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TITLE A CASE HISTORY OF AZON, AN AZIMUTH GUIDED BOMB

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The Azon bomb was developed to provide a bombardier with the means to correct, via radio control, inherent azimuth bombing errors while the weapon was in flight. The Army developed the weapon and in 1944 used Azon in the Italian, European, and China-Burma-India theaters. The results from northern Italy and central Europe were dismal because of poor weather, heavy defenses in the target area, and high delivery altitudes. The planners and crews in the China-Burma-India theater were able to correct for these and successfully employ Azon. The study concludes that Azon met its design criteria.

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PREFACE

This paper is dedicated to tracing the evolutionary development of one of the first "smart" bombs used by U.S. military forces in combat. Very little has been written about the early development of guided weapons; consequently, this thesis was assembled entirely from primary sources to include project and trip reports, messages, memoranda, and letters.

I wish to thank Dr. Dan Haulman, USAF HRC/RI, and Maj Mark Warner, ACSC/EDC, for the assistance they provided in helping me complete this history. Both were more than willing to take time from their busy schedules to answer questions, provide guidance, and proof my work. Additionally, both willingly endured my occasional ravings on the complexity of the subject and the difficulty I had in getting some of the pieces to fit. Never having done this type of historical reconstruction, I would find myself overwhelmed with data and in need of outside assistance in separating the "forest from the trees." Both provided this much needed third party view. To them I say "Thank You."

As a final note, I would like to point out that this paper is being submitted in a double spaced format at the request of my sponsor, Mr. Cargill Hall, USAF Historical Research Center.

ABOUT THE AUTHOR

Major Gordon is a SAC senior pilot with over 3000 flying hours in a wide variety of aircraft. He began his career in 1976 as a T-37 instructor pilot at Laughlin AFB, Texas. In 1978 he became an aircraft commander in the B-52D and moved to Andersen AFB, Guam. In 1979 he volunteered for and was accepted into the U-2 program. He moved from Guam to Beale AFB, California in 1980 to begin training in the U-2C. While at Beale he was mission qualified in the U-2C, U-2R, TR-1A/B, and the T-38. He became an instructor pilot in the U-2R and TR-1A/B in 1982 and an evaluator in the same two aircraft in 1983. In 1984 Maj Gordon went to Hq SAC, Offutt AFB, Nebraska as the U-2/TR-1 Future Plans/Acquisition Officer and the U-2/TR-1 Program Element Monitor for the Future Plans Directorate.

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EXECUTIVE SUMMARY

REPORT NUMBER 87-0995

AUTHOR(S) MAJOR GRANT D. GORDON III, USAF

TITLE A CASE HISTORY OF AZON, AN AZIMUTH GUIDED BOMB

I. Purpose: To provide the history of Azon; a remotely guided bomb developed, tested, and employed by the United States Army Air Force (USAAF) during the Second World War. This history was requested by the USAF Historical Research Center.

II. Problem: Military personnel are generally unaware guided weapons research was being conducted during WW II, or such weapons were employed in combat against targets in western Europe, northern Italy, and Burma. Most feel the first use of such weapons occurred in Vietnam in 1972. The need exists to make people aware of the heritage of our weapons.

III. Data: The early guided weapons were developed to provide bombardiers with the means to correct, via radio control, inherent bombing errors in range and azimuth while their weapon was in flight. In an attempt to expedite the development and fielding of these weapons (engineers were unsure if a free falling bomb could even be controlled in flight), the Army elected to center its research on a single axis of control--the azimuth. The Army was pleased with the resulting control unit, married it to a 1000-pound general purpose bomb, and called its new weapon Azon (azimuth only). Results from western Europe and northern Italy were rather dismal. However, Azon proved to be

CONTINUED

very successful when used by the crews in Burma. Unfortunately, at the height of its success, the tactical need for the weapon faded as the war drew to a close. The end of WW II brought a corresponding end to further research and development on Azon and its follow on variations.

IV. <u>Conclusions</u>: The poor bombing results of Azon in western Europe and northern Italy were due to several variables.

1. Weather--guidance required sufficiently clear weather to maintain visual contact with the weapon to impact.

2. Target defenses--maneuvering to avoid ground fire caused parallax problems for the bombardier if the aircraft maneuvered out of the plane of attack formed by the aircraft, falling bomb, and target.

3. Delivery altitude--the B-17s and B-24s bombed from too high an altitude (20,000-25,000 feet) to be able to compensate for the range variable that resulted from the control surface movements of the bomb.

The success of the crews in Burma was a direct result of not having to deal with or correct the above problems. Weather was much better, target defenses were lighter, and bombing altitudes were reduced to 9,000 to 11,000 feet. This brought the parallax and range errors to a level that permitted near point target accuracy with a weapon that had no pitch (range) control.

V. <u>Recommendations</u>: Distribute this report to military historians and "Project Warrior" OPRs. It provides the type of history and heritage these people desire.

Chapter One

AN INTRODUCTION TO USAAF DEVELOPMENT OF RADIO GUIDED WEAPONS IN WW II

The failure of barrage bombing to damage or destroy certain point targets (bridges, roads, railroads, and maneuvering or anchored ships) resulted in the U.S. Army Air Force (USAAF) initiating a program, during the early stages of the Second World War, to develop a remotely guided bomb. The National Defense Research Committee (NDRC) initiated development of such a weapon in early 1942 under Army Project No. AC-1 (33:1).

The USAAF Test Center at Wright Field in Dayton Ohio was given the responsibility of determining if a free falling bomb's flight path could be controlled during flight. They began experimenting with radio guidance as a way to control the flight path of these weapons. Subsequent refinements included the development of heat seeking and radar seeking warheads (33:1). Unfortunately, the end of hostilities and the atomic bomb brought a corresponding end to these early "smart" bombs and the need for point destruction of those targets. These early weapons were the ancestors of the guided bombs used in Korea and Vietnam and deployed today by our armed forces.

