PDHonline Course M554 (10 PDH)

Boeing 747-100: The Plane That Changed the World

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Boeing 747-100
747
BOEING
747
The Plane That Changed the World

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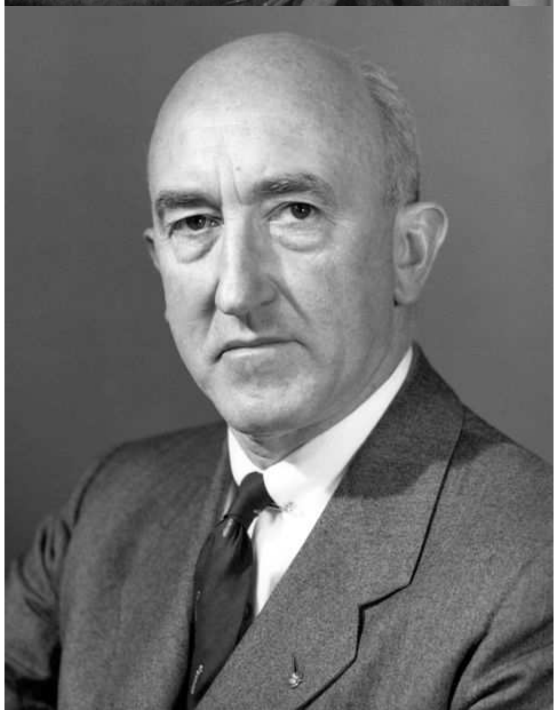
Part 1

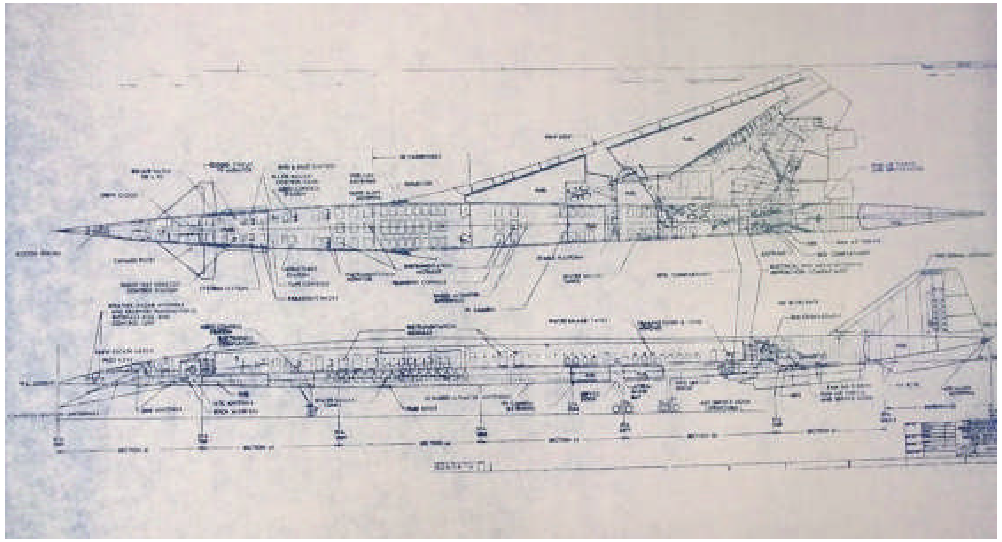
A New World of Flight

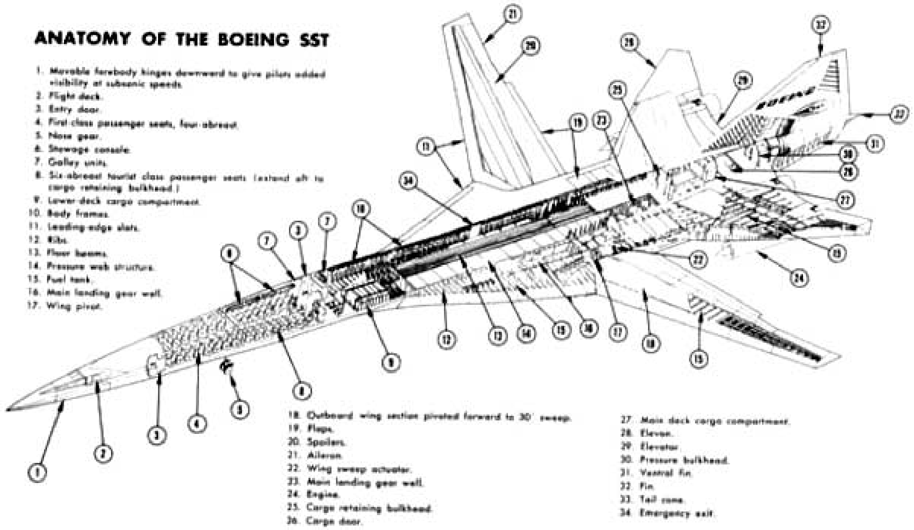
Next Generation

"'Would you build it if I bought it?' 'Would you buy it if I built it?'"

RE: conversation between *Juan Trippe* (top left) of *Pan American Airways* (PAA) and *Bill Allen* (bottom left), Chairman of the *Boeing Company,* while on a fishing trip to Alaska in the summer of 1965. By the end of their outing, there was a verbal commitment between the two aging executives to build an air-craft which was to be a "stop-gap airplane" - to fill the void between the first generation commercial jets; the *Boeing 707* (above left) and the *Douglas DC-8* (above right) and the yet-to-be-built Boeing *Supersonic Transport* (SST).



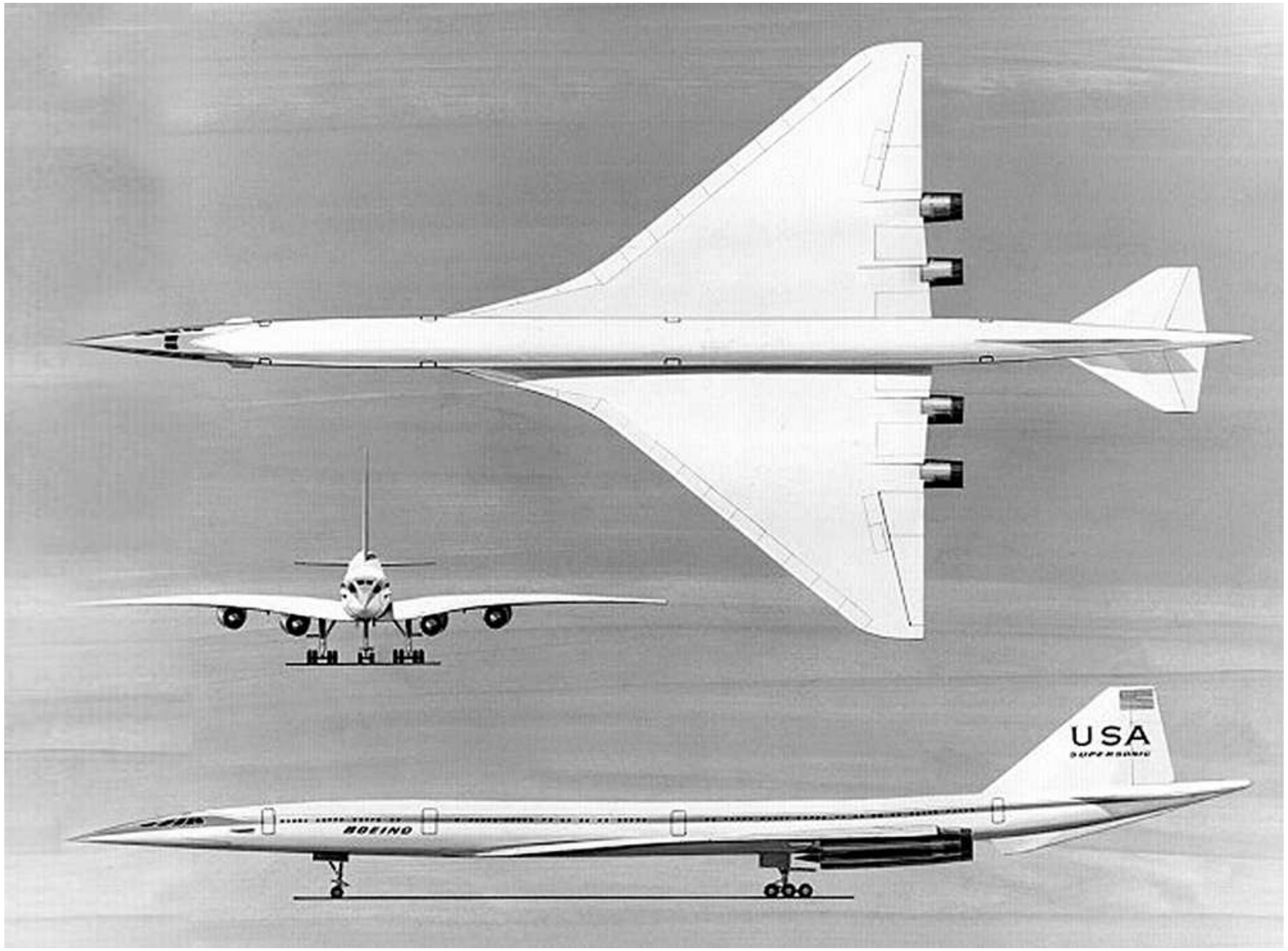




PAA enjoyed unprecedented growth during the 1960s, with passenger traffic increasing an average of about 15% annually. It was time to move forward. At the time, the British and French were planning the *Concorde* SST. In the U.S., there were also plans for an SST, but the costs were considerable. Thus, President Kennedy was put into a difficult position. Kennedy asked the head of the *Federal Aviation Administration* (FAA) *Najeeb Halaby* (he who would later become PAA's Chairman) to ask *Juan Trippe* not to buy the foreign Concorde for PAA. However, Trippe was aware that Kennedy was wavering and decided to force the President's hand. In May 1963, Trippe traveled to England and France and took an option on eight planes, becoming the first airline other than *Air France* and/or *BOAC* to order a super-sonic airliner. This did not go over well with the President. Shortly thereafter, President Kennedy gave the signal for a commercial supersonic program to proceed and Trippe signed up for fifteen Boeing SST's.

