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THE 747 TURNS 50

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SPECIAL TOPIC

THE LEGENDS BEHIND THE 747

The term 'design classic' is frequently mis-applied but in the case of the Boeing 747 it is hard to argue with the enduring success of an aircraft that is still in production half a century after its first flight, and 51 years since the first was assembled. The aircraft's majestic size and humped upper deck easily fulfill the definition of a design classic as an industrially manufactured object with timeless aesthetic value, but it is the 747's legacy as the world's first widebody jet that truly underlines its place in aviation history as a standard of its kind. The progressive evolution of the 747 over an incredible five decades, and its continued production as the 747-8F freighter also satisfy the 'classic' criteria for a concept that remains up to date regardless of the year of its design.

Packed with design innovations and new safety features, the 747 was a step change in capacity that brought affordable air travel to the masses. By democratizing access to long distance travel the 747, and the fleets of widebodied airliners that followed in its wake, the aircraft helped transform modern society and ushered in an era of globe-shrinking interchange on an unprecedented scale. With almost 1,550 delivered by early 2019 the fleet has flown more than 57 billion nautical miles and carried 5.9 billion people – or around 78% of the world's population.

By delving back through almost 55 years of Aviation Week archives this ebook tells some of the story behind the birth of the design and the forces that helped craft one of the most familiar shapes to grace the skies. With e also bring the story up-to-date by reviewing Boeing's strategy of merging the 747-8 and 767 programs to help sustain production into the 2020s

Guy Norris
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Golden Girl

Guy Norris

Half a century after Boeing's 747 took to the skies to begin the widebody era, its most recent descendent, the 777-9, is being readied for flight tests and a certification program that will culminate with entry into service in 2020.

With seating for 425 passengers and a range of 7,600 nm, the 777-9 will expand capacity on long-haul services and operate intercontinental trunk routes that for years were the sole domain of the 747-400. As a direct heir apparent to the most popular variant of the 747—and the latest in a dynasty that has seen almost 5,100 Seattle-designed 747, 767, 777 and 787s delivered since 1970—the debut of the 777X effectively completes a circle that began 50 years ago this month with the first flight of the company's iconic jetliner.

But in 1969, none of this widebody success was guaranteed, and everything was riding on the 747 gamble. Among those watching the aircraft's first flight at Snohomish County's Paine Field on Feb. 9, 1969, it was William Allen, the company's hard-pressed chairman, who likely exhaled the biggest sigh of relief as the white and red prototype emerged from the gloomy Washington overcast skies to land safely after its 1 hr. 16 min. maiden sortie.

Allen had already famously "bet the company" on the go-ahead of the 367-80 "Dash 80" jet tanker-transport prototype that pioneered the 707 in 1952, and he knew that once again Boeing was, quite literally, banking on the 747. Even though a hard test campaign lay ahead, the successful first flight marked the passing of a huge milestone on the road to service entry and much-needed revenue. By this stage, almost three years after Boeing took the internal

The era of the widebody airliner began at 11.34 a.m. on Feb. 9, 1969, when the first 747, RA001, took off from Snohomish County Paine Field's Runway 16R.

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decision to launch the 747, the pressure on the program was palpable.

"The company was also busy with the 727-200, which was brand-new, and Boeing was expanding fast," says company historian Michael Lombardi. "They were building the Everett, [Washington], site from scratch as well the Auburn parts plant and the Space Center in Kent. In terms of scale, the 747 was a huge leap. A lot of people did not believe you could do that, so all around there was a tremendous risk."

Delayed by unusually heavy snowfalls in January 1969 and a longer-than-expected series of preflight ground checks of aircraft systems and engines, the first flight was more than seven weeks behind Boeing's original schedule. Certification was targeted for November 1969, which was when the first two aircraft were due for delivery to launch customer Pan American. The holdups compounded the crippling debt linked to the program, which threatened to engulf not just the 747 but the entire company.

Crew for the first flight was flight engineer Jess Wallick, left; project pilot Jack Waddell, center; and copilot Brien Wygle. Waddell, who would later become Boeing's chief test pilot, was a former U.S. Navy aviator who, together with Wygle, helped with the 747 flight deck design. Wygle, who was lead project pilot for the B-52, also commanded the first flight of the 737 in April 1967 with Lew Wallick, brother of Jess, as co-pilot.

There was worse was to come. Forced to borrow from a banking syndicate to finance development of the giant new airliner and the sprawling Everett facility, the mammoth project would face further slips and development issues. It eventually racked up debts of around $2 billion, roughly $20 billion in today's dollars.

Fifteen months earlier, in a November 1967 report titled "747 Risk Tops Billion Dollars" (AW&ST Nov. 20, 1967, p. 58), Aviation Week disclosed that Boeing's total exposure for the program was expected to be on the order of at least $1.6 billion. However, it added: "The carrot for taking this risk is $4 billion in sales for a near-term 200-aircraft program, with as much as $1.7 billion in foreign exchange from overseas sales. Boeing planning actually is based on an ultimate 488-airplane program."

Fifty years on, with large twin-aisle aircraft commonplace, it is difficult to imagine the step change the 747 represented. More than twice the size of any airliner at the time, it was the world's first widebody passenger aircraft. Powered by Pratt & Whitney JT9Ds, the first commercial high-bypass turbofans, the behemoth was provisionally sized to seat more than 400 and heralded a new era of affordable mass transport that would transform global society.

Yet, as Aviation Week's 1967 market forecast story hinted, the 747 was largely seen as a high-capacity, long-range stopgap transport that could be readily adapted to carry cargo when the much-anticipated supersonic generation arrived. Born in the mid-1960s at the time of the Apollo space program and an unprecedented period of technological advancement, it was a vast engineering challenge because of its scale and short development timescale rather than its speed.

But in the can-do atmosphere of the times, the true holy grail for many at Boeing was not the world's biggest airliner, but the company's 2707 supersonic transport (SST) project running in parallel, which offered airlines globe-shrinking possibilities with its 250-seat cabin and Mach 2.7 cruise speed.

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The late Joe Sutter, the program's first chief engineer, affectionately known as "the father of the 747," recalled to Aviation Week: "Many of the airlines, and the people here at Boeing, thought the 747 was an airplane with a limited future because the SST was going to take all the business. I even had difficulty getting people to work on the 747. People would come up to me and say, 'Keep working on the 747 and when you get done there might be a place for you on the SST.'"

Indeed, when Aviation Week reported in the summer of 1966 on Boeing's official launch of the 747, it noted that the company's market analysts foresaw that "as the supersonic transports begin to make their appearance in the mid-1970s, they predict that the passenger appeal of the faster aircraft will cause the conversion of the majority of the 747s to a combined passenger-cargo configuration and, eventually, to all cargo." (AW&ST, Aug. 1, 1966, p. 28.)

With supersonic airliner developments already launched in Europe and the Soviet Union, Boeing was so confident in the market forecasts for faster-than-sound aircraft that it increased the size of its initial SST proposal to the 600,000-lb.-gross-weight class to compete favorably with the 747 seat-mile costs.