Very little has been done in setting down the history of these early guided weapons. This historical thesis is restricted to a single weapon actually developed and used in combat by the USAAF during the Second World War, the Azon bomb. Azon was an acronym composed of the first two letters of each word describing its axis of control--azimuth only. The intent was to develop a free falling general purpose (GP) bomb capable of being controlled in the azimuth (yaw) axis by a bombardier using a radio relay to a receiver on the weapon (33:1).

This paper will trace the history of the Azon bomb from design concept through development and testing to the operational employment of the weapon in the Italian, European, and China-Burma-India theaters. It will examine Azon's effectiveness and point out recommendations and improvements that resulted from stateside and theater evaluation inputs. Lastly, this paper will examine the employment results of Azon to determine if the bomb met the design criteria established by the Army and NDRC in the early 1940s.

Chapter Two

DETERMINING THE FEASIBILITY OF THE GUIDED MUNITION CONCEPT

The Army began to experiment with dirigible (winged) bombs in the early 1940s. The purpose was to develop a bomb that could be controlled from the carrying aircraft and allow the bombardier to correct for inherent sighting errors (range, azimuth, and wind drift) during weapon flight. The Army's intent was to develop a bomb controllable in both range and azimuth; however, to simplify development and stimulate production, the azimuth (yaw) axis was picked to initially test the concept. It initiated the research and development program that would eventually lead to the production of the Vertical Controllable Bomb, type VB-1, that was to be called Azon (33:--).

Before concept verification could begin, a project number had to be assigned. The weapon was being developed under the auspices of the NDRC and costs were being carried on NDRC contracts. The Army was extremely interested in development, but had not entered into any contracts or obligations for weapon procurement (18:1). The Army and NDRC had been using project number AC-1 during early concept testing; however, the description for AC-1 addressed ". . . the problem of precision bombing while flying above or in an overcast" (3:1). As this description did not actually address the concept of radio guided munitions, the NDRC, on 14 November 1941, recommended AC-1 be rewritten to address controlled trajectory bombs and a new number be assigned to the development of a device to provide precision bombing in or over an undercast. NDRC had begun development of guided weapons under the original project number and did not wish to change numbers (3:2). However, since projects more closely related to the AC-1 description were underway in this program, NDRC was overruled and a new project title of "AC-36: Controlled Trajectory Bombs" was assigned (7:1). With a project description that correctly matched the concept to a guaranteed funding line, NDRC was clear to continue with the actual test and evaluation.

The first tests to determine if a bomb could be controlled in flight were conducted at Eglin Field, Florida between 19 and 23 April 1942. No provision was made for remote control. Instead the controls were moved via a preprogrammed sequence. The test objects weighed 380 pounds and consisted of the control tail and motion picture cameras to record control surface movement and relative position of the ground target during surface movement. These tests proved that the trajectory of a free falling bomb could be controlled while the weapon was in flight. The test report recommended that further testing be conducted using radio control and television guidance to establish the tactical value of such a weapon (48:1-2).

During the month of July 1942 the second concept test was conducted at the Aberdeen Proving Grounds in Maryland. Several different types of bombs were dropped:

1. Ten 100-pound sand loaded practice bombs, with flares, to determine if smoke flares provided sufficient cues to maintain visual contact with the weapon to impact.

2. One 100-pound bomb to verify longitudinal axis stabilization was sufficient to prevent revolution.

3. Two 400-pound bombs, with a camera and recovery parachute, to determine if the bomb would remain stabilized around the longitudinal axis during control deflection (40:1-2).

These tests confirmed flares would provide the visual cues needed to keep the weapon in sight during flight and the weapon could be kept stabilized during control movement.

Further testing was conducted at Eglin Field on 14 and 15 July to follow up on recommendations from the initial April drop test. The July tests were also used to determine the usefulness of employing television to verify control response, but, because of poor picture reception and a narrow field of view, NDRC concluded that television was not a workable method of verification. Engineers recommended the direct visual sight method of using flares be continued (46:1-2). NDRC felt the results of the test series verified their assumption that a free falling bomb could be stabilized and controlled during flight. The remainder of 1942 and early 1943 was spent refining the concept and experimenting with more reliable radio receivers and flares.

The first time any reference was made to an actual project name was in a test report of March 1943. The name, Azon, referred to the axis of operational control on the guidance unit. Also reported were ten test drops conducted to determine if actual control could be accomplished through a radio link. The bombardier on the aircraft that carried and dropped the weapon provided the radio guidance via a toggle switch attached to his bomb sight. The test bombs were lead loaded to 1000 pounds and were equipped with smoke flares to provide the cues necessary to permit visual guidance during the entire free fall period. Although several of the weapons demonstrated lateral deflection on command, the majority were unsuccessful. The report concluded the gyro stabilization was insufficient (five of the bombs spun around the longitudinal axis) and the rudder pivot points needed to be moved to provide better control and avoid control surface actuator stalling as the velocity increased during the fall. The remaining unsuccessful drops were due to flare failure (39:1-2).

Definite guidance for use of the Azon control unit was given by the War Department to the Materiel Command in a 1 June 1943 letter. In it the War Department initiated procurement of a quantity of the Azon control surfaces for test purposes and defined the characteristics of the Azon bomb.

1. If possible, no physical changes would be made to the bomb picked to be matched with the control unit. Nose and tail fuses were to remain unchanged.

2. The control unit would be designed around the 1000-pound general purpose bomb. Every effort would be made to enable the bomb to be loaded on internal 1000 pound bomb stations on all medium and heavy bombers. No weapons would be carried externally.

3. The bombs would be controlled in azimuth only. The project was not to be delayed pending the development of a control unit capable of both azimuth and range control.

4. The bomb would have good ballistic characteristics and the control unit would be suitable to provide the desired maneuverability.

5. Visual contact with the weapon during its fall would be provided by smoke flares mounted in the tail of the weapon.

The War Department felt this weapon, when fielded, could be used against maneuvering ships, bridges, and similar targets (6:1-2).

