GREAT FLYERS II

Brief Studies of Aircraft Designs

THE OHIO STATE UNIVERSITY

NASA USRA

NASA/USRA University Advanced Design Program

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Brief Studies of Aircraft Designs

edited by

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PREFACE

This second volume of *Great Flyers* follows the format established in the first volume: three-view drawings of distinguished aircraft, their specifications, and a brief discussion of the airplane's design concept. Each aircraft presented was selected and reviewed by a senior student of Aeronautical and Astronautical Engineering at The Ohio State University (OSU) as part of the requirements of AAE 694A, Flight Vehicle Design Seminar. The seminar is the first course in a three-course sequence on Advanced Aeronautical Design, made possible by National Aeronautics and Space Administration (NASA) funding and administered by the Universities Space Research Association (USRA). In addition to this written assignment and attendance at lectures by noted aircraft designers, the seminar included a tour of the U.S. Air Force Museum in Dayton, Ohio, where several of the aircraft selected for study by the students are displayed.

Ohio State is one of 43 universities in the NASA/USRA Advanced Design Program, which embraces the disciplines of both space and aeronautics. The Advanced Design Program stresses the systems approach to engineering design in which members of the design class work as teams to solve a problem of national interest. At OSU, the seminar assignment of the first course exposed the students to the entire history of aircraft design. When assembled, these brief summaries represented important lessons in design, which were of sufficient interest to publish for distribution to a wider audience. Volume I of *Great Flyers* was well received. I hope Volume II will be of equal interest.

It may be of interest to detail the subsequent work of the OSU ADP class of 1990-91, the group that wrote these reviews. During the second and third quarters, the class developed a conceptual design for a two-stage-to-orbit transportation system. The first stage, powered by air-breathing engines, took off horizontally and accelerated an orbiter to Mach 6 at 100,000 feet. At that point, the orbiter was released and flew into orbit either by rocket power or by a combination scramjet and rocket. Two design teams produced two different design concepts; each team was divided into two groups, one to examine the first-stage designs and the other to focus upon the second-stage orbiter concepts. The design groups were led by group leaders who coordinated the work of the team of student specialists, just as in industry preliminary design organizations.

The three-course sequence ended with the two design teams presenting their differing concepts to a panel of NASA and industry personnel in May, 1991. This oral review was followed by the submission of two comprehensive design reports to NASA and USRA.

G. M. *Gregorek, Professor*
The Ohio State University

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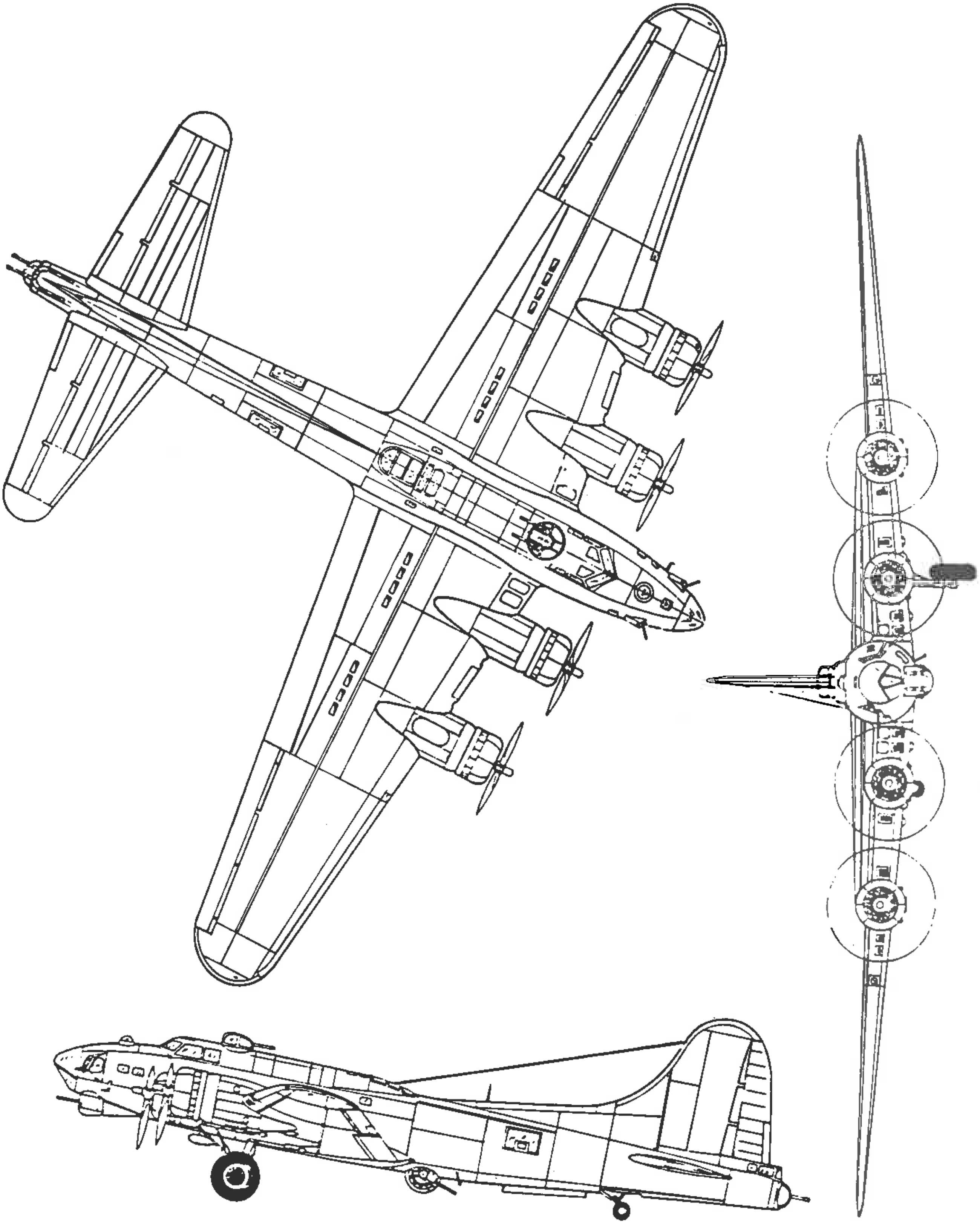

BOEING B-17

D.T. Detwiler

SPECIFICATIONS

Manufacturer	*Boeing*
Date of First Flight	*July 28, 1935*
Number Built	*12,731*
Length	*74.8 ft*
Wing Span	*103.8 ft*
Root Chord	*19 ft*
Tip Chord	*7.08 ft*
Wing Sweep	*8.15°*
Wing Dihedral	*4.5°*
Wing Aspect Ratio	*13.68*
Operating Empty Weight	*48,726 lbs*
Maximum Takeoff Weight	*65,000 lbs*
Maximum Wing Loading	*46 psf*
Maximum Level Speed	*218 mph*
Service Ceiling	*35,600 ft*
Range	*2000 miles*
Engines	*(4) Wright R-1820 Cyclones*
Thrust	*(each) 1200 hp*

In May 1934, a competition for a new multi-engine bomber was announced by the U.S. Air Corps. Boeing designed and constructed a four-engine aircraft for this competition. The aircraft, designated Model 299, was rolled off the assembly line on July 17, 1935. The first flight was made on July 28, and the aircraft flew from Seattle to Wright Field on August 20 for the competition. The 299 averaged 252 mph and set a distance record of 2100 miles nonstop.

The initial performance of the 299 during the competition was very promising but, on October 30, 1935, the aircraft was lost in a crash during a test flight. The crash was caused by an elevator control lock that was not removed before flight. This accident prompted the government to devise a formal, written preflight checklist that is still used today.

The Air Corps was so impressed with the 299 before the crash that it awarded the contract to Boeing. Thirteen more aircraft were ordered and redesignated Y1B-17. The name "Flying Fortress" was given to the aircraft by a reporter covering the unveiling ceremonies.

The Flying Fortress underwent many changes from its initial version, the Model 299, to its final version, the B-17G, but its basic design and structure remained the same. The aluminum body of the B-17 was a combination of a light metal frame surrounded by a thin aluminum covering. This combination formed a strong and rigid structure.

The basic shape of the all-metal fuselage was circular with raised sections for the cockpit and radio compartment. The wings were composed of a framework of metal tubing covered with sheet metal. A symmetrical NACA airfoil was used for the cross-section. The horizontal and vertical stabilizers of the tail were constructed similarly to the wings. Ailerons, elevators, and rudder made up the flight-control system of the aircraft. These surfaces were all cloth covered and each surface had a trim tab.

The B-17 was capable of carrying 6000 lbs of bombs on 2000-mile missions or 10,800 lbs of bombs on short-range missions. It was armed with twelve .50-caliber machine guns and carried 6380 rounds of ammunition. Guns were placed in dual turrets on the top and bottom of the aircraft. There were two remotely sighted guns in the tail and single gun emplacements on each side of the waist and nose of the aircraft.

The B-17 was powered by four supercharged Wright R-1820 Cyclone engines. Each produced 1200 hp giving the aircraft a maximum speed of 318 mph. The fuel tanks of the aircraft held 2490 gallons of gas, which gave the B-17 a maximum ferry range of 3700 miles. The B-17's crew of ten included pilot, co-pilot, navigator, bombardier, flight engineer, radio operator, and four gunners.

The B-17's great success can be attributed to two factors. It was able to fly at 25,000 feet and still drop bombs on target using the Norden Bombsight. The B-17 was also an exceptionally durable aircraft. It stayed in the air after taking severe damage from enemy fighter planes and antiaircraft guns. German Luftwaffe pilots claimed it took twenty 20-mm shells to down one B-17.

During the war in Europe B-17 Flying Fortress bombers shot down 6660 enemy aircraft and dropped 640,000 tons of bombs onto enemy targets.

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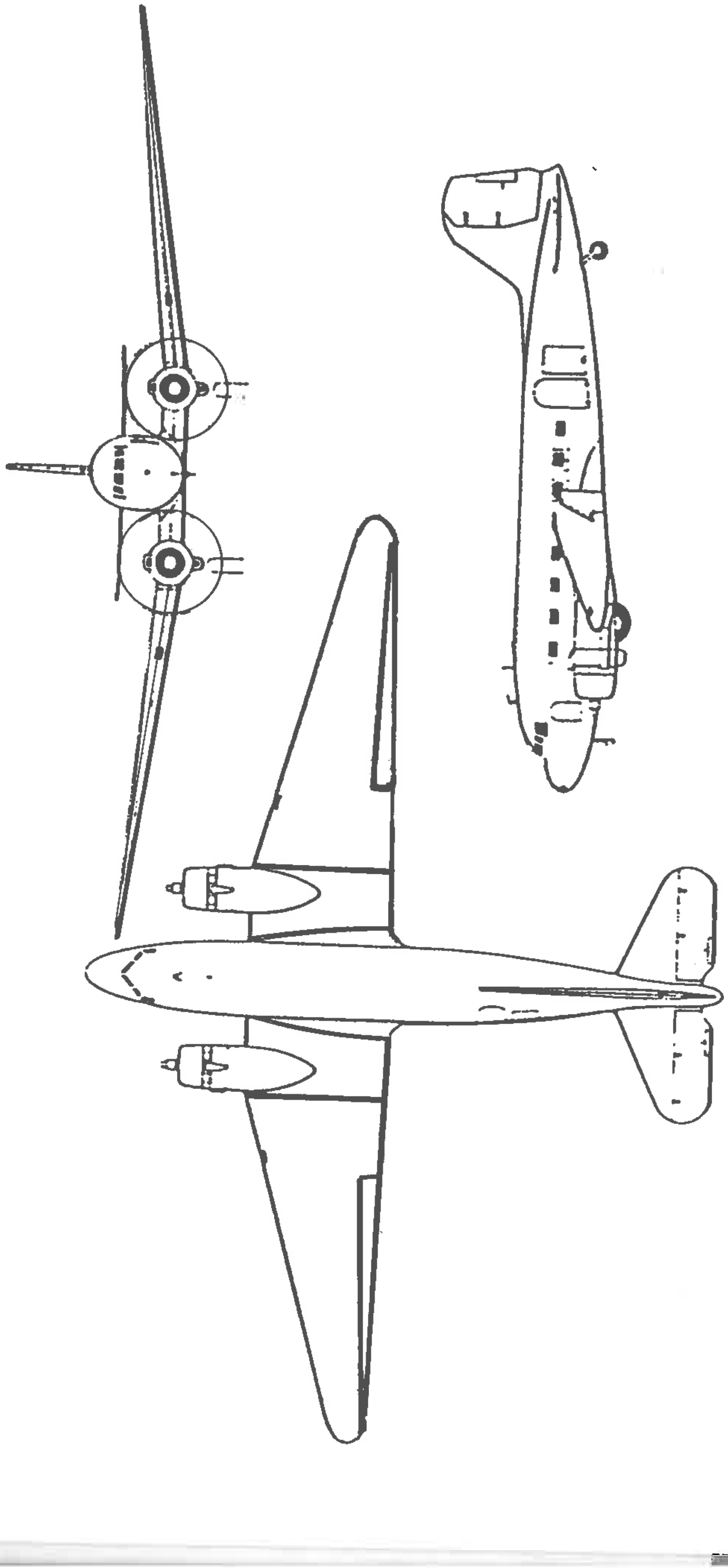

DOUGLAS AIRCRAFT DC-3

D.G. Pheils

SPECIFICATIONS

Manufacturer	*Douglas Aircraft*
Date of First Flight	*December 17, 1935*
Number Built	*10,655 (USA), 7500 (USSR)*
Length	*64.45 ft*
Height	*16.96 ft*
Wing Area	*987 sq ft*
Wing Span	*95 ft*
Operating Empty Weight	*16,865 lbs*
Maximum Takeoff Weight	*25,200 lbs*
Maximum Speed (at 8500 ft)	*230 mph*
High Speed Cruise (at 6000 ft)	*194 mph*
Economical Cruise (at 6000 ft)	*165 mph*
Service Ceiling	*21,900 ft*
Range (max payload)	*350 miles*
(max fuel)	*2125 miles*
Engines	*(2) 1200 hp Pratt and Whitney R-1830-51c36 Twin Wasp Radial Piston Engines*

The DC-3 is considered by many to be the most versatile and most widely loved aircraft of all time. It was the first to support itself financially as well as mechanically, while being used in passenger carrying and utility roles.

In 1934, the Douglas company was requested by Cyrus Rowlett Smith, president of American Airlines, to develop an enlarged version of the DC-2 to be used as a "sleeper" for U.S. transcontinental flights. The first flight of the prototype was on December 17, 1935, piloted by Carl A. Cover, from Clover Field, Santa Monica. The first Douglas Sleeper Transport (DST) was delivered to American Airlines in mid 1936 and began passenger service from Chicago, Illinois to Glendale, California on July 4, 1936.

However, it was the 21-seat, day version of the DST, designated the DC-3, that was to make Douglas Aircraft the world leader in commercial transports of the period, losing that status only at the beginning of the jetliner era with the introduction of the Boeing 707.

The DC-3 is a cantilever low-wing configuration consisting of all-metal construction with the exception of the fabric-covered control surfaces. The transport was equipped with two wing-mounted Pratt and Whitney Twin WASP radial piston engines, each capable of delivering 1200 hp. These engines were equipped with controllable-pitch, three-bladed, two-piston, hydro-controllable propellers. The DC-3 was outfitted with two main and two auxiliary fuel tanks holding a total of 510 gallons of fuel giving it a cruising range of approximately 2125 miles.

The semi-monocoque construction of the fuselage consisted of a smooth, riveted skin constructed from an extra light, aluminum alloy with a thin coating of pure aluminum. This gave the DC-3 high resistance to corrosion contributing to its long airframe life. Also, its almost circular cross-section provided a cabin height that allowed most passengers to stand upright in the offset aisles. The landing gear is a retractable tail-wheel type, with a fully-castoring tailwheel, and the cantilever tail unit is constructed of metal.

It was the load carrying capacity of the DC-3 wing that led to its fame, commercial success, and long service life. The Douglas engineers designed a wing consisting of a thick metal skin that carried much of the load itself, supported internally by a nearly indestructible network of welded boxes. Even if several of these boxes were severed the structure of the aircraft would be preserved. This was in contrast to assembled spars and ribs covered with fabric that was common to aircraft wing designs of the time.

The wing was manufactured in three sections. The center section was built integral with the fuselage to insure absolute rigidity and to eliminate the need for carry-through spars that obstructed the aisles. This wing structure was strong enough to support the engines mounted on a stub-wing center section, one on each side of the fuselage.

Pioneered in the DC-1 and carried on into the design of the DC-3, the DC series developed the innovative concept of landing flaps termed "Douglas air brakes." This gave the plane great versatility during wartime operations and as a peacetime utility aircraft serving smaller airports.

The Douglas air brakes consisted of split trailing edge flaps built into the lower side of the wing to increase lift and drag for slow, restricted landings. When hinged full-down, the flaps caused a gain in lift of 35% and a drag increase of 300%.

When America entered World War II in 1941, 507 DC-3s had been delivered. During the war, the DC-3 was produced on a large scale as C-47s and R4Ds. In the U.S. close to 10,000 aircraft were manufactured, and a further 2000 or so were built under license in the USSR with the designation Lisunov Li-2. The DC-3, in various forms, was almost certainly the only aircraft to serve in all major combat zones in World War II. When the war ended, thousands became available for civil use virtually overnight, forming the nucleus of airline fleets around the world.

Throughout the entire period of production, there was little significant change in aircraft design. The same was not true of powerplants. As new engines became available, they were installed to provide enhanced performance and load carrying capabilities. Manufacturer's lists show 11 different civil and military Pratt and Whitney twin WASP engines installed in prewar and wartime production aircraft, of between 1050 and 1200 hp. There were also 13 variants of the Wright SGR-1820 Cyclone, with ratings from 920 to 1200 hp. The initial versions had 920-hp Wright Cyclone engines but 1200-hp Pratt & Whitneys were soon offered as alternatives in the DC-3A. Delivery of the last manufactured DC-3 for Sabena (Belgium) was made on March 21, 1947.

With an extraordinarily long service life of over 45 years, more than 500 of the Douglas DC-3 aircraft remained in service through the early 1980s for airlines of various sizes throughout the world.

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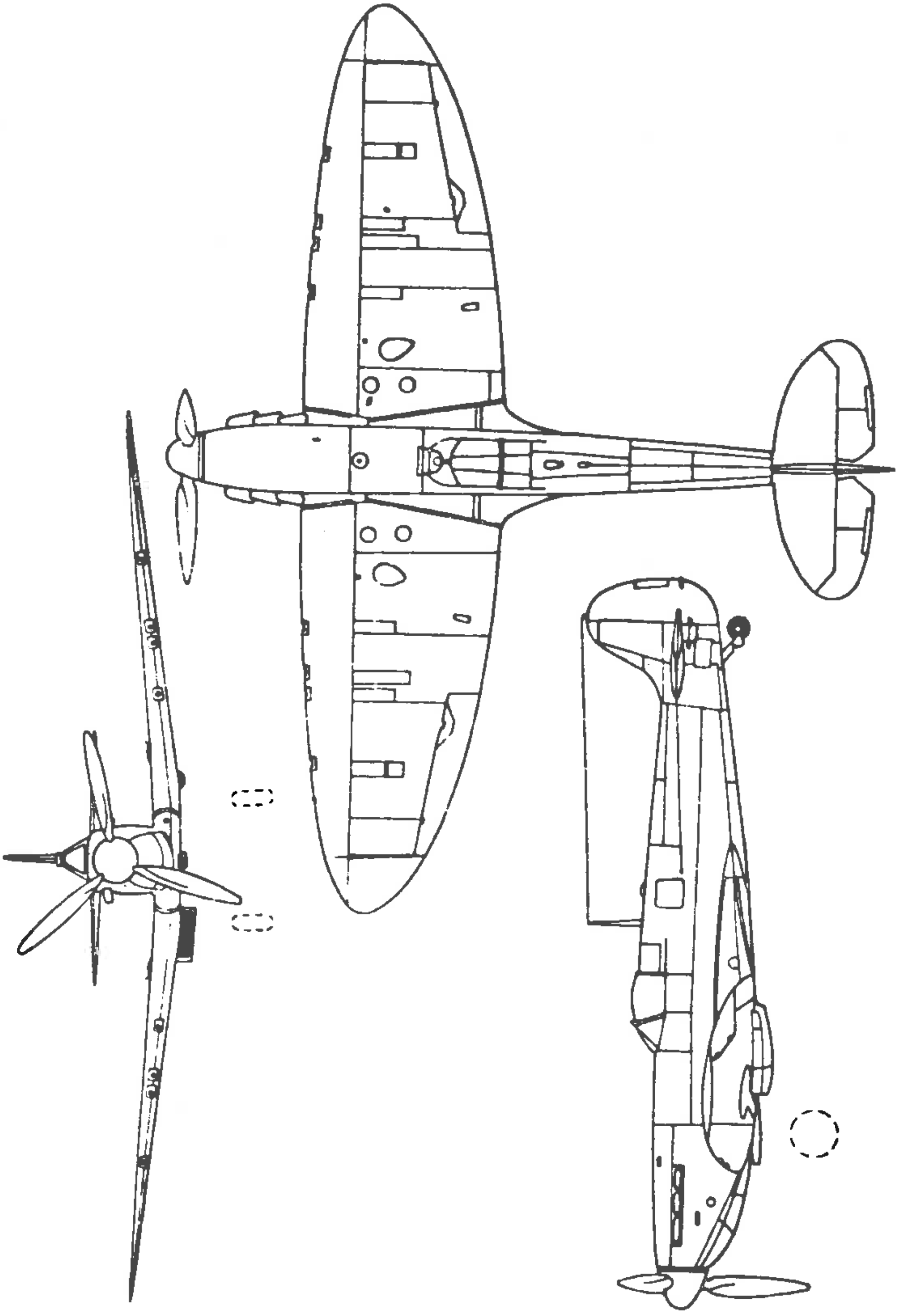

SUPERMARINE SPITFIRE

D.W. Groat

SPECIFICATIONS

Manufacturer	*Supermarine*
Date of First Flight	*March 5, 1936*
Number Built	*20,351*
Length	*29.92 ft*
Height	*11.42 ft*
Wing Span	*36.83 ft*
Root Chord	*8.17 ft*
Tip Chord	*2.25 ft*
Wing Dihedral	*6.6°*
Wing Aspect Ratio	*5.52*
Operating Empty Weight	*810 lbs*
Maximum Takeoff Weight	*5784 lbs*
Maximum Level Speed	*370 mph*
Service Ceiling	*34,000 ft*
Range	*435 nautical miles*
Engine	*(1) 1030 hp Rolls-Royce Merlin V-12*

"A designer never looks at his aircraft and calls it finished. He is always looking into the future, looking at ways to improve his design long before it flies. An aircraft is never complete to its designer," said Reginald Mitchell, chief designer at Supermarine Aviation, who, in 1927, designed and built the S-6B seaplane for the Schneider Seaplane Races. The plane shattered the world speed record by 200 mph when it screamed over the finish line at 407.5 mph.

This relentless pursuit of perfection led to arguably the greatest fighter aircraft in Britain's history, the Supermarine Spitfire.

Originally, the Spitfire was to be an all-metal biplane with fixed landing gear and a fabric-covered fuselage. But seeing that this design would be obsolete before its maiden flight, and, taking into account the increasing Nazi threat, Mitchell got permission to scrap this aircraft for a high-speed monoplane based on his award winning seaplane. Director of Supermarine, Robert McClean, with full confidence in his chief engineer, informed the RAF (Royal Air Force) that, "Under no circumstances will any technical member of the Air Ministry be allowed to interfere with the designer." The result was first flown on March 5, 1936.

The first Spitfire, designated the Mk I (Mark I), incorporated some rather radical designs including an elliptical wing, retractable tail wheel, and an all stressed metal skin construction. This made the Spitfire very sleek and maneuverable, but also made it difficult to build quickly. As a result the Spitfire's counterpart, the Hawker Hurricane, bore the brunt of in the Battle of Britain, even though it was inferior to the Spitfire, because the fabric covering of the Hurricane made it easier to manufacture and repair.

The engine that Mitchell decided on was the Rolls-Royce Merlin V-12 with 1030 hp, the most powerful engine available at the time. The first 77 Spitfires were equipped with a two-blade wooden propellers that were soon replaced with a three-blade, variable-pitch prop that increased the ceiling by 7000 ft and improved the rate of climb considerably.

When war between Britain and Germany broke out on Sept 1, 1939, it became quite apparent that the Spitfire was the only fighter in the RAF that could match Germany's Messerschmitt Bf 109. Unfortunately, Reginald

Mitchell was not able to see the success of his fighter in the defense of Britain, for he had died on July 11, 1937, of tuberculosis.

The RAF, for fear of losing what few Spitfires it had available at the outbreak of the war, put only its best pilots in them. As a result, the Spitfire soon earned itself a reputation as the savior of Britain as the combination of pilot skill, increased firepower, and superior aircraft sent Nazi planes to the ground in droves.

Late in 1943, three RAF pilots returned to base with news that they had just shot down, "an unknown German aircraft with a radial engine." This aircraft turned out to be the Focke Wulf Fw-190, a new and deadly weapon designed by Nazi Germany. It was soon learned that the Fw-190 was seemingly superior to the Spitfire in almost every respect, but designers at Supermarine just dropped in the improved Merlin engine with 1660 hp and the Spitfire soon triumphed over Hitler's latest creation.

Before the war ended the Spitfire underwent eleven modifications, each incorporating an improvement over the previous design. Such improvements included self sealing fuel tanks, armored pilot's seat, a bubble canopy, four-bladed prop, and fitted belly tanks.

The final model, the Mk XI, was designed as a naval carrier plane and dubbed the Seafire. Designed with clipped wings that folded for storage aboard aircraft carriers, the Seafire was equipped with four 20-mm cannon and the monstrous Rolls-Royce Griffon engine that produced 2375 hp. Since the exhaust gases roared out of the engine at speeds approaching Mach 2, some of this power was obtained simply by redirecting these gases rearward through six exhaust baffles on each side. The Seafire, even though the fastest and most heavily armed of all the previous Spitfires, was produced too late for the war and entered service in the RAF from post-WWII until the early 1950s.