Ironically, the greatest legacy of the SST was in helping nudge Boeing's 747 design team toward a very wide fuselage cross-section with a single main deck. Although the genesis of the technology used in the 747 lay in the ashes of Boeing's failed bid to win the U.S. Air Force's CX-HLS future strategic airlifter competition in 1965, the breakthroughs that led to the aircraft's successful design formula were driven by purely commercial factors.

Boeing was beginning to look at airliners much larger than the 707 earlier in 1965, before the CX-HLS loss, after Pan Am founder and President Juan Trippe warned Allen the airline was evaluating Douglas' stretched DC-8 to meet rapidly growing demand. Sparked into action, Boeing's initial concepts placed a slightly enlarged 707 cross-section on top of another to form a basic double-decker. However, as an Aviation Week report noted in November 1967, airline response to this idea had been "unenthusiastic, and it was back to the drawing board." (AW&ST Nov. 20, 1967, p. 60.)

The next major evolution was to a midwing design with double-lobe fuselages permitting 7-8-abreast seating with double aisles on two levels. Although this was an initial step toward the first widebody and produced a cross-section uncannily close to that adopted 15 years later for the 767, the airlines rejected it because of concerns over survivability in case of ditching and inadequate space for cargo containers.

Boeing then homed in on a series of double-deck designs in which the lower deck allowed side-by-side loading of two 8 X 8-ft. containers. Various wing sweeps were considered, including a 40-deg. configuration, but were dropped in favor of 37.5 deg. as a compromise between the range-payload requirements of domestic and international routes. But overall, the short-coupled, bulky fuselage designs were flawed. "The group working for me decided that was the wrong way to go," recalled Sutter. "It's just a clumsy airplane."

In late 1965, the breakthrough came. "Right near the contract signing, we conceived this wide single deck," said Sutter. "Of all the decisions we made, the most important was selecting the single deck. It gave us an airplane that was efficient and extremely flexible and was one of the main reasons for its success." To enable the floor to be accessed for loading directly through the nose as a freighter, the flight deck was also raised up and out of the way to produce the 747's hallmark upper deck "hump."

The nose section was area-ruled by narrowing what had been initially a circular fuselage under the crew compartment for drag reduction. The general reprofiling also increased the size of the aft fairing so much that it created space for an upper deck lounge area. Other refinements included changing from strap-over engine mounting struts to a lower-drag cutback pylon.

Later refinements also included moving the engines farther outboard and redesigning the flaps with a scaled-up derivative of the triple-slotted configuration used on the 727. The engine move was made after Boeing abandoned plans for a blown-flap system using engine bleed air that had been proposed for the military airlifter. The idea was scrapped because of certification requirements for takeoff performance with one engine out, as well as noise issues with a system that relied on higher power settings during approach to landing.

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Underpinning the entire design was an aggressive focus on safety. "Joe Sutter made it part of the culture. Systems redundancy was fundamental to how we built the aircraft, and the long-term results of that approach are still felt today," says Lombardi. "We split control surfaces, inboard and outboard ailerons, split spoilers, split elevators and split rudders," Sutter recalled. "All these systems were powered by four hydraulic systems—an innovation at the time. We even gave it a four-legged main landing gear so that if something happened to part of the gear the pilot could still bring the aircraft home successfully."

The refined configuration also satisfied the unofficial "if it looks right, it is right" design rule, and proved it during the first flight which, other than revealing a minor issue with flap misalignment, went well. Project pilot Jack Waddell, who flew the prototype RA001 on the first flight with co-pilot Brien Wygle and flight engineer Jess Wallick, reported it as "ridiculously easy to fly; it's just a pilot's dream."

The flight, cut short from its planned 2.5 hr. because of the trailing-edge flap issue, ended with a smooth landing using a 25-deg. setting. Describing for the first time a 747 handling characteristic that thousands of pilots would eventually come to experience, Waddell said "coming in for a landing, it just sits there like a stable platform, and the pilot has to keep telling himself to let it alone." The touchdown was also benign, as the large wings and flaps created a zone of ground effect beneath the aircraft that naturally helped cushion the landing impact.

Not everything continued to go so well, and the aggressive flight-test campaign was challenged with everything from engine performance problems to flutter, a potentially destructive airframe vibration phenomenon. This latter danger was finally eliminated from the design by the time flutter tests were wrapped up in late August 1969, six months after Boeing's original plan.

The extra testing and engine problems took Boeing to the brink of bankruptcy. At its peak, 747 development was costing $5 million a day. By the start of 1970, just as Pan Am was beginning the first commercial services, the company was forced to make massive layoffs in a bid to survive. Soon to be impacted by a broader recession and the cancellation of the 2707 SST, Boeing had by mid-1971 cut an astonishing 95,000 workers from its peak of 148,000 in June 1968.

The 747 itself was certified on Dec. 31, 1969, just 3.5 years after program launch and a flight-test effort involving five aircraft, 1,449 flight hours and 1,013 flights. The aircraft would provide a platform for new derivatives and growth that Boeing continues to build on to this day. Every subsequent Boeing widebody generation has benefitted in some way from the 747.

"It was an opportunity that could be lost,"Sutter said, reflecting on some of the criticism of the program's pace. "If Boeing had waited a year longer to do the airplane, the 747 may never have happened. It was an opportunity that happens once in a lifetime to make that change of gauge. Juan Trippe and Bill Allen deserve a lot of credit for being visionaries."

Fifty years on, with its supersonic competitors resting in museums and production of the 747-8 freighter variants sustained into the 21st century by virtue of the high-capacity single deck, it is the 747 that gets the last laugh. As of early January 2019, 1,548 747s have been delivered, and the fleet has flown more than 57 billion nm. Although passenger numbers are slowing as the proportion of freighters in the active fleet increases, Boeing estimates that over its lifetime the 747 has flown more than 5.9 billion people—the equivalent of 78% of the world's population.

Sustained Survivor

Guy Norris

Boeing is introducing fresh improvements to the 747-8 as a slow but steady series of orders continues to sustain production of the freighter version through at least 2022.

Once threatened with termination after a 2014-15 drought in orders, the program is on firmer ground almost three years after Boeing implemented a series of production efficiencies aimed at sustaining the 747-8 until market conditions for the freighter variant improved.

Key to the survival strategy was linking the engineering and production resources of the 747 and 767 models, a move designed to support the 747's profitability at an extremely low assembly rate of six per year—while simultaneously bolstering the 767 through successive production rate increases.

The plan bought time for the international freight market to recover and for the orderbook backlog to build up, a milestone most tellingly passed in February 2018, when express freight company UPS exercised options for 14 additional 747-8Fs, adding to 14 ordered in 2016. In an added boost to the combined enterprise, UPS also ordered four 767-300Fs.

There are presently 24 firm 747-8Fs in the backlog, which at the present production rate, will keep the line busy through the third quarter of 2022. "We have no plans to change that rate," says Bruce Dickinson, vice president and general manager for both the 747 and 767. "As we have merged the 747/767 we have a nice blend of production rate and production people, and that rate seems to work. . . . [Combining the 747/767] really harvested other benefits we frankly had not even thought of."

Although 747-8s and 767s, including the KC-46A tanker version, continue to be put together on different lines in the 40-22 and 40-32 buildings, respectively, in Everett, Washington, both share final assembly positions in the 747's traditional 40-22 area. "The structure of these metallic aircraft is so similar, so for our skilled mechanics the hard-core structures work, in particular, is really very similar," says Dickinson. "This allows us to share resources across the programs.

