. Senate Report 93-385, 28; US House of Representatives, Committee on Appropriations, Subcommittee, "Department of Defense Appropriations for 1975," Part 4, 29 April 1974, 933; US House of Representatives, Committee on Appropriations, Subcommittee, "Department of Defense Appropriations For 1974," Part 7, 488, 1018.

44. "DOD Giving Navy Prime Role in Joint Cruise Missile Development," *Aerospace Daily* (11 July 1973), 50, 51; "Ray Utterstrom Talks About ALCM," *BMA Manager* (January–February 1979), 2, 4; Poncar, 59, 60, 62, 69; "DOD Halts SCAD Development As Costs Rise, Need is Debated," *Aviation Week* (16 July 1973), 22; "Anti-SCAD," *Aerospace Daily* (19 March 1973), 97; "SCAD Seen in Danger of Cancellation," 201; "SCAD Indifference," 305.

45. DOR History, January–June 1973, II, 11; Senator Stuart Symington to William P. Clements, 6 August 1973 [JCMPO].

46. Canfield and Kellett; Robert D. Colvin, "Aftermath of the Elath," *United States Naval Institute Proceedings* (October 1969), 62. The Indians sank one Pakistani destroyer and badly damaged a second in 1971 with Styx missiles. William J. Ruhe, "Cruise Missiles: The Ship Killers," *United States Naval Institute Proceedings* (June 1976), 46.

47. Ryan demonstrated an antiship version of their highly successful drone in March 1971, but to no avail. Wagner, 177. The tactical version of the cruise missile used turbojets because they were cheaper and gave more power relative to the engine's weight than did turbofan engines, whose chief advantage was more economical operation and hence greater range.

48. Brooke Nihart, "Triad to Become Quadrate?" *Armed Forces Journal* (December 1972), 31; Wainstein, 68; Huisken, 29.

49. Levine, 127; Canfield and Kellett; *Jane's All the World's Aircraft: 1971–72*, 556; *Jane's All the World's Aircraft: 1973–74*, 608, 609; *Jane's All the World's Aircraft: 1980–1981*, 656; David G. Clark, "Cruise Missiles: Offense in Breadth Added to Defense in Depth," Naval War College thesis, 1977, 80; Harpoon Weapons System, NCP #W-0555-SH, 13 March 1978 [JCMPO].

50. Canfield and Kellett; Huisken, 30; Wainstein, 61, 69; "Navy's Sub Launching Cruise Missile Moves Toward May Milestone," *Aerospace Daily* (13 April 1973), 249; "SLCM in Trouble?" *Aerospace Daily* (30 April 1973), 337; Levine, 127, 128.

51. US Senate, Committee on Appropriations, Subcommittee, Department of Defense Appropriations for Fiscal Year 1973, 10 May 1972, 42, 43.

52. Levine, 128; US House of Representatives, Committee on Appropriations, Subcommittee, Department of Defense Appropriations for Fiscal Year 1972, part 6, 11 May 1971, 22; Secretary of Defense Memo to Director of Defense Research and Engineering, 19 January 1972 [JCMPO-Briefing, 26 February 1972]; US House of Representatives, Committee on Appropriations, Subcommittee, Department of Defense Appropriations Fiscal Year 1973, 10 May 1972; part 9, 43.

53. Levine, 129; Huisken, 33; Robert L. Pfaltzgraff, Jr. and Jacquelyn K. Davis, *The Cruise Missile: Bargaining Chip or Defense Bargain* (Cambridge, Mass.: Institute for Foreign Policy Analysis, 1977), 7;

John W. Finney, "US Missile Complicates Arms Talks," *New York Times* (16 June 1975), 16; Colin Gray, "Who's Afraid of the Cruise Missile?," *Orbis* (Fall 1977), 519.

54. Levine, 129, 130; US Senate, Committee on Armed Services, "Military Implications of the Treaty on the Limitations of Anti-Ballistic Missile Systems and the Interim Agreement of Limitation of Strategic Offensive Arms," 6 June 1972, 54, 20 June 1972, 141, 198; US Senate, Committee on Foreign Relations, "Strategic Arms Limitation Agreements," 26 June 1972, 140; US Senate, Committee on Armed Services, Fiscal Year 1973 Authorization for Military Procurement, . . . Addendum No. 1, 22 June 1972, 4297, 4340, 4353, 4354, 4358; US Senate, Committee on Armed Services, Report 93-385, 6 September 1973, 29; US Senate, Committee on Armed Services, Research and Development Subcommittee, "Strategic Cruise Missiles," 27 March 1973, 2631.

55. Senate R and D Subcommittee, 27 March 1973, 2635, 2636, 2640, 2656.

56. They varied from the lightest, Convair's 31-inch diameter, 28-foot long, 7,775 pound, and smallest Lockheed's 32-inch diameter, 26½-foot long, 8,316 pound to the largest, LTV's 32.7-inch diameter, 29.3-foot long, 10,631-pound missile. JCMPO Briefing to Dr. Frosch, 14 July 1972; JCMPO Briefing to AIR-05, 3 March 1973 [both JCMPO].

57. These were even more varied than the SCMs, ranging from three to six per tube, and from the smallest (McDonnell-Douglas) 23-inch diameter, 2,890 pound to the largest, (Convair's) 35-inch wedge, weighing 9,610 pounds. JCMPO Briefing to Dr. Frosch, 14 July 1972; JCMPO Briefing to AIR-05, 3 March 1973 [both JCMPO].

58. Huisken, 32; Levine 130, 131; JCMPO Briefing to General Phillips, 15 October 1973; Assistant Secretary of the Navy Memo (Research and Development) to Director of Defense Research and Engineering, 7 July 1972 [Sante Fe Doc. #1]; JCMPO Briefing to NADEC, 6 September 1973; Richard S. Niemczyk, "Cruise Missile Program," 5 October 1973 [all 4 JCMPO]; Clarence Robinson, "Navy to Act on Cruise Missiles," *Aviation Week* (13 August 1973), 13.

59. JCMPO Briefing to PMA-263, 21 August 1973; JCMPO Briefing to NADEC, 6 September 1973 [both JCMPO].

60. Levine, 131; Wainstein, 78, 79; US Senate, Committee on Armed Services, Fiscal Year 1975 Authorization, part 7, 16 April 1974, 3695, 3704; "Air Force, Navy to Develop Cruise Missile," *Aviation Week* (20 August 1973), 24; William P. Clements, Memorandum to Assistant Secretary of Defense (Research and Development), Assistant Secretary of the Navy (Research and Development), Assistant Secretary of the Air Force (Research and Development), 21 December 1973 [JCMPO-Sante Fe Document #13].

61. Senate, CAS, Fiscal 1975 Authorization, part 7, 3624; Huisken, 40; Doug Richardson, "The Cruise Missile," *Flight International* (1 October 1977), 967; Robinson, "Navy to Act on Cruise Missile," 13; JCMPO Briefing to Assistant Secretary of Army (Research and Development), Assistant Secretary of the Navy (Research and Development), and Assistant Secretary of the Air Force (Research and Development), 18 September 1973 [JCMPO].

62. Senate CAS, FY 1975 Authorization, part 7, 3634; US House of Representatives, Committee on Armed Services, Hearings on Military Posture, Fiscal Year 1977, part 5, 26 February 1976, 866; "Industry Observer," *Aviation Week* (4 February 1974), 11; Michael Yaffee, "Cruise Missile Engine Design Pushed," *Aviation Week* (7 July 1975), 43; J. Phillip Geddes, "The Submarine Launched Cruise Missile," *Interavia* (March 1973), 261, 263.

63. Maurice Allward, "Cruise Missiles," *Air Pictorial* (January 1978), 12, 13; US House of Representatives, House Committee on Armed Services, Military Posture Fiscal Year 1977, part 5, 20 February 1976, 866; Robinson, "Navy to Act on Cruise Missiles," 14.

64. CNO to COMNAVAIRSYSCOM OP-OO: et ser. 00/125-75, 26 September 1975 [JCMPO-Sante Fe Doc. #27]; "Navy Halts Vought Cruise Missile," *Aviation Week* (15 March 1976), 203; "Next Vought Cruise Missile Test Seen Critical," *Aerospace Daily* (2 March 1976), 9; "Navy Issues Stop-Work Order on Vought Cruise Missile Effort," *Aerospace Daily* (9 March 1976), 50; "Vought Plans Second Tomahawk Test," *Aviation Week* (1 March 1976), 21; "Cruise Missile Award," *Aviation Week* (22 March 1976), 24; E. H. Conrow, G. K. Smith, A. A. Barbour, "The Joint Cruise Missiles Project: An Acquisition History," RAND, 1982 [I], 7.

65. JCMPO Briefing, DSARC 1A, 18 March 1975; William P. Clements, Memorandum for Secretaries of the Army, Navy, and Air Force, 13 May 1975 [Sante Fe Doc. #25], [both JCMPO].

66. Geddes, "SLCM," 262; Clarence A. Robinson, Jr., "Navy Spurs Cruise Missile Pace," *Aviation Week* (24 November 1975), 13, 14; "E Systems McDonnell-Douglas to Develop TERCOM Guidance for SLCM," *Aerospace Daily* (13 June 1974), 242, 243.

67. CNO to CNM Ser 224D/696020, 29 July 1976; Decision Coordinating Paper for Air Launched Cruise Missile (ALCM) Full-Scale Development Program DSARC II, April 1976, 312 [Sante Fe Doc. #28], [both JCMPO].

68. Clements Memo, 21 December 1973.

69. Richard J. Art and Stephen E. Ockensen, "The Domestic Politics of Cruise Missile Development, 1970–1980," 370 [Richard K. Betts (ed.), *Cruise Missiles* (Washington, D.C.: Brookings Institution, 1981)]; DOR History, January through June 1974, II, 1; Historical Report, ASD/YG, YH, and YX, January through June 1974, 17, 5–4 [ASD]; "DSARC Would Cancel AF ALCM Standardize on Navy Cruise Missile," *Aerospace Daily* (6 December 1974), 194; 195. For the testimony of two USAF generals on the B-1 and the standoff missile see US Senate, Committee on Armed Services, Research and Development Subcommittee, Fiscal Year 1975 Authorization . . . , 22 March 1974, 2724 and 26 March 1974, 2913.

70. "DDR and E, Said to Favor AF ALCM Cancellation; Switch to Navy SLCM Version," *Aerospace Daily* (29 October 1974), 306, 307; US House of Representatives, Committee on Armed Services, 3 February 1976, cited in Colonel Buddy L. Brown to XP, 1 April 1976 [SAC].

71. Interview, Ray Utterstrom, 1 March 1982; "Schlesinger Seeks Senate Restoration of $2.5 Billion for DOD," *Aerospace Daily* (7 October 1975), 204; "Senate Defense Panel Votes $51 Million for Air Force ALCM," *Aerospace Daily* (30 October 1975), 312.

72. Colonel Buddy L. Brown to XP, 1 April 1976, 2 [SAC].

73. Utterstrom interview; Interview, D. J. Smith, 1 March 1982.

74. Allward, 13; "Flexible Missiles," *Aerospace International* (July–August 1977) 14; J. Phillip Geddes, "The Air-Launched Cruise Missile," *Interavia* (June 1976), 581, 582; *The U.S. War Machine* (New York, N.Y.: Crown, 1978), 218; ASD, SCAD Document No. 141, 3.

75. Richardson, 966; DOR History, January through June 1976, Vol. III, 153 [AFSHRC-K140.01, III, January–June 1976]; History Directorate Operational Requirements DCS/R and D, July through December 1976, Vol. III, 99, 100 [AFSHRC-K140.01, III, January-June 76]; History, Air Force Systems Command, 976, 1976, Vol. I, 204, 205 [AFSHRC-K243.01, I, 76]; Historical Reports ASD/YM 69, YM 86, YMA, Sect. 4, January through December 1976, 4–17 [ASD].

76. SLCM Tomahawk Flight Test History, 17 February 1982, 1; JCMPO DSARC II Briefing, 6 January 1977 [both JCMPO]; Richardson, 968.

CHAPTER VI

1977 TO THE PRESENT

The movement toward a redefinition of the cruise missile program grew as the weapon developed, its visibility increased, and political pressures inside and outside the services built. The Air Force continued to insist that they needed only a short range ALCM (Air-Launched Cruise Missile), a position strongly criticized by Deputy Secretary of Defense William P. Clements. Following a meeting on 21 December 1976, Secretary of Defense Donald Rumsfeld asked E. C. Aldridge, Director of Department of Defense Planning and Evaluation, and Malcolm Currie, Director of Defense Research and Engineering (DDRE), to write a plan for the future of the cruise missile. The Secretary of Defense expressed special interest in a ground-launched version of the cruise missile.[1]

The culmination of these discussions came in the Defense Systems Acquisition Review Council (DSARC) meeting of 6 January 1977, probably the most important decision point in the evolution of the weapon. Before laying out the conclusions of that critical meeting, two factors that played major roles in the outcome require emphasis. First, the US Government showed a marked reluctance to cancel any military program on the eve of the SALT (Strategic Arms Limitations Treaty) negotiations. (See below.) Second, in the wake of Jimmy Carter's defeat of President Gerald Ford in November 1976, many believed that any basic decision should be postponed so that the incoming President would have maximum latitude. These factors gave the Boeing ALCM a respite, as some within the Department of Defense (DOD) wanted to use the General Dynamics Tomahawk in both the air-launched and sea-launched role.

Nevertheless, the DSARC meeting made significant recommendations that markedly shaped the program. First, while stressing commonality between the two missile programs, DSARC recommended continuing both the Navy's SLCM (Sea-Launched Cruise Missile) and the Air Force's ALCM programs at a more advanced level termed "Full Scale Engineering Development" (FSED). As the Deputy Secretary of Defense later stated, "a common airframe for all applications may impose unnecessary and unwarranted performance compromises on both weapons systems."[2] However, this line of thought did not preclude a single cruise missile for all launch modes. Second, to manage the two programs and ensure maximum commonality, the council recommended establishing a joint office (Joint Service

Cruise Missiles Project Office, (JSCMPO) with the Navy as the lead service and Captain Walter M. Locke (USN) as director. Third, DSARC recommended that the ALCM program concentrate on the long-range version (AGM-86B) having at least 1,500 nm range, rather than the short-range AGM-86. (The AGM-86A option however, would be maintained.)[3] USAF would strive for an ALCM initial operational capability (IOC) date of July 1980, using the B-52 as the carrier. Fourth, the council recommended refocusing the SLCM program from its previous supposedly equal emphasis on both the conventional antiship and theater nuclear versions, toward a long-range (at least 1,500 nm) nuclear land attack missile capable of launch from submarine, surface ship, and the ground. DSARC also recommended development of a ground-launched cruise missile (GLCM) from the Navy's Tomahawk for the Air Force as a mobile theater nuclear weapon* with "an expeditious IOC." Finally, the council recommended that the antiship Tomahawk should also enter FSED and that the JSCMPO would explore ground-launched antiship versions and initiate research and development for advanced cruise missile technology. Deputy Secretary of Defense William Clements approved the DSARC recommendations on 14 January 1977.[4]

The Joint Office played the major role in the development of the ALCM between 1977 and 1980, and continues to play the key role in the development of the GLCM, MRASM (medium range air-to-surface missile), and SLCM. In late March, Navy renamed the office JCMPO (Joint Cruise Missiles Project Office). DOD did not establish the office until the fall of 1977 due to the complications of setting up such a structure and the jockeying for positions between the two services. As far back as 1973, the aviation press had speculated that the Navy would take over leadership of the program; and the success of Navy's Tomahawk clearly favored the sea service.[5]

Within the arena of a joint office, friction inevitably occurred. In general, interservice cooperation is notable because it is so rare; the historical record reveals few successes and many failures of such efforts. The Navy and the Air Force have different systems and styles of weapons acquisition, subjects beyond the scope of this study, which increase the probability of problems.

Another difficulty arose from JCMPO's location in Washington D.C., and USAF's acquisition system location in Dayton, Ohio. At first, USAF detailed airmen on temporary duty to the nation's capital, and only gradually brought the Air Force complement up to strength after November 1977, a process taking a year. Thus far, the joint program has been essentially successful.

Cruise Missiles and SALT

During the period the cruise missile matured as a weapon, it became increasingly connected with arms limitations. Although these continuing discussions are a

*Unlike the ALCM, the SLCM and GLCM required a booster which General Dynamics already had well under development.

separate subject which are only tangential to this study, nevertheless, the cruise missile increasingly affected the talks and the talks (and agreements) increasingly affected the cruise missile. At first the negotiators paid little attention to the infant cruise missile although they discussed it early on, albeit without results. In April 1970, the United States proposed a limit on the number of SLCMs, other than those of short range, as well as a ban on both GLCMs with ranges over 1,000 km and additional medium- and intermediate-range ballistic missiles. The Soviets objected, arguing that their weapons were tactical, and attempted to pull US carrier aircraft into the discussions.[6] The Americans came back in August with a proposal to prohibit intercontinental cruise missiles but leave all other cruise missiles unrestrained. Eventually, cruise missiles were not included in the provisions of SALT I.

Yet as we have seen, following the 1972 agreement, the Secretary of Defense and the Secretary of State pushed cruise missiles to placate the JCS (Joint Chiefs of Staff) and use as bargaining chips in future arms talks with the Soviets.[7] Two years later, at the November 1974 Vladivostok meeting, the negotiators apparently did not seriously discuss the weapon. But following the meeting and the agreement reached there, the cruise missile emerged as a contentious subject. An aide-memoire to the agreement counted air-launched missiles with ranges greater than 600 km in the overall launcher ceiling. While President Ford offered to limit air-launched cruise missiles to a range of 1,850 miles the preceding August at Helsinki, the Americans maintained that the Vladivostok agreement applied only to ballistic missiles, not air-breathing ones. As the only American bomber-launched missile under development at this point was the cruise missile, the US interpretation was, at best, strained.[8]

By 1975 the Soviets began to take the American cruise missile more seriously. Now, the Americans linked the missile with an equally troublesome Soviet weapon, the Backfire bomber, which the Russians began to deploy in 1974. One American proposal in September 1975 attempted to limit both weapons by excluding 200 to 400 of the supersonic, long-range Russian bombers from the Vladivostok ceiling, for the exclusion of an equal number of American cruise missile carriers. The Soviets rejected this offer in November. The United States regarded ALCMs as just another piece of bomber armament and therefore not accountable under existing agreements. On the other hand, the Soviets wanted to either ban all missiles over 600 km (which would not affect operational Soviet missiles as none of them exceed this range in low-altitude flight), or to count them against the overall strategic missile ceiling.[9]

When the Russians did not make a counter offer, the Americans tried again, no doubt eager to reach an agreement before the 1976 US presidential campaign heated up and paralyzed action. The American proposal in January would permit the Russians to deploy 275 Backfires apart from the 2,400 launcher limit between 1977 and 1982 and, from then until the expiration of the treaty, unlimited numbers. The Soviets would be restricted, however, on how they operated the bomber. The proposal banned Backfire participation in exercises simulating attacks on the United

States, Backfire deployment to bases from which they could reach the United States unrefueled, and Backfire tankers. The Americans proposed to count each bomber armed with 12 to 20 ALCMs of ranges greater than 600 km against the Vladivostok ceiling of 1,320 MIRVed (multiple independent reentry vehicle) launchers and to limit the range of the ALCM to a maximum of 2,500 km. The deal left the submarine-launched SLCMs with no numerical limit but a range limit of 600 km which, because of geography, would close them off as a viable strategic weapon against Russia. Finally, the American proposal would not limit the surface-launched SLCMs in range, but would restrict their numbers to 250 missiles on 25 ships.[10]

The Russians responded that Backfire should not be counted as a strategic system, although they did indicate a willingness to restrict its basing. On the cruise missile issue, the Soviets wanted each bomber carrying 10 or more ALCMs counted against the 1,320 MIRV subceiling. In addition, they wanted ALCM range limited to 1,000 miles (presumably statute miles) and all other cruise missiles limited to a 600 km range. So the differences between the two proposals came down to: (1) Backfire numbers, (2) ALCM range, and (3) surface SLCM range. Most observers believed that the two sides could quickly hammer out an agreement.

This consensus proved incorrect as these final issues remained unresolvable. The Soviets insisted that the Backfire was a tactical bomber, and therefore should not be counted against the strategic launcher ceiling. At the same time, they maintained that all but a few ALCMs (accountable under the treaty) should be limited to a 600 km range. The United States stuck with its basic proposal. In February, President Ford attempted to bypass the trouble spots by including the agreed-upon portions in a SALT II agreement and leaving the bothersome cruise missiles and Backfire to a separate protocol. The Americans offered not to deploy SLCM and GLCM with ranges greater than 600 km, although they wanted the option of testing them up to 2,500 km. The Soviets rejected this proposal the next month. Thus, the SALT process broke down as the American political system went its colorful, quadrennial course.[11]

The fall election brought a new president and a new approach to SALT, for Jimmy Carter campaigned to reduce nuclear weapons. When he first took office it appeared that he would build on the Ford-Kissinger work, at least this could be concluded from his remarks in his first formal press conference during which he indicated a desire for a quick overall agreement and the relegation of the Backfire and cruise missile issues to SALT III. But in March, Carter submitted a far-reaching proposal to the Soviets; indeed, in the context of the US-USSR negotiations, a radical one. He called for major reductions in the agreed-upon ceilings of SALT I and Vladivostok, reducing delivery vehicles from 2,400 to 1,800–2,000, the MIRV limit from 1,320 to 1,100–1,200, and other changes. The President proposed that the Soviet bomber not be counted as a strategic weapon if the Soviets provided assurances that were not made clear in the open literature. Cruise missiles would be limited in two ways. First, they would be limited to a 2,500 km range and second, only heavy bombers (counted against the MIRV ceiling) would be allowed to carry

cruise missiles capable of flying between 600 and 2,500 km. There would be no restriction on cruise missiles with ranges under 600 kms.[12]

Why did Carter take this tack? From the President's point of view, such an approach fulfilled his campaign promise of arms reductions, deflected conservative criticism that the United States had been out-bargained at SALT I and Vladivostok, and permitted the new President to be a formulator of policy, not just a follower of the Ford-Kissinger line. In addition to these political considerations, the proposed reduction would help relieve what American strategists considered the most serious Soviet threat, the buildup of heavy missiles which increasingly imperiled American ICBMs (intercontinental ballistic missile).[13]

But this strategy failed; the Soviets rejected the initiative cold, without a serious counterproposal and with harsh words. In addition to substantive objections, the Soviets apparently resented the break from the Ford-Kissinger work, the public style of the Carter administration, and Carter's emphasis on human rights. In addition, the proposal would force the Soviets, with larger forces, to make greater cuts than would the Americans.[14] Therefore, the Carter proposal derailed the SALT process.

To get the train back on the tracks, the United States proposed a three-tier process in May consisting of an eight-year treaty containing agreed-upon areas, a three-year protocol with temporarily agreed-upon areas, and a statement of principles to provide guidelines for future negotiations. By September the Russians had accepted this procedure and before 1977 was over, the two countries reached a number of major agreements. The most important of these (pertaining to the cruise missile) limited ALCM range to 2,500 kms, made ALCM-carrying bombers accountable under the MIRV subceiling, and dealt with non-ALCMs. A protocol permitted development and testing of GLCM and SLCM up to a range of 2,500 kms, but banned their deployment.[15] A number of serious questions remained: (1) How would the range of cruise missiles be measured? The Russians, attempting to limit the weapon as much as possible, wanted to measure total range, while the United States wanted range measured from launch to target, not including the ups and downs of terrain-following, and the deviations from route. (2) What type aircraft would carry ALCMs and how would this be verified? (3) How many ALCMs would each aircraft be allowed to carry? (4) Apart from nuclear-armed missiles, what provision would be made for nonnuclear-armed cruise missiles and reconnaissance missiles? (5) Would third parties, specifically American allies, have access to the weapon or technology?

The agreements signed by Chairman Brezhnev and President Carter in Vienna on 18 June 1979 seemingly settled all these issues.

(1) ***Range.*** The agreement defined range as the maximum distance in the standard flying mode until fuel exhaustion. But the 2,500 km limit on ALCM did not appear in either treaty or protocol. Apparently the Soviets dropped the ALCM range restriction in exchange for other concessions.[16]

(2) ***Cruise missile carriers.*** The agreement defined any aircraft equipped to launch ALCMs of ranges greater than 600 km as a cruise missile carrier. Once any aircraft is so equipped, all aircraft of that type shall be so regarded. But aircraft fitted with "functionally related observable differences" which can be detected by national technical means, in this case primarily satellite photography, were exempted.

(3) ***ALCMs per carrier.*** As in most bargains struck over numbers, the end result landed halfway between the starting position of each side. The Russians began with a figure of 20, the United States with 36.[17] The agreement limits the number of ALCMs on present US aircraft (B-1s and B-52s) to 20, and on future aircraft to a fleet average of 28.

(4) ***Nonnuclear cruise missiles.*** This agreement treats conventional and nuclear cruise missiles the same. Once a missile flies beyond 600 km, it comes under the provisions of the treaty. External observable differences must delineate which cruise missiles have ranges of more than 600 km. In addition, reconnaissance cruise missiles of ranges greater than 600 km count the same as armed cruise missiles unless they exhibit observable differences. The treaty also prohibits the conversion of cruise missiles to RPVs (Remotely Piloted Vehicles) and the conversion of RPVs to cruise missiles above the 600 km threshold.

(5) ***Third parties.*** The signatories pledge to make no international treaties that would conflict with the agreement.

Another provision of the treaty prohibits testing and deployment of multiple warheads on ALCM. Finally, the protocol bans deployment of SLCM and GLCM of ranges greater than 600 km, but not their development or flight testing.

The negotiators intended the treaty to remain in force until 31 December 1985 and the protocol until 31 December 1981.[18] While the two nations' leaders signed both in June 1979, the US Senate ratified neither. Today the prospects of ratification appear nonexistent, yet both sides continue to act as if the treaty (not the protocol) is in force. Just as the SALT discussions were long and involved, so was the connection between the B-1 and the ALCM.

The B-1

The drawn out and competing stories of the B-1 and the cruise missile came to a conclusion, most thought, in the summer of 1977. Friend and foe alike saw the cruise missile as an obstacle to the deployment of the B-1. Therefore, some supported the cruise missile as a counter to the B-1 and, conversely, some opposed

the cruise missile because of their support for the manned penetrating bomber.

