Jumbo; A Tribute to the Boeing 747

By Clive Irving

Pan American Clipper Constitution *Boeing 747-121, N747PA, was the first production 747, second off the production line, delivered to a commercial airline. PanAm put this plane in service on January 1970. (Photo from the Boeing Company)*

If you were a hotshot airplane designer at Boeing in 1965 there was only one place you wanted to be. The aerodynamicists, the airframe guys, the systems guys, the payload guys, the engine guys…the project they most coveted was the sexiest thing the company had ever dreamed up: the first American SST, the Boeing 2707. This was the future of commercial aviation – a true world-shrinker, triple the speed of subsonic jets.

Boeing President and Bill Allen and Pan Am CEO Juan Trippe (right) celebrate the launch of the Boeing 747 "Jumbo Jet" in 1968. The longtime friends sealed the deal on selling the airplanes to Pan Am with a handshake while on a fishing trip. (Photo from the Boeing Company)

There was, however, another jet taking shape at Boeing at the same time. The document that set out the objectives for this airplane described "a high-capacity, long-range commercial transport…adaptable to passenger-cargo or all-cargo configurations."

The model number was 747. Compared with the SST this seemed so boring that the SST guys would commiserate with the 747 guys that if they proved their chops they might be lucky enough to be promoted to a realm that was faster than sound.

Guess who had the last laugh. The SST never materialized beyond a full-size wooden mockup. Its huge cost and thirst for fuel made it unviable and it was canceled in 1971. The mockup, which had cost $12 million, was sold to a fairground in Florida for $43,000.

The 747 grew out of a deal made between Bill Allen, the chairman of Boeing, and Juan Trippe, the imperious founder and boss of Pan Am. Not so much a deal, more a handshake made on a yacht during a weekend of relaxation.

Trippe believed that the future of commercial aviation would be supersonic. But he thought that some time would go by before that was a reality. In the meantime he needed a stopgap, an airplane more than double the size of the Boeing 707s that he flew and that could be operated at a significantly lower cost. He told Allen that when its time was done this airplane, the 747, could revert to being all-cargo, a Mack Truck of the air.

Now, nearly 50 years later, the last two U.S. airlines to operate the 747 have retired them and elsewhere it is slowly being phased out of service. During that time no other airplane has had quite the same influence on the world. It was the first jet to really democratize air travel. Crucially, it inaugurated a universal phenomenon, the enabling of many millions of people to travel and move around the globe with an ease and economy that was quite new in the human experience.

In the summer of 1965 there was no such arching vision in the mind of Joe Sutter when he was assigned by Allen to be the chief engineer on the 747 program. Sutter had missed being drafted to the SST team because he was fixing early problems on the 737, an airplane that he had partly fathered with a more

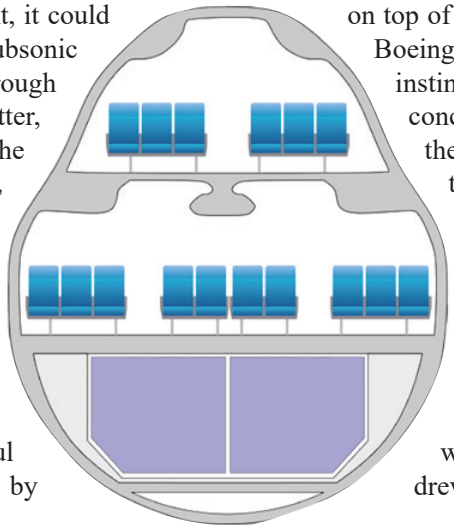
Joe Sutter and his team accomplished initial concept to first flight in roughly four and half years – A remarkable engineering achievement in itself. (Photo from the Boeing Company)

senior designer, Jack Steiner.

Sutter, an aerodynamicist, was left to choose what talent was left to create an airplane whose only innovation was its size. Otherwise, so the theory went, it could safely be capable of flying within the subsonic envelope already familiar to Boeing through their experience gained with the 707. Sutter, however, saw that size was going to be the real challenge – in the mastery of structure, payload, control and the engines -- the first high-bypass turbines that were at that point completely untested.

In any program of the size and complexity of the 747 there are always critical points where, if the wrong call is made, the whole project can unravel. In the case of the 747 there were three fateful moments when, as much by instinct as by science, the right calls were made, and all by different people.

