The Boeing 367-80

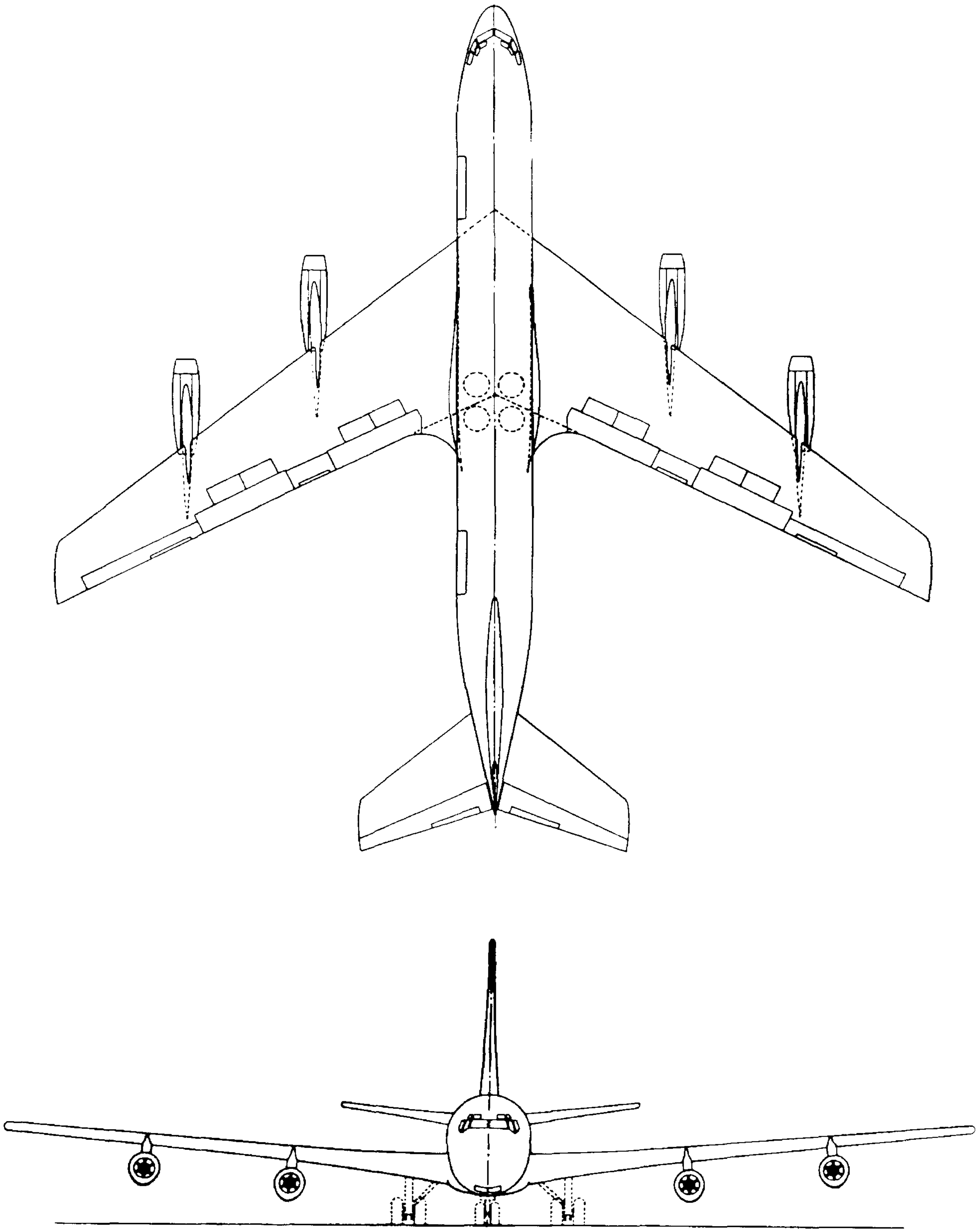
Jet Transport Prototype Mechanical Systems