"When you are at just six per year, you are at a rate where, depending on where the aircraft is in the build cycle, you would not normally keep everyone fully occupied on each stage of what is a 40-day cycle," he says, indicating that the 747 now moves positions only every 40 manufacturing days. "If something is in a position for that period, you are not doing hard-core structures work all that time. That allows us to facilitate additional work on the 767 as it begins to go up in rate from 2.5-3 per month, which happens in mid-2019."

The increased rate is expected to stabilize at the higher pace in January 2020 and, although Boeing is not commenting, could potentially go beyond this to as high as four per month in 2021 if more freighter business from the currently booming e-commerce market is secured. The 767 originally moved to Building 40-32 as part of a major reorganization begun almost a decade ago to make room for the 787. Situated in a smaller footprint on the north side of the huge Everett facility, the current line was designed to handle a rate of two per month, meaning that the shared space with the 747 acts like a welcome relief valve for the twinjet line.

Like the 747, the 767 has been through ups and downs and was itself facing closure in the downturn following the 9/11 attacks, when the backlog dwindled to just 27 aircraft as the industry entered a three-year slump. Surprisingly, demand for midsize jets picked up as the industry recovery began in 2004, and additional orders came as the 787, the 767's replacement, began hitting delays. The program's future through the mid-to-late 2020s was finally cemented with the U.S. Air Force KC-46A tanker win in 2011.

"It was never thought we would be building anything but the tanker at this point, so the fact the 767 freighter dominates the tanker two to one on the line is cool for us, and there are other opportunities for us on the 767 side as well," Dickinson explains. As of January 2019, 1,133 767s had been delivered and the backlog stood at 111, of which 63 were 767-300Fs and 48 were 767-2C/KC-46As.

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The joint 747/767 operation also includes a combined systems-installation area in the 40-22 building, "where electrical people are working on both aircraft," says Dickinson. "It has been an intricate dance of industrial engineering in terms of crew cycling to make sure it is even more of an efficient operation. The benefit has been [in] particularly allowing us to go up in rate on the 767, which we probably could not have done had we not merged them. We modified what was historically only a 747 tool to accommodate 767s, so they are side-by-side now, getting wiring installed."

Significant investments in upgrading and improving the 747-8 also continue. "We just are finalizing a flight management computer (FMC) upgrade, FMC 4.0, which is more of a benefit for the flight management system," says Dickinson. The upgraded system, which is designed to reduce nuisance messages and improve operational efficiency, will be introduced into the fleet "in the next few months," he says. "We just got a little tripped up for final approvals by the government shutdown, but we have finished all of its testing. . . . This is the FMC upgrade that pilots and operators have been anxious to see."

The FMC has been through previous upgrade cycles, notably in late 2013when changes were made to improve navigational performance and step-climb efficiency, as well as reactivating the tail fuel tanks in the 747-8's passenger version, which extended range to about 7,700 mi. with 467 passengers.

"At this stage of the maturity of the aircraft, we are also working on reliability improvements," he says. "Not unlike any other program, we have seen things, and we are upgrading components that have not quite sustained the longevity they should have. We are clearly still investing in it to not only improve dispatch reliability but enhance the overall life-cycle operational costs."

The 747-8 was, for example, designed like the 787 for greater intervals between maintenance checks. Line maintenance intervals are 1,000 flight hours, versus 600 flight hours for the 747-400 A check. The hangar maintenance interval is 10,000 flight hours or 24 months, against the 747-400's C check interval of 7,500 flight hours or 18 months. The more expensive heavy maintenance interval check begins at eight years against the 747 systems D check at six years, and major structural check at eight years.

"We have had initial aircraft we delivered go through those D checks, and we are thrilled to see the maintenance costs we advertised for them have been as predicted," says Dickinson. "That is a significant improvement over the -400. But there are always individual components that are not quite up to what they should be for the life cycle." As an example, he notes, revised ball-screw actuators have been developed for the trailing-edge flap after the flap experienced more wear than anticipated.

In other areas, Boeing's 747-8 engineering team "has a ton of work going on" for the new Air Force One U.S. presidential aircraft, he says. The candidate 747-8s, originally built for defunct carrier Transaero, will be converted into replacements for the current 747-200-based VC-25A aircraft, under a $3.9 billion Pentagon contract awarded in July 2018. The modified aircraft are due to be delivered by December 2024.

As ever, despite the intermittent sales pace of the 747-8F and the current international trade uncertainties, Boeing remains hopeful for the longer-term production potential of the freighter. The company's latest global cargo forecast projects that over the next 20 years some 980 new production freighters will be delivered, of which over 50% will be in the large-freighter category currently dominated by the 747-8 and 777F. "The 747-8F's capability is clearly unmatched," says Dickinson.

Sharing space on the final assembly line with a 767 (pictured) in the background receiving its electrical wiring, the 11th 747-8F for UPS undergoes final body join while the airline's 10th freighter (right) nears completion in the next position.

THE LEGENDS BEHIND THE 747

Evolution of a Widebody

By late 1964 Boeing was already weighing the potential benefits of applying new high bypass engine technology under development for the U.S. Air Force's heavy logistics system (CX-HLS), later the C-5, to a new, high capacity airliner. Boeing lost the CX-HLS contest to Lockheed in 1965 and turned its attention to the new 747 project.

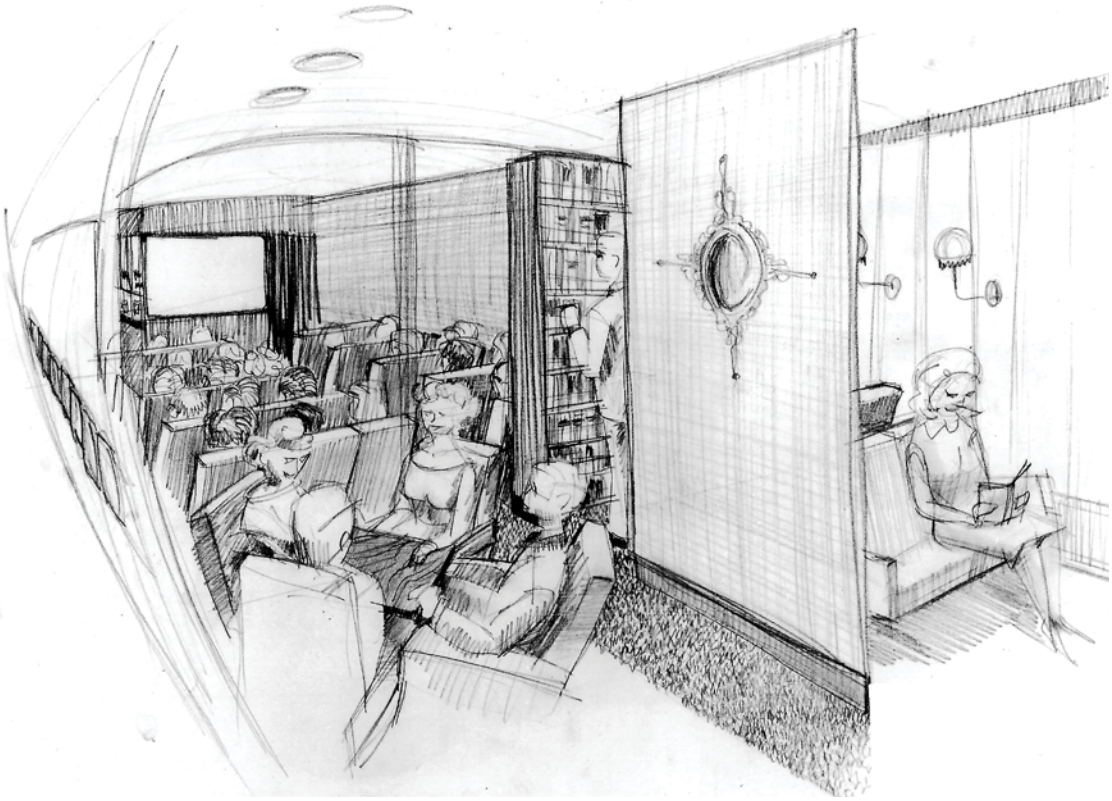
The final 747 cross-section configuration with the 20-ft. wide wide main deck, lower hold and upper deck is clearly revealed in this April 1969 view of an early production aircraft Section 42 prior to mating with the cab Section 41 at one end and the overwing body section at the other.

