WING-FOLDING MECHANISM OF THE GRUMMAN WILDCAT

An American Society of Mechanical Engineers Historic Mechanical Engineering Landmark

DESIGNATION CEREMONY AT THE
KALAMAZOO AVIATION HISTORY MUSEUM
KALAMAZOO, MICHIGAN
May 15, 2006

A Mechanical Engineering Landmark

The innovative wing folding mechanism (STO-Wing), developed by Leroy Grumman in early 1941 and first applied to the XF4F-4 Wildcat, manufactured by the Grumman Aircraft Engineering Corporation, is designated an ASME Historic Mechanical Engineering Landmark. (See Plaque text on page 6)

Grumman People

Three friends were the principal founders of the Grumman Aircraft Engineering Corporation (Now known as Northrop Grumman Corporation), in January 1930, in a garage in Baldwin, Long Island, New York. (See photo of Leon Swirbul, William Schwendler, and Leroy Grumman on page 7)

Leroy Randle (Roy) Grumman (1895-1982) earned a Bachelor of Science degree in mechanical engineering from Cornell University in 1916. He then joined the U. S. Navy and earned his pilot's license in 1918. He was later the Managing Director of Loening Engineering Corporation, but when Loening merged with Keystone Aircraft Corporation, he and two of his friends left Loening and started their own firm — Grumman Aircraft Engineering Corporation.

William T. Schwendler (1904-1978) earned a Bachelor of Science degree in mechanical engineering from New York University in 1924. He was reluctant to leave Long Island, so he chose to join Grumman and Swirbul in forming the new company.

Leon A. (Jake) Swirbul (1898-1960) studied two years at Cornell University but then left to join the U.S. Marine Corps. Instrumental in the founding and early growth of Grumman, he soon became its president. Jake was the inspiration for the policies that developed employee's loyalty and dedication to meeting production goals.

Other key Grumman people were Larry Mead, who received his engineering degree from Princeton University in 1941, and Richard Hutton, who held no degree, but whose innate abilities guided him to make major contributions to the design of the Wildcat and the other Grumman 'Cats. Hutton attended night classes in engineering subjects at the Pratt Institute.

In a recent tribute, David Grumman, Roy's son, characterized both his father and Jake Swirbul as "can-do" type of people, and he attributed much of the company's success to the personnel policies that they instituted. For example, they provided bonus systems to reward employees and built sports fields on company grounds for employees to use during their 40-minute breaks. They provided a car to rove the company parking lot to fix flat tires and other minor automotive defects while employees worked. The car also ran errands such as picking up prescriptions for employees. Grumman had absentee rates about half of those at other aircraft companies. These were key factors that contributed to Grumman's wartime accomplishments.

Grumman's Early History

Despite meager beginnings at the height of the depression, Grumman had early success with U. S. Navy contracts and built a solid reputation supplying a series of biplanes for aircraft carrier service. Grumman and Swirbul managed the company as a "family business."

Leroy Grumman realized the importance of innovative ideas to meet established needs of the U. S. Navy. Soon after the company started in business, Grumman began developing the FF-1, a biplane with retractable landing gear, and a first for carrier-based planes. This feature increased the plane's performance because of the reduced drag and gained Grumman its first production contract. Grumman quickly gained favor with the U. S. Navy, and the company developed improved versions of the biplane though the 1930s. When the Navy announced a competition for new carrier-based aircraft in 1936, Grumman entered a further refined biplane, designated XF4F- 1, in competition against two monoplanes, a Brewster XF2A- 1 Buffalo and a Seversky XFN- 1. The Navy rated the Buffalo as superior, so Grumman immediately redesigned its XF4F- 1 into a monoplane, the XF4F-2. After testing at Grumman, it was provided to the U.S. Navy for evaluation and comparison to the Brewster Buffalo. When engine and other problems developed with the Grumman plane, the Navy awarded a production contract to Brewster, but concerned that Brewster had no prior production experience, the Navy continued to express interest in the Wildcat's development. (While nicknames for Navy aircraft were not commonly used prior to 1940, the Wildcat name was believed to be in use at Grumman early in the development program. The Navy did not officially recognize it until October 1941, but the name Wildcat will be used herein to refer to all models provided to the U.S. Navy containing the F4F prefix, both before and after October 1941.) Consequently, Grumman continued development of its design. The resulting Wildcat, designated XF4F-3, had new wings and tail, and the Pratt & Whitney R- 1830-76 Twin Wasp radial engine, the first engine equipped with a two-stage, two-speed supercharger. Navy tests demonstrated the plane's improved performance, and a contract was issued for production F4F-3 models.

