50th ANNIVERSARY OF NAVAL AVIATION

THE "WILDCAT" STORY

By FRANK L. GREENE

At the height of America's WWII production effort 5927 of these Grumman-designed "Wildcats" were turned out at the Eastern Aircraft Division plant in Linden, N.J. They were produced under various designations, FM-1, FM-2, "Martlet V" and "Wildcat VI", the latter two for British Navy. Most of them served aboard Escort Carriers. Photo - Pratt & Whitney Aircraft No. D-5539.

This year marks the 50th Anniversary of U. S. Naval Aviation and the 20th anniversary of the Japanese attack on Pearl Harbor. It is appropriate at this time to give some attention to an airplane which holds a prominent place in the history of U. S. Naval Aviation and which played a significant role in winning the war that started with this surprise attack. Originally conceived in 1936, the "Wildcat" was built in some nineteen different models including experimental aircraft. The 7898 production aircraft which had been built by the end of the war served the world-wide combat needs of the U. S. Navy, U. S. Marine Corps, and the British Fleet Air Arm on attack carriers, escort carriers, and on land bases. Although the "Wildcat" did not possess performance characteristics which could be described as truly outstanding, its staunch ruggedness and heavy firepower in the hands of skilled and determined pilots nevertheless enabled it to establish a combat record of nearly seven enemy aircraft shot down for every loss.

In the history which follows frequent reference will be made to the qualities and accomplishments of the F4F. These are, of course, merely a reflection of the qualities and accomplishments of the military and political planners, engineers, designers, production workers, pilots and ground crewmen. Its failures were their failures. Its successes were their successes.

BACKGROUND

To begin the story of the F4F, let us review the political, military, and technological situation that existed in the year 1935. Most Americans at this time were preoccupied with the problems of the depression. Far beyond U. S. shores, however, events were taking place which would lead within only ten years to momentous changes. In 1931, Japan marched into Manchuria, and early the following year initiated the first operations in their long war with China. In 1933, Hitler came to power and wasted little time in beginning the development of his resources for aggressive action. By 1935 he felt sufficiently strong to reject the provisions of the Versailles Treaty and to order conscription. In Italy, Mussolini had not been idle. Taking heart from the daring actions of his fellow dictator to the north, he began his successful invasion of Ethiopia late in 1935.

To anyone who would see, it must have been obvious that the dictatorships were on the march. But in safe, isolated America, few, outside of a handful of far-sighted political and military planners, could visualize the long-range implications of these distant rumblings.

In 1935, U.S. carrier aviation undoubtedly led the world. To the first pioneer carrier, the LANGLEY of 1922, had been added the LEXINGTON and SARATOGA in 1927. The RANGER, first U.S. carrier to be designed as such from the hull up, joined the fleet in 1934. In addition two more carriers were on the ways, the YORKTOWN and the ENTERPRISE, both destined to play leading roles in World War II.

Naval aviation in Great Britain, integrated with the land-based Royal Air Force in 1918, had reached something of a plateau. From their early pioneering efforts in the First World War the British had commissioned in 1923 the HERMES, the world's first aircraft carrier designed and built from the beginning for this function. By 1935, Britain had six carriers in operation, the last two having been commissioned seven years before in 1928. Although possessing two more carriers than the U.S., six compared to four, Britain's major aeronautical interest at this time was concentrated on development of bomber and fighter types for the Royal Air Force.

Japan had taken an early interest in the development of carrier aviation and had established an aircraft carrier construction pattern remarkably similar to that of the U.S. By 1934, Japan also had four carriers in commission. A fifth, the SORYU, was under construction and would be commissioned late in 1937. Forward-looking Japanese naval planners were formulating the bold operational doctrine which would reward them with outstanding success in the first six months of the Pacific War.

As to the fighter aircraft operating from these carriers, the standard configuration for all navies in 1935 was the single-engine biplane. Boeing F4B-4's and Grumman F2F-1's were then serving aboard U.S. carriers. (1) The biplane F4B-4, powered by a 550 HP Pratt & Whitney "Wasp", had a maximum speed of 188 mph at 6000 feet. The F2F-1, with a 700 HP P&W "Twin Wasp Jr.", did 231 mph at 7500 feet. The F2F-1, like the F4B-4, was a biplane, but it did feature a retractable landing gear, a novelty for naval aircraft at this time. Undergoing flight tests at this time was the Grumman XF3F-1 with performance similar to the F2F-1 but with improved stability and control characteristics.

Flying from British carriers was the Hawker "Nimrod II", a biplane fighter adapted from the RAF Hawker "Fury" introduced a few years before. Powered by a Rolls-Royce liquid-cooled "Kestrel" rated at 640 HP, the "Nimrod" was credited with a speed of 195 mph at 14,000 feet.

In Japan, the year 1935 saw the first deliveries of the A4N1 (Type 95) biplane carrier fighter. With a radial air-cooled engine of 780 HP, this airplane had a maximum speed of about 350 km/hr (218 mph) at nearly 10,000 feet. For more than 15 years the Japanese had been heavily dependent on Western designers and technology in the development of their military aircraft. It was at this time, however, that Japanese aeronautical engineers and designers were just beginning to strike out on their own. Unknown to outsiders, they were in 1935 conducting flight tests on the A5M cantilever monoplane carrier fighter with fixed landing gear. This fighter with a speed of 265 mph at 10,000 ft. was to enter service in 1937 and thus become the world's first monoplane carrier fighter.

To complete this brief summary of the situation in the year 1935, a few words should be said about the status of air-craft design and technology. The key to aircraft (and missile) performance then as now is the powerplant. Service ratings were then approaching the 1000 horsepower mark. Under Navy sponsorship beginning in the early 20's, the radial air-cooled engine had been brought to a high level of reliability and efficiency and already established a place in Navy service aircraft which would extend through World War II. (2) A two-row radial engine, the P&W R-1535 "Twin Wasp Jr.", was standard for the Grumman F2F-1. Although presenting

(1) William A. Riley, "Fleet Air Concentration - 1935" JOURNAL of A.A.H.S., Vol. 1, No. 4, p.136

(2) For a full description of these see Harvey H. Lippincott, "The Navy Gets an Engine" on Page 247 of this issue.

The XF4F-2, Grumman's first monoplane, followed the XF4F-1 Design No. 16, which was a biplane! The design of the biplane XF4F-1 is shown on Page 226. The pictures above show the XF4F-2 in its original configuration, with Pratt & Whitney's "Twin Wasp" Model SC-G, or R-1830-66, of 1050 HP. Photos - Grumman Nos. 6126 & 6124.

a more difficult cooling problem, the two-row cylinder arrangement permitted the packing of more power into a smaller frontal area, thus reducing the aerodynamic drag of the engine installation. Supercharging, for maintaining engine power at higher altitudes, was also standard and advanced development and testing was proceeding on two-speed, two-stage, and turbo-supercharger variations.

Aircraft propellers had also been greatly improved and by 1935 the metal, two-position, variable-pitch propeller had become standard. The variable-pitch feature permitted the maintenance of high propulsive efficiency under conditions of take-off, climb, cruise, and maximum speed. Continuously-variable, constant-speed propellers, both electrically and hydraulically controlled, were then under development and would soon become standard service items.

The availability of greater engine power brought with it the possibility of greatly increased aircraft speed. This, in turn, resulted in the necessity for giving much closer attention to improved aircraft aerodynamic efficiency. For years, aircraft designers had been aware of the aerodynamic advantages of closed cockpits, retractable landing gear, and unbraced monoplane wing configurations. Until about 1930, however, these innovations, with few exceptions, were rejected mainly because the increased weight, cost, complexity, and maintenance penalties were too high. In many cases structural technology was not equal to the demands. By 1935, however, all of these items were well in hand. All-metal structural wing technology combined with suitable airfoils and flaps for increased lift coefficients and reduced landing speeds were then available. The Douglas DC-3, under construction in 1935 and destined to enter airline service the following year, was a model of aerodynamic and structural efficiency and even after twenty five years is still in world-wide service.

Navy designers were certainly alert to the performance improvements which the unbraced monoplane could offer. In 1934 the Navy had given contracts for the experimental Douglas XTBD-1, the Chance Vought XSB2U-1, the Northrop XBT-1, and the Brewster XSBA-1, all monoplanes with retractable landing gear. Late in 1937, the TBD would be the first monoplane to enter carrier service with the U.S. Navy and would be our standard torpedo-plane at the time of the Japanese attack on Pearl Harbor. The XBT-1 would eventually evolve into the Douglas SBD, which played a very significant role in World War II.

It was perhaps easier to see the range and cruise advantages which the monoplane configuration would offer the heavier bomber aircraft than it was to accept the possible reduced rate of climb and decreased maneuverability which would result for the heavier monoplane fighter. Nevertheless, the Navy had initiated as early as 1933 the Boeing XF7B-1, a low-wing cantilever monoplane fighter with retractable landing gear. Tests late in 1933 and in 1934 showed that the airplane was little better in certain performance categories than current biplane fighters and decidedly inferior in others. A similar fate befell the Northrop XFT-1 (3) and -2 in the next two years. Actually, most of the difficulty could be traced not to the monoplane configuration itself, but to the lack of a sufficiently powerful engine.

It can be said with little exaggeration that, with the availability of efficient air-cooled radial engines, variable-pitch propellers, metal structural technology, and efficient aerodynamic configurations, all of the basic aircraft technologies were available in 1935 to carry Navy aircraft design through World War II.

ORIGIN OF THE F4F

The Grumman Aircraft Engineering Corporation was founded in 1929 by Leroy R. Grumman, Leon A. Swirbul, William T. Schwendler, E. Clinton Rowl, Edmund W. Poor, and Joseph A. Stamm. (Five of these six are still directing the Company, "Jake" Swirbul having died in 1960.) Set up in a small garage at Baldwin, L.I. early in 1930, the Grumman Comapny first did aircraft maintainence work and then designed and built amphibian floats. However, it wasn't long before the company was working on the design of a complete airplane. In April, 1931 Grumman was awarded a contract for the XFF-1, a two-place, biplane fighter. The XFF-1 was uniquely equipped with a landing gear which could be retracted into the fuselage, a feature which would characterize Grumman carrier fighters for the next ten years. Following the award of a production contract for 27 FF-1's in 1932, the company, which had earlier moved to Valley Stream, L.I., moved again to an old service and overhaul shop of the Fairchild Co. at Farmingdale, L.I. Late in 1932 Grumman was given a contract for a single-seat carrier fighter, the XF2F-1; a production contract following late in 1934. In 1935 Grumman was delivering the production F2F's and also conducting flight tests on the new XF3F-1.

Even while the XF3F-1 tests were progressing, Grumman engineers were looking toward its successor. Preliminary studies were formalized in November 1935 when the Navy Bureau of Aeronautics initiated a design competition for a new carrier fighter. Grumman again proposed a biplane configuration (Des. No. 16) with an equal upper and lower wing span of 27 feet as compared to the 32 feet of the F3F-1. Alternate power plants were proposed: either a Wright XR-1670-02 rated at 800 HP at 10,500 feet or a Pratt & Whitney XR-1535-92 also rated 800 HP but at 8,000 feet. Estimated maximum speed with the Wright engine was 264 mph compared with 231 mph for the F3F-1. On March 2, 1936 Grumman was awarded a contract for their new airplane and it was assigned the designation XF4F-1. Thus the original F4F was not the trim monoplane later developed, but a biplane!

While the detail design of the XF4F-1 was progressing during the Spring of 1936, two significant events occurred. Studies had shown that if the F3F-1 were fitted with the more powerful Wright R-1820 "Cyclone", performance could nearly equal that of the XF4F-1. In July 1936 the Navy ordered that one of the production F3F-1's be fitted with a "Cyclone". This new airplane, designated the XF3F-2, became the basis for the production F3F-2 delivered in 1937 and 1938.

In addition, the Brewster Company received a contract in June 1936 for their XF2A-1 monoplane fighter. The net result was that Grumman dropped their biplane design which was then still on the drawing board and laid out a new monoplane fighter. On July 28, Grumman was awarded a contract for the XF4F-2, first of the monoplane F4F's. For the next two years, the Brewster XF2A-1 and the Grumman XF4F-2 were to be the subject of an intense design and evaluation competition.

DESIGN AND DEVELOPMENT OF THE XF4F-2.

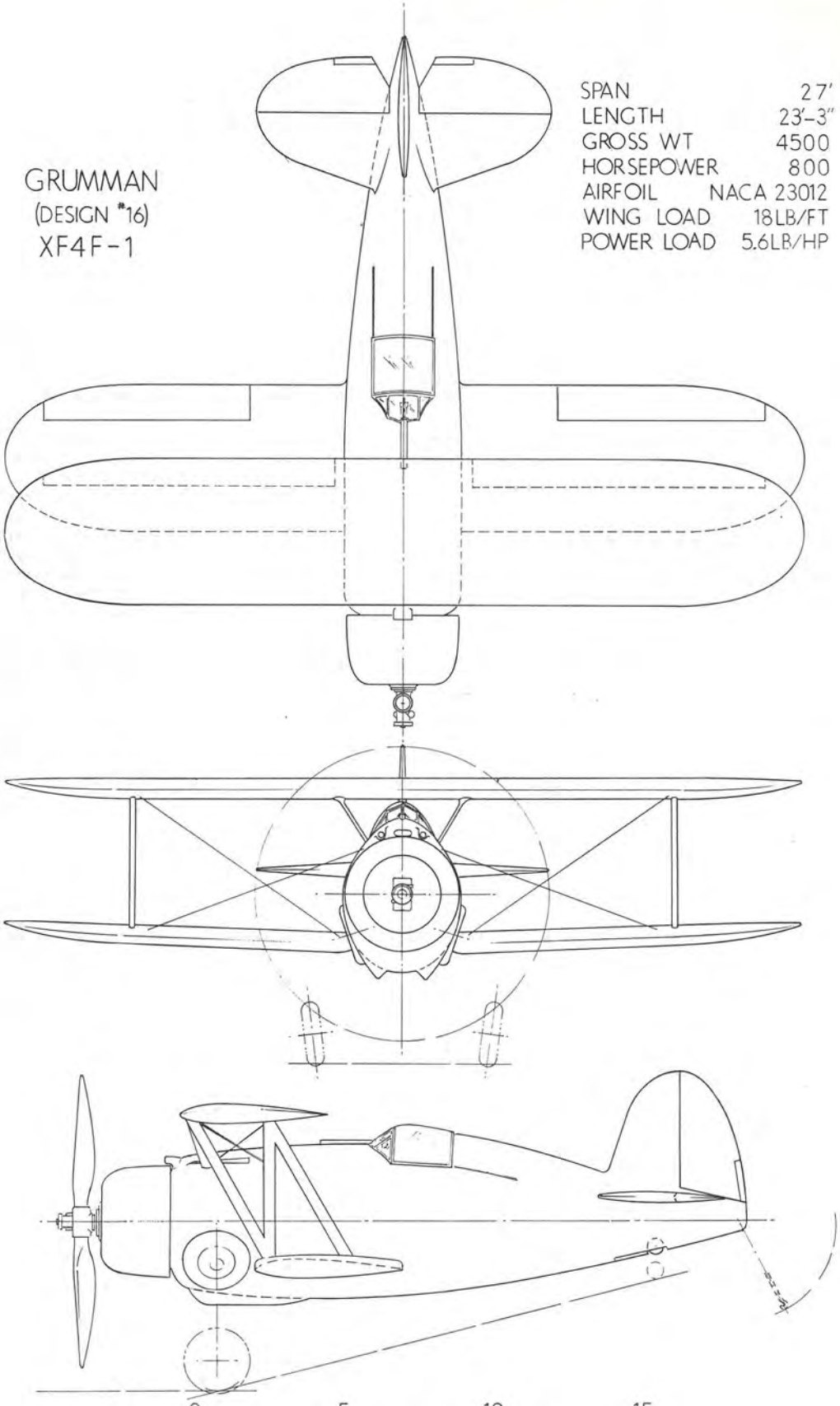
The XF4F-2 was designed around the Pratt & Whitney R-1830 "Twin Wasp", a two-row, fourteen cylinder, air-cooled engine. Designed in 1930 and first run in 1931, the "Twin Wasp" was the first of P&W's long line of two-row radials. By 1936 it was already flying in the Martin 130 "China Clipper", the Consolidated PBY, and was being test flown in a number of aircraft including the XTBD-1 and the Vought V143 (4). It had by this time advanced to what P&W called the "C" series. The actual engine to be used by the XF4F-2 was designated the SC-G "Twin Wasp" by Pratt & Whitney and was known by the Services as the R-1830-66. Rated at 1050 HP for take-off, it was equipped with a single-speed, single-stage supercharger which gave the engine a normal rating of 900 HP at 12,000 feet. With this engine Grumman hoped to obtain a maximum speed of 290 mph, a substantial in-

(3) Northrop XFT-1 Development history. See JOURNAL, Vol. 2, No. 3, p.194

(4) Vought V-143. Sale to the Japanese Army Air Force of design for $100,000. JOURNAL of A.A.H.S., Vol. 1, No. 4, p.167

GRUMMAN
(DESIGN #16)
XF4F-1

SPAN	27'
LENGTH	23'-3"
GROSS WT	4500
HORSEPOWER	800
AIRFOIL	NACA 23012
WING LOAD	18LB/FT
POWER LOAD	5.6LB/HP



DUSTIN W. CARTER 11-12-61

crease over existing or projected biplane fighters.