With the exception of the canopy and propeller, the Spitfire underwent very few changes in its general appearance over the course of the war, which compliments the design abilities of Reginald Mitchell who, despite doctors orders, sacrificed his health and ultimately his life for the development of the Spitfire.

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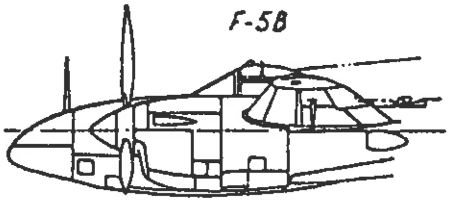

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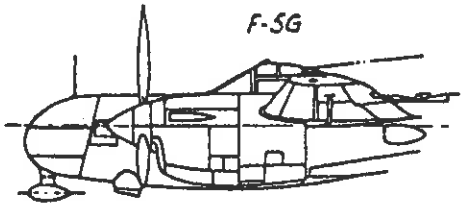
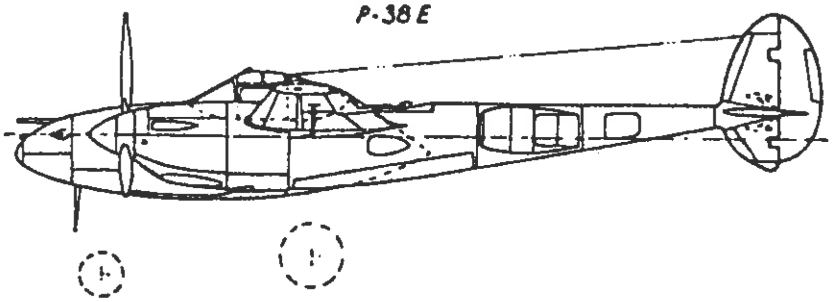
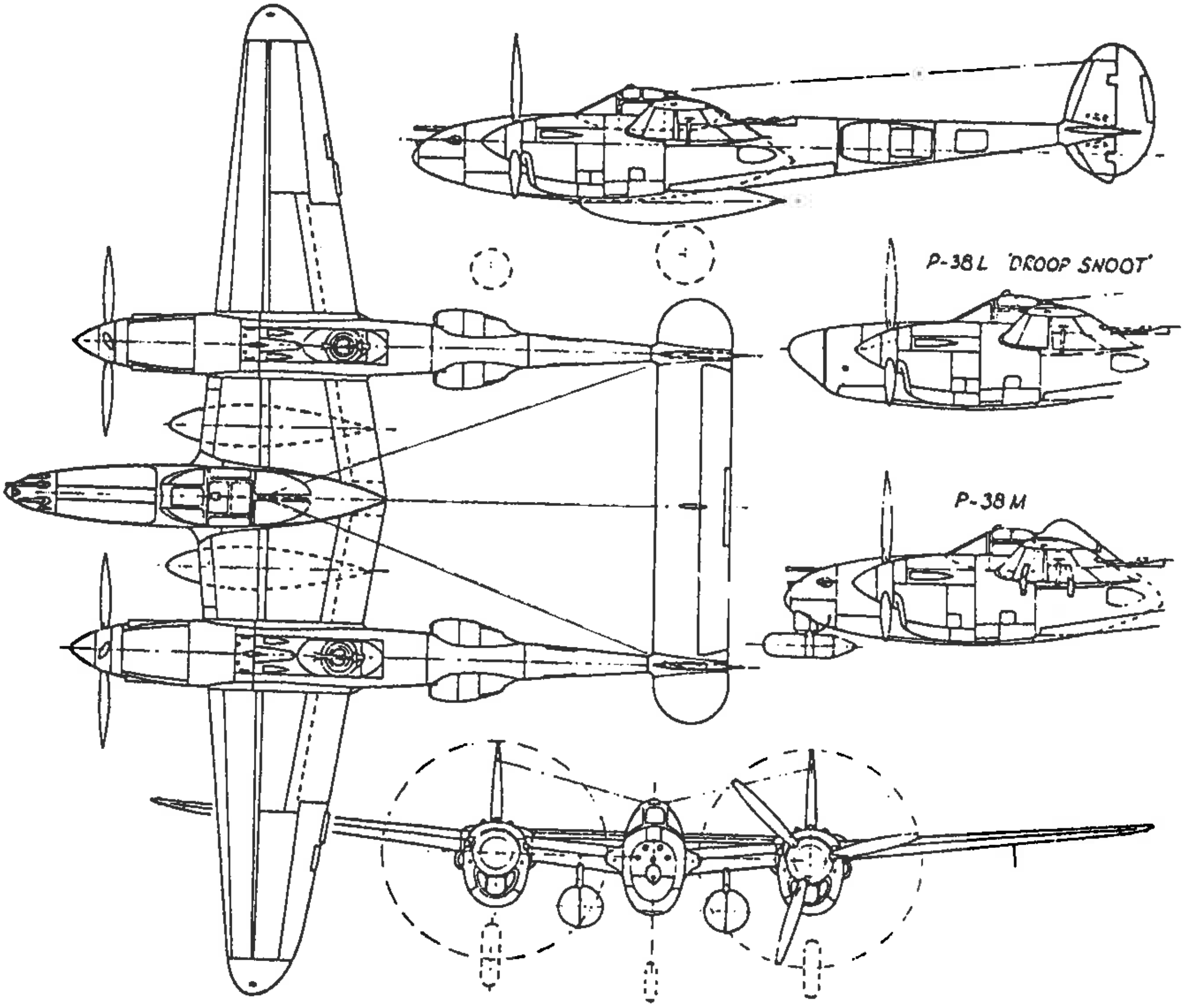


P-38 E





LOCKHEED P-38

S.M. Kelman

SPECIFICATIONS

Manufacturer	*Lockheed*
Date of First Flight	*January 27, 1939*
Number Built	*10,037*
Length	*37.83 ft*
Wing Span	*52 ft*
Height	*12.83 ft*
Wing Area	*328* ft^2
Empty Weight	*12,800 lbs*
Maximum Weight	*21,600 lbs*
Wing Loading	*63.1 psf*
Maximum Speed (at 25,000 ft)	*414 mph*
Service Ceiling	*44,000 ft*
Range	*2,600 miles*
Engines	*(2) Allison V-1710-111/-113*
Thrust	*(each) 1475 hp*

The Lockheed P-38, called the Lightning, took on the full brunt of World War II seeing action in both the European and the Pacific theaters. As the first USAAF fighter to down a German aircraft, and the first USAC plane to land in Japan after V-J Day, the P-38 was the only U.S. pursuit aircraft in continuous production throughout the war. It had roles of pursuit, fighter, night fighter, escort fighter, bomber, and photographic-reconnaissance aircraft.

America's top-scoring pilot with 40 kills, Major Richard Bong, flew a P-38. Close behind were Major Thomas B. McGuire with 38 kills and Col. C. H. MacDonald with 27 — both in P-38s. By the end of the war, 38 other pilots had reached the status of "Ace" flying P-38s exclusively. In fact, no other U.S. fighter has downed more Japanese aircraft than the P-38.

Its unique twin-boom layout housed the turbo-supercharged engines, radiators, and main undercarriage wheels. With the placement of the armament in the central nacelle, there was no need for the added weight of synchronization gear. To improve stability and reduce a torque problem, the propellers counter rotated outward. As seen from the rear, the port propeller turned counterclockwise and the starboard propeller turned clockwise. The pilot, nestled in the center nacelle just behind the machine guns and cannon, had an engine to either side to protect him from incoming enemy fire. It is interesting to note that the cockpit window must be closed upon takeoff to avoid turbulent flow over the tail assembly.

Called the Atlanta in its development stage, the P-38 went through several modifications and improvements during the war. In all, the Lightning had 34 different designation numbers from the earliest experimental XP-30 to the latest photographic-reconnaissance FO-1. Lockheed had proposed to the Navy a carrier aircraft design based on the P-38, that would have folding wings and arrester hooks on a strengthened P-38H airframe. The Navy, however, did not care for the idea of a liquid-cooled-engine aircraft that required large amounts of deck space.

One of the most notable kills by a P-38 was made on April 18, 1943, after U.S. Navy cryptographers decoded a message that Admiral Yamamoto would be flown to Ballale airfield on Shortland Island to make an inspection. The 339th Fighter Squadron was called to intercept the transport. Sixteen P-38s led by Major John Mitchell were assigned the task. The 500-mile journey from Henderson Field, Guadalcanal, to Shortland Island was accomplished using 165- and 310-gallon drop tanks. The P-38 pilots outfought and downed at least five Zeros and two bomber-transports, including the Mitsubishi Ki.21 carrying the Admiral, with the loss of only one P-38. Captain Thomas G. Lanphier fired the final salvo that sent the transport down in flames.

In late 1941, the RAF put in an order for Lightnings. The American authorities were not eager to give the British the turbo-supercharged fighter to use against the Germans. What they sent the RAF was a non-supercharged airplane that had propellers rotating in the same direction. Only three were delivered and they were called the Lightning I. Since their performance was unsatisfactory, they were used as trainers and became known as the Castrated Lightning I.

Original armament consisted of one 23-mm Madsen cannon with 50 rounds of ammunition and four .50-caliber Colt machine guns with 1000 rounds per gun. In later versions, the Colt guns were replaced by .50-caliber Brownings. Other cannons in the center nacelle were the 37-mm Oldsmobile and later the 20-mm Oerlikon.

A triple-cluster of 4.5-inch rocket launchers on either side of the center nacelle and engines was first used on the P-38G, or 1600-lb bombs could be carried beneath the wing center-section. In another set-up, racks for carrying 14 rockets below the outer wings were used. These racks could be strengthened to hold 2000-lb bombs or 300-gallon drop tanks. At maximum capacity, the P-38 could carry a load heavier than the standard bomb load of the contemporary B-17 and B-24 bombers, both of which have four engines.

The P-38M was the night fighter. It was a modified version of a P-38L painted with a glossy black finish. This was a two-seater aircraft with the radar operator behind the pilot which nessessitated a redesigned canopy to accomodate the radar operator. Its features included an AN/APS-6 radar in an external radome beneath the nose, relocated radio equipment, and anti-flash gun muzzles. This version of the plane was introduced near the end of the war.

As a photo-reconnaissance aircraft, the P-38 had increased range and was used heavily in North Africa. The Luftwaffe pilots would not engage the Lightnings at any altitude for fear of being shot out of the sky. The Lightnings found a new use as low-level bombers, taking out tanks and road transports. It was rumored that the Germans called the Lightning "The Forktailed Devil."

The last 113 P-38s were built by Consolidated Vultee. At the end of the war, many Lightnings were scrapped, and a few were sold as surplus, to be used for aerial survey and air races. Still others were sold to foreign military services with 12 sold to Honduras in the late 1940's, the last country to use the P-38s, and with the retirement of the final aircraft, so ended the military service of this historical warplane. Today, the P-38 lives in museums and hangars of a few people lucky enough to own a legend.

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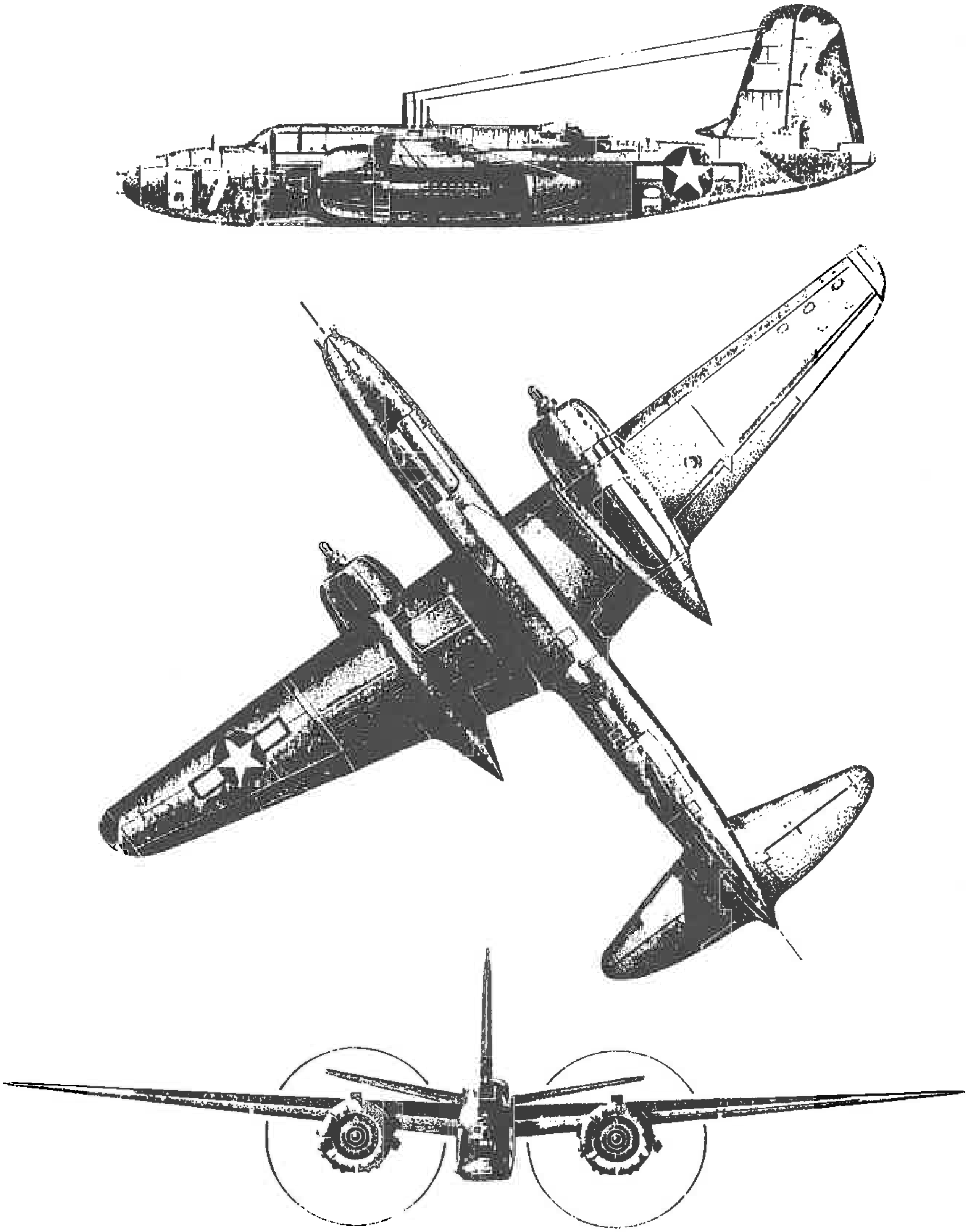

DOUGLAS A-20

M.T. Masterleo

SPECIFICATIONS

Manufacturer	*Douglas*
Date of First Flight	*August 17, 1939*
Length	*48 ft*
Wing Span	*61 ft*
Root Chord	*12 ft*
Tip Chord	*2.5 ft*
Wing Sweep	*0°*
Wing Aspect Ratio	*8*
Operational Empty Weight	*17,200 lb*
Maximum Takeoff Weight	*30,000 lb*
Maximum Cruise Speed (at 10,000 ft)	*308 mph*
Typical Cruise Speed (at 10,000 ft)	*230 mph*
Service Ceiling	*25,000 ft*
Range	*1025 miles*
Engines	*(2) Wright R-2600-23*
Power	*(each) 1600 hp*

The initial design of the A-20 was in response to a need for an attack bomber which could fly at both high and low altitude with equal ease. The response to this need came from Donald Douglas, Jack Northrop and Ed Heinemann, who had worked in concert to develop the A-17 attack bomber. The project was absorbed by the Douglas Aircraft company at its El Segundo division. The changes which accompanied this absorption resulted in the birth of the model 7-B, the prototype for the A-20 series.

The A-20 first flew August of 1939, and from its first flight the aircraft was known as a pilots plane. The aircraft was fast, indeed at 317 mph it could out perform most fighters of the day. It was also maneuverable and comfortable to fly. The pilots and crews knew they had something special, when they climbed aboard the A-20.

Though the Douglas A-20 was not involved in any outstanding military operations throughout World War II, its many variations performed in front line service for the duration of the war. The A-20 had twelve distinct designated variations with even more specialized variants serving in campaigns in the Pacific, Europe and Russian theaters throughout the war. The versatility of this new aircraft was demonstrated by the many types of missions it performed.

The A-20's were used for standard high and low altitude bombing, as well as specialized bombing roles. These specialized roles included day and night hops, naval torpedo bombing, as well as missions that were unique to the A-20. Certain of these unique missions required that the standard A-20 be modified in ways that produced some of the most exotic airplanes of the war.

One of the more interesting of these variations was the Havoc-1 which was fitted with a solid nose, housing four .303-caliber machine guns. This was in addition to the normal four forward firing guns standard on the A-20. The aircraft also carried the A.I. Mk. VI radar, giving the Havoc-1 the ability to bomb at night, a role that it was exclusively used for in World War II.

Some of the other Havoc A-20's were also altered and fitted with a 2700 million candle power Helmore G.E.C. searchlight. The light was housed in the nose of the aircraft and the batteries filled the internal bomb bay. This along with the early air interception radar enabled the "Turbinlite Havoc's" as they were known to search for and illuminate enemy fighters.

Some of the Boston III A-20's even experimented with a top turret and racks of 60 lb rocket projectiles mounted on the wings. The rocket racks never caught on, however the top turret did. All latter models of the A-20 were fitted with a top mounted twin .50-caliber machine guns.

Finally, one of the strangest roles that the A-20's performed was that of aerial mine layer. The planes that were assigned to this role would tow bombs on long cables stored in their internal bomb bays. The mine would hang suspended 2,000 feet below the aircraft and directly in the path of incoming enemy bombers.

All of the variants, no matter what their specialty role low, high, intercept, or night bombing, shared the same basic shape. This is a testimony to the engineering thought involved in the design of the original DB-7/A-20 attack bomber. It can truly be said that the A-20 series was a series of great flyers.

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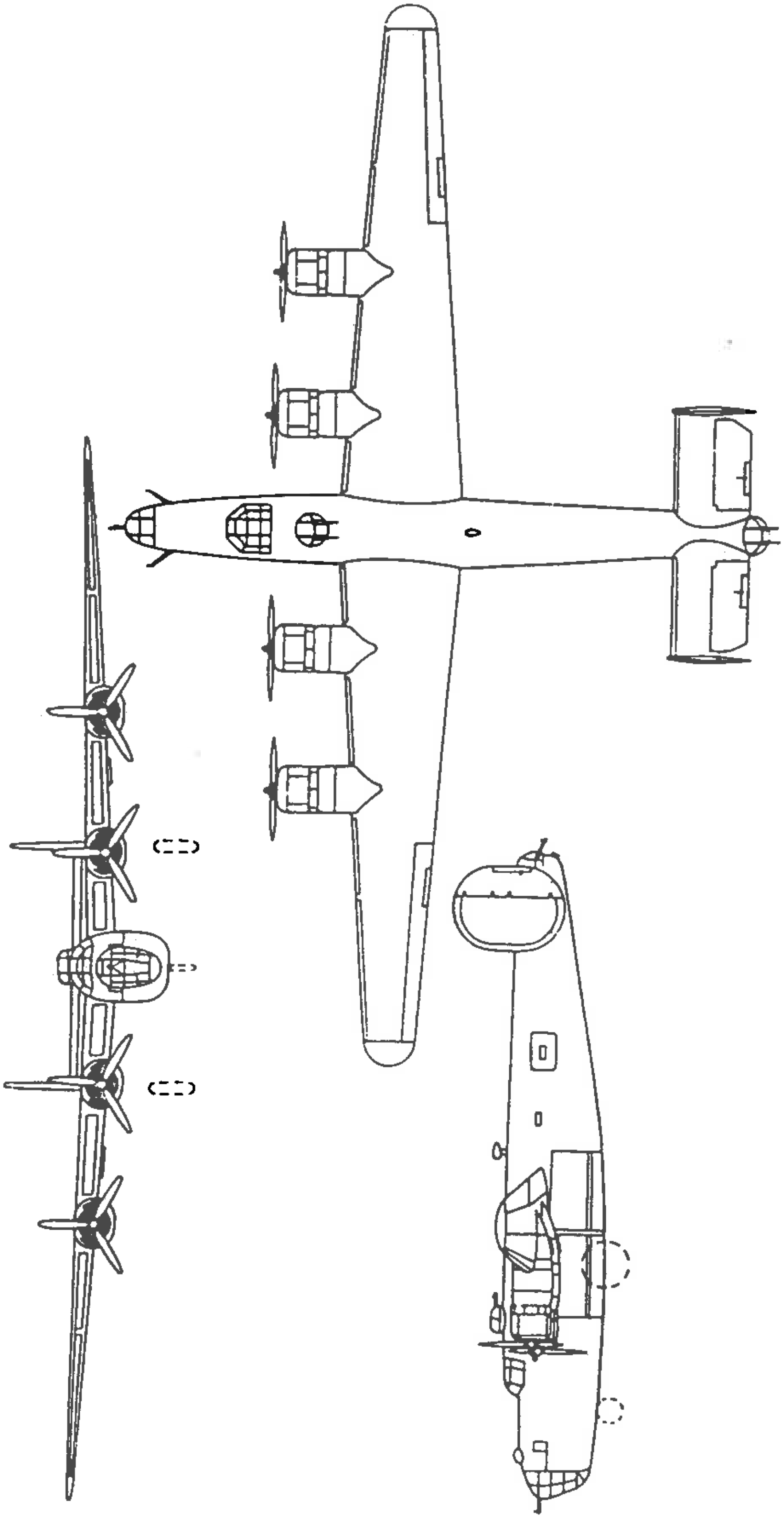


CONSOLIDATED B-24

M.L. Bonello

SPECIFICATIONS

Manufacturer	*Consolidated*
Date of First Flight	*December 29, 1939*
Number Built	*2738*
Length	*66.33 ft*
Wing Span	*110 ft*
Root Chord	*Not Available*
Tip Chord	*Not Available*
Wing Sweep	*0°*
Wing Dihedral	*0°*
Wing Aspect Ratio	*11.55*
Operating Empty Weight	*56,000 lbs*
Maximum Takeoff Weight	*71,200 lbs*
Maximum Wing Loading	*Not Available*
Maximum Cruise Speed (at 25,000 ft)	*303 mph*
Service Ceiling	*35,000 ft*
Range	*2850 mi*
Engines	*4 Pratt and Whitney Twin Wasp R-1830-43 engines*

With the outbreak of World War II, the United States Army became interested in obtaining new four-engine bombers. At that time, it only had the Boeing B-17 Flying Fortress that had not undergone any rejuvenations in recent years. They asked the engineers of Consolidated Aircraft Corporation to design a new bomber with better flight characteristics than the B-17. The major specifications were speeds above 300 mph, a ceiling of 35,000 ft, and a range of 3000 miles.

On March 30, 1939, a contract between the Army and Consolidated Aircraft was signed for a single prototype and the mock-up to be completed in nine months. Before the prototype had even been tested, the U.S. Army, Britain, and France had already placed orders for the aircraft.

One of the outstanding features of the prototype was a wing configuration using Davis airfoils. The airfoils were designed for high lift characteristics and it was claimed that they reduced profile drag by 25% at low speeds and 10% at high speeds. The airfoils were equipped with Fowler area-increasing flaps. The wings were placed high on the fuselage to provide more cargo area and ease in loading. They were constructed on two box-spars with built-up ribs covered by aluminum alloy sheet. The main fuel tanks were located in the center panels.

Other features on the aircraft were the twin vertical tail-rudder configuration and its tricycle-type landing gear. It was the first plane to employ such a landing gear configuration. The front wheel retracted forward into the fuselage while the back structures retracted sideways to rest in open wing stowage. The prototype was powered by four 1200-hp Pratt and Whitney Twin Wasp 14-cylinder, air-cooled radial engines. It was armed with .30-calibre machine guns that were hand held.

The bomb bay was capable of accommodating 8000 lbs of bombs that were stowed vertically in the forward and rear compartments. A catwalk connected the flight deck with the rear of the fuselage. The aircraft also had roller-type doors that retracted into the fuselage. This configuration reduced drag considerably when the doors were open.

The tests of the prototype were successful, although the maximum speed attained was only 273 mph. The first batch of aircraft produced from the XB-24 design were purchased by the British, who gave the configuration the name "Liberator." These aircraft were built to British specifications and used mainly as transport vehicles. In June 1941, the U.S. Army Air Corps received the first B-24A Liberator. It was also used mainly for transport.

The XB-24A was then improved upon to become the XB-24B. This configuration had self-sealing fuel tanks, and the mechanically-supercharged engines were replaced by turbo-superchargers that enabled the aircraft to attain speeds of 310 mph, 10 mph over the initial flight specifications. In addition, because of the new engine configuration, the oil-cooling system was moved from beneath the engine to the engine sides. This resulted in the elliptical configuration of the cowls that was seen on all subsequent versions of the Liberator. The B-24C was the result of these changes.

The B-24D was very similar to the B-24C in that its general configuration was the same except the addition of R-1830-43 engines and more defensive armament. In addition to the .50-calibre, hand-held nose gun, the first 94 B-24D's were equipped with a four hundred r.p.g. for the dorsal turret and a six hundred r.p.g. for the tail turret. The maximum bomb load was still 8000 lbs.