International Historic Mechanical Engineering Landmark

September 24, 1994
Seattle, Washington

American Society of Mechanical Engineers

The Boeing Company

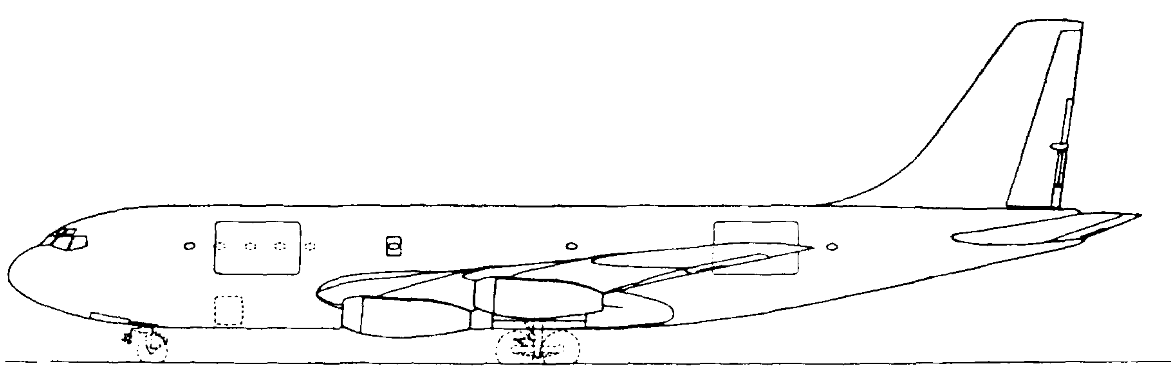


Description

of the Dash 80

The Dash 80 airplane was the prototype of the Boeing 707 commercial airliner. It featured sweptback wings and turbine engines. Major specifications and performance included the following:

Wingspan.	130 feet
Wing area.	2,400 square feet
Sweepback.	35 degrees at 0.25 chord
Aspect ratio.	7
Taper ratio.	0.34 (wingtip/wing root)
Dihedral	7 degrees
Horizontal tail area. . .	500 square feet
Airplane length. . . .	128 feet
Gross weight.	190,000 pounds
Empty weight.	75,630 pounds
Engines.	4 Pratt & Whitney J-57/JT-3
Engine rating.	11,000 pounds sea level static thrust
Design load factor. . .	2.5
Lift coefficient, stall. .	1.8
Takeoff field length. .	7,000 feet
Cruise altitude.	35,000 feet (typical)
Cruise Mach number. .	0.80 (economical speed)
Cruise range.	3,000 nautical miles
Fuel mileage.	25 seat-miles/gallon (at 100 seats)
Fuel capacity.	12,600 gallons
Maximum speed. . . .	575 mph
Landing field length. .	6,300 feet



History

and Significance of the Dash 80

The first landing of the Dash 80 on July 15, 1954.

After World War II, British and Canadian companies and The Boeing Company realized that the new gas turbine engines developed during the war provided the basis for a better commercial transport airplane. Great Britain's "Comet" flew first, but Boeing decided that flexible, sweptback wings would give more speed, a better ride and improved economics. Boeing had gained experience with jet engines and sweptwings on the B-47 and B-52 bombers, which had first flights in 1947 and 1952, respectively.

Many preliminary design studies of jet transports were conducted at Boeing from the end of World War II through 1951. A prototype, the model 367-80, was authorized in 1952. It soon became known as simply the Dash 80. Although the Dash 80 was strictly a prototype, it was designed so that a production version (the 707) would have enough range capability to cross the North Atlantic (New York to London).

Boeing designed and built the Dash 80 in secret. It flew in 1954. The airplane was built with company funds equal to one-quarter of the company's net worth, a big risk. From this prototype came the KC- 135 military tanker and the 707 airliner. The 707 was followed by many commercial airplanes of similar configuration in the United States and Europe, including the DC-8 and Boeing models 737, 747, 767 and the new 777.

The Dash 80 was the first commercial airliner that was economical enough to take the United States airlines off subsidy. Because of its speed, it made the world smaller. Because of its ride comfort, popularity and economics, it brought the people of the world closer together. The sale of more than half its offspring to international carriers resulted in a major contribution to the country's balance of trade.