While Grumman was continuing its development and production of the F3F-1's and 2's over the latter half of 1936 and during 1937, the XF4F-2 was progressing through the mock-up, detail design, and construction stages. Late in 1937 the airplane was completed and after ground tests was ready for its first flight. The XF4F-2 was a mid-wing cantilever monoplane with an all-metal wing which utilized the newly-developed NACA 230-series airfoil. This airfoil was characterized by a good lift-to-drag ratio, a low pitching moment coefficient, and camber and thickness quantities compatible with efficient structural design. The retractable landing gear was similar to that already employed on the F2F's and F3F's. The Bureau of Aeronautics assigned the BuNo. (serial number) 0383 and this appeared prominently on the fin. A wing span of 34 feet gave a total wing area of 232 sq. feet. Primary armament consisted of two fuselage-mounted .50 cal. machine guns synchronized to fire through the propeller. There were provisions also for two additional wing-mounted machine guns or, alternately, two 100# bombs.

The first flight was made at Bethpage on September 2, 1937 by 32-year old Robert L. ("Bob") Hall, today a Grumman vice-president. Naturally elated at the successful first flight of their new airplane, Grumman officials and engineers could hardly have foreseen the difficulties that lay ahead and little realized that almost three years would elapse before the delivery of the first production airplane.

Following initial manufacturer's tests on Long Island, the XF4F-2 was flown by Bob Hall to the Naval Air Station, Anacostia, two days before Christmas. For the next three months the airplane was to undergo manufacturer's and Navy trials both at Anacostia, and at the Naval Proving Ground at Dahlgren, Virginia. Engine troubles hampered the program at first. During this period the R-1830 began to suffer from a series of crankshaft bearing failures. Pratt & Whitney initiated an extensive investigation of the problem and only after many months of very intensive effort was a solution found. This took the form of a silver-lead bearing surface, a development which found extensive use throughout the engine industry.

Flight tests continued during January and February. On February 14th, with the airplane back at Bethpage, a somewhat disconcerting incident occurred. With Hall at the controls at 10,000 feet, several shot bags, which had been placed in the aft fuselage for ballast purposes, suddenly caught fire. The airplane, however, was landed successfully by Hall before disaster could overtake it. It was later theorized that the shot bags had accidently become soaked in gas or oil and had been ignited by a spark passing through several holes in the fuselage skin.

Two days later the XF4F-2 was back at Dahlgren to continue its demonstration flights. Fitted with a motion picture camera to film the instrument panel it was flown on at least one occasion by an NACA test pilot by the name of McAvoy who put the airplane through spins, dives, and other maneuvers both with wing guns and with the guns replaced by 100-pound bombs. Hall performed a series of dives with pull-outs up to 8.5 g's. Spin characteristics were rated as good with no more than 1½ turns required for recovery.

During the last week of February, the airplane was flown back to Anacostia by a Lt. Carson and on March 1st began Navy tests. Also undergoing tests, in competition with the XF4F-2, were the Brewster XF2A-1 and the Seversky NF-1, a "navalized" version of Seversky's army fighter. The three aircraft were to continue in a more or less parallel test program for the next three months and the air was continuously filled with "rumors" with respect to their relative competitive position during this period.

At Anacostia, the XF4F-2 was put through the usual rigorous Navy test program which included maximum performance tests, take-off and landing performance, stability and control characteristics, armament tests, etc. A radio was installed. Checks were made on cockpit carbon monoxide content for different flight conditions. Two different propellers were tried, the original one 10 feet in diameter, and one 9'9" in diameter fitted with a spinner.

By March 11 over 16 hours of flight time had been accumulated. For the next two weeks tests continued with the dropping of water-filled bombs, stall tests with drooped ailerons, machine gun firing, terminal velocity dives, saw-tooth climbs, radio tests, and spins. By the end of March maximum speeds of the competing aircraft were unofficially rated as follows:

XF4F-2	290 mph
NF-1	278 mph
XF2A-1	268 mph

On April 6th, the XF4F-2 was flown to the Naval Aircraft Factory, Philadelphia, to begin catapult and simulated deck landing tests. Here the airplane was weighed in at 5536 pounds for the fighter version and 5786 pounds for the bomber version, presumably with two 100-pound bombs attached. Following measurements of prop clearance, tail rise, hook angles, etc., the tests were begun. The airplane was catapulted by using a link beneath the fore part of the fuselage, the tail being held down by a cable and shear pin. The arresting hook was mounted within the fuselage aft of the tail wheel.

The XF4F-2 here suffered a serious accident. During deck landing checks on April 11, the engine suddenly quit and the pilot, Lt. Gurney, was compelled to make a crash landing on a Campbell Soup farm just across the Delaware River. Upon striking the ground, the airplane turned over, severly damaging the right wing tip, tail surfaces, landing gear, engine cowl, and propeller. Pilot Gurney emerged shaken but fortunately uninjured. The airplane was salvaged and shipped back to Bethpage where two weeks were required to make repairs.

While the Navy was conducting its acceptance tests on the XF4F-2 and Grumman was delivering F3F-2 biplane fighters (fitted with the R-1820 "Cyclone"), the company received an order in June 1938 for the XF5F-1, a twin-engined carrier fighter which led ultimately to the F7F "Tigercat".

Significant events were also taking place in Japan which would bear heavily on the future of the F4F. In October 1937, one month after the first flight of the XF4F-2, the Japanese Navy released their requirements for a new carrier-based fighter with a maximum speed of 500 kilometers per hour at 4000 meters (310.5 mph at 13,123 feet). The design competition was won shortly after by the Mitsubishi Company and work was immediately begun on the prototype of the famous "Zero" fighter, destined to become the F4F's chief antagonist during World War II.

At Anacostia, a selection of one of the three competing fighters was about to be made. Late in April the Navy released the following maximum speeds:

XF4F-2	290 mph
XF2A-1	280 mph
NF-1	250 mph

Because of its low maximum speed, problems in lateral stability, and difficulty in mounting machine guns in the thin wing, the NF-1 was eliminated. The XF4F-2, despite its high top speed, had had perhaps more than its share of difficulties during the test and evaluation program. It was further handicapped in that it was constructed with a wide wing center section integral with the fuselage which made overland shipment difficult even with the outer wing panels removed.

Considerations of this kind resulted in the XF2A-1 being judged the winner of the competition, and in June 1938, the Brewster Company was awarded a contract for 54 production F2A-1's.

DESIGN AND DEVELOPMENT OF THE XF4F-3

The story of the F4F could have ended right here, but it was, in a sense, just beginning. The Navy was impressed with its performance in spite of a number of difficulties. These problems were not deemed to be of a fundamental nature and it was decided to develop the model to its full potential. One most significant decision led to the incorporation of the Pratt & Whitney R-1830 "Twin Wasp" with a two-stage supercharger.

High performance of a reciprocating-engine aircraft in the form of higher maximum speed in level flight, higher ceiling and rate of climb, and reduced time to climb to altitude is dependent in large measure on maintaining engine horsepower with increasing altitude. Such a capability can, for instance, permit a fighter to climb to an altitude above a formation of enemy bombers, putting it in a position to convert its altitude advantage into a speed advantage and permitting the most favorable attack on the bombers themselves or their escorting fighters.

Since the reciprocating engine is basically an air pump, horsepower is roughly proportional to the number of pounds of air that can be drawn into the cylinders per unit time. As the unsupercharged engine is exposed to air of lower density at the higher altitudes engine air flow (pounds/second) is reduced and consequently power falls off. Air flow can be maintained, however, by incorporating a centrifugal air compressor (supercharger) which can be either mechanically coupled to the engine crankshaft or attached to a turbine driven by the engine exhaust gases. In this manner, engine power can be maintained up to an altitude (called the "critical" altitude) which is dependent mainly on the size, speed, and efficiency of the supercharger and its proper "match" to the engine.

For several years single-speed superchargers had been standard equipment on military aircraft, a single-speed supercharger being one whose rotational speed bears a fixed relationship to the crankshaft RPM. Two-speed superchargers, under development in the mid-30's, provided a means of maintaining power over a wider altitude range.

It was recognized that even greater benefits might be derived by compressing the incoming air in two separate compressors or stages. In 1934 Pratt & Whitney built the first two-stage supercharger developed in the United States. This supercharger was integrated with an R-1535 engine and flight tested in a Vought XF3U-1 in 1935. (5) In 1936 the XTBD-1 was fitted with an experimental R-1830 with a two-stage supercharger. By 1938, two-stage development had reached the point where an engine with such an arrangement could be seriously considered for powering a production airplane.

The engine selected for the XF4F-3 was the Pratt & Whitney "Twin Wasp" SC2-G, called the XR-1830-76 by the military. This engine was equipped with a two-stage, two-speed supercharger and was rated at 1050 HP at 11,000 feet and 1000 HP at 19,000 feet. The engine delivered 1200 HP for take-off. For controlling the supercharger the pilot had available in the cockpit a three-position lever. In the "NEUTRAL" position, normally used for take-off, air entering the engine air scoop was directed through the carburetor to the main supercharger and into the intake manifold. In the "LOW BLOWER" position, at altitudes below 11,000 feet, incoming air was first directed through the auxiliary supercharger, then to the carburetor and main supercharger. In the "HIGH BLOWER" position above 11,000 feet, the speed of the auxiliary supercharger was increased, the airflow path remaining the same.

The advantages of two-stage supercharging did not come completely free, though, and the two-stage two-speed engine was somewhat heavier and appreciably more complex than the single-stage, single-speed type. Furthermore, it was necessary to cool the air after its compression in the auxiliary supercharger and before its admission to the main supercharger. This was necessary to prevent destructive detonation effects resulting from the admission into the engine cylinders of a compressed, high-temperature fuel-air charge. Cooling was accomplished by directing the air through intercoolers located between the two supercharger stages. The transition from 87 to 100 octane fuel was also important in alleviating the detonation phenomenon.

The problems of an efficient engine installation with adequate engine cooling, intake air cooling, and maintenance accessibility provided the Grumman-Pratt & Whitney team many headaches over the next two years. Their solution not only led to maintaining the performance of the F4F but formed the basis of engine installations in the F6F and F4U which were used so successfully during the second half of World War II.

Following negotiations with the Navy, Grumman was awarded a contract for the XF4F-3 in October 1938. The next five months were spent in the detail design and ee construction of the airplane. Late in January 1939 the two-stage R-1830 engine was installed and early in February the airplane was ready for its first flight.

Aside from the engine change, the XF4F-3 differed from its predecessor in a number of respects. The wing span had been increased from 34 to 38 feet; wing area had gone from 232 to 260 sq. feet. Gross weight was nearly 6000 pounds, up 600. Instead of rounded wing tips and tail surfaces it appeared with the squared tips which characterized Grumman aircraft for the next ten years. Still remaining however, was the pleasingly plump fuselage, a large part of which was actually salvaged from the XF4F-2. In place of the Hamilton Standard hydraulically-controlled, two-position propeller a Curtiss-Wright electrically-controlled, constant-speed prop was installed. The former XF4F-2 BuNo. (Serial number) 0383 was reapplied.

On the morning of February 12, the XF4F-3, with Bob Hall again at the controls, took to the air for the first time. For 45 minutes, Hall cautiously felt out the characteristics of the airplane, checking handling qualities, engine performance, and systems operation. Another flight was made that afternoon and was progressing well when a fuel pump problem necessitated a premature landing. In Japan less than two months later, the prototype "Zero" made its first flight.

The next six months were a strenuous period of manufacturer's and Navy trials punctuated with the usual process of "wringing out" and "debugging". Following initial flight tests at Bethpage, the airplane went to Anacostia in March. In May the airplane was returned to make certain alterations for improved stability and control. Wing dihedral was increased by about one degree and aileron area reduced; the area of the fin was increased and the rudder horn balance enlarged. On May 18th, the airplane was flown to the Naval Aircraft Factory, Philadelphia, to begin catapult tests, deck landings, and night flying evaluation.

During the Navy tests the XF4F-3 attained a maximum speed of 333.5 mph, slightly above the guarantee of 330. Although the performance of the airplane had been generally satisfactory, acceptable engine cooling, particularly at high altitudes, continued to be a problem requiring a great deal of attention. Various cowl flap arrangements were tried; several propeller spinners were fitted. Wide chord cuffs on the propeller blade shanks were tried, and it was this latter refinement which was ultimately incorporated on the production F4F's. Pratt & Whitney engineers also derived useful data from similar two-stage installations in the Seversky XP-41 and the Curtiss H-75R which were also undergoing tests at this time.

Late in 1939 the airplane was placed in the NACA full-scale wind tunnel at Langley Field, Virginia, for

(5) Vought XF3U-1. See Robert W. Krauskopf, "Vought Fighters - The First Generation". JOURNAL of A.A.H.S., Vol. 5, No. 4, p.275. Performance and Specifications p.280.

The XF4F-2 at Anacostia Naval Air Station, with flotation bags inflated. Photo - U.S. Navy No. 2833.

F4F-3 in landing condition. Landing gear design was a carryover from F3F. Photo - Navy No. AN-53021, 4-3-39.

aerodynamic evaluation. In 1940 the XF4F-3 received the tail changes which characterized the production F4F-3 and throughout the year the airplane continued in a valuable test and evaluation role until demolished in a crash at Norfolk in December 1940.

While the XF4F-3 was still being tested, Grumman was finally rewarded in August 1939 with its first production contract for 54 F4F-3's, exactly two years after the contract had been signed for the XF4F-2, and less than one month before the start of World War II.

F4F-3, FIRST PRODUCTION AIRPLANE

The international situation had meanwhile badly deteriorated. In July of 1937, Japan reopened the war in China, and in December of that year the U.S. gunboat PANAY was sunk. Hitler was beginning to feel his strength in Europe and following successful reoccupation of the Rhineland early in 1936 he was able to complete his occupation of Austria early in 1938. The Spanish Civil War had begun in 1936, and for three years this conflict was to provide a "live" testing ground for German, Italian, and Russian military aircraft and personnel. The passing of the Munich Crisis of September 1938 brought feelings of relief to many, but most military leaders realized that this was only a postponement of the war which, in fact, began just one year later.

The gravity of the situation began to penetrate U.S. political and military leaders. The new carriers, YORKTOWN and ENTERPRISE, were commissioned in 1937 and 1938 respectively, and the Expansion Act of May 1938 raised the inventory limit for naval aircraft to 3000 and provided for an increase in carrier strength. The carrier WASP was already under construction and the HORNET was ordered early in 1939.