<u>Left</u>: caption: "Boeing 2707-200 SST Prototype Aircraft Blueprint"

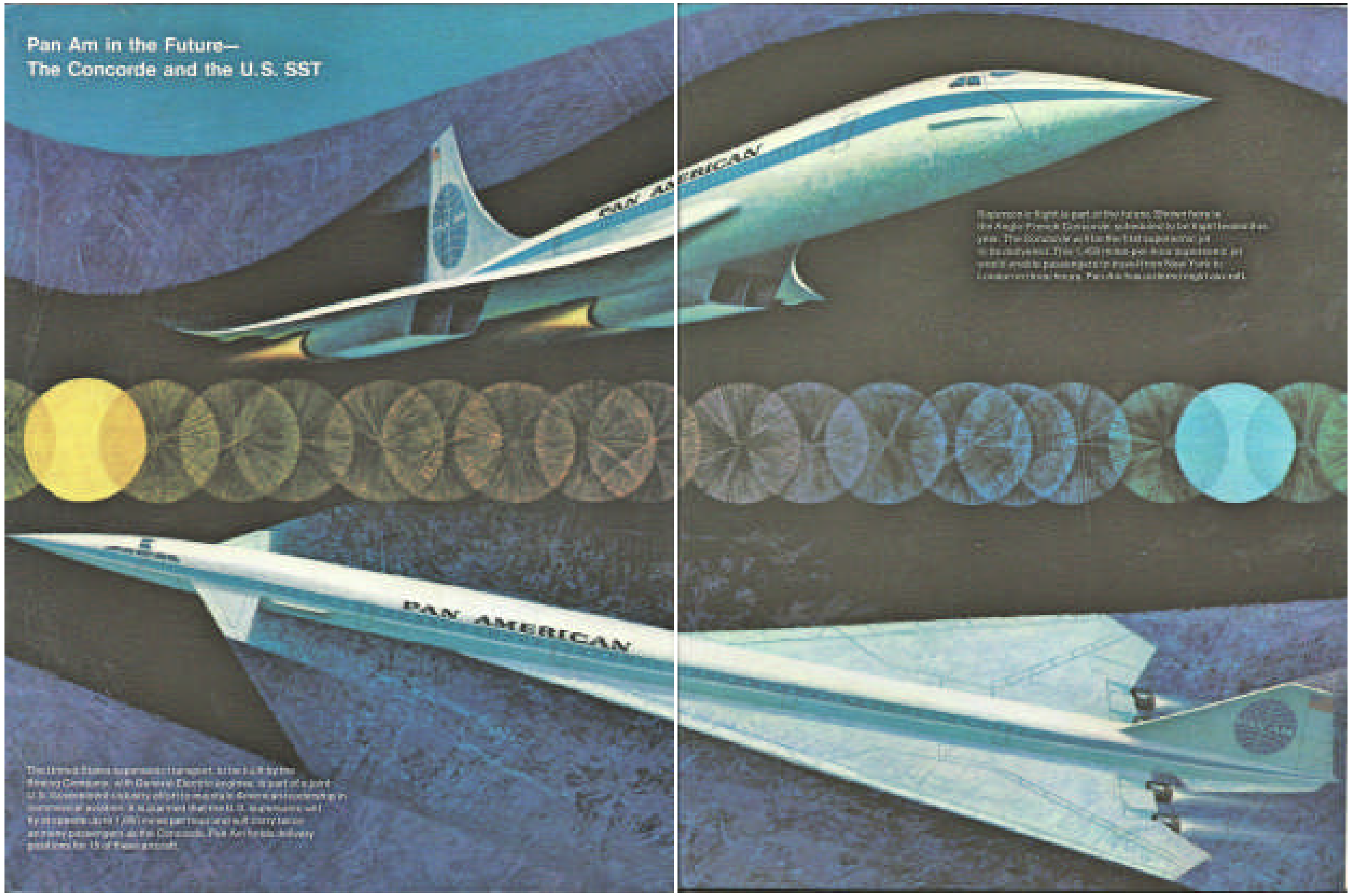
<u>Right</u>: caption: "Anatomy of the Boeing SST"

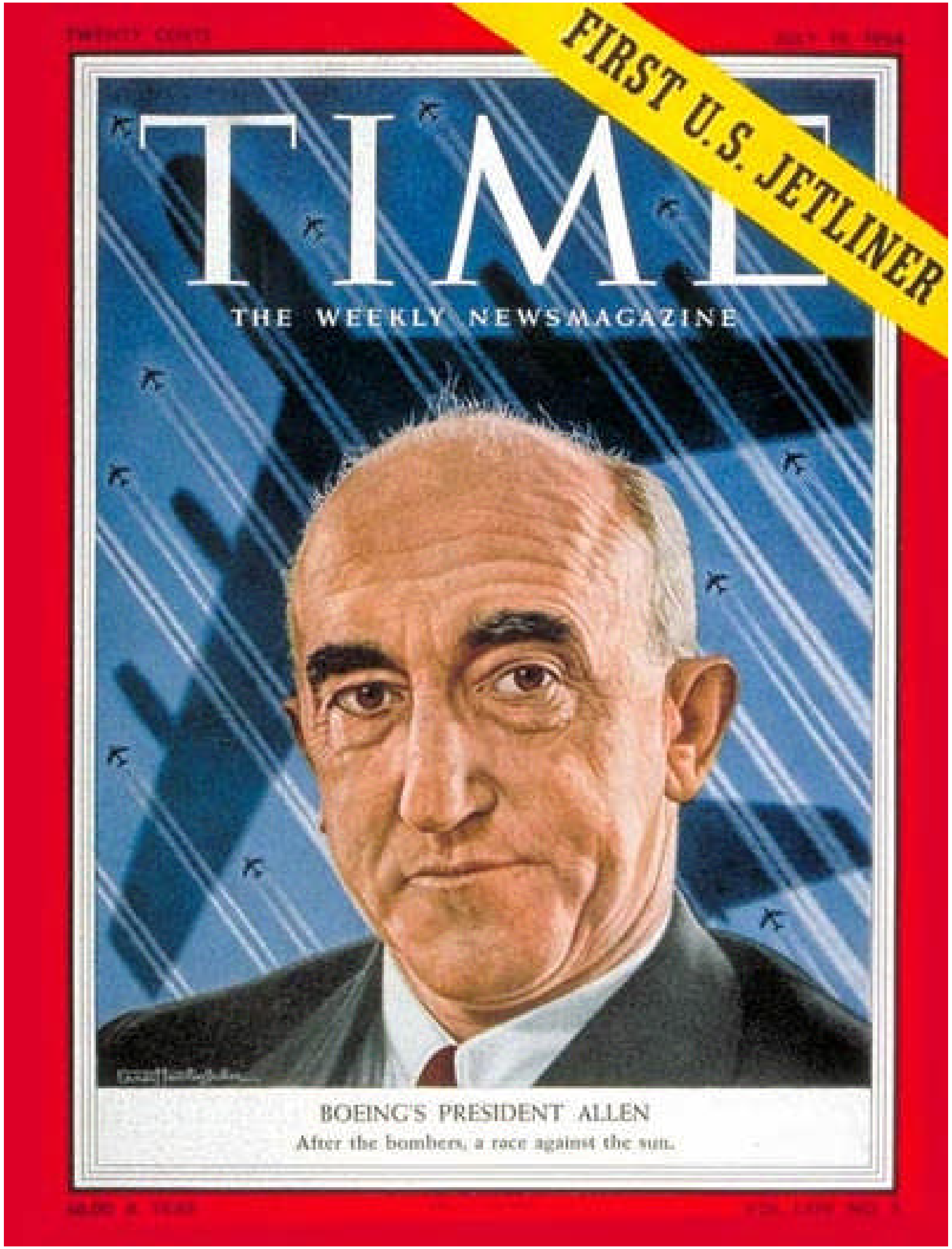

USA
SUPERSONIC
BOEING

The *Boeing 2707* was to be America's supersonic answer to the British/French *Concorde* and the first American SST. *Boeing* and *Lockheed* competed to win government-funded contract to build the faster-than-the-speed-of-sound aircraft. Boeing won the competition with its larger, faster and more complex proposal. The contract was unusual in that the developmental expenses were underwritten by the federal government for what was to be a civilian airliner (much like the collaboration between the French and British government/s to jointly fund the Concorde SST). In the early 1960s, it was thought that the Concorde was so far ahead in its development it would not be worth the bother to build a direct competitor, so a much larger, faster and more advanced aircraft resulted in the Boeing design. Boeing's SST was intended to carry 250 passengers (more than twice as many as Concorde), fly at Mach 2.7 - 3.0 and have a trans-Atlantic range of 4K miles. At 306-feet, it would be some 60-feet longer than even the 747 and it would be a wide-body 2-3-2 cross-section (similar to the much later 767). The speed, size and technology significantly inflated the costs, although it wouldn't significantly improve flight times over its European rival. After Boeing won the contract, the company stated that the construction of the SST prototypes would begin in early 1967 and the first flight could be made in early 1970. Production aircraft could start being built in early 1969, with flight testing in late 1972 and certification by mid-1974. It was projected that SSTs would dominate the skies with subsonic "Jumbo Jets" (such as Boeing's own 747) becoming freighters, for the most part, once the supersonic age of jet travel began in earnest.

"…A new world of flight will begin in 1969. And Pan Am will begin it. Yesterday, they were no more than dreams on a drawing board. Today, they're on their way to reality. And the reality will be a new world of almost unbelievable speed and size, comfort and quiet. Conjure up an image of some triumphant ocean liner suddenly sailing the skies - and you have our 747. Imagine a plane that makes it practical for you to take a business trip from New York to London and back in the same day - and you have our SSTs. Now you know why we can't wait to get these planes off the ground. They are the next generation of great aircraft…"

RE: excerpt from a *Pan American Airways* advertisement (appearing in *LIFE* magazine in April 1967)


Pan Am in the Future–
The Concorde and the U.S. SST
PAN AMERICAN
PAN AMERICAN



"…Here the visionary pioneer made a major miscalculation. The SST would be personified only by the Anglo-French Concorde, and even then only a few would be built. Esthetic and graceful, it was nearly an economic disaster. Designed when jet fuel was literally pennies per gallon, by the time it had completed what was then the most exhaustive test program ever devised, the oil crisis of the early '70s had made the airplane almost prohibitively expensive to operate…"

***Aviation* magazine**

<u>Left</u>: Boeing President *Bill Allen* on the cover of *TIME* magazine (at the time of the launching of the first jetliner in 1958)

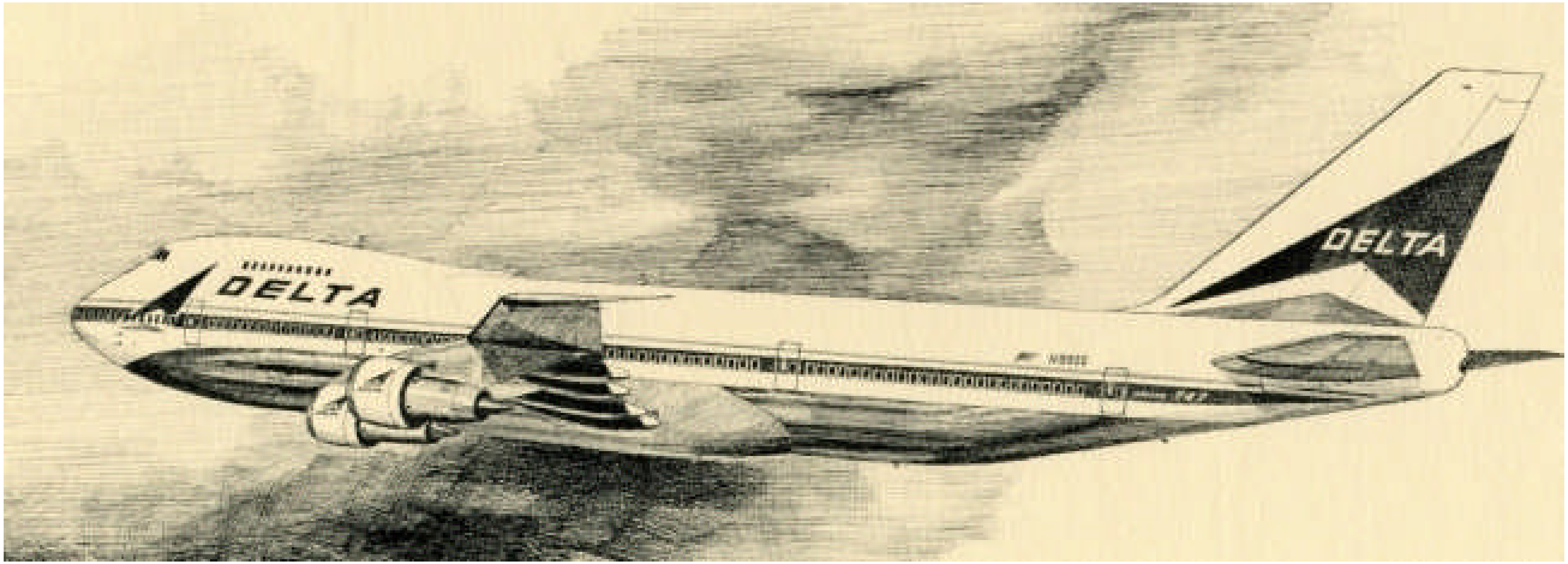
"…It soon became obvious that there would not be squadrons of supersonic transports gracing the skies, criss-crossing the oceans and continents to the world's capitals, slicing flying times from hours and hours to hours and minutes. The United State's answer to the Angle-French Concorde, Boeing's 2707, was slain by the stroke of a Congressional pen. The B-747 would have to carry the trans-oceanic burden, at least for the foreseeable future…"