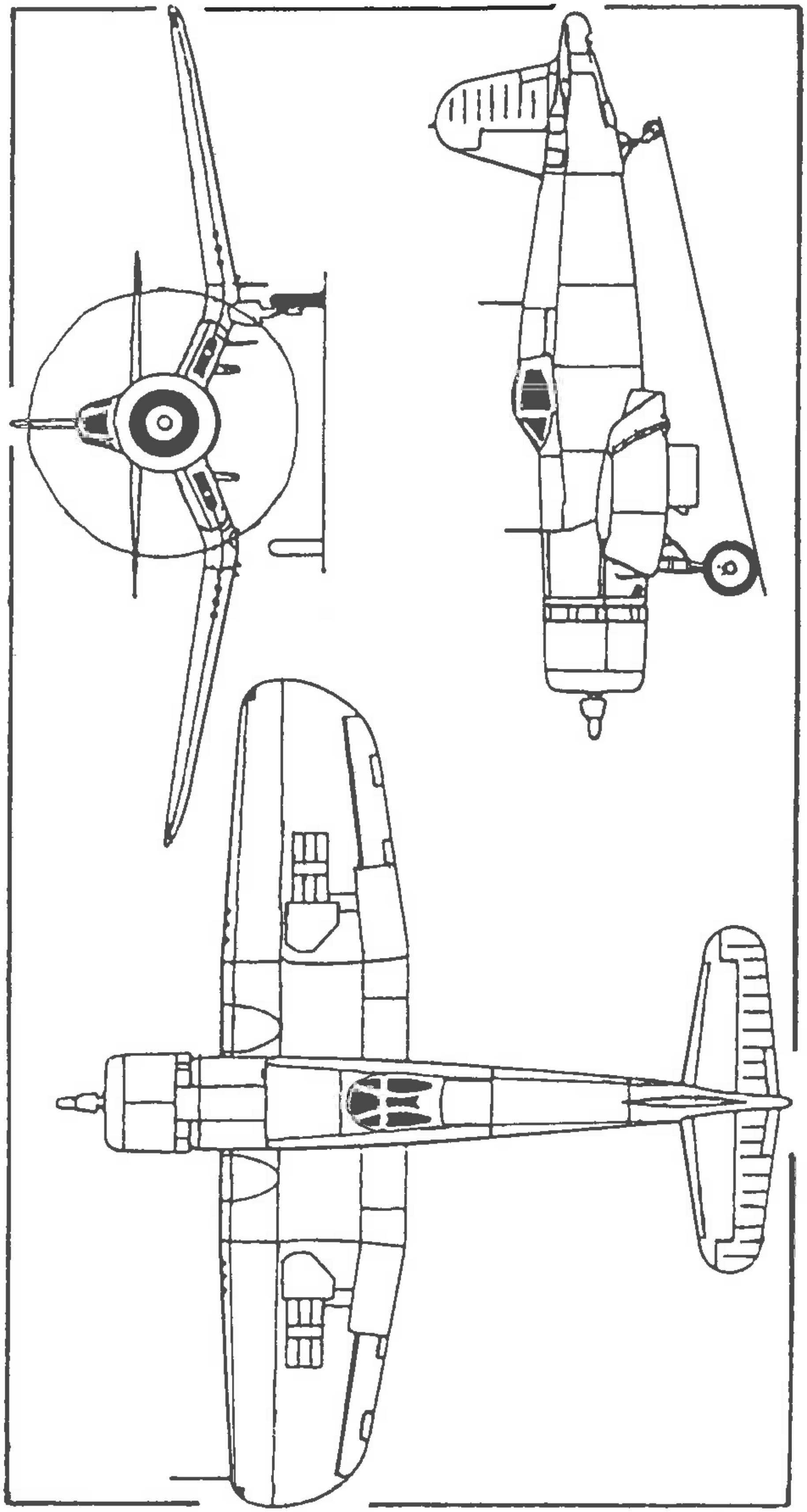
Throughout the production of the B-24D's, increasing amounts of armor were added. Eventually the B-24 contained three hand-held nose guns, two guns in the Martin upper turret, two guns in the Consolidated tail turret, a single ventral gun, and two waist guns. Thus, the B-24D was equipped with ten .50-calibre guns. Its bomb load was increased to 12,800 lbs and its maximum gross weight increased to 71,200 lbs.

The Consolidated B-24 was the most widely produced airplane for the United States and its allies in World War II. A total of 18,188 Liberators and Liberator variants were produced between 1939 and 1945. Of the B-24D series, Consolidated produced 2425 in their San Diego plant and 303 in their Fort Worth plant. Douglas contributed ten from its facilities in Tulsa, Oklahoma. Douglas was assigned to build Liberators by the government to help Consolidated fill their goal of 2000 planes per month. The Ford Motor Company was also requested to produce sub-assemblies of the craft to aid in the mass production of the Liberator. Various versions of the same model aircraft (like the various armaments on the B-24D) were made because these aircraft were produced so rapidly that changes were being made between the time that the plane got on the assembly line and when it got off.

The B-24D version of the Liberator was the first to enter operational services with the United States Air Force bombing unit. They were employed by the Coastal Command of Britain and the United States Air Force and fitted with radar systems to detect submarines at night. Their main purpose, however, was bombing. B-24D's were involved in every theater of World War II from Wake Island to China to Germany. There are many amazing stories of a single bomber engaging in combat with multiple Axis fighters and winning the encounter. When a squadron of B-24D's were being attacked or dropping bombs on their targets, they had the ability to concentrate all of their firepower on one target which made them deadly to encounter.

After the B-24D, there were other modifications of the aircraft to produce the B-24E,G,H,L,M,N, the XB-24F,K, the XB-41, and the C-87, which was a cargo aircraft. The aircraft had modifications in armament, deicing capabilities, and, in the last versions, a single tail surface.

Even though the Consolidated Aircraft Corporation's Liberator was such a widely produced and used aircraft, it was usually in the shadow of the Boeing Flying Fortress. It was frequently referred to as an ugly duckling because of its tricycle-type landing gear and low position from the ground. It is unfortunate that such an adaptable and widely used aircraft never got the recognition that it deserved.



CHANCE VOUGHT F4U CORSAIR

K.E. Thornton

SPECIFICATIONS

Manufacturer	*Chance Vought*
Date of First Flight	*May 29, 1940*
Number Built	*12,571*
Length	*33.69 ft*
Wing Span	*40.98 ft*
Height	*14.77 ft*
Maximum Operating Weight	*15,079 lbs*
Empty Weight	*8873 lbs*
Maximum Speed	*462 mph*
Service Ceiling	*44,000 ft*
Range (with drop tank)	*1735 miles*
Engine	*Pratt and Whitney R-2800-32(E) Double Wasp*
Thrust	*2850 hp*

The Corsair was designed by Rex Beisel and Igor Sikorsky. These gentlemen were faced with the task of designing a naval fighter around the largest propeller and the most powerful engine to be fitted into a fighter of the time. The result of the design challenge was the Corsair. Because this was a naval fighter, expected to operate from aircraft carriers, strong and relatively short landing gear was required. To meet the propeller requirement and the fact that this was to be a carrier fighter the designers chose an inverted gull wing, which gave the necessary clearance for the propeller and the short, strong landing gear it needed. This wing also gave the aircraft visual distinction few other aircraft could match. As with other carrier aircraft of the time, the Corsair had folding wings to save space on the carrier. They also reduced the aircraft's damage potential while on the carrier because there was less area exposed to attack, and only a forcible direct hit would damage the aircraft beyond repair.

The powerful engine enabled the Corsair to be the first United States warplane to exceed 400 mph in level flight. Testing the Corsair led the Navy to redefine two of its older test requirements. All fighters and dive bombers had been required to maintain a zero-lift (vertical) dive for 10,000 ft. The Corsair with its powerful engine and relatively clean aerodynamic shape, could easily attain 500 mph in a vertical dive, which loaded the aircraft up to 9 g's during the pull-out from the dive. At high altitudes, compressibility effects caused trouble such as buffeting and trim changes that led to extreme structural strain, sometimes even failure. The other redefined requirement was that all aircraft were required to be able to recover after a 10-revolution spin. During flat spins, the test pilot found himself fighting the controls of the Corsair and not winning. The aircraft had more force on the control surfaces than the pilot could overcome with the stick. If not for a spin chute the aircraft would have been lost.

The Corsair was versatile, rugged, and long lasting, but lacked shipboard finesse (ease of landing on an aircraft carrier), so it began its operation in the Pacific Theater with the United States Marines as an island-based fighter. With the cockpit placed so far back on the fuselage, the pilot had difficulty seeing the flight deck of the aircraft carriers in order to land. With patience, practice and caution, by the summer of 1944 it was operating off of some carriers, although the British, who were using the plane also, had cleared the plane nine months earlier for carrier operations. The Corsair had two large oil coolers located in the wings, one on each side of the fuselage that "whistled" in flight. As the Marines gained air superiority, the Japanese nicknamed the airplane "Whistling Death."

Through its long production history the aircraft had three producers and several variants. Aiding in Vought's production were the Goodyear and the Brewster companies. The Goodyear aircraft were designated FG and a total of 4008 were produced. Goodyear also produced 10 of its own version, designated F2G using a 3000-hp Pratt and Whitney R-4360 Wasp Major, a 28-cylinder, four-row radial engine. The Brewster company produced 735 Corsairs under the designation of F3A.

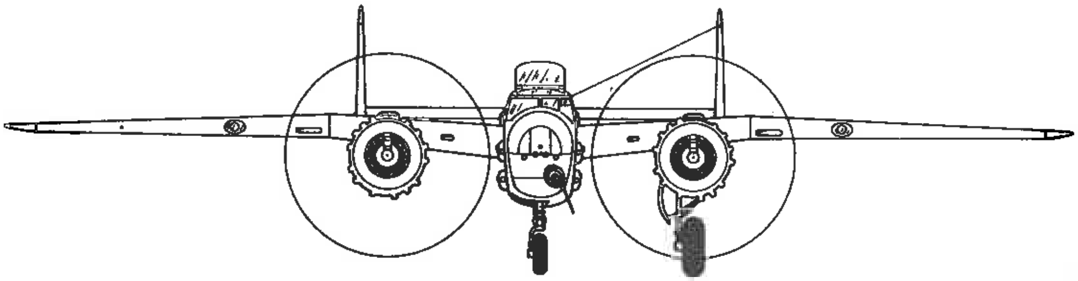
In December 1952 the last of 12,571 Corsairs came off the assembly line. Its military career began with the United States in the 1940s and ended in the mid-1970s when the last South American country withdrew it from service.

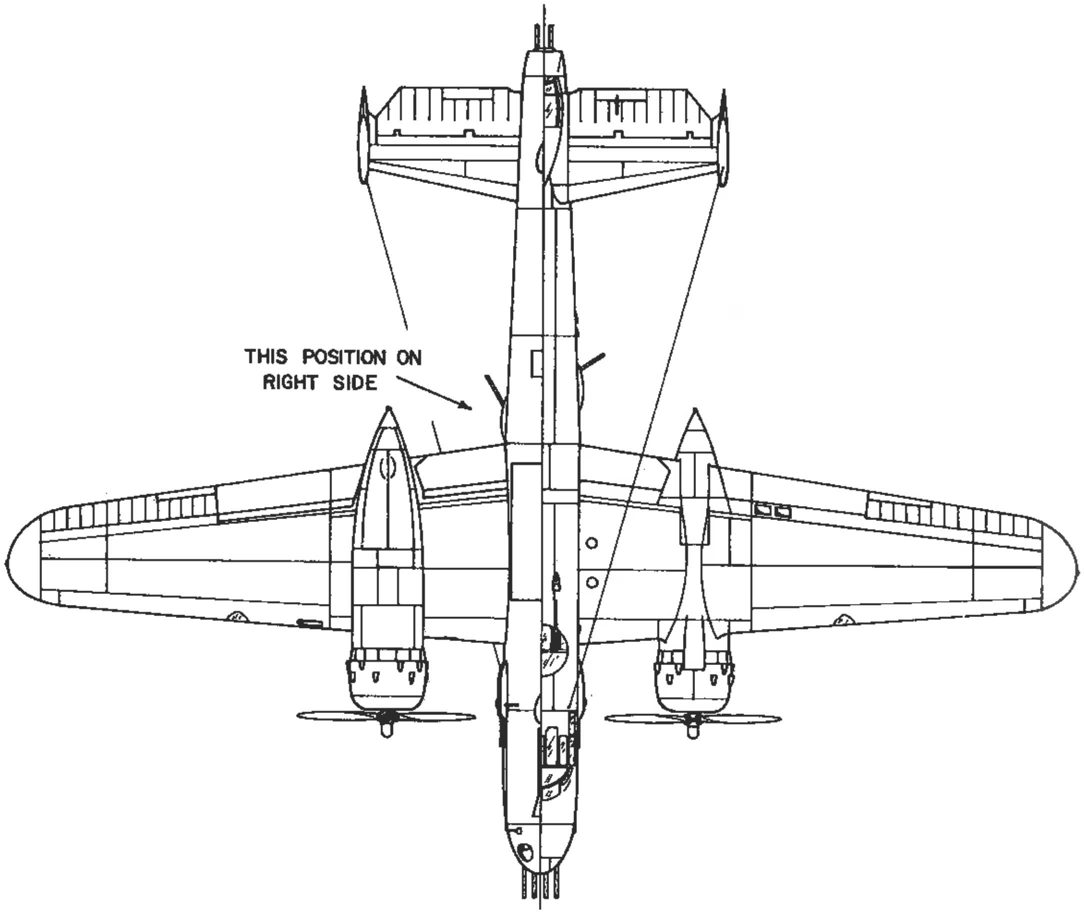
The Corsair used various armament schemes. Originally designed to carry two guns in the fuselage and two in the wing, this armament was changed to six .50-caliber Browning machine guns in the folding outer wings, which gave the aircraft considerable punch. The F4U-1C had four 20-mm cannon as its armament. Later types carried a 160-gallon drop tank to extend range and two 1000-lb bombs or eight rockets. Bombs and rockets were added for two reasons. The first is that pilots were having difficulty finding other fighters to engage because of their spectacular 11 to 1 kill ratio. The second is that pilots found the Corsair a very capable ground attack plane that could carry a variety of stores for this mission.

The Corsair demonstrated its ruggedness and durability as a ground attack airplane in the Korean War. Charles Lindbergh had convinced pilots in World War II that 4000 lbs of bombs could be carried by the Corsair. In Korea it was routinely loaded with 4000 lbs of bombs and sent on ground strike missions, often accompanying the newer and more powerful Douglas Skyraider.

In WW II and Korea, Corsairs were equipped with radar and used as night fighters. The Koreans had slow, wooden, light bombers, undetectable by radar, that skimmed the treetops to bomb front line troops and supplies. It was the job of the Corsair to go up at night to find these planes and destroy them.

The Corsair lives on in the hearts of many and in the sky today. It was featured on the television show "Baa Baa Black Sheep," and can often be seen today at airshows, museums, and air races. With its large, powerful radial engine, distinctive look, and distinguished service, the Corsair will always be a popular airplane. . .indeed a great airplane.

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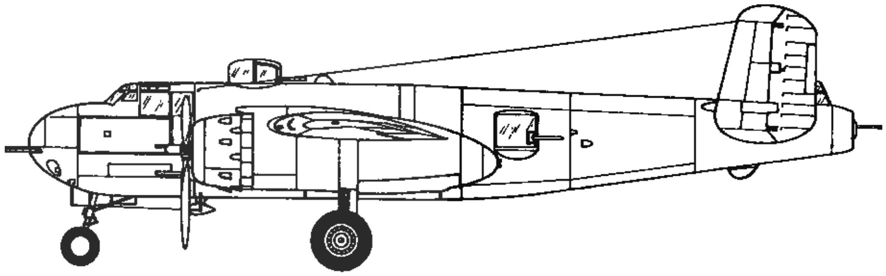

NORTH AMERICAN AVIATION B-25

J.E. Giuliani

SPECIFICATIONS

Manufacturer	*North American Aviation*
Date of First Flight	*August 19, 1940*
Number Built	*~11,000*
Final Model	*B-25J*
Length	*52.917 ft*
Height	*15.750 ft*
Wing Span	*67.583 ft*
Wing Area	*610 sq ft*
Wing Sweep	*0°*
Wing Dihedral (inner wing panel)	*5°*
(outer wing panel)	*0°*
Operating Empty Weight	*21,100 lbs*
Combat Weight	*33,500 lbs*
Maximum Weight	*41,800 lbs*
Maximum Speed	*272 mph*
Normal Operating Speed	*200 mph*
Service Ceiling	*24,200 ft*
Range	*1350 miles*
Engines	*(2) Wright Cyclone Radial R-2600-29*
Power (sea level)	*(each) 1700 hp*
(13,000 ft)	*(each) 1450 hp*
Armament	*(18) 0.5-in. Colt-Browning machine gun*
Bomb Load	*3200 lbs*

Hailed as one of the best and most versatile medium bombers of World War II, the North American Aviation B-25 "Mitchell" saw action in every theater of the war. Produced in larger quantities than any other twin-engine bomber at the time, the B-25 played important roles in the Australian, Chinese, Dutch, English and Russian Air Forces, as well as the American Army Air Corps.

The design of the B-25 came about in response to a 1938 Army Air Corps circular proposing a twin-engine, medium-range attack bomber. A number of proposals resulted from the circular, but the design conceived by the North American Aviation company was selected. This design led to the January, 1939, test flight of a prototype bomber titled the NA-40-1. Even the initial reports from flight testing suggested that the twin-engine bomber was capable of outstanding performance. After the incorporation of numerous design changes to increase the payload and flight performance of the NA-40, North American Aviation was awarded a contract for the production of 184 of these bombers under the designation B-25. With the outbreak of war only a few weeks earlier, the bomber was ordered straight from the drawing board. Approximately one year later on August 19, 1940, the B-25 made its maiden voyage as 24 of the aircraft were delivered to the Air Corps.

In its original form, the B-25 carried a bomb payload of 2400 lbs. Its defensive armament consisted of a .30-caliber machine gun in the nose and one in each of the 2 waist positions. The tail of the aircraft was protected by a single .50-caliber gun in a tail-gunner position.

As the B-25 saw service, many modifications were undertaken to improve the aircraft's performance. These included self-sealing fuel tanks, heavier armor and improved defensive armanent consisting of upper and lower surface Bendix turrets. These improvements brought about 2 new models of the B-25: the B-25A (40 produced) and the B-25B (120 produced).

After the attack on Pearl Harbor and the outbreak of war in the Pacific, the majority of the B-25s were assigned to the 17th Bombardment Group (Medium), which operated over the Pacific. As a result of its excellent overall performance, the B-25 was chosen for one of the most impressive offensive operations of the war, the daring bombing attack on Tokyo, Japan. This operation, which was devised to reassert America's presence in the Pacific, called for an aircraft with exellent range, handling, and payload capabilities: a total range of 2400 miles and a bomb load of 2000 lbs. The aircraft would have to be agile enough to take off from the flight deck of an aircraft carrier, and have the endurance to bomb targets in Japan and fly to landing sites in China. With practice the B-25 crews were able to reduce their takeoff runs to the 700 to 750 ft required for an unassisted carrier launch. On the day of the attack, in April 1942, 16 B-25B Mitchells led by Lt. Col. James H. Doolittle took off successfully from the flight deck of the U.S.S. Hornet, 800 miles from the Japanese coast. Industrial targets in Kobe, Yokahama, Nagoya, and Tokyo were successfully bombed. The important role that the B-25 played in this attack helped provide a much needed boost to American morale after recent setbacks in the Pacific.

Now that the combat ability of the B-25 was proven, large numbers of the Mitchells were being produced. The B-25C model (1619 produced) saw the inclusion of an autopilot feature and the B-25D model (2290 produced) incorporated redesigned fuel tanks for better range and new Wright Cyclone R-2600-29 engines for improved flight performance.

As the war proceeded, the B-25 played an increasingly important role in the Pacific. Combat reports showed that the B-25 was achieving considerable success when attacking ground or ship targets with its fixed forward-firing armament and modifications made to the B-25 production line centered around improving the performance of the aircraft in this type of attack. As a result, a potent attack craft with unprecedented firepower was introduced as the B-25G. To improve its air-to-ground attack capabilities, four .50-caliber machine guns were mounted in a solid nose fairing in combination with a standard Army 75-mm field gun. Weighing 900 lbs and firing 3-in 15-lb shells, the 75-mm cannon could be fired approximately three times in an attack and proved to be quite accurate.

To further improve its forward attack capabilities, the B-25H variant saw the introduction of four additional .50-caliber machine guns mounted on the side of the aircraft in packages below the pilot and a lighter version of the 75-mm cannon with automatic loading. Defensively, the lower Bendix turret was eliminated in favor of a completely new arrangement of rearward-firing armament consisting of two waist-mounted .50-caliber guns and twin .50-caliber machine guns mounted in a tail gunner position. The B-25H, therefore, carried the extraordinarily potent armament of fourteen .50-caliber guns, a 75-mm cannon and a bomb payload of up to 3200 pounds.

Production of the B-25G and B-25H models, 405 and 1000 respectively, led to the final version of the B-25. Designated the B-25J, this version was produced in larger quantity than any other model with 4318 aircraft built between 1943 and 1945. Two versions were produced. One reverted to the Mitchell's original bombing role replacing the 75-mm cannon and forward firing armament with a transparent nose fairing and bombardier's position. Since this design was not suited for the Pacific theater where attacks were performed at low altitudes, the second B-25J model saw eight .50-caliber guns mounted in a solid nose fairing, eliminating the 75-mm cannon. Combined with the package of four guns mounted underneath the pilot, the B-25J was the most heavily armed of the Mitchells with twelve .50-caliber guns for forward ground attack and six guns in defensive positions.

The B-25 Mitchell, named after General William "Billy" Mitchell who in the 1920's was a strong advocate of the need to increase America's air power, is one of the select Allied aircraft that can claim to have served on every major battlefront of World War II. Its excellent overall performance allowed the B-25 to play key roles in many of the offensive operations of the war, especially in the Pacific theater. Reflecting on the performance of this aircraft and the services that it provided, the B-25 Mitchell is truly a "great flyer" in the history of aviation.

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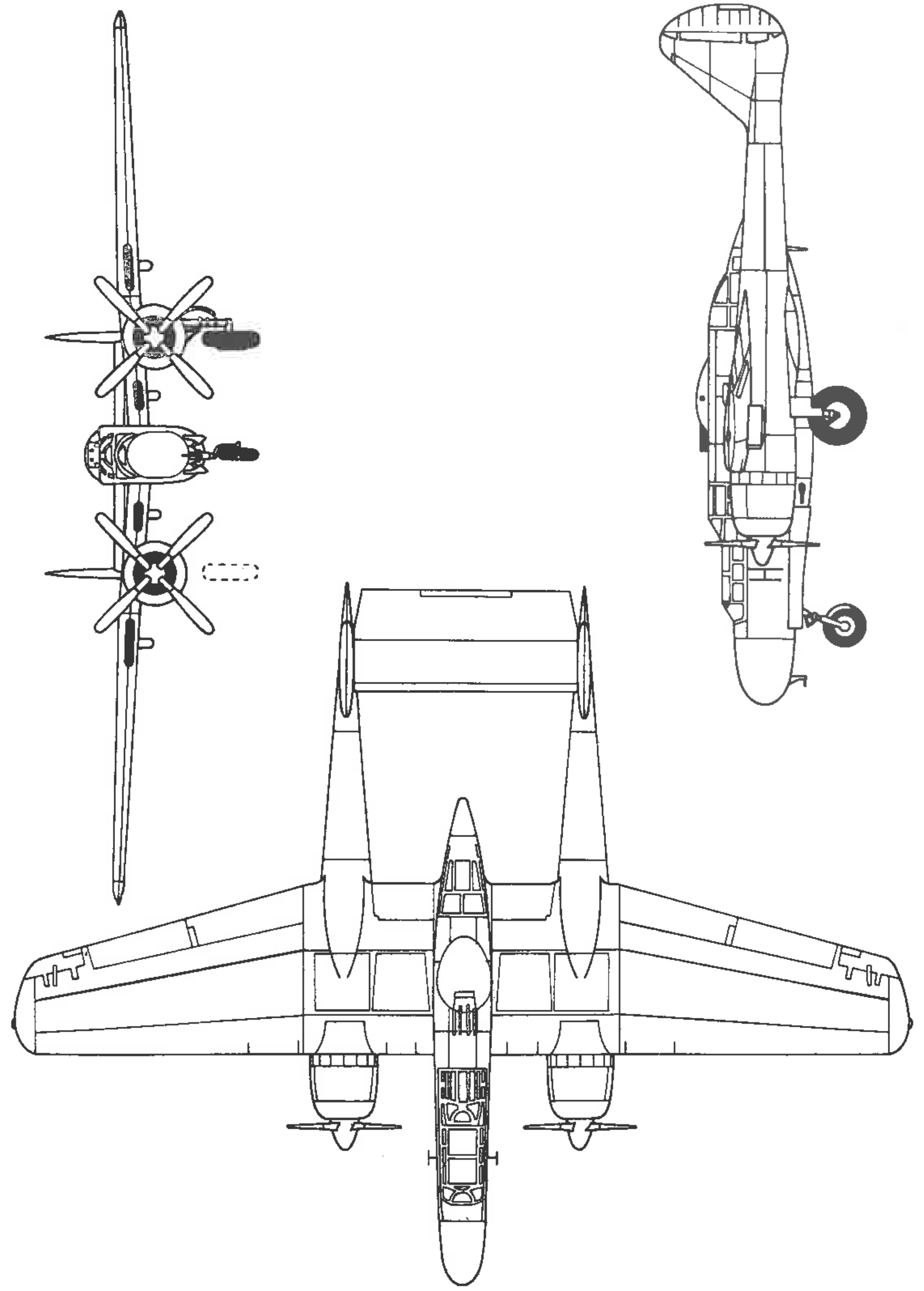

NORTHROP P-61

L.B. Davis

SPECIFICATIONS

Manufacturer	*Northrop*
Date of First Flight	*May 21, 1942*
Number Built	*742*
Length	*49.58 ft*
Wing Span	*66 ft*
Height to Prop Hubs	*7 ft*
Wing Chord at Root	*12 ft*
Wing Chord at Tip	*6.67 ft*
Dihedral of Outer Wing	*2°*
Dihedral of Inner Wing	*4°*
Loaded Weight	*38,000 lbs*
Maximum Speed	*366 mph*
Ceiling	*33,100 ft*
Range	*3000 miles*
Engines	*Pratt and Whitney R-2800-65*

With little chance of the Germans or Japanese attacking the United States during World War II, few nocturnal operations requiring the support of night fighters or night intruders were needed. But it was clear that American forces recrossing the Pacific towards Japan would be vulnerable to nocturnal raids, and so a specification was issued for a long-range night fighter, which became hardware in the form of the powerful Northrop P-61 Black Widow.