The Navy's decision to order Wildcats was validated at the outbreak of World War II. In the opening battles of the war, almost all of the 50 Buffalos were destroyed. Although Wildcats were fewer in number, many survived this bleak period. One important characteristic that was not evaluated for either plane was survivability. The Wildcat's ruggedness, combined with its self-sealing fuel tanks and protective armor plating, far outweighed many of the performance advantages enjoyed by adversaries.

The STO-Wing

With a growing specialty of building planes to meet the unique operational requirements of the U.S. Navy, particularly the demands of flying off aircraft carriers, Grumman's engineers had become accustomed to finding innovative ways to make their airplanes simple and robust. Thus, when the need for airplanes to somehow occupy less space while on board the Navy's carriers became apparent, it was Roy Grumman who came up with the answer. (See Figure 1 at right and Figure 3 on page 7)

An obvious answer was to fold a plane's wings. In fact, folding wings had been tried before, but with poor results. As early as 1920, F. M. Osborne had designed a high-wing monoplane with them. Although he received a patent the next year, his design was never produced

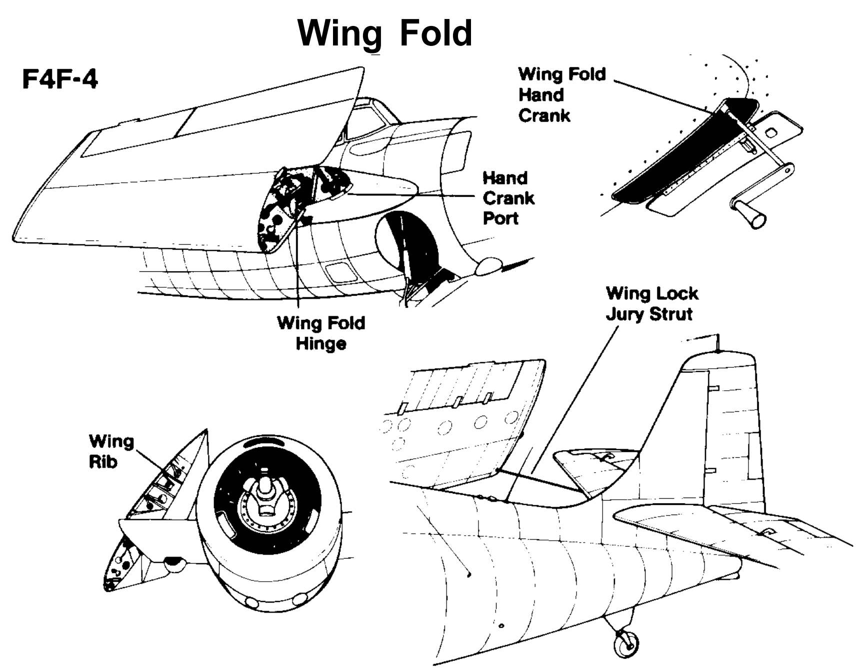


Figure 1

W. Leonard Bonney built his Gull in 1928 that featured a wing-folding motion very much like the one Grumman used. Unfortunately, the Gull crashed on its first flight at Roosevelt Field in New York, killing Bonney. With no demonstrated need, the idea languished until the growth of carrier-based aircraft elevated, to a high priority, the need to save precious space aboard ships.

Grumman's quest to develop a suitable wing-folding mechanism was illustrative of how he and other engineers tackled such problems in a pre-computer age. Grumman's efforts were reported as follows: (See Reference 1, pp. 124-125)

> Many laborious hours were spent over sketches and with models trying to figure out a way to twist the wings to a vertical position and then fold them back along the fuselage. Finally, Roy Grumman, a fine engineer, found the steps. He saw in all probability that the solution revolved around a pivot. So he took a soap eraser, such as those used in drafting, and used that to represent the fuselage of the plane. Then he took two paper clips for the wings and bent out the short end of each of the clips so that it was normal or perpendicular to the body of the clip. Then he began sticking these short ends into the eraser until he found the proper angle and position at which the clip, when twisted to a vertical position, would also fold back snugly against the eraser. Eureka! It was as simple as that. Once the principle of the "STO-Wing" (as it came to be called) was established, all that remained was some hard engineering work by Grumman's fine team of engineers to make the mechanism strong and fail-safe.
>
> The STO-Wing was applied to the Wildcat, the Hellcat and the TBF Avenger. The Grumman folding wing is still in use today, notably on the larger carrier-based aircraft built by Grumman.