***Aviation* magazine**

<u>Left</u>: caption: "PAA promotion for the B2707 SST"

<u>Right</u>: caption: "A British Airways Concorde SST breaking the sound barrier"

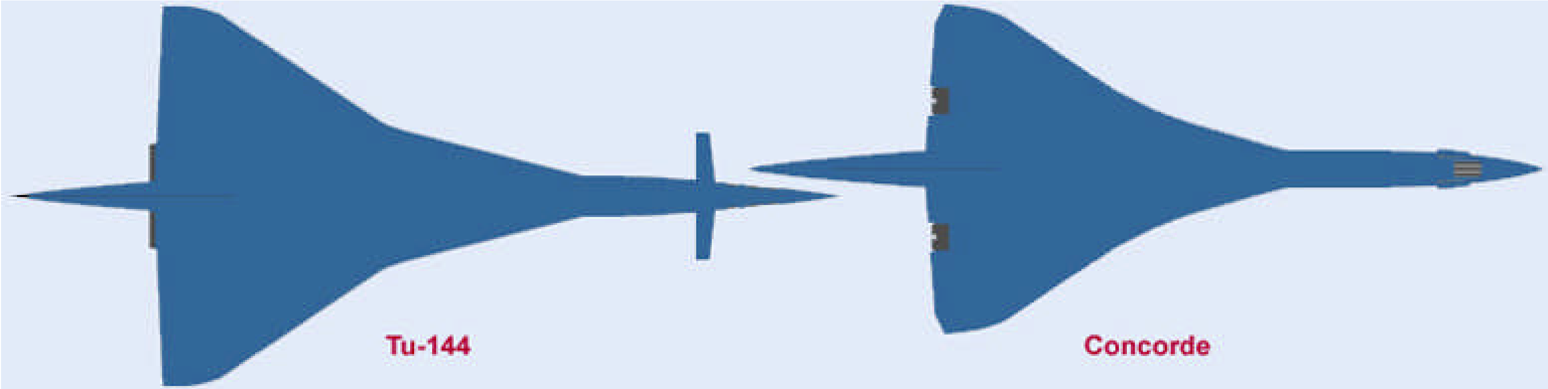
First of a New Breed



"…The 747 is the first of a new breed. It is <u>not</u> America's answer to the French-English Concorde or Russia's TU-144, needle-nosed supersonic darts now being tested. Rather, it is a bigger, faster, more stable, more comfortable version of today's subsonic jets. But that ho-hum description doesn't do the 747 justice. It's an exciting plane, even awesome and majestic…"

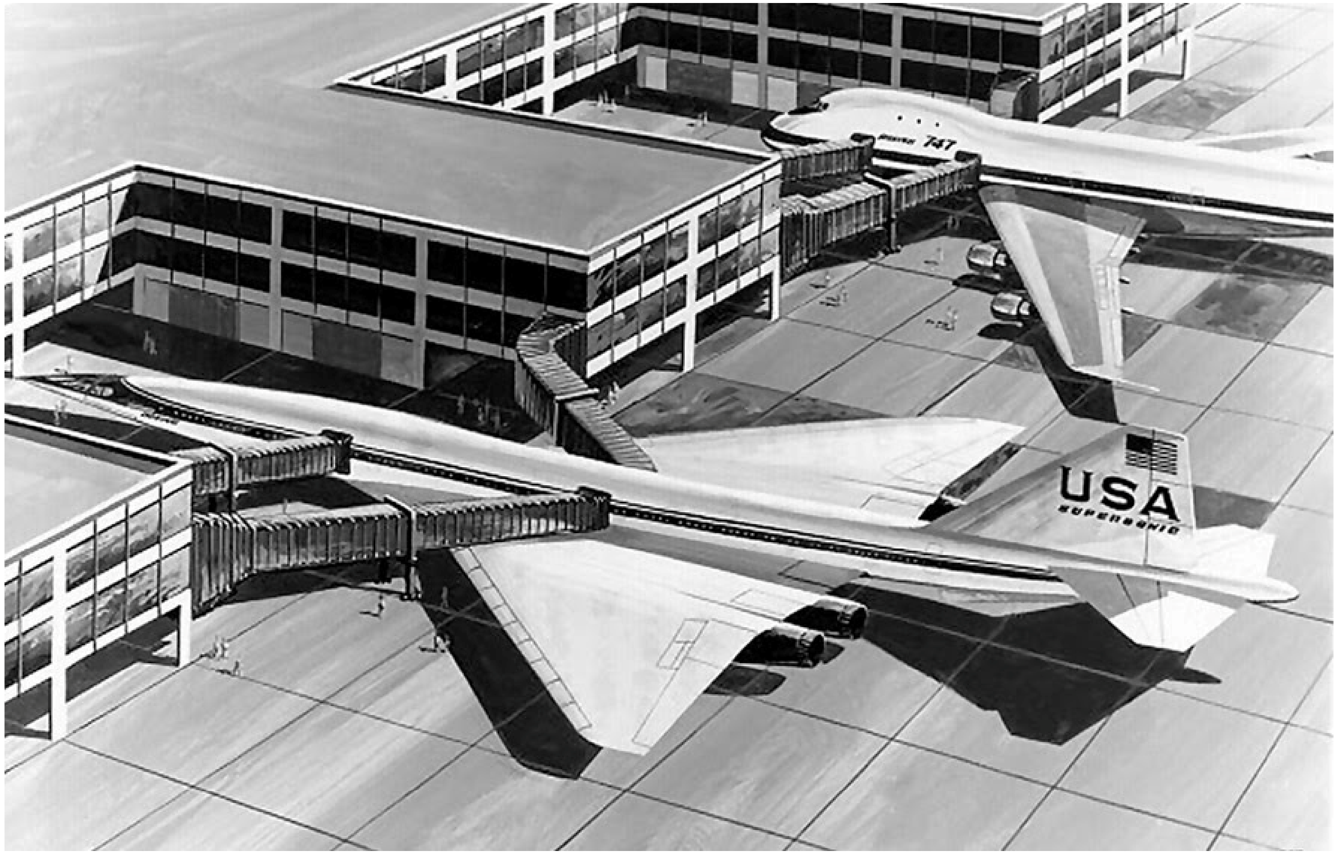
***Popular Mechanics,* December 1969**

<u>Above</u>: caption: "Delta 50th Anniversary (1979) - specially com-missioned illustration of Boeing 747-100"


Tu-144
Concorde


AIR FRANCE

In March 1971, despite the American SST project's strong support by the administration of POTUS *Richard M. Nixon*, the U.S. Senate rejected further funding citing environmental issues as well as a downturn in air traffic during an economic recession, at the time. In the aftermath, letters of support from aviation buffs (containing nearly $1 million worth of contributions) poured in. Even so, the Boeing SST project was canceled on May 20th 1971. At the time, there were 115 unfilled orders by twenty-five airlines while Concorde had 74 orders from sixteen customers. Noteworthy were orders from Concorde operators *Air France* and *BOAC*, as well as all the major U.S. airlines of the era.


747
USA

Although a full-size wood mockup was built, the two prototypes were never completed. The Boeing SST became known as: "the airplane that almost ate Seattle." Due to the loss of several government contracts and a downturn in the civilian aviation market, Boeing reduced its number of employees by more than 60K. One of the wooden mockups was displayed at the *SST Aviation Exhibit Center* (in Kissimmee, Florida) from 1973 to 1981. It's now on display at the *Hiller Aviation Museum* in San Carlos, CA.

<u>Left</u>: caption: "Boeing 2707 SST mock-up near Boeing Field, Seattle, Washington, 1969"

<u>Right</u>: caption: "Mock-up of the Boeing 2707 SST at the Hiller Aviation Museum"


SUPERSONIC
BOEING

Last Hurrah

"…Trippe had always been bolder than his contemporaries in going for larger aircraft; indeed he seemed to have followed a policy of ordering types which were typically twice the size of the previous generation. The only way to increase capacity, apart from adding frequencies - another method of coping with in-creased demand, but which was practically impossible, because of airport and airway congestion - was to increase the aircraft size…"

***Ron Davies*, Author**

RE: the first jets had made world travel available to everyone, not just the elite. Now, an airplane was needed to satisfy the new yearning to travel. In this yearning lay the seeds for the *Boeing 747* – an airplane that could make or break both Boeing and/or PAA. For both Trippe and Allen (both nearing retirement), it would also be their last hurrah.

<u>Above</u>: size comparison of Boeing 707 (foreground) vs. Boeing 747-100 (background)

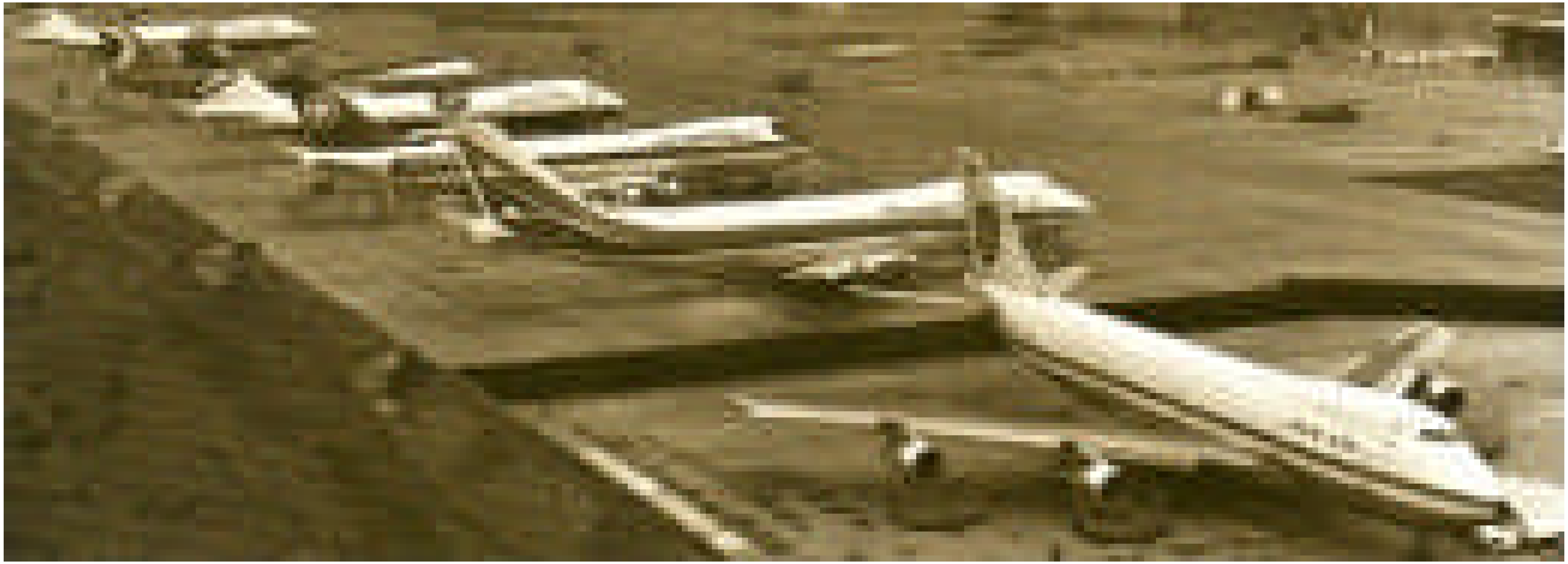
On the Books

"…Pan American has ordered twenty-three of the new Boeing 747 airliners, plus a couple of cargo craft, and will put them into service beginning in three years. In spite of their great size and weight, the new airliners will climb out faster than the present jet transports. They will operate from existing runways. They will be able to fly higher, yet will be so sturdy that the present emergency oxygen system for passengers may not be required…"