This ended the concept phase of the Azon's development. The idea to provide a bombardier the capability to correct sighting errors had proven feasible. NDRC had shown that a free falling weapon could be guided during flight. The Army had great interest in the project and had provided the necessary guidance for continued testing and development. The next step was to marry the control unit to a specific bomb and begin the test and evaluation on the resulting weapon system. Thus the VB-1 (more commonly referred to as Azon) was born.

Chapter Three

RESEARCH AND DEVELOPMENT ON THE AZON BOMB

VB-1 was a 1000-pound GP bomb with the Azon unit mounted in place of the normal tail assembly. The weapon could be controlled 2000-3000 feet either side of its ground track by the bombardier via radio commands to the Azon tail unit. The Azon unit was a radio receiver and control system that relayed the yaw signals to the rudder through electrically powered solenoids. The control package also included a gyroscope and servo mechanism for aileron control to prevent rolling of the bomb. A smoke flare was mounted on the unit to provide visual contact with the bomb during its fall (4:1-2). The total weight of the Azon unit, including control surfaces, was 96 pounds (28:1). The Special Branch, Engineering Division of the Air Technical Service Command represented the Army during the development of Azon. NDRC was the government representative for development and provided the link between the military and the primary contractors (33:1). The contract for the Azon test and production units was let by NDRC to the Gulf Research and Development Company of Pittsburgh, Pennsylvania. The Union Switch and Signal Company, also of Pittsburgh, provided the engineering support and worked up the production drawings for Azon. Various components of the weapon were supplied by Schwien Engineering Company (gyroscopes), Los Angeles, California; Willard Battery Company (six volt power cells), Cleveland, Ohio; and White Rodgers Motor Company (servo motors), St. Louis, Missouri (18:1).

NDRC had shown a free falling weapon could be guided while in flight. Representatives from the Army Engineering Division, Ordnance Service, and NDRC held a conference at Wright Field on 6 August 1943 to discuss weapon refinements. One item discussed was to delete the tail fuse requirement from the initial production version of the Azon bomb. They recommended deleting the fuse because:

1. Nose fuse failures were less than 1%. Although tail fuses would virtually eliminate this factor, a small failure rate was not considered critical in the use of the weapon.

2. Use of the tail fuse would require a redesign of the Azon unit and would considerably complicate the work required to build up the weapon in the field.

3. The urgency of weapon development and testing did not justify the additional production down time necessary to accomplish a redesign.

In addition to weapon fusing, the conference members stressed the need for a more reliable flare. Testing reports were beginning to document a high rate of flares failing to ignite or burning improperly (1:--).

Between 10 and 30 August 1943, 24 additional Azon units were tested. Twelve of the drops were successful with good azimuth control during the entire flight. Three bombs had flare failure and could not be followed, while nine failed to respond to control inputs because of suspected radio failure. Recommendations were made to replace the air-driven gyros in the stability unit with electric gyros, continue testing for a satisfactory flare, and add a rigid tail brace to reduce vibrational stress on the radio unit (31:2).

The Office of the Assistant Chief of Air Staff/Operations, Commitments, and Requirements (ACAS/OCR), on 6 September 1943, consented to delete the tail fuse requirement from the project as had been recommended in the 6 August conference at Wright Field. The OCR's primary concern was to get the weapon fielded; however, it stressed the need to continue investigating the incorporation of the tail fuse into the design. The OCR felt the percentage of nose fuse failures being experienced in theater was greater than the previously mentioned 1% (12:1).

The Engineering Division at Wright Field, upon learning of the deleted requirement for a tail fuse, told the ACAS in mid-October that development had progressed sufficiently to release the Azon bomb for final ballistic and evaluation tests. The first preproduction lot of 200 units was ready in early November; the remainder followed in early January 1944 (5:1).

By early 1944, the Army was ready to deploy the weapon overseas and use it in combat. On 4 February 1944 a crew training program was established to expedite the operational testing of Azon in the European theater. Six B-17s and crews were sent to Orlando, Florida for aircraft equipment installation and crew training. Target date for departure from the U.S. was 1 March 1944 (20:1).

With Army interest confirmed and concept reliability established, emphasis shifted from testing control system feasibility to determining weapon effectiveness. The combination of the Azon control unit with a 1000-pound GP bomb had proven to be a workable combination. Some aspects of weapon development, specifically fuses and flares, continued to present problems. Still, the concept had proven itself and the Army was ready to functionally test its new weapon.

Chapter Four

DETERMINING TACTICAL EFFECTIVENESS AND SOLVING RANGE ERROR

The USAAF was beginning, in early 1944, to determine the tactical effectiveness of its new weapon. Azon had solved azimuth error, inherent in the bombing equation, by giving the bombardier the ability to correct lateral tracking. Range was the only major variable left. To allow Azon to be employed against specific point targets, such as a bridge or road intersection, the range factor had to be determined. Range is the distance between where the weapon falls from the aircraft and where it strikes the ground, or the ground distance traveled by the weapon during flight. Range is based on release altitude, aircraft velocity, and weapon drag. Although range is an important calculation in bombing with standard, unguided GP bombs, the quantity dropped compensated for small errors in determination and calculation. This was not the case when bombing with Azon.

One range variable that could not be determined prior to release was the amount or duration of control inputs needed to correct azimuth. Control surface movement increased induced drag on the weapon and caused a resulting decrease in range; consequently, some alternative method had to be developed to compensate for this variable. The initial solution was to use the weapon against long, straight targets such as roads, railroads and marshalling yards. This type of target would permit azimuth correction and virtually eliminate range error as a hit anywhere along the long axis of the target would inflict damage. In February 1944, the recommended release altitude was reduced to between 10,000 and 12,000 feet, with 9,500 feet being the minimum recommended, in an effort to reduce the time physical variables, such as atmospheric density and parasitic drag, had to act on the falling bomb (29:2). Theater results would prove altitude reduction to be the best solution to solving range error.