The initial STO-Wing design was operated with hydraulic cylinders, but the added weight of the system reduced performance, so a lighter manual system fitted with safety locks was selected for production. When Wildcats were deployed with the Grumman-built TBF Avenger, plane carrying capacities of the early World War II carriers was increased by more than 50 percent. While there were only three U.S. carriers in service in the Pacific at the start of the war, the Japanese Navy had at least ten carriers plus planes on many of the captured islands, consequently, the Japanese would have had a far greater numerical advantage over a U.S. Navy equipped with fixed-wing aircraft. The Grumman F6F Hellcats joined the Wildcats and Chance-Vought F4U Corsairs in 1943, as Wildcat production continued to equip the smaller carriers used for convoy duty in the Atlantic. They also supported the larger Essex Class carriers in the Pacific.

The Wildcat was one of very few U.S. planes to enter production prior to the start of the war and continue throughout the war. Grumman incorporated features to protect the pilot and vital aircraft equipment so that their plane could continue flying and bring the plane and pilot back to the carrier in spite of severe battle damage. Consequently, pilots and competitors commonly referred to Grumman as the "Grumman Ironworks." Considering the fact that most of the planes were fabricated from aluminum and other lightweight alloys, this was a strong tribute to the reliability and durability of the planes.

Even the Japanese pilots respected the ruggedness of their adversary, the Wildcat. The great Japanese ace Saburo Sakai described the Wildcat in his book *Zero* as follows: (See Reference 2)

> I had full confidence in my ability to destroy the Grumman and decided to finish off the enemy fighter with only my 7.7-mm. machine guns. I turned the 20-mm cannon switch to the 'off' position, and closed in. For some strange reason, even after I had poured about five or six hundred rounds of ammunition directly into the Grumman, the airplane did not fall, but kept on flying. I thought this very odd — it had never happened before — and closed the distance between the two airplanes until I could almost reach out and touch the Grumman. To my surprise, the Grumman's rudder and tail were torn to shreds, looking like an old torn piece of rag. With his plane in such condition, no wonder the pilot was unable to continue fighting! A Zero which had taken that many bullets would have been a ball of fire by now.

Grumman and the U.S. Navy

The history of Grumman and the engine manufacturer Pratt & Whitney is intertwined with U.S. Naval history. Grumman focused its development efforts to meet the Navy's needs. The U.S. Navy in the mid 1930s was severely handicapped by a period of rigorous austerity. Additionally, U.S. Naval leaders had just begun to recognize the tactical importance of carrier aircraft. During the 1930s the U.S. Navy did not keep up with performance advancements being made by the militaries of other nations. As world events began leading to the possibility of a major war, U.S. Naval Intelligence discovered that both Japan and Germany had planes that greatly exceeded the Wildcat's performance. Nevertheless, Wildcats were deployed to the U.S. Navy and, with the name Martlet, to the British Royal Navy out of necessity.

In order to overcome the performance deficit, the U.S. Navy established specifications for a new plane with greater performance well beyond the Wildcat envelope. This became the F6F Hellcat. Because of the Wildcat's capabilities, the Navy wanted to find an alternate source to continue Wildcat production so Grumman could concentrate on building Hellcats. The Navy encouraged Grumman to facilitate manufacture of both the Wildcat and Avenger at idled automotive factories. This became quite a challenge for both Grumman and General Motors. (See Reference 1, pp. 155157).

> What followed was a clash of two worlds. GM started out with the idea that it would show the aeronautical industry in general and Grumman in particular how to mass-produce airplanes. Grumman started out with the idea that GM would be lucky if it managed to produce even **one** airplane. In the end, however, it all worked out. General Motors showed it could adapt and Grumman became less defensive. For its part, Grumman produced a great volume of engineering and purchasing information and assistance for GM and ran a very large training program for GM engineers and production workers instructing them about the much tighter tolerances, more complicated manufacturing processes and closer inspections that were demanded by aviation manufacturing. To the automotive industry's (and GM's) credit, the aircraft produced by the Eastern Aircraft Division of General Motors were excellently built airplanes, in a large part thanks to the extensive engineering assistance provided by Grumman and its staff.