***Popular Mechanics,* September 1966**

"…Boeing's decision to build the 747 has stood up. At this writing, over 180 orders from the world's major airlines are on the books. With 33 of the big birds on order, Pan Am is by far the largest buyer…"

***Popular Mechanics*, December 1969**



"…Though almost all the orders are for the passenger plane, a few have come in for the convertible (passengers and/or cargo) and the freighter versions, models that are sure to grow in importance as more goods are shipped by air. The freighter will be able to carry a maximum payload of 260,000 pounds for a distance of about 2,900 miles, or 200,000 pounds nearly 4,000 miles. The convertible can be changed over from freight to passengers, or vice-versa, in about ten hours. Because special weight-adding equipment is needed to provide the versatility, the convertible will carry a somewhat smaller payload than the pure freighter. As a passenger plane, it will be able to carry 374 passengers, plus baggage and 40,000 pounds of cargo, for better than 5,000 miles. These alternate version will have engines with slightly more thrust than the first 747s off the line…"

***Popular Mechanics*, December 1969**


PAN AM Cargo
Cargo

cargolux
cargolux
cargolux

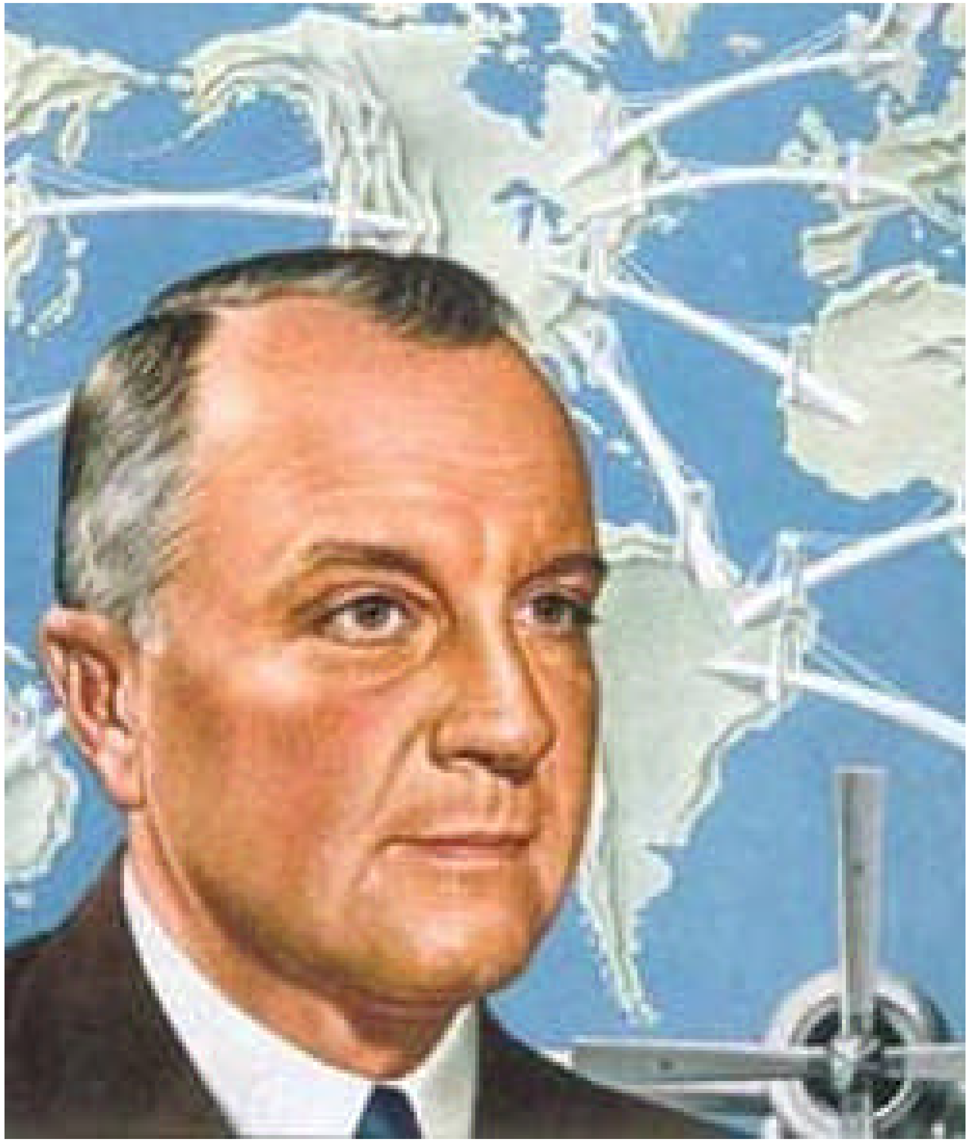
"…If the future passenger market really booms, the big plane could possibly be expanded by stretching the fuselage 50 feet or by running the second deck – now long enough to contain only a lounge in addition to the cockpit – almost all the way back to the tail. The expanded plane could carry as many as 700 passengers…"

***Popular Mechanics,* December 1969**

<u>Above</u>: caption: "747-100 vs. 747-8 size comparison"

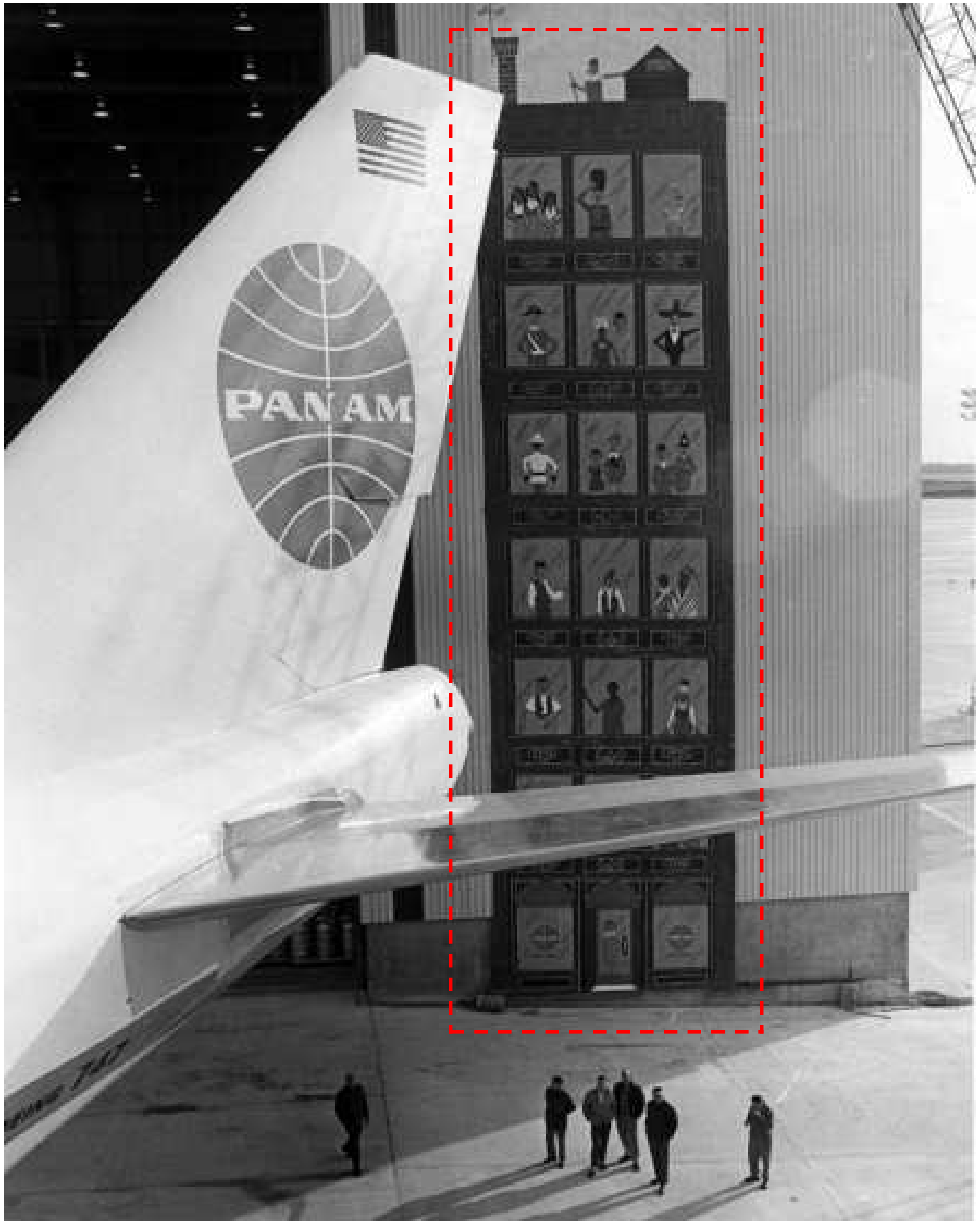
<u>Left</u>: caption: "Evolution of the Boeing 747-series Jumbo Jet"

Future Vision



"Pan Am's Juan Trippe was a visionary executive who dreamed in only one dimension: big. Pan Am was the launch customer for the first successful jet transport, the Boeing 707, and it was Trippe who saw the need for an even larger airplane to keep up with the burgeoning growth in air traffic in the early '70s. In the mid-60's, when the 707 was still a novelty in the world's skies, Trippe took his ideas to Boeing's Bill Allen. He and Allen were alumni of the old school, both of them men of courage and daring, and after many long and sometimes contentious meetings between Pan Am's planners and Boeing's engineers, the decision was made to go ahead with the giant aircraft…"

***Airways* magazine**



"…It was a tremendous gamble. The 747 would embrace new design and technology that up to then had only existed in the dreams of engineers. The technical hurdles that had to be cleared were enormous…"

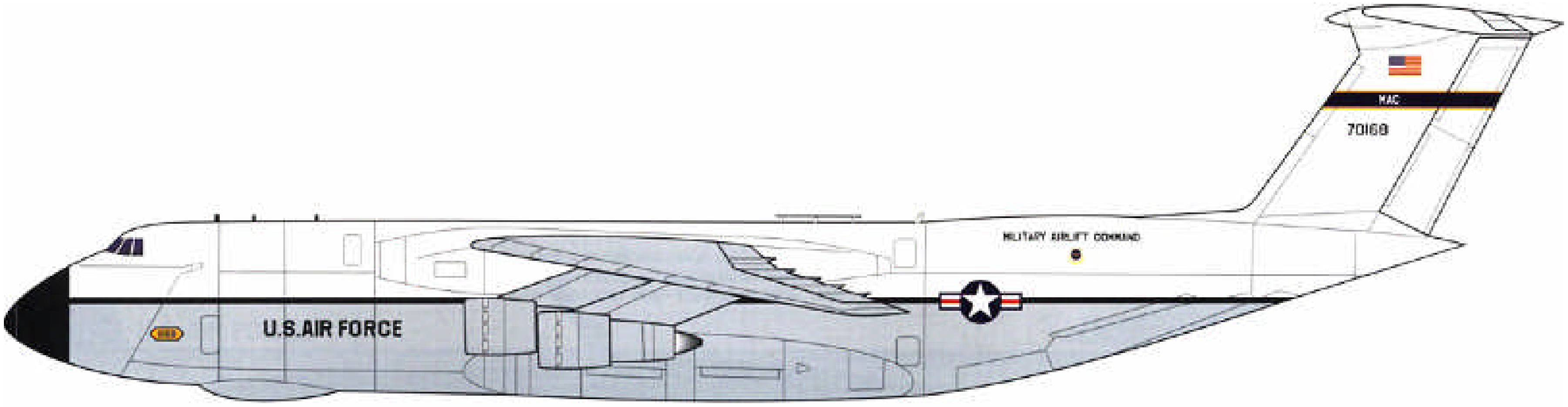
***Airways* magazine**

Left: caption: "Boeing 747 tail is as tall as a seven-story building"