Still, the Army staff and the Test Division at Wright Field continued to investigate other alternatives. Included in a February 1944 letter, from Test Division to USAAF, Special Projects Section, was the suggestion to investigate the use of formation drops to compensate for range error (29:2-3). The Test Division, along with the Special Projects Section of the Army staff, spent the remainder of the war investigating this and other proposed improvements to Azon in an attempt to quantify the unknowns associated with the range variable.

In February 1944 the Army changed the deployment destination of the first operational Azon group. Original guidance had directed assignment of the group to the Eighth Air Force for use in the European theater. However, the Army felt that northern Italy offered a wider variety of the type of targets Azon would prove most effective against. On 17 February the Army redirected the group's assignment to the Fifteenth Air Force and the Italian theater (21:1).

In a 29 March 1944 communique, the Chief of Special Projects Section, Office of Air Communications, mentioned the sending of B-24 aircraft and personnel to the China-Burma-India theater. Planning date for this was 1 May 1944. The letter directed that crews be selected and begin training at Orlando in early April (15:1).

During the training of the B-24 crews destined for Burma, it was discovered visibility was going to be a problem in making Azon work in the aircraft. His limited lateral and rearward view caused the bombardier to lose sight of the weapon as it fell below and behind the aircraft. To remedy this a six inch hole was cut in the right forward corner of his compartment and a plexiglass window was installed to let him follow the fall of the bomb (24:1). Additionally, training was continually plagued with flare misfires. Of the 100 bombs dropped during this training period, ten experienced some type of flare failure. Failure to moisture proof the flares was considered to be the immediate cause. Testing seemed to confirm this, so the interim solution was to pack the flares in moisture proof containers for shipment and storage (45:1). This solution enjoyed limited success, but the misfires continued to cause bombing problems until new flares could be developed and distributed.

During the spring of 1944, the first operational reports from the Italian theater began to arrive at Army headquarters. The theater operations will be addressed in detail in following chapters of this report. The arrival of the field reports resulted in a portion of program manpower being dedicated to solving the associated theater problems and incorporating the recommendations forwarded by the crews and staff. Among these was the recurring problem of reducing range error.

Chapter Five

ATTEMPTING TO IMPROVE WEAPON ACCURACY

On 8 May 1944 the USAAF Project Board released its preliminary findings on the tactical reliability of Azon based on information collected during crew training in Florida. The board confirmed a military requirement for Azon and, as before, pointed out that the optimum targets should be long and straight enough to permit the bombardier, during weapon flight, to reduce cross track errors to zero. The report concluded with the recommendation that Azon be adopted as standard equipment for the USAAF, but emphasized that development needed to continue on a more reliable flare (37:--).

Additionally, the Army concluded that range error was a variable with no predetermined value because of the unpredictability of control movements. Since the range factor could not be quantified, the Army began to investigate alternate methods of delivery. One recommended solution was to use a trail or string release. By using this type of delivery, the Army felt range error could be eliminated by having the weapons impact in a string along the long axis of the target. They felt this would guarantee at least one hit against a point target (36:2). Unfortunately, attempts to control the flight path of the entire group proved to be futile because of dispersion (scattering). Dispersion is the measure of distance between the impacts of individual weapons when dropped in train or salvo. It occurs as a result of the difference in inherent drag between each bomb caused by casing roughness, tail fin misalignment, and other manufacturing or assembly variables (36:1).

Tests had shown that the inherent dispersion of Azon was about three times that of a train of regular bombs. Developers reasoned this was a result of Azon not spinning around its longitudinal axis, as a standard bomb does, during flight. They felt the obvious solution was to develop a device which would allow Azon to spin during the first half of its flight then stop, stabilize and be guided during the remainder of the fall (2:1). This concept was given the name Spazon for Spin Azon (41:1). The Army hoped Spazon would solve the dispersion problem, eliminate range errors, and permit effective delivery in trail (2:1).

While development on Spazon was progressing, the Materiel Command at Wright Field was also given the task of determining the feasibility of developing a light seeker guidance package, used in conjunction with an Azon unit without a radio receiver, to follow a flare in the tail of a guided Azon bomb. The concept was to drop one Azon, along with several of the light seeker bombs, and guide the Azon to the target with the seekers in trail. The developers felt this would achieve the linear pattern of strikes desired. Unfortunately, this idea was defeated by the basic geometry of the falling weapons; the following seeker weapons would need to be able to "look" down and aft to follow the lead Azon (13:1). The technology of the 1940s could not solve this "look" geometry so the concept had to be abandoned and research terminated (14:--).

Other solutions to the dispersion problem were also tested during the same period. The physical tethering of the bombs with 25 to 30 foot lengths of nylon cord or steel cable showed great promise during early experimentation; however, the concept proved unusable because of a tugging action that developed as the weapons fell. The recurring problem of radio receiver failure was felt to be the prime cause of the tugging. Some of the weapons would respond to control inputs while others, with bad or mistuned receivers, would not. The resultant tugging action usually caused cable or cord separation between the guided and unguided bombs (32:1).

By the end of July 1944, the Army was improving the combat effectiveness of Azon by developing an improved flare, designing a tail fuse that was compatible with the Azon tail unit, and solving the dispersion problem. The employment of the Azon bomb had now expanded to the Eighth Air Force and the European theater. As the use of Azon expanded, the test and development units in the states were beginning to feel the pressure to provide the weapon improvements the theaters were requesting.

Further testing was conducted in November 1944 to determine if the shape of the basic 1000-pound bomb had any effect on dispersion. The bomb casing was suspended by its nose and measurements were taken along the longitudinal axis. These measurements showed the bomb casing was extremely asymmetrical. This caused misalignment of the Azon control unit and resulted in the off center stabilizer and rudder inducing unwanted control inputs. This misalignment caused disparity in both range and azimuth. Because of this asymmetry and the failure of the tether (Spazon was still in early stages of testing) the Army recommended that Azon bombs not be used for train drops. The resulting 1500 to 2000 feet separation between individual weapon impacts was not the type of accuracy needed for precision point bombing and did not justify the cost. A recommended alternative was to make massed drops from large formations of aircraft each dropping several Azon bombs. It was felt that this would compensate for dispersion if the target value justified the expense (30:--).