In 1972 Boeing donated the Dash 80 to the National Air and Space Museum. Since then the airplane has been refurbished and restored by Boeing. It is on loan from the National Air and Space Museum for shelter and preservation in the Seattle area.

Technical

Features

The airplane and its production derivatives, the 707 and the KC-135, were substantially faster than the piston-powered airplanes that they replaced and could fly at better (higher) altitudes. They were able to use existing airports that were at least 7,000 feet long. The Dash 80 provided superior ride comfort for the passengers, not only because of the choice of altitude, but because the turbine engines exhibited a pleasant lack of vibration and the flexible, sweptback wings gave a smoother ride. It was smoother because an upward gust bends a sweptback wing so that the wingtip undergoes a reduction in local angle of attack. This gives a shock-absorbing action and a smoother ride in rough air.

The economics of the Dash 80 were better than the economics of the most successful piston engine transport of the time, the DC-6B. The Dash 80/707 had seat-mile costs from 20 percent to 30 percent lower. The 707 had better dispatch reliability in service than the piston engine airplanes that it replaced. The 707 was the commercial version of the Dash 80, with a wider and longer body.

In 1955 the Dash 80 flew from Seattle to Washington, D. C., (2,340 miles) in 3 hours, 58 minutes with a tail wind. Transcontinental flights by commercial airlines using the 707 took only 5 hours. This was some 3 hours faster than the fastest piston-powered airliners.

Experience from the Boeing B-47 and B-52 bombers was useful in the mechanical design of many Dash 80 features. These include engine nacelle locations below and forward of the wing, a yaw damper (B-47), an adjustable horizontal stabilizer (B-52) and wing spoilers (B-52) described in the next section.

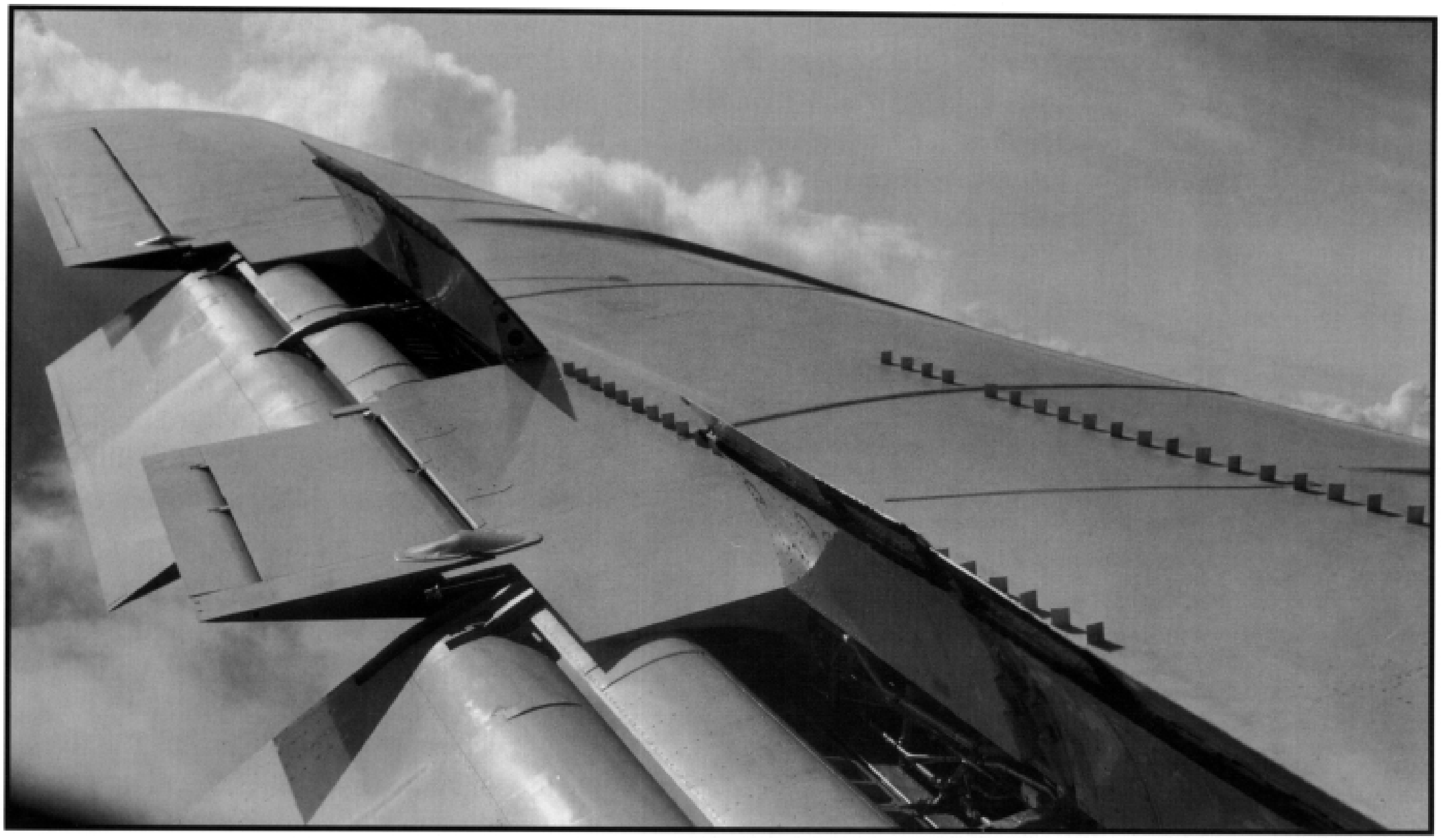
Tooling for the Dash 80 was minimal and existing machinery was used. After all, the Dash 80 was a prototype and it was expected that its successor (the 707) would in all likelihood need different production tools and fixtures anyway.