In the Far East Japanese carrier strength was coming on with a rush. To the four ships of 1935, two had been added by 1939 and a further three were under construction.

Grumman anticipated the August production order, and under the supervision of George F. Titterton, then Production Chief, now a Grumman vice-president, the company had already begun construction of the first two production F4F-3's. Following delivery of the static test article to NAF, Philadelphia in December, the first production airplane, BuNo. 1844, made its first flight in February 1940, and immediately the "debugging" process had to begin again. One of the difficulties now encountered was engine roughness, particularly at high altitude. This was finally attributed to the engine carburetor, aggravated by fuel boiling at the low pressures of high altitude and it led to the incorporation of a fuel tank pressurization system.

For the next few months No. 1844 underwent manufacturer's trials at Bethpage and, as a sideline on at least one occasion in April, was used as a chase plane for the XF5F-1 then making its first test flights. In August the airplane was flown to Pratt & Whitney Aircraft, E. Hartford, Connecticut for engine installation test and development. In the meantime, the second pro-

XF4F-3 after first incorporation of changes, stabilizer at centerline yet. Photo - Navy No. AN-53831, 8-7-39.

XF4F-3 with large prop spinner, one of many attempts to improve engine cooling. Photo - Grumman No. 6580.

XF4F-3 as it appeared in June 1940 with new production stabilizer location. Photo - Navy AN-55136, 6-21-40.

First production F4F-3, BuNo. 1844, prior to flight test beginning in February 1940. Photo - Grumman No. 6945.

duction airplane BuNo. 1845 had flown in July, and was ferried the following month to Anacostia to begin Production Inspection Trials. Rear Admiral John H. Towers, then Chief of the Bureau of Aeronautics, requested that the tests be given the highest priority "since those airplanes are urgently needed by the operating squadrons". Airplanes 1844 and 1845 were fitted with two .30 cal. cowl-mounted machine guns together with two .50 cal. wing-mounted guns. These two aircraft were the only two so fitted, all subsequent F4F-3's having four wing-mounted .50's. Airplanes 1848 and 1851, equipped with four .50's, armor plate, and a stronger landing gear were also included in the evaluation program, 1848 going to Anacostia with 1845, and 1851 being sent to NAF for carrier acceptability and vibration tests. For the next four months all three aircraft were subjected to vigorous Navy evaluation. A review of the confidential final report of these trials (6) is of interest.

The F4F-3 was found to be in correct flying balance, controllable, and positively stable in the air about the three major axes with the exception of some longitudinal instability in the landing condition with power on, in full power climb, and at maximum speed. The airplane, with a few minor exceptions, was found to be satisfactory for use in taking off from and landing on a carrier. The weight empty of 5238 pounds for airplane number 1848 was 103 pounds under the guarantee. A maximum speed of 331 mph at 21,300 ft. was attained, somewhat under the original guaranteed speed of 350 mph. Service ceiling was 37,000 feet and take-off distance into a 25 knot wind was only 194 feet. Recoveries from ten-turn spins were effected in $\frac{1}{4}$ to $\frac{1}{2}$ turn with about 1500 feet loss in altitude before resuming level flight after the dive. Loss of altitude after a stall without power was found to be around 400 feet. Armament tests were made with both machine gun configurations, and some difficulty was encountered with satisfactory belt feed during high-G maneuvers. Bombs of weights up to 116# were dropped at dive angles up to 80 degrees and indicated airspeeds up to 426 mph. It was stated that the installation of the telescope gun sight resulted in a maximum speed loss of only $\frac{1}{2}$ mph. Addition of the four wing guns was found to decrease maximum speed by 3 mph below the maximum speed of the airplane with guns removed and openings covered.

The following are some of the more interesting improvements recommended by the Board. They may be regarded as typical of any airplane in its early production stages:

1. Reduce carbon monoxide to acceptable values.
2. Provide adequate cockpit ventilation.
3. Eliminate possibility of moving fuel valves when operating flap controls.
4. Eliminate excessive draft in cockpit with hood open.
5. Eliminate high pitched note due to vibration of hood.
6. Provide more durable tail wheel.

(6) F4F-3, Final Report of Production Inspection Trials, 1/23/41.

F4F-3, BuNo. 1845, the second production airplane. Photo - Pratt & Whitney Aircraft No. D-2060.

F4F-3 of VF-8, with immediate preWar colors and red and white rudder stripes. Photo - U.S. Navy No. 1519.

7. Eliminate binding or excessive friction in tab controls at low temperatures.
8. Provide adequate cooling of cylinder heads and bases.
9. Eliminate interference with battery switch when operating cowl flaps.
10. Change location of arresting hook operating handle to preclude possibility of fouling pilot's arm on executing "cut signal".
11. Provide means of installing gun camera.

In conclusion the Board recommended that, although the F4F-3 did not meet its guaranteed maximum speed, the airplane with certain defects corrected "should be considered acceptable as a service type for use aboard aircraft carriers at weights up to 7480 pounds."

Following trials at Anacostia, BuNo. 1845 was flown to NACA, Langley Field, and for the next few months, the airplane was operated with a wide variety of cowling and cowl flap configurations in an effort to improve cooling. The size of the propeller cuffs was also varied and nose spinners were sometimes fitted. Eventually a satisfactory cowl flap arrangement together with propeller cuffs without spinner was developed and this was incorporated on later production F4F-3's.

It is of interest to note in passing that at one time early in the Fall of 1940, Grumman officials were thinking of an attempt at breaking the official non-stop transcontinental speed record using the F4F-3. This record had been set in January 1937 by Howard Hughes in his "Hughes' Racer" with a time of 7 hours, 28 minutes, and 25 seconds. Studies showed that the performance of the airplane, when carrying a sufficient weight of fuel to cover the distance of approximately 2400 miles, was such that lowering the record time would be very much dependent on obtaining favorable winds. Since the prospects were marginal and the flight perhaps even impolitic during this crucial build-up period, the plan was finally dropped.

The opening of war in Europe in September 1939 led President Roosevelt to declare a "limited national emergency" and to set up a Neutrality Patrol in the Atlantic. In May 1940, after successful conquests of Poland and Norway, Hitler began his invasion of France. With the full seriousness of the world situation now becoming apparent, Congress (on May 14) authorized a Navy build-up to 4500 aircraft, and just one day later increased this to 10,000 aircraft. Not long after this, a further increase to 15,000 was made. This was at a time when the naval aircraft inventory stood at 1741! Although it cannot be said that the flood gates had been opened, they were at least being unlocked.

FRENCH F4F's, BRITISH MARTLETS, AND THE XF4F-5.

As early as 1938 with the crisis developing in Europe, British and French purchasing commissions had come to the United States to try to fill the gaps in their expanding aviation programs. In 1939 the French became interested in the F4F as a possible suitable carrier fighter. At this time, only one old French carrier was active, the BEARN, small, slow, and obsolescent at best. Two larger and more modern ships, the JOFFRE and the PAINLEVE', were then under construction. An order for 100 F4F's was finally placed in the Fall of 1939. One of the problems at this time concerned the availability of suitable engines. European orders combined with the slow expansion of the U.S. military aviation forces soon placed a serious strain on U.S. engine manufacturers. In many cases priorities had to be set up and alternate power plants considered. The French decided to use the Wright R-1820-G205A "Cyclone" engine, a nine-cylinder, single row radial, developing 1200 HP for take-off and equipped with a single-stage, two-speed supercharger. This was the first of the "Cyclone" installations in the F4F. Flight testing had barely begun in May 1940 when France was invaded.

With the fall of France in June, the British assumed deliveries of the French F4F's along with a number of other French airplane contracts. The now-British airplane was designated the "Martlet". The initial "Martlet" delivery was made July 27, 1940, the first delivery of any production F4F airplane. Over the next three months, through October 1940, 81 "Martlets" were delivered to the Royal Navy Fleet Air Arm.

With difficulties developing with the two-stage R-1830, the Navy also became interested in the Wright installation and in April 1940, by a modification to the original F4F-3 production contract, ordered the third and fourth airplanes, BuNo. 1846 and 1847, equipped with the R-1820-40, similar to the G205A. In June these aircraft, designated XF4F-5, made their first flights and following delivery to Anacostia in July, they were extensively test-flown during the Summer of 1940. Although gradual improvement of the R-1830 installation made it unnecessary at this time to go to an R-1820 production airplane, the two XF4F-5's were the subject of some interesting comparative tests in 1943 which will be described later.

The two-stage installation was not completely out of the woods, however, and late in 1940, the Navy ordered that one airplane be fitted with a Pratt & Whitney R-1830-90 "Twin Wasp" engine equipped with a single-stage, two-speed supercharger. Giving 1200 HP for take-off, the engine delivered 1100 HP at 6100 feet in low blower, and 1000 HP at 12,500 feet in high blower. This airplane was designated the XF4F-6, and the sole airplane, BuNo. 7031, was flown to Anacostia in November 1940 for acceptance tests. The final report of these trials dated March 6, 1941, (7) shows that the airplane attained a speed of 319 mph at 16,100 feet and possessed handling characteristics generally similar to the two-stage F4F-3. The XF4F-6 continued in the role of a flying test bed for many months. As late as February 1942 it was being used to test a specially designed seat and controls which allowed the pilot to be in a crouched position during the pull-out from dives.

Fearing delays in delivery of the two-stage engines, the Navy actually entered into a limited production program for the lower-performing aircraft. A total of 65, designated F4F-3A's, were produced during 1941, most finding their way to Marine Corps squadrons. The British bought similar aircraft which they designated "Martlet" II's and III's.

FIRST DELIVERIES AND EARLY SERVICE PROBLEMS

With the fall of France in June 1940, orders for new aircraft increased rapidly and by the end of the year some 578 F4F-3's and F4F-6's (later redesignated F4F-3A 3A's) were on order from Grumman. Production and delivery rate accelerated slowly however, and by December only twenty-two F4F-3 acceptances had been recorded. By early December these production aircraft began to arrive with the operating units, the Naval Air Station at Norfolk, Virginia being the first to take delivery. As aircraft continued to arrive during December and January they were assigned to VF-4 of the RANGER and VF-7 of the WASP, replacing the biplane F3F's. It is believed that the first actual carrier landing was made at this time on the RANGER, all trials up to then having been simulated at the Naval Aircraft Factory.

The initial production F4F-3's were armed with four .50 cal. wing-mounted machine guns. Although the European War had shown the necessity for self-sealing fuel tanks and armor plate, these items were not yet installed. One claim should be mentioned here, however, and that is that the F4F was the first airplane to enter service anywhere equipped with an engine having a two-stage supercharger.

It is necessary at this point to record what is believed to be the first fatal accident involving an F4F. On December 16, 1940 at Norfolk Naval Air Station, Lt.

(7) XF4F-6, Final Report of Acceptance Trials, 3/6/41.

(jg) W. C. Johnson, while on a familiarization flight in the old XF4F-3, crashed on take-off and suffered fatal injuries. Apparently Lt. Johnson, instead of turning the valve lever to raise the flaps, actually turned the fuel valve, located nearby, to the "off" position. The engine almost immediately stopped and the aircraft plunged into a rail yard beyond the end of the runway.

Late in January 1941 the WASP and the RANGER embarked on a winter cruise to Guantanamo carrying with them the F4F-3's and pilots of VF-7 and VF-4. It was only during this short period of three or four months from December 1940 to March 1941 that the F4F's were to bask in the splendor of the gaudy color and markings characteristic of U.S. Naval aircraft. With yellow top wing surfaces and grey fuselages, colored cowl rings and fuselage bands, the F4F's of the WASP sported all-black tail surfaces and those of the RANGER were daubed with bright green. In March the aircraft went to semi-wartime light grey overall and the days of brightly-colored Navy combat aircraft had ended.

During the Guantanamo exercise, pilots of VF-4 and VF-7 had the usual share of problems incident to transition to a new aircraft. Pilot error resulted in several non-fatal accidents. New design "bugs" also began to show up. Windshield failures eventually resulted in a new reinforced design.

Early in March Lt. Seymour Johnson died in the crash near Anacostia of the first production F4F-3, BuNo. 1844. Lt. Johnson was flying near 40,000 feet when apparently the oxygen system failed. The force of the crash from this extreme altitude completely demolished the airplane, (the engine was buried fifteen feet underground).

Later that month, at Norfolk, the first of two incidents occurred involving the wing-stowed flotation bags. Lt. Bull of VF-42 was diving an F4F-3 from 20,000 feet when suddenly the flotation bags became inflated, causing extreme wing flutter. Lt. Bull was unable to pull the airplane out of the dive and at first was preparing to jump when he found he was unable to get out of the cockpit. He finally managed to pull the airplane out of the dive during which time the bags tore themselves loose. The pilot blacked out and when he regained his senses he was on his back at about 3000 feet. Bull then righted himself and came in for a normal landing. Subsequent inspection of the airplane showed that the right aileron was badly wrinkled and the wings showed signs of buckling. The speed during the dive was estimated at more than 500 mph.

A week and a half later a second flotation bag incident occurred, this time with tragic results. Ensign Harry E. Howell of VF-42 was in level flight near Norfolk when the flotation bags inflated. He was instructed by radio to climb to about 6000 feet and dive in an attempt to tear off the bags. He did succeed in tearing off one bag but the other bag remained intact. This evidently threw the aircraft out of control and in the ensuing crash Ensign Howell was killed. The flotation bag problem was eventually solved by doing away with bags entirely.

F4F pilots were never particularly happy with the manually cranked landing gear when most other combat aircraft by that time had powered retraction systems. Landing gear crank-up was particularly annoying to those F4U and F6F pilots who late in the war were reassigned to escort carrier duty flying FM-2's. It was not unusual also to see and F4F or FM fly a somewhat undulating climb-out flight path following take-off, a sure sign that the cranking motion of the pilot's right hand was being transmitted through his body to his left hand holding the control stick. Wheels-up landings were frequent in the aircraft's early service period. Such landings were sometimes followed by a fire caused by damage to a portion of the fuel system lying near the aircraft's underbelly.

During 1941 F4F deliveries continued to mount and by the first of March VF-71 was equipped with 18 -3's. About this time deliveries of the two-speed supercharger equipped F4F-3A began and the record shows that by May Fighting Squadron VF-6, then at LaMesa, California, were flying the -3A's. The Marines also started to receive F4F's and by October the aircraft roster (8) showed the following squadrons:

Quantico, Virginia	VMF-111	16 F4F-3A
	VMF-121	18 F4F-3
	BAD-1	7 F4F-3
Ewa, Hawaii	VMF-211	15 F4F-3
	VMF-221	1 F4F-3

By December 1941, 183 F4F-3's and 65 F4F-3A's had been delivered to Navy and Marine Corps fighting squadrons. Now named "Wildcats", they were the first of the famous Grumman "cat" family.

The first combat use of the F4F, however, fell to the British. While U.S. squadrons were awaiting delivery of the F4F-3's, the British had already made good use of their Wright-powered "Martlet I's". The first enemy aircraft to fall to the F4F's guns was a German Ju.88 attempting a sneak attack on a Royal Navy base in the Orkney Islands on Christmas Day 1940. This was also the first aircraft to be shot down by an American fighter in service with British forces. Actually a cooperative effort of three "Martlets", the Hamilton Standard propeller of aircraft BJ562 was later presented to the U.S. Navy by the Royal Navy and was subsequently displayed for a time in the Navy Department Building in Washington.

While the "Martlet I" was operating from land bases, the British Fleet Air Arm was looking for a suitable aircraft to serve in the fighter capacity aboard their aircraft carriers. The best single-seat fighter they could muster in 1940 was the carried-based version of the Gloster "Gladiator", a biplane with fixed landing gear which had entered naval service in 1939 and was known as the "Sea Gladiator". Also operating at this time were the monplane Blackburn "Skua" two-place fighter-dive bomber, and the Fairey "Fulmar" two-place fighter. Heavy and of generally low performance, these aircraft, like the obsolete biplane "Sea Gladiator", were at a distinct disadvantage when opposed by the higher-performing land-based German and Italian aircraft.

