Technical Developments in World War II

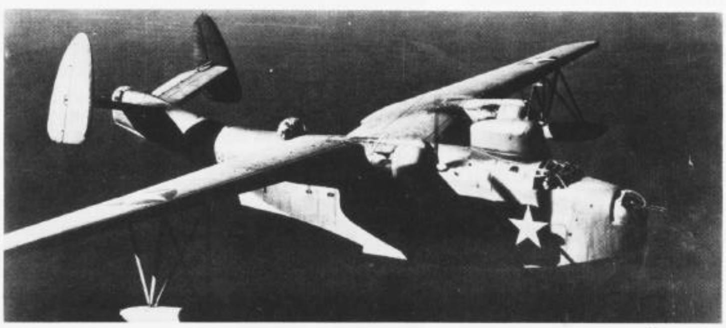
By Lee M. Pearson

WW II technical developments involving combat aircraft, powerplants, the vital new areas of radar and antisubmarine warfare (ASW) and the substantial efforts with helicopters and guided missiles were discussed in *Naval Aviation News,* November–December 1990 through March–April 1991. This article deals with munitions and catapult developments.

Within the Navy Department, the Bureau of Aeronautics (BUAER) was responsible for aircraft and the Bureau of Ordnance (BUORD) for ordnance. The general lines were clear but the details involved in properly fitting bombs and guns in naval aircraft required understanding and accommodation. Thus, the officer with aeronautical responsibilities for the Coordinator of Research and Development told me that his greatest achievement was to introduce the man in BUAER responsible for putting guns in airplanes to the man in BUORD responsible for getting the gun. (The files indicate that he spent much more time trying to coordinate disparate projects involving highly classified guided missiles and rockets.)

A 1941 Army-Navy agreement assigned cross-service responsibilities: Army Ordnance developed and procured most aircraft guns and general purpose and semiarmor-piercing bombs; BUORD similarly handled armor-piercing and antisubmarine bombs, i.e., depth charges. In nomenclature, the letter "M" indicated equipment was Army developed and

A TBF Avenger on its way to bomb Tinian and support landing operations during the second day of the invasion. Note the turret and the tunnel on the aft fuselage.
USN 247982



The Navy initially experimented with gun turrets on several types of aircraft, including patrol planes such as this PBM Mariner. Turrets were removed from early production Mariners because of weight problems, but installed in all later models.

Consolidated Catalina flying boats stand on the field at the American advance base, Amchitka, Aleutian Islands, awaiting the call of duty. In the foreground bombs are brought to the field prior to loading on the Catalinas. NH 98483

"Mk," or Mark, indicated it was Navy developed. The prefix "AN" meant that the gear had been tested and approved (standardized) by both services. The frequency of this prefix indicated a seldom-noted but highly successful example of interservice cooperation in areas of massive production and use.

Guns

After WW I, .30-caliber machine guns were generally mounted in naval aircraft for both offensive and defensive missions. Heavier but more powerful .50-caliber guns were adopted in 1935 for installation in new naval aircraft; by the end of 1941, most operational aircraft were equipped with .50s. Two larger guns were being developed in 1939, a .60-caliber adaptation of the German 20mm Mauser and a 20mm Hispano Suiza, a French design.

During the war, improvements to the .50 caliber continued. In the decade 1935 to 1945 firing rate doubled from 600 to 1,200 rounds per minute; at the same time, muzzle velocity and magazine capacity were increased. Remote charging mechanisms—hydraulic, pneumatic and electric—and remote electric triggers were developed, which increased the flexibility in mounting guns and permitted underwing mounts and gun packages in lieu of bombs. A new "Stellite" gun barrel, developed by the National Defense Research Committee (NDRC), greatly improved barrel life.

Development of the .60-caliber gun continued while the 20mm was placed in service; the F4U-1C fighters were fitted with four 20mm guns in lieu of six .50-caliber guns in other *Corsairs* and in F6F *Hellcats*. The SB2C *Helldiver* dive-bomber, in most models, was equipped with two 20mm guns. The twin-engine F7F *Tigercat*, being readied for service at the end of the war, was fitted with a mixed battery of four .50-caliber and four 20mm guns.

Turrets

By the late thirties larger guns, multiple gun installations and higher aircraft speeds made the aiming of flexible guns difficult and led to power-driven gun turrets. The Navy's first aircraft gun turret project began in June 1937 as part of the XPBM-1 patrol plane development. The first turret-equipped aircraft to be operated by the Navy, however, was the PBO *Hudson* patrol plane built for the British by Lockheed and obtained in the fall of 1941 for ASW patrol from northern bases during the coming winter. The PBO turret contained twin .30-caliber guns.