Wings. These are of aluminum alloy, two-spar construction. Two slotted trailing edge flaps on each wing provide maximum lift/low drag for takeoff and high lift/high drag for slow-speed approach and letdown. The flaps are driven by two hydraulic motors through torque tube and ball bearing screw actuator systems. Leading edge flaps are located inboard of the outboard nacelles. Fuel tanks are integral.

Lateral control is by midspan high-speed ailerons, supplemented by spoilers on the upper surface of the wing and outboard low-speed ailerons when trailing edge flaps are down. The outboard aileron is locked in neutral when the flaps are up, thereby avoiding "aileron reversal" at high speeds. Aileron reversal occurs when the increased air loads at high speed neutralize the ailerons by twisting the wing. The spoilers act together as speed brakes for landing.

Technical

Features



Lateral controls showing trailing edge flaps down and spoilers up.

Control Power. The design of the flight control system was mechanical engineering at its best. Two independent 3,000-psi hydraulic systems (left and right) provide the major power source for all controls and control surfaces. Each system receives its power from two engine-driven pumps, one pump on each engine. Each system is independent with a manually controlled crossover valve capability in the cockpit. This permits the power from either system to cross over and drive the entire landing gear and wing flap systems in the event of failure of one power system.

The left system provides power to the left lateral control and drag spoilers, copilot's brakes, left main gear actuator, nose gear actuator, left main gear door actuator, nose gear door actuator, nose gear lock actuator and nose gear steering. The right system provides power to the right lateral control and drag spoilers, pilot's brake and auto-brake valves, right main gear actuator, right main gear door actuator and the wing flaps. Normally, the four engine-driven variable displacement pumps (9-cylinder piston type) supply all power for these systems. There are also two electric motor-driven emergency pumps with a standpipe reserve system installed. Selection switches are located in the cockpit.

An accumulator, preloaded to 2,000 psi, is installed in each system to reduce system noise, reduce shock loads and provide reserve pressure. An additional accumulator, preloaded to 1,500 psi, is installed in each system upstream of the brake metering valves. It is isolated from the main system by a check valve. Its function is to provide reserve pressure for the pilot's brakes in the event of a hydraulic system failure. The elevator and lateral controls are very satisfactory without hydraulic servos, but hydraulic power and a yaw damper were added to the rudder after the first flight.