In short order the argument between these two weapons focused on *Modernizing the Strategic Bomber Force*, a 1976 Brookings study critical of the B-1. Its authors noted that the bomber failed to meet its original performance estimates, probably on the average of 11 percent less, and suffered horrendous cost escalation, from $39 million per aircraft in 1969 to $84 million in 1975, and perhaps (as reported by the authoritative *Aviation Week)*, over $100 million. The study concluded that there was "no reason to make a commitment to produce the B-1 although there was considerable justification for exploring alternatives based on the use of standoff missiles."[19]

The Air Force responded with the Joint Strategic Bomber Study (JSBS) completed in December 1974, essentially a line-by-line critique of the Brookings study. The outside observer encounters difficulty assessing the arguments of these two different, complex, and detailed studies since they employ different basic assumptions and costing rules. For example, Brookings used "equal effectiveness" forces while the JSBS used "equal cost" forces.[20]

Partially as a result of these arguments, on 30 June 1977, President Carter cancelled the B-1 project. According to Secretary of Defense Harold S. Brown, the administration considered six air-breathing options: a modernized FB-111, a rebuilt and upgraded B-52, a less expensive penetrating bomber, a standoff cruise missile carrier, a reworked existing B-52, and the B-1. The choices quickly narrowed to the last two options. After considering how well each would survive preemptive attacks and Soviet en route defenses, Brown concluded that "a B-1 force that would have equal capability to B-52s with cruise missiles would have been about 40 percent more expensive."[21] Brown put the savings at $10 billion (fiscal year 1978) over the next six years. While the B-1 could penetrate at a higher speed than the cruise missile, it also penetrated at a higher altitude. Brown expressed more confidence in the missile's small radar cross section (RCS) to confound the Soviet defenders than in the B-1's ECM (electronic countermeasures). Consequently, the administration based its choice on cost and military effectiveness. Other factors influencing the decision included the missile's growth potential, which simply meant the weapon could easily and quickly be proliferated. The decisionmakers also considered the impact the cruise missile would have on "the world's perception of the potency of our forces." The United States would retain and demonstrate "clear technological superiority" with a weapon lacking first strike capability.[22]

Carter's B-1 decision shocked the top echelon of USAF. They had calculated that the Air Force would probably get 150 B-1s, and even in the worst case obtain 90. Some of the impact of this decision can be sensed in the lead sentence in an *Air Force Magazine* article: "The Strategic Air Command (SAC), with grim professionalism, is picking up the pieces of a planned force structure and a doctrine shattered by cancellation of the B-1 bomber."[23] Now the Air Force found itself without its future penetrating bomber and with the cruise missile instead. Clearly, this gave new impetus to the ALCM program.

ALCM Selection

The B-1 cancellation made the cruise missile more important than ever. For now it, not a new bomber, would modernize the air-breathing leg of the Triad and ensure the bomber's continued effectiveness in the face of increasingly potent Soviet air defenses. The military establishment (most of all, USAF) must now get to the issue, take it seriously, and select an ALCM. Decisionmakers again carefully considered adopting a common ALCM/SLCM. Such a selection would save $165 to $373 million. But the dollar savings had to be weighed against a loss of performance; a 1976 study, for example, noted that SLCM was not optimal for the ALCM role.[24]

By the time of the B-1 decision, the two American cruise missile programs possessed distinct characteristics. While both evolved from the same basic technology and utilized the same engine and guidance, they developed in somewhat different ways. The General Dynamics missile could fly further than the Boeing missile and had flown 16 tests while the ALCM A had flown only six times. However, Boeing designed its missile specifically for the ALCM role, and from the start built it to be integrated with a Boeing bomber. In addition, only six Tomahawks could be carried in a B-52 rotary launcher versus eight Boeing missiles. Finally, while all six ALCM A launches were "cold-launched" (the engine ignited after the missile was dropped) as would be the operational procedure, in all 14 of the SLCM's air launches from A-6s, the missile's engine was started prior to the drop. Because of these unequal factors and the prospect that a flat choice one way or the other would probably provoke a strong protest, if not a legal challenge, DOD ordered a direct competition.[25]

On 30 September 1977, the Director of Defense Research and Development, William Perry, set the wheels in motion with a memo to the Secretaries of the Air Force and Navy. He came right to the point, opening the memo:

> It is a matter of highest national priority, especially in the light of the B-1 decision, to develop an air-launched cruise missile (ALCM) with optimum performance and minimum cost and schedule delays. I believe we can best accomplish those program objectives by conducting a competitive flyoff between Boeing and General Dynamics to determine which of their missiles will be the ALCM to be flown on the B-52 and, as appropriate, other cruise missile carriers.[26]

Perry insisted that the emphasis on component commonality between the ALCM, SLCM, and GLCM continue. The ALCM program would maintain an early 1980 target date for a limited IOC and receive the highest national priority. JCMPO would continue to manage the program until DSARC approved the ALCM production decision.

The Joint Office would conduct the competition, which would include operational tests by SAC crews. The selection itself would be recommended by a Source Selection Advisory Council consisting of equal numbers of senior Air Force and Navy officers, one of whom, the Commander of Air Force Systems

Command, would serve as chairman. So the selection of a key weapon for the Air Force would not only be assisted by the Navy, but the final recommendation would be partially made by naval officers as well. The Secretary of the Air Force would be the Source Selection Authority.[27]

The competition used three areas of selection criteria: operational design/utility, adequacy of the program, and costs. The military subdivided the first and most important area into six equally important parts: survivability, operability, accuracy and time control, mission preparation, life cycle cost realism, and range. The testers divided the second major area, program adequacy, into nine items of equal importance. The third major area consisted of production and remaining research, development, test, and evaluation costs.[28]

An important question for the testers was exactly what would compete. At first, it appeared as if all but the common equipment (such as the missile engine and guidance) would be involved. In due course, however, the government deleted the test equipment, ground support equipment, and pylons, leaving only the two missiles to compete. In February 1978, the government awarded full scale engineering development contracts to the two companies. The schedule called for the first test flight in February, a decision in October 1979, and a limited IOC in March 1980.[29]

One area of conflict concerned the protection of proprietary data. General Dynamics claimed that since Boeing Wichita was the contractor for integrating the missile to the B-52 (pylon, wiring, etc.), it would be at a disadvantage.* Conversely, McDonnell-Douglas built computers and inertial platforms for both manufacturers. Since Boeing used only the McDonnell-Douglas hardware and its own software, while General Dynamics got both from McDonnell-Douglas, Boeing asserted that McDonnell-Douglas would gain more from a General Dynamics victory than one by Boeing. Boeing objected in February 1978 that the arrangement between General Dynamics and McDonnell-Douglas constituted a teaming arrangement, making McDonnell-Douglas a competitor of Boeing, an objection sustained by the military.[30]

At least some of the Boeing people thought that Navy involvement in the selection of the ALCM put Boeing at a disadvantage. They feared that the Navy-run JCMPO would go through the motions of a competition before selecting General Dynamics. In fact, the competition was well-run and fair; neither the documents nor conversations with involved individuals indicate any major problems.

At the same time, it should be noted that Boeing maintained two major advantages going into the competition. First, it enjoyed a long and successful association with the Air Force dating back to the 1920s and extending through such stalwart USAF bombers as the B-17, B-29, B-50, B-47, and continuing with the long-lived B-52. In addition, that company built the SRAM. Boeing knew the Air Force, and the Air Force knew Boeing; in short, Boeing knew how to please USAF.[31]

Before the competition occurred, the military conducted another series of tests consisting of seven Tomahawk flights flown against US equipment (such as F-14,

*Under the Boeing corporate structure, the manufacturer of the missile, Boeing Aerospace Company, Seattle, is essentially a different company than that of the B-52 integrator, Boeing Military Aircraft Company, Wichita.

F-15, AWACS, Chaparral, improved Hawk, Roland, Stinger, and Patriot) and captured or borrowed (from third parties) Soviet equipment. The tests sought to simulate Russian defenses present and future to answer some of the questions regarding the cruise missile's ability to penetrate Soviet defenses. The military concluded from the tests completed in September 1978 that current Soviet air defenses were ineffective against cruise missiles.

These survivability tests revealed one major problem, that the radar altimeter, a commercial instrument, could be detected up to 30 nm away. Therefore, the military installed in later missiles a modified device which varies its power as required, which, along with other features, greatly reduces its detectability. During a test of the new device, operators at the receiver site asked: "Are you sure the altimeter is turned on?"[32]

According to William Perry (DDRE), the Soviets required 50 to 100 SUAWACS (Soviet Airborne Warning and Control System), a fleet of 2,000 advanced interceptors (look down/shoot down)[33] equipped with new air-to-air missiles, and 500 to 1,000 SA-10 missile sites. Such a defensive effort, Perry estimated, would require $30 to $50 billion and 5 to 10 years to build and yet would destroy only half of the 3,000 cruise missile attack it might face. In February 1980, a general put the figure at $90 to $100 billion; nevertheless, a defensive effort which the cruise missile would largely negate. Various sources put the ratio of defense spending to offense spending at least at 10:1.[34]

The government set the general conditions of the flyoff competition and allowed the two companies to work out the specific details. The flyoff gave each contractor 10 flights to perform certain tests and to reach certain goals. The Air Force supplied a B-52 to each company and, to ensure that both companies got a fair shake, compartmentalized the operation.[35]

The GD Tomahawk enjoyed a considerable lead over the Boeing missile by the time the flyoff competition began in July 1979, having successfully flown 36 times on 43 flights for a total of 37 hours and 12 minutes. However, the Tomahawk SLCM version differed from the Tomahawk ALCM, as GD had to adapt the BGM-109 to the harsher environment of the air-launch from just above sea level to over 40,000 feet. The most obvious change removed the booster and capsule. In addition, GD added oxygen for engine start, and changed the fuel from the safer TH Dimer to less viscous and less dense fuel (JP-9) for operations at the oxygen-rare, and colder, higher altitudes.[36]

Meanwhile Boeing considerably changed its missile. As related above, USAF took two approaches to extend the range of the AGM-86A. USAF cancelled the first, the belly-tank version, in 1977, at about the same time it cancelled the AGM-86A.[37] The other effort was to enlarge the missile. To do this, Boeing stretched the AGM-86A, referred to by Boeing as the basic air vehicle (BAV), into the heavier and longer extended range vehicle (ERV).[38] (See figure 8.) In time, the ERV evolved into the AGM-86B which is almost 500 pounds heavier and almost 15 inches longer than the ERV, and has a rounded, rather than a duck-bill, nose. But the ERV and AGM-86B share essentially the same wings and profile.[39] Similarly,

the fuselage of SCAD, the "A" model, and the first eight "B" models are the same, consisting of 28 welded forgings which required considerable time and skill to properly machine and align. In early 1978, Boeing adopted bolted aluminum castings which cut the number of pieces to four. Although the new process added 80 pounds to the airframe's weight, this procedure cut structural costs, which are almost half the missile's cost, by one-third. Henry Runkel, Boeing's chief engineer for the ALCM, gets special credit for this innovation.[40] These measures almost doubled the range of the missile, to over 1,300 nm.[41] But other problems remained: the SRAM launcher could accommodate neither the new Boeing missile nor the Tomahawk ALCM; finally, and most importantly, the AGM-86B had never flown.

The military rescheduled the flyoff for May, but poor weather and contractor problems with support equipment, as well as problems with the B-52 carrier aircraft, forced a postponement until the summer. The 20 competitive ALCM sorties required a considerable organizational and logistical support effort. In addition to the 20 free-flight sorties (54 hours of flying time), the flyoff competition included 23 captive sorties (the missile retained aboard the carrier aircraft) and 17 jettison sorties (the missile simply dropped without the engine starting).[42] (See figures 9, 10, and 11 for air-launch sequence.)

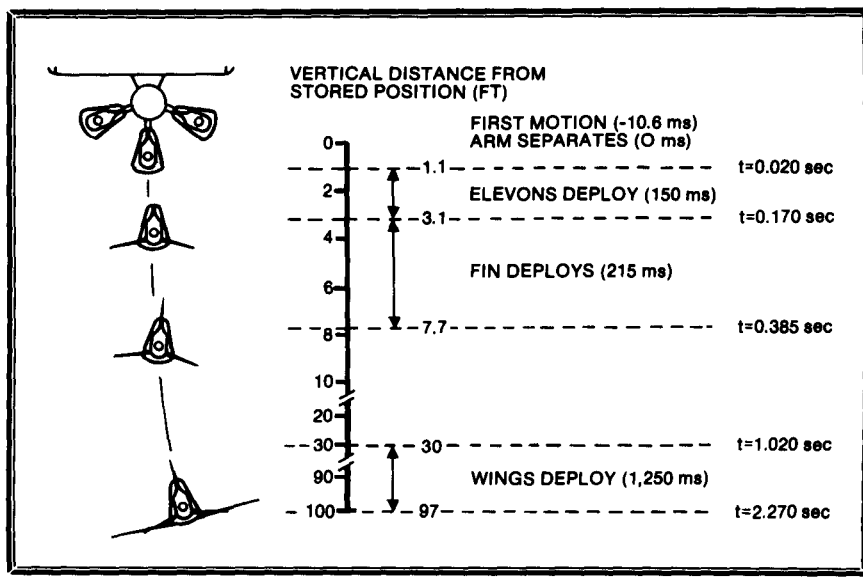


Figure 9. External (center position) air-launch sequence.

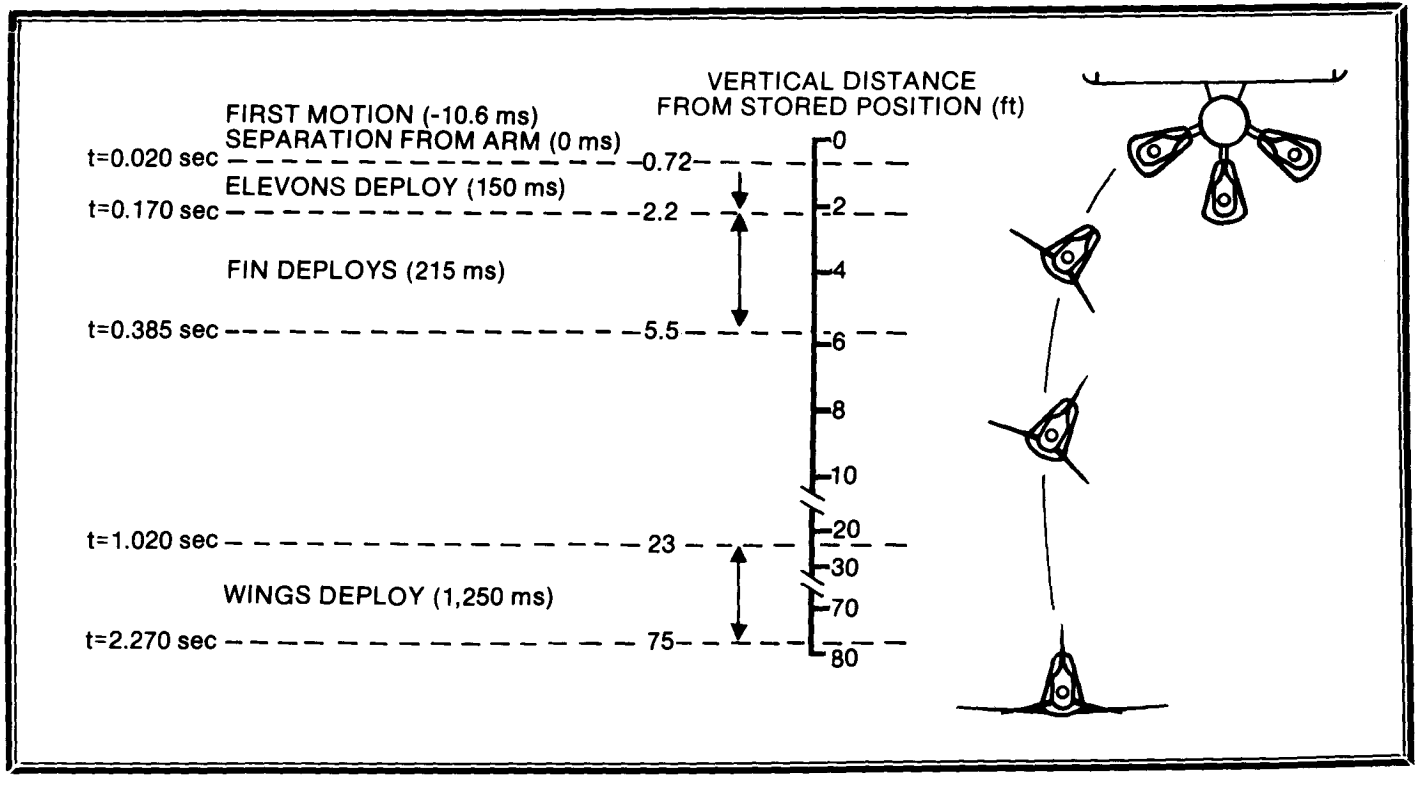


Figure 10. External (shoulder position) air-launch sequence.

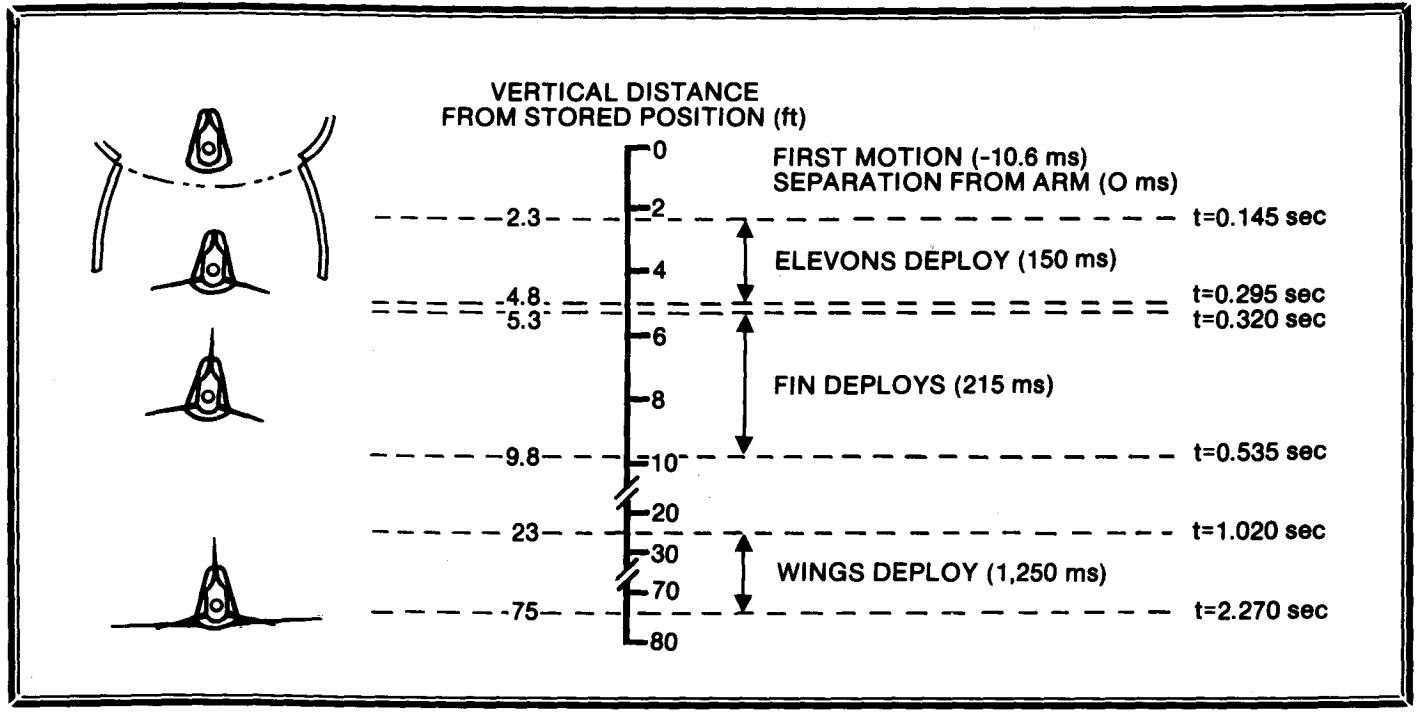


Figure 11. Internal air-launch sequence.

The Tomahawk successfully flew its first free-flight on 17 July 1979. On its ten flight attempts, GD logged a total of 22.2 hours while suffering four crashes. It successfully flew its tenth and last flight on 8 February 1980. GD recovered two of its missiles on two attempts.[43]

The Boeing missile also logged six successful flights on its ten test flights, even though it crashed after 44 minutes of its first test flight on 3 August. Despite mishaps, however, the Boeing missile registered 31.7 hours of free flight time (almost one-third more than the GD missile) and logged 67 TERCOM (terrain contour matching) updates. It also completed 9 jettison and 12 captive carry tests. But Boeing had difficulties in recovering its missile, succeeding on only two of five tries.[44]

Both companies encountered problems with excessive oil consumption of their common engine. Just as the survivability tests indicated a problem with the radar altimeter, the flyoff confirmed what JCMPO already knew; the engine used too much oil, or more specifically, its consumption rate exceeded engine specifications. While the specifications called for an oil consumption rate of .014 gallons per hour, the Tomahawk averaged a consumption rate of .236 gallons per hour on its ten flights while the Boeing missile's consumption rate ranged from .018 to a rate twice that figure.[45]

The Source Selection Evaluation Board, consisting of 200 Air Force and Navy officers, assessed the results of the competition and the Source Selection Advisory Council, a joint board of senior Air Force and Navy officers, reviewed these findings. They concluded that both missiles met the performance goals set by the Air Force and differed little, but that these differences were significant. Although each company lost four missiles, the testers regarded the Boeing crashes as less serious. In contrast, the evaluators considered the causes of three of the four GD crashes of a major nature. Therefore, the Boeing missile was recommended in a unanimous decision.[46]

Secretary of the Air Force Hans Marks announced his decision awarding the entire contract of 3,418 ALCMs to Boeing on 25 March 1980. In a news conference following his decision, Marks cited three reasons for selecting Boeing. The Secretary first mentioned superior Boeing guidance performance, which meant that since McDonnell-Douglas manufactured the hardware for both missiles, Boeing's software was best. Second, the military believed that the AGM-86B promised cheaper and easier maintenance than did the AGM-109. Finally, the Boeing bird demonstrated lower terrain-following abilities and flew better over rough terrain than did the Tomahawk. These advantages may stem from the basic design of the two missiles; after all, the Boeing effort is essentially a small unmanned aircraft while the GD product is a winged torpedo. (The latter's small fins and noncoinciding wingline undoubtedly complicate stability and control.) DSARC III approved the decision on 17 April, as did Deputy Secretary of Defense, W. Graham Clayton, Jr., on 30 April. Consequently, the ALCM returned to USAF control. JCMPO retained authority over the cruise missile's common items (guidance, altimeter, and engine), as well as over the SLCM and GLCM. This

decision also authorized the production of up to 225 ALCMs in Fiscal Year 1980 and a buildup to a production rate of 40 per month.[47]

Testing, of course, continued after the flyoff, especially since that endeavor had been less than an overwhelming success. Although the competition demonstrated the missile's design, the crashes also damaged the missile's public image. Crashes are bad publicity because, regardless of their cause or how much is learned from them, the public views crashes as simple, clean, and dramatic evidence of failure. William Perry expressed dissatisfaction with the missile's reliability, and expanded the original 11 planned follow-on tests to 19. Despite this expansion of the test program, the ALCM's IOC remained as it was.[48]

The tests began on 12 June 1980 and continued into 1982; by January 1982, 15 tests had been conducted, accumulating over 48½ hours of flying time. During these tests, the AGM-86B suffered four failures, including one crash on 20 November 1980. Therefore Boeing's AGM-86B did better than it had in the flyoff, crashing only once on 15 flights, compared with 4 on 10; and in addition, the testers recovered 6 birds on 8 attempts, compared with only 2 out of 5.[49]

Nevertheless, USAF is less than overwhelmed by the results. In 1980, AFTEC (Air Force Testing and Evaluation Center) stressed the limits of the tests and the need to do more testing. It rated the cruise missile satisfactory in 13 areas, deficient in 3 (test launch payload, technical data, and mission reliability), with results inconclusive in 8 other areas.* The testers singled out as the most critical area the lack of testing of the operational carriers, the OAS (Offensive Avionics Systems)-modified B-52. AFTEC's other two areas of concern focused on the lack of complete testing of the support equipment, especially the ESTS (Electronic System Test Set), and the reliability and maintainability testing. In spite of these reservations, AFTEC gave an overall positive assessment to the ALCM. OSD's director of defense test and evaluation concluded, in April 1980, "The ALCM air vehicle is potentially capable of meeting operational requirements. There were no major problems found in the basic design . . . [so that] there are no test related issues which preclude commitment to production of the AGM-86B."[50]

A September 1981 AFTEC report, however, stated, "Based on testing to date, operational effectiveness and operational suitability are both rated deficient when measured against the test thresholds established by the user."[51] AFTEC noted four areas of particular concern: missile performance (especially terrain-following), mission planning, reliability/availability, and pylon uploading. The evaluators criticized the ALCM as too heavy for both its wing area and engine power which contributed to two performance shortcomings: large turning radius and limited climbing ability. A number of other areas such as terminal accuracy, launch envelope, and time of arrival could not be assessed. AFTEC also lacked adequate information on storing the missile and the resulting reliability, and thus availability.[52]

Understandably, testing continues. On 10 October 1982, USAF completed ALCM test number 20 of the series begun in June 1980. The Air Force plans 15

*Overall operational effectiveness, terminal accuracy, terrain following, launch envelope, mission planning, software suitability, weapon's system compatibility, and interoperability.