Described in cold catalogue language as "an airplane designed for the interception and destruction of hostile aircraft in flight during periods of darkness or poor visibility," the XP-61 prototype first flew on May 21, 1942. By 1943 the production model P-61A Black Widow Nightfighter began to replace the Douglas P-70 Night Havoc. Black Widows reported for duty in the southwest Pacific with the 18th Fighter Group in May, 1944, and shot down their first enemy aircraft on July 7, 1944.

The P-61 was a twin-engine, twin-boom, mid-wing monoplane, carrying a crew of three in an enclosed nacelle that divided the center wing panel along the centerline of the airplane. The twin booms extended aft from the engine nacelle and supported the tail surfaces.

The crew nacelle contained the pilot's cockpit and stations for a gunner and radio operator. The gunner's compartment was located directly behind the pilot's cockpit and was connected by an access door. The radio operator's position was in the aft section of the crew nacelle and was separated from the other two compartments by the gun turret and radio equipment.

The inner wing connected the crew nacelle with the engine nacelle. Housed in these inner wings were two fuel tanks and a section of wing flaps. The outer wing panels contained an oil tank and cooler in each. Six slotted flaps were mounted on the trailing edges of the wings, two on each outer panel and one on each inner panel.

In the extended position, there was a gap between the leading edge of the flap and the trailing edge of the wing, which permitted a flow of air from the lower surface of the wing, to the upper surface of the flap. This tended to smooth the air flow over the flap, thereby increasing lift at low subsonic speeds and high angles of attack. The P-61 landed slowly and had a quick takeoff time, which reduced the takeoff and landing hazards that were typical of small blacked-out airstrips. Much of the easy handling characteristics were attributed to the flaps and the retractable ailerons, which were a first for any airplane.

An interesting armament configuration was chosen for the P-61: four .50-caliber machine guns were mounted on the top turret and four 20-mm cannons were mounted in the belly. The .50-caliber guns were remotely controlled by either the gunner, radio operator, or pilot and could be traversed through 360°. The 20-mm cannons were controlled by the pilot and fired forward.

In addition, the Black Widow contained the most sophisticated, state-of-the-art radar equipment of the day. Developed at the Massachusetts Institute of Technology, the P-61 carried seven sets of radar equipment (more than any other contemporary airplane). The nose section forward of the pilot's compartment was constructed of resin-impregnated fiberglass enclosing the intercepter radar. This radar could scan 180° in front of the aircraft and detect the presence of another plane 12 miles away.

In addition to the intercepter radar, the Black Widow also contained an interrogator and responder, which identified friendly aircraft, and a defensive tail-warning radar that would ring a bell if another aircraft approached from behind.

To power this large fighter the aircraft utilized a pair of four-bladed Curtiss electric full-feathering "high activity" propellers. These propellers were powered by a pair of Pratt and Whitney R-2800-10 Double Wasp radial engines rated at well over 2000 hp for takeoff.

Equipped with retractable, tricycle-type landing gear, the two main gear units extended from each engine nacelle, and the nose gear extended from the crew nacelle. When retracted, each gear was completely enclosed by doors which, when closed, formed the lower contours of the nacelles.

In retrospect, the P-61 was one of the finest aircraft built for military service. During its short tour in the European theater, the Black Widow shot down 58 enemy aircraft while losing only 25 to all causes. The last blow of the war was struck on August 15, 1945, when a P-61 Black Widow shot down a Nakajima KI-43 fighter.

After the war some P-61s were used as scientific research aircraft. In April, 1946, a pilotless drone was flown into severe thunderstorms to obtain vital stress and remote-control statistics. In August of that same year Larry Lambert became the first human being to eject from an airplane when the P-61 was used to test automatic emergency escape equipment.

When the Air Defense Command was formed in 1946, Black Widows became their Night Interceptors until 1948, when they were replaced by North American P-82 Twin Mustangs. The surviving Black Widows were redesignated RF-61C in the new USAF until being retired in 1952. When production ended in 1946, a total of 742 P-61 variants had been built for the USAAF, including 36 as the F-15A(RF-61C). Contracts for many more were cut back because of limitations of postwar funds.

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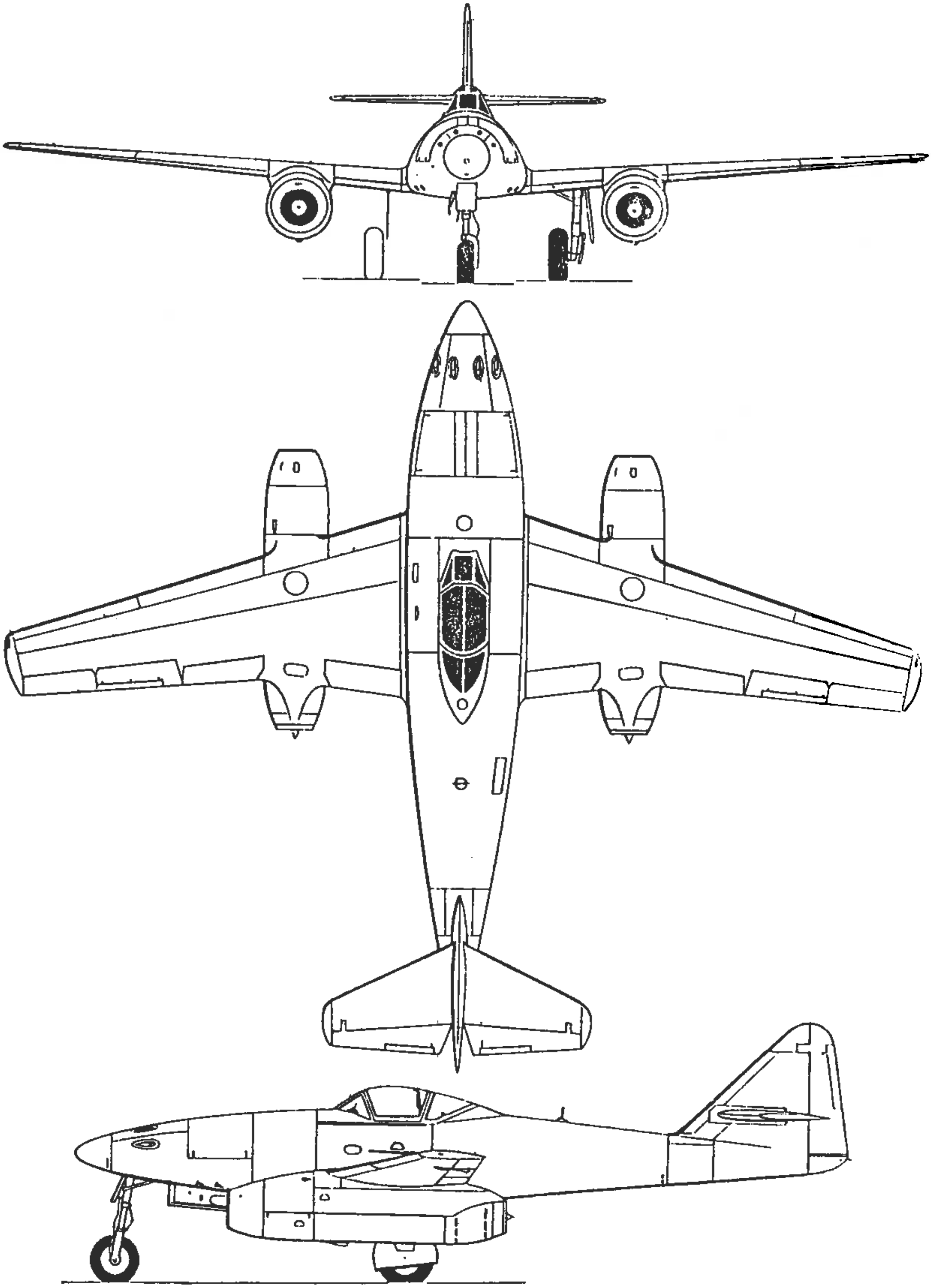


MESSERSCHMITT 262

J.M. Younkman

SPECIFICATIONS

Manufacturer	*Messerschmitt*
Date of First Flight	*July 18,1942*
Number Built	*Not Available*
Length	*34 ft*
Wing Span	*40.96 ft*
Root Chord	*Not Available*
Tip Chord	*Not Available*
Wing Aspect Ratio	*6.837*
Operating Empty Weight	*9742 lbs*
Maximum Takeoff Weight	*14,267 lbs*
Maximum Speed (at sea level)	*514 mph*
(at 19,685 ft)	*540 mph*
Range (at sea level)	*298 miles*
(at 19,685 ft)	*526 miles*
Initial Climb Rate (at sea level)	*3937 ft/min*
(at 19,685 ft)	*2165 ft/min*
Service Ceiling	*(approx) 34,000 ft*
Engines	*(2) Junkers Jumo 004B-1(-2,-3) axial flow turbojets*
Thrust	*(each) 1980 lbs*

During wartime, technical innovations sometimes arise that can cancel out overwhelming numerical superiority. The Me 262, had it been introduced in time, could have done just that. There is still controversy on whether the Me 262 could have been introduced earlier, some say up to six months earlier, in mass production. There were problems that the Me 262 had to overcome, but these problems were only magnified by interference and indecisiveness of the German leadership. The air war over England may have ended differently had the Me 262 been able to participate. However, even as history stands, the Me 262 still has its place as the first warplane employing the turbojet to achieve operational status. And it was the combat airplane of what would become a new era in aerial warfare.

Design development began in late autumn of 1938. The plane was meant to accommodate two new axial flow turbojets that BMW was designing. The BMW P3302 power plants were projected to produce 1320 lbs of thrust each and would be available by December 1939. The plane was originally conceived as an interceptor- fighter, but despite the disagreement from Messerschmitt and high ranking military officials, Hitler wanted it converted into a fighter-bomber. BMW was overly-optimistic, however, about when the engine would be ready, and ultimately, the inlet of the engine (originally to be placed in the wing root) had to be enlarged, and a total redesign was undertaken on May 15, 1940.

By July, 1940 the first metal cuts of prototypes were completed, but the BMW 003 (officially named) had a maximum thrust of only 570 lbs. During this same time, however, Junkers also had been making the Jumo 004. Their requirements were the same: 1320 lbs of thrust at 560 mph. In November, 1940 the first tests were run with this engine, but major difficulties were encountered.

The first prototype, the Me 262V1, was completed with Junkers Jumo 210G 12-cylinder, liquid-cooled engine in the nose to allow airframe testing while waiting for the turbojets. On April 18, 1941 the airplane flew, and dives were performed to reach operating speeds. A few minor problems were discovered and adjustments were made.

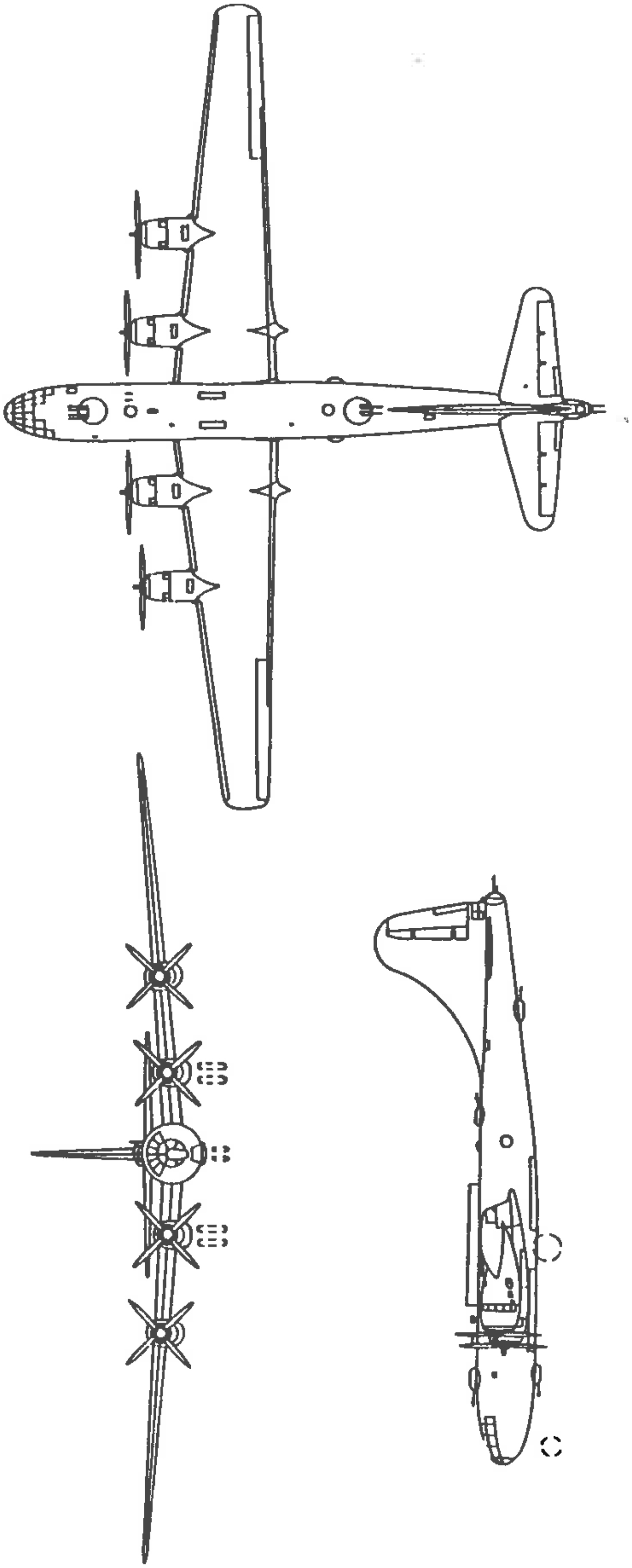
The first flight-cleared BMW 003s were ready by November, 1941, with a nominal thrust rating of 1015 lbs each. The engines were mounted to the V1 along with a piston engine for safety. Static tests were performed, and then on March 25, 1942, under full power from all three engines, the Me 262 lifted off the ground, but at 165 ft the port engine flamed out followed by the starboard engine a few seconds later. The engines had to be redesigned for a greater mass flow.

In the meantime Junker's problems were overcome. Their engines were mounted to the Me 262V3 with no piston engine. The Jumo 004s had 1850 lbs of thrust each and a takeoff weight of 11,000 lbs. Calculations suggested that the plane should leave the ground at 112 mph. On July 18, 1942 flight was attempted, but the plane could not take off because of excess drag due to the wing's high angle of attack when the tail rests on the ground. A suggestion to touch the brakes as the aircraft accelerates to throw the tail into the air was tried and the plane became airborne. Once the plane was in the air it was a sheer pleasure to fly this new machine. But the problems were not yet over.

Twelve prototypes in all were completed before the plane was put into production. Tricycle gear (eliminating the low tail problem), cockpit canopy pressurizing and armor/weapon modifications, including adaptation for bombs demanded by Hitler, were the major changes. Engine problems continued, but were not as severe and included compressor blade fracturing, exhaust nozzle adjustments, and fuel flow difficulties. Major delays were caused by the difficulty of obtaining materials to build the turbojets.

Three main designs came from the prototypes. The first was the Me 262A, nicknamed the Swallow, which began production by July, 1944. This plane was a single-seat interceptor with bombing capabilities. The Jumo 004B-1 (-2,-3) engines powered the all-metal, riveted (for easy manufacturing) airplane. The wing skin thickness varied between 1 and 3 mm. The plane also had a bullet-proof windscreen. Although the Me 262 could not turn as sharply as piston planes it could hold its speed in tight turns much longer. Acceleration and deceleration of the Me 262 was slower than that of piston aircraft. A slight yaw problem was noted but it was easily adjusted for by the rudder. The Me 262 flew efficiently on one turbojet at 280-310 mph and could extend its endurance to a maximum of 2.25 hours by cutting one engine at 25,000 ft but had to restart it at 10,000 ft. The Me 262 was capable of landing on one engine, but was considered dangerous. The second Me 262 in production was the Me 262B. This airplane was a two-seat trainer and was in production by November, 1944. By mid 1945 a nightfighter version of the Me 262B had been designed. The Me 262C was in production by early 1945 and was equipped with rocket boosters for assist in takeoff and climbing. From a standing start it was capable of reaching 38,400 ft in 4.5 minutes.

The first squadron began forming in April of 1944 and by July 25, 1944 a first encounter with an Allied reconnaissance plane occurred. The reconnaissance plane was able to avoid being shot down by maneuvering through a series of tight turns and eventually reaching cloud cover. The Me 262 was most successful at attacking B-17 Flying Fortress formations, because the 262s were faster than the fighter support. The last squadron was overrun by a U.S. armored regiment on May 3, 1945 in Salzburg-Maxglan. During its existence, the Me 262 saw only about one month of actual combat, but in that one month it had launched a new era of aerial warfare.



BOEING B-29

D.D. Sujudi

SPECIFICATIONS

Manufacturer	*Boeing*
Date of first flight	*September 21, 1942*
Number built	*3974*
Length	*99 ft*
Span	*141.23 ft*
Wing Area	*1739 ft*
Height	*27.75 ft*
Empty Weight	*69,610 lbs*
Gross weight	*105,000 lbs*
Maximum Speed (at 25,000 ft)	*365 mph*
Cruising Speed	*220 mph*
Service Ceiling	*31,850 ft*
Range	*5830 miles*
Engines	*(4) Wright R-3350-23*
Thrust	*(each) 2200 hp*

The name B-29 Superfortress is etched in history as the first airplane to deliver nuclear weapons. Development of the B29 began in 1938 as a study conducted by Boeing to design a pressurized version of the B-17. Five years later, on September 21, 1942, a B-29 prototype, designated XB-29, made the first flight. By that time, orders were already placed for 1500 aircraft.

The B-29 was the first bomber to use remotely controlled gun turrets. Two turrets were located on top of and underneath the fuselage. Each of these turrets was armed with two .50-caliber machine guns (later variants carried four machine guns in the upper front turret), and each could be controlled from primary or secondary sighting stations. A fifth turret was located at the very aft end of the tail section. The usual tail armament of two .50-caliber machine guns and one 20-mm cannon could only be controlled by the tail gunner, who sat directly under the rudder. This configuration, instead of manned turrets, was considered most suitable for the operating altitude of the B-29.

The B-29 was the first U.S. bomber to have completely pressurized crew stations. For practical reasons, only crew areas were pressurized, not the entire fuselage. Crew members, except for the tail gunner, could move to other areas of the plane using a tunnel that ran between the nose and mid-fuselage of the plane. The tail gunner had an isolated compartment accessible only during unpressurized flight.

The B-29's reason for being, the bombs, were carried in two tandem bomb bays. Bombs were released alternately between the two bays to maintain aircraft balance. Unmodified, the B-29 could carry a variety of bomb loads, usually divided into four 4000-lb bombs, eight 2000-lb bombs, twelve 1000-lb bombs, forty 500-lb bombs, fifty 300-lb bombs, or eighty 100-lb bombs. Some modified versions only had a single bomb bay, which was used to carry a single 22-ton bomb. Others were also modified to carry a Block Buster under each wing.

In its time, the B-29 was the heaviest production airplane in the world. To deal with problems during takeoff and landing, Fowler-type flaps were installed. These devices increased the lift coefficient of the wing as well as the total wing area.

To lift all this weight, four 2200-hp Wright R-3350 twin-row radial engines were used. Each of these 18-cylinder piston engines was fitted with two turbo-superchargers. The propeller shaft was geared down to 35% of the engine RPMs to maintain good propeller efficiency.

It was decided that the best use of the Superfortress would be in the Pacific theater in the war against Japan. B-29s were deployed at Kharagpur, India on April 2, 1944, and on June 5 of that same year, conducted the first operation, a raid on Bangkok. B-29s were also based in Chengtu, China. Ten days after the bombing of Bangkok, the B-29s of Chengtu carried out a raid on Japanese territory. This was the first bombing mission on the Japanese mainland since the Doolittle raid of April 18, 1942. After the U.S. captured the Mariana Islands (about 1400 miles south of Tokyo) in the summer of 1944, B-29s were also operated from there, resulting in more frequent and devastating bombing of Japan. The Superfortress was effective in reducing Japan's industrial might and in lowering its citizens' morale. Its most historic mission was flown on August 6, 1945, when the B-29 *Enola Gay* dropped an atomic bomb on the city of Hiroshima. On August 9, another B-29, *Bockscar*, dropped a second bomb on Nagasaki. Six days later, Japan surrendered unconditionally.

During its years of service, many modifications were made to the basic B-29. The B-29B was a stripped version of the basic B-29, having only the tail turret, allowing it to achieve a higher top speed and increased bomb load. The KB-29D was a tanker version equipped with a refueling system known as the Flying Boom, which was an aerodynamically controlled swiveling and telescoping arm located at the tail. The F-13 was used for photo reconnaissance. An escort variant was fitted with 19 machine guns, two 20-mm cannon, and a 37-mm cannon. A B-29B was further modified to carry the first manned supersonic airplane, the Bell X-1, for air launching. These and other modifications extended the life of the B-29. After years of honorable service, the last of the B-29s was retired in 1960.

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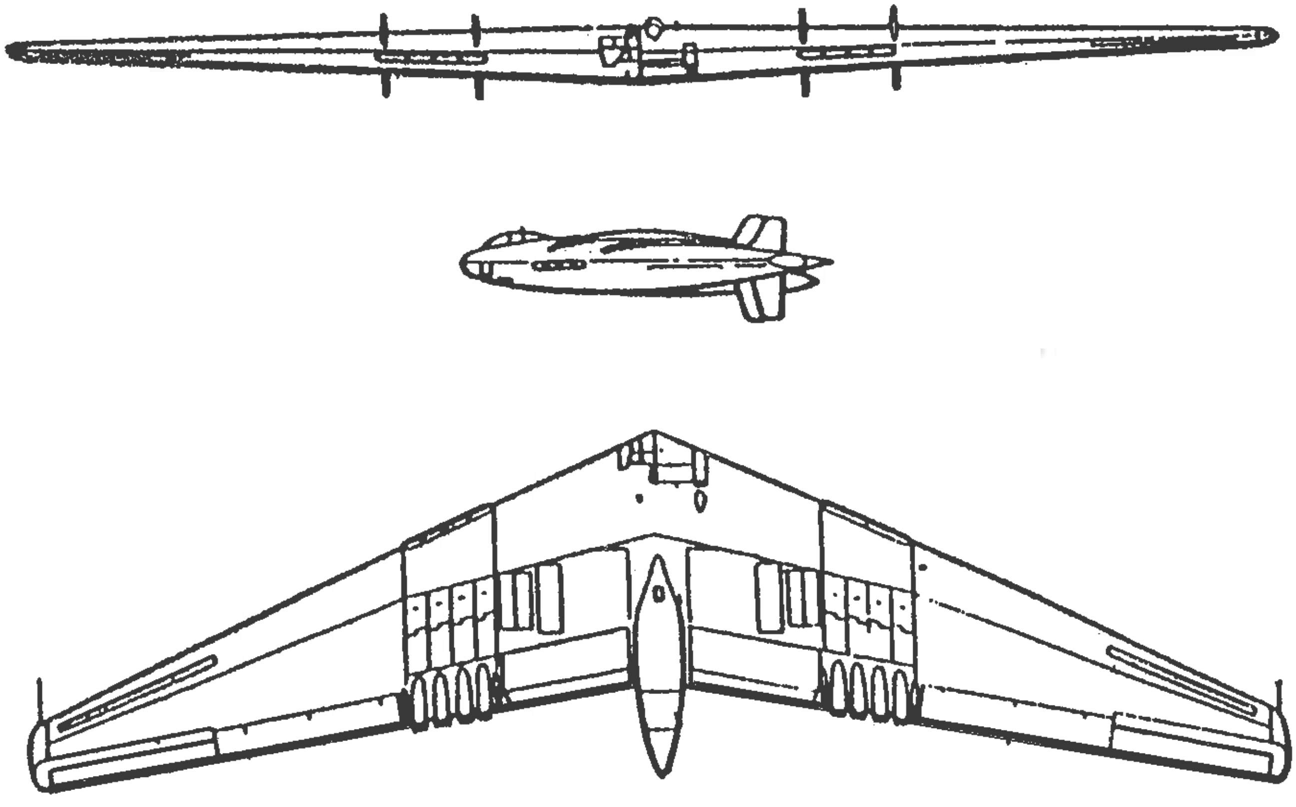

NORTHROP YB-49

R.S. Cleaves

SPECIFICATIONS

Manufacturer	*Northrop*
First Flight Date	*October 24, 1947*
Number Built	*2*
Wing Span	*172 ft*
Root Chord	*37.5 ft*
Wing Sweep	*28°*
Wing Dihedral	*1°*
Empty Weight	*89,600 lbs*
Loaded Weight	*216,600 lbs*
Service Ceiling	*40,000 ft*
Range (with 10,000 lb payload)	*2800 miles*
Maximum Speed (at 30,000 ft)	*520 mph*
Engines	*(8) Allison J35-A-5 turbojets*
Thrust	*(each) 4000 lbs*

Prompted by the limited range of existing bombers, namely the B-29, the Air Force issued a specification for an advanced bomber capable of carrying a 10,000-lb payload over 5000 miles or a 72,000-lb load over shorter distances. This bomber was to have a top flight speed between 300 and 400 mph at an altitude of 35,000 ft.

Among the contractors hired by the Air Force, Northrop Aircraft, founded by John Northrop, had worked as far back as 1927 on a "flying wing" configuration. Such a plane would have reduced drag characteristics and therefore longer ranges and expanded payload deployment potential. A flying wing flew for the Air Force in July 1940, and by September 1941 had made over 200 test flights.

In 1942, design work for the advanced XB-35 started with the help of the Wright Field Engineering Division and by June 25, 1946, a prototype of this aircraft was delivered. The XB-35 was the predecessor to the YB-49 and was pusher-propeller-driven by four 3250-hp Pratt and Whitney R-4360-17/21 engines.