Body. The body is an all-metal aluminum structure with a cross section consisting of two semicircles joined at the floor and faired at the sides. Maximum width of the body is 132 inches. Maximum height is 164 inches. The main cabin is 90 feet long. The Dash 80 cabin pressurization system provides improved passenger comfort compared to the lower cruise altitude on previous Boeing airplanes. The flight deck accommodates three crew members.

Tail. This is an aluminum alloy structure. The horizontal tail has a span of 39 feet 8 inches. A jackscrew drive repositions the complete horizontal stabilizer for all flight regimes. Both horizontal and vertical tail are sweptback. The vertical tail is removable for improved assembly and maintenance.

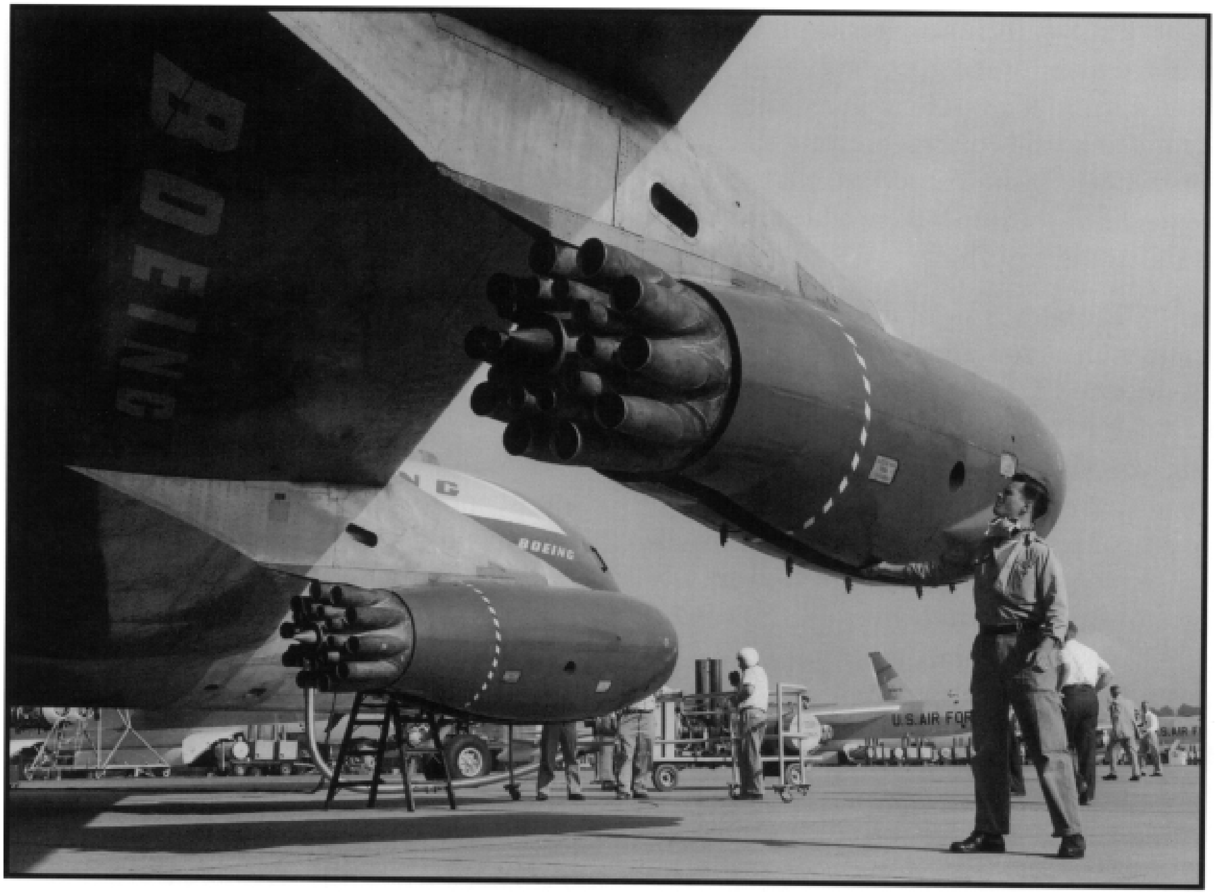
Landing Gear. This is a retractable tricycle type with hydraulic actuation. Main units are four-wheel bogies that retract inwardly into the underside of the thickened wing root and the fuselage and are mounted (cantilevered) off the rear spar unlike predecessors such as the B-47 and B-52, which had bicycle landing gears. The dual nosewheel unit retracts forward into the fuselage. The wheelbase is 44 feet and the track is 21 feet long.