"…it would have been impossible to build this plane fifteen or even ten years ago. We now know more about stability and how to attain it without excessive structural weight and complexity. And we know much more about how to control a plane…"

Brien Wygle, **Assistant Director of Flight Operations – *The Boeing Company***

The C-5A Technology



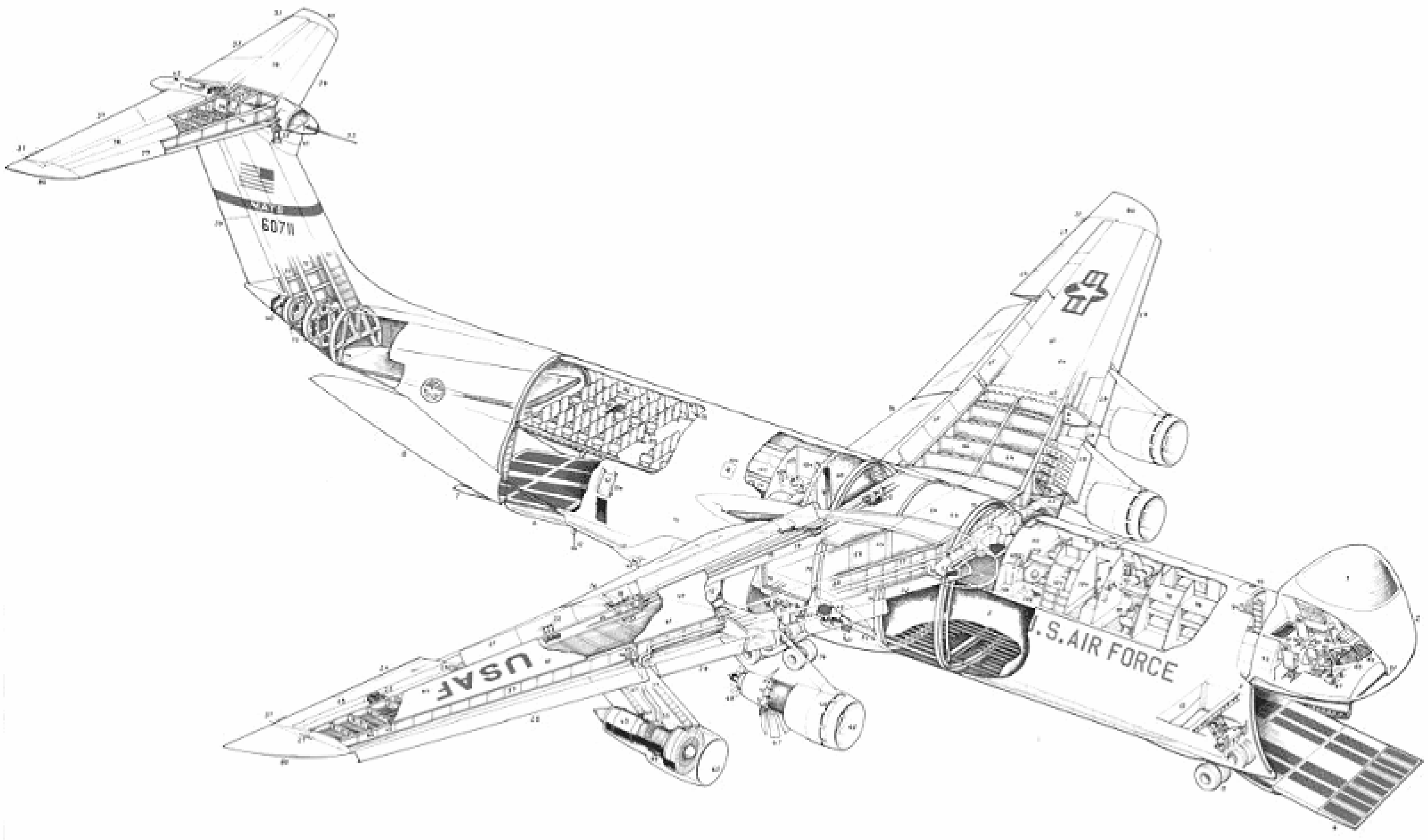
"…This brand-new development in air travel stems from what's called the 'C-5A technology.' The C-5A is a monster transport that the Air Force has ordered, for carrying more than 100 tons of cargo farther than 3,000 miles at 550 mph. Engine manufacturers have been developing its power plants. Boeing, Douglas and Lockheed designed their own versions of the C-5A, with each design incorporating the latest knowledge in high lift-wing devices and other improvements. Lockheed won the military contract and is building fifty-eight of the transports. The first will fly in less than two years…"

***Popular Mechanics,* September 1966**

<u>Above</u>: caption: "Lockheed C-5A Galaxy 67-0168 of the 436th Military Airlift Wing, 1970. Finished in the white and gray scheme which was standard."

"…the C-5A will be 245 feet long, almost 100 feet longer than the present big 707 airliner, with a wingspan of 222 feet. The top of its tail will be 65 feet above ground. The plane has 28 wheels to allow it to land and take-off at unimproved fields. After being parked, it can 'kneel down' for unloading. Its cargo compartment (19 feet wide and 121 feet long) can house a mixed cargo such as a large helicopter, a tank, an intermediate range missile and an assortment of trucks and jeeps, plus all the crews and maintenance personnel…"

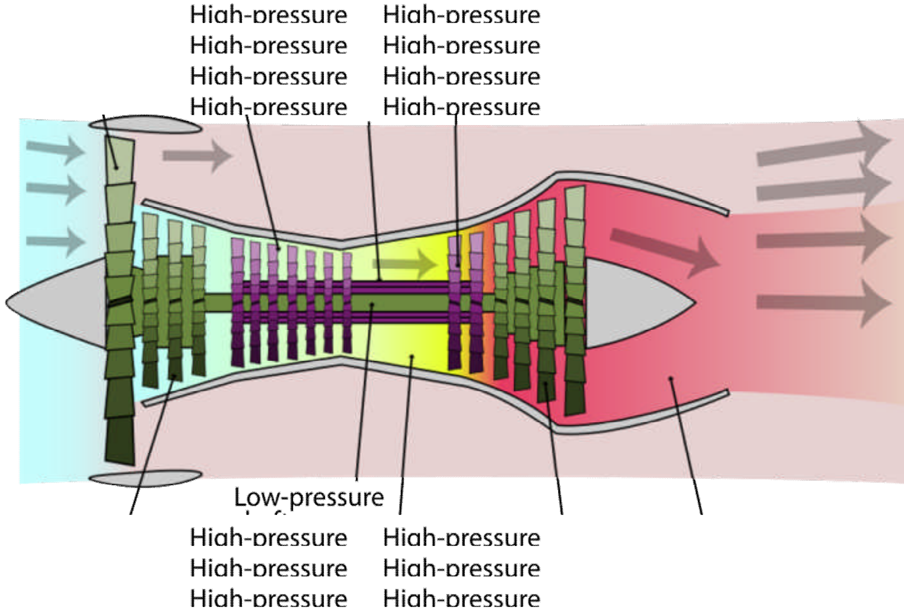
***Popular Mechanics,* September 1966**



60711
USAF
U.S. AIR FORCE

"…The plane will be powered by four 'high-bypass' fanjets that develop 41,000 pounds of thrust apiece. Basically, a fanjet is a turbojet that uses much of its power to spin a large-diameter fan attached to the front of the engine. The fan blows more air back around the outside of the engine than flows through it. This bypass principle creates more thrust at the same time that it reduces specific fuel consumption. The new fanjets have a bypass ratio of eight-to-one, four times greater than in present fanjets, and are considerably more efficient. They are big engines. The fan is more than eight feet in diameter…"

***Popular Mechanics,* September 1966**

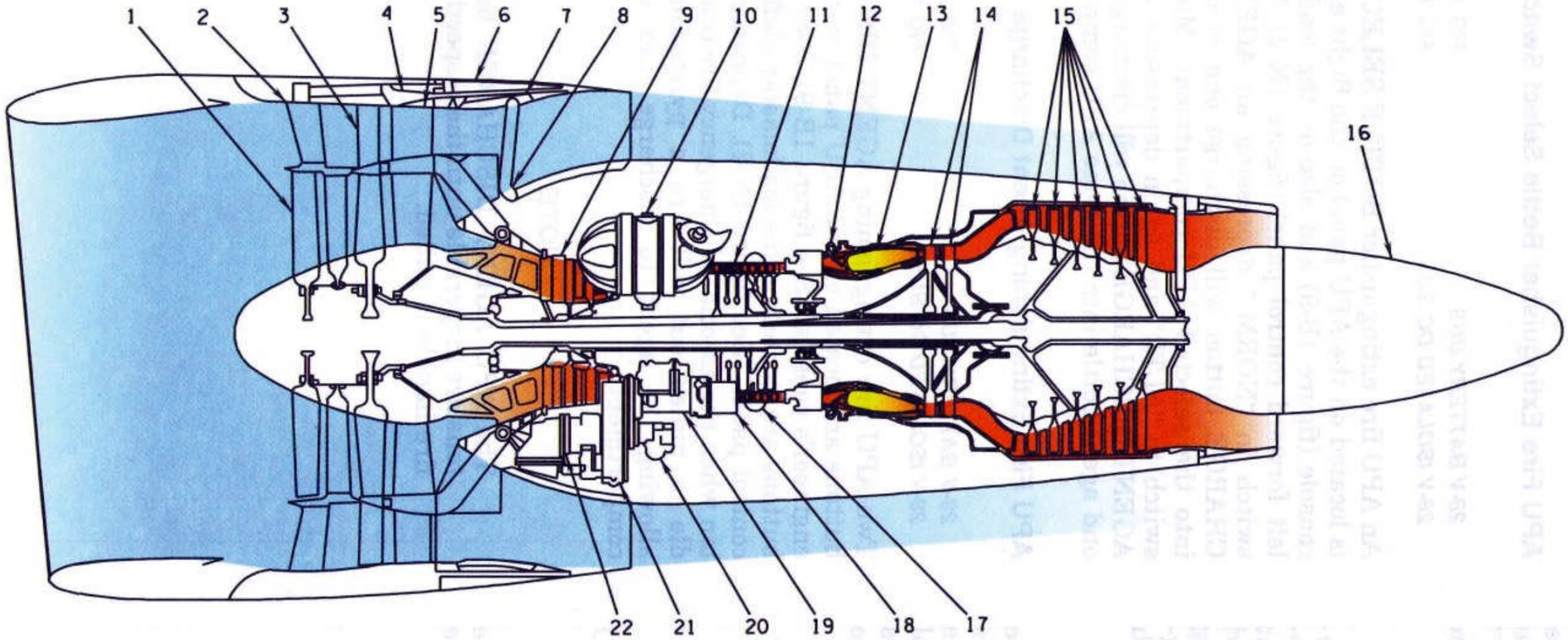


The turbofan (a/k/a "fanjet") is a type of air-breathing jet engine. In the word "turbofan" ("turbine" + "fan"), the *turbo* portion refers to a gas turbine engine (which takes mechanical energy from combustion) and *fan* = a ducted fan (which uses the mechanical energy from the gas turbine to accelerate air rearwards). Thus, whereas all the air taken in by a *turbojet* passes through the turbine (through the combustion chamber), in a *turbofan* some of that air bypasses the turbine. Thus, a turbofan can be thought of as a turbojet being used to drive a ducted fan, with both contributing to developing thrust. The ratio of the mass-flow of air bypassing the engine core as compared to the mass-flow of air passing through the core is referred to as the "bypass ratio." The engine produces thrust through a combination of these two portions working in concert; engines that use more *jet thrust* relative to *fan thrust* are known as *low-bypass turbofans*, conversely those that have considerably more fan thrust than jet thrust are known as *high-bypass turbofans*. Most of the air flow through a high-bypass turbofan is low-velocity bypass flow. Turbofan engines are significantly quieter than a pure-jet of the same thrust.