The XB-35's all-metal wingspan reached 172 ft and had a root chord of 37.5 ft. The wing had a sweep angle of 28° and a 1° dihedral. Directional control surfaces were mounted on the wing tips and the elevators were placed between these and the engine nacelles. All control surfaces were hydraulically controlled, including leading edge slats designed to open at stall. The fuselage nacelle was fully pressurized and had room for a nine-man crew consisting of pilot, co-pilot, bombardier, navigator, flight engineer, radio operator, and three gunners. Because of the XB-35's slower speeds, heavy armaments were required. Of these, there were gun housings including six turrets above and below the wings armed with .50-caliber machine guns. The XB-35 was also equipped to carry a reserve crew of six and required the placement of six folding bunks toward the rear of the fuselage. The pilot's cockpit was located left of the centerline under a pop-up bubble canopy, while the bombardier's station was placed to the right side of the aircraft, on the lower surface of the wing, with forward vision through the leading edge. The second XB-35 was delivered in 1947 and the "winterized" version was designated the YB-35. By October 21, 1947, the YB-35 was fitted with eight Allison turbojets and redesignated the YB-49. Each engine nacelle was fitted with vertical stabilizers designed to improve directional stability. The crew was reduced to seven and of these, only one was a gunner. The empty weight of the YB-49 was 89,600 lbs and it weighed 216,600 lbs at takeoff. This included 37,400 lbs for bombs alone. The top speed of the YB-49 was 520 mph as compared to the YB-35's of 393 mph. In spite of this advantage, the aircraft's range was considerably reduced as the turbojets on the YB-49 required more fuel.

The flying wing design was characteristically unstable. Because there were no horizontal control surfaces to longitudinally stabilize the main wing, there was only a small region of stability in the performance envelope. In using the flying wing design, Northrop was forced to put strict tolerances on the amount of c.g. travel. This and the omission of any horizontal control surfaces resulted in an easily-manufactured, unstable aircraft. Because of instability problems, the aircraft proved to be a poor strategic bomber. However, in 1948, the YB-49 set the endurance record, staying aloft for 9 hours and 30 minutes, covering a distance of 3458 miles at an average speed of 382 mph. This led the Air Force to believe that a reconnaissance version of the YB-49 would be a viable concept. In fact, in February 1948, it was decided that 30 airplanes would be built for this purpose with the designation YRB-49A. Of these, nine of the previous XB-35's were to be converted by reducing the number of engines from eight to six. This would provide the reconnaissance version with a greater range, but also reduce its top speed. In 1949, the YRB-49A contract was canceled, but not until after the first airplane was built. It had four engines mounted inside the wing, and two beneath in pods. It flew on May 4, 1950. The YRB-49A had a six-man crew and carried highly sophisticated camera equipment to function at a ceiling of 40,000 ft.

Bad luck in the form of a midair explosion on June 5, 1945, killing all five of its crew placed the final nail in the YB-49's coffin and a second identical explosion on March 15, 1950 drove the Air Force to cancel the entire YB-49 project. Upon investigation of the wreckage, the most likely cause of the explosion was the fuel tank design. The report stated that the tanks were not designed properly for the wings in which they were mounted. However, this problem was thought to have been fixed before the second explosion occurred.

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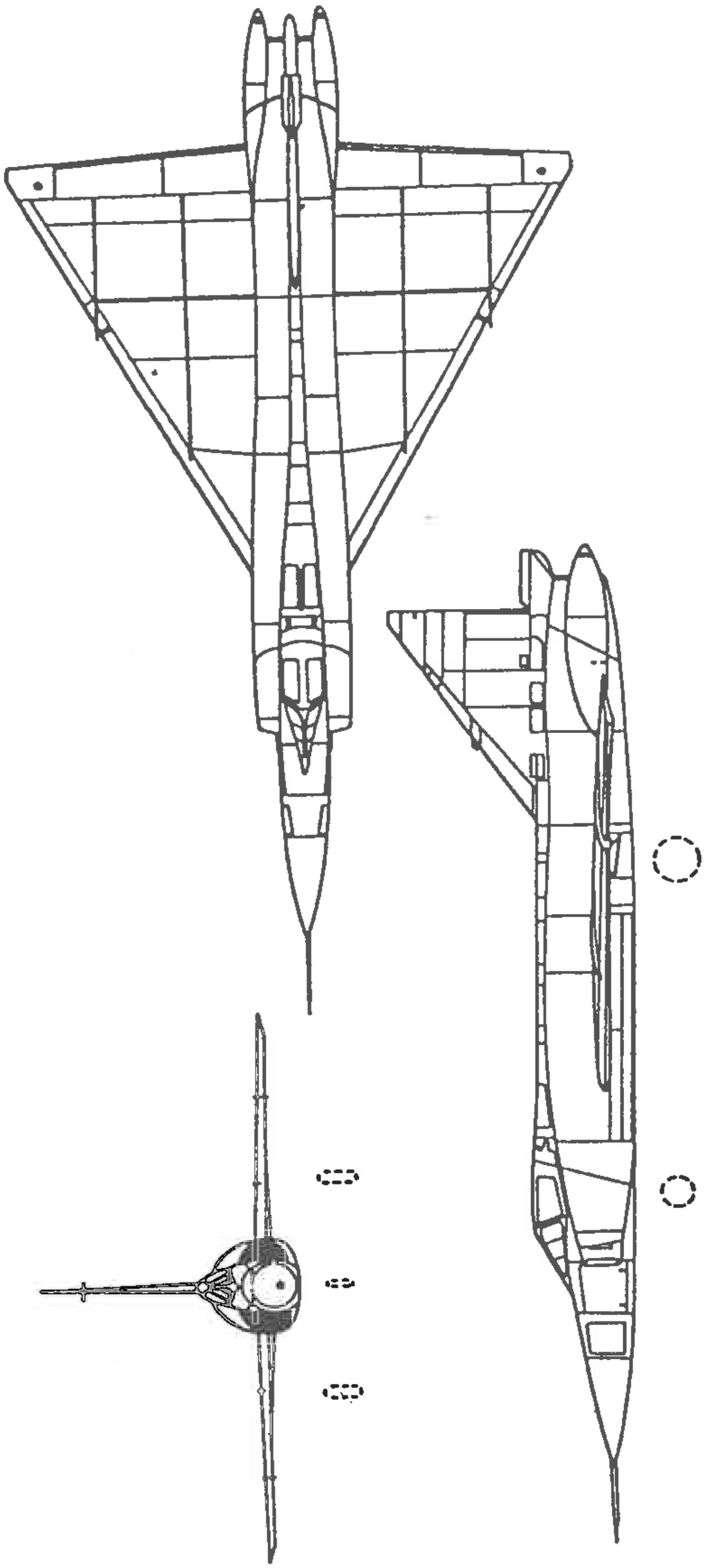


CONVAIR F-102

J.B. Cunningham

SPECIFICATIONS

Manufacturer	*Convair*
Date of First Flight	*October 24, 1953*
Number Built	*975*
Length	*68.33 ft*
Wing Span	*38.08 ft*
Height	*21.17 ft*
Maximum Speed	*810 mph*
Cruising Speed	*600 mph*
Weight	*31,559 lbs*
Range	*1000 miles*
Service Ceiling	*55,000 ft*
Engine	*(1) Pratt and Whitney J-57*
Thrust (with afterburner)	*16,000 lbs*

The idea behind the Convair F-102 was to design a supersonic, all-weather, fighter jet that could quickly intercept and destroy enemy aircraft. The concept was initiated to add a fighter to the military inventory that would keep the United States' air superiority intact.

With this in mind, the Convair engineers designed and developed a prototype of the F-102 designated as the YF-102. According to the engineering data, the YF-102 was expected to easily break the sound barrier. This was to be accomplished by using a delta wing planform and the brute force of the new Pratt and Whitney J-57 jet engine. At that time, the J-57 was the most powerful jet engine available at 16,000 pounds of thrust when afterburner was used. The highly swept, sharp leading edges of the delta planform could cut through the supersonic shock waves while at the same time providing a large internal volume for fuel storage. During the initial flight tests, however, the fact that the YF-102 would not go supersonic became painfully clear: as the aircraft accelerated, the transonic drag rise was much larger than expected, and the thrust from the J-57 could not push the airplane through the sound barrier.

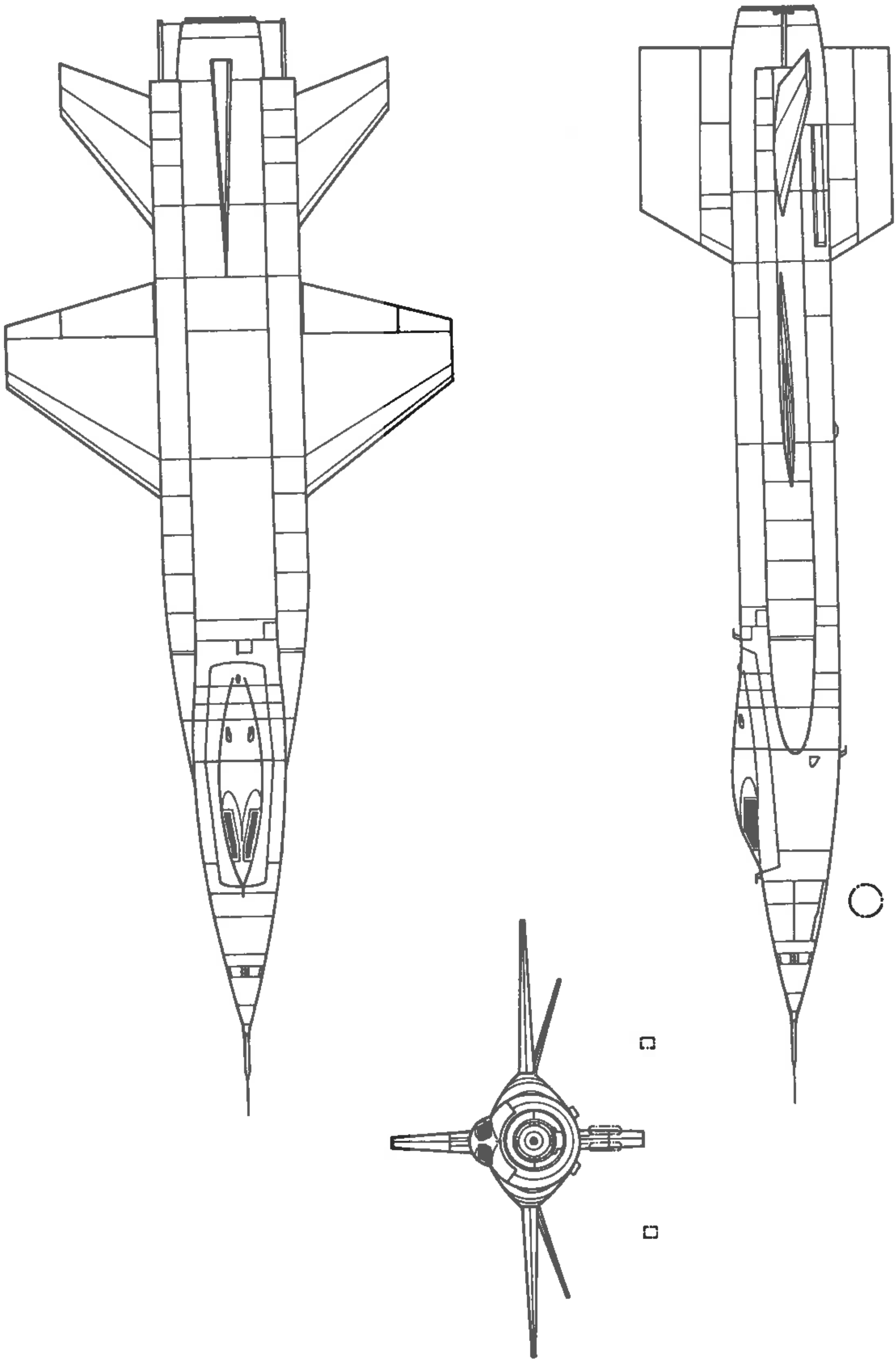
Faced with this problem, the Convair engineers went to NASA Langley Research Center to confer with Dick Whitcomb. Earlier, Whitcomb had proposed an "Area Rule" that had the promise of large reductions in the aircraft drag as the plane approached Mach 1. Transonic wind tunnel tests with small models had convinced Whitcomb that if the cross-sectional areas of aircraft were smooth, with no discontinuties or rapid cross-sectional changes, the wave drag would be reduced to the low values of simple axisymmetric minimum drag bodies. After discussions with Whitcomb, the engineers decided to apply the "Area Rule" to the F-102 configuration.

The original F-102 design had a typical cylindrical fuselage. Engine inlets, cockpit canopy, wing, and vertical surfaces caused the distribution of cross-sectional area of the aircraft to have several discontinuities and rapid increases. The engineers modified the fuselage shape to minimize these area changes. The most noticeable result was the wasp-waist look caused by the reduction of the fuselage cross-section as the added cross-sectional area of the wing was smoothed. Area was even added near the tail to provide additional smoothing. The new wasp waist shaped aircraft was designated the YF-102A. When wind tunnel tests of the new configurations looked promising, full-scale design was completed and the prototype YF-102A was quickly fabricated.

On December 20, 1954, almost nine months after the initial flight, the YF-102A did break the sound barrier while still climbing. The flight test proved the value of the Area Rule, increasing the top speed of the YF-102 by an incredible 25%.

The F-102A was the world's first supersonic, all-weather interceptor, and in addition, it was the world's first operational delta-wing fighter aircraft and the first to employ the Area Rule. Produced in the San Diego production line of Convair, 1101 F-102s were built, of which 975 were the F-102As. In addition, 111 were built as trainers with side-by-side seating, designated as TF-102s.

For combat, the F-102A was fitted with a state-of-the-art electronics guide system. With this new electronic system the job of the pilot was simply to fly the aircraft to the general vicinity of enemy aircraft. The pilot would then turn the controls over to the "electronic pilot" who, with the help of the radar, would maneuver the aircraft into an attack position. Once in position the system would automatically fire the F-102A's air-to-air rockets and missiles and then return control to the pilot.



NORTH AMERICAN X-15

L.E. Marin

SPECIFICATIONS

Manufacturer	*North American*
Date of First Flight	*June 8, 1959*
Number Built	*3*
Length	*52.45 ft*
Wingspan	*22.3 ft*
Wing Sweep (at 1/4 chord)	*25°*
Wing Dihedral	*0°*
Wing Aspect Ratio	*2.5*
Operating Empty Weight	*18,340 lbs*
Maximum Launch Weight	*56,130 lbs*
Limit Maneuver Factors (before burnout)	*-2.0 g to 4.0 g*
(after burnout)	*-3.0 g to 7.33 g*
Maximum Speed	*6650 ft/s*
Maximum Altitude	*354,331 ft*
Range	*275 miles*
Engine	*(1) Reaction Motors, Inc. XLR99*
Thrust (at sea level)	*50,000 lbs*
(at 100,000 ft)	*57,850 lbs*

The X-15 project was born on June 24, 1952 when the National Advisory Committee for Aeronautics (NACA) passed a resolution to explore flight characteristics of atmospheric and exo-atmospheric designs capable of Mach 4 to 10 speeds and 12- to 50-mile altitudes. Because of the vague purpose of hypersonic aircraft at that time, very little support was provided for research. Initially, more considerations were given to wind tunnels, rocket-boosted models, and other laboratory techniques, but after two years it became evident that the most effective tool was the manned aircraft. In July, 1954, NACA was assigned technical responsibility for project 1226 that would be financed by the U.S. Air Force and the Navy.

Three X-15's were built under the contract number AF33(600)-31693. There were to be three aircraft built, designated X-15-1, -2, and -3, and were assigned the serial numbers 56-6670, 56-6671, and 56-6672, respectively. Construction for all three X-15s took over two years and on October 15, 1958, the X-15-1 was rolled out in Los Angeles. On November 9, 1962, an accident involving the X-15-2 caused serious damage to the aircraft. It then was modified to the X-15A-2 configuration on May 13, 1963, under the contract AF33(657)-11614, but didn't make its first flight with tanks until 1966.

Because this aircraft had to be air launched, the B-36, B-50, B-52, and B-58 were looked at as possible carriers. Two B-52s were chosen because they could be easily remodelled to carry the X-15s. The redesigning included increased lift, all-around improved performance characteristics, and better reliability of the B-52s.

Accompanying the performance breakthroughs of the X-15 were pioneering developments in construction, systems, and equipment. This was crucial since this was the first aircraft that would require high-temperature structures and have high-temperature aerodynamic characteristics. Steel, titanium, and a nickel alloy, Inconel-X, composed most of the aircraft. Steel and titanium were stronger at higher temperatures, but their strength properties fell sharply above 800°F. Inconel-X had only a gradual drop in strength up to 1200°F and therefore was selected to be the skin material of the entire aircraft.

A variety of materials composed the internal structure. High-strength aluminum alloy (2024-T4), 8 Mn titanium (the highest strength alloy available), 5A1-2.5Sn, and a high-strength, weldable titanium alloy (6A1-4V) were used. Fusion welding was necessary throughout the construction.

In the design studies, hypersonic stabilization was one of the major obstacles already encountered with the X-1 and X-2. Since the X-15 was to fly at much higher speeds, it became a challenge to design an aircraft that would allow for stable flight at Mach 6. The trapezoidal wings were very thin with an aspect ratio of about 2.5 and a thickness-to-chord ratio of .05. The leading edge was swept 25° at the 1/4 chord and was very thin but not sharp, and the trailing edge was blunt with a 2-inch thickness at the root and 0.375-inch at the tip. The wings were not equipped with ailerons, but they had small hydraulic flaps on the inboard trailing edges of each wing.

At that time it was believed that the horizontal tail should be located far above or well below the wing chord plane in order to avoid undesirable shock-wave interaction. Then it was discovered that it could be placed in the plane of the wing between the regions of high downwash to eliminate difficulties in stability. The two slab stabilators had the same airfoil section and thickness-to-chord ratio as the wings. They were placed with 15° of anhedral, separately, at the aft end of each fuselage tunnel/chine. This was the first time an all moving slab stabilator that could be moved differentially for roll control or symmetrically for pitch control was used in a high-speed aircraft.

The supersonic airfoil section of the tail was modified to a 10° wedge shape. It had the ability to vary the wedge angle which helped provide quick recovery from a divergent maneuver. It also allowed for more research flexibility in variation of the stability parameters. The range of attitudes for reentry allowed by heating conditions was greatly extended by the ability to enter in a high-drag condition because of the large wedge angle. The lower portion of the vertical stabilizer had to be jettisoned just prior to landing to prevent it from scraping the ground.

Limit maneuvering factors of +4.0 g and -2.0 g before burnout and +7.33 g and -3.0 g after burnout were enforced. The X-15 could withstand a maximum dynamic pressure of 2500 psf. A pull-out at 7.33 g at maximum dynamic pressure could only be done once, otherwise, the heated structure would be overloaded.

Landing gear was composed of a conventional nose wheel assembly and two boat-shaped, steel skid-type main gear. Landing gear requirements specified a sink rate of 9 ft/s with touchdown speeds of 164 to 200 kts at a 6° ground attitude. All landing gear was manually retracted and extended with aerodynamic downloading and gravity. Nose wheels prevented shimmying and the skids allowed only for roll and pitch. This was a great oportunity to study skid-type main landing gear, thus the X-15 was instrumented to measure gear loads, gear travel, and accelerations.

The windshield was made up of a single outer pane and a double inner pane with an interlayer. The outer pane was made of aluminum-silicate, 3/8-inch-thick, with a 25,000-psi temper. The inner pane was made of soda-lime and type K interlayer with a 14,500 psi temper. A great deal of knowledge was learned from the X-15 windshield: from the type of glass needed for windshields and passenger windows in high-speed aircraft, to the installation and environmental factors of these new materials.

At extreme altitudes where the lifting surfaces could not be used for stability and control, hydrogen peroxide reaction jets were implemented. The decomposition of the hydrogen peroxide created a superheated steam that was exhausted through four nozzles at the wingtips and eight nozzles in the nose. Each reaction jet could produce 40 to 110 lbs of thrust.

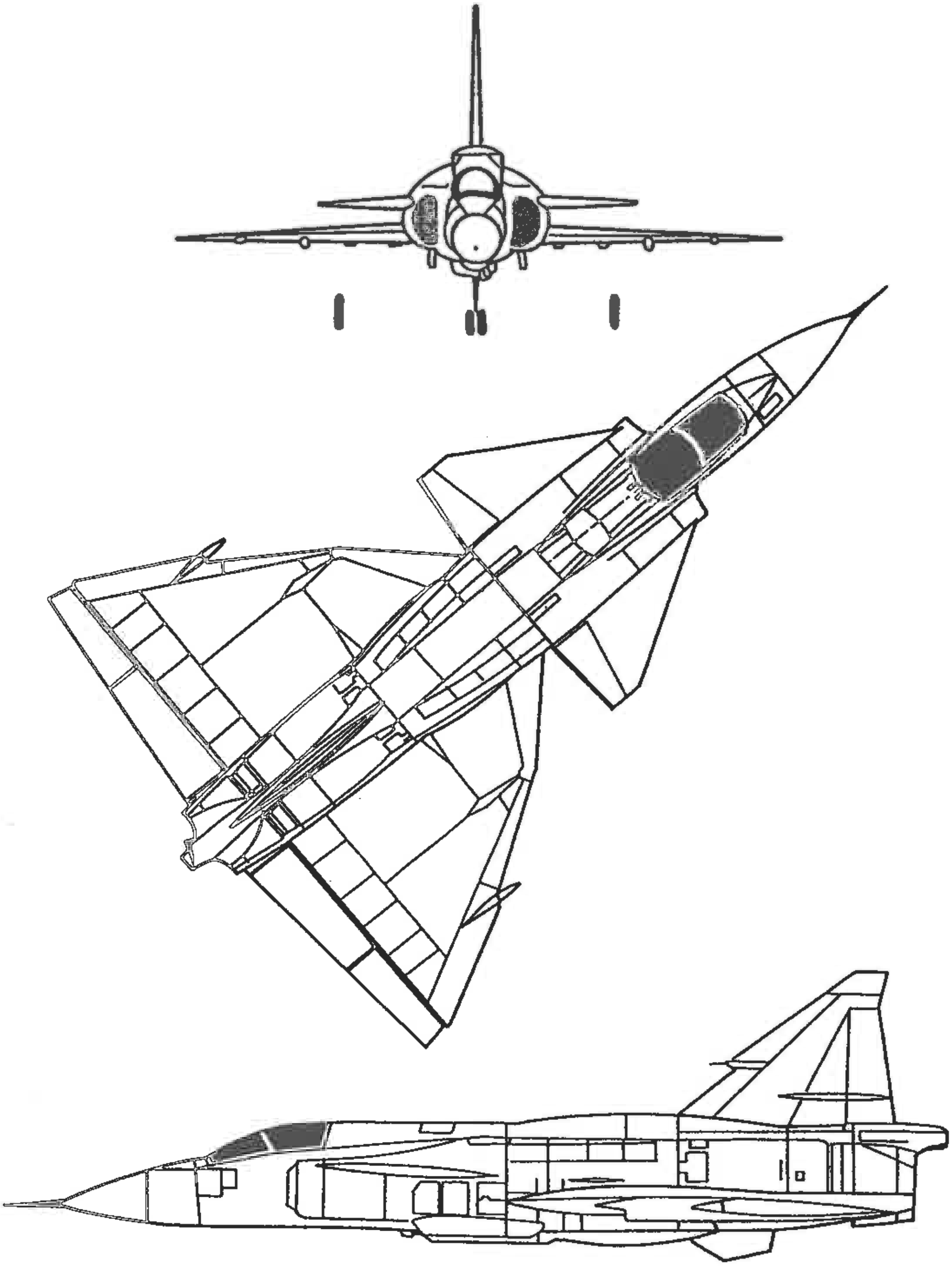
The X-15A-2 introduced the concept of using external tanks to increase engine burn time by 20%. The left tank carried helium for propellant tank pressurization and 793 gallons of liquid oxygen. The right tank contained 1080 gallons of anhydrous ammonia. Thus the left tank was about 2000 lbs heavier at launch. These jettisonable tanks were brought to ground by parachute for reuse. The X-15A-2 also used an experimental ablative coating developed by the Martin Marietta Corporation under the name MA-25S. Made of a resin base catalyst and glass bead powder, it was sprayed on the surface to ablate friction-generated heat at high speeds. It was difficult to apply and labor-intensive because it had to be completely stripped off and replaced with fresh ablator for each flight. The X-15A-2's powerplant was the Reaction Motors Inc. XLR99 with a one-hour service life and a throttling range from 30% to 100%. It had a specific impulse of 276 lb-s/lb at 100,000 ft and duration limited only by propellant supply. With a dry weight of 915 lbs, chamber pressure of 600 psi, and oxidizer/fuel ratio of 1.25, it reached a thrust of 50,000 lbs at sea level or 57,000 lbs at 100,000 ft.

Some the X-15's accomplishments include:

- Peak altitude of 67 miles in August 1963 (3 times higher than any other winged aircraft of its time.)
- Study of high-noise-induced metal fatigue.
- First detailed full-scale drag data in the speed range from Mach 2 to 6.
- Spherical nose sensor indicating to the pilot angles of attack, sideslip, and dynamic pressure, an adaptive flight control system that would add safety and reliability to future aircraft. The self adaptive system by Minneapolis (Honeywell MH-96) allowed control with the aerodynamic or jet control system or a combination of both.

- Provided the development of piloting techniques at high speeds, high g's, weightlessness, atmospheric exit, and reentry.
- First "energy management system" in case of a premature engine shutdown, (computer estimates energy available and how far it can go without power). The pilot can be directed to a landing area during his glide pattern, using a radar map of the flight path and a map of terrain over which it is flying.
- Emergency ejection seat between 80 mph and Mach 4 at altitudes from sea level to 120,000 ft.
- Biological signs closely monitored with an electrocardiogram, a suit/cockpit differential sensor, suit/helmet differential sensor, and an oxygen flow sensor.
- First fully pressurized suit (A/P 22S-2), predecessor to the suits worn by the Mercury, Gemini, and Apollo astronauts and very similar to those worn by U-2, A-12, F-12, and SR-71 pilots.
- Cameras measured energy emissions of stars with ultraviolet stellar photography.
- Wingtip pod collected samples of micrometeorite and extraterrestrial dust at high altitudes.
- Other experiments in horizon-seeking stabilization systems, atmospheric density measurements at high altitudes for high speeds, vapor-cycle cooling, high-altitude sky brightness, supersonic decelerators, and high-temperature leading edges.
- First restartable man-rated throttleable rocket engine.
- Development of nitrogen cabin conditioning.
- Discovered that hypersonic boundary layer is turbulent and that turbulent heating rates are significantly lower than predicted.
- First direct measurement of hypersonic skin friction concluding it was lower than predicted.
- Discovered hot spots generated by surface irregularities, and methods to correct wind tunnel drag data.
- Studies of hypersonic acoustic measurements used to define insulation and structural design requirements for the Mercury spacecraft.