F4F-4 Wildcat Specifications

The Wildcat has a wingspan of 38 feet and a length of 29 feet. The plane's empty weight is 5,895 pounds with a gross weight of 7,975 pounds. It had a single Pratt & Whitney R- 1830-86 rated at 1,200 horsepower with the two-stage, two-speed supercharger. The Wildcat had a maximum speed of 320 MPH and a maximum range 1,275 miles.

In addition to the STO-Wing, the Wildcat had other notable firsts for carrier aircraft. It was the first successful monoplane in carrier service, replacing the biplanes previously used. The pilot was able to retract and deploy the landing gear using a hand crank in the cockpit connected with a chain to the landing gear mechanism. The Wildcat was the first U.S. Navy plane with self-sealing fuel tanks and armor protection for the pilot. Aviation historian Joe Baugher noted (See Reference 3) that the Wildcat also was the first aircraft with a new type of supercharger:

> The Wildcat prototype was modified by installing the Pratt & Whitney R- 1830-76 engine with a two-stage, two-speed supercharger. Two intercoolers were also installed. This was the first fighter to enter service with such an engine installation.

The Wildcats manufactured by Eastern Aircraft, designated FM-2, were essentially identical to the Grumman planes, but the Navy chose to have most of them equipped with Curtiss-Wright R-1820 engines. While having only a single-stage supercharger, these engines were actually more powerful than the R-1830s. With over 4,700 planes produced, the FM-2 was by far the most numerous version of the Wildcat.

The Wildcat at the Kalamazoo Aviation History Museum

(Commonly called the AIR ZOO)

The AIR ZOO, located at 6151 Portage Road in Portage, Michigan, was founded in 1977 by Preston and Sue Parish to preserve and display historic aircraft. It began with a Grumman F8F-1 Bearcat, and has grown to include more than 80 aircraft. Many of them are restored to air-worthy condition in the AIR ZOO's restoration center. For further information about the AIR ZOO, see http://www.airzoo.org or call (269) 382-6555.

The Wildcat on display, BuNo 86581, (Eastern Construction Number 5635) was manufactured in the last Wildcat production run at a converted Chevrolet plant in Linden, New Jersey, under U.S. Navy contract number 227. It was delivered to the U.S. Navy at the Naval Air Station (NAS) Tillamook, Oregon, on 25 June 1945. It was held as a "pool" aircraft at NAS Tillamook until January 1946 and stricken from the Navy's inventory on 28 February 1946. The aircraft was donated to New Mexico Highlands University, Las Vegas, New Mexico, on 25 March 1946. The plane was used to train aircraft mechanics for about 23 years until sold to Robert L. Younkin of Fayetteville, Arkansas, on 19 September 1968. Younkin registered it with the FAA as N86581 and began restoration after obtaining additional parts from Texas, Washington, and Venezuela. (Readers should note that this was well before Internet access was available.) At the time Younkin began restoration, the "Hobbs Meter" that records engine operation read only 50 hours. Younkin sold the Wildcat to Gunther W. Balz in Kalamazoo, Michigan, on 27 August 1967, still registered as N86581. Balz hired Richard Schaus, now the Director of Attractions Maintenance at the AIR ZOO, to perform additional restoration. Balz sold the Wildcat to Preston Parish in Hickory Corners, Michigan, on 15 December 1971, who registered it as N1PP. Parish donated it to the AIR ZOO on 24 December 1977, still registered as N1PP The plane attended the 1975 Experimental Aircraft Association Convention and Fly-in at Oshkosh, Wisconsin, where it was recognized with the Grand Champion Warbird Award, and it has flown to and participated in many shows and demonstrations all over the U.S. (See Figures 4 & 5)

References

1. Thruelsen, Richard, *The Grumman Story,* New York: Praeger Publishers, Inc. 1976.
2. Sakai, Saburo, Zero (Publisher and publication date unknown).
3. Baugher, Joe, "Grumman F4F Wildcat" http://www.csd.uwo.ca/-pettypi/elevon/baugher_other/f4f.html, accessed April 12, 2006.