Left: caption: "Schematic diagram of a high-bypass turbofan engine"

Right: caption: "High-bypass turbofans on C-5A Galaxy"

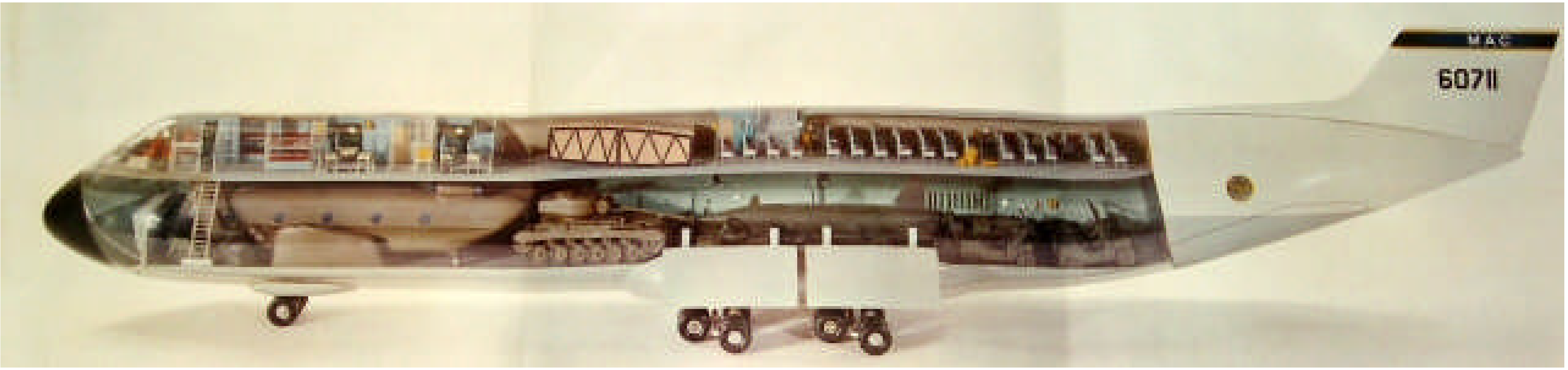
The Engine



TYPE TF39-GE-1C

1. FIRST STAGE FAN (N_1)
2. FAN INLET GUIDE VANE
3. SECOND STAGE FAN (N_1)
4. TRANSLATING COWL ACTUATOR
5. FAN AIR EXIT VANE
6. TRANSLATING COWL
7. BLOCKER FLAP
8. BLOCKER LINK
9. HIGH PRESSURE COMPRESSOR INLET GUIDE VANE
10. ENGINE OIL TANK
11. HIGH PRESSURE COMPRESSOR (N_2)
12. FUEL NOZZLE
13. COMBUSTION CHAMBER
14. HIGH PRESSURE TURBINE
15. LOW PRESSURE TURBINE
16. EXHAUST CONE
17. 13th STAGE BLEED AIR MANIFOLD
18. FUEL CONTROL
19. FUEL PUMP
20. LUBE SCAVENGE PUMP AND N_2 TACHOMETER
21. ACCESSORY DRIVE GEARBOX
22. TRANSFER GEARBOX

<u>Above</u>: caption: “Basic schematic showing the operation and parts of the General Electric TF-39 high bypass turbofan engine, from the C-5A Galaxy flight manual”

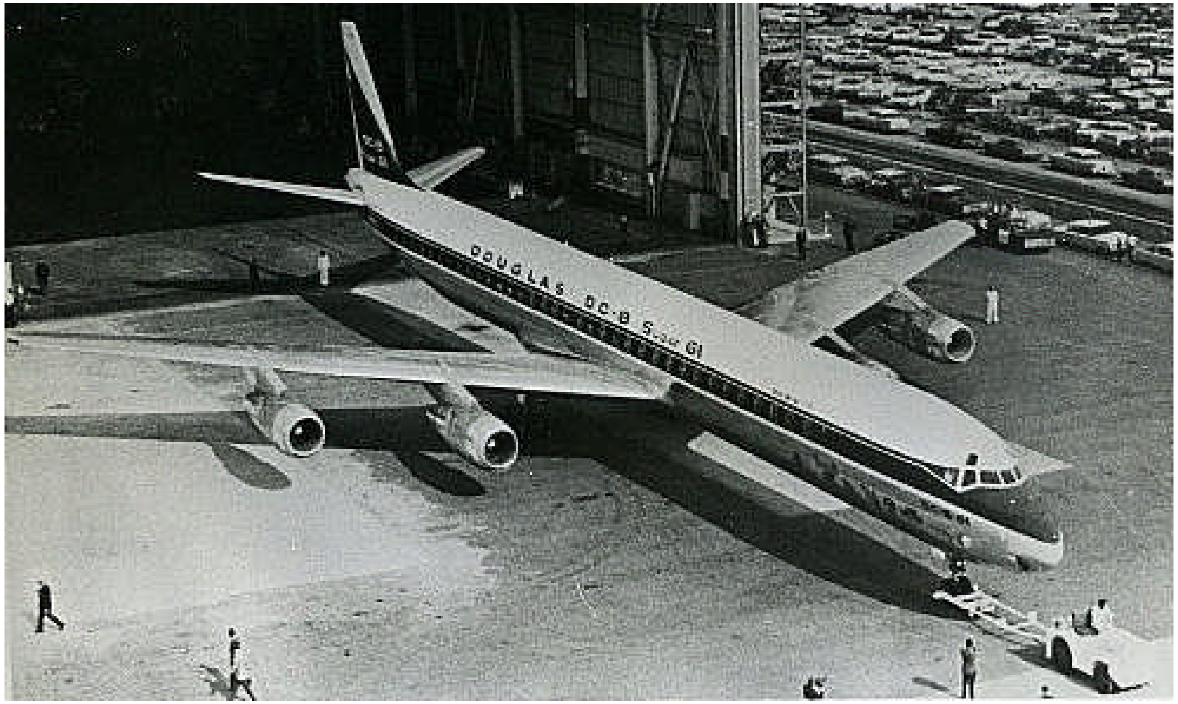


"…Each of the companies that competed for the C-5A contract new the huge airliners were going to be needed sometime in the future. The date depends on how fast the volume of air travel grows and on how many passengers the upcoming supersonic transports will steal from the subsonic jets. The companies knew, too, that with some modification and possible reductions in size, their C-5A design would be ideal for subsonic airliners. This is a case where each of the companies, one way or another, has gotten the jump on its competitors. Lockheed won the military contract and Boeing got the first order for a super-sized airliner…"

***Popular Mechanics,* September 1966**

<u>**Above**</u>**: caption: "Inside view of the C-5A Galaxy"**

Making Hay



"…Douglas, in the meantime, is making hay with its DC-8 Super 61, the largest airliner now flying. The Super 61 carries as many as 251 passengers versus 189 in the standard model. Airlines have ordered 73 of them recently and Douglas is prepared to 'stretch' the design to 350-passenger capacity when the high-bypass fanjets are available…"

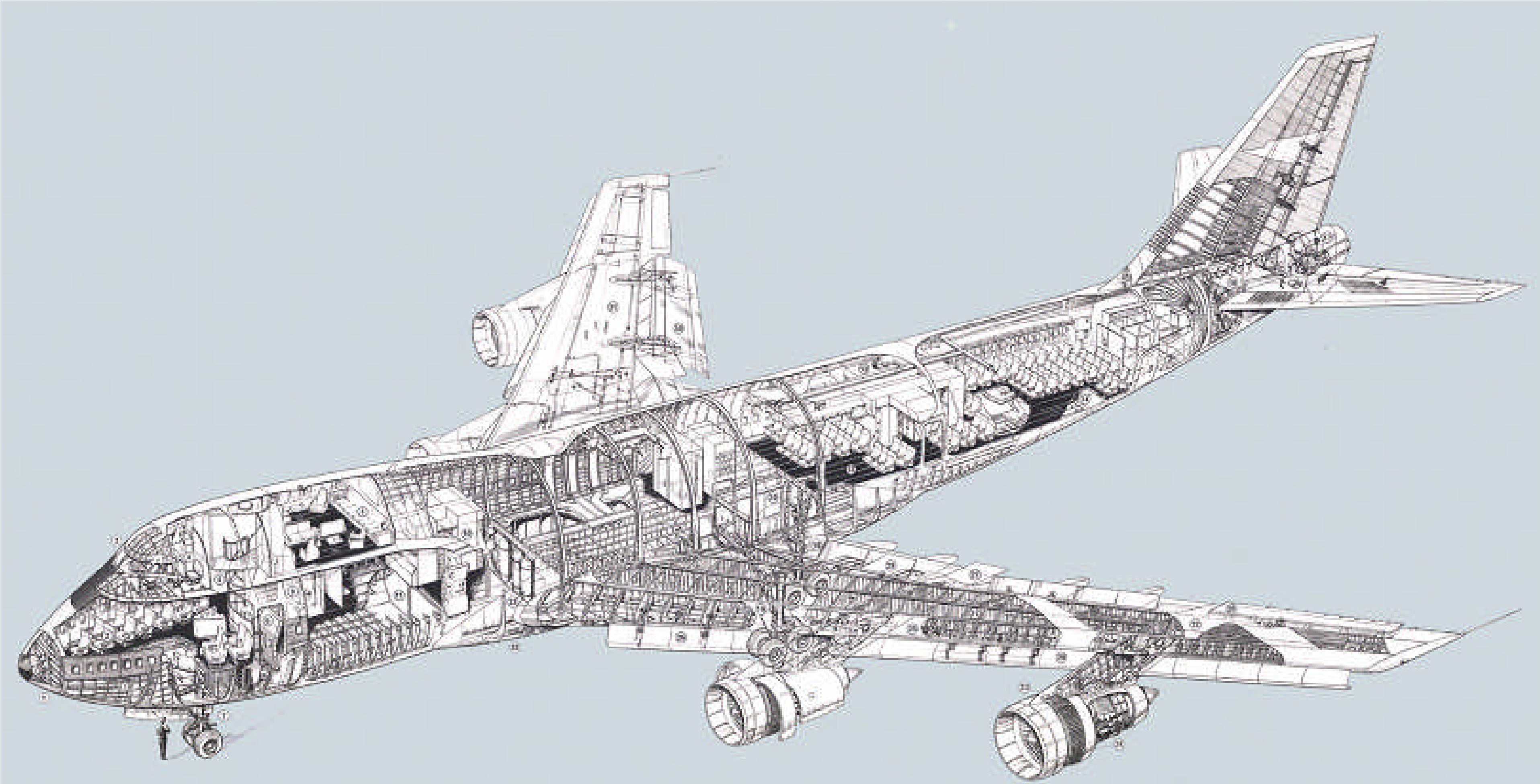
Popular Mechanics, **September 1966**

<u>Above</u>: caption: Long Beach, Calif., January 24, 1966 – HUGE NEW AIRLINER ROLLED OUT – The Super 61 DC-8, which Douglas Aircraft Company calls the world's largest commercial airliner, leaves a construction hangar at Long Beach, Calif., in a roll-out ceremony today. The plane, 187.4 feet long, will carry 251 passengers. Current DC-8s are 150 feet long and carry 189 passengers in an all-economy configuration. First flight of the Super 61 is set for this spring."