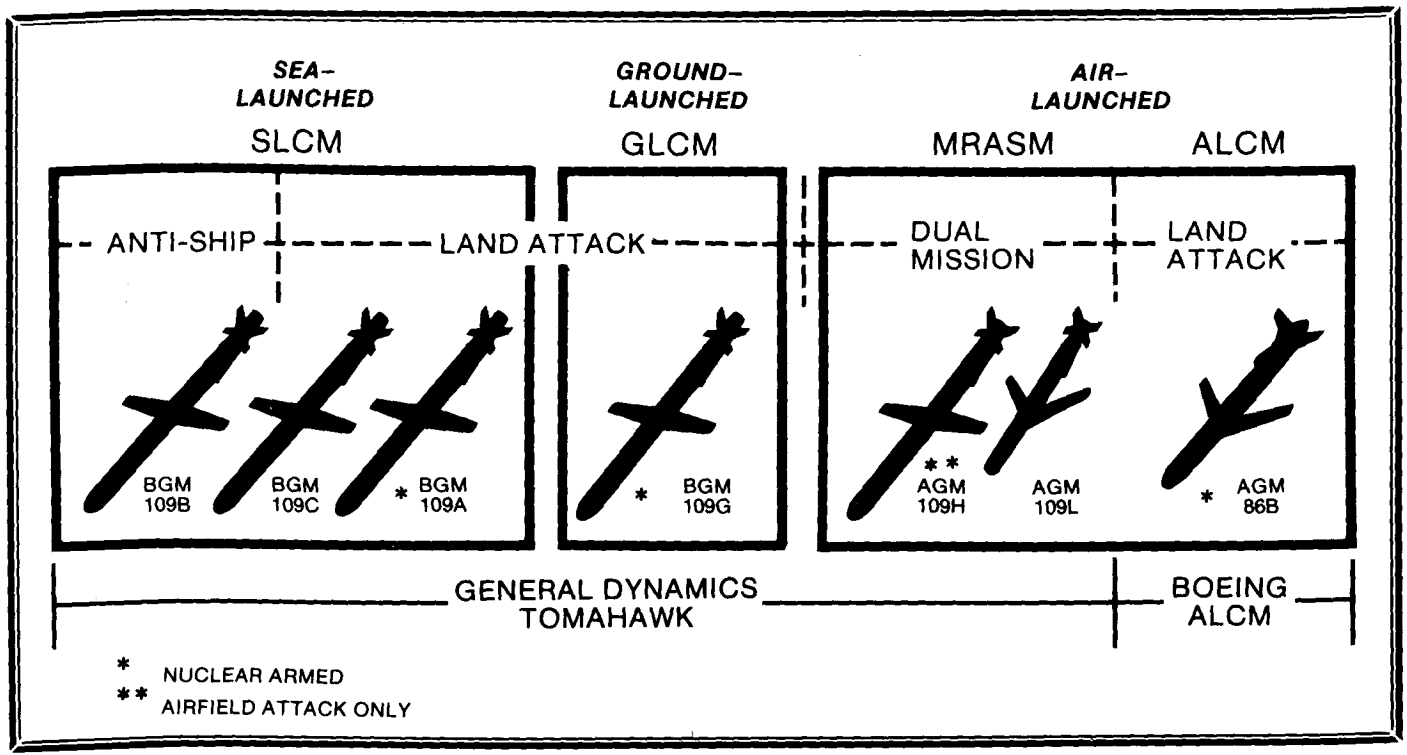


Figure 12. US cruise missile family.

integrated weapons system tests by SAC and AFTEC. These tests got off to a bad start, with missile failures on the first two attempts on 19 December 1982 and 24 May 1983, the latter culminating in a crash which the Air Force attributed to an isolated failure in the software. The next two test flights in June were successful. Another series of 15 test flights is scheduled in Canada.[53] As Canadian terrain and foliage resemble that of the Soviet Union, this test series will provide the most realistic test of the system.[54] Thereafter, SAC will operationally test 12 cruise missiles a year.[55]

The first SAC unit equipped with the AGM-86B is the 668th Bombardment Squadron, 416th Bombardment Wing, stationed at Griffiss Air Force Base, New York. USAF selected it because of its location relative to Soviet targets and initial TERCOM mapping restrictions. The unit received its first modified B-52G (sn 58-0247) with non-jettisonable pylons on 15 August 1981 and received 13 ALCMs on 3 September. The 668th became the first operational ALCM squadron in December 1982.[56]

The first production missile (number 25) rolled off the line in November 1981, varying slightly from the test (or preproduction) models. (See figure 12.) The most noticeable changes are a new all-metal whale-shaped nose (reducing RCS, possible flying object damage, and production costs) and the removal of the winged US insignia and lettered "Air Force." Boeing made other changes to cut costs: substituting an elevon housing machined from a titanium casting for a steel forging, and graphite epoxy elevons for aluminum ones. In addition, USAF adopted a new fuel. JP-4 powered the ALCM until the Air Force authorized the use of high density fuel. But JP-9, the new fuel used in the flyoff, is very expensive, currently costing about $45 to $50 a gallon. In April 1981, the Air Force began using JP-9 as a primer and JP-10 ($15 to $20 a gallon) as the principal fuel in the AGM-86B. The two have about the same energy, which is 20 percent more per unit volume than JP-4.[57]

One last aspect of the missile deserves treatment. USAF adopted the unusual "wooden round" concept of maintenance, essentially "store and forget," first used by USAF with the SRAM, for the ALCM. The concept relies on the massive electronic systems test set, originally designed for the SRAM, which tests the AGM-86B for both factory and field acceptance. ESTS checks the guidance system, altimeter, controls—everything except the engine and expendable actuators. USAF stores the missiles, loaded on pylons, for 36 months before another ESTS test and engine certification in the field. Thirty months later, the ALCMs return to the factory for further checks, an engine change, and a fuel check.[58]

Cruise Missile Carrier

For the immediate future the cruise missile carrier will be the OAS-modified B-52, the first of which Boeing delivered in June 1982. USAF considered other

aircraft as the cruise missile carrier but because of the B-52's availability, it was the logical choice. The electronics modifications on these B-52s give the Boeing bomber markedly increased capabilities, improving navigational accuracy perhaps by a factor of four. This is very important because the more accurately the launch point is fixed, the easier is the missile's task of navigation. In addition to doing the basic job of navigation, the new system also increased reliability and supportability while decreasing the aircrew's workload.[59]

USAF will modify all but 67 B-52Gs to carry 12 ALCMs externally. SAC will store the six ALCMs and pylon, which weigh about 25,000 pounds, as a unit to facilitate rapid uploading and easy handling when not mounted between the bomber's inboard engines and the fuselage. There is, of course, a performance cost for carrying the weapons externally. Flying at 6,000 feet and Mach .55, the loaded pylons increase drag by almost 12 percent. Following the modification of the "G" and "H" fleet with these external missiles, USAF will fit these same B-52s with a rotary launcher (carrying eight ALCMs) for internal carriage. USAF does not now have such a rotary launcher for the AGM-86B; therefore in late 1980, it instituted a competition involving eight contractors. The Air Force wants a rack compatible with the B-1 to meet an October 1985 IOC.[60]

There are of course structural differences on the cruise missile-carrying B-52. In addition to the pylons and interface equipment, Boeing added a strakelet to satisfy the unratified SALT II agreement regarding "functionally related observable differences." (See above.) It can be described best as a rounded faring smoothing out the juncture between wing and fuselage. Estimates in 1980 put the cost of these modifications at $11.5 million per B-52 ($5.4 million for OAS, $5.6 million for carriage, and $.5 million for FROD).[61]

USAF considered a number of different airframes for the cruise missile carrier following cancellation of the B-1 in 1977, beginning with wide-bodied commercial transports. It wanted such a carrier to supplement or to replace the B-52 if the new bomber failed, or if it needed to deploy more cruise missiles. Within a year, the search widened to include quite diverse aircraft. In May 1978, USAF let study contracts to Boeing (to examine the 707, 747, and C-14), to Lockheed (C-5, C-141, and L-1011), to McDonnell (DC-10 and C-15), and later to Rockwell (B-1).

Commercial aircraft offer a number of advantages as cruise missile carriers, primarily ease of manufacture and cost. As these aircraft are in production and service, they could be quickly bought and modified, presumably at considerable cost savings. In this way, large numbers of cruise missiles could be rapidly deployed.

While this option may look good at first glance, especially to the layman, it does present serious problems. USAF wants a cruise missile carrier with good escape characteristics (rapid takeoff and climbout), nuclear hardening, offensive and defensive avionics, long range, and heavy payload. But commercial transports, designed for an understandably more benign environment than military aircraft, require extensive modifications for carrying and launching the ALCMs, for increasing takeoff and escape performance, and for adding nuclear hardening and

the required communications, command, and control equipment, and wartime-capable navigation equipment. But attempts by penetrating bomber supporters to tag the wide-bodied transport costs (purchase plus modifications) at the same level as that of the B-1 are ridiculous. From the Air Force's point of view, the biggest problem with using wide-bodied transports is that such an aircraft would not be able to penetrate Soviet defenses, an issue which, while relevant to this study, goes far beyond its scope. Less controversial are two other criticisms of the civilian transports. First, the transports possess poor escape characteristics relative to USAF bombers. Second, the large aircraft create very lucrative targets. The 747 could carry 48 to 90 cruise missiles, the C-5, 69 to 72, and the DC-10, 48 to 75, clearly making them high value targets. Congress also criticized this idea and, consequently, it died in August 1979.[62]

Not surprisingly, the Air Force opted for the B-1 as the best cruise missile carrier in a report dated November 1979. As a strategic ALCM launcher, the B-1 requires considerable modification to accommodate an eight-ALCM launcher internally and 14 missiles externally. USAF scheduled a flight demonstration for the second quarter of 1982 to include two live ALCM launches. In 1980, the Air Force made its pitch to Congress, stating if the air service were to design a cruise missile carrier from scratch, the carrier would look like the B-1.[63] In 1981, the Reagan Administration restored the bomber as the B-1B.

Rationale for Multiple Cruise Missile Variants

Why then are cruise missiles being built? Throughout the 1970s, the question was asked in this manner: "What is the mission of the cruise missile?" Critics answered: "The weapon has none." Before we can answer, three factors must be clarified.

First, those involved with the cruise missile regarded the different types of cruise missiles differently even though these variants share the same technology. During the years 1973-77, nuclear-armed strategic ALCMs and SLCMs were the two chief actors. Since 1977, however, there has been a relative decline of interest in the nuclear-armed SLCM. Meanwhile, the GLCM and MRASM and tactical versions of Tomahawk became important, as we shall see. So one must specify which cruise missile variant is being discussed.

Second, different groups had dissimilar views of the weapons. For example, the Air Force hierarchy wanted most of all to restrict the ALCM in range so as not to endanger the B-1. On the positive side, USAF saw the cruise missile as a means to extend the useful life of the B-52. On balance then, the resulting USAF attitude toward the ALCM fell somewhere between hostile and ambivalent; favoring the missile as a bomber aid, but resisting it as an independent weapon system.

The Navy developed cruise missile technology, but used the strategic cruise

missile as a stalking horse for the weapon it really wanted—the long-range, tactical antiship weapon. There, too, the aviators, principally those on carriers, wanted the weapon restricted or at least not emphasized.

DOD took an opposite view to that of the military. It saw cruise missiles as cost-effective and flexible weapons with great promise, and therefore pushed both SLCM and ALCM during this period, using competition to spur the missile contractors and interservice rivalry to probe both the Air Force and Navy. High officials in the executive branch initially saw cruise missiles as pawns in both the arms control game and the propaganda game. Here too, the importance of cruise missiles changed over time.

Third, the cruise missile must be set in the context of its times because the missions, or purported missions, changed as part of the evolutionary process.

What then is the rationale behind the various versions of cruise missiles? The ALCM will enhance the bomber. The principal question that arose was whether the ALCM was required to maintain the viability of the penetrating bomber, which in turn raised the issue of whether the cruise missile would be strictly an aid to the penetrating bomber or simply a standoff weapon. Clements, in his December 1973 memo, merely called ALCM an "adjunct to the strategic bomber force" which would "present a highly proliferated low altitude attack to avoid and/or exhaust the defense system and provide improved penetrativity for manned strategic bombers."[64] But the ALCM contribution, while significant, and perhaps even vital for the B-52's penetration ability, was nearly inconsequential from the standpoint of the B-1's penetration ability. Therefore, some believed that the B-52 could substitute for the B-1; that is, a standoff missile could replace a penetrating bomber.

The rationale for SLCM was much more complex and variable. As already related, SLCM began officially as part of Secretary of Defense Laird's move in 1972 to bolster US strategic capabilities, to respond to domestic political pressures, and to amass bargaining chips for future arms agreements. Three other reasons put forth by missile proponents in June 1972 for pushing the weapon were that it was not limited by SALT I, it was highly survivable when based on submarines, and it would greatly stress Soviet defenses.

In March 1973, Naval officers stated that the cruise missile would provide a credible deterrent and more diversified offensive mix. You will recall Kissinger's two letters to Clements, in June and July 1973, emphasizing the value of cruise missiles as a bargaining chip. On his own part, Clements, in his key December 1973 memo, saw SLCM providing "a new dimension to our strategic retaliatory forces." It not only "would provide an effective, low-altitude strategic penetrator from the highly survivable launch base of our nuclear submarine force" but would "further provide for proliferation of the submarine strategic force in that every tactical and strategic submarine becomes [a potential SLCM carrier]."[65]

The SLCM rationale shifted as the Navy replaced older nuclear-powered, ballistic missile submarines as platforms with newer ones in 1974. At a congressional hearing in 1974, Admiral G. E. Synhorst noted that a few cruise missiles aboard highly survivable attack submarines would multiply the number of

American nuclear weapons. Moreover, Navy witnesses repeated that SLCM would stress Russian defenses and would be a hedge against a successful Soviet antiballistic missile. At this time, Synhorst, and the SLCM program manager, Captain Walter M. Locke (USN), publicly introduced a new concept: submarine-based cruise missiles as a survivable, strategic reserve force.

Late in 1974, the Assistant Secretary of Defense for Program Analyses and Evaluation wrote that, aside from being a SALT chip, there was no strong reason for deploying SLCM beside compounding the Soviet's defensive problem. The Secretary noted, however, that SLCM would be valuable as a flexible response in a tactical situation; that is, its one warhead was less ambiguous than the existing option, Poseidon's 6 to 10 warheads. He also raised the advantages of SLCM's better survivability and its use as a reserve force.[66]

The next year, the Director of Defense Research and Engineering stated that SLCM would be a desirable augmentation, giving an unambiguous, controlled single weapon response and an invulnerable reserve force. *Aviation Week* wrote that US SLCMs could prevent reloading of Soviet ICBM silos. At the same time, because of the cruise missile's relatively long travel time to the target, it cannot realistically be seen as a first strike weapon.[67]

Following President Carter's decision cancelling the B-1 in August 1977, Secretary of Defense Harold Brown set out two issues beyond the actual US-USSR military balance. He defined the first of these as a "hedge against the unexpected," such as a defensive breakthrough in antisubmarine or antiballistic missile technology. Brown's second issue concerned the perception of American-Russian strategic balance which had been moving away from US superiority. "We must be sure," Brown told Congress, "that perceptions are such that no doubts as to our capability or our will exists in the minds of the Soviet leaders, or in the minds of our allies, or even in our own minds should we be faced with a moment of deep crisis."[68]

Since 1977, the concept of perception appears to have motivated American decisionmakers. Two major studies of the cruise missile agree on this point. The first attributes the cruise missile's overall development to this factor.

> The proposal to develop the strategic cruise missile was, in essence, psychologically motivated: to strengthen the signal to the Soviet Union that the United States would vigorously contest any Soviet bid for strategic superiority, and to help alleviate internal anxieties that the United States had lost its self-confidence and the will to compete.[69]

The other study states that cruise missiles make an obvious contribution to US strategic posture. They will somewhat offset Soviet strategic nuclear advantages because of their newness, diverse platforms, and "alleged capabilities." More specifically,

> at a minimum, the ALCM will mitigate the perception of US strategic inferiority by preserving the role of the bomber leg of the triad. At a maximum, it will encourage the perception of a net increase in capability that will help plug the window of vulnerability before more impressive counterforce capabilities (the MX and D-5 ballistic missiles) become available.[70]

Perceptions of American strategic power at home and abroad surely are important factors in the development of the cruise missiles. The perception of a shifting strategic balance in favor of the Soviets became increasingly important in the late 1970s and early 1980s. Since the cruise missile has appeared in many variants and has changed over time, no single factor can be identified as most important in its development. The perception issue is just one of a number of factors that help explain the missile's development.

Among these other factors, two basic characteristics of cruise missiles intrigued planners and decisionmakers from the outset: its relatively low cost and the absence of man. The first meant that a significant number of missiles could be procured, a vital consideration in an era when costs increasingly preclude purchasing more than a handful of machines. Absence of man meant that the weapon could be stripped of redundant systems and flown in conditions where man could not safely operate.

Another factor is the "newness" of cruise missiles which appeals to the general public and especially to Americans who have an enduring fascination with technology. While cruise missiles are not really new, as the foregoing chapters demonstrate, they are new weapons in the public's mind. The recent cruise missile technology yielded enhanced characteristics and capabilities (small size, long range, low altitude, and extreme accuracy) to be integrated into a new weapon.

The United States' commanding technological lead provided a powerful pull, just as Soviet numerical superiority provided a powerful push, for developing the weapon. Finally, two events played a major role in fostering the missile's development. (That is not to say that without either event there would be no cruise missile, only that they markedly changed both the direction and speed of the missile's development.) The first event was the ongoing SALT discussions. The cruise missile played various roles in SALT, including bargaining chip, loop hole, and major component, if not a stumbling block, in those discussions. In short, it evolved from a lever to force concessions from the Russians into an issue of almost unmanageable proportions. The SALT process brought the cruise missile not only to the attention of the public, but to the attention of the military as well. The second major event was the cancellation of the B-1 in the summer of 1977. As a result, the ALCM became vital to extend the effectiveness of the B-52 against improving Soviet air defenses; it evolved into a crucial weapon, not just a "nice-to-have" one.

SLCM

After its initial prominence, the SLCM's popularity with the military declined during the 1970s, as that of the ALCM rose. The main argument against the SLCM is that it ties down submarines from other missions and competes for scarce space aboard the boats. Nevertheless, the numbers of SLCMs programmed increased from

U.S. Navy's Harpoon being launched from an armored box launcher 12 December 1979. The Harpoon program began in the early 1970s and was the Navy's short range tactical missile. (USN)

1,200 missiles in July 1977 (one-half nuclear, one-half antiship), to 3,994 in August 1981. The IOC for submarine cruise missiles is September 1983 for the antiship version and September 1985 for the follow-on land attack conventional version (vertical attack capable).

The naval Tomahawk (see below for GLCM Tomahawk) comes in a number of versions, albeit all with the same airframe and engine.[71] (See figure 12.) The first SLCMs to join the fleet were the conventionally armed, land attack version and the antiship variant fitted on the USS *New Jersey* in March 1983. The former carries a 1,000-pound warhead 500 to 700 nm. The Tomahawk antiship missile carries the same 1,000-pound warhead less than half the distance of the land attack version since it requires more sophisticated guidance (seeker) equipment.[72]*

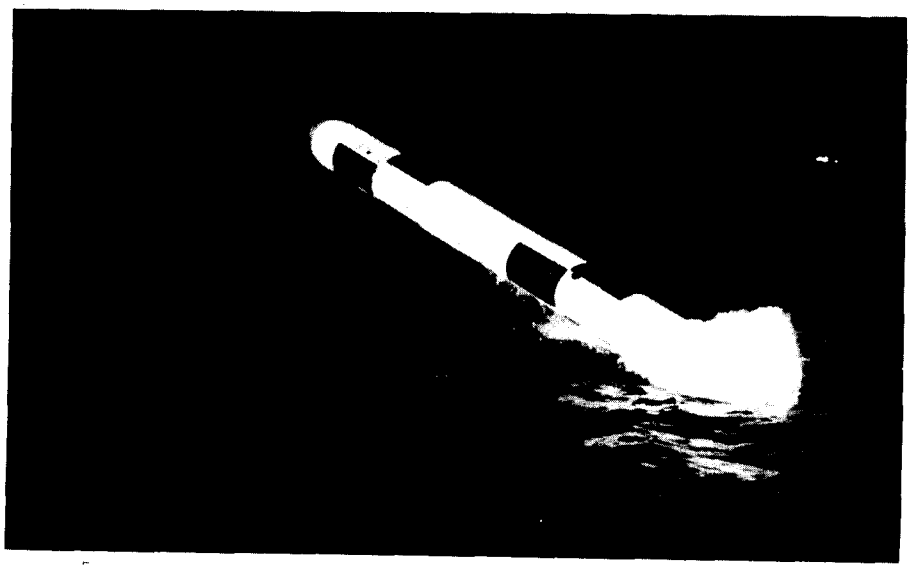
While some may question the military efficiency of the conventionally armed land attack missile, the antiship Tomahawk is another matter. The success of the 1960 technology antiship missiles, the Soviet-built Styx against both Israeli (1967) and Pakistani (1971) destroyers, and the achievements of the French-built Exocet against British warships (1982) have shaken all navies. Compared to the Exocet, the Tomahawk increases range tenfold and warhead weight fourfold, while adding other features. The chief question may well be, are there enough hostile targets to justify such a weapon?

The Navy scheduled the nuclear-armed, land-attack version as the last SLCM to

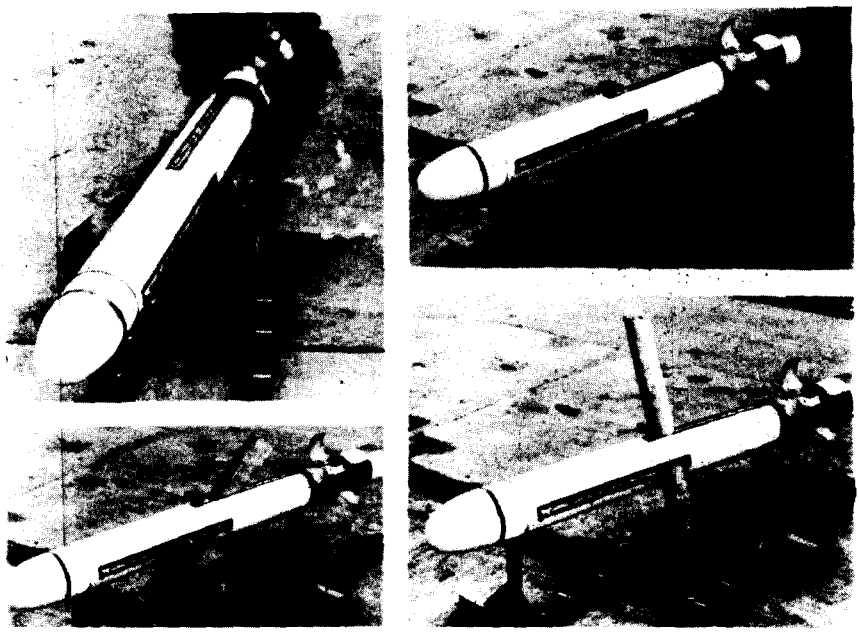
*The most difficult aspect of long-range antiship missiles involves target acquisition. The US Navy first demonstrated its over-the-horizon system (Outlaw Shark) in January 1977.

become operational, but this weapon has gained a higher priority as reflected in its accelerated IOC (June 1984) for both submarines and surface ships. It will carry a nuclear warhead, with many times the power of the Hiroshima bomb, up to 1,400 nm.[73]

The launch mode and the renewed interest in vertical launch of the SLCM require discussion. You will recall that the Navy considered vertical launch beginning in 1972 but cancelled it by 1974. A test in April 1976, however, showed such a method to be feasible, reliable, 30 percent cheaper, and 25 percent lighter than a horizontal launch system. Two basing schemes emerged, the first from submarines. DOD and Congress considered arming the eight usable and retiring Polaris submarines with vertically-launched cruise missiles, four to seven SLCMs per ballistic missile tube. The Navy rejected the idea because of the cost ($2 billion), the short remaining life of the boats, and its desire to use these boats as attack submarines.

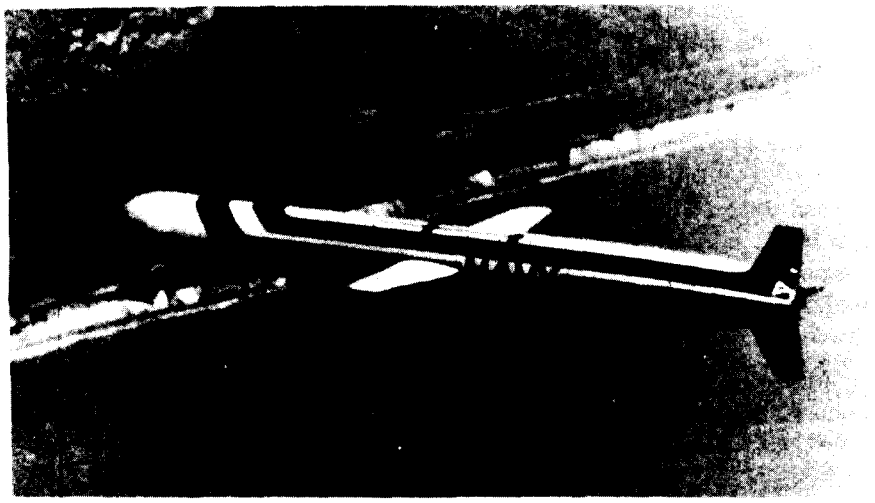


To select a strategic missile, the Navy conducted a flyoff between missiles built by Chance Vought and General Dynamics. Here, the Chance Vought BGM-110 emerges from the sea. (Vought Corporation)

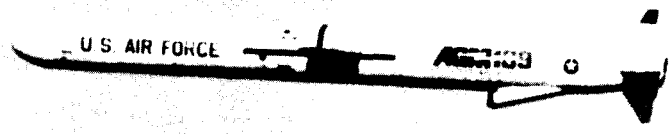


The BGM-110 had two unusual features, its wing and tail. An explosive sheds the shroud (upper left) from the missile, permitting the three-piece, curved, wrap around tail to deploy (upper right). Then, the one-piece wing pivots 90 degrees through thin slots in the fuselage (lower left) toward the extended position (lower right). (Vought Corporation)

The General Dynamics BGM-109 won the Navy's SLCM missile competition. (General Dynamics)



BGM-109 Tomahawk in flight. The major external differences between the Boeing and GD missile are the location of their inlets and the sweep of their wings. (USN)

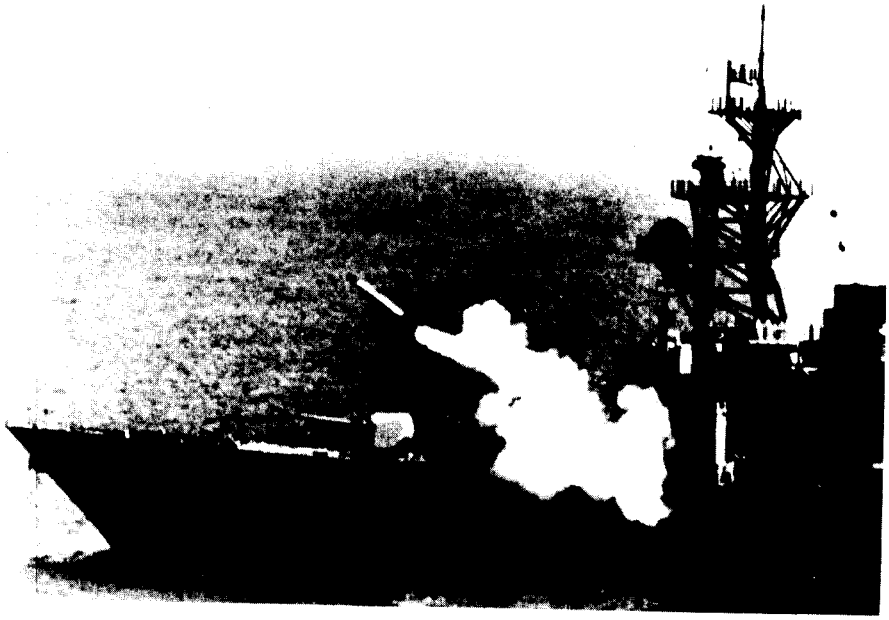


General Dynamics also competed for the USAF ALCM contract with its SLCM. A flyoff for that contract was held between Boeing and GD in 1979-1980. (USN)