In order to fill this need, the British ordered a quantity of 100 Pratt & Whitney-powered F4F's in mid-1940 which were designated "Martlet II's" by the British and as G-36B by Grumman. Similar to the XF4F-6 and subsequent F4F-3A, the "Martlet II" used the "Twin-Wasp" S3C4-G, P&W's designation for the military R-1830-90. Since this engine was fitted with only a two-speed, single-stage supercharger, the airplane was somewhat inferior in speed and altitude performance to the two-stage F4F-3. A shortage of the two-stage engines, however, forced the British to use the single-stage. First flight of the "Martlet II" was made in October 1940 and following several months of shaking-down, the first production airplane, AM954, was ready for delivery the following March. The first ten aircraft, AM954 through AM963, had non-folding wings although it is reported that folding wings were retrofitted at a later date. The remaining 90 aircraft were equipped with folding wings. By the end of March, aircraft AM955-963 were ready to go, the usual procedure being to fly accepted aircraft to nearby Roosevelt or Floyd Bennett Field where they were disassembled and packed for overseas shipment. Aircraft AM954 was retained at Grumman for test purposes. The follow-on folding-wing aircraft were slow in coming, however, and it wasn't until the Fall of 1941 that deliveries began. Through the Fall and Winter of 1941-42 continuous acceptance flights were made by British test pilots including Squadron Leader Sayers and Wing Commander McKenna. By the Spring of 1942, deliveries were completed.

(8) William T. Larkins, "U.S. Marine Corps Aircraft, 1914-1959". Pub. Concord, Calif. 1959.

On September 20, 1941, "Martlets", flying from the British escort carrier HMS AUDACITY, shot down a German Focke Wulf Fw 200 four-engine bomber, the first of a number of such aircraft to fall to "Martlet" guns. Through 1942, and in fact throughout the remainder of the war, "Martlets" continued to serve with distinction aboard British carriers and many details of their actions are given in References 31 and (32).

While the British were occupied with their "Martlet II" contract, a Greek delegation approached U.S. officials in an effort to obtain combat aircraft to bolster their defenses. Italy had invaded Greece in October 1940 but the Italians had been ignominiously thrown back. Pressure continued, however, and the threat of a new invasion effort with German assistance was gravely contemplated. The Navy agreed to divert the first 30 of their F4F-3A's to Greek forces. When the need for carrier arresting gear was questioned, the head of the Greek Navy unit reportedly replied, "Mussolini has a carrier, and we'll have it in a little while. Leave the hook there. We'll be using it". So the hook stayed and the first aircraft was ready for delivery on March 18, 1941; soon thereafter all thirty were en route to Greece. They never reached their destination, however, since on April 6th the German began an invasion which ended within a month in the complete evacuation of Allied forces. The thirty F4F-3A's were taken over by the British at Gibralter and redesignated "Martlet III's". Operated extensively by land-based Royal Navy units in North Africa, some were still on the lists in 1945.

FURTHER DEVELOPMENTS

Mention has already been made of the folding-wing F4F, first delivered for service to the British as the "Martlet II". The Navy recognized, as early as 1939, the desirability of a folding-wing version of the F4F to permit utilization of the standard carrier elevators and to make possible more efficient stowage of aircraft on both hangar and flight decks. A contract change in March 1940 provided for the installation of folding wings on one of the F4F-3's then on order. The wing-folding mechanism devised was a model of simplicity and effectiveness. The story goes that it was worked out one day over a drawing board using erasers, paper clips, and bits of cardboard, tools standard to those particularly ingenious designers who work out the kinematics of wing-folding mechanism and landing gear retraction systems. For the F4F, the outer wing panels were hinged to inboard wing stubs in such a way that as the wings were folded back parallel to the fuselage they would twist to bring the wing chord into a vertical plane. This reduced the wing spread width of the airplane from 38 feet to the wing folded width of 14 feet, 4 inches. The same system was used with equal effectiveness on Grumman's later TBF and F6F. It was not until April 14, 1941, however, that the folding-wing XF4F-4, BuNo. 1897, made its first flight. A month later it was delivered to the Navy for acceptance tests including deck handling trials by VF-42 aboard the YORKTOWN. Although the wings of the XF4F-4 were hydraulically folded, it was decided that the added weight and complexity of a hydraulic system could not be justified and therefore the wings of the production F4F-4's were spread and folded manually by the flight deck crew. The first F4F-4's were accepted by the end of the year. A further 1164 followed in the year 1942, bringing the total F4F-4 deliveries to Navy and Marine Corps squadrons to 1169.

Another development of interest in 1941 was the F4F-7, long range, photo-reconnaissance airplane. Conscious of the requirement for an extended-range, reconnaissance aircraft, the Navy decided to convert an F4F to a long-range configuration. A fixed wing was used, filled with no less than 555 gallons of fuel. The emergency tank behind the pilot was removed and replaced by a camera. The total fuel capacity including the main fuselage tank was 685 gallons, raising the airplane gross weight to a ponderous 10,328 pounds. No armament was fitted. Externally, the F4F-7 could be distinguished by the curved plexiglas replacing the bullet-resistant windscreen and the fuel dump lines which projected out the aft end of the airplane just below the rudder. An automatic pilot was installed. At one time an endurance of 24 hours was claimed for the airplane, which must have brought great joy to everyone except the prospective pilot.

First flight of the F4F-7 was made on December 30, 1941, and two weeks later it was flown to Anacostia for evaluation. On its first full load flight test an amusing incident occurred. To be on the safe side the wings were filled with water. The flight was satisfactory, but the wing tanks were supposed to be emptied before landing because of the high gross weight. When the pilot attempted to dump the water, using the manual dump valves, nothing happened. The water had frozen the valves. Clearance to land on the long runway at nearby Washington National Airport was granted and the overloaded Navy fighter was then "greased in" without further incident following a long, gentle "Army" approach.

Another incident involving an F4F-7 concerned a non-stop flight to the West Coast which must have established some kind of record. At that time, flight plans were filed with the Army and the soldier who received the call later called back to say that there must be a mistake as he had a listing for a non-stop flight to the West Coast by a Navy fighter. The sailor who was questioned replied, "That is correct; all Navy fighters have a 3000 mile range." The actual flight made by Lt. Cdr. Andy Jackson, now a Rear Admiral, took approximately 11 hours. It was never publicized because of wartime security.

At one time, more than 100 F4F-7's were on order but only 21 were actually produced. At least two of these found their way to Guadalcanal in October 1942. It is reported that those that survived were eventually converted to folding-wing F4F-4's.

PEARL HARBOR AND WAKE ISLAND

By December 1941 the U.S. Navy and Marine Corps had on hand some 5260 aircraft. A total of eight aircraft carriers were in commission including the small recently-converted escort carrier, the U.S.S. LONG ISLAND. The devastating Japanese surprise attack on Hawaii on the morning of December 7th found three U.S. carriers in the Pacific, none fortunately at Pearl Harbor itself. The LEXINGTON was 420 miles southeast of Midway, and the ENTERPRISE, returning from its mission to Wake Island, was 200 miles west of Oahu. The SARATOGA was about to enter San Diego harbor some 2500 miles to the east. With the exception of a flight of SBD's from the ENTERPRISE which inadvertently stumbled into the combat area, none of the carrier aircraft participated in the air battle.

The introduction of the Japanese "Zero" to the F4F caught the latter somewhat at a disadvantage. Early in the attack a flight of strafing "Zeros" surprised a group of eleven F4F-3's of Marine Fighter Squadron 211 (VMF-211) line up at Ewa, the Marine Corps air station in southwestern Oahu. Nine of the eleven were destroyed or severly damaged. As far as is known, no Navy or Marine Corps F4F's were able to take to the air during the Pearl Harbor attack.

Four days earlier, however, a group of 12 F4F-3's from VMF-211, under the command of Maj. Paul Putnam, had been delivered by the carrier ENTERPRISE to the lonely outpost of Wake Island. The small group was immediately beset by operating problems. The runway was 5000 feet long, some 200 feet wide, and surfaced with crushed coral. No shelters or revetments were available. There was little or no ground handling equipment, presenting any number of maintenance and servicing difficulties. Equipment for refilling oxygen bottles was improvised and refueling was done largely by hand. It was found

that the 100-pound bombs did not fit the bomb racks. Bands from practice bombs had to be fitted. Of the aircraft themselves, only two had self-sealing fuel tanks and armor-plate had not been installed. (9) however, suggests that some seat armor had been fitted). The fact that no instruction manuals or handbooks were available certainly didn't help matters. To top it off, the pilots themselves had had only a few hours in their newly-acquired aircraft and were still largely in the familiarization stage. In light of these problems the performance of pilots and ground crew in the epic struggle which was to begin is even more remarkable.

Midway was warned by radio of the Pearl Harbor attack early on the morning of December 8 (Midway time). Since radar was not available, a standing combat air patrol was ordered. Just before noon on December 8, a flight of four F4F's were patrolling at 12,000 feet. Suddenly a formation of 36 Japanese twin-engine bombers swept in at an altitude of only 2000 feet. The effect was devastating. Seven of the eight "Wildcats" on the ground were destroyed and the remaining one was damaged but later salvaged. Almost two-thirds of the defending fighter force had been cut down with no loss to the enemy. The next two weeks saw a succession of triumph and tragedy. The next day pilots Kliewer and Hamilton combined to shoot down a Japanese bomber, first of the enemy to fall to the guns of the F4F operated by U.S. forces. On the 10th, Capt. Elrod shot down two in a raid of 26. On the 11th, the Japanese staged their first invasion attempt. The F4F's struck the invasion fleet with 100-pound bombs and strafing attacks. Capt. Elrod managed to drop a bomb on the fan-tail of a destroyer causing an explosion which sent it to the bottom. A medium transport was also hit. Two more bombers fell to Lt. Davidson. In all, 10 sorties were flown, 20 bombs dropped, and 20,000 rounds of .50 cal. ammunition expended. This magnificent effort combined with that of the surface defenses completely routed the Japanese invasion forces. At the end of the day, however, only two "Wildcats" were still operational.

On the 12th, Pilot Tharin managed to shoot down a prowling Japanese 4-engine flying boat. The following week was a struggle to keep the remaining F4F's flying. At various times only one to three aircraft were operational simultaneously. On December 22nd the Japanese, increasingly annoyed by the heroic resistance of Wake's defenders, sent over a flight of thirty-three carrier-based bombers and six "Zeros". The two remaining F4F's plunged into the formation and Capt. Freuler shot down at least one "Zero", first to fall to an F4F. Both of the remaining "Wildcats" were lost, however, Freuler having to crash land his aircraft. Shortly after, a new invasion was launched, the defenders were overwhelmed, and the epic of Midway came to an end. Capt. Elrod was killed during the ground fighting. When the story of his exploits became known after the war, he was posthumously awarded the Medal of Honor. (The successful invasion of Wake Island provided the Japanese with their first opportunity to examine the F4F. Although a number of captured Allied aircraft were restored and flight tested by the Japanese during the course of the war, there is no evidence to suggest that this was ever done with the F4F.)

1942 - YEAR OF DECISION

The year 1942 opened with the Japanese continuing their offensive in the Southwest Pacific. The invasion of the Philippines was proceeding to its inevitable conclusion. The British defense of Malaya and Singapore had been dealt a severe blow with the sinking of the REPULSE and PRINCE OF WALES. In order to relieve some of the pressure, a series of island raids by our limited carrier forces was planned. The first of these was a strike on Japanese installations on the island of Maloelap. Five F4F's from the carrier ENTERPRISE participated in this raid and were credited with destroying two Japanese aircraft. On February 20, an incident took place which was fully-publicized and which did much to boost sagging Allied morale. About 4:30 in the afternoon, the LEXINGTON approaching the Japanese base at Rabaul for a planned strike, detected an incoming raid of Japanese bombers. (These aircraft, erroneously reported as single-engine, carrier-based "Kates" (10B) were actually twin-engine, land-based "Bettys". This was confirmed in a conversation with John S. ("Jimmy") Thach in August 1961. One of the pilots in the defending force of F4F-3's was Lt. Edward H. ("Butch") O'Hare. During the course of the interception O'Hare found himself alone between the carrier and the approaching flight of bombers. Swinging around on the tail of the bomber flight, O'Hare plunged in and out of the formation, each time bringing his four .50 cal. machine guns to bear on an enemy airplane. In the space of a few minutes, five bombers had fallen and O'Hare became the second U.S. Navy ace in two world wars, equalling the record set by David S. Ingalls in World War I. For this magnificent display of skill and courage, O'Hare was awarded the Medal of Honor.

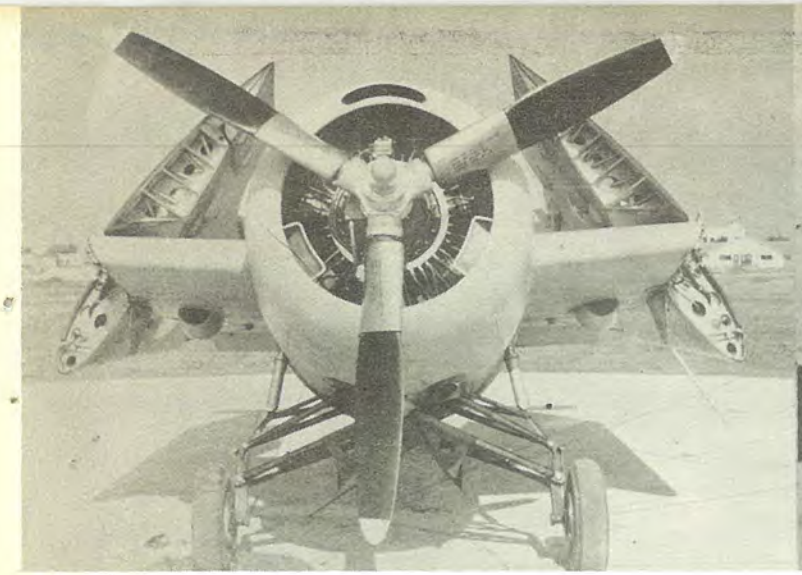
On April 18, 1942 the carrier HORNET launched 16 Army B-25 bombers for their historic raid on Japan. Accompanying the HORNET was the ENTERPRISE, carrying the 27 F4F-3's and -4's of VF-6 as fighter cover for the operation.

Late in April the Japanese were gathering sea and air forces for their attempt to seize Port Moresby on the southern shore of New Guinea. Standing in defense were the LEXINGTON with 20 F4F-3's of VF-42 and the YORKTOWN with 22 F4F-3's of VF-2. The clash of opposing fleets began on May 7th. During an attack on the two U.S. carriers, nine of 27 Japanese carrier planes were shot down for the loss of two F4F's. In this action Lt. Paul G. Baker was credited with three enemy aircraft. This is believed to be the first time that aircraft operating from opposing carriers engaged in air combat. On May 8, while escorting TBD's during an attack on the Japanese carrier SHOKAKU, F4F's are reported to have knocked down a dozen defending "Zeros". Simultaneously, however, a fatal attack on the LEXINGTON could not be prevented. The Battle of the Coral Sea was tactically a draw, each side losing an aircraft carrier. The Japanese, however, were blocked in their attempt to seize Port Moresby, and strategically the battle represented a significant Allied victory.