From conception through phases of design, construction, test, and operation, the X-15 program continued for 11 years of exploration that produced data paramount in the design of the space shuttle and other reentry vehicles. In 1962, four of its pilots received the Robert J. Collier trophy from president John F. Kennedy for "the greatest achievement in aeronautics and astronautics in America, with respect to improving the performance, safety, or efficiency of air vehicles." On October 24, 1968 the project flew the 199th and final mission of the most technologically complex single-seat aircraft of its day.



SAAB-SCANIA VIGGEN JA37

J.O. Akerjordet

SPECIFICATIONS

Manufacturer	*Saab-Scania*
Date of First Flight	*February, 1967*
Number Built	*300+*
Length	*16.3 m*
Height	*5.8 m*
Span	*10.6 m*
Wing area	*46.0 m*
Canard Span	*5.45 m*
Canard Area	*6.20 m2*
Normal Takeoff Weight	*15,000 kg*
Maximum Takeoff Weight	*20,500 kg*
Wing Loading	*325 kg/m2*
Maximum Speed (at 12,000 m)	*Mach 2.0+*
Service ceiling	*(approx) 15,200 m*
Engine	*(1) RM8A*
Thrust	*6690 kg (11,790 kg AB)*
Fuel capacity	*(approx) 5700 liters*

In 1961, the Swedish Air Force (Flygvapnet) together with the SAAB-SCANIA aircraft division in Linkping, started the first studies for designing a replacement for the existing SAAB J35 Draken (dragon). The Flygvapnet had specified several design requirements such as Mach 1 low-altitude strike and reconnaissance missions at sea level, Mach 2 at high altitudes, STOL performance enabling the Viggen to use suitable Swedish highways for takeoff and landing, and good acceleration and climb.

The first prototype of the Viggen had its maiden flight in February 1967, and by 1968 the Swedish government had approved the production of 100 airplanes with an option on a further 75, and also agreed on the development of the reconnaissance version, SF37. The initial models were the AJ37 attack version and the SK37 operational trainer. By 1970, the first JA37 rolled out of the SAAB-SCANIA factory in Linköping.

In order to meet the Flygvapnet's requirement, the design team decided to combine a double-delta type main wing, much like the SAAB Draken J35, with a forward-mounted canard. One of the key factors in the choice of the canard was the requirement for STOL performance. The canard could control pitch by adding lift to the nose, thus adding to the total lift. Conventional aircraft use elevators to lift the nose by applying a downward lift component on the tail, thus sacrificing some of the total lift.

On the Viggen, the canard and the wing are closely coupled. The canard is also highly loaded making the aircraft naturally longitudinally stable. However, the Viggen is still extremely maneuverable at all speeds, and it has a reputation of being a "pilot's plane." With its unusual configuration, the Viggen has been described by some to be virtually a supersonic biplane.

Most of the Viggen's fuselage is made of aluminum alloys, except for hot areas where titanium is used. Honeycomb is used in control surfaces, canard, fin and undercarriage doors.

The design criteria required the Viggen to be a Mach 2.0 aircraft. To meet this goal, the Swedes used a redesigned Pratt and Whitney JT8D civilian type engine. Volvo-Flygmotor added their own afterburner and also changed the number of fan and compressor stages. The turbine inlet temperatures were raised by modifying the combustion chamber and HP turbine. Eventually the redesign was finished, and the engine was designated as RM8A. In 1971 Volvo-Flygmotor introduced an improved version of the RM8A, named RM8B.

Several different models of the Viggen have been built. They are all based on the same basic configuration, but are equipped differently. There is a reconnaissance version, the SF37, with a modified nose equipped with cameras and infrared night technology. A maritime version of the same SF37 is designated SH37 and is equipped with an improved surveillance radar. Studies of a Viggen interceptor were started in 1968. The first true JaktViggen, JA37, flew in December 1975, and the first production JA37 was airborne in November 1977. This version of the Viggen series is largely improved by its more capable electronics and powerplant.

The Viggen can carry a variety of weapons on seven hardpoints, three under the fuselage and two on each wing. A 30-mm Oerlikon KCA long-range high-velocity cannon is carried in a belly-mounted gunpack on all models except on the JA37, where it is mounted internally. Weapons that the Viggen can use include AIM-9 Skyflash, AIM-9L Sidewinder, AGM-65 Maverick, SAAB RB.04E anti-ship missile, SAAB RB.05A air-to-surface missile, iron bombs, launchers for unguided rockets, plus external fuel, jamming pods, reconnaissance pods etc.

One basic requirement is shared by all models of the Viggen is the ability to operate from dispersed, wartime, road-type STOL runways. As mentioned above the canard is a contributing factor here, but the Viggen has something else that is quite unique. The Viggen carries its own built-in arrester system, which is a highly efficient thrust reverser. As the nose wheel strut is compressed, the thrust reverser is automatically actuated. Swedish pilots land their Viggens on 500-m (1640-ft) roads using techniques similar to carrier landings. They use a no-flare landing assisted by autothrottle and use the reverser as soon as they touch down.

Today, more than 300 Viggens have been built. This is impressive considering that Sweden is a nation with only about eight million people. Furthermore, the Swedes are not yet finished with fighter aircraft. A new fighter, JAS39 Grypen (J-Jakt,(fighter); A-Attack; S-Spaning, reconnaissance), is under development and is scheduled for deployment at the end of the century. This fighter is even more complex than the Viggen, as well as much more versatile. In true Swedish tradition, the powerplant is to be a General Electric F404 augmented turbofan, uprated by Volvo-Flygmotor, designated RM12, and it has a forward mounted canard.

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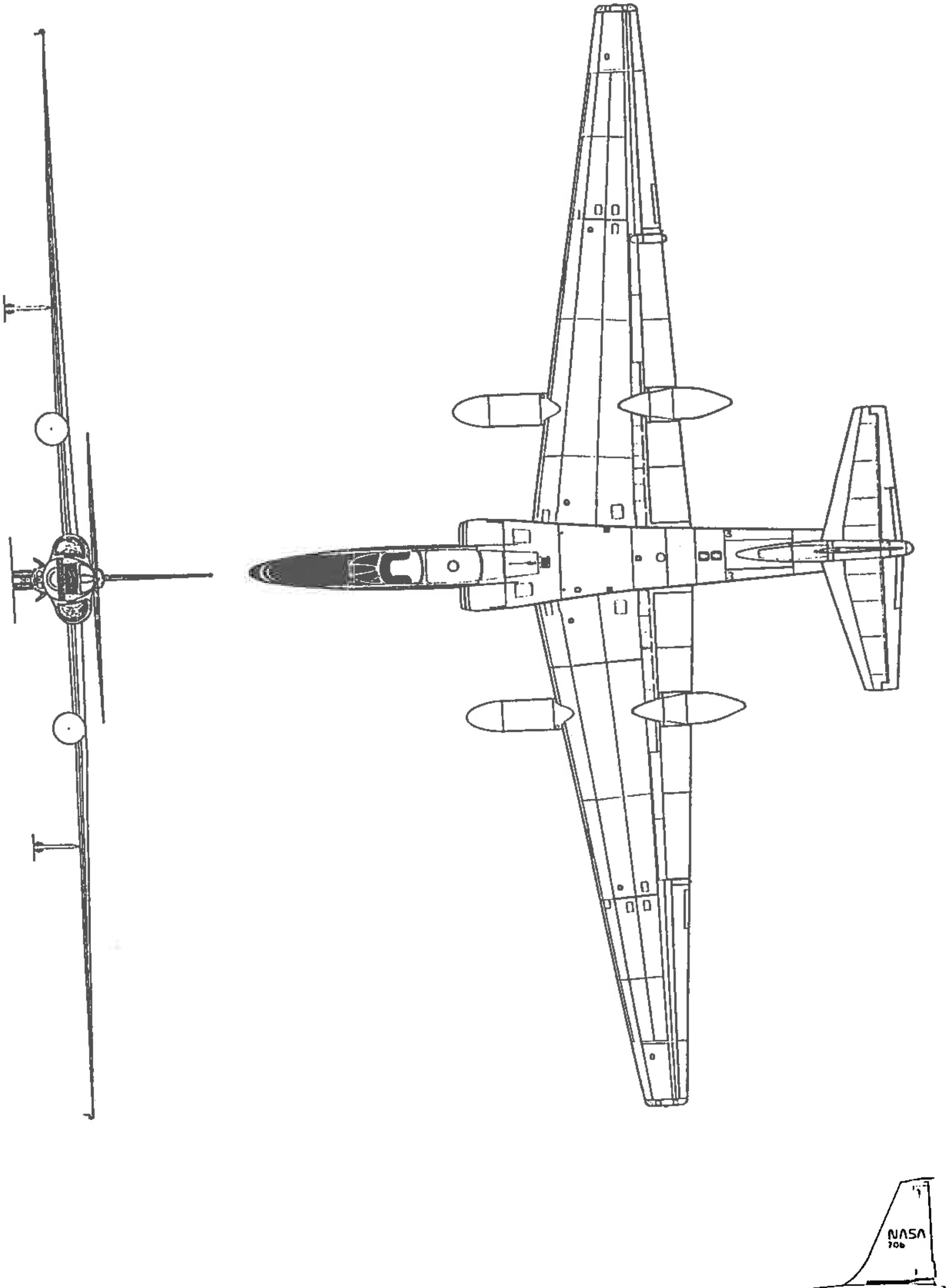
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LOCKHEED U-2R

B.S. Richmond

SPECIFICATIONS

Manufacturer	*Lockheed*
Date of First Flight	*August 28, 1967*
Number built	*(approx) 30*
Length	*63.08 ft*
Wing Span	*103.33 ft*
Root Chord	*15.5 ft*
Tip Chord	*3.79 ft*
Wing Sweep	*6°*
Wing Dihedral	*0°*
Wing Aspect Ratio	*10.67*
Operation Empty Weight	*14,000 lbs*
Maximum Takeoff Weight	*37,150 lbs*
Maximum g Limit	*2.5*
Maximum Cruise Speed (at sea level)	*532 mph*
Maximum Cruise Speed (at 35,000 ft)	*536 mph*
Normal Cruise Speed (at 72,000 ft)	*435 mph*
Service Ceiling	*78,000 ft*
Range	*7500 miles*
Engine	*(1) Pratt and Whitney J75-PW-13B*
Thrust	*17,000 lbs*

The existence of the U-2 was revealed to the world in May of 1960 when the high altitude reconnaissance aircraft flown by Francis Gary Powers was brought down over Soviet territory by a surface-to-air missile. Conceived in secrecy in the mid fifties and designed by Lockheed's Kelly Johnson, the U-2 was produced by the famous "Skunk Works" of Lockheed. The U-2 had the wide, high-aspect-ratio wings and lightweight structure of a soaring glider. When powered by the J-57 the U-2 could attain then unprecedented altitudes that allowed it to cruise over hostile territory with impunity.

The U-2R was the second major generation of the family and was essentially a whole new aircraft designed by Johnson and his team at the "Skunk Works" in Burbank, California. The U-2R is still the best subsonic, high-altitude, air-breathing, reconnaissance aircraft in the world even though it was designed in the mid 1960s. The date of the first flight was August 28, 1967, just one year after the contract with Lockheed, the U.S. Air Force, and the Central Intelligence Agency was signed. Six months later the U-2R was flying its first reconnaissance mission over China.

The U-2R is about 40% larger than the original U-2. The wing span was increased by 23 ft to a total of 103.25 ft, with a planform area of 1001.4 sq ft, an aspect ratio of 10.67, and a lift-to-drag ratio (L/D) of 27. This allows the U2R to fly with minimal drag to increase the range and endurance of the aircraft. The fuselage volume was increased 33% by making a larger-diameter fuselage and increasing the length by 8 ft for a total length of 63 ft, increasing the internal fuel capacity from 1320 gal to 2950 gal giving the aircraft the capability of 14-hour missions without refueling.

One of the biggest advantages of the increased diameter of the fuselage was that it allowed the pilot to wear a full pressure suit with helmet (such as the A/P-22S-2) where before there was hardly enough room for a partial suit. This allowed climate control, enabling the pilot to fly longer, more comfortable missions.

The biggest change was from the original Pratt and Whitney J57 engine to the Pratt and Whitney J75-PW-13B rated at 17,000 lbs thrust with afterburners and 15,100 lbs thrust at cruise. The engine (43-inch diameter × 240-inch long, weighing 4900 lbs) is a dual-spool axial compressor with 15 stages (8 low and 7 high) that deliver a pressure ratio of 12:1 at sea level. Eight burner cans in the combustion chamber burn JP-TS. The first turbine drives the high pressure compressor and the second and third turbines drive the low pressure compressor. The Pratt and Whitney J75-PW-13B gave the needed extra thrust to compensate for the additional weight.

The fuselage configuration consists of three major portions: the nose, the cockpit and electronics, and the aft engine sections. The nose section contains most of the electronics and communications systems. The cockpit contains a single ejection seat with pressurized oxygen for breathing. The center console contains most of the attitude indicators and an optical viewing system that uses mirrors to project the terrain being overflown. On the left console are the controls for the flaps, throttle, landing gear, pressure suit, and communications. On the right console are the navigational and autopilot controls, and a mission recorder. In the center is the control column and at the edge of the seat between the pilot's legs is the ejection D-ring. The middle section also holds the so-called "Q" and "E" bays that contain most of the electronics required for each particular mission. In the aft section is the engine and the 4-ft exhaust augmentor nozzle. Having three sections allows for ease of repair on particular equipment without accessing unnecessary sections of the aircraft.

The wings are divided into the inner, middle, and outer sections. The inner and middle sections contain the flaps with deflection angles ranging from 0° to 50° and located forward of them are the wing spoilers with deflection angles ranging from 0° to 60°. Just outboard of the wing spoilers are the roll assist spoilers with deflection angles from 0° to 16°. Between the middle and outer sections are the fuel dump tubes. Along the outer sections are the main ailerons and the tip ailerons. In the middle of the wing, on the leading edge, are small retractable stall strips that are used to decrease the lift in that section of the wing during landing. On the tip of each wing is a 10-inch vertical skid plate that protects the wing tips during landings since the U-2R has only centerline wheels. The outer 5.83 ft of the wings easily fold up with the removal of three pins so that the aircraft can be stored on an aircraft carrier.

The landing gear consists of four assemblies. The main landing gear is a pair of 26-inch × 6.6-inch 16-ply tubeless tires at 300 psi that supports all of the weight at landing until a nominal speed is reached. It is located in the center of the fuselage approximately at the leading edge of the wing. The rear landing gear is small, rugged, and steerable (± 6°) by cables interconnected with the rudder system, which consists of two pairs of three 8-inch-diameter solid rubber tires and, other than the oleo action of the strut, there is no damping for shocks. On each wing at about mid-span is a "pogo" type assembly that free-falls at takeoff, and consists of a leaf spring and a pair of solid rubber tires. These can rotate freely through 360° or can be locked in position. The "pogo" assembly decreases the inflight weight and also decreases the drag on the wing that would be associated with retractable landing gear.

The "Super Pods" (32-inch diameter × 286-inch long) seen on many configurations, located between the inner and middle sections of the wings, are used to carry additional electronics and equipment. There are several other pods and configurations that are used for many different roles. These allow the U-2R to be adaptable for each specific mission.

Clarence L. "Kelly" Johnson and his team at "Skunk Works" did a remarkable job by redesigning the world's best subsonic, high-altitude, air-breathing aircraft and making it better.

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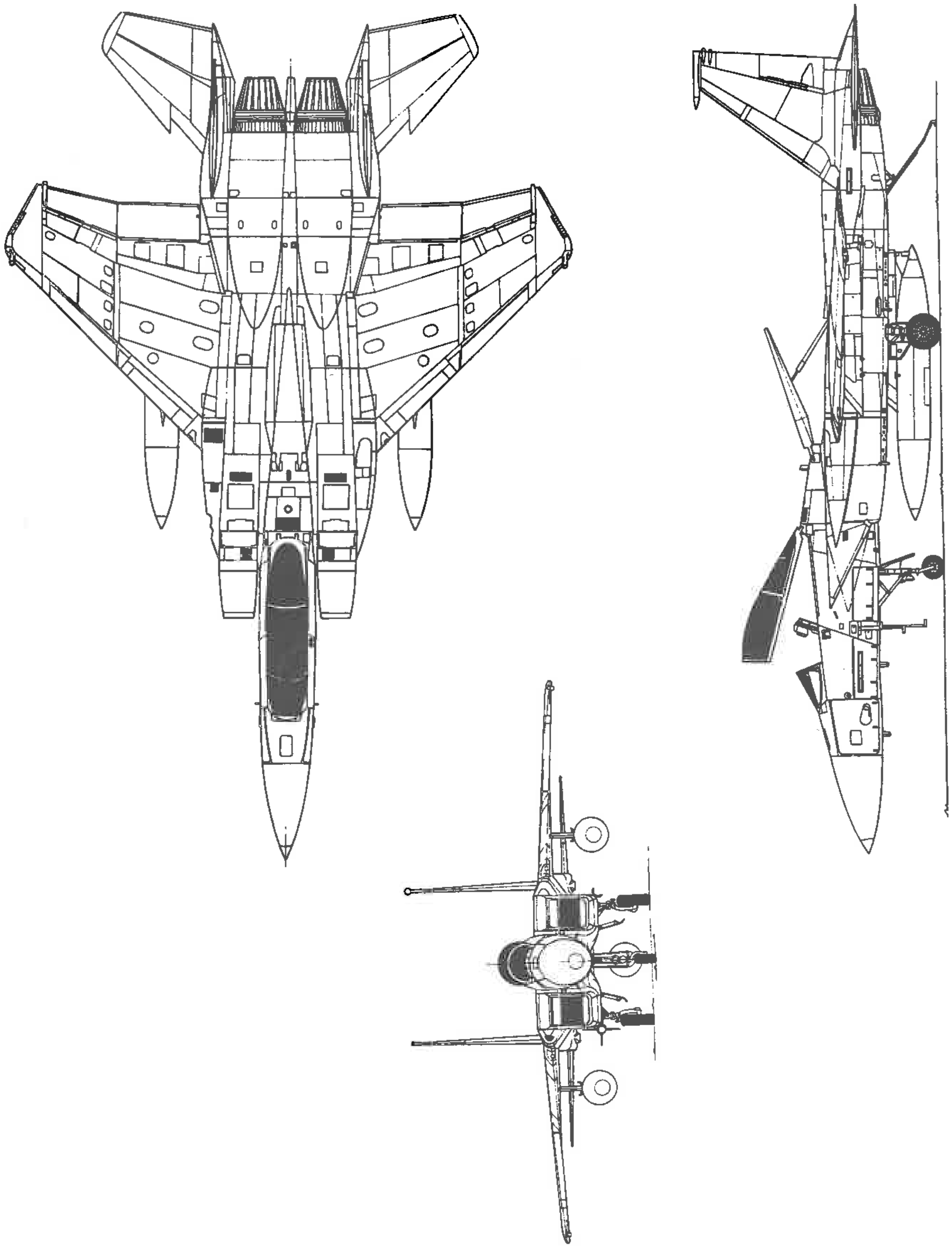


McDONNELL DOUGLAS F-15

J.D. Tressler

SPECIFICATIONS

Manufacturer	*McDonnell Douglas*
Date of First Flight	*July 27, 1972*
Number Built	*(as of 1987) 1060*
Length	*63 ft 9 in*
Wing Span	*42 ft 9.75 in*
Root Chord	*19 ft*
Tip Chord	*7 ft*
Wing Sweep (LE)	*45°*
Wing Anhedral	*1°*
Wing Aspect Ratio	*3*
Wing Loading (Takeoff)	*70 psf*
Operating Empty Weight	*28,600 lbs*
Maximum Takeoff Weight	*56,000 lbs*
Maximum Level Speed	*1350 ft/sec*
Service Ceiling	*65,000 ft*
Range (ferry)	*2500 nm*
Engines	*(2) Pratt and Whitney F100-PW-100*
Thrust (with afterburner)	*(each) 25,000 lbs*

Establishing air superiority is the best description of a fighter aircraft's purpose. Probably no other aircraft fully satisfies this purpose better than the F-15 Eagle. The Eagle puts together unprecedented power, agility, avionics, and versatility. With these capabilities, the F-15 can be adapted for many roles.

Spurred by the unveiling of the Soviet MiG-23 Flogger and MiG-25 Foxbat in the mid 1960s, the USAF needed to replace the aging F-4 Phantom with a fighter superior to present and future Soviet threats. Thus, work began on an air superiority fighter in the tradition of the P-51 Mustang and F-86 Sabre. After many paper studies, the USAF awarded the contract to McDonnell Douglas in December, 1969, and two and a half years later, on July 27, 1972, the first Eagle flew. The F-15 had become a reality. Single-seat versions were designated F-15A and two-seaters, F-15B.

From the very beginning the Eagle proved to be a great flying machine. Powered by two powerful Pratt and Whitney F100 turbojets, the F-15 can achieve a thrust-to-weight ratio of 1.15:1 with a full internal fuel load and a ratio of 1.4:1 with half internal fuel load. These large ratios give the Eagle the ability to accelerate in a vertical climb to supersonic speeds. This ability was put to good use in a slightly modified F-15 called the Streak Eagle to dramatize its incredible power. The Streak Eagle was used to break the then-existing time-to-climb records established by a Navy F-4B and a MiG-25. In January, 1975, the Streak Eagle, stripped of weapons, radar, and even paint, broke all time-to-climb records flying to 98,425 ft in 207.8 sec, breaking the MiG-25 record by 15%. It flew faster than the Apollo moonshot to 49,000 ft and bettered the F-4B record to this height by 33%.

The high thrust-to-weight ratio along with low wing loading make the Eagle very maneuverable and agile. With a half internal fuel load the F-15 has a wing loading of 57 psf and a thrust-to-weight ratio of 1.4:1 as compared to 80 psf and .85:1 of its predecessor, the F-4. These parameters have an important effect on the turning performance. As the aircraft banks, more lift is needed to counteract the combination of gravity and centrifugal force from the turn. Since the turn radius depends upon the bank angle, it follows that the minimum turn radius of an aircraft depends on how well it can continue to develop lift as the bank angle increases. The F-15's low wing loading and high thrust enable it to maintain and even increase speed in high banked turns. Thus, compared to the F-4, the F-15 can take off in a shorter distance, accelerate faster to a maximum speed, turn in a smaller radius at higher rates, and fly higher. This makes the F-15 a formidable foe.

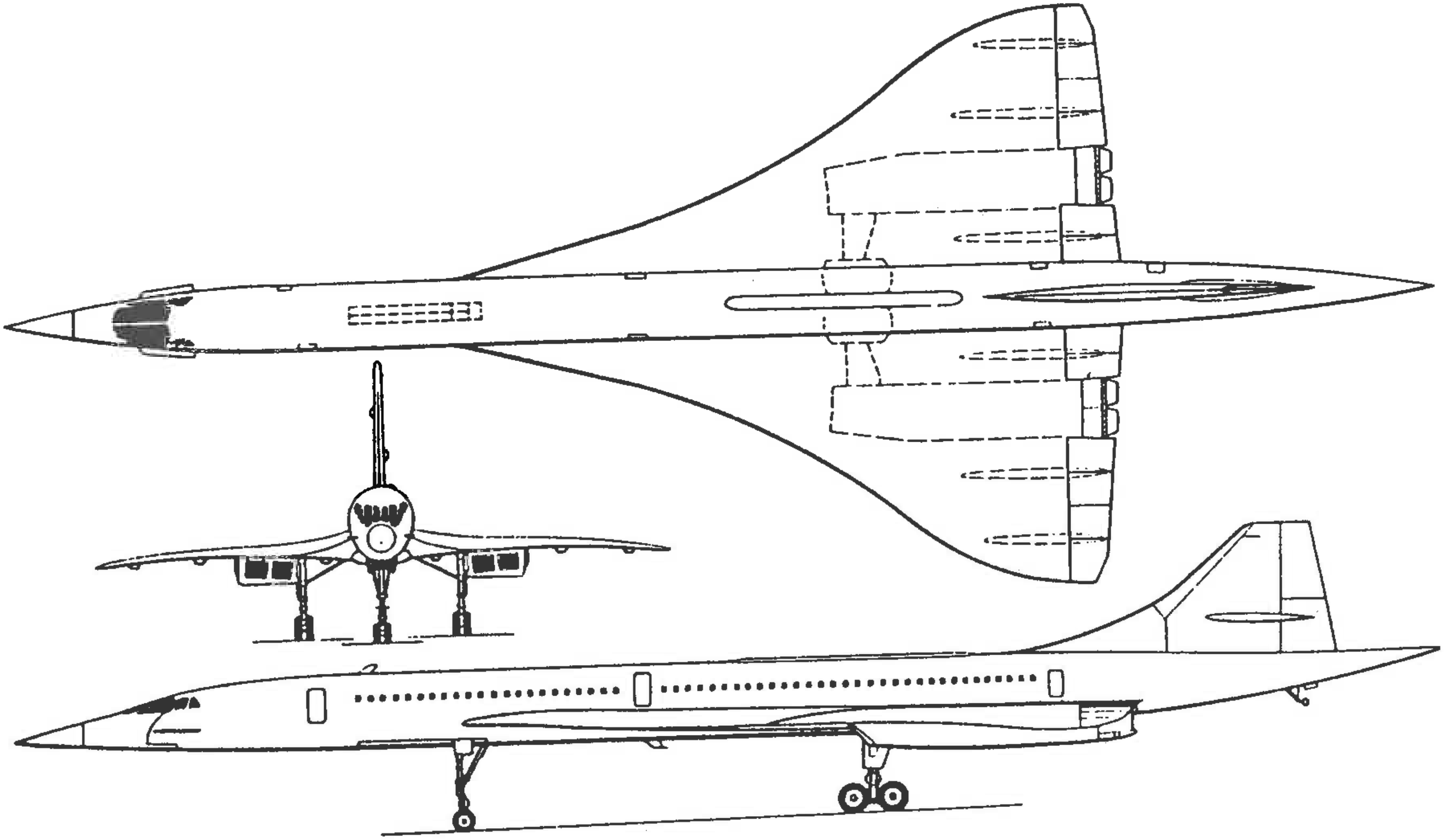
In addition to its exceptional performance, the Eagle has very sophisticated avionics that are the key to its combat capability. The main avionics feature is the Hughes AN/APG-63 radar. The APG-63 is a multi-mode, pulse Doppler radar, that has the ability to lock onto a target in excess of 100 miles. It can present clutter-free tracking and missile guidance even when targets are flying as low as 20–50 ft above the ground. It also has air-to-ground modes for ground bombing and a ground mapping mode. The pilot has the ability to fly without ever looking in the cockpit by use of the multi-displays of the heads-up display (HUD). A radar warning system displays threat information as alphanumerics. The most immediate or greatest threat is enclosed by a diamond while a missile site has a circle around it that will start to blink when a missile is fired. The countermeasures equipment automatically allocates jamming power to counter a hostile weapon system or radar. The newest versions of the radar have a ground resolution of 10 ft, which means that at a distance of 20–30 miles, power lines and field boundaries are visible to the pilot. Further advancements include the LANTIRN (Low Altitude Navigation and Targeting Infra-Red for Night) and FLIR (Forward Looking Infra-Red). These systems give the pilot access to a laser designator and range finder, automatic target recognition, and missile boresight correlator, all of which can be displayed on the HUD. With the extra room behind the pilot in the single seat version, the F-15A, there is plenty of space to allocate for new and advanced electronics. This is definitely a cost-saving benefit since redesign to make space for additional or new electronics is not necessary.