Discover Hawaii 1967
...in the world's biggest, newest jet – the Super DC-8
Starting this month, United puts new luxury into the skies between California and Hawaii. The luxury of flying in the world's newest, roomiest jet . . . the luxury of 2 extra stewardesses serving up United's famous "Extra Care." Add the exotic foods and beverages, six channel stereo, wide-screen color movies, and – well, it's like being in Hawaii 5 hours ahead of time! Join us? United's the only airline flying the "Big New Ones" to Hawaii and we're looking forward to welcoming you aboard.
"It's like one big happy Luau!"
fly the friendly skies of United.
Mail Credit Card Application:
United Air Lines, Box 8800, Chicago, Ill. 60666
UNITED

"…Beyond that, the company would jump to its proposed two-deck 550 passenger jumbo DC-10. Douglas is telling the airlines that its two-deck design is the most efficient for either passengers or cargo, that the DC-10 would cruise at mach 0.9 (about 650 mph) and that seat-mile costs would be about 25 percent less than in existing jets (its competitors say that two decks would create unnecessary loading problems at the terminals and a serious problem if ditching was necessary)…"

Popular Mechanics, **September 1966**



"…Boeing says that its design, with up to 450 passengers on a single deck in a longer fuselage is best (its competitors say that the skin surface per passenger is greater, hence the design is less efficient)…"

***Popular Mechanics,* September 1966**

<u>Above</u>: caption: "Cut-away view – Boeing 747-100"

Costwise

"…Lockheed is saying that the basic C-5A would make the best passenger transport of all, after rearranging the interior to accommodate 750 passengers or more. Costwise, this would save many millions in extra engineering and tooling (its competitors say <u>their</u> versions are much faster, that the C-5A high wing is inefficient for commercial operations and that it will be a long time before 750-passenger aircraft are needed)…"

***Popular Mechanics,* September 1966**

In the Long Run

"…Arguments like these are normal in the aircraft industry and in the long run it's the public that profits from them. The fast and inexpensive transportation made possible by the Jumbo Jets will completely alter the transportation industry…"

***Popular Mechanics,* September 1966**

<u>Left</u>: the August 14th 1978 cover of *TIME* magazine. By the late 1970s, cheap fares and Jumbo Jets had made flying both routine and, to many airline passengers, an unpleasant experience

On December 22nd 1965, *Juan Trippe* and *Bill Allen* signed a *Letter of Intent* for the *Boeing 747*. On April 13th 1966, PAA formally ordered twenty-five 747-100s. However, On March 30th 1965, President Johnson invited the *Business Council* to a formal dinner. Both Trippe and Allen were in attendance. Johnson pleaded for austerity due to economic problems caused by the Vietnam War. This jolted both Trippe and Allen, whose 747 project was taxing the financial resources of both companies. After the dinner, Trippe approached Johnson to press his case for the 747. Johnson asked Trippe if anyone knew about the project. Trippe responded: "no, except for Bill Allen." Johnson then asked Trippe to come to the White House the next day to see someone. The next day, Trippe was taken to the Pentagon to discuss the project with Secretary of Defense *Robert McNamara*. At the time, another large capacity aircraft, known as the *C-5A Galaxy* was being developed for the Pentagon by *Lockheed*. McNamara pressed Trippe on the possibility of his waiting for a commercial version of the C-5A. Trippe argued his case for the 747, noting the impracticability of creating a commercial version of the C-5A. McNamara agreed and brought Trippe back to the White House where Johnson ordered that they "work it out." Both Trippe and Allen worked it out with the White House and the Pentagon, after which they both sought approval from their respective Boards of Directors. With Johnson's approval, the PAA directors were convinced. So convinced that an option for an additional ten planes was authorized for incorporation into the contract, thus making it the largest order for a single aircraft model in the history of commercial aviation (up to that time).

Ant Eaters & Double-Deckers

<u>Above</u>: this Boeing 747 design model (nicknamed “The Ant Eater”) actually led to the final configuration of the 747. At first the 747 was considered a stop-gap measure until the anticipated entry into service of the SSTs in the early 1970s. Many believed that most 747s would be relegated to freighter service, replaced by the SST for passenger service thus, the flight deck had to be clear of the main cargo deck. In this design, the flight deck was located below the passenger cabin.

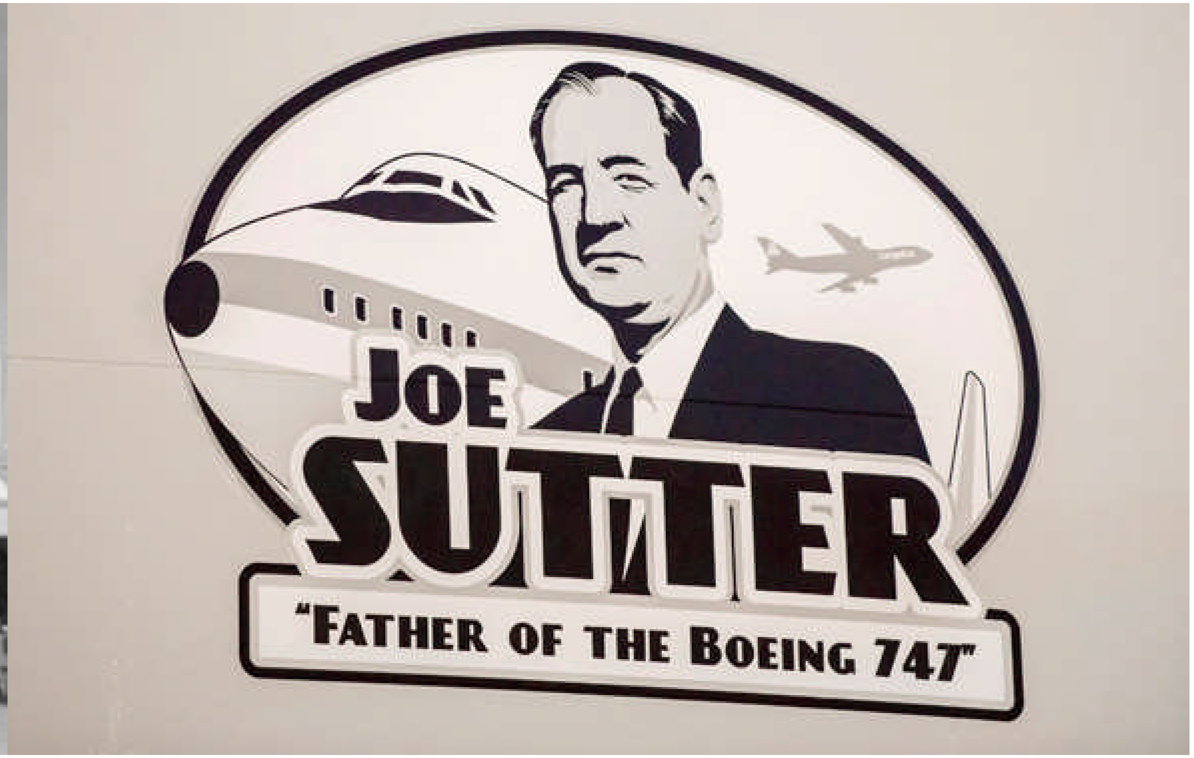
The *Boeing 747 Double-Deck* (model above) was detested by 747 Project Chief Engineer *Joe Sutter.* When he took charge of the program, the double-decker (with six-abreast seating) was basically considered two 707s stacked on top of one another. He called the design a "turkey," detesting them for their poor use as cargo aircraft, emergency evacuations and even poor aesthetics. When the cross-section was widened to around 20-feet (double that of the 707), seating went from six to ten abreast (with twin aisles as well as twin cargo containers no more than 8x8-feet, placed side-by-side). This new wide-body configuration alleviated the need for a full double-deck fuselage.


PAN AM
BOEING 747
757
TWA

A Steady Evolution

“…Boeing pilots and engineers stress the fact that the 747 is the end result of a steady evolution, including all the technical improvements initially used in the 707, 727 and 737, plus some new ones. Boeing first started thinking ‘Big’ back in the early ‘60s when it competed with Lockheed for an Air Force contract to produce a long-range, big-capacity transport. Lockheed won the competition, and the huge C-5A is a reality today. Boeing then turned its thoughts to the passenger-plane market, hoping to make use of expensive research and development already carried out. The manufacturer became convinced that there was a need for a big subsonic craft in the long-haul market…”

Popular Mechanics, **December 1969**



"And so they gave me a few engineers and we started studying how the hell to build a big airplane and that was what resulted in the 747 concept, the concept of the wide body that has been copied now by a lot of people…Everybody thought the 747 was going to be an interim airplane that wouldn't last very long once the supersonic technology took off, so it was a struggle to get people and wind tunnel time and budgets and we had to do it in a hell of a hurry"

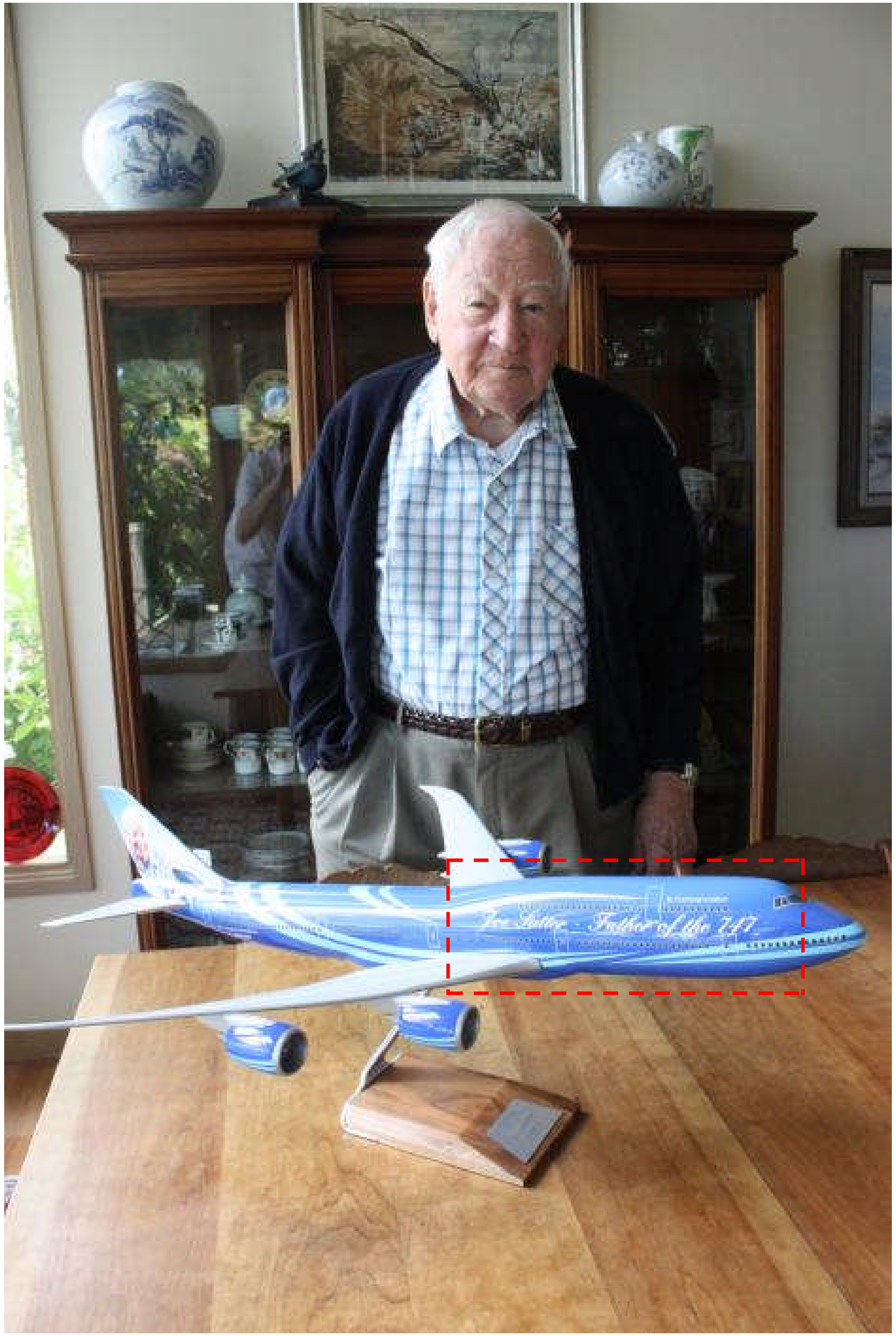
***Joe Sutter,* 747 Project Chief Engineer (a/k/a "Father of the Boeing 747")**