Propulsion. Originally, four Pratt& Whitney 11,000-pound sea level static thrust turbojet engines in separate nacelle pods were mounted on swept-forward struts located under the wing. The struts are mounted at 40 percent and 70 percent of the wing semispan. Nacelle location is optimum considering accessibility, safety, low-interference drag, flutter resistance and wing weight (bending relief).

The engines are fitted with clamshell-type thrust reversers for landing and 21 -tube sound suppressors. The thrust reversers allow stopping with less brake wear and provide increased safety, especially on ice. The sound suppressor system contributes lower cabin and community noise than previous large jet-powered airplanes. At present the Dash 80 is fitted with higher thrust (18,000 pounds) Pratt & Whitney turbofan engines and new air conditioning inlets along the top of the nacelles similar to the larger 707-320B. These new engines give better fuel mileage.

Notable

Firsts



Noise suppressor containing 21 tubes.

The Dash 80 was the first airplane:

- To incorporate clamshell engine thrust reversers that folded into the engine exhaust after touchdown to assist braking.
- To incorporate engine noise suppression to reduce community and internal cabin noise.

It was the first commercial airliner:

- To use integral wing fuel tanks.
- To use structural honeycomb panels for flap skin panels to reduce weight. This application led to many innovative manufacturing techniques and processes. This knowledge was later used extensively in the space program.
- To use 75ST aluminum alloy, a new, stronger lightweight material.
- To use both high-speed and low-speed ailerons for superior control during all flight regimes.
- To use fail-safe structural design concepts to control fatigue crack propagation.
- To incorporate engines mounted on pylons below and forward of the wing to provide a clean air intake for the engine. This design also allowed severely damaged engines to separate from the wing without causing major structural damage to the wing itself.
- To use a jackscrew drive to position the complete horizontal stabilizer for improved stability and control during the cruise and landing flight regimes.

Dash 80 testing a model 727 body-mounted nacelle.

- To incorporate a removable vertical tail design for improved manufacturing and maintenance procedures.
- To use leading edge slats, which provide higher lift and improved takeoff.

Other uses of the Dash 80

From 1958 to 1970, the Dash 80 was used for flight testing a number of improvements and conducting research on the 707 and other airplanes. These included an Air Force airborne weather station, boundary layer control research, low-speed testing, high flotation landing gear, variable stability, direct lift control, auto-land system testing, NASA space shuttle support and testing the model 727 body-mounted nacelle.

Derivatives

and Other Dash 80 Offspring

The E-6 military jet (right), aside from its larger engines, looks remarkably like the Boeing 707 prototype, known as the Dash 80 (left).

The Dash 80 is the parent of the 707 series of airliners such as the 707-120, the 707-120B, the 707-320 and the 707-320B, the B denoting turbofan-powered aircraft. It also had a great influence on the physical appearance of the other aircraft shown in the accompanying chart. For example, the body cross section above the floor was the same for the 707, 727, 737 and 757 airplanes.