The F-15 can carry a large variety of weapon loads. Normally, in its air superiority role, the F-15 carries medium-range air-to-air Sparrow missiles, short-range heat-seeking Sidewinder missiles, and is armed with a 20mm cannon. Although this may seem adequate, the Eagle also must be adaptable so that it can operate in variety of roles. It can carry an extensive array of ground attack weapons as well as electronic warfare pods and additional external fuel tanks for greater range.

With this large diversity in weapons loads, the Eagle has earned a few new and different roles. One is the dual-role fighter designated F-15E. It is a two-seat version with a modified airframe capable of performing long-range, deep-interdiction, high-payload air-to-ground missions by day or night in adverse weather, while retaining its air-to-air superiority. The rear cockpit has four displays for radar, weapon selection, and monitoring enemy tracking systems, while the front cockpit has displays for navigation, weapons delivery, moving map displays, radar mapping, and terrain following.

Another role for the F-15 is the carrying and launching of the ASAT (anti-satellite) missile. In this role, the Eagle acts as a first stage for the ASAT before launching it at high altitudes on the proper trajectory for destruction of enemy satellites.

With all of its power, maneuverability, advanced technology, and versatility, it is no surprise that the F-15 Eagle has been the USA's premier combat aircraft for nearly two decades. The design of the future generation of air superiority aircraft, to replace the Eagle, will be a nearly impossible task if it is to perform better and be more versatile than the potent F-15 Eagle.



BAC/AEROSPATIALE CONCORDE

E.O. Medici

SPECIFICATIONS

Manufacturer	*British Aerospace/Aerospatiale*
Date of first flight	*December 6, 1973*
Number built	*16*
Length	*203.75 ft*
Wing span	*83.83 ft*
Root chord	*90.75 ft*
Tip chord	*Not Available*
Wing sweep	*Not Available*
Wing dihedral	*Slight Anhedral*
Wing aspect ratio	*1.7*
Passengers (max, 32 inch pitch)	*144*
Operating Empty Weight	*173,500 lbs*
Maximum Takeoff Weight	*408,000 lbs*
Maximum Wing Loading	*100 psf*
Max Cruise Speed (at 51,500 ft)	*1974 ft/s*
Service Ceiling	*54,500 ft*
Range	*4090 miles*
Engines	*4 Rolls Royce/SNECMA Olympus 593 turbojets*
Thrust	*(each) 38,050 lbs*

The Concorde was a 50/50 joint venture between British Aerospace and Aerospatiale. The English and French governments (and respective manufacturers) signed agreements on November 29, 1962, which concluded negotiations concerning the development of a joint effort supersonic transport aircraft. British Aerospace developed and built the three forward sections of fuselage, one rear section, the vertical tail, and many of the systems. Aerospatiale developed and produced the wings, wing controls, rear cabin, flight controls, and navigation systems. The fuselage is pressurized and made of aluminum alloy, while the nose and tail sections are not pressurized. Two airframes were static and fatigue tested and two prototypes completed flight testing and were granted full passenger carrying certificate of airworthiness in 1975.

To give the pilots a good view during takeoff and landing, the entire nose can be hydraulically hinged downwards. Referred to as a "droop snoot," the nose is raised during high speed flight to improve aerodynamics. A visor is also raised over the windscreen to reduce drag.

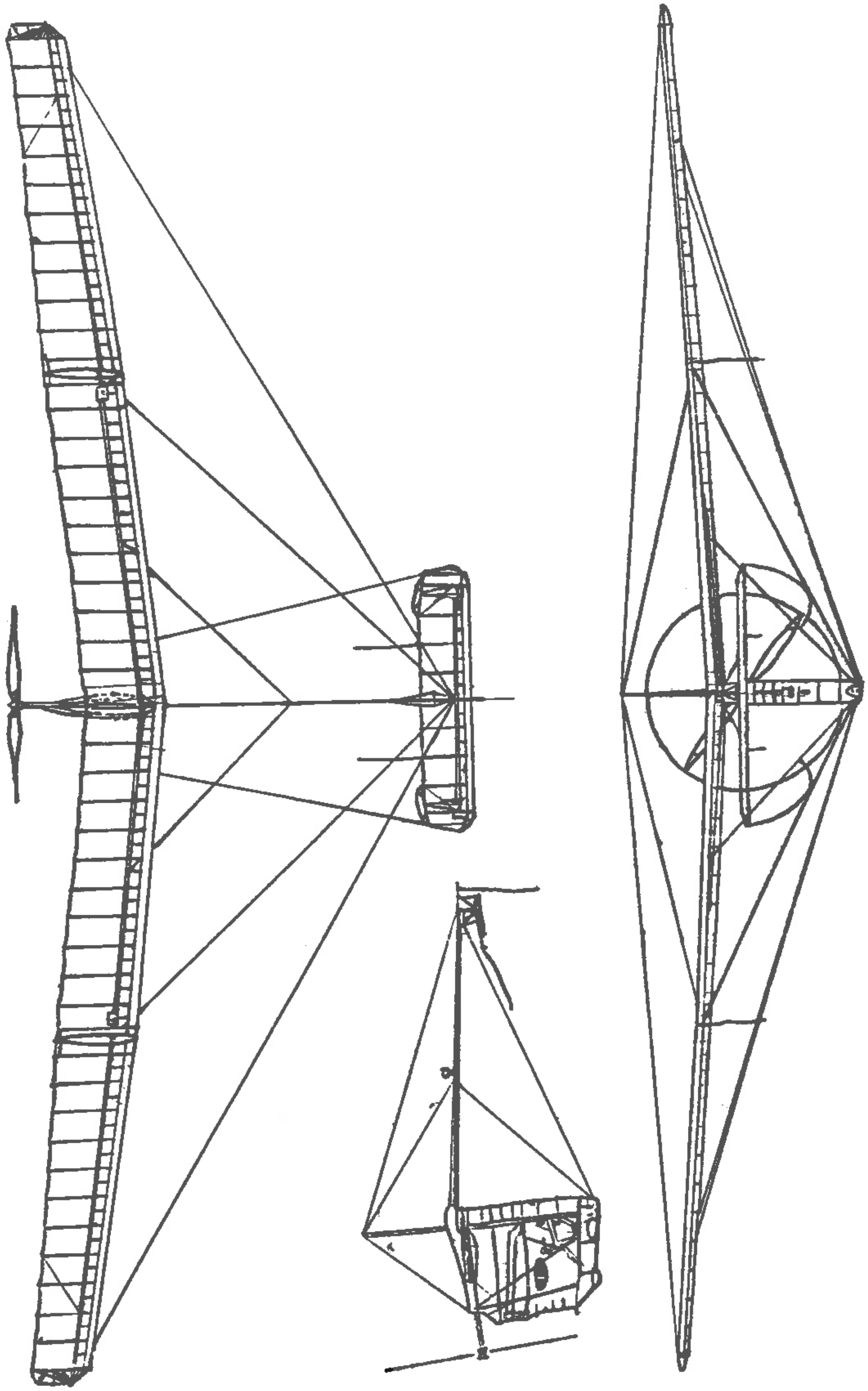
The British Olympus turbojet was almost a perfect match for the Concorde, but it had to grow along with the plane. Each engine has a short (17%) afterburner and a variable nozzle doubling as a thrust reverser. Each engine is rated at 38,050 lbs of thrust. The variable-area ramp inlets are made of an aluminum alloy with steel leading edges, which are de-iced electrically. Most of the engine nacelles are made of titanium because of its strength and high-temperature characteristics.

When compared to subsonic passenger jets, an SST design has a far greater fuel fraction and associated operating fuel cost. This large amount of fuel is used for several things besides the engines; it is used as a heat sink and to maintain correct trim conditions. The 17 fuel tanks are divided into two groups, the main group and the trim group. The main group includes five tanks in each wing and four in the fuselage, which are connected to an automatic c.g. stabilizing system to maintain a constant c.g. as fuel is depleted. Fuel is moved rearward during acceleration to compensate for aerodynamic forces. The trim group controls the static margin (the distance between c.g. and the aerodynamic center of pressure). The high skin temperatures encountered at supersonic speeds is controlled by using the fuel as a heat sink, which raises the fuel temperature an insignificant amount.

The wing is an ogival delta planform located low on the fuselage. It has constant camber and a slight anhedral angle. Each wing has three independently operated elevons, which act either as ailerons for roll control or elevators for pitch control. The controls are equipped with hydraulic mechanisms to give the pilot a "feel" for controlling the airplane and also to prevent excessive wing loads caused by pilot over-control.

Several factors have prevented the supersonic transport from being more widely used: the most severe is the 3000% increase in fuel cost since 1962. This drove up the operating costs which in turn drove the ticket cost to more than twice that of a similar subsonic flight. Another major problem is the sonic boom associated with supersonic flight; most countries, including the US, prohibit flight over land areas. In addition, the powerful jet engines of the Concorde are so noisy that many airports will not grant the Concorde landing privileges because of its noise level, and those that do have special exemption for the Concorde above the normally allowable noise levels. Despite these drawbacks (that affect supersonic flight in general) and far fewer than projected flying hours, the Concorde continues to operate at a profit for British Airways.

The Concorde is very reliable and will probably be in service for many years to come. More than just a passenger transport, it was the first attempt at an SST, as well as a symbol of Britain and France. With interest once again focusing on supersonic flight, the Concorde will be a model that we can learn from and use toward future SSTs. But, until the economics of SSTs improve there might not be any feasible SSTs produced. This would leave the Concorde in a class by itself.



GOSSAMER ALBATROSS

D. J. Ensminger

SPECIFICATIONS

Manufacturer	*Dr. Paul B. MacCready Jr*
Date of First Flight	*June 12, 1978*
Number Built	*2*
Length	*33 ft*
Wing Span	*93 ft 10 in*
Root Chord	*5 ft 6 in*
Tip Chord	*3 ft 4 in*
Wing Sweep	*7.5°*
Wing Dihedral	*4°*
Wing Aspect Ratio	*21.2*
Operating Empty Weight (Without Pilot/Engine)	*75 lbs*
Maximum Takeoff Weight (With Pilot/Engine	*216 lbs*
Maximum Wing Loading	*Not Available*
Maximum Level Speed	*17 ft/s*
Service Ceiling (Maximum Attained)	*35 ft*
Range	*22 miles*
Engine	*(1) Pilot/(1) Propeller*
Thrust	*Depends On Pilot*
SHP (Level Flight)	*0.27-0.34*

* *All specifications are approximate.*

The Gossamer Albatross, named for the graceful sea bird with the largest wingspan of any bird, has lived up to its namesake as a "great flyer." Several man-powered aircraft have been built and flown since the turn of the century, including Dr. MacCready's Gossamer Condor, but none have achieved the records or fame of the Albatross. The Gossamer Albatross is a remarkable aeronautical engineering achievement that shows what can be accomplished with ingenuity and hard work.

Dr. Paul MacCready designed the Gossamer Albatross with one goal in mind: to win the £100,000 (about $220,000 in 1979) Kremer Prize for the first man-powered flight from England to France over the English Channel. The Kremer competition was sponsored by the Royal Aeronautical Society in Great Britain, which set up specific guidelines for the flight. These guidelines drove the Albatross' design. They specified that the aircraft must be heavier than air, must not exceed an altitude of 50 meters for any extended time (e.g., no thermal gliding), must be controlled and powered by the crew over the entire flight (e.g., no outside assistance at any time, including launch), and must land somewhere in France. Rules designed to guard the pilot's safety were also included.

Man-powered aircraft require designs that are very lightweight and aerodynamically efficient, so that it takes very little power to keep them aloft. This is especially true for an aircraft required to be flown for an extended time such as the Albatross. The airframe and planform reflect these requirements directly.

The Albatross' planform was essentially that of a flying wing. The main wing's extremely high aspect ratio, low wing loading, and use of ground effect make it a very efficient lifting device. The wingspan of the Albatross is very large, within feet of the wingspan of a DC-9. The canard was chosen for pitch control because it provides lift to trim the aircraft, making the design more efficient. The canard could be banked independently of the main wing and used to control yaw as well as pitch. The enclosed fuselage pod smoothed the airflow around the pilot and acted as a vertical stabilizer as well. Vents were built into the cockpit to provide the pilot with fresh air and exhaust. Wing warping was used to control the roll of the aircraft, as the flexible wings were very conducive to this means of control.

The Albatross was constructed almost entirely of plastic and composites. The majority of the framework, including the wing spars and the fuselage boom, was made of graphite-fiber-reinforced plastic tubing formed in the Albatross' hangar using a makeshift oven. The leading edges were made of polystyrene foam sheet, as were the wing ribs. The ribs were reinforced by carbon-fiber tape and Kevlar. The wing and much of the aircraft was covered with thin Mylar film: .5 mil thick on the top surfaces of the wing and .3 mil thick on the bottom. The Mylar film was made to stretch more in the longitudinal direction than laterally when heat was applied, so when stretched over the wing and heated, the wing surface was made tight without warping the airfoil shape much. The Albatross used stainless steel bracing wires to support and stabilize the wing and canard, and braided Kevlar to connect the control surfaces to the cockpit. The sweepback angle and the wing dihedral angle could be changed by adjusting the tension on these bracing wires.

The avionics and electronics on board the Albatross were cut to a bare minimum. It was decided that a two-way radio, an airspeed indicator, and an altimeter would be required. The team used a stripped-down radio with headphones for communication with the pilot, and installed an optical airspeed sensor. The altimeter was a modified sonar rangefinder from a Polaroid SX-70 autofocus camera. This rangefinder was modified to give a digital altitude display and mounted in front of the cockpit.

The drivetrain of the Albatross contained most of the metal parts of the aircraft. The pedals, cranks, chain sprockets, seat post, and the cables on the drivetrain were all made of metal. The drive chain was not a normal bicycle chain, but a pair of cables joined by small plastic wheels appropriately spaced to fit the sprockets. The propeller was designed on computer by students at the Massachusetts Institute of Technology, and the plans were donated to the Albatross team. The propeller was made of a carbon-reinforced plastic tube, with dense blue polystyrene foam at the root and balsa at the tip. The propeller shaft was made from carbon-fiber-reinforced plastic tubing.

The heart of the Albatross was its pilot/engine. The pilot/engine had to be a trained athlete who could put out a constant high level of power with a low body weight. Bryan Allen, a bicycle racer from Southern California, fit the bill and was the primary pilot of the Albatross. Daily workouts included riding a bicycle a minimum of 50 miles and working out on an ergometer for an hour. The ergometer was calibrated in horsepower so it could measure his ability to keep the Albatross aloft, since it took .27 to .34 horsepower for steady level flight, and more for takeoff and climb.

The Albatross made several flights over a period of exactly a year before it flew the Channel. Throughout this time the Albatross was crashed, modified, damaged, and rebuilt countless times. Sometimes repairs after even "minor" crashes would take days to weeks to complete. The design specifications changed so often that even Dr. MacCready did not know what they were when Bryan Allen piloted the Albatross across the English Channel.

The historic flight took place on June 12, 1979. Pilot Bryan Allen pedaled off the pad near Folkestone, England at 4:51 Greenwich Mean Time headed for France. The flight started smoothly, but very nearly ended in failure several times. Head winds, turbulence caused by passing ships, and turbulence caused by the unsteady interface between the air and the waves caused problems for the extremely sensitive Albatross, and brought about extra work for its pilot. At one time, the Albatross came to within inches of crashing into the waves, and at another, Allen signalled to the chase boats that he was giving up and needed a tow. Both times Allen and the Albatross lifted above the surface and pushed on without assistance. Leg cramps near the end of the flight nearly finished it as well, but Allen pushed on to land at Cap Griz-Nez, France at 7:40, Greenwich Mean Time to claim the Kremer Prize. The Gossamer Albatross demonstrates the accomplishments possible with a strong will to succeed, a little ingenuity, and a good bit of hard work, and can serve as an inspiration to try what "cannot" be done.

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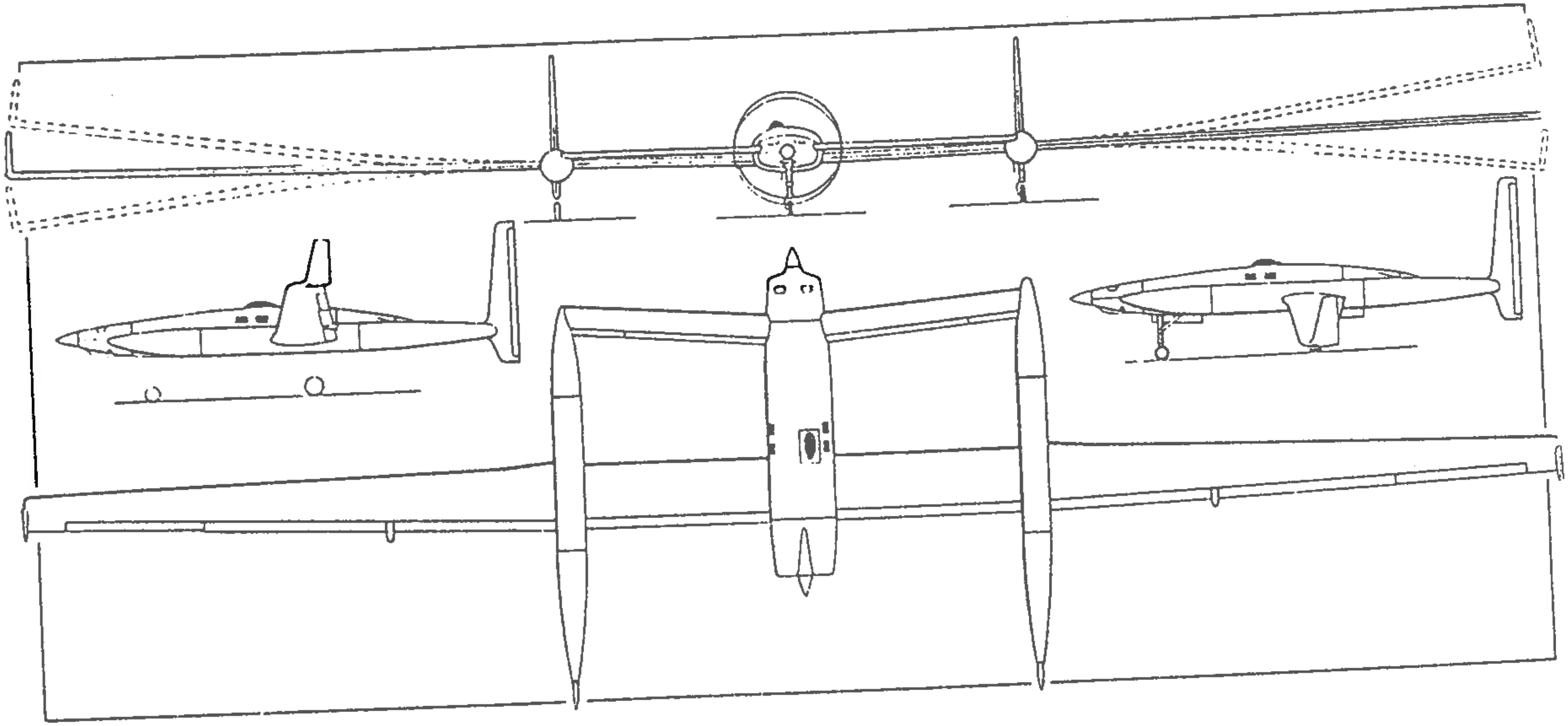


VOYAGER

D. D. Lowe

SPECIFICATIONS

Manufacturer	*Voyager Aircraft*
Date of First Flight	*June 22, 1984*
Number Built	*1*
Wing Area	*363 sq ft*
Wing Span	*110 ft 10 in*
Wing Span after winglet loss	*108 ft 8 in*
Wing Aspect Ratio	*33.8*
Canard Area	*61 sq ft*
Canard Span	*33 ft 3.5 in*
Canard Aspect Ratio	*18.1*
Fuselage Length	*25 ft 4.75 in*
Fuselage Width(maximum)	*3 ft 3.5 in*
Height Over Tail Fins	*10 ft 3.5 ine*
Cabin Dimensions	*7 ft 6 in long 3 ft 4 in wide 3 ft high*
Weight (dry)	*2759 lbs*
Fuel Weight	*7011.5 lb*
Takeoff Weight	*9694.5 lb*
Landing Weight	*2699 lbot*
Takeoff Roll	*14,200 ft*
Cruising Speed	*115.8 mph*
Range	*25,012 miles*
Engine Manufacturer	*Teledyne Continental (both)*
Engine type	*Pusher: 10L-200 (Liquid-cooled)*
	Tractor: 0240 (Air-cooled)
Engine Rating	*Pusher: 110 hp*
	Tractor: 130 hp

**Average world flight speed*
***World Flight*

By the early 1980s, after designing several airplanes for home-builders of aircraft, the Vari Viggen and the Vari Eze, for example, Burt Rutan was ready to accept one of the last remaining challenges of long distance flight: an around the world flight, nonstop, with no refueling. Several times since World War II, strategic bombers have performed this feat, but always with several in-flight refuelings. It was generally accepted that a plane carrying sufficient fuel to make the flight without such refuelings would be too heavy to get off the ground. Through the use of lightweight composite materials, with which he had already demonstrated expertise, Rutan was convinced he could develop an aircraft to circumnavigate the world. His earlier aircraft had already established numerous distance and endurance records in their size and weight classes. The Long Eze, for example, had flown from Anchorage, Alaska to the West Indies in 1981, a distance of 4563 miles.

The Voyager was to be a unique aircraft; it needed to fly a single specific mission: fly around the world on a single tank of gas. Further it needed to perform its mission only once. Burt Rutan had to come up with an aircraft whose aerodynamic shape and propulsion system, when combined with a minimum, lightweight structure, could fly more than 20,000 miles, nonstop.

Rutan made a key decision at the start—the entire flight would be conducted at modest air speeds. High speeds, near Mach 1 and above, require high power with corresponding large fuel loads and, therefore, large heavy airplanes. However, by flying at low airspeeds, the duration of flight was extended, approaching a duration of ten days. Two pilots would be required since the endurance of a single pilot was expected to be 30 hours. The configuration of the Voyager evolved logically from this starting point into the high-aspect-ratio, twin-boomed aircraft, mounting a slender center fuselage pod with tandem engines. Of course, the Voyager had a canard, a forward wing, that had become a Rutan trademark.

To obtain the lowest possible air resistance, the wing had a high aspect ratio, 34, to minimize the drag due to lift. The airfoils used on all the flying surfaces were specially contoured by John Roncz to maintain a low-drag, laminar boundary layer over a large extent of the airfoil's surface. The fuselage was slightly more than 3 ft wide and high to reduce the frontal area and keep fuselage drag low. That confined cabin space did not make for crew comfort, however.

The propulsion system for the Voyager was carefully thought out. A single large engine, powerful enough to take the fully loaded airplane off the ground, would be operating at very low power settings a few days into the flight as the fuel burned off, reducing the Voyager weight. Reciprocating engines operating at low power are not fuel efficient. Hence, two engines were to be used for takeoff with one to be shut down as the level-flight power requirements are lessened. By mounting one engine in front driving a tractor propeller and the other engine aft on the fuselage turning a pusher propeller, the thrust would always be along the aircraft centerline.

This precise operation of the engines was necessary, since Rutan felt the aircraft had to be operated at the flight speed that would provide the maximum range. The speed for maximum range depends upon the weight of the aircraft, with the speed decreasing as the weight decreases. As the Voyager uses fuel during the flight the aircraft would either ascend or speed up if the power remained the same. It would therefore depart from the speed for maximum range and consume excess fuel unless the power was reduced to maintain the proper speed. The Voyager, therefore, had to fly slower and slower as the flight progressed.

Another aerodynamic factor that influenced the maximum range is the lift-to-drag ratio. This term, when coupled with the ratio of takeoff weight to no-fuel weight, determines the maximum range. With a lift-to-drag ratio above 30, Voyager was in the class of high-performance soaring gliders. Lift-to-drag ratios of this order still required takeoff weight to no-fuel weights approaching 5 to perform the circumnavigation of Earth.