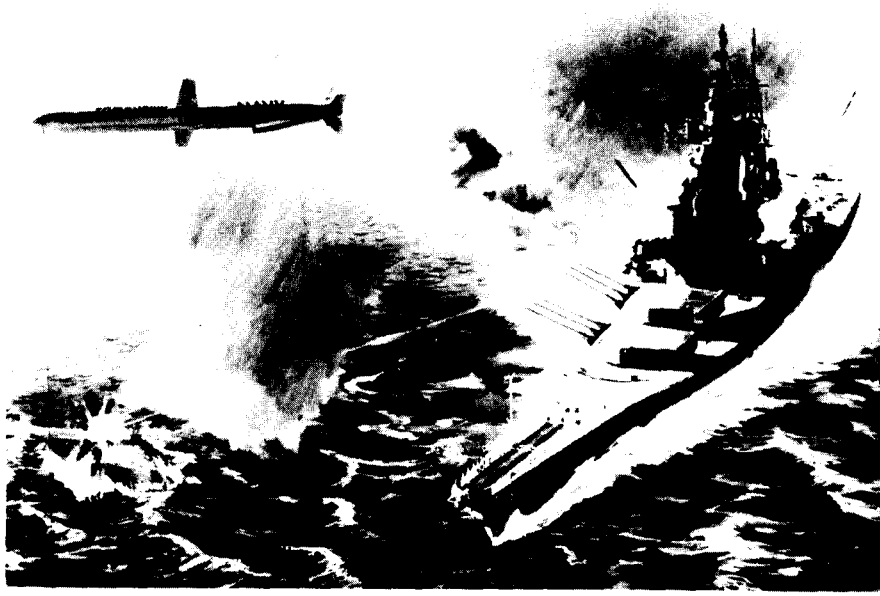
AGM-109 being launched during the flyoff competition. Note the empty ALCM pylon on the B-52's left wing. (USAF)

Boeing won the ALCM contract. The first ALCM equipped B-52 unit (the 416th Bombardment Wing) became fully operational with the weapon in December 1982. This photo shows a Griffiss based B-52 with full pylon load of ALCM. Note the SALT faring of the bomber's wing root. (USAF)

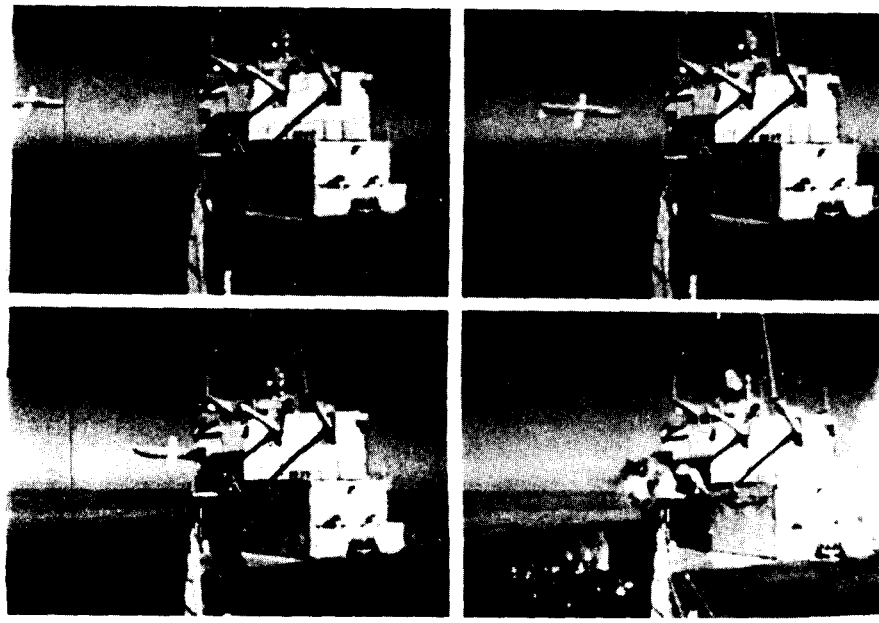
The present plan calls for initially fitting torpedo-tube launched SLCMs on the new *Los Angeles* (688) class attack submarines. Later, the Navy will install up to 12 vertical tubes in the forward ballast tanks outside the pressure hull where they will not interfere or compete with other weapons. In this way, the boats will serve as a strategic reserve. The Navy plans to put 88 aboard 11 attack submarines by 1983. The Navy's other basing scheme will put both vertically-launched and horizontally-launched Tomahawks aboard surface ships. These ships will include destroyers (963 class), cruisers (CGN9/36/385 and CG47), and four *Iowa* class battleships. The battleships will be taken out of mothballs and will initially be armed with 32 cruise missiles, later with over 300. The Navy completed initial modernization for the first of these, the USS *New Jersey,* at a cost of $326 million in December 1982.[74]



The GD Tomahawk can also be fired from surface ships. On 19 March 1980, the destroyer USS *Merrill* (DD-976) launched the first such missile from an armored box launcher that carries four missiles. (USN)

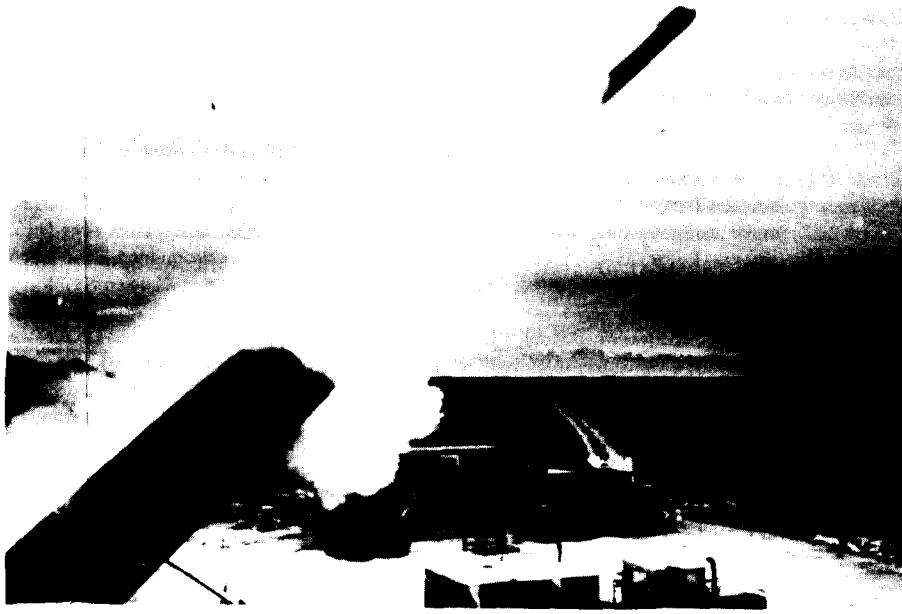


A number of U.S. Navy ships will operate with the Tomahawk, including the renovated battleship USS *New Jersey*. Initially, the *New Jersey* will carry 32 Tomahawks. (General Dynamics)



Tomahawk tactical anti-ship missile scoring a direct hit with an inert warhead in January 1981. (General Dynamics)

Tomahawk squarely hitting and emerging from target at Tonapah Test Range, Nevada on 10 July 1981. The missile was launched from a submarine and flew 300 miles. (General Dynamics)



First flight of BGM-109 GLCM on 16 May 1980. (USN)

GLCM

The ground-launched cruise missile is the third major sub-division of the cruise missile. As related above, USAF operated such land-launched weapons at both European and Pacific bases during the 1950s and 1960s. The first consideration of the new technology cruise missiles (SLCM) for a land-launched tactical nuclear force role came in 1973. Indeed, political and military considerations in the North Atlantic Treaty Organization led to the present development of GLCM.[75]

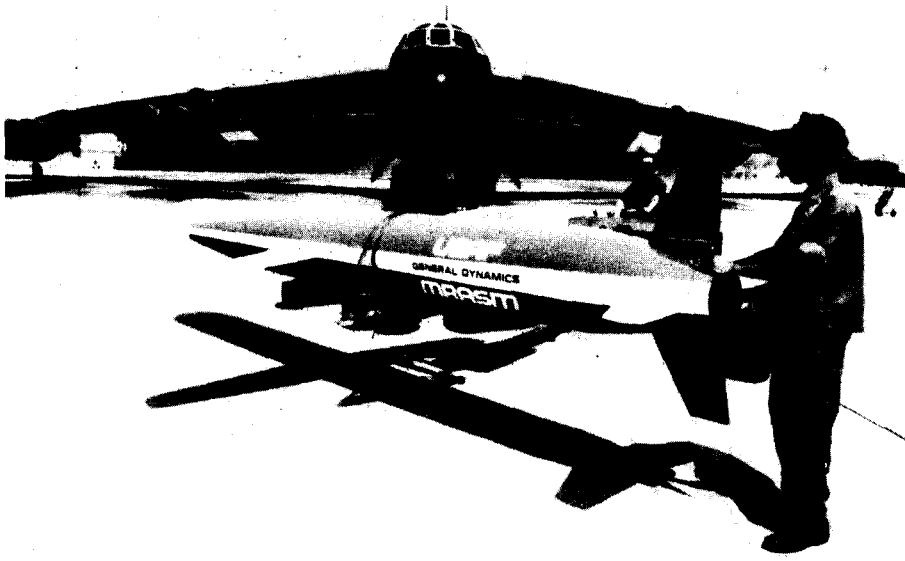
The military pressures on the alliance stemmed from the growing capabilities of the Warsaw Pact Alliance during the 1970s which threatened the survivability of western tactical nuclear forces. Clements wrote in his crucial December 1973 memo that cruise missiles could be deployed on land as "an effective potential replacement for the existing forward based [theater] nuclear force which is vulnerable to prelaunch attack."[76] Because of the apparent shift in the nuclear balance toward the communist bloc, NATO simply wanted more nuclear and conventional firepower. By deploying nuclear-armed cruise missiles, the western allies would enhance nuclear capabilities as well as release tactical aircraft committed to the nuclear role.

Growing political considerations superseded these military pressures. Some of the NATO allies viewed with alarm not only the communist buildup but also the US reaction or, better put, inaction. The war in Southeast Asia and the development of detente fed the lingering European suspicion that the United States could not be relied upon. The former stripped men and machines from American forces stationed in Europe, while the latter restricted the Europeans from acquiring certain equipment and limited American cruise missile deployment. (See SALT above.) The Europeans sensed a growing imbalance of theater forces even before the Soviets began deploying their new mobile ballistic missile, the SS-20. After that, the defense issue took on new life, also becoming one of perception of modernity, balance of forces, and political resolve and thus a priority issue. In this context the GLCM seemed an effective way to help bolster the western military and political cause.

In October 1977, West German Chancellor Helmut Schmidt spoke of the need to deal with the imbalance of East-West tactical nuclear weapons and specifically urged the United States to meet the challenge of the Soviets' new, three warhead, SS-20 intermediate-range ballistic missile. It is not surprising that in a January 1979 meeting in Guadeloupe, the leaders of Britain, France, Germany, and the United States agreed to President Carter's proposal to deploy Pershing II ballistic missiles and GLCMs to NATO. The allies linked the missile deployment with a simultaneous US offer to begin negotiations with the Soviets on limiting intermediate-range missiles in Europe. NATO unanimously approved this two-track proposal in December 1979.[77]

The GLCM possessed many military advantages. First, the mobile GLCM is

General Dynamics GLCM fired from its TEL (Transporter-Erector-Launcher). (General Dynamics)



Mockup of GD Tomahawk MRASM in front of a B-52 at March AFB. MRASM will give US aircraft a standoff capability against heavily defended targets. (General Dynamics)

much better able to survive prelaunch attack than either aircraft on the ground or stationary missiles. Second, its deployment will release aircraft now assigned to tactical nuclear roles for other tasks. Third, the device potentially has extraordinary accuracy.* And most important, compared to other tactical nuclear weapons (Pershing and Poseidon), it is more cost effective, perhaps three times that of the Pershing II in the nuclear role.[78]

The political advantages are even more striking. Unlike the Poseidon, the cruise missile is a high visibility weapon that vividly demonstrates US resolve and commitment. It also permits the United States to capitalize on its technological superiority, as the Soviets presently lack this new generation of cruise missiles. Some maintain that deploying GLCM in a number of NATO countries will bind the alliance closer together as these countries and the United States mutually share the burden of defense. But demonstrations in 1983, protesting missile deployment, cast some doubt on this conclusion. The cruise missile will help arrest the swing in the theater balance of power away from the west that has come increasingly to bother western Europeans. Certainly GLCM will give the NATO military more capabilities.[79]

*While the cruise missile demonstrated outstanding inflight accuracy, there is no indication in the open literature that the device has been tested for terminal (into the target) accuracy.

As with the other cruise missile variants, GLCM's support came from a strange coalition. First, the US Army had little to no interest in the weapon. Prior to 1977, the ground service considered using cruise missiles from Lance launchers, one missile per launcher. But the precedent of the Matador/Mace, the prospect of deploying a manpower intense weapon, and the allure of the Pershing led the Army to withdraw from the cruise missile project. Some, particularly in the State Department, proposed the Pershing II as the theater nuclear weapon. The cruise missile's support came mainly from within DOD and NATO. Except in Tactical Air Command, which had the tactical nuclear mission, USAF demonstrated little interest in the weapon.[80]

As DOD could not choose between the Pershing and GLCM, it used a traditional bureaucratic solution, adopting both with the rationale that they complemented each other. In December 1979, NATO accepted the American plan to base 464 GLCMs (160 in Great Britain, 112 in Italy, 96 in West Germany, 48 in Belgium, and 48 in Holland) and 108 Pershing IIs in Europe. The first weapons became operational in December 1983. Quite vocal support for the cruise missile in general and the GLCM in particular emanates from the Reagan administration, especially from Secretaries Weinberger and Carlucci.[81]

Three factors inhibit implementing this decision. First, an active antinuclear movement is forcing western politicians to rethink the NATO deployment decision, if only for political effect. For example, in December 1982 the Danes suspended money intended to support deployment of the GLCM and Pershing II. Despite the election of conservatives in Germany and Great Britain in 1983 who support the NATO nuclear buildup, clearly there is deep public sentiment on both sides of the Atlantic to at least slow, if not stop or reverse, the arms buildup. The second major pressure is the intense Soviet reaction. The Russians appear to be genuinely fearful of the missile, especially in German hands, sometimes calling GLCM the "German-launched cruise missile." The third major pressure is cost. In early 1983, DOD announced the cost of 560 GLCM missiles and associated equipment to be $3.6 billion. These rising costs, coupled with the need to trim defense budgets, may very well adversely affect the weapon's future.

As of this date (August 1984), the cruise missile and GLCM seem secure as the Reagan administration continues its plans to carry out the NATO cruise missile deployment despite opposing pressures. However, the situation must be considered against the background of arms reduction talks such as the dramatic Reagan nuclear cutback proposal for a complete withdrawal of all tactical nuclear weapons from Europe. Arms reduction talks resumed in the spring of 1982. President Reagan responded to a Soviet call for a freeze on nuclear arms with a counterproposal to cut long-range missiles on each side to a common ceiling of 850. In November 1981, Reagan also proposed foregoing the planned GLCM and Pershing II deployment if the Russians would withdraw their present force of medium-range missiles. The *New York Times* reported that the Soviets are willing to accept the latter deal with certain reservations, including "strength restrictions on all future cruise missile deployments."[82] Soviet and American negotiators worked out a possible

compromise in Geneva in July 1982, limiting GLCMs and SS-20s in Europe to 75 on each side. While this gave the Soviets a superficial advantage in matching three-warhead ballistic missiles against single-warhead cruise missiles, the agreement permitted the British and French to retain their 162 missiles. However, neither Washington nor Moscow would go along with this proposal. The new Soviet leader, Yuri Andropov, made a counterproposal in December 1982 to reduce the number of SS-20s aimed at NATO to 162 (to match the 162 French and British missiles) if the United States would not deploy the Pershing IIs and GLCMs. The diplomatic and political sparring continued until the Soviets broke off the talks when the United States began the initial cruise and Pershing missile deployments in December 1983. A negotiated settlement seems most unlikely in 1984 as both sides seek public favor and political advantage, and as the American election approaches.[83]

In contrast to the complicated diplomatic maneuvering, USAF organization and concept of operations for the GLCM are rather straightforward. A mobile transporter erector launcher (TEL) carries four missiles, organized four TELs to a flight. Each flight has two launch control centers (LCCs), a primary and a backup. The Air Force normally will base the GLCMs in sites hardened against nonnuclear weapons on well-protected bases. When necessary, USAF will disperse the GLCMs into the countryside in convoys consisting of 22 vehicles and 69 personnel. In the field, the units will be capable of self-contained operations for a period of time.[84]

Meanwhile, the missile itself continues to progress. (See figure 12.) It successfully completed its first platform launch in February 1981, and its first successful launch from its TEL a year later. By June 1983, GLCM had completed its ninth test, all but one successfully. Although initial deployment began as scheduled in December 1983, doubts remain. For example, a March 1980 USAF report on the ALCM noted problems with terrain-following, accuracy, and reliability. It also commented on mapping problems, namely that, while 86 percent of the terrain in the European operational area has little roughness, only 26 percent of the test terrain was of a similar roughness; specifically, while only 7 percent of the European terrain has roughness exceeding 200 feet or more, half of the test terrain has such roughness. The report also raised questions on the number of test crashes and the possible deleterious effects of long term storage on the missiles.[85]

MRASM

The last subdivision of the cruise missile is the medium-range air-to-surface missile (MRASM). Essentially parallel programs began as studies by USAF in 1975 and Navy in 1977; the Air Force's Advanced Conventional Standoff Missile and the Navy's Supersonic Tactical Cruise Missile. In the late 1970s, Congress made clear to the Navy that only a joint program with the Air Force would suffice. In June

1978, *Aviation Week* mentioned the cruise missile's ability to carry submunitions. Before the year ended, the aviation press reported a successful demonstration of MRASM neutralizing airfields. In May 1978, a modified Tomahawk flew 403 miles from its launch point to the Dugway Proving Ground, guided by TERCOM and scene-matching area correlator (SMAC) terminal guidance, and dropped 11 of its 12 bomblets dead on its runway target. It then returned over the target, simulating a photo reconnaissance run.[86]

The United States assigned little priority to the program until March 1980. In the wake of the ALCM decision, Under Secretary of Defense Perry wrote: "It is a matter of national importance that a joint tactical medium range air-to-surface missile (MRASM) be added to our strike warfare systems as soon as possible."[87] Interest emerged at this point probably because of the successful demonstration of the strategic cruise missile and its maturing technology. Perry went on to state that: "Only by taking advantage of the BGM-109 conventional land attack cruise missile development and the AGM-109 assets can an early IOC be attained and can minimum cost be achieved."[88] Some suspect that General Dynamics got the contract because of its loss of the ALCM contract. The fact that MRASM underwent no competition, as did the ALCM, fed these speculations. This overlooks the fact that competition takes time and money and that Perry's emphasis was on speed. In addition, many of the MRASM's subsystems had already been competed for within both the SLCM and ALCM programs.[89]

The MRASM differed from the strategic cruise missile in three ways: requiring much less range, a terminal guidance system, and a different munition. The demands of range and accuracy appear to be well in hand. The technology to get a cruise missile hundreds of miles within hundreds of feet of a target, with TERCOM, and then within tens of feet of the target, with terminal guidance (DSMAC or SMAC), is both available and demonstrated. The developer's biggest problem centers on the munition, which according to the aviation press is the reason for the conservative schedule. The concept is to crater the runway and taxiway at 2,000-foot intervals. The MRASM can carry 50 to 80 submunitions totaling up to 1,000 pounds of payload.[90]

Beginning in 1976, the United States and Great Britain jointly developed such a munition, the JP-233 runway buster. "Was" is the key word, because in early 1981 Congress decided the United States should withdraw from the program, primarily because of cost, much to the chagrin of the Air Force. The JP-233 contains cratering and delayed action mines as well as antipersonnel devices. The RAF used it in the 1982 Falkland Islands campaign.[91]

Other runway-busting munitions under development included the Lawrence Livermore Laboratory's tactical airfield attack munition (TAAM). It is a 3.35-inch diameter, 13-pound, two-charge munition fitted into mortar tubes. The cruise missile discharges 60 to 80 of these devices, each retarded by a parachute before detonation. But the US military cancelled TAAM because of technical problems in July 1982. The Germans demonstrated the same type of weapon, the STABO, to American authorities at Eglin AFB in September 1982. The German STABO also

uses a two-charge system, as does a similar munition—the boosted kinetic energy penetrator (BKEP)—under development by the Air Force Armament Division. After release from MRASM, a rocket charge in the BKEP drives a steel spike through the runway concrete where it explodes and creates a large crater. The Air Force MRASM can carry 28 BKEPs or 30 STABOs.[92] Other munitions considered for this role include the 70-pound BLU-81 Grasshopper, the 16-pound Martin Dual Charge, and the 45-pound cluster airfield denial munition (CADM). But to knock out a 240-foot-wide runway may require multiple sorties (the kill probability of a 15-shot load of BLU-81s is .5, a 40-shot load of Martin Dual Charge is .6, and a 20-shot load of CADM is .3). The Air Force narrowed its attention to the STABO and BKEP, and conducted a direct competition in September 1982 to choose between the two. In February 1983, the JCMPO recommended purchase of the BKEP.[93]

While runway-busting has received the most attention, USAF envisions other missions for the conventionally armed cruise missile. These include defense suppression, antiarmor, ECM, and reconnaissance roles. (See above for antiship.) Another submunition linked with the cruise missile is the BLU-97B combined-effects bomb. It weighs 3.2 pounds and measures 6.6 inches in length, 2.5 inches in diameter. The device has three modes of operation: fragmenting, armor-piercing, and incendiary. The baseline Tomahawk (219 inches in length) can carry 320 BLU-97Bs.[94] A number of the other munitions considered as a payload on the cruise missile against unprotected vehicles, structures, and personnel include the .4-pound M-42, .9-pound BLU-63B/M-74, 1.3-pound MK-118, 2.7-pound BLU-61, 14-pound BLU-87/BLU-49B, and 990-pound Bullpup fragmenting warhead. Finally, unitary warheads, a 90-pound BLU-73 fuel air explosive, and a 13-pound shaped-charge hard structure munition are also possible conventional cruise missile payloads.[95]

Just as the warhead for the MRASM differs from the baseline strategic missile around which this study centers, so does the vehicle. (The commonality between the MRASM and SLCM is put at 15 percent.) The Air Force and Navy are building two different missiles based on a GD Tomahawk guided by TERCOM and DSMAC with strapdown inertial ring laser gyros. (See figure 12.) US Navy ammunition elevators and the safe return weight of its primary attack aircraft, the A-6E, restrict missile weight and length; therefore, its versions, the AGM-109C, I, L, and J,* weigh 2,200 pounds and measure 192 inches in length. The Navy variants carry a unitary warhead of 650 pounds and are distinguished by the 15 degree sweep of their wings. An F109 turbofan powers the "C" model which is slated for operation in fiscal year 1983, to be followed the next year or two by the "J," a low cost model. In July 1980, Secretary of Defense Brown cancelled the "I" which would use a low cost TERCOM and imaging infrared (IIR) terminal guidance and a warhead from the Condor program. A Teledyne J402 turbojet engine powers both the Navy 109C and J and the Air Force's 109H.[96]

In contrast to the 192-inch, 2,200-pound Navy missile, the Air Force's AGM-109H measures 230 inches, weighs 2,700 pounds, and has a straight wing. Like the

*The BGM 109A is the nuclear land attack version, the B&E antiship, and the G is the GLCM. See figure 11.

AGM-109C, it is guided by TERCOM and DSMAC, and is scheduled for IOC in fiscal year 1984 to 1985. USAF is also considering a "K" model (with IIR) as a land and sea attack missile. Unlike the H's 1,200-pound multiple payload, it will deliver a unitary 1,000-pound warhead.[97] The Navy plans to fit four MRASMs on the A-6E, F-18, and P-3, while the Air Force will load eight externally on the B-52, two (possibly four) on the F-16, and is considering using the F-111 as well.[98]

Cancellation of the Navy's low cost "I" version, what they really wanted, encouraged that service to investigate an IIR sensor mounted on a Harpoon missile. While MRASM would be perhaps 1½ to 4 times as expensive as such a weapon, the MRASM will carry a heavier warhead (1,000 versus 510 pounds) further (over 300 miles versus 60 nm). Left with two missiles it did not want and a USAF missile too big for its purposes, in February 1981 the Navy withdrew from the joint project with the approval of DOD.[99] But the incoming Director of Defense Research and Engineering, Richard D. Delauer, promised congressmen at his confirmation hearing, in his words, "to revisit" that decision. He did just that. Within a few months the Navy rejoined the program, although it continued to develop the IIR Harpoon. USAF also wanted to kill the joint project during that same time frame. But after initially approving such action, the Department of Defense retained the program, to some degree because of strong congressional support.[100]

But the problems in the joint MRASM project remain unresolved. In 1982, the press published reports that DOD planned to allow the Navy to withdraw from the MRASM program and considered cancellation of the program. The Navy insists that the improved Harpoon is adequate for its needs and less costly than MRASM. In addition, the Navy is also looking at Norway's Penguin and the 20- to 25-mile-range Standoff Attack Weapon (SAW) as alternative systems. Estimates are that MRASM will cost $.9 to $1.5 million each, Harpoon $.78 million each, and SAW $.1 million each. Congress maintains its support for a joint effort while the aviation press continues to report that neither Air Force nor Navy want the weapon.[101]

Since 1978, the United States has planned a total buy of 3,500 MRASM missiles, with about three out of four going to the Air Force. By 1981, the press reported a total buy ranging between 3,000 and 5,000 MRASMs with an IOC scheduled for 1987 or 1988. Escalating costs, however, continue to be a factor. Estimates of the total costs of the MRASM program are now $3 to $6 billion.[102]*

ALCM "C," ASALM, ATCM

The quest for improved cruise missile performance continues, even as the services deploy the initial weapons. These efforts have essentially gone along three lines.