Early strands of the 747's DNA can be traced to the single deck mock-up of the CX-HLS airlifter.

Boeing's initial 747 family concept, dubbed the 747-3, -4 and -5, was a double decker based on a scaled-down version of the finalized CX-HLS double-bubble fuselage configuration proposed to the Air Force. Passenger capacities varied from 311 to 433, with a highest maximum take-off gross weight of almost 600,000 lb. In the highest capacity variant, the upper deck had 263 seats while the lower deck, truncated by the mid-fuselage wingbox, seated around 170.

THE LEGENDS BEHIND THE 747

Creative Cabins



Once defined the enormous cabin area of the 747 sparked some imaginative and fanciful interior concepts. This 1966 vision from Boeing shows a movie theater showing "first run films" along with "a TV or conversation area and a library." Other ideas proposed included a bar, a stage and live entertainment.

Entered via the spiral stairway at the front of the cabin, United Airlines 747-100 upper deck lounges seated up to 16 in first class. Five regional themes were used in their 1970s décor.

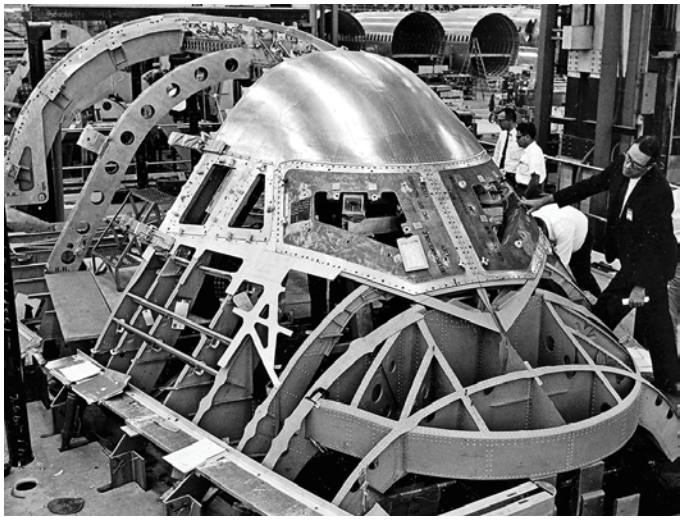
Creative Cabins (continued)

American Airlines eventually operated 19 747s, including two 747SPs, and installed Wurlitzer electric pianos in the coach class main deck seating zone 5 area on its early 747-100s. The pianos had truncated keyboards and were bolted to the deck.

TWA proudly installed wider screens for in-flight movies in coach class. "TWA is offering two films (mature and general) on every flight. The passenger has his choice," said the airline in 1970.

THE LEGENDS BEHIND THE 747

Building the First 747



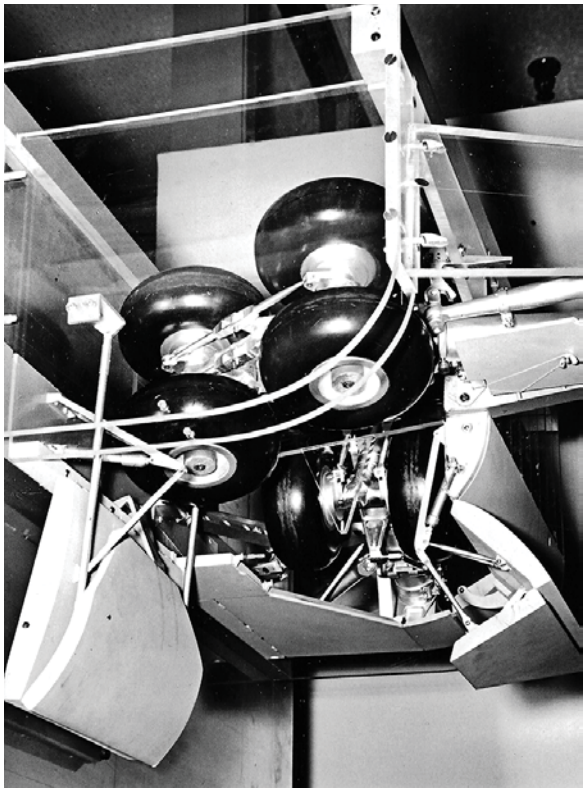
With 737 fuselage sections in the background, the first cockpit section for the 747 prototype, RA001, is seen under assembly in 1968 at what was then Boeing's Wichita Division.

Having earlier considered a blown-flap arrangement the finalized 747 featured a complex, articulating triple-slotted trailing edge flap system. When fully extended, together with the leading edge flaps, total wing area increased by 21% and lift by up to 90%. In flight tests stall speed at light weights of around 400,000 lb. and flaps at 30 deg. was only 92 kt. Even at the early aircraft's maximum landing weight of 564,000 lb. stall speed with the same flap setting was a stately 110 kt.

The 747 was the first commercial airliner to be designed from the start with an inertial navigation system (INS) as part of the baseline avionics. Recently developed for the Apollo space program as well as strategic missile guidance by the Charles Stark Draper Laboratory at MIT, the units were built by the Milwaukee-based AC Electronics Division of General Motors. Known as the Carousel IV (C-IV) navigator, the main components of the 747 system included a digital computer and power supply, and an inner turret, containing two vertical gyros and two accelerometers, which rotated continuously to offset gyro drift rates. Three C-IVs were on each aircraft and, because of their accuracy, meant that specialist navigators were no longer required for long range overseas flights.

Building the First 747 (continued)

Another key component of the C-IV was the control and display unit which could indicate a digital read out of the aircraft's precise latitude and longitude and the distance and direction to the destination. The novel layout, now so familiar, included a keyboard with push-buttons that enabled pilots to program in up to eight navigational waypoints enroute.