The first was by a low-profile engineer named Rowland "Row" Brown, the head of the configuration group, who should by rights be credited as the true father of the world's first widebody airplane.



Engineer Rowland Brown is credited with the idea that created the 747's wide-body configuration. Starting with two standard cargo containers placed side-by-side, he drew a circle around them, setting the fuselage diameter. Twin aisles were necessary to assure adequate evacuation times. (AAHS archives)

Trippe had assumed that the most efficient way of seating 400 passengers was simply to stack one single-aisle cabin on top of another, creating a double-decker. The first Boeing drawings for the 747 did just that, but Sutter instinctively resisted the idea – one of his main concerns was the evacuation of passengers from the top deck in an emergency. Another was that the cargo hold was too small in relation to the airplane's size.

In one stroke Brown solved both issues for Sutter. After looking at scores of configurations he placed two standard cargo pallets side-by-side and drew a circle around them. This produced a cavernous cargo hold and a main deck nearly 20 feet wide. To handle the evacuation problem he drew two aisles. Like many flashes of genius Brown's wide-body cabin looked so obviously right once it was conceived.

The hump of the upper deck that became so much an expression of the 747's profile was created to anticipate its final role as an all-cargo airplane with

The upper flight deck stemmed from the anticipation that the 747 would eventually serve as a cargo carrier. (Photo from the Boeing Company)

a nose that opened for loading and a flight deck above. With successive models that upper deck has been extended to cover almost half the length of the lower deck.[1]

In 1990 I interviewed more than a score of the engineers who led the 747 program while researching the history of the airplane for a book. Brown was the only one of them who declined my request to talk. He was, Sutter explained, an innately private man. Sutter himself was no shrinking violet but he never tried to obscure the importance of Brown to the team he led.

The other two most consequential decisions came from interventions made from outside the team.

The first was by Trippe himself. Once he accepted that he wasn't going to get the double-decker he told Sutter that every airplane he had ever bought from Boeing had turned out to be too small in its first iteration. Even though by then the 747 drawings were close to being frozen he demanded that the fuselage be extended by 80 inches, which added three rows of seats in the cabin. Despite the fact that this added 7,500 pounds to the weight when weight had become critical, Sutter obliged.

The second was by the man most revered by all the Boeing engineers, the company's legendary Ed Wells who, as a young prodigy, had designed the B-17 and later conceived the idea, decisive in settling the form of the swept-wing jet, of hanging the engines on pylons beneath the wings. For reasons much like Trippe's, that he sensed the 747 could later be stretched, he told Sutter to increase the wing area from 5,200 square feet to 5,500 square feet. Lightening the wing loading not only allowed the stretch, it made the 747 a notably easy airplane to land without sacrificing its high cruise speed of Mach 0.855.

Nonetheless, the most serious structural problem to surface was in the wing. An old maxim at Boeing was "*the wing is*

Boeing was not only creating a brand new aircraft design, they also had to build a completely new facility in which to build it. The Everett, Wash., factory where the 747 is built is still the biggest building in the world by volume. (Photo from the Boeing Company)

where you're going to fail." This was, as Sutter told me, "a big limber airplane" and in the wind tunnel the wing turned out to be a bit too limber when, at high speed, the nose suddenly pitched upward.

Sutter called in W.T. Hamilton, Boeing's doyen of wing design. Hamilton confirmed Sutter's fear that the only cure was to redesign the wing with a decreasing angle of attack on the outboard section. A complete redesign at this stage would setback the program by as much as year. Hamilton came up with a much easier solution – to make a barely perceptible break in the leading edge at the outboard engine pylon and "twist" the

Passenger comfort and care are provided by the twin-aisle configuration seen here in Pan American's coach class cabin. (Photo from the Boeing Company)

First Class (and later Business Class) passengers were forward of the main cabin entrance on the lower deck as seen here in PanAm's seating configuration for early 747s. (Photo from the Boeing Company)

The upper deck was generally reserved for First Class passengers with some airlines actually using it as lounge area for the passengers. (Photo from the Boeing Company)

wing from there to the tip. It was not an elegant solution, but wind tunnel tests confirmed that it cured the problem.