The evolutionary line began in late 1980. US studies indicate that big

*MRASM was cancelled in 1984.

performance gains could be derived from increasing engine performance and decreasing observability. The press reported that an upgraded Williams engine would be fitted into the ALCM, beginning with the fiscal 1984 buy. There are no present plans to retrofit ALCM B missiles with the improved engine. The new engine, scheduled to be installed in the SLCMs and GLCMs beginning in fiscal years 1986–87, will have 50 percent more thrust and yet have a specific fuel consumption 6 percent less than the engine in the "B" model. Such improved engine performance is quite an accomplishment, exceeding the goals of increasing thrust 35 percent and decreasing fuel consumption 5 percent. In addition, the new engine will extend the time between engine certifications from three years to five.[103] The press claims revised software will be fitted to the ALCM C. Other changes offer little performance gains, although extending the fuselage will permit longer range; and lengths of 304 to 315 inches have been proposed.[104]

In February 1983, the Air Force reoriented its ALCM program by reducing the planned ALCM buy from 4,348 missiles to about 3,000. The USAF now plans to field about 1,715 ALCM Bs and about 1,300 new generation cruise missiles, called advanced cruise missiles (ACM). This missile, with the modifications already discussed, may have double the range of the ALCM B. Further, stealth technology will greatly reduce the defender's chances of detecting and intercepting the missile by significantly reducing RCS. Unclassified reports also mention the incorporation of a "passive" TERCOM system that would reduce or eliminate the ALCM's electronic emissions. The result is a much longer range, less vulnerable, more accurate missile, albeit a much more expensive one. In April 1983, the Air Force awarded the ACM contract to General Dynamics. In view of the company's manufacturing difficulties (see below), this selection surprised some observers.[105]

Why the change to a more sophisticated cruise missile? Most of the unclassified reports attribute the move to improved Soviet defenses. These relate that the Russians deployed their AWACS, their MiG-25s with look down/shoot down radar, and their SA-10s faster than had been anticipated. But Secretary of the Air Force, Verne Orr, testified that Soviet defenses did not drive the change. Others advance more sinister motives. Representative Norman Dicks is reported as suspecting that the Air Force made the change to assure the development of the B-1B bomber and the Advanced Technology Bomber. It should be noted that Representative Dicks is from Washington, the home of Boeing, which builds the ALCM B but neither the ACM nor B-1B. Some Boeing proponents claim that the ACM move was the Pentagon's response to Boeing's attempts to overturn the government's decision in the purchase of the C-5A transport, another aircraft not built by Boeing. A third, less conspiratorial reason for the ACM decision may be technological determinism. Students of technology have noted that frequently something is built because it can be built.[106]

USAF awarded design study contracts for the Advanced Strategic Air Launched Missile (ASALM) in 1971, ramjet engine study contracts in 1971 and 1972, a propellent contract and guidance contracts in 1972, and ASALM integration, propulsion, and guidance in 1974.[107] In late 1977, the military restructured and

accelerated the program. In March 1980, it validated the propulsion unit after seven test flights. The ASALM guidance will be an updated inertial system coupled with both passive antiradiation and active radar homing devices for its air-to-air role. By 1980, Raytheon and McDonnell-Douglas were teamed for ASALM development while Martin Marietta and Hughes were collaborating for guidance subsystems.[108]

Another line of development is the ATCM (Advanced Technology Cruise Missile). The Air Force restricted the ATCM in two ways. The B-52's bomb bay and eight-missile rotary launcher dictated a maximum diameter of 19 inches while its external tandem carriage dictated a maximum length of 249 inches. The resulting paper designs emphasized survivability and missile ranges of 2,300 to 2,600 miles. According to the press, General Dynamics, Boeing, and Lockheed were competing for a full scale development contract beginning in the spring of 1983.[109]

Another concept that need not detain us is the Long Bow, a cruise ballistic missile, underway since at least 1979. It is intended to be vertically launched from a Minuteman silo, then transition to a cruise missile configuration, cruise toward its target, loiter if necessary, and finally fly a ballistic path into the target. Unclassified accounts describe it as the size of a Boeing 727 with a 88-foot wing span. In early 1983, Vought won a $12.1 million contract to study this concept.[110]

Three rapidly developing technologies (computers, airfame, and engine/fuels) promise the next generation cruise missile increased capabilities. Greatly increased computer capacities will enhance guidance, maneuver, and ECM opportunities with no weight and volume penalties. The resulting cruise missile will do much more than just terrain-follow to the target; it will be more accurate, and be able to respond to hostile defenses. In 1983, USAF will test a satellite updating navigational system, using the NAVSTAR GPS (Global Positioning System).

Stealth technology will be incorporated into cruise missile airframe designs. Although less-than-ideal from an aerodynamic standpoint, stealth technology will make the individual cruise missile much more difficult to detect and track. The prospects of hundreds, if not thousands, of such weapons must give defenders sleepless nights.

The third and perhaps most critical technology centers on engine and fuels. Greater efficiency permits greater range, to outreach expanding Soviet defenses, and greater power compensates for the weight and drag penalties produced by adding the improvements to the cruise missile. Because engine and fuels appear as key elements to future cruise missiles, considerable effort has gone into their development. A 1979 study reported that substituting ceramics in the F107 turbine would offer over 50 percent greater thrust as well as 8 percent lower fuel consumption. It went on to state that redesigning the engine would reduce fuel consumption by almost 27 percent for 1985 and that 1995 technology offered a reduction of 46 percent.[111]

A number of new engine designs being tested provide even better performance. In the Williams Research recuperative design, hot engine gases recycle through the engine to boost inlet temperatures and thus significantly increase thrust. Garrett Corporation's compound turbine cycle consists of a high bypass ratio engine driven

by a high speed, supercharged diesel engine. A third new engine type is Teledyne's eccentric turbine engine with a third spool mounted perpendicular to the engine shaft.[112]

Final Words

In August 1982, the Navy replaced Rear Admiral Locke (Director of JCMPO) with Rear Admiral Stephen Hostettler. Locke learned of his removal only one day before the Navy informed the press; and Hostettler took over a mere week later. Locke's operation was under review at the time, but contrary to normal practice, JCMPO had not yet received a written report (it had not been written) and hence had not been able to respond to it.

The press used words such as "relief," "firing," "dismissal," and "ouster," to describe the action. For its part, the Navy insisted that the change was appropriate as the missile moved from development and testing into production. In any event, the reader should recall not only Locke's long connection with the program, but most especially the considerable progress the weapon made under his command.

The press speculated that two major reasons accounted for the move. Most frequently mentioned were the problems with the missile's reliability. The Navy considered Tomahawk's 68 percent test success rate inadequate compared with their standard of 90 percent. While some claim there was no pattern to the failures, others focus on quality control. General Dynamics received a series of warnings from JCMPO on the issue of quality control, including a "Method D" in June 1982, the strongest measure possible short of a stop work order, and the only such "Method D" issued since 1945. JCMPO went so far as to take award fee funds away from the San Diego firm. Secretary of Defense Weinberger told the House Appropriations Defense Subcommittee that quality control was a central issue to Locke's removal. The second problem area mentioned by the press involved the schedule delays for the conventionally armed land attack and anti-ship missile which failed to make the scheduled IOC in the summer of 1982.

To be sure, Locke and the joint program had a number of opponents. Neither service liked the idea of a joint program. Some in the Navy apparently feared that Locke might become another Admiral Rickover. After all, he had been with the cruise missile program for over 10 years and had become popular with the civilian leadership in the Pentagon and with congressmen. GD reportedly made a strong effort early in the year to displace Locke, after the government granted a second source contract for the Tomahawk to McDonnell-Douglas.[113]

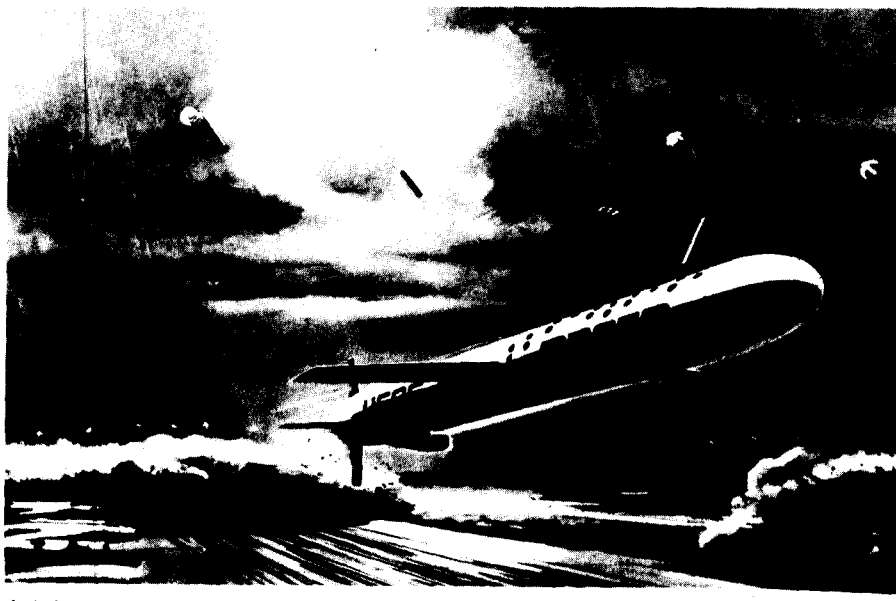
The direction the program takes under Admiral Hostettler may explain much of the story of this personnel change. The two areas to be especially watched are the concepts of commonality and second sourcing. Both of these gave the joint program its particular character as well as many of its problems. These were also two of the main items pushed by Locke.

Since the change in command, a number of events have taken place. In December 1982, the Navy lifted the "Method D" from General Dynamics. In 1983, the Tomahawk's test failures were less visible. While some problems continue, the program appears to be coming along. In June 1983, for example, the Navy recorded the fifth straight successful Tomahawk flight.[114]

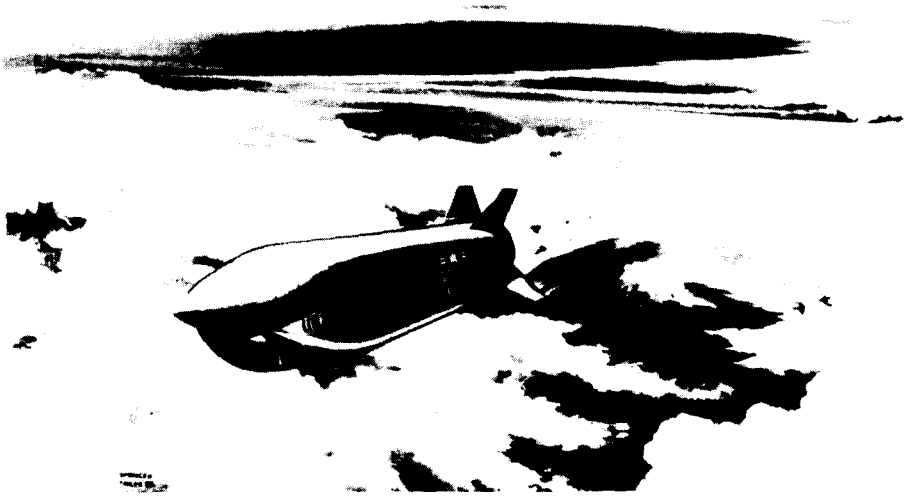
The point is that there are problems with the cruise missile, but how serious remains to be seen. The most prominent of these is reliability. In view of the weapon's long history, these problems should not be unexpected.

Nevertheless, the future of the cruise missile is bright. The first generation missile is in production and in service. Its performance has exceeded expectation while its schedule and costs are consistent with major systems developed during the 1970s.[115] A second generation missile is on the way. While there are questions as to the impact arms limitations agreements might have on the entire family of cruise missiles (one senator recently suggested limiting SLCM deployment[116]), the cruise missile appears secure at this moment. Improvements of the present generation missile are well underway and are being incorporated into later versions of the ALCM production run.

Technology for the future generation cruise missile is also well advanced. At this time the key areas appear to be electronics, engines, and fuels. These promise to produce reliable and markedly improved performance in short order. Therefore, these next generation cruise missiles should maintain the lead the present ones enjoy over current enemy air defenses. This prospect of continued technological superiority ensures that the cruise missile will be vital to American security in the foreseeable future. As such, the cruise missile will come to occupy an increasingly important place in the weapons arsenal of the West.



Artist's conception of a MRASM attack on a hostile airfield with runway-busting submunitions. (General Dynamics)



Artist's conception of a follow on to the cruise missile. This is a view of ASALM (Advanced Strategic Air Launched Missile). (USAF)

Artist's conception of the delta-shaped, advanced technology cruise missile. (USAF)

NOTES

CHAPTER VI

Data within the brackets indicate the location of the material and, in the case of the Air University Library and Simpson Center, their call numbers. The following abbreviations are used: Aeronautical Systems Division, Wright-Patterson AFB, Ohio [ASD]; Air University Library, Montgomery, Ala. [AUL]; Joint Cruise Missiles Project Office, Washington, D.C. [JCMPO]; Albert F. Simpson Historical Research Center, Montgomery, Ala. [AFSHRC]; Headquarters Strategic Air Command, Offutt AFB, Nebr. [SAC]; Air Staff, Strategic Aircraft Division, Washington, D.C. [RDQB].

1. Pre-DSARC Cruise Missile Briefing to Dr. Currie, 21 December 1976; Memorandum for the record of meeting with Under Secretary of the Navy, 21 December 1976 [both JCMPO].

2. Deputy Secretary of Defense William P. Clements, Memorandum for the Secretary of the Air Force, Secretary of the Navy, Chairman of the Joint Chiefs of Staff, and the Director of Defense Research and Engineering, 14 January 1977 [JCMPO-Sante Fe #35].

3. At the January 1977 DSARC meeting, the USAF pushed for the AGM-86A for internal carriage in the B-52's SRAM launcher and a June 1980 IOC, and for the AGM-86B (three per pylon) for external carriage with a June 1981 IOC. History Directorate of Operational Requirements, January–June 1977, Vol. V, 82 [AFSHRC-K140.01 V Jan–Jun 1977].

4. Clements Memo to the Secretary of the Air Force, et al., 14 January 1977.

5. "DOD Giving Navy Prime Role in Joint Cruise Missile Development," *Aerospace Daily* (11 July 1977), 50; Harold Brown to President Jimmy Carter, 26 January 1978 [JCMPO]. The best study of the JCMPO is E. H. Conrow, G. F. Smith, A. A. Barbour, "The Joint Cruise Missiles Project: An Acquisition History," RAND, 1982, 2 volumes. Hereafter cited as Conrow.

6. Raymond L. Garthoff, "Soviet Perspectives," 341, 342 [Richard K. Betts, (ed.), *Cruise Missiles* (Washington, D.C.: Brookings Institution, 1981)]; for a slightly different version see Gerald Smith, *Doubletalk* (New York, N.Y.: Doubleday, 1980), 190. Also see Charles A. Sorrels, *U.S. Cruise Missile Programs: Development, Deployment and Implications for Arms Control* (New York, N.Y.: McGraw-Hill, 1983).

7. Most sources contend that Kissinger intended to trade the cruise missile for the Backfire, but the military grew to like the missile. Kissinger, however, states that the United States created the cruise missile to aid the strategic bomber and never intended to give it up entirely. "Kissinger Critique," *The Economist* (3 February 1979), 21. Thomas W. Wolfe, *The SALT Experience* (Cambridge, Mass.: Ballinger, 1979), 352; Harry D. Levine, "Some Things to All Men," *Public Policy* (Winter 1977), 151, 155; Colin S. Gray, "Who's Afraid of the Cruise Missile?" *Orbis* (Fall 1977), 519; John W. Finney, "U.S. Missile Complicates Arms Talks," *New York Times* (16 June 1975), 16; Robert L. Pfaltzgraff, Jr. and Jacquelyn K. Davis, *The Cruise Missile* (Cambridge, Mass.: Institute for Foreign Policy Analysis, 1977), 7.

8. "Pact with Soviets on Missile Curbs Reported in Peril," *New York Times* (16 October 1975), 1, 9; Ronald Huisken, *The Origin of the Strategic Cruise Missile* (New York, N.Y.: Praeger, 1981), 181; Johan J. Holst and Richard Burt, "Technological Change and Arms Control," 180, 185 [Uwe Nerlich

(ed.) *Beyond Nuclear Deterrence* (New York, N.Y.: Crane and Russak, 1977)]; Gerald Ford, *A Time To Heal* (New York, N.Y.: Harper and Row, 1979), 303.

9. Wolfe, 201; Alexander Malzeyev, "Soviet Air-Launched Cruise Missiles—Irrelevant to SALT II," *International Defense Review* (January 1978), 44.

10. Wolfe, 212, 213; Ford, 357, 358.

11. Robert J. Art and Stephen D. Ockenden, "The Domestic Politics of Cruise Missile Development," 396 [Betts]; Wolfe, 214–217.

12. Wolfe, 219–222.

13. Art and Ockenden, 397.

14. Wolfe, 220, 223, 224.

15. Ibid., 226, 227; Art and Ockenden, 398.

16. Wolfe, 233.

17. Strobe Talbott, *Endgame* (New York, N.Y.: Harper and Row, 1979), 182, 183, 218.

18. United States Department of State, "SALT II Agreement," Selected Documents #12A.

19. Alton H. Quanbeck and Archie L. Wood, *Modernizing the Strategic Bomber Force* (Washington, D.C.: Brookings Institution, 1976), 93, 28, 29.

20. United States Senate, Committee on Armed Services, Fiscal Year 1977, DOD Authorization, part 2, 11 March 1977, 5960–6108. For other defenses of the B-1 and criticisms of Quanbeck and Wood, see Francis P. Hoeber, *Slow to Take Offense* (Washington, D.C.: Center for Strategic and International Studies, 1977) and Elmo R. Zumwalt, "An Assessment of the Bomber-Cruise Missile Controversy," *International Security* (Summer 1977).

21. United States Senate, Committee on Appropriations, Subcommittee, Supplemental Appropriations for Fiscal Year 1978, 20 September 1977, 15. The same remarks are in "Triad's Air Breathing Systems," *Air Force Policy Letter for Commanders: Supplement* (October 1977), 8, and in "The B-1 Cruise Missile Decision," *Commander's Digest* (15 September 1977), 10.

22. See Brown's statement, footnote 21. Also see Brown's press conference 1 July 1977, "The B-1 Decision," *Air Force Policy Letter for Commanders: Supplement* (August 1977).

23. Edgar Ulsamer, "A Strategic Blueprint for the 80s," *Air Force Magazine* (September 1978), 47; M. Heard, draft memo to S. Zeilberg, "A Review of the Air Launched Cruise Missile Program," 31 March 1978, 1 [JCMPO].

24. Heard draft, 2, 3; Government Accounting Office, "Confusion and Uncertainty as to the Need for and Use of Air Launched and Tomahawk Cruise Missile Programs," PSAD-77–36, April 1977, iii; "Clements Mismanages Cruise Missile Program, Proxmire Says," *Aerospace Daily* (2 May 1977), 3.

25. Heard draft, 3; DSARC II (6 January 1977) [JCMPO]; Conrow, I, 7, 14; Conrow, II, 61.

26. William J. Perry, Memorandum for Secretary of the Air Force, Secretary of Navy, 30 September 1977, 2 [JCMPO]. On EXCOM, see Conrow, I, 13, 14.

27. Perry, 30 September 1977 memo, 2.

28. ALCM Source Selection Plan [JCMPO].

29. Interview, Colonel Cary Daniels, 7 April 1982; Aeronautical Systems Division, Historical Report, July-December 1977, part 20, ASD/YY, 4 [ASD].

30. Daniels Interview; Heard draft, 4, 5; Executive Committee (EXCOM) 5 Minutes (10 March 1978) [JCMPO, RDQB].

31. Interviews with Boeing personnel, 4 March 1982; Daniels Interview; Interviews with Griffiss Air Force Base personnel, 31 March 1982; EXCOM 5 Minutes.

32. "Cruise Missile Radar Altimeter Deficiencies Found, Corrected," *Aerospace Daily* (3 May 1979), 17; Interview, Colonel Joseph Rutter, 29 March 1982; Interview, M. D. Mobley, 1 March 1982; Minutes EXCOM 4 (17 January 1978), EXCOM 5 (10 March 1978).

33. In October 1978, *Aviation Week* reported that the Soviets successfully tested a look down/shoot down fighter against a cruise missile or simulated cruise missile flying below 200 feet. The Department of Defense vigorously denied the story. Later reports indicated that the Russian target was a drone the size of a T-33, or about 20 times the size of the Tomahawk. In 1975, an American F-15 flying at 10,000 feet and Mach .72 downed a drone 22 miles away simulating a cruise missile flying at 50 feet and Mach .75. "Perry Hits Cruise Missile Report," *Aviation Week* (20 November 1978), 24; "Pentagon Confirms

Look-Down Test," *Aviation Week* (1 January 1979), 17; "Cruise Missile to be Tested Against F-14, Hawks," *Aerospace Daily* (4 November 1977), 28; "Soviet Anti-Cruise Missile Test Debate Heats Up," *Aerospace Daily* (3 November 1978), 15, 16.

34. "Overtime Schedule Pressures Irk Cruise Missile Technicians," *Aerospace Daily* (7 November 1977), 37; "Current Soviet Defenses 'Inadequate' Against Cruise Missile Perry Says," *Aerospace Daily* (15 November 1978), 64, 65; J. Phillip Geddes, "The Air-Launched Cruise Missile," *Interavia* (June 1976), 580; "U.S. Cruise Missile Briefing," *Defense and Foreign Affairs Daily* (20 November 1978), 1, 2; "Soviets Held Defenseless Against Cruise Missiles," *Washington Post* (2 June 1978), A6; "Pentagon Officer Predicts Soviet Air Defense Effort," *New York Times* (22 February 1980), 5; "Pentagon Official Outlines Latest Thinking on Cruise Missile," *Interavia Air Letter* (15 November 1978); "Pentagon Rebuts Criticism of Cruise Missile," *Baltimore Sun* (1 November 1977); Norman Kempsten, *Los Angeles Times* (15 November 1978), 1; John Rhea, "Can Russia Catch the Cruise Missile?," *Flight International* (12 November 1977), 1411; "Cruise Missile Called Costly to Counter," *Aviation Week* (12 June 1978), 20.

35. Daniels Interview.

36. July 1979 Program Managers Assessment, Executive Committee Briefing, #15, 7 July 1979; DSARC II, Briefing, 6 January 1977 [both JCMPO]; Minutes EXCOM 2 (17 November 1977), 2.

37. History Directorate Operational Requirements, July–December 1977, I, 86 [AFSHRC-K140.01 Jan–Dec '77]; History, Aeronautical Systems Division, 1976, Vol. I, 204 [AFSHRC-K243.01 I '76]; Memo for the Record, Major W. E. Dermooy, Jr., SAC (XPHN), "Visit of Captain Walter M. Locke, USN," 22 April 1977 [SAC History, 1977, Historical Study No. 166, Vol. VII AFSHRC-K416.01-166, '77, VII, Exhibit 53 S-78-214].

38. Wing area increased from 10 to 11 square feet, while the angle of the wing sweep decreased from 35 to 25 degrees. Boeing retained the BAV's nose shape, but fitted the ERV with a "bobtail" to reduce drag.

39. ASD, "AGM-86A (SCAD) Final Report," Vol. III, Chapter 14, SCAD Document #141, July 1973, 3; ASD Historical Report, January–June 1973, part 6, SCAD Document #138 [both ASD]; History Air Force Systems Command, 1976, I, 196, 197, 204 [AFSHRC-K243.01 I '76]; Boeing, "Air Launched Cruise Missile," 11, 14; Doug Richardson, "The Cruise Missile," *Flight International* (1 October 1977), 967; "Ray Utterstrom Talks About ALCM," *BMA Manager* (January–February 1979), 4; Clarence A. Robinson, Jr., "ICBM Guidance Curbs Alarm Planners," *Aviation Week* (11 July 1977), 16; Dean Sampson to author, 10 June 1982 with chart "ALCM History," FAD 4403.

40. Interview, Ray Utterstrom, 1 March 1982; Mobley Interview; Interview, J. G. Galimanis, 1 March 1982; Interview, G. J. Knight, 1 March 1982; Marc C. Turner, "Air Launched Cruise Missiles," *Combat Crew* (March 1981), 22; Richard G. O'Lone, "ALCMs Delivered Ahead of Schedule," *Aviation Week* (17 January 1983), 103.

41. *Jane's All the World's Aircraft: 1980–1981*, (London: Jane's, 1979), 661; *Jane's All the World's Aircraft: 1978–1979*, 652.

42. Each missile free-flight mission required the support of the B-52 carrier aircraft, three F-4 chase planes (for range safety), two T-38 photo chase planes, two KC-135 tankers, one advanced relay instrumentation aircraft (ARIA), a converted C-135 serving as a telemetry recording and relay aircraft, and two recovery helicopters. During the duration of the competition and tests, the B-52s flew 129 sorties and 725½ hours, the F-4Es, 152 sorties and 722 hours, the ARIA, 110 sorties and 608 hours, and the KC-135s, 134 sorties and 54½ hours. Air Force Testing Center, "AGM-86 Air Launched Cruise Missile (ALCM), DT and E Competitive Test Program," 1980, Volume I, 1, 2 [AUL-M35260-23]; Strategic Air Command History, 1979, Historical Study #181, Vol. I, 412 [AFSHRC-81-I]; Irving Levin, "The Challenge of Cruise Missile Flight Testing," *Canadian Aeronautics and Space Journal* (First Quarter 1981), 62–65; ALCM Test Manager's Book 1978–1980, JCM-A-40 [RDQB].

43. AFTC, "AGM-109 Air Launched Cruise Missile (ALCM) Competitive Test Program," 1980, Vol. II, 2–4, 2F, 9F, 10F, 35, Vol. III, 3 [AUL-35260-24-V II].

44. AFTC, AGM-86, I, 1-3, II, 5T, 9F, 10F, III, 7, V, 9: Minutes EXCOM 20 (23 January 1980) 5, 6; Isham Linder, Director Defense Test and Evaluation, Memorandum for Under Secretary of Defense for Research and Engineering, et al., 11 April 1980, 2, 3 [RDQB].

45. AFTC, AGM-109, III, 5; AFTC, AGM-86, III, 1; Minutes EXCOM 13 (13 April 1979), 5; Minutes EXCOM 14 (25 May 1979), 5.

46. Interview, Rear Admiral Walter Locke, 7 April 1982; Griffiss Air Force Base Interviews; Jeffrey M. Lenorovitz, "ALCM to Enter Inventory Next Year," *Aviation Week* (16 June 1980), 177.

47. News Briefing by Secretary of the Air Force Hans Mark, Colonel Allen Chase, Rear Admiral Walter Locke, 25 March 1980 [JCMPO]; "DOD's Clayton Approves DSARC-3 Recommendation on Boeing Cruise Missile," *Aerospace Daily* (5 May 1980), 19; W. Graham Clayton, Jr., Memorandum for the Secretary of the Air Force, 30 April 1980 [JCMPO]; "Program Management Directive for Air Launched Cruise Missiles (ALCM)," 8 July 1981 [ASD-Historical Reports, Jan-Jun 1981, ASD/YY, Vol. 15]; Richard Holloran, "Boeing Gets Control As the Major Builder of the Cruise Missile," *New York Times* (26 March 1980), D5; History of the Directorate of Operational Requirements, January–June 1980, 26 [AFSHRC-K140.01 Jan-Jun '80].

48. Minutes EXCOM 14 (25 May 1979), 3–6; United States Senate, Committee on Armed Services, Department of Defense Authorization for Fiscal Year 1981, 21 February 1980, 525; United States House of Representatives, Committee on Appropriations, Subcommittee, Department of Defense Appropriations for Fiscal Year 1981, 27 February 1980, 307; "Perry Says He Can't Solve Army's 'Bow Wave' Procurement Problem," *Aerospace Daily* (8 February 1980), 209.

49. Memorandums for the Secretary of the Air Force, 31 October 1980, 5 January 1981, 29 August 1980, 31 July 1980 [ASD-Semi-Annual Report, Jul–Dec '80, ASD/YY, Vol. 16]; Semi-Annual Historical Report, HAF-CHO (AR)-7101, July-December 1981 [ASD-Semi-Annual Historical Report, Jul–Dec '81, Vol. 14]; Boeing, "Air Launched Cruise Missile," 9, 10.