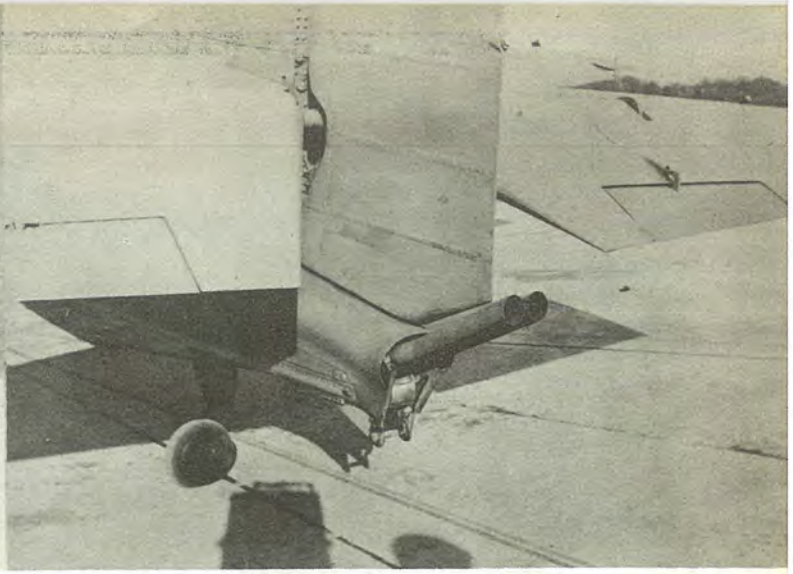
The battle scene then shifted to the Central Pacific where late in May a formidable array of Japanese carriers, battleships, and troop transports were approaching the island of Midway for an invasion attempt. Aware of the Japanese plan, the U.S. managed to pull together the carriers YORKTOWN, ENTERPRISE, and HORNET to block the Japanese. The 25 F4F-4's of VF-3 commanded by Lt. Cdr. John S. Thach were ready on the YORKTOWN. The ENTERPRISE and HORNET carried VF-6 and VF-8, each with 27 F4F-4's. Based at Midway were 20 Brewster F2A-3's of VMF-221 reinforced by seven F4F-3's. Early on the morning of June 4th the Japanese launched a massive attack of carrier fighters and bombers on Midway. Warned of the approach of enemy aircraft by radar, the island's F2A's and F4F's scrambled to defensive positions. The result was devastating. Vastly outnumbered and outperformed, 13 of the obsolete F2A's were shot down and two of the F4F's. In spite of this initial defeat, attacks on enemy carriers soon began. Thach's fighter

(9) W. S. Cunningham, "Wake Island Command". 1961.

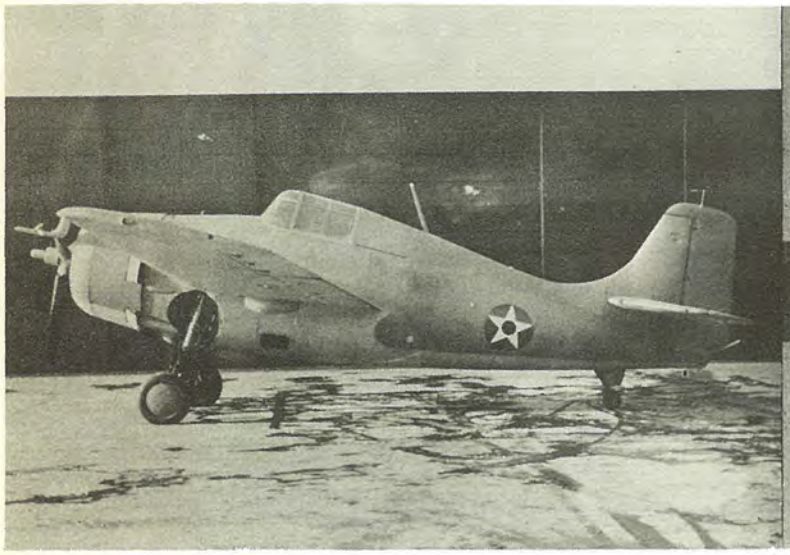
(10) Samuel Eliot Morison, "History of United States Naval Operations in World War II"
A. Volume II, Operations in North African Waters, (1947)
B. Volume III, The Rising Sun in the Pacific. (1948)
C. Volume IV, Coral Sea, Midway and Submarine Actions. (1949)
D. Volume V, The Struggle for Guadalcanal. (1949)



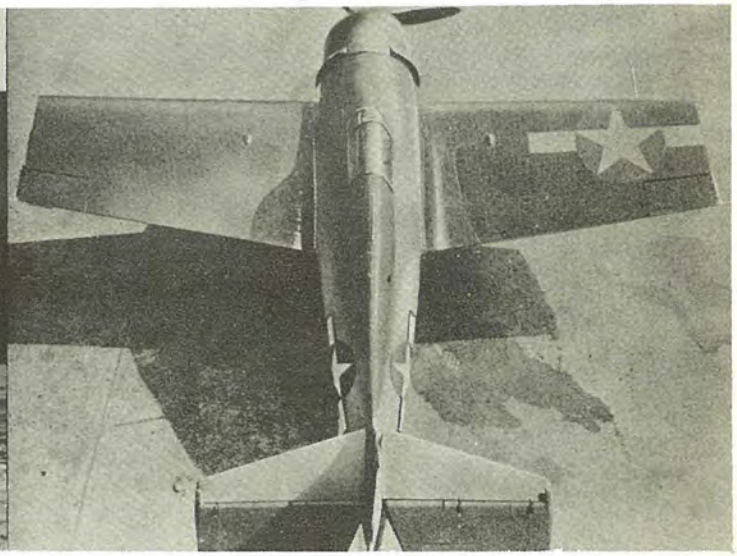
XF4F-4 with wings folded. Photo - U.S. Navy No. AN-58417, 8-30-41.



F4F-7 fuel jettison discharge lines. Photo - U.S. Navy No. AN59702, 4-21-42.



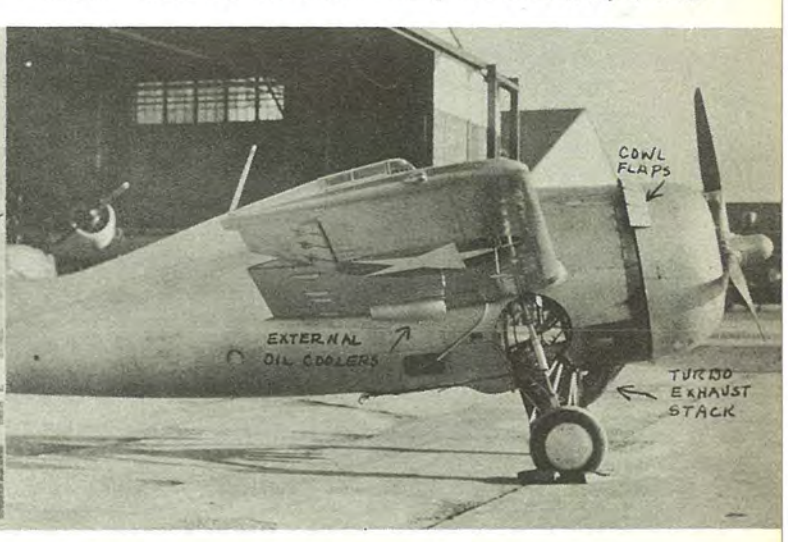
F4R-7 long range reconnaissance airplane, BuNo. 5263. Photo - Grumman No. 8401.

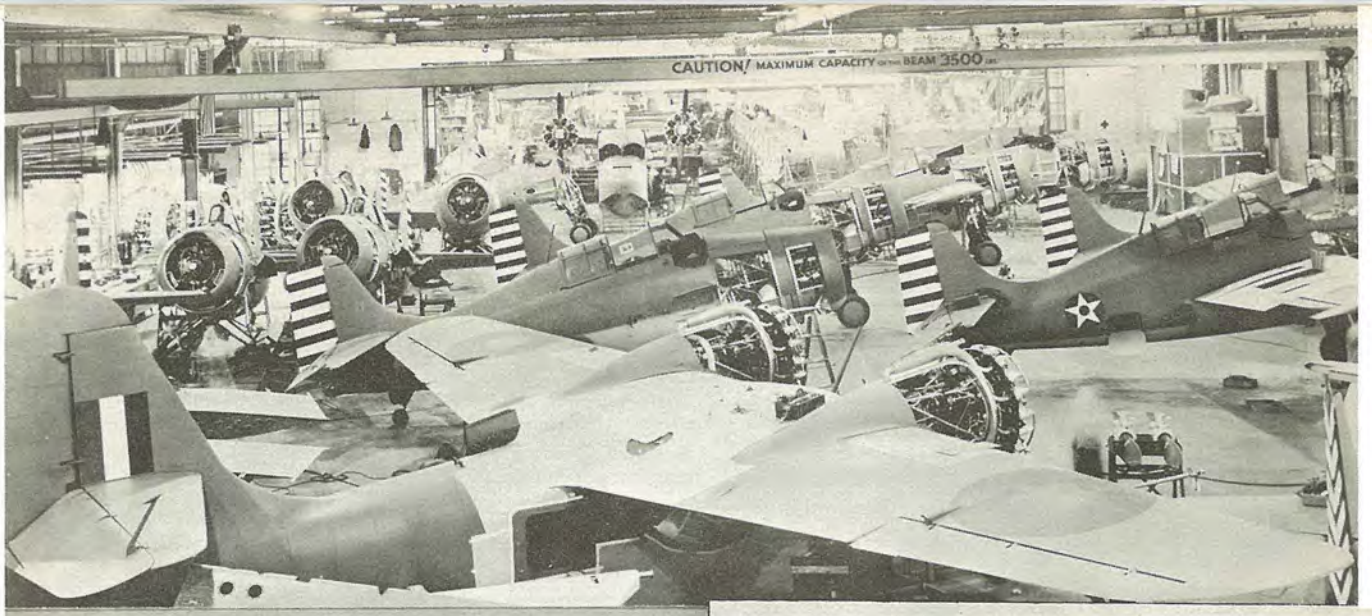


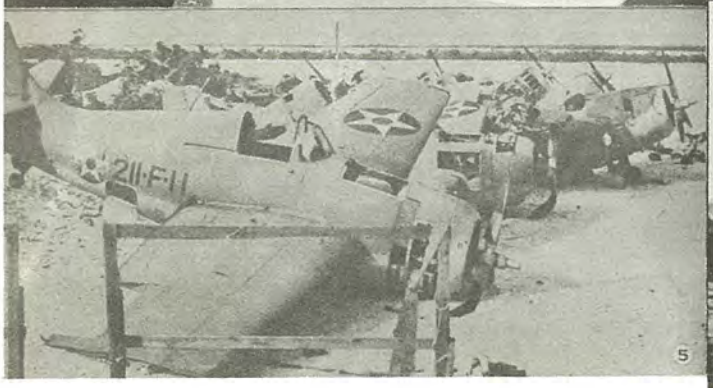
F4F-3 with breakaway wingtips, tested in 1944. Photo from N.A.C.A. report.

F4F-3, BuNo. 4038, with twin floats. Photo - Grumman No. P-926, 12-2-44.

XF4F-5, BuNo. 1846, with R-1820-54 engine supercharger installation. Photo - Navy No. AN-61322, 2-8-43







Top - Interior of Grumman Factory, 1943. F4F-4's in Assembly, "Goose" in foreground. Photo - Grumman.

Above left - Wrecked F4F-3's of VMF-211 at Wake Island, 1942. Photo from Japanese magazine of 1943.

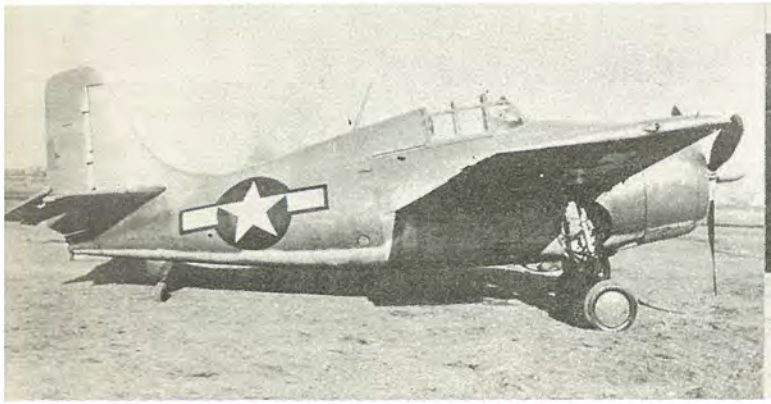
Above right - The XF4F-4, BuNo. 1897, as it appeared in April, 1941. Photo - Grumman No. 7894.

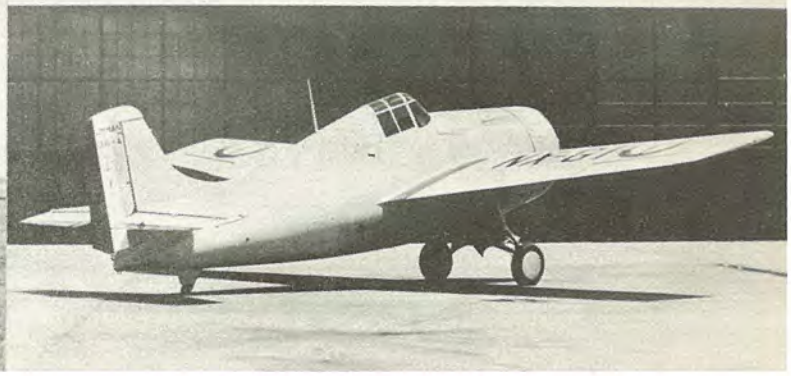
Right - FM-2 in Navy dark blue. Photo - U.S. Navy No. 189117, 9-14-45. Courtesy of Roy Cross.

Below left - XF4F-8, BuNo. 12229, with enlarged vertical fin and rudder. Photo - U.S. Navy No. PRT2280,

Below left _ XF4F-8, BuNo. 12229, with enlarged vertical fin and rudder. Photo - Navy No. PRT2280, 1-4-44.

Below right p Model G-36A in markings of the French Navy, with Reg. No. NX-G1. Photo - Grumman No. 7296.





group, returning from escorting dive and torpedo bombers, is reported to have held off greatly superior numbers of "Zeros" by employing what was called the "Thach weave". This was a maneuver by which two fighters flying parallel could crisscross back and forth each covering the other's tail. Later that day, 12 of Thach's F4F-4's shot down or scared off over half of 18 attacking "Val" dive bombers. Before the end of the battle, four Japanese carriers had been sunk for the loss of the YORKTOWN. This momentous victory was to mark the turn of the tide in the Pacific.

The Coral Sea and Midway actions showed the need for increased numbers of fighters on aircraft carriers and greater range to escort the slower, more vulnerable dive and torpedo bombers. Larger numbers are reflected in the F4F-4 complements given for July 1942 (10C). VF-5 of the SARATOGA had 34 aircraft; VF-6 of the ENTERPRISE now had 36; and VF-71 of the WASP now entering the Pacific action was equipped with 29 F4F-4's.

On the 7th of August the first U.S. offensive action of the war began with the landing of Marines on the Japanese-held island of Guadalcanal. This day marked the beginning of a fantastic array of land, sea, and air battles, which took place over the next five months. Only the barest outline of these actions emphasizing F4F participation can be given here. First to land on the nearly completed Japanese air strip on the north side of the island were 19 F4F-4's of VMF-223 which arrived on August 20. These airplanes were catapulted from the USS LONG ISLAND, first of the U.S. small escort carriers. The next day the pilots had their first taste of combat when Capt. John L. Smith shot down a "Zero". In this engagement one F4F was badly shot up and was forced to crash land on the field. On August 24 the Japanese sent in a force of 15 carrier-based bombers escorted by 12 "Zeros". The defending Marines shot down 16 including half of the "Zeros" for a loss of four F4F's. Two days later 13 of a raiding force of 16 twin-engine bombers were destroyed. Many more engagements followed including one on the 30th in which John Smith shot down four enemy aircraft and Marion Carl got three.

As the struggle continued additional Marine Corps units were flown in, including VMF-224 toward the end of August, VMF-121 in September, VMF-212 in October, VMF-112 and 122 in November. On October 16th, as the 19 F4F-4's of VMF-212 were circling for a landing, they ran into a raid of 9 "Val" dive bombers. Lt. Col. Harold W. Bauer, with fuel tanks nearly dry, proceeded to shoot down four of the attacking aircraft, a feat which earned him the Medal of Honor.