Following the XPBM-1, all new dive-bomber, torpedo plane and patrol plane developments included turrets; a turret was developed with the XTBF-1 *Avenger*, and combat *Avenger*s used turrets throughout the war. A similarly developed turret for the SB2C was installed in early production aircraft but was removed during the *Helldiver*'s prolonged teething period.

The first Navy-developed turrets were fitted with a single .50-caliber gun, but later models contained twin or quad mounts while 20mm turrets were under development. Gyro-stabilized, lead-computing sights were going into production at the end of the war and radar-controlled turrets were under development. Efforts to develop a lightweight, high-performance drive failed because of production problems, as did efforts towards a standardized turret intended for various positions on different aircraft.

Operational patrol planes were fitted with turrets, although when early PBM *Mariners* were found to be underpowered, the turret was one of the items removed in a weight-reduction program.

Turrets were developed for many new aircraft that never went beyond experimental status. As one example, remote-controlled upper and lower turrets developed for the Douglas XSB2D-1 dive-domber preceded similar turrets installed in the Army's Douglas A-26 *Invader*. Gun turrets continued to be of interest in aircraft development for a few years after the end of the war, but a variety of tactical, technical and strategic factors led to their abandonment.

Armor

Aircraft armor was of little interest in the interwar years as its weight would have penalized aircraft performance. In 1938, as war shadows darkened, BUAER began studying armor for aircraft pilots and the next year specified that new experimental aircraft contain space and weight provisions for armored seats or bulkheads. Basic investigation was also conducted into the effectiveness of various steel and aluminum alloys. In mid-1940 BUAER ordered armor that could protect against .50-caliber bullets fired from 200 yards. About the same time, it requested that airframe contractors design armor installations for various service, production and experimental aircraft, and in 1941 contractors were made responsible for armor procurement and installation. By the end of 1941 armor ordered by BUAER had been received and new aircraft were delivered with armor already installed. The timing was fortuitous as we entered the war with most aircraft equipped with armor. The importance of armor was noted by Pacific Fleet analysts, who considered it a significant factor in the favorable survival rate of our fighters at Midway.

The main parameters laid out from 1938 to 1941 did not change during the war. Concern for performance led to some relaxation of requirements from early 1942 into 1944, but a redefined .50-caliber protection standard was adopted by February 1944.

Efforts to improve protection included continual study of various compositions of homogenous and case-hardened armor. Tests of laminated nylon in May 1941 were so promising that three years were devoted to an unsuccessful effort to substitute transparent plastic for bullet-resistant glass. Flak suit, helmet and fuselage curtain investigations began in 1943 and led to production orders in March 1945—too late for large-scale wartime use.

Rockets and their development became paramount for the U.S. and its allies during WW II. Here, an F-4U Corsair launches a trio of rockets during testing at the Naval Ordnance Test Station, Inyokern, Calif.

Rockets

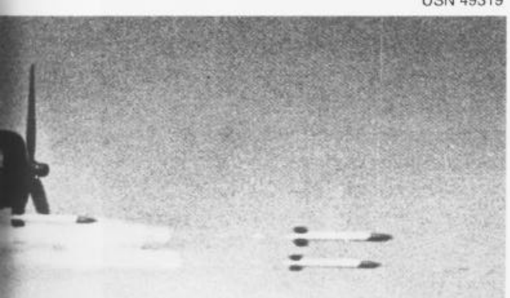
WW II brought about a resurgence in the use of rockets. The major European combatants all had extensive rocket programs, and the long-range German V-2 was the most spectacular of many weapons. The Russians, in 1941, strafed invading German troops with airborne rockets. In America interwar rocket development was in the hands of a few dedicated individuals, most notably Dr. Robert H. Goddard. Total U.S. production of military rockets zoomed from zero in 1940 to a billion rounds per year by 1945.

American military rocket programs began in mid-1940 at the behest of NDRC. BUORD agreed that rocket propulsion could increase the penetration of large armor-piercing bombs. Thus, an NDRC rocket program commenced at Naval Proving Grounds, Dahlgren, Va., but was soon relocated to Naval Powder Factory, Indian Head, Md. In mid-1941 the NDRC rocket program was expanded and realigned: the East Coast effort was relocated to George Washington University, Washington, D.C.; the West Coast effort was begun by the California Institute of Technology (CIT), which did the most work of naval interest.