50. Isham Linder, Director of Defense Test and Evaluation, Memorandum for the Under Secretary of Defense for Research and Engineering et al., 11 April 1980, 8, 5 [RDQB].

51. AFTEC, "Air Launched Cruise Missile Operational Test and Evaluation," 1981, 14 [AUL-M43018-18eS].

52. Ibid., iii, 14, 17.

53. "Cruise Missile Tests Suspended," *New York Times* (2 June 1983), 12; "Cruise Missile Tests Halted After Failures," *Washington Post* (2 June 1983), 11; "ALCM Fault Identified," *Aerospace Daily* (16 June 1983), 257; "ALCM Successful in Fourth Test Flight," *Aerospace Daily* (20 June 1983), 278.

54. Henry Ginger, "Canada to Allow U.S. to Test Cruise Missiles," *New York Times* (11 April 1982), 10; "Air Force Still Optimistic on ALCM Testing in Canada," *Aerospace Daily* (8 April 1982), 226.

55. Griffiss AFB Interviews; Colonel Joseph G. Rutter, ALCM Program Review, 23 July 1981 [ASD-Semi-Annual Historical Report, Jul–Dec '81, ASD/YYP, Vol. 14].

56. Griffiss AFB Interviews; Weekly Activity Report, 20 August 1981 [ASD-Semi-Annual Historical Reports, Jul-Dec '81, ASD/YYA, Vol. 13].

57. Rutter Interview; Interview, Dean Sampson, 10 June 1982; ALCM Program Review, 23 July 1981; Lenorovitz, "ALCM to Enter Inventory Next Year," 183; Leonard Wainstein, "The Origins of the Cruise Missile," IDA P-1386, 1980, 22 [AUL-M40381-11-S#1386]; Minutes EXCOM 23 (2 October 1980), 6; Dean Sampson to author, 28 July 1982.

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CHAPTER VII

CONCLUSION

The two major themes that emerge from an examination of the historical record of the cruise missile are the impacts of technology and politics. From the early American, British, and French experiments with the missile in World War I until the 1970s, inadequate technology prevented the cruise missile from becoming an effective military weapon. Since 1970, new technology improved the missile, making it a potent weapon. At the same time, political considerations became increasingly important, complicating deployment of the weapon. Today, politics, not technology, tends to dominate the cruise missile story.

The missile originated with incorporation of gyroscope technology into existing aeronautical technology. Gyroscopes permitted more-or-less stable, straight and level, constant-heading flight for small biplanes powered by piston engines. Thus, the first guided missiles were miniature, unmanned aircraft.

Despite numerous efforts, however, these early winged missiles achieved limited success because severe problems of reliability hampered development. Taking man out of the machine left it prey to many seemingly overwhelming technical problems—and crashes resulted. Even when the missile worked as designed, infrequently as that turned out to be, its accuracy was far more a dream than a reality. Indeed unreliability and inaccuracy hindered the device from its inception until recently.

In the next major technological advance beyond the gyroscope, engineers installed radio control. While experiments conducted with this method during World War I failed, designers achieved some success in the early to mid-1920s. But the airman's options were restricted because a mother ship was required to escort these radio-controlled missiles to their target.

World War II brought an outpouring of funds and a new urgency to the field of unmanned powered weapons. Nevertheless, the United States could not produce a militarily effective guided missile based upon existing guidance and propulsion technology. Not that both the Army and the Navy did not try. The US Navy produced a number of useful target drones, as well as several offensive devices. Prior to Pearl Harbor, the Navy conducted a series of successful cruise missile

experiments, including one that launched a torpedo and another that crashed into a moving target. The Army also reentered the cruise missile field with a device that first flew just prior to World War II. But because this missile differed little in performance from its predecessors of the previous two and one-half decades, the Army Air Forces (AAF) cancelled the project. Both services employed guided missiles in combat, but neither the Navy assault drone program in the Pacific nor the essentially joint Army-Navy radio-controlled unmanned aircraft program in Europe offered significant military advantages.

Concurrently, the Germans employed a cruise missile in combat: the V-1 or "flying bomb." The V-1 differed from American cruise missiles in using a new technology engine, the pulsejet. The cheap V-1 had relatively high performance for its day.

But the V-1 bombardment of England, while politically, psychologically, and diplomatically startling, had little military impact. First, the Allies devised a formidable defense within a matter of weeks that destroyed most of the incoming missiles. Second, competing priorities, such as the V-2, left the Germans with inadequate numbers of V-1s. Third, poor German intelligence hindered their operations. But perhaps most important, the V-1's technical failings (unreliability, inaccuracy, and small warhead) limited its military effectiveness.

The Americans quickly built a copy of the V-1, shamelessly copied from salvaged German pieces. Although the AAF's grandiose plans for massive employment of this weapon against both the Germans and Japanese never came to pass, the United States built over one thousand JB-2s, which provided both AAF and Navy considerable missile experience. In addition to ground-launching the JB-2, the AAF air-launched the device while the Navy sea-launched their V-1, the Loon, from the deck of a submarine. Meanwhile, the AAF's other flying bomb project, the Northrop JB-1, turned out to be an expensive failure, even after the airmen fitted it with a pulsejet engine. Nevertheless, after numerous false starts, the V-1/JB-2 got the US military establishment finally and firmly into the cruise missile business.

American interest in missiles continued after the war, as did the technical problems of reliability and accuracy. The Air Force's intercontinental range Northrop Snark and North American Navaho dominated the winged missiles of the late 1940s and 1950s. Considerably larger than the World War II V-1, the two differed from the German missile in propulsion and guidance. A turbojet engine, the same as those used in jet aircraft of the day, powered the Snark, but the major innovation of the Northrop project was its inertial stellar guidance system. The Snark went into service, but only for a few months because inaccuracy, unreliability, and crashes fatally marred the program. In contrast, the Navaho was a much bolder project: a missile pushed to supersonic speeds and intercontinental range by ramjets. But Navaho encountered even greater technical difficulties than the Snark, prompting the Air Force to cancel Navaho well before it entered service. So despite considerable effort and expense, neither of these two cruise missiles could successfully compete with either the tried and proven bomber or the new intercontinental ballistic missile.

Unlike these dramatic, large, and unsuccessful intercontinental missiles, the shorter-range Martin Matador and Mace and the Vought Regulus were much more successful. The Martin missiles used various guidance systems from ground-based radio control to radar map-matching systems, and served operationally for about 15 years. During the 1950s, the Navy got a similar missile, the Regulus, operational from submarines, carriers, and cruisers. The Navy planned a number of follow-on projects, but none, except the Regulus II, flew.

In the 1950s, the Air Force also worked with two other categories of missiles in the cruise missile family: decoy and standoff missiles. Together these represent an increasingly important additional theme in the cruise missile story, and a radical departure from previous concepts; these missiles were to aid, not replace, the bomber. In the 1950s, USAF planned to deploy a family of decoy missiles to deceive enemy air defenses. Three were tested but only the Quail went into service. However, the Quail's size and weight cut the bomber's range, speed, and weapons load while newer radar systems seriously diminished its effectiveness. By 1970, the Air Force considered the Quail obsolete. During this same period, USAF tested two standoff cruise weapons, and put the North American Hound Dog into service. It gave the B-52 a standoff capability, but the Hound Dog's weight and drag cut the bomber's performance; and the missile's reliability and accuracy proved marginal.

Therefore, the American military made numerous efforts with winged missiles during the quarter century following World War II, albeit with only meager success. Because of the cruise missile's inherent technical limitations (inaccurate and unreliable operation), more effective weapons pushed aside winged missiles. The promise of cruise missiles seemed illusionary, their problems insurmountable, and their value limited. So it seemed in 1970.

At this time, two technological breakthroughs transformed the cruise missile. The first of these came in the area of guidance. Rapid technological advances not only greatly reduced the size, weight, and cost of computers, but also dramatically increased computer capabilities. Coupled with satellite mapping, these computer developments permitted the emergence of a small, practically autonomous, reliable, long-range, and highly accurate guidance system called TERCOM. The computer also enabled the vehicle to fly very, very low, making it difficult to detect and destroy.

The second major technical development came in the area of propulsion. The small, efficient turbofan jet engine allowed use of a smaller airframe. Small is beautiful, for the less weight, volume, and drag, the less power and fuel required. This smaller size also reduced radar cross section (RCS) and costs, and increased both the number of weapons that could be carried aboard aircraft or submarines and the relative ease with which the land-launched version could be handled and concealed. Development of high density fuels and miniaturized warheads also assisted in this shrinking process. So, at the same time the missile's size dramatically decreased, its capabilities markedly increased.

While these technologies coalesced, events in Southeast Asia laid the groundwork for the emergence of the present cruise missile. The success of RPVs

(remotely piloted vehicles) in the Vietnam War indicated the promise of small, unmanned, low-flying air vehicles against intense and advanced air defenses.

Concurrently, USAF required a replacement for both its bomber decoy and standoff missiles. To fill this first need, the Air Force developed the SCAD (subsonic cruise armed decoy), the first cruise missile based upon the new technologies. Although intended by different groups for different ends, SCAD emerged with remarkable performance and offered great potential for the future. Small enough to fit into the B-52's SRAM launcher and yet fly 800 nm at low levels, the missile could either deliver a nuclear warhead with astonishing accuracy or confuse enemy air defenses.

Meanwhile the Navy's cruise missile emerged from its surface-to-surface anti-ship missile program, the Harpoon. When coupled with the new technologies, SLCM too had nothing short of spectacular performance. Therefore, a long-range, very accurate missile, flying low, and small enough to baffle air defenses, could be based on and fired from essentially invulnerable nuclear submarines.

But while the engineers basically solved the device's technical problems in the early 1970s, political consideration became increasingly important. Some in the military opposed the new weapon. Resistance to the cruise missile centered around aviators, both in USAF and USN. Air Force flyers saw the ALCM at worst as a bomber replacement, at best an unneeded bomber aid. On balance, the airmen perceived the cruise missile more as a menace to the B-1 than as a helpful bomber decoy or standoff weapon. At the same time, naval aviators, primarily those aboard carriers, viewed the cruise missile as unnecessary. Some in the military were, of course, for the weapon; however, its most vocal and influential support came from civilians within the Department of Defense. Additional support for the missile came from others within the Executive Branch, who saw it as a bargaining chip for SALT (Strategic Arms Limitation Talks), and Congress, intrigued by the potential cost savings.

Technical progress continued after the redirection of the program in 1973. The Navy picked General Dynamics to build their missile, while the Air Force stayed with Boeing, the manufacturer of SCAD. In 1976, both services first flew and began testing their missiles.

Subsequently, a crucial event in the development of the cruise missile was a Defense System Acquisition Review Council (DSARC) meeting held on 6 January 1977. The council recommended full-scale engineering development of the ALCM and SLCM under the management of the Joint Cruise Missiles Project Office (JCMPO) established under the leadership of the Navy. The Air Force would emphasize the long-range missile version while the Navy would emphasize both the anti-ship and nuclear versions of the Tomahawk. Finally, DSARC recommended development of a GLCM derived from the Navy's Tomahawk.

Another major influence on the missile's progress was the arms limitation talks. Initially, the negotiators thought little of the cruise missile and did not include it in SALT I. Gradually, however, they realized the missile's importance. By 1973, the United States regarded the missile useful for domestic and foreign political

purposes; and within two years the Russians also paid it attention. The SALT II treaty and protocol, agreements signed in June 1979, banned deployment of the GLCM and SLCM, and restricted the ALCM. While the treaty has not been ratified, both parties are adhering to its terms.

Besides signing SALT II, President Carter cancelled the B-1 bomber. The President's decision in June 1977 increased the importance of the cruise missile, for ALCM now became the means by which the United States would maintain the viability of the aging B-52s and the air-breathing leg of the Triad. Hence over the short run, the various versions of the cruise missile will be the major new technology to modernize the American military.

In the early 1980s, the cruise missile went into service. The first Air Force squadron became operational with ALCMs in December 1982. The Air Force considered a variety of aircraft as the carrier of the ALCM, but chose the B-52 and the B-1. This decision and the adoption of the extended-range ALCM (AGM-86B), which is not compatible with the B-52's SRAM launcher, means that both bombers must be considerably modified. Initially, USAF will fit 12 ALCMs externally on B-52s modified with improved offensive avionics systems. Once USAF configures most of the B-52G and H fleet, it will install eight more ALCMs in an internally mounted rotary launcher. The concept of operation with 12 missiles is to shoot and then penetrate; with the 20 ALCM load, it is to strictly standoff and shoot. Later, the Navy fitted the modernized battleship USS *New Jersey* with the first of its planned complement of SLCMs.

A recent and important event to impact upon the cruise missile program was the Navy's release in August 1982 of Admiral Locke, the only Director of the JCMPO and whose connection with the cruise missile program spanned over 10 years. While the Navy maintains that the move logically followed the missile evolution from development and testing into production, the press emphasized problems with both the Tomahawk's reliability and General Dynamics' quality control. But more important than why the Navy made this personnel change is what will result. What happens to the cruise missile, the joint program, and to the concepts of commonality and second-sourcing remain to be seen.

While there are clear military reasons for deploying the family of cruise missiles, there is also a strong, if not predominant, political element involved as well. Cruise missile deployment permits rapid expansion of US nuclear weapons and forcefully demonstrates American will to friend and foe alike. Moreover, missile deployment also seems to involve an element of technological determinism—taking advantage of a technological lead.

Rationale for deployment differs for the cruise missile variants. The ALCM will enhance the air-breathing threat. The reasons for the MRASM are about as simple—to increase the conventional capability of western aircraft. But the reasons for the GLCM are not quite as easy to follow. They include political symbolism, releasing dual purpose aircraft for other tasks, and improving theater nuclear capabilities. Probably the most complex and changing rationale involves the SLCM. The emphasis on SLCM has now shifted to about equal attention to anti-

ship and nuclear versions, the latter justified as a secure strategic reserve force.

The US military continues to plan improvements in the cruise missile. The ALCM "C" (AGM-86C) will have an improved engine and perhaps active and passive defense devices. Later, this new engine will be fitted in both the GLCM and SLCM. More advanced cruise missile designs are also on the drawing boards. New types of engines and fuels promise greater power and less fuel consumption. Stealth technology will decrease the cruise missile's visibility and diminish the enemy's chance of detecting, engaging, and destroying it. Improved computers will increase accuracy and permit lower flying; and they may allow evasive maneuvers. Present trends indicate that the cruise missile will maintain its lead over the enemy's air defense, thereby presenting a relatively cheap weapon that can foil much more expensive enemy defenses. In short, the cruise missile is a cost-effective weapon now and for the foreseeable future.

Having reviewed the evolution of the cruise missile, we have now arrived at the time of reckoning. What are the explicit answers to the research questions posed at the onset?

Question: What has changed and what has remained constant between the earlier and current versions of the cruise missile?

Answer: While at first glance today's cruise missile resembles its predecessor, close examination reveals significant technical improvements. In one sense, the cruise missile is like its ancestors, a miniature aircraft: it has the same type of power plant and the same basic airframe as contemporary aircraft. But while inaccurate and unreliable operations hobbled its predecessors for 50 years, today's cruise missile is fundamentally different. Advances in computers, the evolution of the TERCOM and terrain-following systems, and the development of small and efficient jet engines as well as small nuclear warheads, give the weapon radically increased capabilities. These developments enable the present cruise missile to fly very far, very low, and very accurately. This marks the difference between the aerial torpedo/flying bomb of yesterday and the cruise missile of today.

Question: What advantages and disadvantages are inherent to cruise missiles as a class of weapons?

Answer: The cruise missile attracted the attention of the military for a number of reasons. Built for a one-time, one-way trip with no crew, the missile was relatively cheap to build and operate. It could be used in large numbers, thereby increasing the likelihood of successful penetration of enemy defenses; and it could be employed in the most hazardous of conditions since man was not put at risk. In addition, because there was no crew to be inhibited by psychological factors, the weapon could only be defeated by direct intervention. Certainly the missile's small size and crewless flight made it less vulnerable than a manned aircraft.

Conversely, the cruise missile also has a common list of disadvantages

throughout its history. Taking man out of the machine had a number of important consequences. First, if anything went wrong, nothing could correct the situation. Another result of removing man from the machine was that, once launched, the missile followed its program and nothing more. And because it lacked both flexibility and real time reaction capability, the cruise missile could be defended against, and could be defeated.

Nevertheless, today's cruise missile offers a number of important and obvious advantages over other weapons. Militarily, it offers excellent (if not unparalleled) accuracy and a high probability of penetration. Also significant is the variety of launch platforms available to the cruise missile, enhancing both flexibility and survivability. Because of its high mobility, low cost, and high accuracy, the cruise missile has potential to supplant today's more costly and less accurate fixed ICBMs. At the same time, the cruise missile's low cost, high accuracy, ubiquitous platforms, small size, and low flying ability challenge the manned penetrating bomber. At the very least, the ALCM will be very important to preserving the air-breathing leg of the Triad. The relatively low cost permits many cruise missiles to be deployed. Finally, the cruise missile has the potential of staying ahead of air defenses. And it is a threat which will cost enemy defenders many times what it will cost the United States. While other weapons equal or out-perform the cruise missile in some areas, the cruise missile combines these advantages.

The cruise missile also offers a number of distinct political advantages. Its newness demonstrates continuing American technical superiority. Cruise missile deployment shows US will to both foes and allies, and should help assuage domestic political groups demanding a rapid and massive arms buildup. If need be, the cruise missile can be bargained against weapons the United States considers most dangerous to its security. At the same time, it is not inherently a first strike weapon; and because it is not a first strike weapon, it is not destabilizing as are ballistic missiles.

Question: Why were cruise missiles not successfully introduced on a large scale into military inventories before? What obstacles has the weapon encountered?

Answer: Throughout its development, technical problems have hindered the cruise missile. This resulted, in part, because designers did not sufficiently recognize the impact of removing man from the machine, especially the crew's ability to respond to unforeseen problems, to correct them immediately, and to report back the results. Neither guidance nor reliability received adequate attention. In short, the developers just did not do their homework patiently and systematically in designing, testing, and then integrating the required components. Therefore, the cruise missile could not deliver on its promise because of technical failings and could not compete with other strategic weapons. In the one large-scale use of the cruise missiles in combat, the V-1 failed as a militarily effective weapon. Similarly, American cruise missiles developed between 1945 and 1970 left much to

be desired. The record of American missiles range from disastrous (Navaho), to failures (Snark), to mediocre (Matador, Mace, and Regulus), to helpful (Hound Dog and Quail). In brief, aircraft and ballistic missiles could deliver more ordnance, more accurately, more reliably than could the cruise missile.

In general, the development of the cruise missile has been a sideshow. That is, a small group of military men, an individual, or a company have pushed it, but, with the exception of the Snark and Navaho in the early 1950s, until recently cruise missiles have never had massive national support similar to that received by ballistic missiles and bombers. While some within the military enthusiastically championed the weapon, the services as a whole never have.

Until recently, the cruise missile's sorry record certainly justified skepticism. The military repeatedly tried the device over a long period of time, but it never delivered on its promise; instead, the cruise missile proved unreliable and inaccurate. Technological breakthroughs in the late 1960s, however, seem to have overcome most of the weapon's technical difficulties.

Unfortunately, military attitudes have not changed. If anything, they seem to have hardened as the improved missile threatened existing force structures. As a result, today's problems with the cruise missile are more in the arena of politics (numbers, costs, and modes of deployment) than in the area of technology. The Air Force's reaction to the ALCM in the 1970s is a classic, if tragic, example of service parochialism. Indeed, the services can take little credit for fostering the cruise missile's recent development. If anything, the machine developed in spite of their opposition or apathy. More recently, the staunchest supporters of the missile were civilians within the Department of Defense.

Question: Overall, what lessons can be gleaned from the historical record of the cruise missile? What are the useful parallels?

Answer: It would appear that there are at least five. First, although the cruise missile looks like a miniature aircraft, may perform somewhat like one, and has often been treated like one, it is, in fact, quite different. The obvious, basic, and key difference between aircraft and winged missiles is man. The military must recognize from the outset that the cruise missile is not just a small aircraft, and that taking man out of the machine makes a considerable impact upon both the positive and negative sides of the ledger. To get the most out of the weapon, and at the same time not overestimate its potential, this fact must be fully appreciated by all hands from the design phase all the way through deployment of the missile. In other words, the cruise missile requires different handling than aircraft.

Second, the cruise missile possessed a number of basic characeristics throughout its history.* Its principal advantages continue to be its relative cheapness, compared with aircraft, and the fact that it operates without putting man at risk. At the same time, its main disadvantages also stem from taking man out of the loop: inflexibility, unreliability, and inaccuracy.

*See Air War College Survey, Appendix B, on the issue of advantages and disadvantages.

Third, it must be emphasized and reemphasized that the technology which emerged in the late 1960s radically improved the capabilities of the cruise missile, giving the present day missile performance superior to its predecessor. Its small RCS and low-flying ability ensure that the cruise missile has a high probability of successfully penetrating enemy defenses. Moreover, its small size enables it to be stored in numbers and launched from a wide variety of platforms. Another key attribute is the missile's high accuracy. In sum, these enhanced and new capabilities make the new cruise missile quite different, and far better, than its predecessors.

Fourth, the cruise missile case illustrates the difficulty of incorporating new technology into military force structures. The missile story tells, in almost classic fashion, how domestic and foreign politics, including complications introduced by interservice and intraservice rivalry, can influence the introduction and deployment of a new weapon.

Fifth, the historical record indicates that weapons must be rationally assessed or there will be problems. Novelty by itself is not an adequate reason to deploy a weapon. The examples of the V-1 and Snark illustrate missiles put into service well before they were ready. Prior to 1970, the cruise missile was hampered more by technological shortcomings than by policy or political considerations; since then, an influential number of individuals within the military have retained their negative attitudes while the machine has considerably improved. The cruise missile should be judged strictly on its merits—what it can do for national defense, not what it might do to individuals' careers, services' missions, or contractors' profits.

Question: Finally, how important is the cruise missile? Is the cruise missile just another weapon like so many others, or does it represent a revolutionary class of weapon?*

Answer: If the estimates of today are close to the realities of tomorrow, the cruise missile will be very important to the future of US security over the short run. In shoring up the air-breathing leg of the Triad and increasing US capabilities vis-a-vis the Soviets, the cruise missile will help close the much talked about "window of vulnerability" if, in fact, such a vulnerability exists.

The influence of the cruise missile may be even greater over the long run, since the missile has great potential for growth. By making use of advanced technology such as computers, electronics, and small jet engines, the cruise missile represents the cutting edge of new and better technologies. Greater flying performance will result as new engines and new fuels are used. As engineers mate stealth technology, ECM (electronic countermeasures), and real time reactive capabilities to the machine, its detectability and vulnerability will decrease, thereby improving military performance and putting greater stress on the defense. Other new technologies will surely emerge and, in turn, will be added to the missile, further increasing its already considerable capabilities.

*See Air War College Cruise Missile Survey, Appendix B, on the issue of the cruise missile as a revolutionary weapon.

As a result of these developments, there remains the distinct possibility that the penetrating bomber will be supplanted as a primary strategic delivery system.* Improving enemy defenses make successful penetration increasingly difficult for all but the most sophisticated bombers. At the same time, the rapidly escalating costs of such aircraft compared with the costs and military effectiveness of ballistic and cruise missiles raises serious questions about the cost effectiveness of the penetrating bomber. At some point in the future, the penetrating bomber may well be assigned to a standoff role, penetrating only in follow-on missions (after the initial nuclear exchange) when the manned bomber's flexibility and real time reaction are needed and enemy defenses are degraded. So there has been a shifting in roles over time; the cruise missile which, at one point, was strictly an aid to the bomber, may now become the bomber's chief weapon. The overall result will be a more capable and credible bomber force.

The cruise missile also promises to be a carrier of conventional ordnance. Since the machine has the capabilities, the significant question is simply one of cost: can the price of the device be lowered sufficiently so that a large number of the missiles can be put into service? If so, the impact could be very important, and possibly decisive, in a battle in western Europe. For in the first days of an intense war there, NATO forces will require large numbers of air strikes to survive. Such airpower could be provided, at least in part, by large numbers of highly accurate cruise missiles. This mode of operation would conserve aircraft for later use when enemy air defenses are dislocated, enemy forces are more vulnerable, and maximum use can be made of the aircraft's advantages.

Another area of great promise in conventional operations is the use of the cruise missile as an RPV. Coupling the aerial performance of the cruise missile with real time direction will greatly enhance the missile's military impact. And if the machine could be recovered, then the all-important question of cost could probably be satisfactorily answered.

Therefore, the prospects are that the cruise missile will play an important role in American defense over both the short and long run, and its impact on western and American military establishments will be major. But since the missile performs roles now primarily handled by the Air Force, the impact on that service will be much greater than that on any other. If the cruise missile eclipses the ICBM and penetrating bomber as a primary strategic weapon, and if in the first days of a major war the tactical aviation needs of the military are met largely by the cruise missile, then that device will have a revolutionary impact on the Air Force.

But to play such a role, the cruise missile must prove itself so as to convince both military and civilian leadership of its value. The cruise missile must demonstrate that it can do the job not just as well, but better than alternative weapons. It must deliver on its promise and live up to its press. The military must rationally assess the cruise missile's worth, then accommodate the new weapon, adjusting both its organization and strategy to make best use of the missile's advantages.

*See Air War College Survey, Appendix B.

Just as the military must properly assess the cruise missile, so must the politicians. Civilian leaders must avoid the temptations of bartering the weapon away for illusionary gains in arms limitations agreements, and of saving money by not adequately funding it. This is not to say that the cruise missile should be blindly built and protected, but that the device must be carefully assessed for what it can do for national defense either as a deployed weapon or as a bargaining counter.

Having written a number of things that will certainly startle, upset, or irritate many readers, I wish to make sure that these conclusions are put into the proper perspective. All of these speculations are based upon the assumption that the cruise missile will approach its potential; that is, there will be no major political or technical obstacles to prevent the cruise missile from achieving its promise.

The last note is one of optimism. The cruise missile is a weapon with great potential for western defense. But to realize its potential, it must be properly appreciated and skillfully handled. Those responsible or interested in national defense must keep in mind that knowledge is the first step on the way to understanding which, in turn, must come before adequate plans and decisions can be made. One of the challenges the western defense establishment, especially the United States, must meet in the 1980s and beyond is to know and to understand cruise missiles so as to make optimum use of them. Hopefully, this study will assist decisionmakers, planners, and operators to successfully meet this challenge.