Although the exchange ratio was running possibly 5 to 1 in favor of the Guadalcanal F4F's, the squadrons suffered many operational losses due to inexperienced pilots and poor operating conditions. There was a continuing problem of making up for combat and operational attrition. A number of Navy F4F's were flown in for Marine use and at one point a Navy carrier squadron was operating from the airstrip. On October 23, 24 F4F's from two Marine and one Navy squadron were credited with shooting down 20 "Zeros" and 4 bombers, the heaviest enemy toll since the beginning of the Guadalcanal operation. In this engagement, Capt. Joseph J. Foss of VMF-121 got 4 "Zeros" and three days later got 4 more. By January 15th, Foss had brought his score to 26, first to equal that of Eddie Rickenbacker, America's World War I top scoring ace.

While the Marines were operating from Guadalcanal, the seas about the island were churning with a succession of vital naval actions. Two involving aircraft carriers were the Battle of the Eastern Solomons in August and the Battle of Santa Cruz late in October. The carriers ENTERPRISE and HORNET participated in the latter action, the ENTERPRISE with 34 F4F-4's of VF-10 and the HORNET with 36 F4F-4's of VF-72. It was during this battle that Lt. Stanley W. Vejtasa of VF-10 in one flight shot down 5 "Kate" torpedo bombers.

By February 1943 Japanese resistance on Guadalcanal had ceased. It was in this month that the new Vought F4U "Corsair" made its combat debut in the hands of the Marines. Not until the summer months, however, did the F4U generally replace the F4F. Sporadic air combat involving the F4F continued, one notable feat occurring on April 7th when 22-year old Lt. James E. Swett earned a Medal of Honor by downing seven "Val" dive bombers in 15 minutes.

While the struggle for Guadalcanal continued in the Southwest Pacific, the invasion of Northwest Africa began on November 8. Participating in this operation were 27 F4F-4's of VF-41, both squadrons based on the RANGER. Air cover was also furnished by the 29 F4F-4's which formed VGF-27, -28, and -30 aboard the escort carrier SUWANNEE and the 12 F4F-4's of VGF-26 on the SANGAMON. Overcoming the light aerial opposition encountered, the these aircraft were able to give effective assistance to the ground troops during this amphibious operation.

Both America and Japan suffered heavily in the first year of the war and for a time a comparative lull settled over the Pacific while each tried to rebuild its force of men, ships, and aircraft. It was during these months that the new Grumman F6F was phased in as a replacement for the veteran "Wildcat" on the large carriers. By the Fall of 1943 the transition had been completed and the F6F was ready for combat.

SPECIAL PROJECTS

While "Wildcats" were scoring victories on the Pacific and European fronts, a number of special projects were initiated at home. During the Guadalcanal and Aleutians operations, a Japanese fighter floatplane appeared. Designated "Rufe" by the Allies, the airplane was actually a modified "Zero" with a large central float and two small floats attached to the wing tips. The Japanese were operating the aircraft from sheltered waters and using them for air cover until strips for land-based airplanes could be carved out. In the Fall of 1942 the Navy became interested in this approach, transferring an F4F-3, BuNo. 4038, to the Edo Corporation of College Point, Long Island, for the float design and installation. The airplane emerged early in 1943 with twin floats attached by struts to the fuselage. To compensate for the decreased yaw stability produced by the large float area forward of the airplane c.g., small movable rudders linked to the movements of the main rudder were attached to the tips of the horizontal stabilizer. The first flight was made by Grumman test pilot F. T. ("Hank") Kurt on February 28, 1943. But, during this time, the Navy's construction battalions were beginning to exhibit their ability to transform jungle and coral into air bases in amagingly-short times. This capability, plus greatly expanded carrier aviation, made the floatplane fighter unnecessary and the program was eventually dropped.

Another project made use of F4F-4 BuNo. 5262 (with a fixed wing) as a test bed for an experimental full-span ("Duplex") flap installation. Although details are lacking, it is known that the flaps were controlled by electric motors. The project was abandoned following a flight during which one wing flap came down and other didn't, throwing the airplane out of control and killing pilot Jimmy Taylor.

In (33) the following intriguing note appears under the date 5/10/42: "The possibility of increasing the range of small aircraft, by operating them as towed gliders, was demonstrated at the Naval Aircraft Factory when LCDRs. W. H. McClure and R. W. Denbo hooked their F4F's to tow lines streamed behind a twin-engine [illegible] (Army A-20), cut their engines and were towed for an

(33) Adrien O. Van Wyen and Lee M. Pear[illegible] Aviation, 1910-1960", NAVWEPS 00-80P-1. Washington: Gov't Printing Office, 1960.

(10C) See Page [illegible]

hour at 180 knots at 7000 feet."

A letter from Capt. R. S. Barnaby, (11) who was in charge of this project, contained the following details: "The F4F's were used principally because they were equipped with Curtiss Electric propellers which, by use of a storage battery accumulator system, could be feathered and unfeathered when the engine was stopped. Starting up was easy. You just unfeathered the prop until it started to windmill. After it had turned over a few turns, the ignition switch was turned on, and the engine started. After a short warm up, you could release the tow-line and away you'd go."

Capt. Barnaby, who himself made a number of hook-ons and releases, added that dual fighter tows were also carried out on May 6, using an Army B-17 borrowed from Wright Field. "On that occasion, McClure and Denbo hooked their two F4F's onto the B-17's tow-lines and were towed for eight hours over a triangular course of about 180 miles. At the end of the eight hours, they restarted their engines, warmed them up, released, and returned to Mustin Field."

Another F4F project which did not develop until 1944 involved the use of breakable wing tips. Theory suggested that several hundred pounds in wing structural weight might be saved if the wing were designed with tips that would break off when subjected to a specified high-g loading, perhaps of the order of 8 to 9 g's. This would relieve the wing bending movement and prevent catastrophic failure of the entire wing. The practicability of the idea was proved by modifying and successfully testing an F4F equipped with breakable wing tips. Each tip measured $3\frac{1}{2}$ feet in span. When attached, the overall wing span was 36 feet, two feet less than the normal span of the standard F4F. After breakaway the span was reduced to 29 feet. The possibility of incorporating this approach in the F8F was seriously considered. A few problems remained unsolved, however, including the possibility of asymmetrical failure, and it is not believed the idea was carried any further.

It will be recalled that in 1940 two F4F's, BuNos. 1846 and 1847, had been equipped with Wright R-1820 "Cyclones" and tested by the Navy under the designation XF4F-5. During the Winter of 1942-43 these two aircraft were further modified and made the subject of a series of comparative flight tests. (12) Airplane 1846 was fitted with a Wright R-1820-54 with a turbo-supercharger, one of the very few such installations in U.S. Naval aircraft. (Others include the XF4U-3, a TBF, and a modification to the XPBY-1.) The exhaust stack from the turbine projected down and aft from the bottom of the engine cowl. A Wright XR-1820-48 with a two-stage supercharger was installed in airplane 1847 with jet exhaust stacks and an integrally-cowled oil cooler, the normal wing-mounted oil coolers being removed. The cowling of 1846 had a row of flaps across the top but no cowl flaps were provided for 1847. The aircraft were ballasted to the same useful load, which gave a gross weight of 7,084 pounds for No. 1846 (turbo) and 6,791 pounds for No. 1847 (two-stage). In comparative flight tests, the turbo-supercharged airplane showed a maximum speed of 340 mph at 26,400 feet and the two-stage airplane, a maximum speed of 316 mph at 19,300 feet, both with "normal" engine power. Performance with "military power" was slightly higher. The test report showed that:

"(a) No. 1847 (two-stage) is superior at low altitudes.
(b) There is little to choose at moderate altitudes
(c) No. 1846 (turbo) is superior at high altitudes, superiority increasing with height."

(11) Capt. Ralph S. Barnaby, U.S.N. (Ret.) A.A.H.S. Member, Elder Statesman of Aviation, JOURNAL of A.A.H.S., Vol. 6, No. 2, p.22

(12) XF4F-5, Report on Experimental Engine Installations, 3/20/43.

"WILDCAT" VS. "ZERO"

The Japanese "Zero" was a distinct tactical surprise to Allied forces. In the hands of combat veterans of the China War and usually in overwhelming numbers, it was for a number of months held somewhat in awe by Allied forces and considered by some to be practically invincible. The performance curves show a comparison of maximum level speed and rate of climb between the F4F-4 and two versions of the "Zero". The "Zeke 21" ("Zeke" was the Allied code name eventually assigned to the "Zero") was the standard carrier fighter version for the first six months of the war. The "Zeke 32" with increased engine power and shorter wing span was introduced at Guadalcanal. Later the "Zeke 22" appeared with the wing span restored. Performance of the "Zeke 22" is not shown but was similar to the "Zeke 32" with perhaps some improvement in rate of climb and turn radius with the increased wing area. Improved, higher-performing "Zeros" appeared later in the war but they were opposed mainly by the F6F and F4U. Examination of the curves shows that the "Zero" was generally superior to the much heavier F4F-4 in maximum speed and greatly superior in rate of climb.

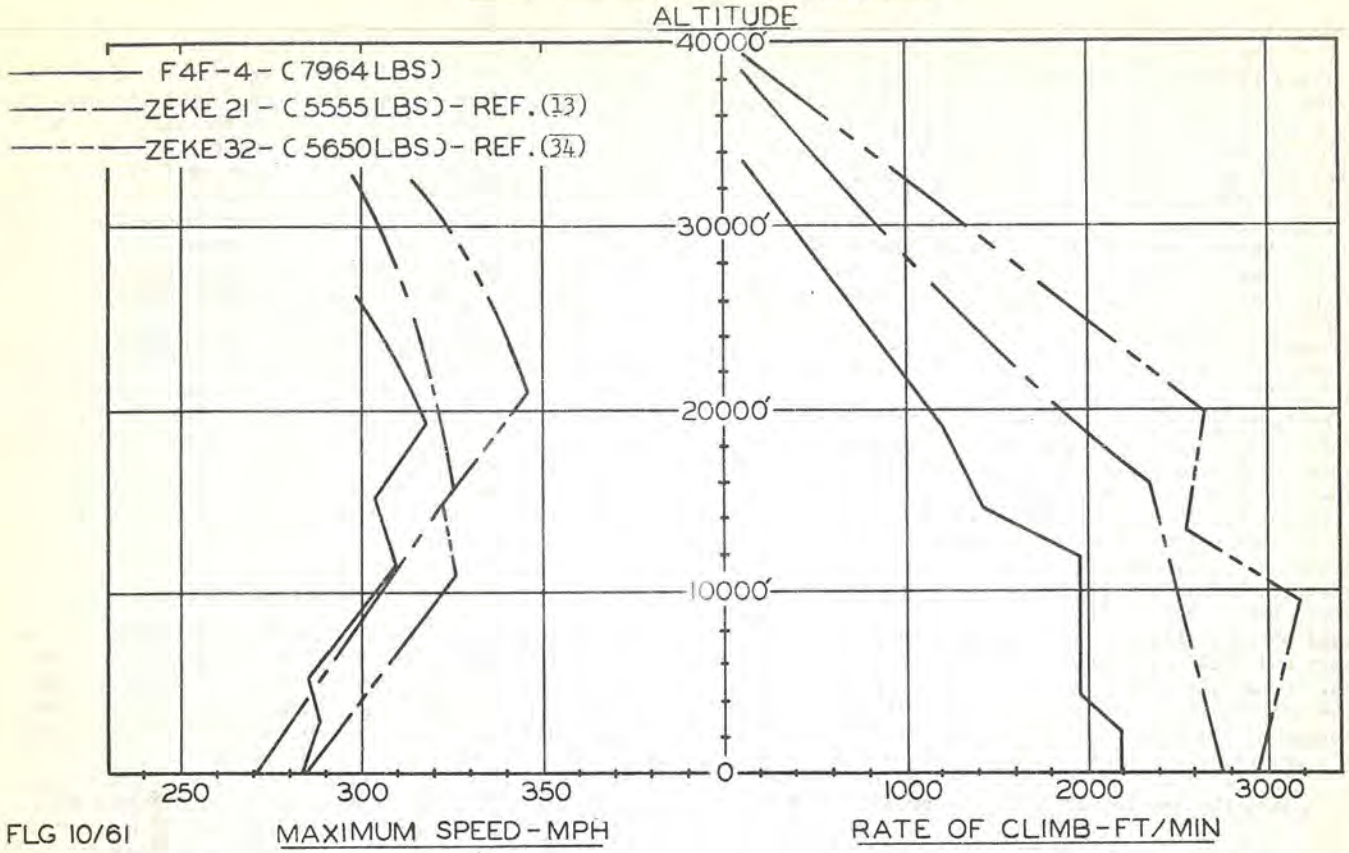
The first opportunity to actually flight evaluate a "Zero" fighter came in mid-1942 when a "Zeke 21" was recovered in the Aleutians. This airplane had taken part in Japanese diversionary attacks in the Aleutians during the Battle of Midway. In attempting a crash-landing in an island bog, the airplane flipped over and the pilot suffered a broken neck. The aircraft was not significantly damaged and the Navy quickly took advantage of the opportunity to restore it to flying condition. Flight tests were conducted at the Naval Air Station, San Diego in September and October 1942. In the preliminary test report (13) the following comparison was made with the F4F-4: "The "Zero" is superior to the F4F-4 in speed and climb at all altitudes above 1000 feet, and is superior in service ceiling and range. Close to sea level, with the F4F-4 in neutral blower, the two planes are equal in level speed. In dive the two planes are equal with the exception that the "Zero's" engine cuts out in pushovers. There is no comparison between the turning circles of the two airplanes due to the relative wing loadings and resultant low stalling speed of the "Zero". In view of the foregoing, the F4F-4 type in combat with the "Zero" is basically dependent on mutual support, internal protection, and pullouts or turns at high speeds where minimum radius is limited by structural or physiological effects of acceleration....Advantage should be taken, where possible, of the superiority of the F4F in pushovers and rolls at high speed, or any combination of the two."

Although the F4F was inferior in speed and climb to the "Zero", it was nevertheless generally superior as a combat weapon for the following reasons:

1. It had greatly superior armament,
2. It was of rugged construction and equipped with armor plate and self-sealing fuel tanks, and
3. It was flown by skilled pilots well-schooled in effective offensive and defensive air combat tactics.

Perhaps most important of all was the skill and quality of the F4F pilots and their ability to develop combat tactics which would take advantage of their equipment's strong points and minimize its weaknesses. While Japanese pilots tended toward individual exhibitionism, Navy and Marine pilots were concentrating on team operations, standardizing the two-plane fighter element, and developing tactics such as the "Thach-Flatley" weave. The standard attack maneuver was to get as far above the enemy as you possibly could, plunge through the formation in a high overhead pass,

(13) Preliminary Test Report of Japanese Nagoya Type "Zero", U.S. Naval Air Station, Anacostia, 10/31/42.



continue in a high-speed dive until able to zoom safely to a favorable position and altitute for another attack.

Reference (14) contains U.S. Navy statistics which credit the F4F with a 5.9:1 superiority in air combat victories to losses for the year 1942. The ratio for the entire war for F4F/FM types is given as 6.9:1. (The same list shows a ratio for the entire war of 19.1:1 for the F6F and 11.3:1 for the F4U.) There is no breakdown of victims between fighter and bomber types. Certainly with respect to the unarmored, inflammable land and carrier-based bombers, the effect of the F4F's powerful armament was deadly. Combat with the "Zero" was perhaps not as clear-cut. Nevertheless examination of combat accounts, even allowing for the inevitable exaggerations, leads to the conclusion that the record against the "Zero" was still significantly on the side of the "Wildcat".