Early flight testing encountered another serious wing defect: flutter. Chief test pilot Jack Waddell reported in his laconic way "low damping." The wing shook and would not settle. Again the fix was inelegant but simple: 700 pounds of spent uranium ballast added to the outer engine nacelles effectively "damped" the flutter.

But the most troublesome innovation throughout the 747's development and its early airline service was the Pratt & Whitney JT9 engine. GE pioneered the high-bypass turbine with its signature big fan, but Boeing had a long and happy history with Pratt and went with them, even though the JT9 had no military background behind it, as had all the jet engines previously chosen for new commercial jets. The first engines were plagued with many reliability issues and fell short of the promised 40,000 pound thrust. When time for the first flight came, on Sunday February 9, 1969, Boeing went through 30 engines before they found four that were deemed fit.

The troubles continued. As the first production models rolled out people joked that Boeing was assembling a fleet of the largest gliders in the world – so many were parked awaiting engines. Altogether, 87 engines were used in flight testing and 60 of them were destroyed. There were so many changes to the JT9 specifications that some test airplanes flew with several different versions. After a short time in flight the turbine casings were susceptible to ovalization, jeopardizing the clearances for the turbine blades. As a desperate temporary fix for the shortfall in power, the engines on the first batch of 747s delivered to Pan Am were equipped with water injection to boost thrust for takeoff.

In January 1970, the first Pan Am 747 flight, *Clipper Constitution*, departed from Kennedy Airport in New York for London with 324 passengers -- after a seven-hour delay and a switch from one airplane to another because of engine problems. (I made my first flight on a 747 operated by TWA in the summer of 1970, from London to Los Angeles. It was two hours late departing and we had an unplanned four-hour stopover in Seattle for engine maintenance.)

However, once those problems were resolved the 747 met Trippe's target of drastically reducing the number on which the whole project was based, the seat/mile cost. Pan Am told Boeing that their 747s were achieving a cost of 6.6 cents per mile – one third of the 707's cost.

It was a game-changing achievement that first foretold, for the airlines, the transformative economic impact of wide-body jets. And all this had been done with a deadline to meet that today seems extraordinary. The 747 program was given the green light on April 12, 1966, when Pan Am signed up for the first 25 airplanes. Sutter issued the detailed specification to the heads of manufacturing that September. In little more than four years a radically new airplane (with equally innovative engines) had gone from paper to regular airline service.

But, in truth, Boeing had bet the whole company on creating a market that had not previously existed. And in doing so they were brought to the brink of bankruptcy. At the peak of the program Sutter had been spending $5 million a day. By Christmas

1969 the company was so deeply in the red that $100 million had to be slashed from the operating costs. Over the next 18 months 60,000 jobs were cut. Seattle's unemployment rate jumped to 17 per cent, leading to a billboard that became legendary: "Will the last person to leave Seattle turn out the lights."

Yet Boeing came out of the crisis a leaner and smarter company. It had the jumbo jet market to itself until the arrival of the Airbus A380 in 2005. When the latest model, the 747-8, comes to the end of its run (it has sold slowly) Boeing will have produced more than 1,550 747s, way beyond what its creators imagined possible.

Sutter was only 44 when he took charge of the program. Many of his team were at least 10 years older. I first met him 20 years later when he had become, as Ed Wells had been, a revered company elder who was asked to cast his eye over all the later iterations of the 747 and any other program that needed his wisdom. He revealed to me that there had been a critical moment when his whole career hung in the balance. The corporate cost-cutters descended on him in the middle of the design process and demanded that he cut several hundred engineers from his staff. He refused and, defiant, said he needed 800 more. He went home and told his wife he expected to be fired the next day.

He was not. He got the additional engineers. From that moment nobody doubted that Sutter, a compact and implacable man, ran the show. In 2011, when I saw him again during a visit to see the 747-8 being produced, he said, "I had a lot of fun spending all that Boeing money."

One of the 747's characteristics that Sutter did not design into it and was surprised to discover when it first flew was its self-cushioning float to the tarmac in the final seconds of landing. Ground effect, with the downdraft compressed between the machine and the ground, was pronounced and benign. Even with a new wing, the 747-8 behaves the same way. "It still has that characteristic of landing itself" Sutter said, "I didn't know it was going to turn out that way."