The design of the lightweight structure to carry a fuel load four times its basic structure was possibly Rutan's greatest contribution to the Voyager design. This structure was so efficient that it led to a particular concern when fueling the aircraft on the ground prior to flight. Care had to be taken to assure the fuel was taken on board in a manner to avoid unduly stressing the wing, since the wing was designed to take the upward directed lift loads, not the downward loads of gravity. Further, the deflection of the wing during fueling caused a problem with the location of a fuel vent. To prevent the fuel from running out of the vent, the vents were placed in the top of the winglets. The main purpose of the winglets was to maintain the vent above the fuel level, not as is the usual case, to increase the effective aspect ratio.

Voyager was handmade at Mojave over a period of 18 months and completed in early 1984. The main structure was made entirely of lightweight composite, specifically, Nomex honeycomb and Kevlar manufactured by Hexall. The aircraft was powered by a 0-240 forward engine and a IOL-200 engine aft, both of which were donated by Teledyne Continental. The two-bladed metal propellers were designed by John Roncz and donated by TRW Hartzell Propeller, Inc. The avionics were donated by King Radio.

The Voyager began her taxi and flight-test program on June 22 with Burt's brother Dick Rutan and Jeana Yeager at the controls, and completed numerous endurance tests over the next two years. Preparations for the around-the-world flight continued through the autumn and early winter of 1986 and included an overhaul of both engines and the replacement of the wooden propeller blades originally developed for the aircraft after an in-flight failure of a blade on the front propeller.

A second incident during flight test almost caused a re-design of the canard. During a test flight, Dick Rutan encountered rain; the airplane pitched over into an uncontrolled descent. Fortunately, the rain ended, the Voyager recovered, and Dick returned to Mojave. Subsequent tests verified this pitch trim change with rain; other aircraft with thick laminar flow airfoil sections for canards had encountered this identical behavior. Prior to such drastic action as disassembly of the Voyager and replacement of the canard, a section of the canard was fabricated and brought to Ohio State University to be tested in the 3′ × 5′ subsonic wind tunnel, Professor

Michael Bragg tested the canard and measured a maximum lift-to-drag ratio of 140 when the airfoil was clean and a lift coefficient of 0.9 at zero angle of attack. When a tape strip was added at the airfoil leading edge to represent the turbulent boundary layer caused by rain, the lift coefficient decreased to 0.5 as the flow separated at the airfoil high point. Vortex generators designed by Professor Jerry Gregorek of OSU corrected this flow separation when attached to the model airfoil upper surface, ahead of the airfoil maximum thickness. The canard lift was restored at little increase in airfoil section drag. Dick Rutan positioned these triangular vortex generators on the Voyager canard surface and reported no further problems when the aircraft was flown into rains.

The flight test culminated with Dick, Jeana, and the Voyager setting the world record for closed-course distance in July 1986. This elongated, ellipitical course originated at Vandenberg AFB and stretched up the California coast from San Luis Obispo to a point 250 miles north of San Francisco. After five days, the Voyager touched down at Mojave 11,857 miles later, of which 11,600.9 miles were within the closed course. The previous record, set in 1962, was held by a B-52 that flew 11,336.9 miles.

With a takeoff weight of 9700 lbs, Voyager began the takeoff roll at Edwards AFB on the morning of December 14, 1986, with Dick and Jeana at the controls on their way to fly around the world. The wings deflected under the enormous weight of 7000 lbs of fuel and scraped the runway surface as Voyager accelerated. The right winglet was broken, the left winglet detached, and over a foot of composite material was torn from the undersides of the wings. Nevertheless, Dick Rutan pulled the Voyager into the air at 8:02 a.m. and headed out toward the California coast. Meanwhile, Burt was in a chase plane inspecting the damage to the wings and decided that the Voyager could continue but directed Dick into a right sideslip maneuver to cleanly snap the right winglet off.

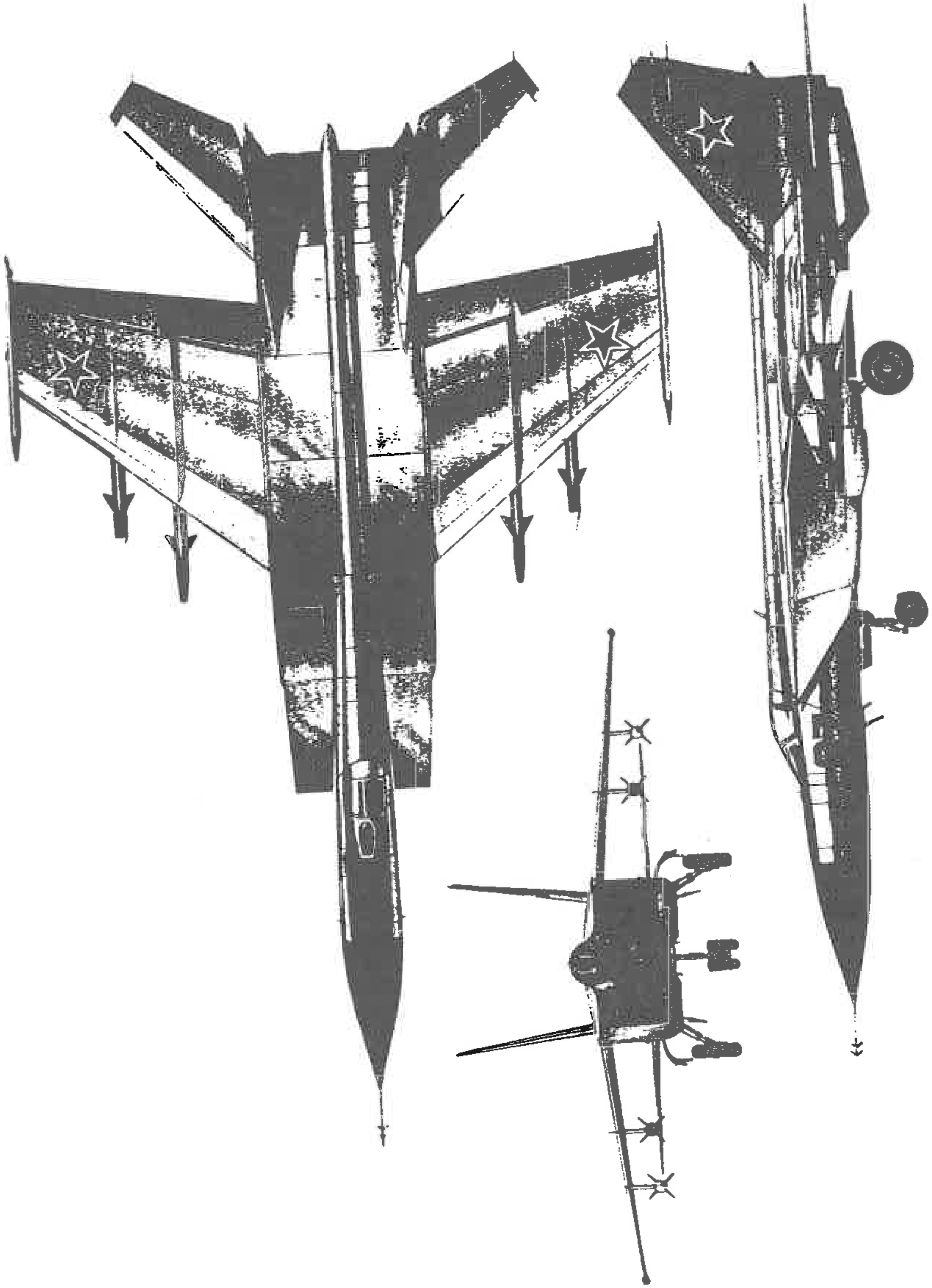
The optimum weather window for the flight was estimated to be between September and November and the plan was a west-to-east flight, but this plan was reversed since the flight was not made until December, so Voyager headed out across the Pacific. Voyager encountered typhoon Marge and was forced to fly 2000 miles north of the intended flight path over Australia. Though most of the flight was flown between 7000 and 11,000 ft, thunderstorms over Africa forced the Voyager up to 20,000 ft. Over the Atlantic, the Voyager encountered a tail wind that pushed its speed to 165 mph. As a result, an oil warning light appeared for the aft engine. With Jeana at the controls, Dick pumped extra synthetic oil into the motor, which corrected the problem.

Near Brazil, an unexpected storm produced the worst turbulence encountered and nearly ended the mission when the Voyager banked nearly 90 degrees. Having steadied the aircraft, Rutan continued up the east coast of South America toward the Gulf of Mexico and an intended route across Texas but altered course and crossed the continent at Costa Rica to avoid storms.

Off the coast of Mexico the aft engine fuel pump failed so fuel was drawn directly from the tank, bypassing the pump. This modification worked until the Voyager descended to 8500 ft in search of lower headwinds. On the descent the system devised to bypass the fuel pump failed and the aft engine quit. With the forward engine not running either, Voyager was a glider until the engines could be restarted. After this scare both engines were kept running for the rest of the mission.

On the morning of December 23, 1986, Voyager flew over Edwards AFB where the flight had originated nine days earlier and touched down at 8:06 a.m.

The Voyager took off with 1192.3 gallons of fuel and returned with 18.3 gallons. The 25,012-mile flight had been a success, and Voyager's last flight on January 6, 1987, a short, 18-mile trip to Mojave airport, ended the story.



MIKOYAN GUREVICH 25

T.F. Dietrichs

SPECIFICATIONS

Manufacturer	*Mikoyan Gurevich*
Date of First Flight	*1964*
Number Built	*Unknown*
Length	*78.15 ft*
Wing Span	*45.75 ft*
Height	*20.05 ft*
Wing Area	*611.7 sq ft*
Wing Sweep (LE)	*40°*
Operating Empty Weight	*44,092 lbs*
Maximum Takeoff Weight	*79,806 lbs*
Maximum Speed (with 4 AA-G AAMs)	*1849 mph*
Service Ceiling	*80,050 ft*
Combat Radius	*702 miles*
Engines	*(2) Tumansky R-31 afterburning turbojets*
Thrust	*(each) 24,250 lbs*

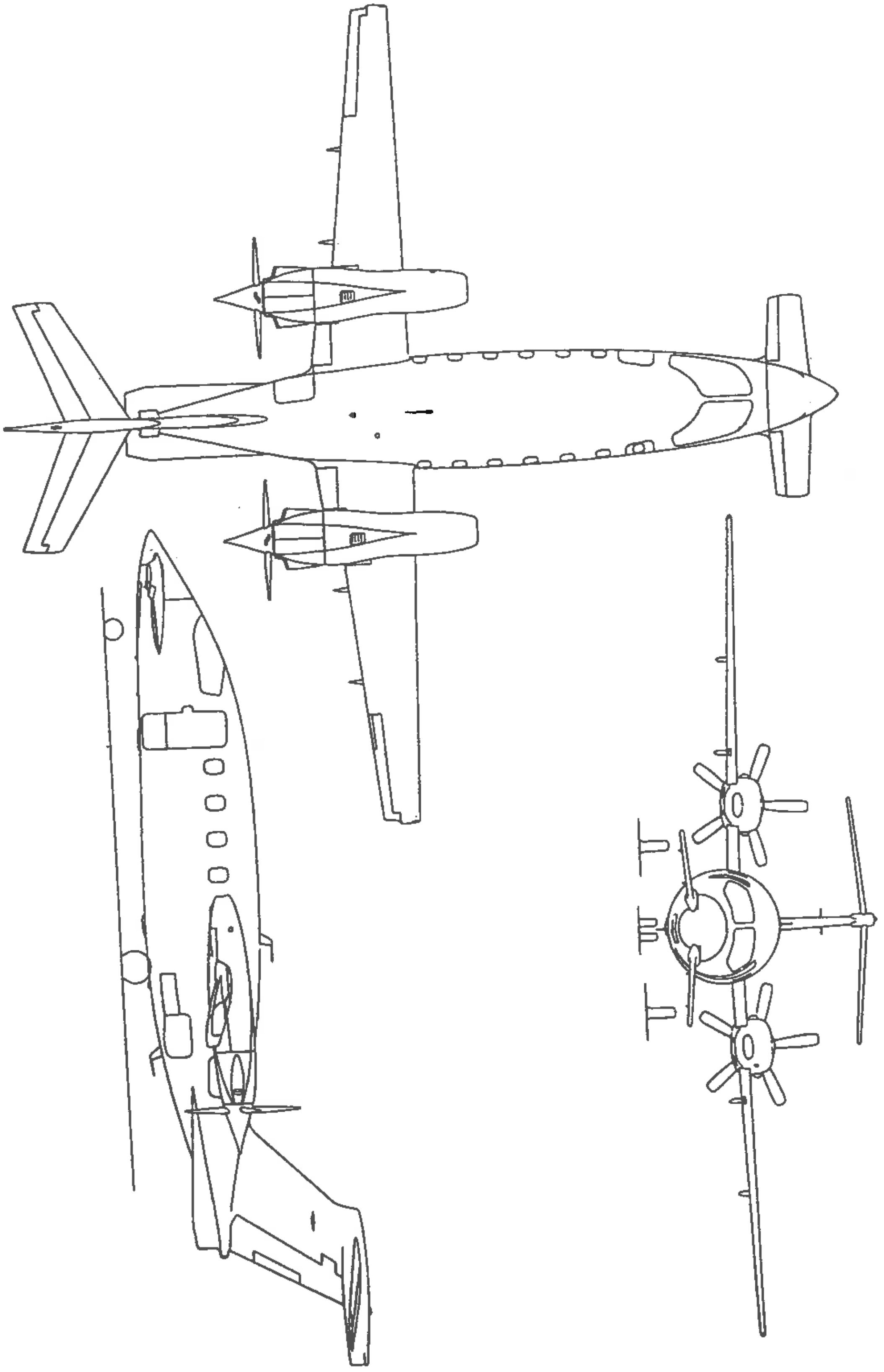
One of the most famous events in recent aviation history involved Lt. Viktor Belenko and his MiG-25, known as the Foxbat to NATO forces. It was a September day in 1978 above the Hakodate Airport in northern Japan when Lt. Belenko and his plane appeared in the sky. Darting around an All Nippon Airways 727, he dove for the runway and touched down at just over 250 mph. Utilizing full brakes and the parachute, Belenko and his plane ultimately came to rest at just over 800 feet into the overrun zone. His defection would turn out to be the largest single contribution to technical intelligence in the cold war era.

The MiG-25 was developed to counteract the threat of the proposed B-70 Valkyrie that was being developed by the U.S. The B-70 was to be a supersonic replacement of the B-52. In December 1957, North American was chosen to build the new bomber. Their proposal detailed a bomber that would fly at Mach 3 throughout its mission at an altitude of 70,000 ft. It was to be based on the 'compression lift' theory where the aircraft would be designed such that it could trap its own shock wave beneath its wings, providing more lift and conserving energy.

Although the B-70 would eventually be canceled, the proposed bomber caused great concern in the Soviet Union. Their response to this threat was the development of a new supersonic interceptor. The final decision was made in 1959 for the Mikoyan Gurevich Design Bureau to design the new supersonic interceptor, designated the MiG-25. For the structural design, steel alloys were chosen over aluminum for higher strength. Most of the structure was arc-welded and the skins stiffened with welded-on steel stringers. The complex structural components were built through a series of welding processes. This was in contrast to the West were it was common practice to use aluminum as much as possible and to forge many of the structural members. However, the main structural members for the MiG-25 were indeed forged from steel, while some aluminum was used on the trailing edges, flaps, and ailerons. Titanium, a relatively new technology utilized in the West, was used only around the leading edges and tailpipes. The fuel tanks were not of the typical integral type but were built from continuously welded sheets of steel. The resultant airframe could pull a maximum of 5 g with the fuel tanks much more than half empty. Most current fighters are designed to pull 9 g with half fuel. The propulsion system was designed strictly for high speed and therefore provided very poor low speed performance. The huge inlet allowed massive quantities of air to enter without encountering high thermal loads and is believed to have attained compression ratios in excess of 30:1. The majority of the thrust at high speed was generated by expansion through the convergent-divergent nozzle. This was driven by the combustion of massive quantities of fuel in the augmentor. Since most of the compression in the supersonic turbojet engine is done at the inlet, and most of the thrust is generated in the expansion nozzle, this engine could be called a 'turboramjet'.

An interesting comparison can be drawn between the MiG-25 and the F-15. While the F-15 weighs about half as much as the MiG-25, when both are carrying missiles and half internal fuel, the MiG has only 12 percent more static thrust, but is 60 percent faster. This is due to the powerplants which differ due to their respective mission requirements. While the F-15 is a highly versatile fighter, the MiG-25 is by design, a straight-line interceptor, which once in range could deploy the various missiles necessary to bring down a supersonic bomber.

In the months following the episode at the Hakodate Airport, the mystique associated with the MiG-25 was slowly dismantled as experts in the West pieced together the truth behind the elusive plane. Up until that point, the MiG-25 was so feared because it was believed to have Mach 3+ capability similar to the SR-71. Although it deprived the US of a great deal of intelligence information, that belief led the US Government to not use SR-71s or D-21 drones for penetration of Soviet air space. The assumed Mach 3 capability of the MiG-25 was due to a variety of misjudgments and miscalculations, aided by the stringent controls within the Soviet security system. In fact, it was out of the hysteria surrounding the initial reports on the Mig-25 that the US Air Force revised its requirements for a new tactical fighter. Ultimately, after an incredible amount of effort and expense was consumed, a new tactical fighter that would counter the supposed threat of the MiG-25 was produced: the F-15 Eagle.



PIAGGIO P-180

R.J. Leiweke

SPECIFICATIONS

Manufacturer	*Piaggio*
Date of First Flight	*August, 1986*
Number Built	*14*
Length	*46.5 ft*
Wing Span	*45.5 ft*
Root Chord	*4.60 ft*
Tip Chord	*1.56 ft*
Wing Sweep	*5°*
Wing Dihedral	*2°*
Wing Aspect Ratio	*12*
Operating Empty Weight	*7370 lbs*
Maximum Takeoff Weight	*10,810 lbs*
Maximum Wing Loading	*61.1 psf*
Cruise Speed (36,000 ft)	*Mach 0.67*
Service Ceiling	*41,000 ft*
Range (Maximum)	*1800 nm*
Engines	*(2) Pratt and Whitney PT6A-66 Turboprops*
Power (flat rated to 25,000 ft)	*(each) 850 shp*

In 1979 the Piaggio Company decided to design a new business-class aircraft, the P-180. Several years later as the design firmed up, the aircraft was named the Avanti, meaning "forward" in Italian, and what a step forward it is! During the last four decades a great deal of effort has been applied to the advancement of military aircraft technologies; however, many general aviation aircraft in use today are still designed according to well established conventions developed in the 1940s and 1950s. Aircraft manufacturers have been very reluctant to incorporate state-of-the-art aerodynamic and structural advancements into unproven designs. The reason for this has been economic; until the early seventies fuel was cheap, and manufacturers were building aircraft at low costs while selling them as fast as they were made. This situation began to deteriorate when the oil embargo of 1973 induced world-wide fuel rationing and high prices. Not surprisingly, the auto industry moved rather quickly toward fuel-conscious design of vehicles as consumers demanded more miles per gallon with suitable comfort. Likewise, corporate executives wanted the luxury of flying at "LearJet" speeds without paying "LearJet" fuel bills. With a few exceptions (for example, Scaled Composites, Inc.), changes in aircraft design within the general aviation industry have occurred slowly, and usually as modifications to existing models.

In 1979, Dr. Rinaldo Piaggio accepted the challenge to design a more fuel efficient business aircraft capable of carrying seven to nine passengers at executive jet speeds with the same cabin comforts. Specifically, the aircraft was to maintain a smooth, quiet ride with a large cabin height and width, comparable to the LearJet. Dr. Piaggio and his engineers knew that a turboprop could (with uncompromising aerodynamics and weight reductions) cut fuel consumption up to 50% compared to existing turbofan engine aircraft. However, turboprop noise would have to be reduced in order to maintain a quiet ride. They understood that an extensive research and design effort would be necessary to achieve their demanding goals. However, to avoid delays in the certification process, Piaggio decided to use existing powerplants. This decision was really not a compromise at all since engine modifications could be made as needed at a later time.

The Avanti P-180 meets these design goals and is regarded within aviation circles as a magnificent airplane with many unconventional features. These features include a three lifting surface configuration with far-aft main-wing mount, high wing loading, pusher props, liberal use of composites, state-of-the-art aerodynamics, unique fuselage shaping with sharp attention to detail, a cruise speed of about 400 knots at 36,000 ft, and a cabin pressurization of 9 psi (0.61 atm) that allows operation up to 41,000 ft.

The unique three lifting surface configuration of the Avanti came about from the desire of Dr Piaggio to have a large comfortable cabin. A mid-fuselage location of the wing was desired since it has the lowest interference drag. However, such a location would reduce the cabin space. Engineers at Piaggio placed the wing aft of the main cabin, with the stability of the aircraft intially to be maintained by a forward wing (or canard surface). Analysis of this canard configuration uncovered a problem: when the wing flaps were lowered to slow the aircraft for landing, the nose down pitching moment of the flaps could not be counter-acted by the canard control surface. An increase in wing area could be used to produce slow landing speed if the flap useage was limited, but this would increase the aerodynamic drag and require more power—and therefore more fuel—to achieve the 400-knot top speed of the Avanti. Instead, the engineers chose a novel approach: They added a conventional tail as the control surface. The front wing is equipped with a flap that is interconnected to the main wing flaps. During landing and takeoff as the flaps are lowered on the main wing, the flaps on the canard surface also are lowered, providing increased lift while the conventional aft tail provides pitch control. With this three lifting surface configuration an efficient flap system is obtained reducing the total lifting surface area when compared to other aircraft, resulting in a lower parasite drag. The small wing area increases the wing loading of the aircraft to a jet-like 61 pounds per square foot, a factor that contributes to the smooth ride of the Avanti.

The pusher prop has been a Piaggio trademark for years. It eliminates slipstream interference, provides smooth flow over the wing and, in the Avanti, maintains laminar flow on the wing and substantially reduces cabin noise. Piaggio worked with The Ohio State University to develop the pusher propeller. A five-blade propeller with new airfoil sections, and twist and camber optimized for Mach 0.67 flight was designed by Dr John D Lee of OSU. Hartzell Propeller, Inc. manufacture this propeller.

The engines are counter-rotating to give the airplane good stability and trim characteristics while reducing drag by allowing trim surfaces to be aligned with the main surfaces during cruise.

Structurally, the Avanti was designed using finite-element methods and experimental models. Flutter tests were performed in the Convair wind tunnels in San Diego, California. To reduce weight without a delay in certification, Piaggio strategically introduced composites into 20% of the total structure. Most of the airframe is aluminum, but the nacelles, vertical and horizontal stabilizers, forward wing, nose, flaps, ailerons, and other small nonload-bearing parts are built of carbon composite material. Weight is further reduced by a clever arrangement where the main wing spar, the aft pressure bulkhead, and the main landing gear all converge to a single attachment point.

Use of advanced aerodynamic concepts has produced one of the cleanest airplanes in flight today. The low drag characteristics stem from the high aspect ratio (12) wing, Natural Laminar Flow (NLF) airfoil sections, streamlined fuselage, area ruled engine nacelles, and tight manufacturing tolerances. The high-aspect-ratio main wing minimizes induced drag. The wing is the product of research begun by Piaggio with the help of NASA's Aircraft Efficiency Program in 1976 and continued by The Ohio State University in 1980 to develop a transonic, laminar-flow wing for the Avanti. The airfoils, designed by Dr. G. M. Gregorek of OSU, provide 45% and 55% maximum NLF over the upper and lower surfaces during cruise respectively. To maintain NLF, care must be taken to provide and maintain smooth surfaces with the minimum pressure points at the maximum thickness-to-chord ratio. As mentioned above, the pusher prop helps maintain NLF by providing a smooth flow. In addition, the small sweep angle and high aspect ratio reduce the boundary layer instabilities over the wing caused by flow components normal to the streamlines. However, the critical Mach number decreases with smaller sweep angles and becomes a significant problem in the transonic flight regime.

An interesting problem, unnoticed in early wind tunnel tests, occurred during flight testing when the Avanti rolled suddenly when stalled at high altitudes. It was found that above 25,000 ft and at high angles of attack near stall, the upwash from the forward wing vortex helped the flow exceed Mach 1 on the main wing airfoil, causing shock-induced separation on the leading edge. This caused the Avanti to roll severely at stall. The roll-off was corrected by altering the leading edge nose shape, which reduced the Cp spike (and lift) for a negligible penalty, as shown in Fig. 1.

The sweep of the anhedral horizontal tail minimizes the interference effect from the wing wake, which increases elevator power in post-stall conditions. Two ventral fins, located aft of the main wing below the tail, increase lateral stability at high angles of attack and also avoid deep stall problems encountered with T-tail configurations. The fuselage was optimized by computer techniques starting from a low drag airfoil surface of revolution. The result is laminar flow over large portions of the fuselage. Attention to detail, including tight manufacturing tolerances, reduction and/or shaping of external appendages, reduces major sources of interference drag in control surface areas and across the fuselage. Interference effects were modeled analytically by Piaggio in Genoa using the computer code VSAERO.

Wind tunnel testing in Boeing's transonic wind tunnel revealed that interference at the wing-nacelle junction was causing shock-induced stall at high Mach numbers. The problem was solved by area rule techniques used to design the engine nacelles. Assuming small perturbations in a transonic flow field, the area rule states that an aircraft with a smoothly changing longitudinal cross-sectional area distribution will have a lower wave drag. This is seen intuitively when one looks at the "coke bottle" shape of the nacelles where compressibility effects can become significant in high subsonic flow fields.

With the ever increasing operational costs, the quality and efficiency criteria may spell long-term success or failure in the business aviation sector. The Avanti has provided the benchmark for a new generation of general aviation business aircraft that have the potential to reduce these costs and extend conventional lifetimes through thoughtful design, attention to detail, and high-quality craftsmanship.

FORWARD WING AIRFOIL LEADING-EDGE MODIFICATION

MAIN WING TIP AIRFOIL LEADING-EDGE MODIFICATION

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