EASTERN AIRCRAFT AND ESCORT CARRIERS

While Grumman was in the midst of its F4F-4 production program during 1942, two other projects were coming in for increased effort. The TBF-1 torpedo-bomber, badly needed as a replacement for the ancient Douglas TBD-1, had made its first flight in 1941 and production had begun early in 1942. In addition, progress was ~~bei~~ being made on the F6F development, the XF6F-1 with the Wright R-2600 engine making its first flight in June 1942 and the XF6F-3 with the Pratt & Whitney R-2800 following a month later. The XF6F-3 was selected as the prototype for the production airplane and immediately a production program was initiated. The first production airplane was delivered in January 1943, only six months after the first flight of the prototype. The Navy recognized that the bigger, higher-performing F6F would be the successor to the F4F but realized that it would be some months before sufficient numbers of aircraft and pilots would be ready for combat duty. In order to facilitate production of the F6F and yet maintain the flow of F4F's, it was decided early in 1942 to eventually shift production of both the TBF-1 and the F4F-4 to another manufacturer.

Eastern Aircraft, established officially January 21, 1942, was made up of five East Coast plants which had formerly been engaged in automobile assembly as part of General Motors. It was decided that the Linden, New Jersey plant would build the F4F and the Trenton plant would assemble the TBF with the other three plants in support. Immediately the long, arduous, and sometimes painful process of converting machines and men from producers of automobiles to builders of aircraft was begun. On April 18, 1942, Eastern was awarded a contract for 1800 FM-1 airplanes, essentially a "Chinese" copy of the Grumman F4F-4. The first airplane made its first flight at Linden on August 31, 1942. Although only 21 FM-1's were accepted before the end of the year, the production rate increased rapidly to the point where a further 818 had been delivered by the Fall of 1943. At the same time, aircraft were being delivered to the British under the designation "Martlet V", two by the end of 1942 and a further 309 in 1943. Many, if not most, of the FM-1's were destined to see operational service on the new escort carriers.

Although the possible need for large numbers of small aircraft carriers had been recognized as far back as the early 1930's, it wasn't until March 1941 that the first step in that direction was taken when the conversion of the cargo ship MORMACMAIL to a small carrier was begun. Three months later the ship emerged as the U.S.S. LONG ISLAND, the first of more than 100 escort carriers or CVE's. About the same time the keel was laid for the U.S.S. INDEPENDENCE, first of eleven somewhat larger light carriers or CVL's. Escort carriers became an important factor in the war against the submarine in the Atlantic and in the Pacific they lent valuable support to the many amphibious operations in that area. Before the end of the war no less than 114 escort carriers were

(13) See Page 238.
(34) "Japanese Aircraft Performance and Characteristics, Technical Air Intelligence Command, Manual No. 1", December 1944.
(14) "The Aircraft Year Book for 1946".

delivered to the operating forces, including 38 transferred to the British.

It was recognized that the shorter flight deck of the smaller carriers posed a problem for the F4F's already groaning under an increasing military load. Though some thought was given to a newer, more powerful, and heavier, version of the F4F, perhaps using an R-2000 or R-2600 engine, it was finally decided that an effort in the opposite direction, toward a much lighter airplane, might be more rewarding. It was therefore decided to combine the new Wright R-1820-56 "Cyclone" engine with the F4F-4 airframe. The -56 with a single-stage, two-speed supercharger featuring new forged cylinder heads was considerably lighter than the two-stage R-1830. Furthermore it offered a take-off horsepower rating of 1350, 150 HP more than the R-1830.

The first Wright-powered airplane, designated the XF4F-8, BuNo. 12228, was first flown at Bethpage on November 8, 1942 and was delivered to Anacostia late the following month. The second airplane, 12229, followed shortly thereafter but was retained for a time at Grumman. Both were subject to Navy evaluation over the next five months. (15).

Besides having the new Wright engine, this model differed from other F4F's in having slotted wing flaps instead of split flaps. They were not completely satisfactory and 12228 was eventually refitted with split flaps. It was also found necessary to increase the size of the vertical tail in order to counteract the increased torque of the more powerful engine, an effect particularly severe during take-off and during a carrier wave-off. This change was incorporated on No. 12229 and later became the configuration of the production airplane.

Early in 1943 a contract was signed with Eastern for the production of 1265 Wright-powered aircraft to be designated the FM-2. The aircraft was to be phased in to succeed the production of FM-1's then accelerating at Eastern's Linden plant. On the Fall of 1943 the first production FM-2 was delivered. Its maximum speed in level flight was roughly the same as the F4F-4. The reduced weight and greater engine power significantly improved rate of climb and maneuverability and also shortened the take-off run, an important characteristic due to the shorter flight deck of the smaller carriers. A water-injection system was later provided to further improve performance. By the end of 1943, 310 FM-2's were accepted. The production rate increased rapidly and during 1944 and 1945 a further 4127 were accepted. These, combined with 340 aircraft delivered to the British under the designation "Wildcat VI", brought the total production figure for the FM-2 to 4777.

In October 1944 a conference was held at the Navy's test station at Patuxent River, Maryland to discuss fighter aircraft requirements (16). Available to the service and contractor representatives for flight evaluation were an impressive collection of 23 production and experimental fighter aircraft including the latest Army and Navy types. Among these was an FM-2. A summary of the opinion of the FM-2 as expressed by six Army, five Navy, and 12 contractor pilots is of interest. Opinions in many cases were highly contradictory and depended heavily on individual preference and experience. It should also be remembered that at this late date comparisons were being made with such formidable competitors as the P-47D, P-47M, P-51D, F6F-5, XF4U-4, and XF8F-1, representing at least a second generation over the older FM-2. In spite of this, the airplane measured up reasonably well.

(15) XF4F-8, Final Report of Service Acceptance Trials, 3/17/44.

(16) Report of Joint Fighter Conference, Naval Air Station, Patuxent River, Md., 16-23 October, 1944.

SUMMARY AND FINAL TRIBUTE

It cannot be stated that the F4F possessed outstanding speed and performance qualities. With its basic design features laid down long before the war, the "Wildcat" was penalized severely by the wartime lessons which showed the need for armor plate, heavier firepower, more fuel and any number of combat accessories. Nevertheless, as a weapon it proved itself superior to enemy aircraft having greater speed and climb performance. Later on, a version of reduced weight and complexity proved ideal for use on the escort carriers which played such a significant part in the Allied offensive.

In addition to its combat victories, the F4F made a significant contribution to the "Corsair" and "Hellcat". The two-stage supercharger installations for both aircraft profited from the experience derived from the F4F, and the staunch qualities of the F4F were inherited by its bigger but younger brother, the F6F.

The "Wildcat" served the country well during a crucial period in its history. It will live long in the annals of U.S. Naval Aviation.

ACKNOWLEDGMENT

This history was made possible only by the devoted efforts of many people over a considerable period of time; the author can only hope that the brief recognition given here will in some small measure reward them.

Especial thanks are due to Dusty Carter, who executed the fine 3-views and side-views in the extremely short time allotted. My gratitude also to Grant Daly at Grumman whose contributions were great and whoe enthusiasm for the project equalled my own, Hal Andrews at the Navy Department who did so much to dig out the significant Navy material, and Roy Cross of England who contributed so much on British "Martlets".

Others making significant contributions were: Don Carr and Joe Chew, former FM-2 pilots, John Eckhart, (former F4F pilot and member of VF-10 "The Grim Reapers") Harvey Lippincott, Vernon Muse, Paul Smith, Miss Tatyana Kreyditch, all seven of Pratt & Whitney; George Titterton, Bob Hall, Edward Clexton, Warren Allen, Frederick Trapnell, and the Public Relations Dept. personnel of Grumman; Lee M. Pearson and Adrian A. Van Wyen of the Navy Department; and Robert Johnson of Curtiss-Wright. Also I had the help of Capt. Ralph Barnaby, Richard Bueschel, Esther B. Mueller, (formerly of the Air Force Museum); Ron Gerdes, Ray Wagner, Peter Grosz, George Lee and James J. (John) Sloan. Gracious thanks also to others who may inadvertently have been omitted.

Finally, my gratitude is extended to my wife, Margery, who gladly assumed the typing chore in addition to her many other duties and responsibilities.

ABOUT THE AUTHOR

Upon joining the American Aviation Historical Society in mid-1966, Author/Member Frank L. Greene supplied the following introduction of himself. It is about as complete as could be gained to describe the man; his work speaks for itself.

Frank L. Greene, BEE from Yale 1950. Engineer on Drones & Missiles Eng., Aeronautical Equipment Div., Sperry Gyroscope Co., N.Y. Amateur radio operator (K2GGL). Recently became active in private flying. Formerly Historical Associate, IAS. Broad aeronautical interests, but somewhat inclined toward the technical. In the historical line some of the high spots are: US a/c WWI & II; a/c 1903-1914; Dev. of Missiles; Application of wireless to a/c; Transport airplane dev. in US. Collections - modest collection of books, manuals, newspaper clippings, periodicals, and misc. literature gathered over a period of about 17 years. Several hundred aircraft photos, mostly U.S. military types, a fair portion of which are my own work.

F4F/FM PERFORMANCE AND CHARACTERISTICS

Mfr	Mod	Engine	S/C	Prop	Span	L'gth	Wing Area	Armament	Gross Weight	Weight Empty	Max.Speed/ Altitude	Climb	Ser. Clg.	Range	First Flight	No. Built	Refs.
G	XF4F-1	WAC XR-1670-02 (?)	1/1	HS/CP	27-0	23-3	250	1X.50+ LX.30	4594	3320	264/10500	7.6/15000	29400	853	-	0	
		or PWA XR-1530-92 875	1/1														
G	XF4F-2	PWA R-1830-66 1050	1/1	HS/CS	34-0	26-5	232	4X.50's	5386	4035	290/10000	2650/SL	27400	740	9/37	1	
G	XF4F-3	PWA XR-1830-76 1200	2/2	C/CS	38-0	28-0	260	2X.30's+ 2X.50's	6099	4863	334/20500	2800/SL	33500	907	2/39	1	(17)
G	F4F-3	PWA R-1830-76,86 1200	2/2	C/CS	38-0	28-9	260	4X.50's	7065	5238	331/21300	2300/SL	37000	860	2/40	285	(18)
G	F4F-3A	PWA R-1830-90 1200	1/2	C/CS	38-0	28-9	260	4X.50's	6876	5216	312/16000	2430/SL	34300	825	1941	65	
G	XF4F-4	PWA R-1830-76 1200	2/2	C/CS	38-0	28-9	260	4X.50's	7489	5776	326/19500	1900/SL	34000	-	4/41	1	(19)
G	F4F-4	PWA R-1830-86 1200	2/2	C/CS	38-0	28-9	260	6X.50's	7964	5766	318/19400	2190/SL	33700	-	1941	1169	
G	F4F-4A	Was to be F4F-4 with R-1830-90 engine. None built.															
G	F4F-4B	Redesignated Martlet IV.															
G	XF4F-5	WAC R-1820-40 1200	1/2	HS/CS	38-0	28-10	260	-	6063	4887	306/15000	2350/SL	35500	-	6/40	2	(20)
G	XF4F-6	PWA R-1830-90 1200	1/2	C/CS	38-0	-	260	-	7065	4985	319/16100	2600/SL	34000	-	10/40	1	(7)
G	F4F-7	PWA R-1830-86 1200	2/2	C/CS	38-0	29-10	260	None	10328	5456	310/19400	1765/SL	26900	3700	12/41	21	
G	XF4F-8	WAC XR-1820-56 1350	1/2	HS/CS	38-0	-	260	4X.50's	7080	5365	321/16800	3125/SL	36400	-	11/42	2	(15)
E	FM-1	PWA R-1830-86 1200	2/2	C/CS	38-0	28-9	260	4X.50's	7404	5732	Perf. sim. to F4F-4				8/42	839	(21) (22)
E	FM-2	WAC R-1820-56, 1350 56W	1/2	C/CS	38-0	28-11	260	4X.50's	7431	5542	320/16800	2890/SL	35600	-	1943	4437	
G	Mart.I	WAC GR-1820-G205A 1200	1/2	HS/CS	38-0	-	260	4X.50's	Weights and perf. sim. to XF4F-5					930	5/40	81	(23)
G	Mart.II	PWA TwinWaspS3G-4G 1200	1/2	C/CS	38-0	29-1	260	6X.50's	7512	5345	293/13000 (a)	-	31000 (a)	890	10/40	100	(24) (25)
G	Mart.III	PWA R-1830-90 1200	1/2	C/CS	38-0	28-9	260	4X.50's	Weights and perf. sim. to F4F-3A						1941	30	
G	Mart.IV	WAC R-1820-40B 1200	1/2	HS/CS	38-0	28-5	260	6X.50's	7904	5773	298/14000 (b)	-	30100 (b)	-	1942	220	(26) (27) (28)
E	Mart.V	PWA R-1830-86 1200	2/2	C/CS	38-0	28-9	260	4X.50's	Weights and perf. sim. to F4F-4, FM-1						1942	311	
E	Mart.VI	WAC R-1820-56,56W 1350	1/2	C/CS	38-0	28-11	260	4X.50's	Sim. to FM-2		314/13252 (c)	Sim. to FM-2			1944	340	(18)

NOTES: G - Grumman
E - Eastern
PWA - Pratt&Whitney Aircraft
WAC - Wright Aeronautical Corp.
Number under engine desig. is takeoff horsepower.
Supercharger - No.Stages/No.Speeds
HS -Hamilton Standard
C - Curtiss
CP - Controllable pitch
CS - Constant speed
Span and length in feet-inches
Wing area in square feet
Weights in pounds
Max.Speed/Altitude - Mph/Ft
SL - Sea level
Climb - Ft.perSec./Altitude except for XF4F-1, which is Minutes/Altitude
Service ceiling - Feet
Range - Statute miles

(a) At 7790 lbs. from Ref. (24)
(b) From Ref.(26)at unknown weight
(c) At 7000 lbs. from Ref. (18)

The performance data shown on Page 241 is representative of the airplane type in its "normal" configuration; an effort has been made to make these compatible with the weights given.

It should be remembered that no two airplanes of the same model will show the same performance in exact figures. Furthermore, as each airplane becomes older, subjected to rigors of combat flying, a gradual decline in performance can be expected due to deterioration of both airframe and engine.

F4F/FM ENGINE CHARACTERISTICS

Mfr	PWA	PWA	PWA	PWA	WAC	WAC	WAC	WAC
Mil. Model	R-1830-66	R-1830-76(a)	R-1830-86	R-1830-90	R-1820-40	R-1820-56,56W(b)	R-1820-48	R-1820-54(c)
Mfr. Model	Twin Wasp SC-G	Twin Wasp SSC5-G	Twin Wasp SSC7-G	Twin Wasp S3C4-G	GR-1820-G205A	-	-	-
Takeoff horsepower	1050	1200	1200	1200	1200	1350	1155	1200
Comp. Ratio	6.7:1	6.7:1	6.7:1	6.7:1	6.7:1	6.55:1		
Gear Ratio	.667	.667	.667	.562	.667	.667		
Diameter(o/a)	48.0	48.06	48.19	48.19	55.12	55.12		
Length(o/a)	59.25	71.31	67.44	63.41	48.40	47.56		
Dry Weight	1370	1550	1560	1495	1315	1333		
Installations	XF4F-2	F4F-3, XF4F-4	F4F-3,-4,-7, FM-1,Mart.V	XF4F-6, F4F-3A, Mart.II,III	XF4F-5, Mart.I,IV	FM-2, WildcatVI	XF4F-5	XF4F-5

NOTES: PWA - Pratt&Whitney Aircraft
WAC - Wright Aeronautical Corp.
(a) XR-1830-76 (PWA Twin Wasp SC2-G) similar. Used in XF4F-3.
(b) XR-1820-56 similar. Used in XF4F-8. -56A similar. Water injection ratings not known.
(c) Believed to be R-1820-40 with turbo-supercharger.