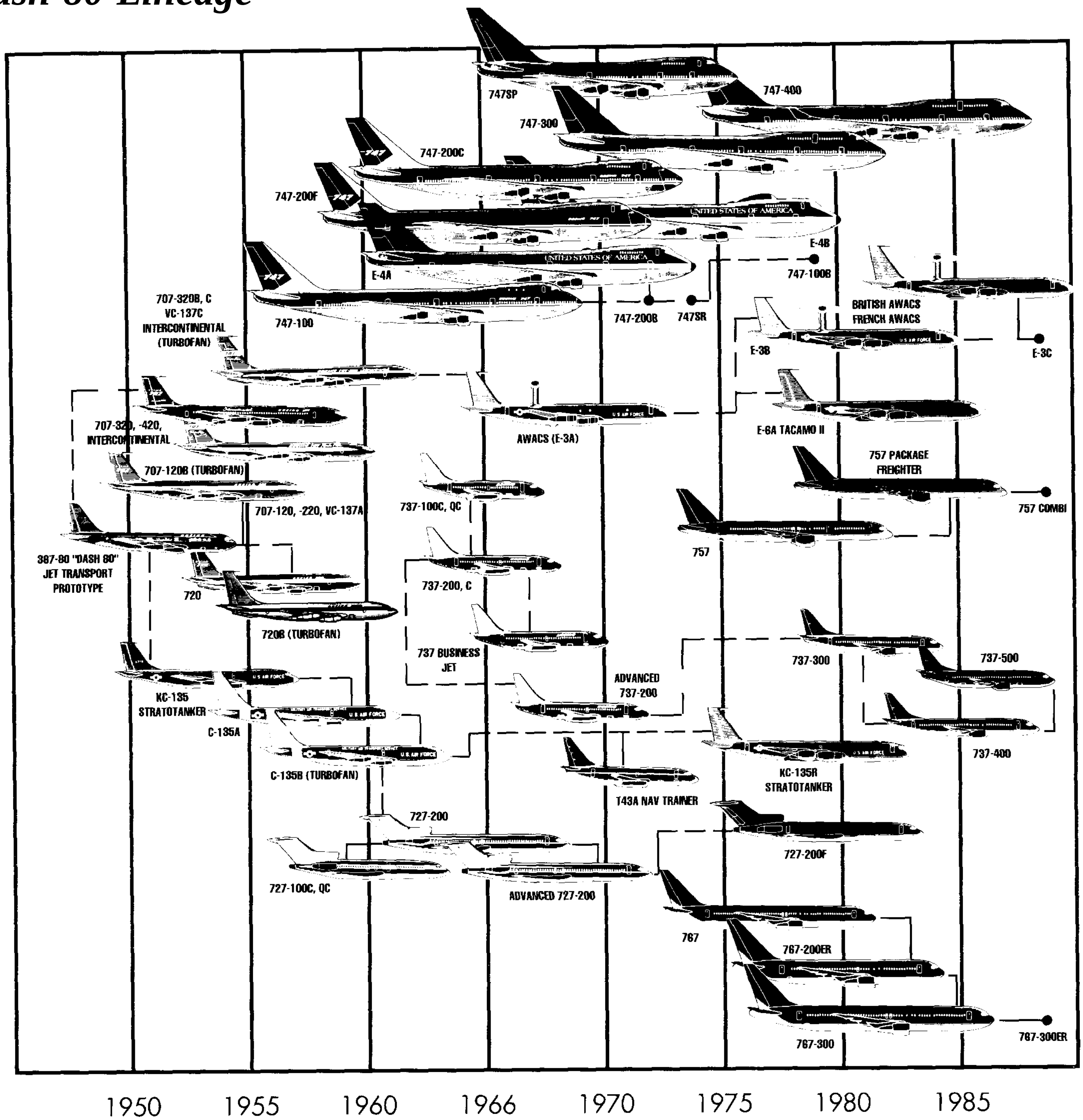
Military derivatives of the Dash 80 include:

- KC-135 tanker (approximately 700 airplanes)
- RC-135 geo-mapping airplane (10 airplanes)
- E-3A AWACS command and control airplane (68 airplanes)
- E-6 TACAMO communications airplane (17 airplanes)

After seeing the Dash 80 prototype in 1954, Air Force General Curtis LeMay, commander of the Strategic Air Command, convinced the government to purchase a tanker version of it rather than wait for the winner of a “paper” competition.

The KC-135 tanker can fly faster in formation with a bomber such as the B-52 while delivering more fuel than could the previous tanker, the KC-97 piston airplane. The hookup and fuel transfer is also much easier for the bomber pilot.

Dash 80 Lineage



Biographical Sketches

E. C. Wells, G. S. Schairer, J. E. Steiner and M. L. Pennell (left to right) discussing an aeroelastic model with wind tunnel engineer E. Storwick.