HISTORIC MECHANICAL ENGINEERING LANDMARK

GRUMMAN WILDCAT "STO-WING"" WING-FOLDING MECHANISM

1941

THE WILDCAT'S INNOVATIVE "'STO-WING" MECHANISM DEVELOPED ON THE XF4S-4 PROTOTYPE BY LEROY (ROY) GRUMMAN 11895-19826, A FOUNDER OF GRUMMAN AIRCRAFT ENGINEERING CORPORATION, WAS CRUCIAL TO THE U. S. NAVY'S SUCCESS DURING WORLD WAR II. ONBOARD AN AIRCRAFT CARRIER, THE "'STO-WING" MECHANISM FOLDED THE WINGS PARALLEL TO THE FUSELAGE IN ONE SWEEPING MOTION, REDUCING THE AIRCRAFT'S OVERALL SIZE. THIS ALLOWED EASIER MOVEMENT AROUND THE SNIP AND INCREASED THE CARRIER'S AIRCRAFT CAPACITY BY 50 PERCENT. THE SIMPLE DESIGN HAD THE RUGGEDNESS AND RELIABILITY REQUIRED FUR CARRIER SERVICE, AND IT BECAME THE MODEL FOR MANY SUBSEQUENT NAVAL AIRCRAFT.

ASME

2006

COURTESY OF DAVID GRUMMAN

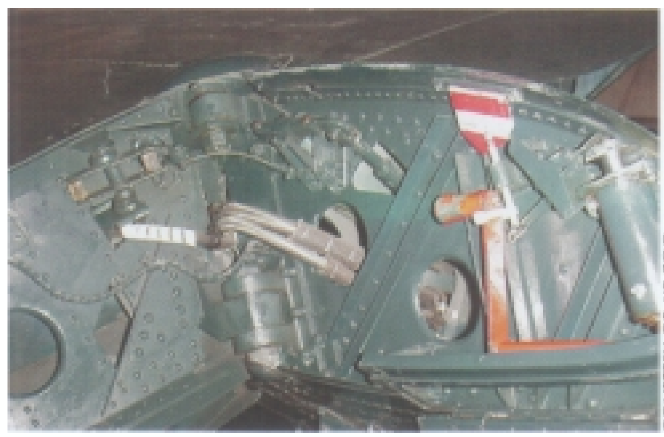
CLOCKWISE FROM ABOVE:

Figure 2: Jake Swirbul. Bill Schwendler, and Leroy Grumman on an Avenger. left to right (rare color photo) ca. 1942.

Figure 3: AIR ZOO Wildcat wing hinge. The hinge is positioned at 45° inboard and 45° rearward so that the wing rotates into a vertical orientation as it traverse\ toward the rear to minimize both the lateral and vertical space required when the plane is parked.

Figure 4: AIR ZOO Wildcat (at right) with two “friends” in an air show.

Figure 5: Wildcat (at right) performs in a “Flight of the ‘Cats”



COURTESY OF AIR ZOO

COURTESY OF AIR ZOO

COURTESY OF AIR ZOO

The History and Heritage Program of ASME

The History and Heritage Landmarks Program of ASME (the American Society of Mechanical Engineers) began in 1971. To implement and achieve its goals, ASME formed a History and Heritage Committee initially composed of mechanical engineers, historians of technology and the curator of mechanical engineering at the Smithsonian Institution, Washington, D.C. The History and Heritage Committee provides a public service by examining, noting, recording and acknowledging mechanical engineering achievements of particular significance. This Committee is part of ASME's Center for Public Awareness. For further information, please contact Public Awareness at ASME, Three Park Avenue, New York, NY 10016-5990, 1-212-591-8614.

Since the History and Heritage Program began in 1971, 237 landmarks have been designated as historic mechanical engineering landmarks, heritage collections or heritage sites. Each represents a progressive step in the evolution of mechanical engineering and its significance to society in general. Site designations note an event or development of clear historic importance to mechanical engineers. Collections mark the contributions of a number of objects with special significance to the historical development of mechanical engineering.

The Landmarks Program illuminates our technological heritage and encourages the preservation of the physical remains of historically important works. It provides an annotated roster for engineers, students, educators, historians and travelers. It helps establish persistent reminders of where we have been and where we are going along the divergent paths of discovery.

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