REFERENCES

(17) XF4F-3 Final Report of Service Acceptance Trials, 5/29/41
(18) "Wildcat VI", Level Speed Trials With and Without Water Injection, Boscombe Down, 6/20/45.
(19) XF4F-4, Final Report of Service Acceptance Trials, 11/19/41.
(20) XF4F-5, Final Report of Service Acceptance Trials, 7/12/41.
(21) FM-1, Erection & Maintainence Instructions, 12/15/43
(22) FM-1, Pilot's Handbook, 11/26/43
(23) "Martlet I", Range Trial.
(24) "Martlet II", Flight Test Report, 11/42.
(25) "Martlet II", Erection, Maintainence & Repair Manual, 6/19/41.
(26) "Martlet IV", Flight Test Report.
(27) "Wildcat IV", Weights & Loading Data, Boscombe Down. 2/13/44
(28) F4F-4B ("Martlet IV") Erection & Maintainence Instructions 12/24/43

OTHER PRINCIPAL REFERENCES

In addition to the specific footnotes in the accompanying text and charts the following sources were generously used, as were the company records of:
Grumman Aircraft Engineering Corp.
Pratt & Whitney Aircraft Division, United Aircraft Corp.
Wright Aeronautical Division, Curtiss-Wright Corp.

F4F-4, Pilot's Handbook.

F4F-7, Final Report of Production Inspection Trials, 5/30/42.

FM-2 ("Wildcat VI") Pilot's Handbook, 6/15/45.

Navy Dept., Bureau of Aeronautics, Washington, D.C., "Changes on F4F Airplanes.

U.S. Dept. of Commerce, "U.S. Military Acceptances, 1940-1945".

AIR PICTORIAL (Magazine), October 1956 and April 1957.

Owen Thetford, "British Naval Aircraft, 1912-1958". Putnam & Co., Ltd., London, 1958.

Owen Rutter, "The British Navy's Air Arm". New York, 1944.

Buford Rowland and William B. Boyd, "U.S. Navy Bureau of Ordnance in World War II. Washington,

THE BEE-HIVE (Magazine), Vol. 17, No. 7, (July 1942). United Aircraft Corp., Hartford.

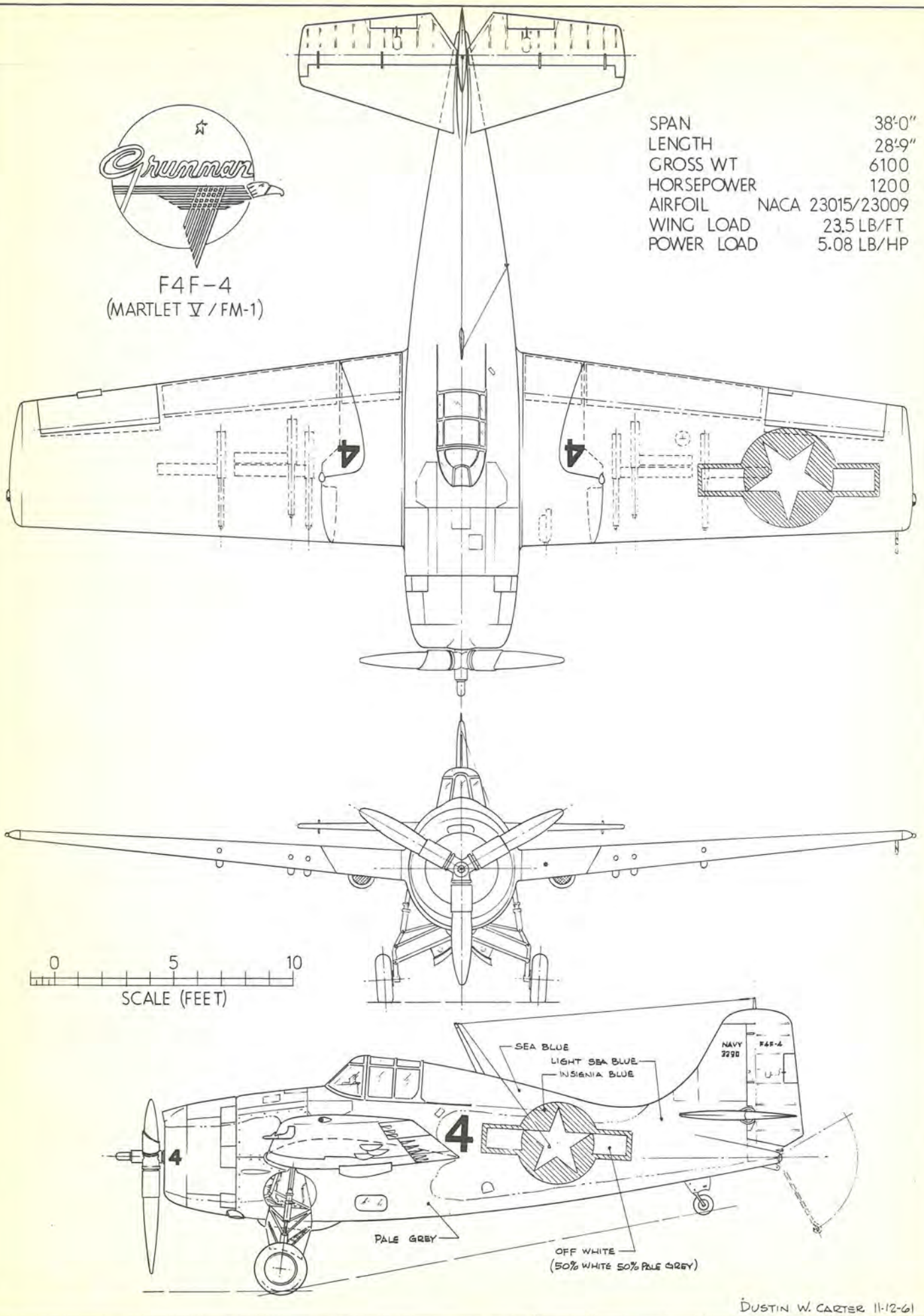
Robert Sherrod "History of Marine Corps Aviation in World War II". Combat Forces Press, Washington 1952.

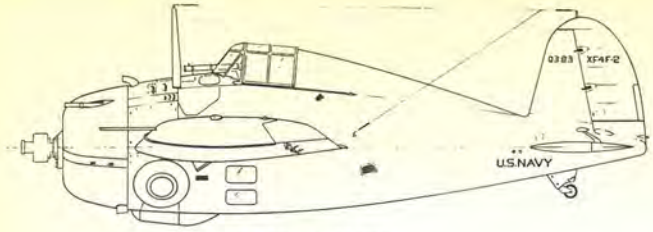
"A History of Eastern Aircraft Division, General Motors Corp." General Motors Corp., Detroit, 1944.

Robert Schlaifer and S. D. Heron, "Development of Aircraft Engines and Fuels". Boston, 1950.

EVERY MEMBER GET A MEMBER

Attached to this issue of the Journal, as with the Fall issue, is an application blank form. Send it to one of your friends who would like to know about the A.A.H.S. We must have a substantial increase in membership in 1962 in order to continue to publish the JOURNAL, even with totally volunteer efforts by the officers, directors and editor.


Grumman
F4F-4
(MARTLET V / FM-1)
SPAN 38'-0"
LENGTH 28'-9"
GROSS WT 6100
HORSEPOWER 1200
AIRFOIL NACA 23015/23009
WING LOAD 23.5 LB/FT
POWER LOAD 5.08 LB/HP
0 5 10
SCALE (FEET)
SEA BLUE
LIGHT SEA BLUE
INSIGNIA BLUE
NAVY 3290
F4F-4
PALE GREY
OFF WHITE
(50% WHITE 50% PALE GREY)
DUSTIN W. CARTER 11-12-61



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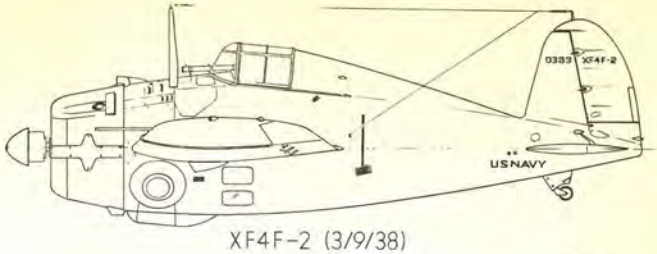

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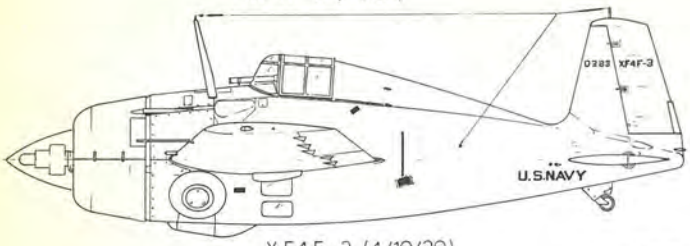

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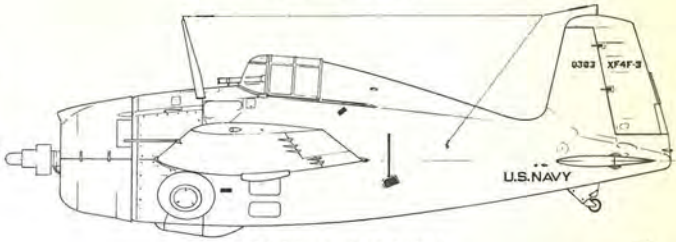

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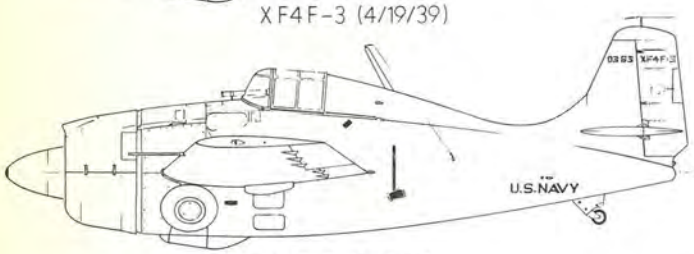

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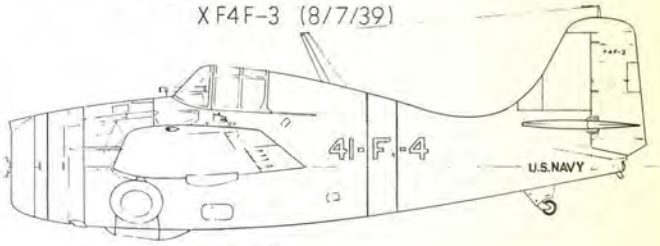

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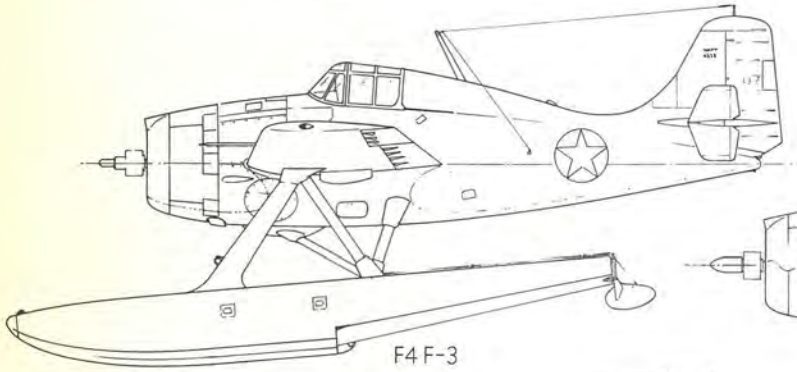

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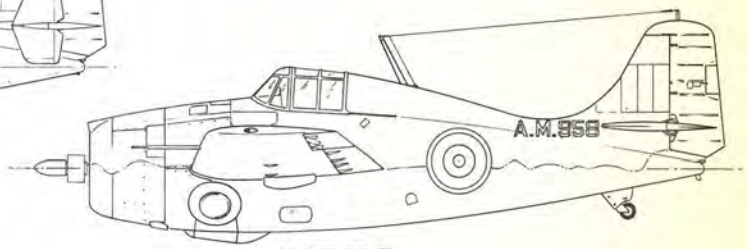
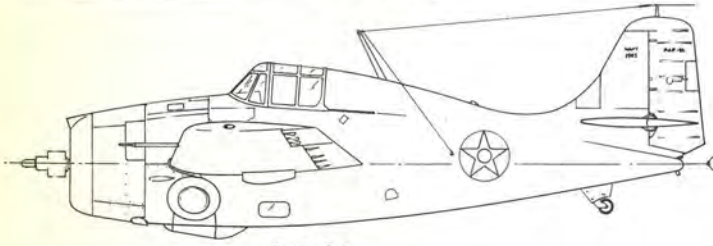
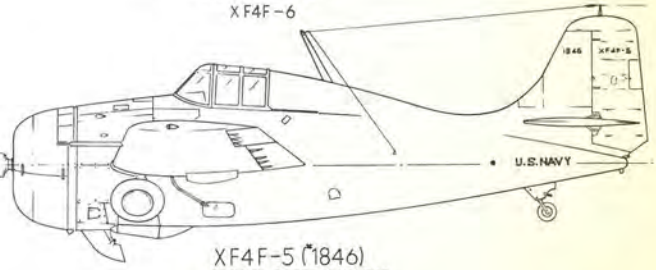


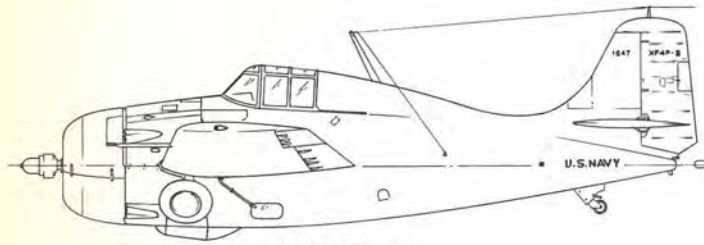
MARTLET II
XF4F-6



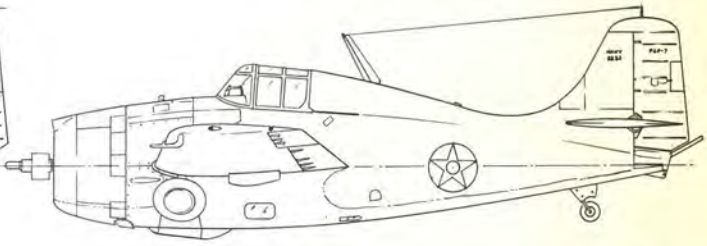
F4F-3A
MARTLET III



XF4F-5 ("1846)
TURBO-SUPERCHARGER



XF4F-5 ("1847)
TWO STAGE SUPERCHARGER



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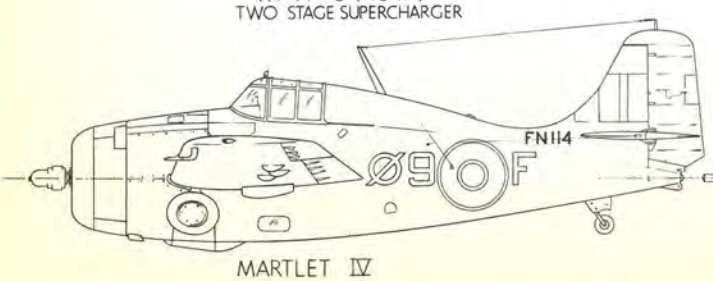
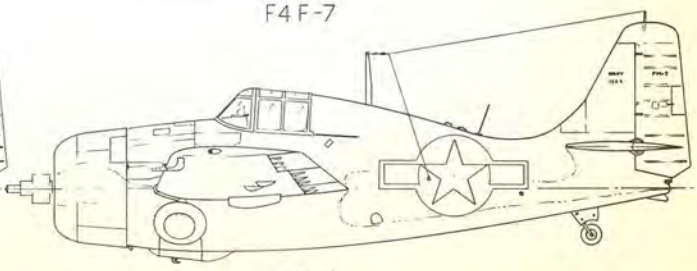


MARTLET IV
F4F-4B



FM-2
WILDCAT VI

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