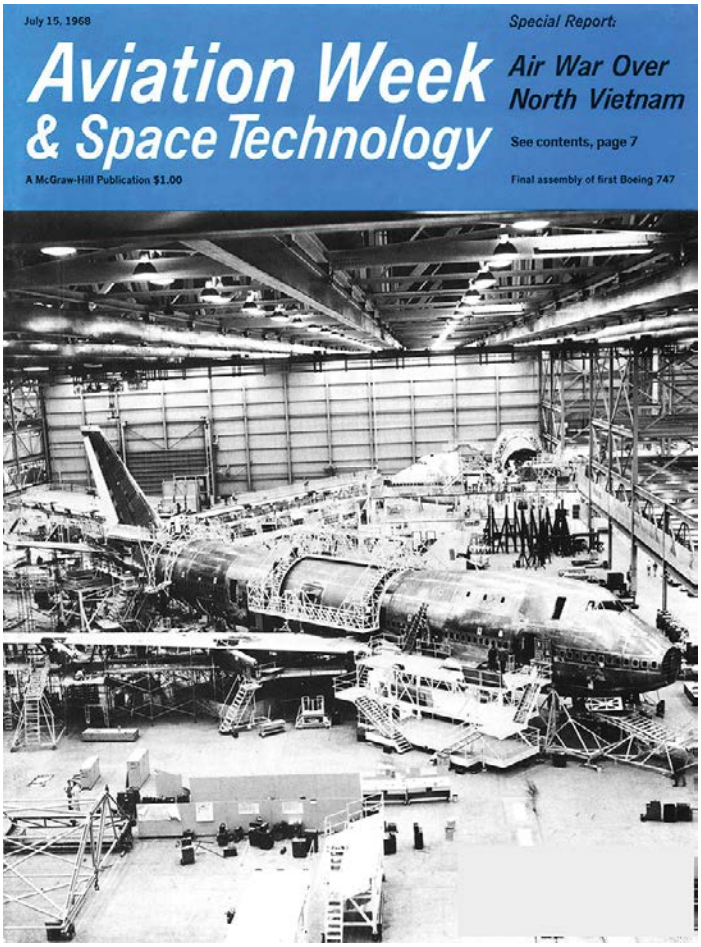


Designed to handle the 747's weight and provide extra redundancy, the packaging of the aircraft's complex main landing gear was one of configuration's most ingenious aspects. Illustrated here in mock-up form, the wing-mounted gear bogie retracted inward while the body gear bogie retracted directly into the fuselage. A massive body bulkhead divided the bays and formed the main landing gear beam carry-through structure. A large keel member, which connected the forward and aft fuselage sections, formed the inboard walls of the unpressurized undercarriage bays.

The full fuselage of RA001 begins to come together for the first time as the combined wings and center fuselage Section 44 is maneuvered on air bearings into position for mating with the newly joined forward Sections 41/42. Although the parts fitted together smoothly the process did not go without incident. At one point a jack failed and punched a hole in the left lower wing skin but no stringers or other structure was damaged and the area was quickly repaired.

Building the First 747 (continued)

Towering 63-ft. 5-in. above the Everett assembly line floor, the 747 vertical tail fin supported a two-piece rudder for multiple redundancy. The lower half, yet to be fitted in this image and measuring 9-ft 3 in. in height, was moved with dual hydraulic actuators, while the upper half was moved with three actuators. Maximum rudder travel was 24 deg. either side.



The complete 747 airframe is shown for the first time on the cover of Aviation Week's July 15, 1968 edition. Major assembly was completed in just six days, although key elements such as the trailing edge flaps and Pratt & Whitney JT9D engines still remained to be fitted.

THE LEGENDS BEHIND THE 747

Taking Flight

With pressure mounting to get the giant airliner into the air, the crew cleared the 747 ready for flight in early February 1969 after achieving 165 mph and, at one point, a 9-deg. nose high attitude during fast taxi tests. "A few more knots and we'd have been airborne prematurely," recalled Waddell at the time.

The era of the widebody airliner began at 11.34 am on Feb. 9, 1969, when the first 747, RA001, took off from Snohomish County Paine Field's runway 16R. With the four JT9D's each generating around 39,000 lb. thrust the huge aircraft weighing around 467,500 lb. became airborne after a ground roll of around 4,300 ft.

Flanked by Boeing's Canadair-built Sabre chase aircraft, the 747 broke out of the overcast into brighter weather over Puget Sound on the first test flight which achieved a top speed of 280 miles per hour and a maximum altitude of 15,000 ft. Originally set to last over 2 hr. the flight was cut short when a flap misalignment, experienced as a 'bump' on the flight deck, forced a precautionary early return.

THE LEGENDS BEHIND THE 747

Wow! Isn't it Big!

To underline the impressive scale of the 747, the first few aircraft were frequently posed alongside other aircraft or everyday objects to emphasize the vast leap in sheer size. Here Pan American's first 747 is seen with the airline's first Ford Trimotor, an aircraft flown in 1929 by Harold Gray who – by the time of the 747 – had become the airline's chairman of the board.

Pan American also saw an opportunity to brag about the 747's size by comparing it to automobiles. Even by the standards of the large U.S. gas guzzlers of the 1960s and 70s, the 747 would come out on top. According to Pan Am's publicity at the time "four passengers in each of these Ford autos would little more than fill half the 747."

Simply maintaining and servicing the 747 required development of a wide range of ground service equipment capable of extending to the tip of the 63-ft. 5-in. tall tail fin.

Wow! Isn't it Big! (continued)

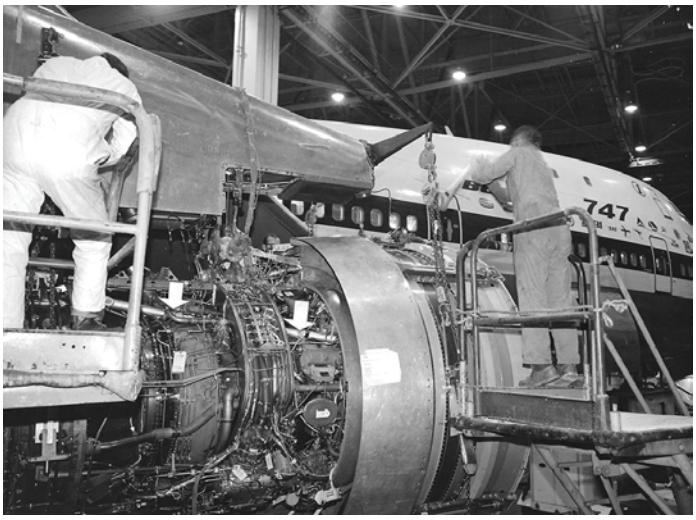
Taken at Everett in 1969, this classic early Pan American publicity image of the airline's first 747 was staged to illustrate the coming change in scale compared to one of the carrier's 145-seat 707-321Bs. This 747, 'Jet Clipper America' was refurbished after taking part in the certification program and, despite being involved in a serious take-off accident at San Francisco in 1971, went on to serve the airline until it ceased operations in 1991. It later flew with a variety of operators before ending its days as a converted restaurant in South Korea where it was scrapped in 2010.