1944 ended without any significant changes to Azon. Flare failures continued to be a problem. Development proceeded on the tail fuse. Several ideas were tested in an attempt to solve the basic dilemma of how to resolve the range equation and permit Azon to be used against point targets. Unfortunately, as the invasion progressed in Europe and the Japanese retreated in the Pacific, the need for a weapon like Azon decreased as desirable targets were removed from the target list. The end of the development cycle for Azon was near.

Chapter Six

THE BEGINNING OF THE END

In January 1945 the USAAF Engineering Division completed development of a tail fuse to be mounted between the bomb casing and the Azon tail unit (10:1). Additionally, a new reliable flare had been developed and was being distributed (8:1). Two of the reliability problems for Azon had been solved and were beginning to be fielded. Testing continued on Spazon. Several drops were made in late 1944 and early 1945 at Wendover, Utah. Of the 18 bombs dropped, 17 spun as desired, stopped, stabilized, and were controllable during the remainder of their flight (41:1). The future for the Spazon and Azon looked promising; unfortunately, the improvements were too late.

On 26 February 1945, the Office of the Assistant Chief of Staff of the Army Air Force stated the development efforts in the controlled missile field (to include guided vertical bombs, glide bombs, glider bombs, and jet bombs) was not as productive as desired and placed most of the blame on the Army's failure to establish valid requirements. The Army Air Force Board was tasked to determine military requirements and characteristics for these weapons. Until the study could be completed interim fundamental guidelines were established to include all-weather, target seeking, release, and control capabilities. Specific instructions directed the continued development of Azon through the Spazon phase (22:1).

However, continuation of testing was for technology purposes as actual production of the Azon tail unit had stopped on 19 September 1944 (nearly a year earlier) at the request of the Operations, Commitments, and Requirements Office of the Assistant Chief of Air Staff. Of the 110,600 units authorized for purchase by the Army in 1944 and 1945, only 14,070 were actually delivered by 4 October 1944 when the cancellation notice went to the venders. Several reasons were cited for cancellation.

1. Train drops were not as successful as envisioned.

2. Azon could not be used in marginal or bad weather because of the need for continuous visual contact.

3. Because of the Allied invasion forces, bridges were off limits in France. This restriction removed one of Azon's primary objectives from its target list.

4. Air superiority and plentiful supplies encouraged

standard mass (high tonnage) bombing.

5. Theaters had a plentiful supply of Azon tails in stock (22:--).

Azon would continue to be used during the remainder of the war, but the desire for the weapon waned as targets continued to be put off limits. No further refinements or improvements were made to the weapon. Although the Army had officially accepted Azon under the designation VB-1 on 21 April 1945 (33:9), the end of the war spelled the end of Azon and follow on weapons as the need for such precision weapons disappeared.

The original intent of the Azon development had been to provide the bombardier with a way to correct for inherent bombing errors during an actual combat run. The last chapter of this report will briefly analyze the concept and development of the weapon to see if the design requirements were met. The next several chapters will address the use of Azon in the Italian, European, and China-Burma-India theaters.

Chapter Seven

THE ITALIAN THEATER

In early February 1944, the Army decided to test Azon in an operational environment. The original theater picked was Europe with the gaining unit to be Eighth Air Force. Crews, technicians, airplanes, and the necessary equipment were assembled at Orlando, Florida for training. The original departure date was 1 March 1944 (20:1). However, based on discussions addressing the tactical use of the weapon, the Army decided, in mid-February, to change the deployment of the unit to the Fifteenth Air Force and use Azon against targets in northern Italy. Because the range problems had not yet been solved, the deployment was delayed until 15 March 1944 in order to accumulate more information on the effect of control application (21:1). The crews and equipment finally arrived in theater in early April and flew the first operational mission with the Azon bomb on 17 April 1944.

The objective of the first mission was to destroy railroad bridges along the Rimini to Ancona rail line. The mission consisted of three Azon equipped B-17s and 16 P-38 fighters for cover. Unfortunately, weather caused a mission abort and no weapons were dropped (35:tab 1). As was pointed out in numerous theater reports, weather was one of the primary factors affecting the success of Azon in theater. Planners had to wait until 24 April for the weather to clear sufficiently to execute the second mission.

Mission two was targeted against the same railroad line and bridges. This mission consisted of five Azon equipped B-17s and 18 P-38s. After the high percentage of hits attained in a training environment, the results of the first combat use of Azon were rather dismal. Nineteen Azon bombs were dropped with no confirmed hits against the target bridges although a collateral hit was made on a factory/warehouse at the Cisano River crossing. Of the 19 bombs dropped three had flare failures and several experienced loss of control during the latter portion of flight (35:tab 2).

The third mission was flown on 29 April and consisted of five B-17s with 24 P-47 escorts. The target area was the same. The five bombers dropped 24 Azon, experienced four flare failures, and again lost control of several during the latter stages of flight. Success was not much better than mission two. Bombardiers claimed an apparent hit on a railroad bridge at Senegallia, a highway at Pasaro, and on a rail line south of

Rimini (35:tab 3).

The railroad line between Fano and the Esine River was the target area for mission four. The strike force was again composed of five B-17s; however, their fighter escort got lost enroute to the rendezvous point and the bombers had to fly the mission unescorted. Results were considerably better than the previous three missions in both system reliability and confirmed hits. Thirty bombs were dropped with no reported spinners or flare failures and only one report of control loss. Crews reported direct hits on the Fano River bridge and the Fano highway. The Cesano River bridge was reported as a "possible" with a confirmed hit on the Cesano highway and several reported near misses on both. The Esino River bridge escaped damage although crews reported two possible hits on the highway (35:tab 4).