APPENDIX A

SPECIFICATIONS OF VARIOUS CRUISE MISSILES

Name/ Company Designation	*Span (Ft)*	*Length (Ft)*	*Launch Weight (Lb)*	*Payload (Lb)*	*Powerplant*	*HP*	*First Successful Flight*	*Remarks*
Navy-Sperry	25	15		1,000	OX-5	100	March 1918	90 mph
Kettering Bug	15	12.5	525	180		35–45	October 1918	120 mph
Royal Aeronautical Establishment 1921 Target	23	18	630	200		45	September 1924	103 mph
RAE Larynx	19.8	14.6	1,200-1,400		Lynx IV	200	September 1927	200 mph
General Motors A-1 Bug	21.1	16.3	1,400	500		200	December 1941	200 mph/400 mi
Fleetwings XBQ-1	48.6		7,698	2,000	Franklin	2x225	May 1944	225 mph/1,717 mi
Fleetwings XBQ-2A	48.6		7,700	2,000	R-680	2x280		Same as XBQ-1 except different engine and jettisonable landing gear
Fairchild XBQ-3	52.8	31	15,300	4,000	V-770	2x450	July 1944	Converted AT-21 220 mph/1,500 mi
Interstate XBQ-4 (USN TDR-1)	48		5,916	1,950	0-435	2x220		140 mph/425 mi
						(Thrust-Lb)		
Fieseler V-1	16.4	25.4	4,762	1,830	Argus	860	December 1942	373 mph/146 mi
(US V-1) JB-2	17.7	23.6	5,021	2,100	PJ-31-1	850–900	October 1944	350–425 mph/150 mi
Northrop JB-1A	29.2	11.8	7,213	3,630	2 x B-1	400	April 1945	400 mph/200 mi
Northrop JB-10	28.3	10.5	7,080	4,000	PJ-31-1	850–900		

APPENDIX A CONTINUED

Name/ Company Designation	*Span (Ft)*	*Length (Ft)*	*Launch Weight (Lb)*	*Payload (Lb)*	*Powerplant*	*Thrust (Lb)*	*First Successful Flight*	*Remarks*
Northrop Snark N-25	42.5	51.9	28,000		J33		April 1951	Mach .85/1,500 mi
Northrop Snark N-69A	42.3	69.9	49,603	6,230	J57	10,500	June 1954	561 mph at Target; 5,200 mi; Booster weighed 11,365 Lb and produced 134,000 Lb thrust
Northrop Snark N-69E	42.2	67.2	49,000	7,000	J57	9,500	August 1957	524 mph at Target 5,500 mi
North American XMS-64 Navaho	40.2	87.3	120,500	7,000	2xRJ47	20,070	March 1957	Booster weighed 169,500 Lb, produced 415,000 Lb thrust
Martin Matador TM-61A	28.6	39.7	11,550	3,000	J33	4,600	March 1949	620 mi
Martin Mace TM-61B (TM-76)	28.6	46.8	18,750	3,000	J33	5,200	1956	540 mi Low altitude, 1,288 mi High altitude
Chance Vought Regulus	21	33	14,522		J33	4,600	March 1951	600 mph/600 mi
Chance Vought Regulus II	20	67.2	22,564	2,920	J79 (Afterburner, 15,000)	9,600	November 1957	Mach 2/800 nm
Radioplane Cross Bow XGAM-67	12.6	19.1	2,700	1,000	YJ69	1,000	March 1956	Mach .9 at Target; 247 nm
North American Hound Dog AGM-28B	12.2	42.5	10,147	1,742	J52	7,500	April 1959	Mach 2/674 nm
Fairchild Bull Goose XSM-73	24.4	33.5	7,700	500	J83	2,450	June 1957	Mach .85/4,773 nm
Consolidated Vultee Buck Duck XGAM-71	14	13	1,550	0	XLR-85	90	1955	Mach .55/200 nm
McDonnell Green Quail XGAM-72 (ADM-20A)	5.3	12.9	1,006	100	J85	2,450	August 1958	Mach .95/445 nm
McDonnell Quail ADM-20B	5.4	12.9	1,198	94	J85	2,450	March 1960	Mach .95/347 nm

APPENDIX B

DISCUSSION OF AIR WAR COLLEGE CRUISE MISSILE SURVEY

In the spring of 1982, the author distributed a survey on the cruise missile to a selected sample of one-third of the USAF students in the Air War College class of 1982. Of the 60 surveys distributed, 49 were returned and used. The two-part survey included an eight-question quiz and a number of questions relating to attitudes and opinions on the cruise missile and other weapon systems.*

The level of knowledge shown by the group on the first part was not high. Over two-thirds of the respondents (34/49) missed four or more of the multiple choice questions.

On the attitude/opinion part of the survey, the consensus was that the most important reasons why the US was building the cruise missile were, first, to add to America's military capabilities and, second, to aid the penetrating bomber. These were considered more important than political considerations. One set of questions asked the respondents to rate six current US weapons systems** in order of their importance in three time frames. The respondents believed that, of these new weapons, the cruise missile will be fairly important in the short run (second to the Trident-SLBM), but then decline in relative importance. The next question asked was what were the most positive attributes of the cruise missile. High accuracy was ranked most important, with small radar cross section (RCS) listed second. As to what were the most negative attributes of the weapon, the respondents noted the missile's long time to the target and that it had no recall capability. The entire group was then asked what might prevent the cruise missile from being deployed. The factors rated highest were arms limitation agreements and political action by the president or Congress. A series of questions followed regarding the relative value of various versions of the cruise missile (ALCM, GLCM, MRASM, and SLCM) in three time frames. The group's rank order of their importance was ALCM, GLCM, SLCM, and MRASM, with the first two declining in importance over time, while the last two increased in importance. The next question asked: "In your opinion, can the cruise missile replace the manned penetrating strategic bomber?" Of those who answered this question, 14.8 percent responded yes, 23.4 percent responded maybe, and 61.7 percent answered no. The last question asked what impact the cruise missile will have on the USAF. While the majority (53.1 percent) thought it

*See Appendix C for the questionnaire and the overall responses.

**The six systems were the B-1B, cruise missile, MX missile, space systems, stealth bomber, and Trident-SLBM.

would have considerable impact (similar to the MIRV), 28.6 percent believed it would have a major impact (similar to the ballistic missile), and 18.4 percent said it would have only a minor impact (similar to weapons such as the SRAM and Hound Dog).

The survey results were then cross-tabulated in a variety of ways.* First, those who missed the fewest questions on the eight question quiz (15 missed three or less questions) were compared with those who missed the most (14 missed five or more questions). The second cross-tabulation compared those 34 respondents who had no official contact with the cruise missile with the 15 who stated they had anywhere from slight to considerable official contact with it. The third series of cross-tabulations compared the responses of the 26 rated respondents with those of the 22 non-rated ones. The final cross-tabulation compared the responses of the 18 respondents who answered that the cruise missile could or might be able to replace the bomber, with the 29 who answered negative to that question.

What impact did knowledge, or at least command of testable facts, have on opinions and attitudes? Those respondents who had no contact with the cruise missile and those who were rated (pilots or navigators), tended to miss more questions than those who had some contact with the weapon and those who were non-rated. The group that did best on the quiz rated the cruise missile as a weapons system about the same as did the less successful group. There were few differences between the two groups on each cruise missile variant. The informed group rated ALCM, GLCM, and SLCM about the same as did the less informed group, but rated MRASM higher in the period 1987–97. Finally, the better informed group was more likely to believe that the cruise missile could replace the bomber and that it would have a major impact on the USAF than did the less informed group.

Similar to the better informed group, the group with contact valued the cruise missile as a weapons system about the same as did the entire sample. As to the value of the four cruise missile variants over these three time frames, the group with contact put a lower value on MRASM in the period 1982–87, and rated SLCM lower for the period 1982–92 than did the group without contact. The rest of the time, the group with contact put about the same value on the variants as did the other group. The group with contact was more likely to believe the cruise missile could replace the penetrating bomber.

The survey does not indicate resistance by rated officers to cruise missiles. Rated respondents ranked the cruise missile as a weapons system the same as did non-rated respondents over the entire period. The rated group also ranked the cruise missile variants the same as the non-rated group, except for the GLCM which they rated lower for the period 1992–97. Yet the flyers answered yes or maybe to the question of whether the cruise missile could replace the bomber only slightly less (33 percent) than did the non-flyers (41 percent), and the entire group (38 percent).

The subgroups which might be expected to show the widest difference of opinion were those who believed the cruise missile either could, or perhaps could, replace the bomber and those who believed it could not. But the results refute the

*See D for breakdown of the cross tabulation.

expectations; that is, the group that answered yes or maybe to this question thought the same of the cruise missile, as a generic type, as did the group that answered no. However, the group that answered yes or maybe thought less of the ALCM (1982–87, 1992–97) and GLCM (1982–87) variants than did the group which answered no. The two groups ranked all other variants and all other time frames the same. The two groups put the impact of the cruise missile on the USAF at about the same level.

Like most survey efforts, there is both more and less here than meets the eye. There is possibly more that could be ferreted out both by a survey more detailed in content and one distributed over a broader population. In other words, more and improved research may be justified. Putting guesses and opinions, whether educated or not, through a computer may tell us something about the respondents; but it tells little about the subject.

APPENDIX C

CRUISE MISSILE SURVEY
AIRPOWER RESEARCH INSTITUTE
AIR WAR COLLEGE

The Airpower Research Institute is chartered to study major issues confronting the USAF now and in the future. One research project currently underway concerns the cruise missile. While this study is intended to reach a wide audience, two key groups are commanders and planners, groups with which you have already been, or soon will be, a part. This survey is probing for information on: (1) how well AWC students are informed about the cruise missile, (2) what value they place on the cruise missile and why, and (3) what future they see for cruise missiles.

Instructions

This survey is divided into two parts. Part I deals with your knowledge of the cruise missile and is mainly factual. Part II asks you to rate various aspects of the cruise missile and is mainly opinion.

The term "cruise missile" is used in a generic sense referring to all versions of the weapon (i.e.; ALCM, GLCM, MRASM, and SLCM).

The term "military value" refers to both deterrence and to war-fighting capabilities, conventional and nuclear.

After you have completed the 24 items, you are encouraged to add any comments as to the context or structure of this survey. These comments will be read and appreciated.

As with other surveys you have completed here, your identity will be protected.

Please circle your responses.

Please return the completed form to the evaluation drop box no later than 1700 7 May.

NOTE: This is the actual questionnaire used, except that the added numbers in the left margin for questions 1–11 and 22–24 are frequencies, for questions 12–21 the average score for the entire group.

Biographical Information

1. Have you had direct official experience with cruise missiles?

34	a.	none
9	b.	slight (infrequent contact)
4	c.	some (occasional contact)
2	d.	considerable (direct duty for 1½ years or less)
0	e.	great (direct duty for 1½ years or more)

2. Are you rated or non-rated?

24	a.	pilot
2	b.	navigator
22	c.	non-rated
1		[missing]

Part I

3. How well informed do you believe you are on the subject of cruise missiles relative to others in your class?

1	a.	way below
7	b.	below average
34	c.	average
5	d.	above average
1	e.	way above
1		[missing]

4. What type engine will power the cruise missile?

11	a.	ram jet
3	b.	rocket
21	c.	turbofan*
12	d.	turbojet
2		[missing]

5. The ALCM, GLCM, and SLCM share the same:

7	a.	airframe

*Correct answer

1	b.	booster
19	c.	engine*
9	d.	all of the above
9	e.	none of the above
4		[missing]

6. The cruise missile uses what kind of guidance system?

2	a.	inertial only
34	b.	inertial plus TERCOM*
1	c.	inertial plus stellar
9	d.	TERCOM only
1	e.	none of the above
2		[missing]

7. The first version of the cruise missile to become operational is the:

41	a.	ALCM*
6	b.	GLCM
0	c.	MRASM
0	d.	SLCM
2		[missing]

8. What company is building the GLCM airframe?

25	a.	Boeing
16	b.	General Dynamics*
1	c.	McDonnell-Douglas
4	d.	North American
3		[missing]

9. What company is building the SLCM engine?

10	a.	Garrett
13	b.	General Electric
9	c.	Teledyne
3	d.	Westinghouse
8	e.	Williams*
6		[missing]

10. What is the range of the ALCM?

4	a.	800nm
4	b.	1,000nm

*Correct answer

36	c.	1,500nm*
0	d.	2,000nm
3	e.	2,500nm
2		[missing]

11. How many missiles will the B-52 *INITIALLY* carry?

5	a.	6
14	b.	8
20	c.	12*
2	d.	16
7	e.	20
1		[missing]

Part II

***Rate* the following items by assigning a value to each. More than one item may be assigned the same value.**

The values are arranged from the lowest (or most negative) on the left, to the highest or most positive on the right.

These are opinion questions.

12. Please *RATE* the importance of each of these reasons for building cruise missiles today, using the following:
1. no importance 2. low 3. some 4. high 5. highest.

3.71	a.	bargaining chip	1. 2. 3. 4. 5.
4.43	b.	add new military capabilities	1. 2. 3. 4. 5.
3.88	c.	political signal to the Soviets	1. 2. 3. 4. 5.
4.04	d.	aid the penetrating bomber	1. 2. 3. 4. 5.
3.65	e.	force Soviet defence spending	1. 2. 3. 4. 5.
3.20	f.	increase the number of warheads	1. 2. 3. 4. 5.

13. Please *RATE* the systems identified below in your view of their order of military value for the period *1982–87* using the following:
1. no value 2. little value 3. some value 4. high value 5. highest value

3.61	a.	B-1B	1. 2. 3. 4. 5.
4.22	b.	cruise missile	1. 2. 3. 4. 5.
3.43	c.	MX	1. 2. 3. 4. 5.
3.18	d.	space systems	1. 2. 3. 4. 5.

*Correct answer

2.69	e.	stealth bomber	1. 2. 3. 4. 5.
4.47	f.	Trident/SLBM	1. 2. 3. 4. 5.

14. Please *RATE* the systems identified below in your view of their order of military value for the period *1987–92* using the following:
1. no value 2. little value 3. some value 4. high value 5. highest value

4.00	a.	B-1B	1. 2. 3. 4. 5.
4.21	b.	cruise missile	1. 2. 3. 4. 5.
4.18	c.	MX	1. 2. 3. 4. 5.
4.18	d.	space systems	1. 2. 3. 4. 5.
3.60	e.	stealth bomber	1. 2. 3. 4. 5.
4.38	f.	Trident/SLBM	1. 2. 3. 4. 5.

15. Please *RATE* the systems identified below in your view of their order of military value for the period *1992–97* using the following:
1. no value 2. little value 3. some value 4. high value 5. highest value

3.55	a.	B-1B	1. 2. 3. 4. 5.
3.92	b.	cruise missile	1. 2. 3. 4. 5.
4.19	c.	MX	1. 2. 3. 4. 5.
4.63	d.	space systems	1. 2. 3. 4. 5.
4.18	e.	stealth bomber	1. 2. 3. 4. 5.
4.15	f.	Trident/SLBM	1. 2. 3. 4. 5.

16. The following are considered positive attributes of the cruise missile. Please *RATE* each of these attributes in your view of their order of contribution to the cruise missile's effectiveness using the following:
1. no value 2. little value 3. some value 4. high value 5. highest value

3.73	a.	low cost (more affordable)	1. 2. 3. 4. 5.
3.92	b.	small size (carry more, conceal easier)	1. 2. 3. 4. 5.
4.31	c.	small radar cross section (less vulnerable)	1. 2. 3. 4. 5.
4.54	d.	high accuracy (military effectiveness)	1. 2. 3. 4. 5.
3.67	e.	no man at risk (military effectiveness)	1. 2. 3. 4. 5.
4.06	f.	low altitude (less vulnerable)	1. 2. 3. 4. 5.

17. The following are considered negative attributes of the cruise missile. Please *RATE* how negative using the following scale:
1. Most negative 2. 3. 4. 5. Least negative

3.64	a.	vulnerability	1. 2. 3. 4. 5.
2.87	b.	no recall capability	1. 2. 3. 4. 5.
2.75	c.	long time to target	1. 2. 3. 4. 5.

3.02	d.	inflexibility (no man in the loop)	1. 2. 3. 4. 5.
2.98	e.	no post-strike target information	1. 2. 3. 4. 5.
3.54	f.	unreliability	1. 2. 3. 4. 5.

18. Please *RATE* how likely the problems identified below will prevent the successful deployment of the cruise missile? For rating use the following:
1. not likely 2. little 3. somewhat 4. very 5. most likely

2.71	a.	cost overruns	1. 2. 3. 4. 5.
2.54	b.	unreliability	1. 2. 3. 4. 5.
3.44	c.	arms limitations agreements	1. 2. 3. 4. 5.
2.73	d.	failure to meet performance goals	1. 2. 3. 4. 5.
3.33	e.	political (congress or president)	1. 2. 3. 4. 5.
2.67	f.	competition with other weapons	1. 2. 3. 4. 5.

19. Please *RATE* the military value the specific cruise missiles will have in *1982–87* using the following:
1. no value 2. little value 3. some value 4. great value 5. greatest value

4.32	a.	ALCM	1. 2. 3. 4. 5.
4.09	b.	GLCM	1. 2. 3. 4. 5.
2.98	c.	MRASM	1. 2. 3. 4. 5.
3.67	d.	SLCM	1. 2. 3. 4. 5.

20. Please *RATE* the military value the specific cruise missiles will have in *1987–92* using the following:
1. no value 2. little value 3. some value 4. great value 5. greatest value

4.25	a.	ALCM	1. 2. 3. 4. 5.
4.15	b.	GLCM	1. 2. 3. 4. 5.
3.42	c.	MRASM	1. 2. 3. 4. 5.
3.90	d.	SLCM	1. 2. 3. 4. 5.

21. Please *RATE* the military value the specific cruise missiles will have in *1992–97* using the following:
1. no value 2. little value 3. some value 4. great value 5. greatest value

3.94	a.	ALCM	1. 2. 3. 4. 5.
3.90	b.	GLCM	1. 2. 3. 4. 5.
3.43	c.	MRASM	1. 2. 3. 4. 5.
3.88	d.	SLCM	1. 2. 3. 4. 5.

22. How should the ALCM primarily be used?

35 a. standoff

11	b.	shoot then penetrate
2	c.	suppress enemy defenses
0	d.	none of the above
1		[missing]

23. In your opinion, can the cruise missile replace the manned, penetrating, strategic bomber?

7	a.	yes
11	b.	maybe
29	c.	no
2	d.	cannot tell at this time

24. What impact do you think the cruise missile will have on the USAF?

0	a.	revolutionary (change the entire way of thinking)
14	b.	major (similar to the ballistic missile)
26	c.	considerable (similar to the MIRV)
9	d.	minor (just another weapon like the Hound Dog or SRAM)
0	e.	little or none (it will not live up to its press reviews)
0	f.	none of the above

Thank you very much for your help.

You are encouraged to add any comments regarding either the content or structure of this survey.

APPENDIX D

CRUISE MISSILE SURVEY CROSS TABULATION

Questions 13–15: Rate weapon system over time (1982–87/1987–92/1992–97

	Missed fewest: Missed most	Some official contact: None	Rated: Non-rated	Replace/ Maybe replace Bomber: Not Replace
B-1B	0 0 –	0 0 0	0 0 0	– – –
Cruise Missile	0 0 0	0 0 0	0 0 0	0 0 0
MX	– – –	0 0 0	+ 0 –	0 – –
Space System	0 – 0	0 + 0	+ + 0	– 0 0
Stealth Bomber	– – 0	+ + 0	+ + 0	– – –
Trident/SLBM	0 0 0	0 0 0	0 0 +	0 0 0

Question 16: Positive Cruise Missile Attributes

	Missed fewest: Missed most	Some official contact: None	Rated: Non-rated	Replace/ Maybe replace Bomber: Not Replace
Low Cost	0	0	+	0
Small Size	0	+	0	0
Small Radar Cross Section	+	0	0	–
High Accuracy	+	–	+	0
No Man at Risk	0	0	0	0
Low Altitude	0	0	0	0

Question 17: Negative cruise missile attributes

	Missed fewest: Missed most	Some official contact: None	Rated: Non-rated	Replace/ Maybe replace Bomber: Not Replace
Vulnerability	0	–	+	0
No recall	+	0	–	+
Long time to target	–	0	0	0
Inflexibility	0	0	–	0
No post-strike information	0	0	0	+
Unreliability	+	–	+	0

Question 18: Problems likely to preclude cruise missile deployment

	Missed fewest: Missed most	Some official contact: None	Rated: Non-rated	Replace/ Maybe replace Bomber: Not Replace
Cost overruns	–	+	0	0
Unreliability	0	+	–	0
Arms agreements	0	0	0	0
Failure to meet performance goals	–	+	0	–
Political (Congress or President)	0	0	+	–
Competition with other weapons	0	0	+	0

Questions 19–21: Rank cruise missile variant over time (1982–87/1987–92 1992–97)

	Missed fewest: Missed most	Some official contact: None	Rated: Non-rated	Replace/ Maybe replace Bomber: Not Replace
ALCM	0 0 0	0 0 0	0 0 0	– 0 –
GLCM	0 0 0	0 0 0	0 0 –	– 0 0
MRASM	0 + +	– 0 0	0 0 0	0 0 0
SLCM	0 0 0	– – 0	0 0 0	0 0 0

Question 23: Will the cruise missile replace the penetrating bomber?

	Missed fewest: Missed most	Some official contact: None	Rated: Non-rated	Replace/ Maybe replace Bomber: Not Replace
Yes	2:1	4:3	2:4	
Maybe	5:2	2:9	6:5	
No	7:11	8:21	16:13	

Question 24: Impact of the cruise missile on USAF

	Missed fewest: Missed most	Some official contact: None	Rated: Non-rated	Replace/ Maybe replace Bomber: Not Replace
Major	5:1	4:10	6:8	5:9
Considerable	5:10	8:18	15:11	10:14
Minor	5:3	3:6	5:3	3:6

APPENDIX E

SNARK FLIGHT RECORD

Item	Date	Serial Number	Duration (Minutes)	Remarks
		Holloman AFB Tests - N-25		
1	21Dec50		–	Launcher failure.
2	8Mar51		–	Ground radio control failure.
3	16Apr51		38	Recovered.
4	8May51		58	Recovered.
5	24May51		–	Launcher failure.
6	26Jun51		81	Dynamic stability. Recovered.
7	17Jul51		73	Destroyed landing.
8	8Aug51		90	Stall & stability tests. Recovered.
9	21Aug51		33	Autopilot malfunction.
10	30Aug51		–	Booster misfired.
11	25Sep51		57	Erratic autopilot.
12	2Oct51		76	Lost in stall test.
13	16Oct51		38	Unintentional stall.
14	24Oct51		142	Dynamic stability tests. Recovered.
15	15Nov51		127	Dynamic stability tests. Recovered.
16	29Nov51		153	Performance & stability tests, Mach. 88, 35,000 ft. Recovered.
17	14Dec51		150	Performance tests, 1,000 miles. Recovered.
18	25Jan52		165	Airspeed calibration, stall tests. Recovered.
19	1Feb52		34	Airspeed calibration.
20	20Feb52		66	
21	28Mar52		146	Mach .97 in dive. Recovered.

Snark Flight Record (Continued)

Item	Date	Serial Number	Duration (Minutes)	Remarks
		Atlantic Missile Range		
22	29Aug52	Dynamic Model #2		1st Snark test at AFMTC. Stage 1 firing.
23	1Oct52	Dynamic Model #1		2nd test of N-73 launcher.
24	30Oct52	Dynamic Model #3		3rd zero-length launcher test.
25	26Nov52	(N-25), GM-246		1st N-25 launch from zero-length launcher.
26	19Dec52	(N-25), GM-972		2nd N-25 launch over AMR
27	6Feb53	(N-25), GM-974		Failed structurally during terminal dive.
28	10Mar53	(N-25), GM-2337		Completed Stage 1 tests.
29	6Aug53	(N-69A),GM-3391	.4	1st N-69 launched AFMTC.
30	15Oct53	(N-69A), GM-3393	4.6	Lost wings & burst into flames.
31	2Feb54	(N-69A), GM-3395 N-3270	7.7	Out of trim, pitch up, lost wings and exploded.
32	18Feb54	(N-69A), GM-3396 N-3271	.3	Dive brakes jam open. Impact 200 yds off shore.
33	26Apr54	(N-69A), GM-11111 N-3272	.2	Electrical failure, impact 3,000 ft from launcher.
34	3Jun54	(N-69A), GM-3394	211	1st attempt to skid land missile at Cape, rear skid not locked, excessive sink rate, explosion.
35	21Jul54	(N-69A), GM-3392 N-3267	168.3	Last in aerodynamic test series. Engine surge after skids extended.
36	21Sep54	(N-69B), GM-11113 N-3274	51.5	Fuel transfer system malfunction. Missile return uprange for shallow water dump.
37	12Oct54	(N-69B), GM-11114 N-3275	173	Lost telemetry at launch, became unstable after landing skids extended impacted 28 miles off shore.
38	12Nov54	(N-69B), GM-11116 N-3277	159	Carried North American guidance capsule. Stall after skids extended.
39	10Dec54	(N-69B), GM-11115 N-3276	31	Hydraulic system failure. Went out of control.
40	13Jan55	(N-69B), GM-13097 N-3278	4.9	Last of modified B type carrying N2C data recorder, engine fire.
41	10Feb55	(N-69C), GM-13106	2.3	Start of Phase II testing. 1st C model Snark, steep climb at launch, stall.

Snark Flight Record (Continued)

Item	Date	Serial Number	Duration (Minutes)	Remarks
42	6Apr55	(N-69C), GM-13107	181.8	1st terminal dive test, insufficient control effectiveness, broke up in terminal dive.
43	26Apr55	(N-69C), GM-13108 N-3289	.3	Rudder trim failure, N-69C broke up at T+15 seconds.
44	13May55	(N-69A), GM-11112 N-3273	110.3	Collided with photo plane, T-33 OK, missile crashes.
45	13Jul55	(N-69C), AF 51-17579 GM-13112, N-3293	1.1	Engine fire, impact 5 miles off shore.
46	9Aug55	(N-69C), AF 51-17580 GM-13113, N-3294	88.9	Last of unmodified N-69C missiles.
47	26Oct55	(N-69C), AF 52-1710 GM-52-10972, N-3296	69	1st N-69C with modified ballistic nose.
48	26Nov55	(N-69D), AF 52-10977 GM-52-1715, N-3301	257.5	1st unmanned flight with stellar-inertial guidance. Guidance power failure, switch to radio control. Skid off runway, fire.
49	9Dec55	(N-69C), AF 52-10973 GM-52-1711, N-3297	77	Ballistic nose performance excellent.
50	16Dec55	(N-69C), AF 52-10974 GM-52-1712, N-3298	63.3	Divergent oscillations due to loss of pitch rate. Nose delivery not satisfactorily demonstrated.
51	27Jan56	(N-69C), AF 52-10971 GM-52-1709, N-3295	76	Fuel dump system failure. Nose delivery system failed to operate.
52	8Feb56	(N-69D), AF 52-10978 GM-52-1716, N-3302	1.9	Stellar guidance test. Boosters do not eject.
53	17Feb56	(N-69C), AF 52-10975 GM-52-1713, N-3299	19	Hydraulic failure, out of control. Nose test failed. Flights suspended for component qualification tests.
54	10Jul56	(N-69C), AF 51-17577 GM-13110, N-3291	74	Ballistic nose test.
55	26Jul56	(N-69C), AF 52-10976 GM-52-1714, N-3300	60	Ballistic nose test. Engine oil starvation, engine fails.
56	31Aug56	(N-69C), AF 51-17571 GM-13104, N-3290R	61	Nose test. First use of alternate impact area.
57	13Sep56	(N-69D), AF 52-10981 GM-52-1719, N-3305	262	Stellar guidance test. Fuel leak, fuel starvation.