Other airlines were quick to follow Pan American's lead in showing off their new 'Jumbo Jets". Before beginning services with its first 747 in April 1971, Air Canada invited the public to visit the aircraft in Montreal. Over two days more than 60,000 filed through the aircraft which was positioned next to one of the carrier's 48-seat Vickers V700 Viscount turboprops for scale. Air Canada's initial 747 served with the airline until 1983 and was ultimately converted into a freighter, finally being scrapped in 1995. Air Canada operated several generations of 747s until retiring the last in 2004.

THE LEGENDS BEHIND THE 747

Powering Giants

Unlike today's commercial airliner programs in which engine development generally precedes that of the airframe by a significant margin, Pratt & Whitney's pioneering JT9D high bypass ratio engine was developed virtually in parallel with the 747 and thus inevitably suffered reliability problems before and after entry-into-service. The challenge was exacerbated by the 747's rapid weight growth which forced a faster-than-expected increase in thrust requirement. Beginning with a rating of 41,000 lb. the JT9D was pushed quickly to 43,500 lb. and then 45,000 lb., a trajectory that resulted in turbine temperature problems. During the flight test program some 55 engines were changed compared to just one on the JT8D-powered 737 test program.



To overcome problems with 'ovalization' – or bowing of the engine during take-off which resulted in compressor blades rubbing excessively against the casing, Pratt developed several remedies to stiffen the attachments holding the engine to the strut. One of these, indicated with white arrows, was a Y-shaped frame which transferred thrust loads to the intermediate casing of the compressor. Eventually all 747s were provided with retrofitted engines.

By mid-March 1970 completed 747s were emerging at the astonishing rate of one per three working days, the highest rate ever achieved in the program's history. The late Robert Rosati, a Pratt veteran who led the formation of International Aero Engines was JT9D deputy program manager during the crisis years and recalled "we couldn't supply upgraded engines fast enough, so Boeing was hanging concrete blocks off them. They were desperate days."

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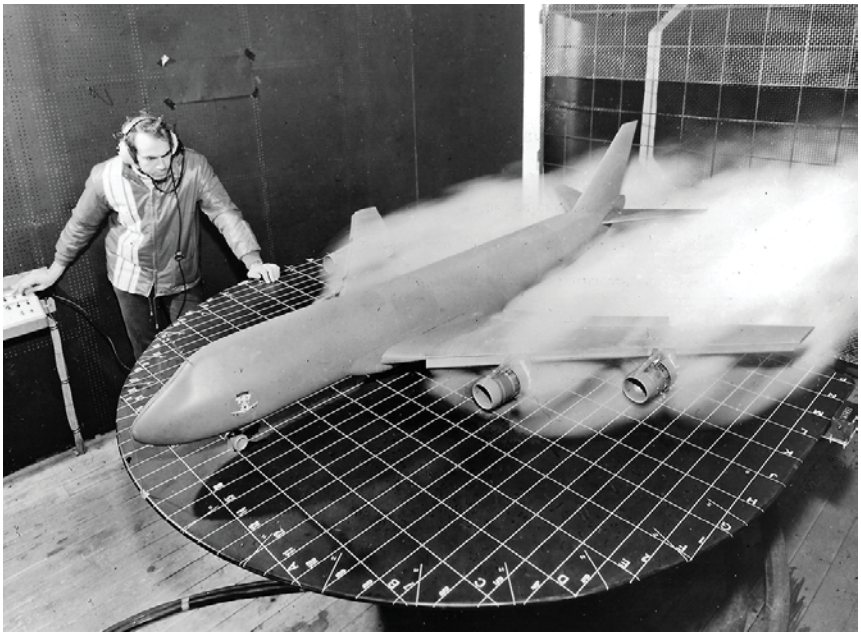
Powering Giants (continued)

The reliability and performance of the JT9D eventually improved and the engine became a focus of attention for its unprecedented size at the time. Here, representing a very different world and time, three Iran Air cabin attendants pose inside the No.2 inlet during an early 747 demonstration tour stop in Tehran, Iran. The airline eventually went on to operate over 20 747s of different versions, including the 747SP of which it was the last commercial operator.

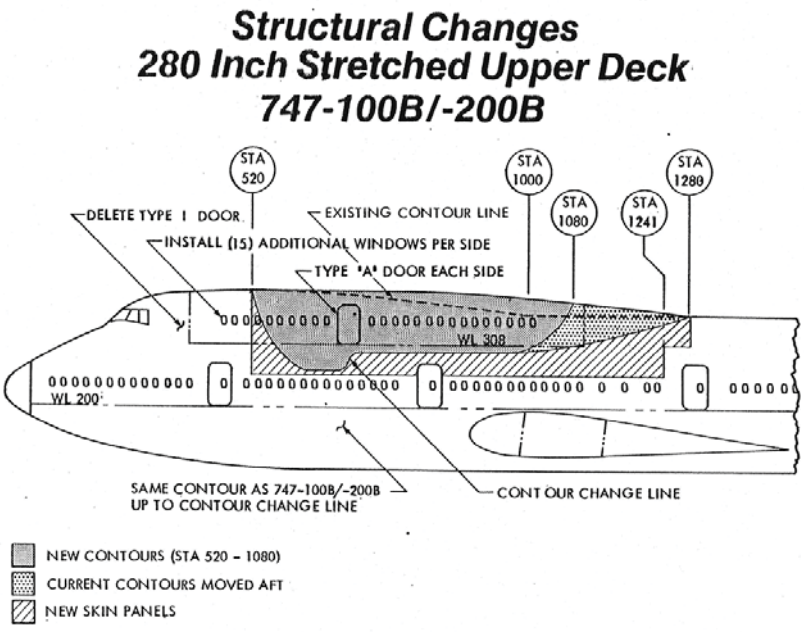
Pushed strongly by Thornton 'T' Wilson, who became Boeing CEO in 1969 and chairman in 1972, the risky decision of offering a second engine option on the 747 with General Electric's newly developed CF6 was announced in August 1972. The prototype was re-engined with CF6-50s and flown for the first time with the new engines on June 26, 1973. Derived from the TF39 engine developed for Lockheed's C-5, the CF6-50 was also in development for the Airbus A300B and McDonnell Douglas DC-10-30 and, with a higher thrust rating of 51,000 lb. thrust and more, offered greater range potential. The first production 747 with GE-engines, an E-4 airborne command post for the U.S. Air Force, was delivered in 1974 and the first commercial version, a 747-200B Combi with CF6-50Es, was handed over to KLM in October 1975.



Rolls-Royce became the third engine maker to power the 747 when line number 292 powered by RB.211-524s flew for the first time on Sept 3. 1976. Ordered the previous year by British Airways, the RB211-powered variant could fly 700 nm. further than the airlines' original JT9D-powered 747-136s and carry up to 15,000 lb. higher payload from hot and high airports like Nairobi, Kenya. During flight tests to measure noise in November 1976 the Rolls-powered test aircraft set a new world record for mass lifted to 2,000m when it took off from Lemoore Naval Air Station, Calif., at a weight of 840,500 lb. A wind tunnel model of the RB211-524 configured 747 is pictured undergoing thrust reverser flow analysis.