The primary purpose of these missions was to test the operational effectiveness of Azon and to see how the weapon performed in a combat environment. The crews observed that the bombing accuracy enjoyed with Azon during training was not evident in actual combat. The need for short run-ins to the target, evasive action to avoid ground fire, and having to aim on several targets in rapid succession markedly decreased their ability to achieve the desired results (35:1).

Lieutenant Colonel P. F. Helmick, the Azon project officer in Italy, sent his first report back to the states on 30 April 1944. In it he documented the four Azon missions, included a comprehensive list of problems experienced, and offered solutions and recommendations. He caveated the report with the planning complications caused by the weather and the need to consider this when tasking missions. Near unlimited visibility was needed to effectively employ Azon. Other problem areas cited were bad batteries in the bomb mounted Azon unit, radio failure due to the receivers drifting off frequency, and dud bombs caused by fuse failures (35:--). His report prompted engineers at Wright Field to begin working on solutions.

Among the recommendations forwarded to the states by the crews was one they felt would overcome the short run-in and rapid re-aim problems. The crews wanted a second bombardier on the aircraft to actually guide the bomb after release. One bombardier would be responsible for the aiming and release, letting him direct his attention totally to this task, while the second was responsible for guiding Azon after release. The crews, agreeing with Lt Col Helmick, felt a more reliable fuse was needed, preferably a tail fuse (35:2). This, in combination with the nose fuse, would hopefully eliminate the dud problem.

The accuracy and limited success of Azon were sufficient to convince Lt Col Helmick of a need for this type of weapon. He pointed out this type of precision guided bombing eliminated the need for large formations of aircraft dropping several tons of explosives to achieve comparable results against point targets (35:2-3).

On 30 May 1944, four Azon equipped B-17s participated in a large mass bombing raid against the Avisso Viaduct north of Trento on the Brenner Pass railroad. The Azon aircraft reported four hits on the target from 22,000 feet (27:1). This was followed by another raid on 22 June against the railroad marshalling yard at Oradea, Rumania. Six Azon aircraft participated as part of the 301st Bombardment Group's bombing effort. Each of the Azon aircraft dropped four standard 1000-pound GP bombs and two Azon in salvo. All the Azon were tuned to a common frequency and controlled by the lead bombardier in the second element. Release altitude was 22,400 feet. Faulty releases caused by bomb racks hanging up and an overshoot of the aiming point resulted in a noneffective delivery as most bombs struck past the target (9:1).

While the B-17s were using Azon against targets in northern Italy, the B-25s of the 321st Bombardment Group were taking the Azon to Corsica. Although the bomb load capacity of the B-25 is below that of the B-17, the B-25s were obtaining very good results. The project officer, Major Frank C. Ziglar, felt that a greater number of aircraft (at least three flights of six aircraft) attacking the target in a column formation would guarantee, with near 100% certainty, the target would be destroyed. Maj Ziglar reported about 75% of the Azon units functioned properly with the majority of the failures being attributed to faulty flares. Additionally, he noted the fuses in theater caused little damage to steel trestles. The fuses available for Azon were the nose type (two delay times, zero and one-tenth second--the zero delay exploded too early to cause anything but superficial damage while the one-tenth second delay permitted the bomb to pass completely through the trestle before detonation). Maj Ziglar felt the obvious solution was a .01 second (one-one hundredth second) delayed tail fuse (16:1). He appealed to the stateside engineers and developers to solve this problem and incorporate a tail fuse into the Azon weapon.

During the remainder of the war the Fifteenth Air Force continued to forward observations and recommendations addressing the usefulness of Azon as a combat weapon. Among these were:

1. Limit bombing altitudes to 18,000 feet with 15,000 feet being the most advisable. It was found that the normal bombing altitude of between 22,000 and 25,000 feet permitted the velocity of the bomb to exceed the ability of actuators to move control

surfaces into the slip stream. When control was most critical, as the bomb neared impact, corrections could not be made.

2. Avoid heavily defended areas. The aircraft could not maneuver, after release, to avoid ground fire because the bombardier would lose sight of his weapon.

3. Crews felt the accuracy of Azon could be improved if a second bombardier was included to guide the bomb after release.

4. The staff and crews felt Azon was, tactically, more suited for medium bombers as they avoided flak by flying faster, presented a smaller target to ground fire, and routinely operated within the revised recommended altitudes (26:--).

Although Azon continued to be used in the Italian theater, many of the targets it was developed to destroy were made off limits. Invading forces needed the remaining bridges, roads, and rail lines for their advance. Consequently, employment of the weapon was severely restricted for the remainder of the war. Additionally, weather continued to be a major planning restriction. The latter bombing successes were not repeated because of the targeting and weather restrictions. Planners and crews using Azon in Europe encountered the same mission restrictions.

Chapter Eight

THE EUROPEAN THEATER

In late April 1944, Lieutenant Colonel W. G. Brown, Office of the Assistant Chief of Army Staff, stated in a department memo that consideration should be given to testing Azon in the European theater as had been originally planned in February 1944. The suggestion had the support of the Army staff so implementation was relatively easy (17:1). The support given his suggestion resulted in nineteen Eighth Air Force B-24 aircraft being fitted with Azon. Ten were equipped while in the states and carried sufficient spares to retrofit the additional nine in theater. The original ten arrived in England on 16 May 1944. Theater interest also resulted in sixteen B-26s being fitted with Azon prior to a July 1944 deployment. As with the B-24s, sufficient spares were carried to equip an additional two B-26s in theater (19:1).

By early July 1944, the B-24s had flown five missions against targets in central Europe. Although the theater staff felt sufficient missions had been flown to prove the functional reliability of the weapon, they were skeptical of its tactical value because of the dismal results. Still, theater personnel were fair in their evaluation. They pointed out that planning and execution of missions were plagued with lack of suitable weather and the loss of critical technicians and equipment to a higher priority project (42:1). As a result of these planning roadblocks, only twelve missions had been flown by the end of September 1944. The accumulated total of targets confirmed destroyed for the twelve missions was one bridge. A variety of methods were tried to improve accuracy, but none were to prove effective. Railroad tracks leading up to the target bridges were destroyed more often than the bridges. The Eighth Air Force placed the majority of the blame on three conditions:

1. The European theater did not have the type of visual bombing conditions needed to properly employ Azon. A majority of the time, even on clear days, the ground was obscured by haze.