The extended upper deck and winglets on the Boeing 747-400 are easy differentiators of this series from the original 747-100. Seen here are the two prototypes flying in formation. (Photo from the Boeing Company)

Designed before fly-by-wire took the tactile contact out of the cockpit, the 747 has always been a pilot's airplane. Tom Imrich, a Boeing pilot who has flown versions of the 747 from the very first one, test airplane RA001, through the 400 series and then as co-captain on the first flight of the 747-8, told me, "Every time I had the chance to take one airborne, or to test it to its limits, and often beyond, it was uniquely special. It will always stand alone for its grace, beauty, agility, strength speed and faithful response.

"It rode out the worst of turbulence exceedingly well, coped with hellacious winds, safely negotiated the worst of monsoons, edges of typhoons, blizzards, icing, fog and thunderstorms. Forced to fly against its will at very low airspeeds approaching a stall it would clearly talk back to you, with unmistakable feedback, warning you not to go any further. Forced to fly beyond its Mach limits it was steady as a rock."

Until the 400 series, launched in 1989, the 747 had a

The 747-100's cockpit layout with "clockwork" gages. Note the flight engineer's position at the right side of the photo behind the copilot's seat. (Photo from the Boeing Company)

The 747-400's glass cockpit. Note the flight engineer's position has been eliminated. Automation has reduced the workload allowing the plane to be safely operated with just two pilots. (Photo from the Boeing Company)

The current version of this design is represented by the 747-8F, which will mostly soldier on in freighter versions for the next 20, or so, years – quite likely allowing the design to celebrate a 75th anniversary! (Photo from the Boeing Company)

"clockwork" cockpit with more than 360 instruments and a third flight crewmember, the engineer who sat at a side console. The 400 introduced the glass cockpit, two pilots and far greater fuel efficiency. The 100 had a range of 5,300 miles. The 400 has a range of 7,670 miles and was by far the largest seller, with 694 delivered before production ended.

At the peak of its use there were around 350 747s in the air across the world at any given moment, carrying about 150,000 passengers. Even though American passenger carriers are not flying 747s any more, around 45 of the passenger version of the 747-8 will be flying well into the 2030s and British Airways is not retiring its 747-400s until 2024.

Ironically, the seeds of the 747's obsolescence were of its own making. Its economic efficiency fundamentally changed the way airlines scrutinized the numbers on a newly offered airplane. In the first decade of the Jet Age, from the introduction of the 707, the payload calculation was simple. The sheer leap in speed and the thrill of the ride were enough. Boeing, Douglas and Lockheed, the principal players, just put into the cabin as many seats as were comfortably possible. The early passengers, the Jet Set, were mostly well-heeled and prepared to pay premium prices for the privilege.

However, as flying opened up to millions the economic equation changed. It involved a more sophisticated combination of seats, range, cargo capacity and fuel efficiency. To an airline executive today the management of capacity is everything. It is now a refined art that uses a highly complex algorithm and includes price points spread from first class to coach. These numbers virtually design the airplane, single-aisle or wide-body, and demand optimal efficiency. As a result the new Boeing 777X, for example, can carry 414 passengers, as many as the 747-400, with only two engines and deliver a range as much as 7,600 miles and is 12 percent more fuel efficient than earlier 777s.

But the 777 has been refined to the point where it is so efficient that it is anodyne. It has none of the character of the 747, that great friendly bulbous nose sitting at the gate. When I wrote *Widebody, The Triumph of the 747,* I realized that I wasn't just writing about a machine, but the biography of the machine and its creators: the machine was, in fact, an extension of those men and their core beliefs about airplane design. The first page of Sutter's specification for the 747, which became known in Boeing as "the Bible", opened: "Safety is the prime design objective of the 747 design program; it shall be given first priority in all design decisions. The designer shall insure attainment of this safety objective."

To this day, when I board a 747 and think about all its details, visible and invisible, I also hear the voices of those whose work it was, performed under relentless pressure and with a vision of what commercial aviation then stood on the threshold of achieving. As Tom Imrich said to me, "It safely and reliably carried millions of people and tons of cargo to all corners of the earth, over all the oceans and both poles. It made the world smaller, affordably brought cultures together, and likely fostered the world's movement toward global peace and stability." ✈

Endnotes

1 Editor's note: Extending the upper deck back also provided a side benefit by smoothing transonic area rule profile reducing drag and extending the range. Introduced on the 747-300 series, it carried the added benefit of providing slightly increased passenger capacity.