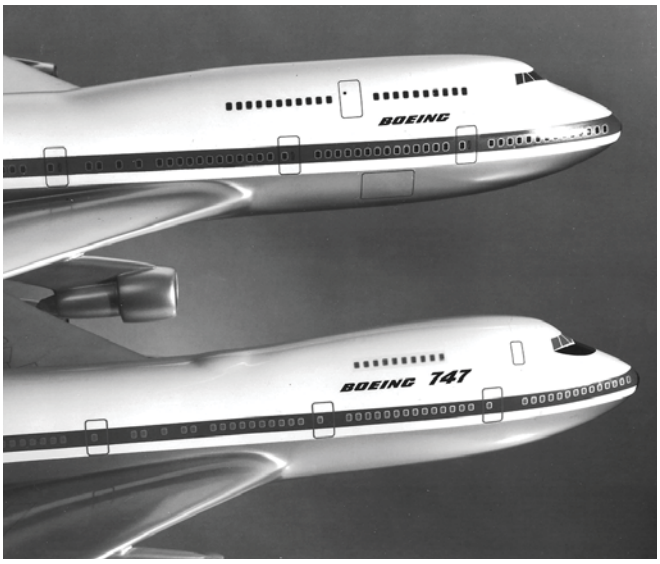
Growing the Family

Boeing originally planned an aggressive growth derivative strategy involving a 747B with a 219-ft. span wing and outer engines moved further outboard. However continuing engine issues caused a rethink and a more modest plan was adopted which focused on a higher gross weight version with a maximum take-off weight of 775,000 lb. and 400 nm greater range or 15,000 lb. more payload. Numerous structural changes included revised side of body ribs to beef up areas of stress discovered on the original static tests, thicker wing skins, gear beams and keel beams and new 30-ply tires which could run faster for hot and high take-offs. The variant, which first flew on Oct 11. 1970, also provided a platform for greater use of the upper deck. Although external dimensions remained the same the interior was extended to seat 16 for take-off and landing and fitted with 10 windows on each side in place of the original three. Re-named the -200B, the first was delivered to Qantas in July 1971. An interim -100B variant with stronger landing gear for operation at weights up to 750,000 lb. was also developed. Until the advent of the 747-400 in the late 1980s the baseline -200 configuration was the most popular 747 variant with 389 produced, some 225 of which were -200B passenger models.



In response to airline requests for greater capacity Boeing developed the 747SUD (stretched upper deck) which later became the 747-300. Capable of seating 91 in all-economy on the upper deck the development was a far cry from the luxurious exclusivity of the original lounge concepts of the original design. The upper deck included additional windows and two larger exits and was accessed by a straight stairway that led aft from the main deck. The stretch added around 10,000 lb. empty weight but unexpectedly had lower drag and higher speed, and could typically cruise at Mach 0.85.

Growing the Family (continued)



The difference in the stretched upper deck of the -300 against the baseline upper deck was clearly distinguished by the additional windows and upward opening upper exit. First deliveries to UTA of France and Swissair took place in 1983 and although overall sales amounted to a disappointing 81 including Combi freight and passenger models, the stretch upper deck provided must of the structural foundation for the best-selling -400.

To satisfy the growing demand for much longer-range capability Boeing developed the short bodied 747SP special performance derivative, the first of which is pictured being rolled out of the Everett facility alongside the prototype 747-100 in the summer of 1975. The design reduced capacity to around 281 in three-classes and cut overall length to 176 ft. 9 in., or about the same as the 767-300 which would follow a decade later, but enabled ranges of 5,700 nm and more at higher cruise altitudes of 49,000 ft.

Taking to the air for the first time on July 4, 1975, with test pilot Jack Waddell in command, the 747SP certification program was completed in less than seven months. Although issues were discovered such as an unexpected local shock around the wing-fuselage fillet which was cured with a reprofiled fairing, the aircraft's long-range cruise performance was 0.1% better than predicted and overall weight 1% lower than forecast. Launch customer Pan American took delivery of the first aircraft, Clipper Freedom, on March 5, 1976. However, the SP market niche was short lived and with the development of longer range 747-200s and competing trijets, the orderbook was closed after the sale of the 45th aircraft which was delivered to the United Arab Emirates in 1987.

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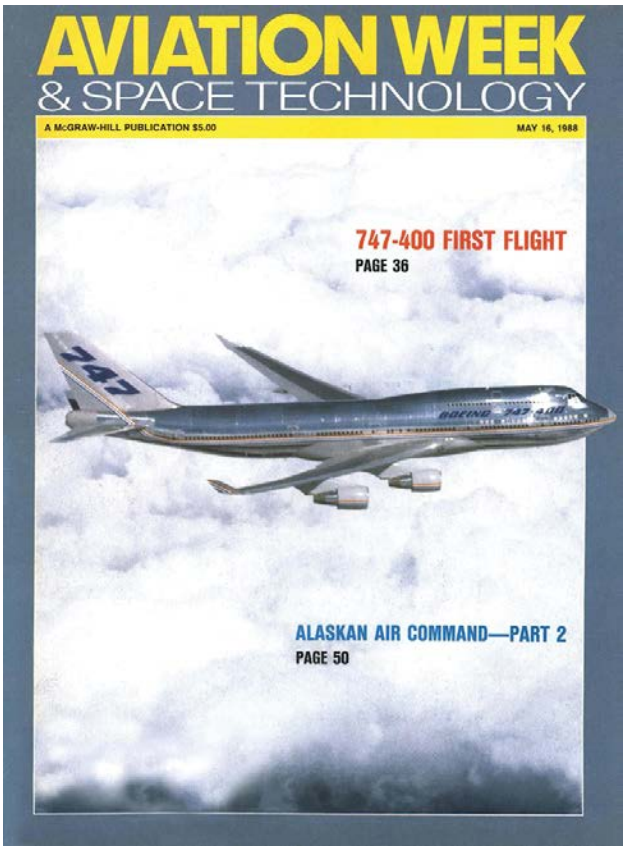
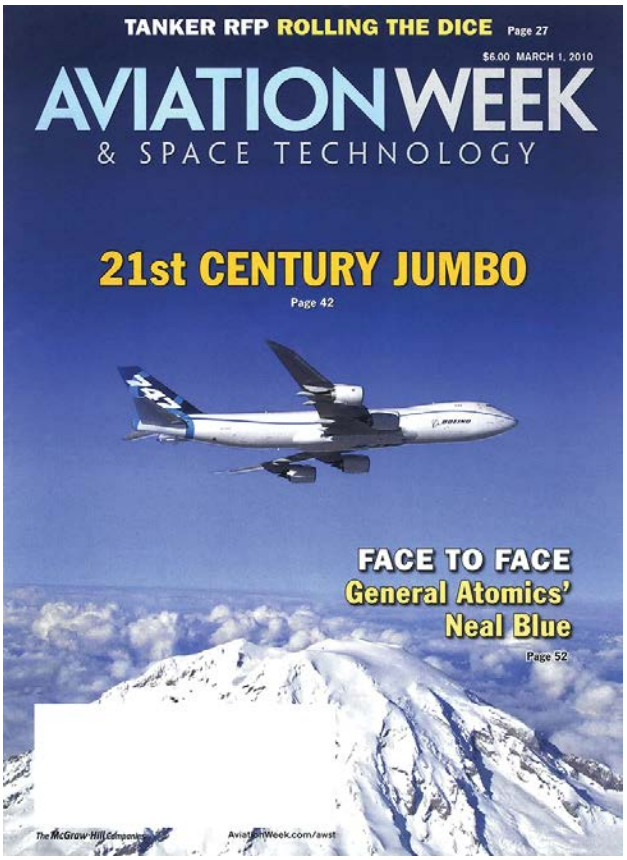
Growing the Family (continued)