2. The ever present ground haze, in combination with the high bombing altitudes, caused visual parallax for the bombardiers. Numerous near misses were attributed to this loss of depth perception.

3. The B-24 bombardier's restricted field of view, even with the plexiglass port modification, prevented him from effectively following and guiding the bomb in flight (34:--).

The B-26 unit tried Azon once and decided it was not usable as a tactical weapon. The mission was flown on 4 August 1944 by six (five were Azon equipped) Ninth Bomber Command B-26s. The targets were a railroad embankment and three highway bridges at Epernon, France. A total of ten Azon bombs were dropped. The need for evasive maneuvers immediately after weapon release degraded the bombardiers ability to accurately guide his weapon. The lead bombardier was aiming for the entire flight and had insufficient time to acquire and aim on target two. Consequently, he had to direct a withhold against it (43:2). Because evasive action negated the guidance advantage of Azon, the B-26 crews felt it was no more effective than an ordinary GP bomb and never used the weapon again (11:1).

After these unimpressive results the Azon program was terminated in the European theater. Along with the above noted difficulties, the invasion forces were moving into Europe. Bridges and other strategic targets were put off limits for tactical bombing purposes. Although Azon did not perform well the crews and planners did provide feedback on problem areas and recommended improvements.

1. Flare failures were experienced on about 15% of the drops as a result of either flare breakup or failure to ignite properly

after release. Crews felt flak may have been one of the causes for the failures and recommended armoring the flares with light steel tubes.

2. A limiting factor with Azon was fuse availability. The only fuses available were nose type with instantaneous delay. Crews felt weapon success hinged on getting a tail fuse accommodation for the Azon unit (42:1-2).

3. In agreement with the crews flying in northern Italy, the European flyers felt Azon could best be employed using medium bombers dropping from 10,000 to 15,000 feet (35:--).

Army Air Forces in Europe were not overly impressed with Azon although they did consent to the functional reliability of the weapon. The inherent short comings of the weapon contributed to this poor performance. Yet, when Azon was finally used in a benign environment (clear weather and light defenses), as was enjoyed by the Tenth Air Force in the China-Burma-India theater, the success of the weapon was to be outstanding.

Chapter Nine

THE CHINA-BURMA-INDIA THEATER

A 29 March 1944 communique from the Chief of Special Projects Section, Office of the Air Communications, first mentioned the sending of Azon equipped B-24s with crews and maintenance personnel to the China-Burma-India theater. The crews began their training at Orlando, Florida in early April 1944. Their projected departure date was 1 May (15:1). Although the crews completed training and departed as an integral unit, they became scattered upon arrival in theater. The theater, therefore, lost its Azon capability for nearly eight months. It was only after the arrival, in early December, of Mr. T. J. O'Donnell, an Azon technical advisor, that the program was able to develop any momentum. Immediately upon his arrival in theater, he briefed the potential of Azon to the staff of the Eastern Air Command. After finishing with the staff, he traveled to the headquarters of Seventh Bombardment Group, Tenth Air Force in Burma. The Seventh had been the intended destination of the original cadre of Azon crews. He found, of the ten Azon equipped B-24s sent to the theater, four were in China, three had been lost in combat, and the remaining three had never had their Azon equipment used.

After considerable reluctance on the part of the crews and staff of the Seventh (they figured he was just another stateside "egghead" with a weird idea on how to end the war), he was able to assemble the remaining Azon assets (25:2).

The targets selected were primarily Japanese lines of communication.

> A rail line from Rangoon through Mandalay to Cashio, with short spur lines supplying the north Burma front; a rail line north from Rangoon to Prome and a road running west and north from Prome to the Arakan front; and the famous Burma-Thailand railway, running from Bangkok to Moulmein and then to Rangoon (25:1).

The light opposition at the targets permitted each aircraft to make several passes, dropping one bomb on each pass. The formations usually consisted of three aircraft flying in close trail. At times, not all the aircraft were Azon equipped. The unequipped would salvo their bomb load on the first pass then maintain formation for the remainder of the mission (25:2).

The first mission was flown on 27 December 1944 and was targeted against a three span steel railroad bridge on the railway line between Rangoon and Mandalay. Each of the three aircraft carried four Azon and four regular bombs. After a practice pass on the rail line several miles short of the target, three passes were made on the bridge with the aircraft dropping one Azon and one regular bomb on each pass. Bombing altitude was 9,300 feet. The center span was destroyed and another span was damaged by the Azon bombs. All the regular bombs missed. The bridge had been a target for two years and, until this mission, had never been damaged (25:2).

The second sortie was flown on 30 December against a road bridge on the Japanese supply line to the Arakan front. Two other bridges along the same road were assigned as alternates (25:3). The second mission was so successful that, after destroying the primary and two alternate targets, a fourth bridge, which had been attacked unsuccessfully earlier by a non-Azon equipped squadron, was attacked and destroyed. Four B-24s dropped 28 Azon bombs from 10,000 feet. The targets were a 225-foot steel railroad bridge and a 75-foot wooden bridge both at Nyaungchidank on the Taungup-Prome road, a 200-foot steel bridge at Okshitpin, and a 400-foot steel and concrete bridge at Taungup (25:3).

The remaining missions were flown against bridges on the rail line between Bangkok and Moulmein. The third was flown on 1 January 1945. Four bombers attacked the bridges from 10,500 feet in very poor weather--4/10ths to 10/10ths cloud cover. One bridge was destroyed and two were claimed as "possibles." Between 3 and 11 January, four more sorties were flown against other bridges on the railway. The missions consisted of three to six bombers and were flown at altitudes of 8,000 to 10,500 feet (25:3-4).