Snark Flight Record (Continued)

Item	Date	Serial Number	Duration (Minutes)	Remarks
58	26Sep56	(N-69C), AF 52-17578 GM-13111, N-3292	63	Ballistic nose test.
59	2Oct56	(N-69D), AF 52-10979 N-3303	262	1st successful recovery of Snark at Cape Canaveral.
60	31Oct56	(N-69C), AF 51-17572 GM-13105, N-3286	70	Completed ballistic nose test program, Phase II.
61	14Nov56	(N-69D), AF 52-10982 N-3306	256	Stellar guidance test. Drag chute does not deploy, skid off runway.
62	5Dec56	(N-69D), AF 53-8172 N-3309	332*	Refused guidance and destruct signals. Landed in South American jungles.
63	20Dec56	(N-69D), AF 53-8171 GM-52-2329, N-3308	266	Stellar guidance test.
64	11Jan57	(N-69D), AF 52-10983 GM-52-1721, N-3307	287	Guidance test. Skid landed OK.
65	23Jan57	(N-69D), AF 53-8173 GM-52-2331, N-3310	245	Guidance test. Drag chute fails, major damage on landing.
66	5Feb57	(N-69D), AF 52-10983 GM-52-1721, N-3307	276	Guidance test. Chute failed to deploy, major damage on landing.
67	20Feb57	(N-69D), AF 53-8175	271	Guidance test. Skid landed OK.
68	12Mar57	(N-69D), AF 53-8174	270	Guidance test. Skid landed OK.
69	13Mar57	Inertial #1		Mobile launcher test.
70	15Apr57	Inertial #2		Mobile launcher test.
71	16Apr57	(N-69D), AF 53-8176 N-3313	274	Guidance test. Skid landed OK.
72	3May57	(N-69D), AF 53-8178	4.3	Guidance test. Broke up 25 miles downrange.
73	28May57	(N-69D), AF 53-8177 GM-52-2335, N-3314	223	Guidance test & initial pylon tank drop. Drag chute lost in flight. Destroyed on landing.
74	20Jun57	(N-69E), AF 53-8184 N-3321	.1	1st operational prototype. Rate gyro polarity reversed, crashed.
75	12Jul57	(N-69D), AF 53-8176 3313(-2)	229	Hydraulic failure. Crashed into sea near station #5.

*Estimated

Snark Flight Record (Continued)

Item	Date	Serial Number	Duration (Minutes)	Remarks
76	16Aug57	(N-69E), AF 53-8186 N-3323	107	1st N-69E to meet test objectives. Rudder failure, crashed near sta #9.
77	27Aug57	(N-69D), AF 53-8180 N-3317	370	1st Snark flight to station #10 area. Completed Phase III contractor guidance tests.
78	19Sep57	(N-69E), AF 53-8185 N-3322	326	Flew to 1365 miles point and returned.
79	1Oct57	(N-69D), AF 53-8179 N-3316	357	1st all-military Snark launching by 6555th GMS. Recovered.
80	31Oct57	(N-69E), AF 53-8187 N-3324	496	Entire flight with automatic celestial navigation. 1st missile flight to station #12, Ascension. 6nm long.
81	20Nov57	(N-69D), AF 53-8179 GM-52-2337, N-3316(-2)	286	Drag chute ripped, destroyed in skid landing.
82	5Dec57	(N-69E), AF 53-8189 N-3326	504	2nd flight to Ascension.
83	25Jan58	(N-69E), AF 53-8190 N-3327	493	Landed on target at 5,000 mile range.
84	14Feb58	(N-69E), AF 53-8191 N-3328	500	Impact in station #12 area.
85	8Mar58	(N-69E), AF 53-8193 N-3330	458	Loss of hydraulic pressure. Flew to station #12 area.
86	3Apr58	(N-69E), AF 53-8192 N-3329	371	Ballistic warhead. Track lost between stations #9 and #12. Loss hydraulic pressure. Destruct ordered.
87	7May58	(N-69E), AF55-3147 N-3409	499	Nose released by radio control in station #12 area.
88	28May58	(N-69E), AF 55-3148 N-3410	71	Last contractor programmed flight. Left pylon tank does not eject. Crashed 615 nm downrange.
89	27Jun58	(N-69E), AF 55-3151 N-3413	84.5	1st E & ST launch by 556th SM Sq. assisted by 6555th GMS. Possible electrical failure, pylon doesn't eject. Crashed 635 nm downrange.
90	25Aug58	(N-69E), AF 55-3149 N-3411	33	Turbulent weather, structural failure. Contact lost at T+33 min. Destruct ordered.

Snark Flight Record (Continued)

Item	Date	Serial Number	Duration (Minutes)	Remarks
91	30Aug58	(N-69E), AF 55-3150 N-3412		Turned around at sta. #9 & returned to sta. #1 impact area for nose release.
92	19Sep58	(N-69E), AF 55-3152 N-3414		Completed Phase IV tests. Guidance system power failure.
93	23Oct58	(N-69D), AF 53-8181 N-3318		1st follow-on Phase V test using Airborne Parabolic Arc Computer.
94	8Nov58	(N-69D), AF 53-8180 N-3317(-2)		1st SAC training flight, used recovered missiles. Again recovered with slight damage.
95	11Dec58	(N-69D), AF 53-8182 N-3319		2nd APAC test, crashed during landing approach.
96	16Dec58	(N-69D), AF 53-8171 GM-52-2329, N-3308		2nd SAC training flight. Throttle stuck full open, turned around at station #7 & ditched off of Cape Canaveral.
97	12Feb59	(N-69D), AF 53-8175 N-3312(-2)		556th SM Sq., 3rd SAC training flight. False radar plot caused destruct near sta. #5.
98	10Mar59	(N-69D), AF 53-8183 N-3320		3rd APAC R&D launch. Returned and landed at Cape.
99	6Apr59	(SM-62A), AF 57-008 N-3422		1st of 3 extended Phase IV tests. First production model SM-62A, 556th SMS launch. 2 mi long, 3.71 mi left.
100	21Apr59	(N-69D), AF 53-8183 N-3320(-2)		APAC R&D test. Missile recovered.
101	5May59	(SM-62A), AF 57-009 N-3423	514	Extended Phase IV test. Longest flight to date.
102	26May59	(SM-62A), AF 57-010 N-3424		Last extended Phase IV test.
103	2Jul59	(N-69D), AF 53-8183 GM-52-2341, N-3320(-3)		3rd launch for this APAC vehicle. Rear skid not locked down. Accomplished 3rd landing.
104	25Sep59	(SM-62A), AF 57-001 N-3415		1st production type Snark to carry APAC. Left booster failed to ignite, crashed 200 yards from pad.
105	6Nov59	(SM-62A), AF 57-003 N-3417		2nd APAC flight. Missile lost 2,200 miles downrange. Destruct by automatic flight termination system (AFTS).

Snark Flight Record (Continued)

Item	Date	Serial Number	Duration (Minutes)	Remarks
106	11Dec59	(SM-62A), AF 57-002 N-3416		Destroyed itself at 3,000 mile range (AFTS).
107	16Dec59	(N-69D), AF 53-8180 GM-52-2338, N-3317(-3)		Last programmed N-69D flight. Drag chute ripped. Missile recovered.
108	12Feb60	(SM-62A), AF 57-011 N-3425		1st of 11 APAC extended tests. Launched by 702nd SM Wing, SAC.
109	3Mar60	(SM-62A), AF 57-012 N-3426		APAC extension test. 702nd SMW, SAC. Weather caused structural failure.
110	6Apr60	(SM-62A), AF 57-013 N-3427		APAC extension test. 702nd SMW, SAC. Impact Station #12.
111	16May60	(SM-62A), AF 59-1874 N-3444		APAC extension test. 702nd SMW, SAC. AFTS. Impact Station #12.
112	16Jun60	(SM-62A), AF 59-1875 N-3445	6	APAC extension test. 702nd SMW, SAC. Flight control failure stalled and crashed.
113	8Jul60	(SM-62A), AF 59-1876 N-3446		6th of 11 modified Category II APAC Extension Program. Launched by 702nd SMW. Scheduled for Sta #12 impact Telemetry lost. Impact 2550 mi D/R attributed to guidance failure.
114	26Aug60	(SM-62A), AF 59-1878 N-3448		SAC launch crew, NORAIR tech support. 7th modified Category II. Impact Sta #12 area.
115	26Sep60	(SM-62A), AF 59-1882 N-3452		SAC crew launch, NORAIR backup. 8th Category II. Automatic ballistic nose release at Sta #12.
116	14Oct60	(SM-62A), AF 59-1884 N-3454		SAC launch crew backed up by NORAIR. 9th modified Category II Extension missile. Electrical failure.
117	14Nov60	(SM-62A), AF 59-1890 N-3460		SAC launch crew backed up by NORAIR. 10th modified Category II Extension Program.
118	5Dec60	(SM-62A), AF 59-1888 N-3458		SAC launch crew backed up by NORAIR. 11th and last modified Category II Extension Program missile. Last SNARK programmed for launch at AMR. Programmed Sta #12. Lost.

SOURCES:

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Snark Chronology Jan 54–Oct 59 [ASD].
Air Force Systems Command, "Index of Missile Launchings by Missile Program: July 1950–June 1960" [AFSHRC-K241.04-1 July 50–Jun 60].

APPENDIX F

X-10 LAUNCHINGS

Item	Date	Serial Number	Duration (Minutes)	Remarks (Speed and Altitude)
1	3Sep53	GM-19307		Taxi Test.
2	29Sep53	GM-19307		Taxi Test.
3	14Oct53	GM-19307	31.7	M.75, 20,900 feet.
4	5Dec53	GM-19307	35.3	M.73, 24,400 feet.
5	25Feb54	GM-19307	38.3	M.69, 18,900 feet.
6	1Apr54	GM-19307	32.4	M1.47, 38,700 feet.
7	5May54	GM-19308	72.5	M.77, 31,200 feet.
8	4Jun54	GM-19308	34.7	Left tire fails on takeoff, minor damage. 17,000 feet.
9	1Jul54	GM-19308	8.3	M.6, 24,300 feet. Control lost, crash.
10	12Aug54	GM-19310	39.6	M1.3, 40,800 feet.
11	3Sep54	GM-19307	32.8	M.52, 15,380 feet. Landing gear malfunctions, wheels up landing, minor damage.
12	28Sep54	GM-19310	36.5	M1.84, 40,900 feet. Missile destroyed on landing.
13	7Dec54	GM-19307	15.7	M.54, 23,250 feet.
14	16Dec54	GM-19307	16.5	M.55, 21,500 feet.
15	22Feb55	GM-19311	41.8	M.99, 41,800 feet. Both afterburners fail, radio control problems. Crashed on landing approach.
16	11Mar55	GM-19309	.4	Exploded on takeoff.
17	29Mar55	GM-19307	20.3	M.54, 17,580 feet.
18	19Aug55	GM-19312		1st test at AMR. Wrecked in landing.
19	24Oct55	GM-52-4		Wrecked in landing attempt.
20	3Feb56	GM-52-1		1st successful missile landing on Cape skid-strip.
21	29Feb56	GM-52-1		Completed aerodynamic and takeoff tests.

X-10 Launchings (Continued)

Item	Date	Serial Number	Duration (Minutes)	Remarks (Speed and Altitude)
22	20Mar56	GM-52-1		Satisfied high-angle approach landing test requirements.
23	24Apr56	GM-52-2		1st terminal dive test; missile lost prior to dive-in.
24	5Jun56	GM-52-5		1st autonavigator test. Missile landed on skid-strip.
25	18Jul56	GM-52-5		Autonavigator test.
26	27Aug56	GM-52-1		Terminal dive test.
27	21Sep56	GM-52-6		Autonavigator test.
28	24Oct56	GM-52-6		Autonavigator test.
29	20Nov56	GM-52-6		Final X-10 program launch, autonavigator test, & terminal dive test.
30	24Sep58	GM-52-5		1st X-10 drone used as Bomarc target. Failed to engage runway barrier on landing. Ran off end of skid-strip and burned.
31	13Nov58	GM-19313		Broke runway barrier and burned on skid-strip.
32	26Jan59	GM-52-3		Final drone. Missile lost 57 miles down range.

SOURCE: Office of Information, "Index of Missile Launchings by Missile Program: July 1950–June 1960" [AFSHRC-K241.04-1 July 1950–June 1960].

APPENDIX G

NAVAHO LAUNCHINGS

Item	Date	Serial Number	Duration (Minutes)	Remarks
1	6Nov56	AF 52-10989		1st XSM-64 missile launched. Missile #1, Booster #3, Part II.
2	22Mar57	AF 52-10990		Missile #2, Booster #6, Part II test. Impacted 25 miles downrange.
3	25Apr57	AF 53-8272		Missile #5, Booster #7, Part II test. Fell back on pad and exploded.
4	26Jun57	AF 53-8270		Missile #3, Booster #8, Part II test. Ramjets failed.
5	12Aug57	AF 53-8271		Missile #4, Booster #9, Part II test. Ramjets failed at 230 mile range.
6	18Sep57	AF 54-3095		Missile #6, Booster #10, Part II test. Completed 1/3 of 1500 mile flight.
7	13Nov57	AF 54-3096		Missile #7, Booster #11, Part II test. Crashed 90 miles downrange.
8	10Jan58	AF 54-3098		Missile #9, Booster #13. Flameout occurred after turn around at Sta #9.
9	25Feb58	AF 54-3097		Program final. Missile #8, Booster #12. Booster shut-off T+20 seconds caused destruct.
10	11Sep58	AF 55-4223		Booster #14, 1st RISE launch. Ramjets failed to ignite. Crashed 82 miles downrange.
11	18Nov58	AF 55-4222		Booster #14, RISE program cancelled. Broke up at 77,000 ft.

SOURCES:

Air Force Systems Command, "Index of Missile Launchings by Missile Program: July 1950–1960" [AFSHRC-K241.04-1 July 1950–June 1960].

J. Allen Neal, "Development of the SM-64 Navaho Missile, 1954–1958," 101–107 [AFSHRC-K243.042-4 II '54–58].

History of the Air Force Test Center, I (July–December 1958), 161; I (January–June 1958), 142, 143 [AFSHRC-K241.01 I date].

APPENDIX H

TOMAHAWK LAUNCHINGS

Item	Date	Missile/Flight Number	Launch Platform	Type	Remarks	
1	13Feb76	T4:1	HTTL	AF	Launch and boost.	S
2	15Feb76	T6:1	HTTL	AF	Launch and boost.	S
3	28Mar76	T7:1	A/C	AF	Integration of missile, engine and guidance	S
4	26Apr76	T8:1	A/C	AF	Flutter stability & control.	S
5	16May76	T8:2	A/C	AF	Flight envelope expansion.	S
6	5Jun76	T9:1	A/C	LA	Integration of missile, engine and guidance.	S
7	11Jun76	T8:3	A/C	AF	Flight envelope expansion.	S
8	16Jul76	T9:2	A/C	LA	Nav, TERCOM, and terrain following	S
9	30Jul76	T9:3	A/C	LA	Nav, TERCOM, and terrain following.	F
10	8Aug76	T8:4	A/C	AF	Airspeed calibration and low-level flight.	S
11	27Aug76	T10:1	A/C	LA	Aero performance buildup.	S
12	1Sep76	T8:5	A/C	AF	Terminal maneuver & flight envelope expand.	S
13	30Sep76	T10:2	A/C	LA	Simulated operational mission.	S
14	14Oct 76	T11:1	A/C	AF	Aero performance buildup.	S
15	15Nov76	T11:2	A/C	AF	Aero performance buildup.	S
16	7Dec76	T12:1	A/C	AS	Expand over-the-horizon (OTH) area search and acquire target.	S/S
17	29Jan77	T10:3	A/C	LA	Scene matching area correlation (SMAC)	S

Tomahawk Launchings (Continued)

Item	Date	Missile/Flight Number	Launch Platform	Type	Remarks	
18	11Feb77	T12:2	A/C	AS	Expand OTH area search & acquire target.	S
19	24Feb77	T5:1	GRD	AF	1st Tomahawk cannister launch. 1st Truck launch, transition boost to powered flight.	S/S
20	19Mar77	T10:4	A/C	LA	Free flight inland route. SMAC.	S/S
21	12Apr77	T12:3	A/C	AS	Project "Outlaw Shark" OTH; expand flight envelope.	S/S
XXX	9Jun77	T6:4	HTTL	AS	Tomahawk anticircular run capability demo.	S/S
22	20Jun77	T3:1	HTTL	AS	Precursor to 1st sub launch.	S/F
23	7Jan78	T10:5	A/C	LA	Survivability demo; evaluate use of IFF.	S/S
24	21Feb78	T4:2	SUB	LA	1st submarine launch; Launch at scope depth; demo trns launch	S/S
25	2Feb78	T14:1	SUB	AS	Perform launch from periscope depth.	S/F
26	16Mar78	T11:3	A/C	LA	Demo eng st low level; fly predetermined mission. Survivability demo.	S/S
27	18Apr78	T11:4	A/C	LA	Survivability demo.	S/S
28	24Apr78	T4:3	GND	LA	Launcher/booster, guidance sys, and flight demo.	S/S
29	26May78	T10:6	A/C	LA	Demo safe submunition ejection/separation. Airfield attack.	S/S
30	21Jun78	T11:5	A/C	LA	Fly pre-determined mission. Survivability.	S/S
31	25Jul78	T13:1	SUB	AS	OTH search trajectory demo and recover.	F/F
32	25Jul78	T18:1	SUB	AS	OTH search trajectory demo and recover.	F/F
33	28Jul78	T11:6	A/C	LA	Fly pre-determined mission; eval terrain following. Survivability.	S/S
34	14Sep78	T4:4	SMS	LA	Surface launch from dynamic platform. Survivability.	F/F

Tomahawk Launchings (continued)

Item	Date	Missile/Flight Number	Launch Platform	Type	Remarks	
35	30Oct78	T11:7	A/C	LA	Fly pre-determined mission; eval terrain following. Survivability.	S/F
36	13Dec78	T11:8	A/C	LA	Fly pre-determined mission; terrain following. Survivability.	S/S
37	29Jan79	T20:1	GND	AS	Demo sealing sys; pyro sys; engine start & trans.	S/S
38	14Feb79	T18:2	SUB	AS	Demo sealing sys; pyro sys; engine start & trans.	S/S
39	22Feb79	T24:1	SUB	AS	Demo TASM at depths & pressure vent system.	S/S
40	13Apr79	T20:2	GND	AS	Validate quality test (QT) eng start; evaluate flt w/QT engine.	S/S
41	21Apr79	T11:9	A/C	LA	Verify new TERCOM/ terminal maps. Survivability.	F/F
42	7Jun79	T10:7	AC	LA	Verify new TERCOM/ terminal maps. Survivability.	F/F
43	28Jun79	T18:3	SUB	AS	Real time OTH. 1st with MK117 FCS. Survivability.	S/S
44	17Jul79	AL2:1	A/C	LA	1st ALCM flight. Navigation.	S/S
45	19Jul79	T24:2	SUB	AS	PL2 search & PI/DE select attack.	S/S
46	1Aug79	AL1:1	A/C	LA	Navigation.	
47	8Aug79	T17:1	SUB	LA	DOE instrumented; TERCOM update and penetration. Full TLAM mission demo.	F/F
48	9Aug79	T20:3	SUB	AS	Demo MK117 FCS, PL2 search & PI/DE select attack. OTH. Survivability.	F/F
49	9Sep79	T24:3				
50	14Sep79	T18:4	GND	AS	1st vertical launch; utilize SWT mode.	S/S
51	29Sep79	AL4:1	A/C	LA	Aero performance.	

Tomahawk Launchings (Continued)

Item	Date	Missile/Flight Number	Launch Platform	Type	Remarks	
52	27Oct79	AL2:2	A/C	LA	Target impact.	
53	7Nov79	T17:2	SUB	LA	Verify DOE S-band TNSM; warhead env data rcd. Full TLAM mission.	S/S
54	15Nov79	AL6:1	A/C	LA	High altitude, high Mach launch.	
55	6Dec79	AL1:2	A/C	LA	Aero performance.	
56	27Dec79	AL4:2	A/C	LA	Minimum altitude launch. Aero performance.	
57	24Jan80	AL7:1	A/C	LA	High altitude, high Mach launch. Target impact.	
58	8Feb80	AL5:1	A/C	LA	SAC planned mission. Aero performance.	
59	13Mar80	T19:1	GND	AS	Demo launch from armored box launcher (ABL); utilize SWT mode.	S/S
60	19Mar80	T27:1	SHIP	AS	1st ship launch. Demo ship/IWCS/ABL interfaces.	S/F
61	16May80	T16:1	GND	LA	1st transporter erector launcher (TEL) launch. Demo TEL ETU/AUR mechanical interfaces.	S/S
62	6Jun80	T20:4	SUB	AS	MK117 MOD (6T); OTH-T; seeker guidance demo.	S/S
63	8Jul80	T24:4	SUB	AS	Maximum depth, maximum speed launch. Shaped trajectory sequencing.	F/F
64	16Aug80	T15:1	A/C	LA	Demo block I DSMAC/BLOCK III CMGS system operation.	F/F
65	26Nov80	T16:2	GND	LA	Prim OBJ & demo vert align and launch from Proto VLS.	S/S
66	16Dec80	T27:2	SUB	AS	Maximum depth, maximum speed launch. Eval prod MSL hardware; demo shaped trajectory.	F/F
67	15Jan81	T42:1	SUB	AS	Demo MSL performance in PL2 search mode.	S/S
68	21Jan81	T28:1	SUB	AS	Demo MSL performance in BOL search mode.	S/S

Tomahawk Launchings (Continued)

Item	Date	Missile/Flight Number	Launch Platform	Type	Remarks	
69	23Jan81	T43:1	SUB	AS	Demo performance in PL4 seeker search mode.	S/S
70	15Feb81	T17:3	SUB	LA	1st conventional land attack mission. Make DSMAC scene using prototype conv strike sys.	S/S
71	20Mar81	T40:1	SUB	AS	Demo MSL performance in PL3 search mode.	S/S
72	28Mar81	T50:1	SUB	LA	Demo TERCOM & DSMAC nav update.	S/S
73	10Jul81	T51:1	SUB	LA	Demo conventional theater mission planning system. 1st TLAM hit.	S/S
74	30Jul81	T50:2	SUB	LA	Assist TWS, TMPS for convn TLAM & Eval LCS.	S/S
75	2Aug81	T41:1	SUB	AS	Demo MSL performance PL2 search mode.	F/F
76	19Sep81	T17:4	A/C	LA	1st night flight. Eval DSMAC at night & TMPS select & generation.	S/S
77	27Oct81	T52:1	SUB	LA	TALM-C assessment.	S/S
78	7Nov81	T54:1	SUB	LA	TALM-C assessment.	F/F
79	14Dec81	T53	SUB	LA	TALM-C assessment.	
80	28Jan82	T48	SUB	AS		
81	25Feb82	T72:1	GRD	LA	2nd GLCM launch.	(TEL/LCC)
82	25Mar82	T73:1	GRD	LA	GLCM.	
83	30Mar82	T56	SUB	LA	TLAM-C. Operations Evaluation (OPEVAL).	
84	19May82	T74:1	GRD	LA	GLCM.	
85	21May82	T55	SUB	LA	TLAM-C.	
86	8Jul82	T60	SUB	AS	TASM OPEVAL. Hit target.	
87	18Jul82	T45	SUB	AS	TASM OPEVAL. Hit target.	
88	20Jul82	T46	SUB	AS	TASM OPEVAL. Missed target.	
89	26Jul82	T107	SUB	AS	TASM OPEVAL. Missed target.	

Tomahawk Launchings (Continued)

TYPE: AF (Airframe/Aerodynamic)
AS (Anti-Ship)
LA (Land Attack)
SMS (Ship Motion Simulator)

LAUNCH: HTTL (Hydraulic Torpedo Tube Launcher)
A/C (Aircraft)
GRD (Ground)
SUB (Submarine)

REMARKS: S (Success)
F (Failure)

SOURCE:

"SLCM Tomahawk Flight Test History," 17 February 1982 [JCMPO].

APPENDIX I

BOEING AGM-86A AND AGM-86B FLIGHT TESTS

Item	Date	Serial Number	Duration (Minutes)	Remarks	
			BOEING AGM-86A FLIGHT TESTS		
1	5Mar76		10	1st powered flight, SRAM launch. 15,000, M.65, flew as planned.	S
2	18May76			25,000, M.77.	S
3	22Jun76			30,000, M.84.	S
4	9Sep76		31	1st guided flight (4TERCOM sets) 20,000, M.84.	S
5	14Oct76		8	Inertial system failed, crashed.	F
6	30Nov76		75	Three engine flame outs, crash.	F
			BOEING AGM-86B FLIGHT TESTS		
1	3Aug79	FTM-1	44	Angle of attack exceeded.	
2	6Sep79	FTM-2	249	Recovery.	
3	25Sep79	FTM-3	269	Missed recovery.	
4	9Oct79	FTM-6	107	Terminated due to test equipment.	
5	21Nov79	FTM-7	158	Engine failure. Rotary launch.	
6	29Nov79	FTM-10	265	1st low altitude launch. Rotary launch.	
7	4Dec79	FTM-9	261		
8	18Dec79	FTM-4	271		
9	5Jan80	FTM-12	269	1st SAC planned mission.	
10	22Jan80	FTM-5	19	1st high altitude launch. Rotary launch. Software error.	
11	12Jun80	FTM-15	246	Rotary launch.	

Boeing AGM-86B Flight Tests (Continued)

Item	Date	Serial Number	Duration (Minutes)	Remarks
12	22Jul80	FTM-13	205	Lost engine oil pressure.
13	21Aug80	FTM-8	64	Engine turbine burn through.
14	23Oct80	AV-1	213	1st production model. High altitude launch.
15	12Nov80	FTM-14	210	
16	20Nov80	FTM-9R1	00	Ejection failure.
17	19Feb81	AV-2	34	Engine fuel controller failure.
18	25Mar81	FTM-14R1	232	1st production engine, lost telemetry. Recovered.
19	16Apr81	AV-10	241	
20	24Apr81	FTM-10R1	249	1st flight with JP-10.
21	30Apr81	FTM-12R1	245	
22	25Jul81	AV-9	259	1st OAS/ALCM mission.
23	13Sep81	FTM-12R2	252	Recovery.

SOURCES:

Historical Reports, ASD, January–December 1976, ASD/YM69, YM86, and YMA, Volume 16, [ASD].
DSARC II Review, Air Launched Cruise Missile: ALCM, AGM-86, 6 January 1977, RDQ Portion [JCMPO].
Boeing, "Air Launched Cruise Missile," 1982 [Boeing].

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