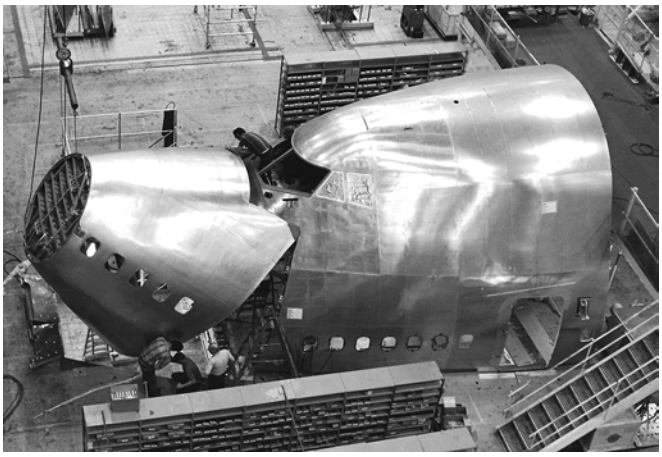


The 747-400 propelled the model into the 21st century with a radical redesign that included a new two-crew flight deck, new avionics, strengthened structure, updated engines and a bigger wing span with winglets. Development proved more difficult than expected, partially due to the over-ambitious plan to attempt flight test and certification of three different engine-airframe combinations in as many months. The timetable was also complicated by completion challenges with numerous different customer configurations, some of which were delayed by supplier delays, and by an upper-deck floor redesign to meet European safety regulations. Despite the issues the 747-400 proved to be the most popular variant ever developed with 694 of all versions delivered. Making its first flight in April 1988, the final -400 variant, a 400ERF freighter, was delivered to Kalitta Air in December 2009.

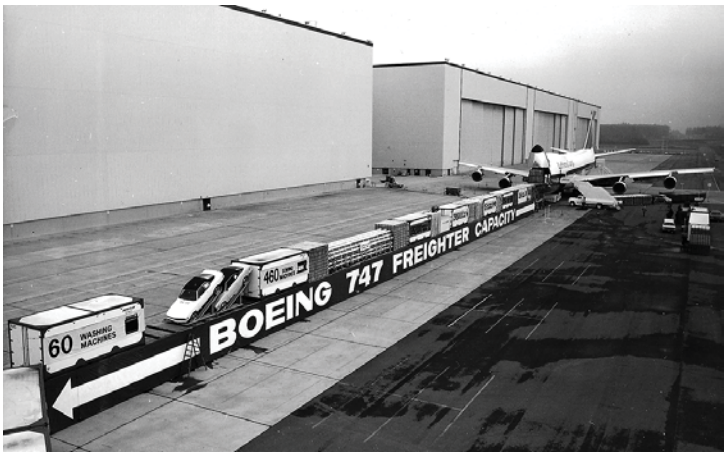


After decades of studying a potential stretch of the 747 and facing the threat of the newly-developed Airbus A380, Boeing launched the high capacity and long range 747-8 in 2005. The third generation 747 design leveraged new generation General Electric engines developed for the 787 and took advantage of improved aerodynamics for a new 224 ft. 7 in.-span wing. In common with past family members both passenger and freighter models were developed with both based on a fuselage stretch of 18.3 ft over the 747-400, bringing the total length to 250 ft 2 in. The 747-8F made it first flight in February 2010 followed by the initial 747-8 Intercontinental in March 2011. Although sales of the passenger version had resulted in a disappointing 47 deliveries through 2018, demand for the freighter version proved more robust with 84 in service by early 2019 and orders in the pipeline to maintain production through 2022.

Cargo King



Despite being designed from the outset with the ability to load cargo directly through the nose, the first freighter variant – a 747-200F – was not produced until 1971. The 747C convertible passenger-cargo variant, which followed into initial production in 1972, retained windows in the upward hinging nose section.



Ordered by Lufthansa, the first 747-200F was posed with a variety of payloads to illustrate the new model's enormous 17,000-cubic ft. cargo capacity. In this Lufthansa publicity shot the load includes three automobiles, 60 washing machines, 460 sewing machines, 1,392,000 spools of thread, 1,690 adding machines, 2,800 pairs of shoes. 35 computers, 290,000 bottles of perfume and 26,190 knitted sweaters.

With its polished aluminum gleaming under the Everett factory lights, the first Lufthansa 747-200F was rolled out in a delivery ceremony in March 1972. Soon in service on the North Atlantic, the -200F could carry three times the load of the airlines' 707 freighters and was occasionally loaded with up to 72 Volkswagen cars. Although cargo variants were slow to sell to start with, business for the line and the associated conversion market would soon accelerate. The last -200F, which was also the very last -200 made, was delivered to Nippon Cargo in 1991, marking the end of a 21-year production run. In all some 164 variants were produced including combis and 73 dedicated freighters.

Cargo King (continued)

BOEING DEBUTS FIRST CARGOLUX 747-8F

Boeing has rolled out the first 747-8F in the colors of launch airline Cargolux and, despite recent test delays, says delivery remains on track for the fourth quarter.

The second flight test aircraft, RC521, has resumed fuel burn tests following a delay caused by a ground collision with a parked tug. RC521 sustained damage to the No. 4 engine inlet and fan cowl while being towed at Victorville, Calif., on June 3. The incident follows a flap vibration issue thought to be a contributing factor to a potential delay to certification.

However, Boeing says, "We are making steady progress in flight test. We recently completed flutter testing and high-speed clearance. The trailing edge vibration, affecting the inboard flaps when set at 30 deg., has been resolved through aerodynamic tweaks, not major structural changes." Changes are mainly to the undercarriage doors, as well as the addition of flow modification devices to the flaps.

Following completion of the modification and further progress on flight tests, Boeing says it is "working toward TIA [expanded type inspection authorization]." RC501, the first test aircraft based at Moses Lake, Wash., is completing further flutter work. The third test aircraft, RC522, is at Palmdale, Calif., where it is being used to conduct interior and systems tests.

Six 747-8Fs have been produced with a further two in final assembly. Boeing is also 95% complete on the design of the 747-8I passenger model; assembly of the first wing spars and panel has begun. "Assembly of the fuselage (Section 41) will begin in a couple weeks," the company adds.

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First delivered to Cargolux in 2011, the 747-8F is the ultimate derivative of the family and still based on the basic single main deck concept of the original design. Distinguished by its shorter upper deck, the aircraft's 18-foot-3-5 in. fuselage stretch is just before and aft of the wing. Designed with a 975,000 lb. maximum take-off weight with a payload capability of 308,000 lb., the 747-8F has a range of 4,390 nm. The stretch provides space for four extra pallets on the main deck, with either two extra containers and two extra pallets, or three extra pallets on the lower deck.