On the seven missions flown, 154 Azon bombs were dropped on 17 different bridges and one section of track. Fourteen bridges were confirmed destroyed, one was considered a "probable", and two were "possible but doubtful." Of the 154 bombs, 35 were "wasted" due to jettisoning for engine/aircraft problems, bomb rack malfunctions, or personnel errors. Others were used unnecessarily against targets already destroyed. As Mr. O'Donnell so aptly pointed out:

> The overall economy of Azon bombing on these seven missions is somewhat startling. . . . We can say that one out of five Azon gave a damaging hit. I do not have available the figures on standard bombing. . . but I should say that one damaging hit out of fifty bombs would be an over-optimistic guess. On this basis. . . Azon is ten times as effective against bridges as standard bombing. . . (25:4).

The positive successes of Azon in Burma aroused great enthusiasm within the theater. All the bombing squadrons wanted the capability. Unfortunately, insufficient supplies and personnel limited any expansion of the operation.

Azon had finally demonstrated the cost effectiveness and precision the designers had in mind when they developed the weapon. However, the war was coming to an end and, as in other theaters, the availability of targets was dwindling rapidly.

The last report to be published on Azon was an operational analysis done by the Tenth Air Force in March 1945. It summarized the employment of Azon in the China-Burma-India theater, pointed out the overall results of its use, and presented future plans for the bomb. The analysis observed:

1. The best bombing altitude was 8,000 to 10,000 feet with single vice train or salvo releases.

2. The best results were obtained by flying a six ship formation flown in two three ship elements stacked down.

3. Nose fuses, without tail fuse back up, resulted in an unacceptable number of duds (12 out of 24 bombs on one occasion).

4. After enemy ground fire, the most serious restriction to Azon bombing was weather (38:1-2).

Thus ends the history of Azon. As with numerous other weapon systems, the end of the war sounded the death knell for the bomb. After a rather slow start, the weapon was to finally prove to be a cost effective method of destroying key lines of communication if employed in a relatively agreeable environment. Azon cost about four times as much as a standard iron bomb, yet proved to be a technical leap in correcting azimuth bombing errors that more than justified the expense. A fitting epitaph for one of the early guided weapons. The final chapter will analyze the combat use of the weapon to determine if it met the design criteria.

Chapter Ten

AN ANALYSIS OF AZON

Azon was designed, developed, and fielded to solve a specific problem. This chapter will readdress the concept that precipitated the weapon, briefly detail the decisions made during early stages of development which affected weapon capabilities, and outline errors made in employment. The goal is to show that, although Azon results were dismal in Europe and Italy, when the weapon was employed properly it did indeed satisfy the original intent for which it was designed.

The basic idea behind the development of Azon was to permit a bombardier to correct for the inherent sighting errors that were a part of the bombing equation. The research was carried out under the guidance contained in "AC-36: Controlled Trajectory Bombs." The project called for the ". . . development of devices which will enable the bombardier to control the direction of fall of a bomb during its flight, and of devices to indicate to him the need for and effect of such control" (7:1). Only after the NDRC had shown the feasibility of this concept did the military attempt to define the type of target against which the weapon could be used. The War Department, in early June 1943, defined the characteristics of the weapon they called Azon and stated the weapon could be used against maneuvering ships, bridges, and similar targets. In actuality, the weapon could be used against long straight targets but, without range control, had insufficient maneuverability to attack the point targets the War Department listed. The Army eventually recognized the restriction and unsuccessfully tested several concepts in an attempt to solve the range problem and the aggravation to range caused by control surface activation.

A second programmatic decision made by the military, that had a long range effect on employment, was to not delay the development and testing of Azon in an attempt to incorporate a tail fuse into the design. The limited availability of the nose fuses in the desired delays resulted in duds and ineffective detonations against targets that would have been destroyed had they been struck with bombs having effective nose fuses and backup tail fuses.

Lastly, testing done in early 1944 had shown that the optimum bombing altitude for Azon was between 10,000 and 12,000 feet with 9,500 feet being the minimum (29:2). This was known prior to any of the overseas deployments, yet the planners in Europe and Italy bombed from much higher altitudes. Whether they chose to ignore the revised altitudes or were unaware of them could not be determined; although, recommendations from these theaters noted that lower bombing altitudes were more effective. However, in fairness to the theater planners, the B-17 and B-24 were high, not medium, altitude bombers.

A combination of misunderstanding proper target subsets for Azon, not understanding the effect control surface movements had on range, and failing to use recommended bombing altitudes led personnel in the Eighth and Fifteenth Air Force to expect more from the weapon than it was capable of providing. Both theaters discounted the tactical value of the weapon based on its ineffectiveness against point targets when dropped from the normal operational altitudes for the B-17 and B-24. They also felt visual problems and bombardier parallax were among the reasons Azon had not proven productive. Their evaluations seemed to overlook the fact that Azon was employed in theater to test its functional reliability, not to evaluate the weapons ability to hit point targets. The Eighth and Fifteenth Air Forces admitted the weapon was functionally usable. Reliability was affected by bad flares and incorrect fusing, not improper targeting.

When dealing with the use of the weapon in combat, it must be understood that range was a variable the bombardier could not control without physically being able to guide the weapon in the pitch axis. Due to reduced time of flight, lower bombing altitudes nearly eliminated the range variable. Once Azon was used against the proper targets, in a benign environment, and at a reasonable altitude, it was to prove extremely successful. The crews of the Tenth proved Azon did have tactical value if employed correctly.

Azon was the first in a family of guided free falling bombs. The follow-on configurations would have the two-axis control capability the Army desired. Unfortunately, the war ended before the other configurations could be fielded. Azon was the only weapon in the family to be used in combat. When employed, it provided the bombardier the capability to make azimuth corrections while the bomb was in flight and eliminate cross track error. It met the design goal and satisfied the parameters established in "AC-36: Controlled Trajectory Bombs."

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