USN 269073

Ordnancemen load rockets on a TBF Avenger on the flight deck of the escort carrier Core .

USN 49319



Initial tests were carried out at Salton Sea and some of the dry lakes in the Mohave Desert; the first airborne tests were at Goldstone Lake. In the fall of 1943 Navy tests were concentrated in the China Lake area, and in November Naval Ordnance Test Station (NOTS), Inyokern (forerunner of today's Naval Air Warfare Center Weapons Division), was established.

The first U.S. Navy rocket grew out of a 7.2-inch British antisubmarine projectile, Hedgehog, which could be fired by destroyers or larger ships. The U.S. Navy used the same warhead but converted it to a rocket, Mousetrap, which being recoilless could be used by smaller vessels. CIT also redesigned the warhead to increase explosive load and improve range.

The Navy's first airborne rocket was adapted from Mousetrap. Magnetic Airborne Detector (MAD) gear enabled a low-flying airplane to detect a submarine directly under it. A vertical fall weapon, needed to utilize that information, was obtained by increasing Mousetrap's propulsive charge so that when it was fired astern by an airplane, it would (hopefully) drop vertically onto the submarine. The first airborne firing was at Goldstone Lake on 3 July 1942. Development continued for a year and retrorockets were procured for service in late 1943 for issue to MAD-equipped squadrons.

Successes of British and Russian airborne rockets led the Navy to begin development of forward-firing aircraft rockets in June 1943. Expected advantages included greater range, accuracy and velocity than bombs; greater striking power than machine guns; and less weight than heavy guns. CIT, BUORD and Commander Fleet Air, West Coast, cooperated. The first experimental firing on 14 July at Goldstone Lake came just five weeks after the go-ahead.

In a little more than two years, five different aircraft rockets were developed and factories and loading plants were erected or converted so that in July 1945 nearly 530,000 aircraft rockets were manufactured. To achieve this, CIT and NOTS began initial production of a model before development was complete, providing for testing and early operational use while obtaining the configuration needed for mass production.

Every feasible shortcut was taken. Therefore, the first rocket, the 3.5-inch Aircraft Rocket (AR) was adapted from a British ASW rocket. It had a 3.25-inch motor but its 3.5-inch head was redesigned to double underwater travel; an explosive head was also developed for use against surface targets. The second, a 5-inch AR, was obtained by attaching a refuzed 5-inch gun projectile to the same 3.25-inch motor. Thereby, an airplane was literally given the punch of a destroyer salvo. A third rocket used a newly developed 5-inch motor attached to the 5-inch warhead, restoring range and speed. This round, the High Velocity Aircraft Rocket, or more popularly "Holy Moses," was air delivered to Europe and first used in July 1944 by the Army in the St. Lo area of France prior to the breakout from Normandy.

The fourth rocket, Tiny Tim, involved an 11.75-inch motor for the 500-pound, semiarmor-piercing bomb providing a round slightly heavier than a 1,000-pound bomb. Combat introduction by the carrier *Franklin* at Okinawa failed because a Kamikaze devastated the ship before it made a Tiny Tim strike. Hence, Tiny Tim's WW II use was very limited. The fifth rocket was SCAR, a 2.25-inch Subcaliber Aircraft Rocket used for training. Manufacturing began in January 1945 and by July accounted for about half of the Navy's aircraft rocket production.

The first aircraft rocket launcher was a British type ordered in August 1943 for 200 TBF/TBM *Avenger* torpedo planes. Being slotted aluminum rails about 90 inches long, they lowered aircraft performance, particularly in multiple installations. Tests, in which the rails were progressively shortened, showed no loss of accuracy; launch stability and accuracy were provided by 200 knots airspeed. The rails were replaced by two posts, which released the rocket after less than an inch of travel. These "zero-length" mounts went into production in May 1945.

The aircraft rockets used fixed fins for stability, but some effort went into pop-up fins and spin-stabilized rockets. Such rounds could be stowed much more densely than fin-stabilized rounds. Launchers were also developed. One was similar to a revolver in that the rounds were stored in a rotating carriage and fired sequentially. Another, developed by Douglas Aircraft as part of the XBT2D/AD *Skyraider*, stored rounds inside the wing and moved them horizontally into firing position.