William M. Allen

After serving as the company lawyer for many years, William M. Allen was chosen president of Boeing on September 1, 1945. All government contracts were canceled September 2, 1945, so Allen decided to build 50 Stratocruisers in 1945 to keep the company going. He risked one-quarter of the company's net worth with the decision to go ahead with the Dash 80 in 1952. ASME honored him with the Guggenheim Award in 1973. Allen died in 1985 after retiring as board chairman.

Edward C. Wells

Edward C. Wells hired into the company from college in 1931. From 1934 to 1937, he did extensive mechanical design work on the B-17 bomber, including landing gear, armament and a sophisticated wing landing flap system. Wells was named chief engineer in 1943, and he was vice president, engineering, from 1948 to 1957, "the Dash 80 years." He was named senior vice president, technical, and director in 1972. Wells died in 1986.

Maynard L. Pennell

Maynard L. Pennell joined Boeing engineering in 1940 after working on the Douglas DC-3. He was named chief of preliminary design in 1948. Pennell initiated studies of jet transports leading to the Dash 80 and was promoted to Dash 80 chief project engineer in 1953. He was named Boeing vice president in 1964 and retired in September 1974. Pennell lives in the Seattle area with his wife.

George S. Schairer

George S. Schairer was brought to Boeing from Convair as chief aerodynamicist in 1939 by the great test pilot Eddie Allen. He was very influential in the configuration of the Dash 80. Schairer was named chief of Boeing technical staff in 1951 and was promoted to vice president, research and development, in 1959. He received the ASME Spirit of St. Louis medal in 1967. Schairer currently lives in the Seattle area with his wife.

A. M. "Tex" Johnston

In 1942 Tex Johnston was a Bell Aircraft Company test pilot. After joining Boeing, he flight-tested the B-47 bomber in 1949. Johnston was named chief of flight test in 1952 and flew the Dash 80 first flight as test pilot in 1954. He was president, Aerospace lines, in 1967. Johnston lives in western Washington with his wife.

Joseph F. Sutter

Joseph F. Sutter joined Boeing as an aerodynamicist in 1945. He was aerodynamics unit chief on the Dash 80. He was named chief of technology, model 727, in 1961 and became chief of technology, Boeing Commercial Airplane Division, in 1963. Sutter was promoted to chief engineer, model 747, in 1965 and named head of the Commercial Airplane Division in 1971. He has been a Boeing consultant since retiring. Sutter lives in the Seattle area with his wife.

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History and Heritage Program of ASME

The ASME History and Heritage Program began in September 1971. To implement and achieve its goals, ASME formed a History and Heritage Committee, composed of mechanical engineers, historians of technology and the curator of mechanical and civil engineering at the Smithsonian Institution. The committee provides a public service by examining, noting, recording and acknowledging achievements of particular significance as mechanical engineering landmarks.

Each landmark reflects its influence on society, either in its immediate locale, nationwide or throughout the world. A landmark represents a progressive step in the evolution of mechanical engineering. Site designations note an event or development of clear historical importance to mechanical engineers. Collections mark the contributions of a number of objects with special significance to the historical development of mechanical engineering.

The ASME History and Heritage Program illuminates our technological heritage and serves to encourage the preservation of the physical remains of historically important works. It provides an annotated roster for engineers, students, educators, historians and travelers, and helps establish persistent reminders of where we have been and where we are going along the divergent paths of discovery. For further information, please contact the Public Information Department, The American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017 (212-704-7740).

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International Historic
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1954

The 367-80 is the prototype for most jet transports; its success is due largely to its mechanical systems, including turbine engines with thrust reversers and noise suppressors, redundant hydraulic control systems, and an improved cabin-pressurized system. Honeycomb flap panels were introduced, along with a strong, lightweight structural design that controlled fatigue cracking. These led to several innovations in aircraft tooling and manufacturing techniques. The 367-80 flew in research and development service with Boeing until 1970.

The American Society of Mechanical Engineers – 1994

Text of the plaque installed on the 367-80.