Fire Control

Accurate fire-control instruments and trained crews made ships' gunfire very accurate. Limits on space, weight, time and crew necessitated simple solutions to airborne fire-control problems, primarily simple sights enhanced by a seaman's eye and doctrine based on past experience. Precise instruments, while theoretically possible, were not practical. For example, the highly accurate Norden bombsight, developed by BUORD in the twenties and early thirties, required a stabilized run of several seconds and had to be used at high altitudes to minimize exposure to antiaircraft fire. In consequence, ships avoided falling bombs by maneuvering. Of the over 40,000 bombsights produced, most were used by the Army. Of the nearly 6,500 kept by the Navy, only the stabilized bombing approach equipment was generally used; it made an excellent automatic pilot.

Despite considerable development effort bomb, torpedo and rocket fire control relied heavily upon sights for fixed guns with varying doctrinal procedures for the different weapons. The major exception was a toss bombing sight, Bomb Director Mark 1, which utilized speed, dive angle and altitude to compute the release point.

Through the 1930s ring and post sights, similar to those on a hunting rifle, were used to aim fixed guns. Aside from requiring the pilot's concentration at the expense of other tasks, their major drawback was in giving no estimate of lead. In 1937 BUORD began development of lead-computing sights incorporating gyroscopic stabilization and control. The first models were unsatisfactory and two other types of gunsights were undertaken in 1941. A telescopic sight unacceptably narrowed the user's vision. Illuminated sights were also designed. In these, the image of a bore-sighted lens was reflected onto a glass plate within the user's normal field of vision. A Navy design and a modified British design were developed. The Mk 8 illuminated sight for fixed guns and the Mk 9 for flexible guns were developed, produced and placed in service early in the war, filling a vital need in aviation ordnance.

Development of the more complex, but potentially more useful, lead-computing sight continued. The Mk 18 for use with flexible guns was in fairly wide use by the end of the war. The result, as the BUORD historians reported, was that "firepower of aircraft turret guns went up, ammunition expenditures dropped." A similar sight for fixed guns entered service in 1945 but had not found widespread acceptance by war's end.

Catapults

Many factors led to increased use of carrier catapults. Most wartime changes increased weight and, even with more powerful engines, lengthened takeoff run. Takeoffs were affected by the carrier's deck length and speed. As the war progressed, aircraft strikes became larger, which shortened the deck length available for the first planes off. Both the light carrier (CVL) and the escort carrier (CVE) had short flight decks, and the CVE had only about half the speed of a fast carrier. Therefore, as the war progressed, catapulting became more important.

Before WW II, carrier catapults were used for limited experimental purposes. This was despite the fact that from the earliest days of Naval Aviation, catapults were viewed as a means of operating aircraft from ships. During the interwar years, catapults were installed on battleships and cruisers and quickly became essential for their aircraft operations. Based on 1940 tests, plans were even made to install catapults on some new destroyers.

The Navy's first carrier, *Langley*, commissioned in 1923, had bow and stern catapults for launching seaplanes. In the spring of 1925 a landplane was catapulted from the ship, but no follow-up appears to have been made. In fact, her catapults were removed in mid-1928 because they had not been used for three years. Despite that, flywheel catapults for launching seaplanes were installed on the Navy's next carriers, *Lexington* and *Saratoga*. Two powder catapults planned for athwartships mounting on the hangar deck of *Ranger* (the first U.S. ship designed as a carrier) were eliminated to save money. A 1934 proposal to install the first experimental flush-deck catapult on *Ranger*'s flight deck was overridden on the grounds that catapults belonged on the hangar deck. *Ranger* finally received catapults in 1944.

In mid-1931 the Navy began design of flush-deck catapults (both powder and compressed air) that could be installed on the hangar deck to launch

Another major development during WW II was the catapult. Heavier, more powerful aircraft created the need for a more reliable launching mechanism. Below, an F6F Hellcat prepares to catapult off Lexington.

landplanes. Hydropneumatic catapults soon followed, and in November 1934 the Naval Aircraft Factory (NAF), Philadelphia, Pa., began constructing the H-1 flush-deck catapult.

Yorktown and *Enterprise*, commissioned in 1937 and 1938 (as well as a few subsequent carriers), were each fitted with an athwartships catapult on the hangar deck, along with two bow catapults on the flight deck. Both ships made their first catapult launches on 4 August 1939, scarcely a month before the outbreak of war in Europe. *Wasp*, during her first year of operation, mid-1940 to 1941, made only three dozen live catapult launches. After the U.S. joined the war, hangar deck catapults were removed from existing carriers. Until mid-1943, however, *Essex*-class carrier plans called for hangar deck catapults.

In April 1943 *Enterprise* recommended her catapults be removed because they were so limited to small, slow airplanes that they were of no use. Instead, they were replaced with updated H2-1 catapults capable of accelerating an 11,000-pound airplane to 70 mph in a 73-foot run. In February 1944 Commander Naval Air Force, Pacific Fleet, reported that catapults were important for all carriers and were vital for CVEs and CVLs. They became so essential to the CVE mission of aircraft resupply that all Army fighters earmarked for the Pacific were fitted for catapults while on the production line.

Most catapult development was carried out by the Naval Air Material Center, Philadelphia, Pa., and its predecessor, NAF. Catapults for carriers, battleships and cruisers underwent continuous improvement.

Several specialized catapults were developed. Expeditionary catapults for overseas bases were diverted to training command air stations. A catapult to launch a 60,000-pound flying boat from a large barge was designed, built and tested and plans were made to join two of them to launch a 120,000-pound flying boat. Conversion of the *Mars* PB2M patrol planes to JRM transports and cancelation of other large flying boat projects eliminated those needs. Jet Assisted Take Off, developed by Engineering Experimental Station, Annapolis, Md., and CIT, eliminated the need for catapulting smaller boats.

1 May: CVBG-74, the first large carrier air group in the U.S. Navy, was established at NAAF Otis Field, Mass., for duty on board *Midway* (CVB 41).

2 May: First helicopter rescue — Lt. August Kleisch, USCG, flying an HNS-1, rescued 11 Canadian airmen who were marooned in northern Labrador about 125 miles from Goose Bay.

9 May: *U-249*, the first German submarine to surrender after the cessation of hostilities in Europe, raised the black surrender flag to a PB4Y of Fleet Air Wing 7 near the Scilly Islands off Lands End, England.

10 May: In a crash program to counter the Japanese Baka (suicide) bomb, the Naval Aircraft Modification Unit was authorized to develop Little Joe, a ship-to-air guided missile powered with a standard JATO (jet assisted take off) unit.

15 Jun: Experimental Squadrons XVF-200 and XVJ-25 were established at Brunswick, Maine, to provide, under the direct operational control of Commander in Chief, U.S. Navy, flight facilities for evaluating and testing tactics, procedure and equipment for use in special defense tasks, particularly those concerned with defense against Kamikazes.

16 Jun: Naval Air Test Center, Patuxent River, Md., was established under a commander responsible for aviation test functions formerly assigned to Naval Air Station, Patuxent River.

A spring catapult to launch "cub" aircraft from LSTs (tank landing ships) was tested. The Army's Brodie Gear with a wire cable for landing and takeoff was installed on one LST.

In later experiments, pressure in a hydraulic catapult neared the critical point where fluid would flash into vapor with an enormous increase in volume and the potential for a disastrous explosion. In December 1944, based upon a German device, study of a slotted cylinder catapult began. Fluid pressure moves a piston through a cylinder, and a linkage through the slot connects the airplane and piston so they move together. The key element is a flexible sealing strip that tightly closes the slot behind the piston. Activating fluids studied included gas, steam and fuel oil. Thus, if the steam catapult was not anticipated, its possibility was foreseen.

On a more urgent level, at war's end projects were under way to improve almost every detail of catapults, including improved bridle catchers, retracting chains to reposition battleship and cruiser catapults, and piston decelerators. Looking to the immediate future, the XH8 hydropneumatic catapult was developed for jet aircraft; the goal was to launch a 15,000-pound aircraft at 120 mph with 40-second intervals between launches.

Flywheel catapults based on those originally on *Lexington* and *Saratoga* were studied; a large spinning flywheel stored a lot of energy, but problems with the clutching mechanism were never solved. Electric catapults were tested: an electric motor's rotor and stator were replaced by flat surfaces so that electricity pulled one over the other directly providing forward motion. An electric catapult was operated at Patuxent River, Md., for several years.

Wartime Technology

A brief article cannot thoroughly survey the vast scope of aeronautical development. During the war, improvements were made in almost everything involving flight and flight support: shipboard gear, such as arresting gear, barriers and barricades; safety and survival gear, including oxygen equipment, anti-G suits and life rafts; aircraft instruments; aerological and meteorological equipment; photographic equipment and interpretation; Link trainers and target aircraft and kites for training; and construction materials and finishes. The list could go on and on.

A follow-on half century of vigorous development of military technology has yielded few entirely new areas, notably lasers, transistors, infrared devices, supersonic aerodynamics and flight and high-altitude photography. Science and engineering have made great refinements in all areas of Naval Aviation, but in most respects, modern equipment can be traced to WW II antecedents. ■

Mr. Pearson was a naval historian from 1947 to 1977, when he retired from the Naval Air Systems Command.