RE: while others at Boeing thought the only way to go was to build a double-decker, Sutter (above L&R) and his team created the wide-body concept that would not only fit 350 passengers, but could also double as a freighter

“All the hot shots that were there got those choice assign-ments and my first job was to clean up the Stratocruiser”

***Joe Sutter,* 747 Project Chief Engineer**

RE: after receiving a degree in Aeronautical Engineering from the *Univ-ersity of Washington* in 1943, Sutter served in the U.S. Navy during WWII. After the war, Sutter was offered jobs at both *Douglas Aircraft* and Boeing (he chose Boeing since his new wife was a native of Seattle, just like Boeing). The *Boeing 377 Stratocruiser* had a lot of problems and as Sutter fixed them one by one, he learned a lot of things that weren’t in his college textbooks. His superiors at Boeing took notice, recognizing Sutter’s knack for aerodynamic design and his ability to work within federal certification rules. Sutter became the “go-to-guy” who could get things done. He worked on several planes over the next few years, incl-uding the 367-80, 727 and 737 (with its engine-under-the-wing design that would play an important role in his next project, the 747).

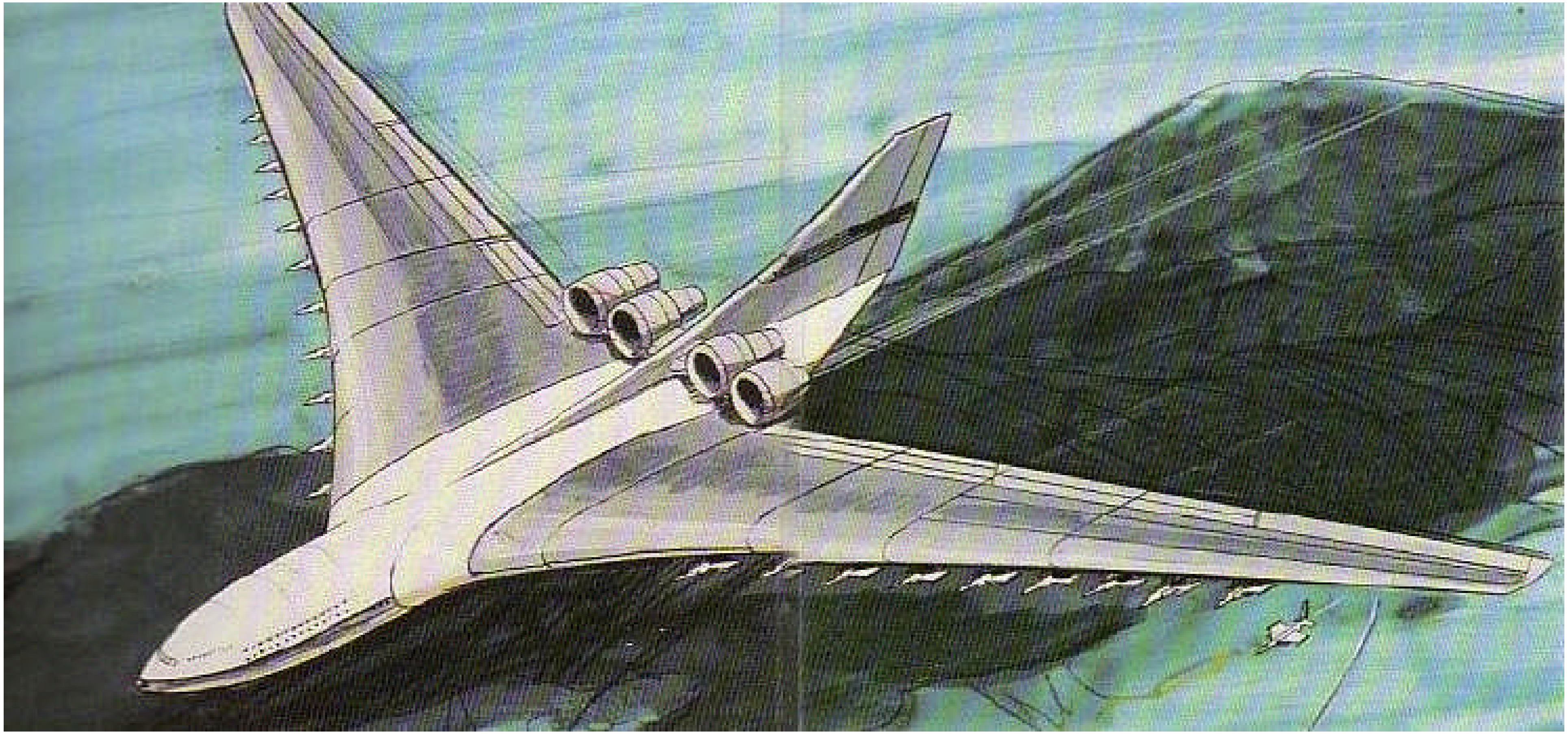


As the project moved along more and more funding was necessary. Boeing CEO *Bill Allen* went to the banks once again to ask for a loan. The bankers were getting weary and it was proposed that Sutter's team might need to get rid of 1K engineers to reduce costs. Sutter knew he couldn't afford to lose a single engineer, no less a thousand, if they were going to build the plane in its very tight twenty-nine month schedule. When asked by Allen how the cuts were coming along he replied: *"Hey, we need 800 more engineers!"* Sutter figured that was the day he lost his job at Boeing, but he went to work the next day and nobody said anything, so Joe Sutter just kept on working.

<u>Left</u>: caption: "Joe Sutter at his West Seattle home, June 11, 2013"

Joe Sutter **ran the 747 program for ten years and then went on to become Boeing's "Chief of Engineering and Product Development" for the remainder of his career. Retiring after forty memorable years, Sutter continued to work as a consultant for Boeing. He also served on the** ***Rogers Commission*****, helping investigate what went wrong in the 1986 space shuttle** ***Challenger*** **disaster.**

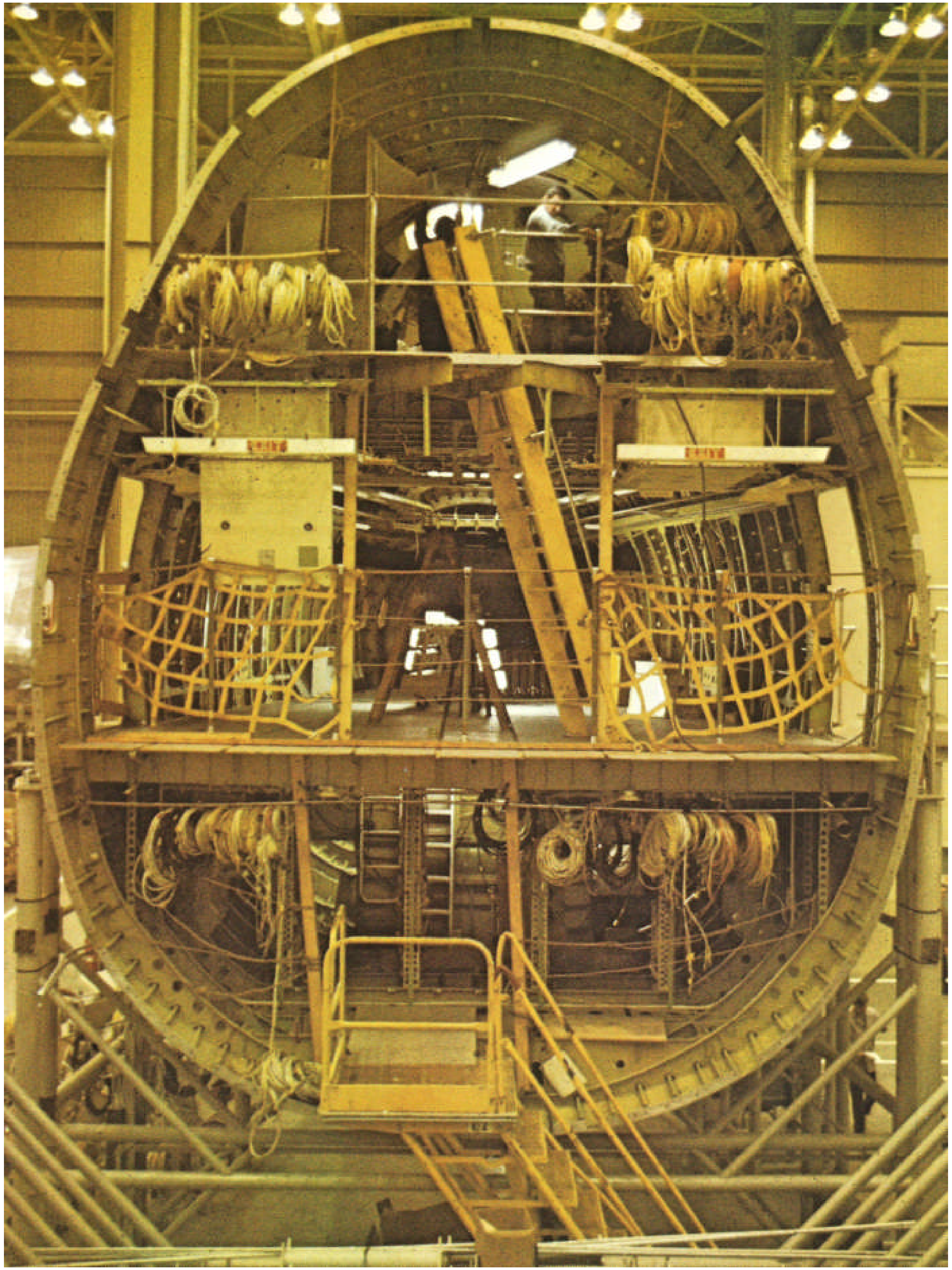
<u>Above</u>: this Boeing 747 model (less the upper deck windows) bares a very similar appearance to what, ultimately, became the ***Boeing 747-100*****. Six windows (three per side) were added when** ***Juan Trippe*** **insisted on including a lounge on the upper deck (since there was additional space behind the flight deck) for First Class passengers. The flight deck was placed above, out of the way of the passenger deck to allow the nose to swing up for freighter configurations.**



"…Other builders are saying that Boeing's Jumbo Jets <u>aren't large enough</u>! Douglas is thinking about a 550-passenger DC-10 and Lockheed is talking about a gigantic L-500 that could carry from 750 to 900 passengers. Lockheed says its plane could fly you coast-to-coast for the price of a bus ticket, and make a profit. Or carry cargo at truck rates…"

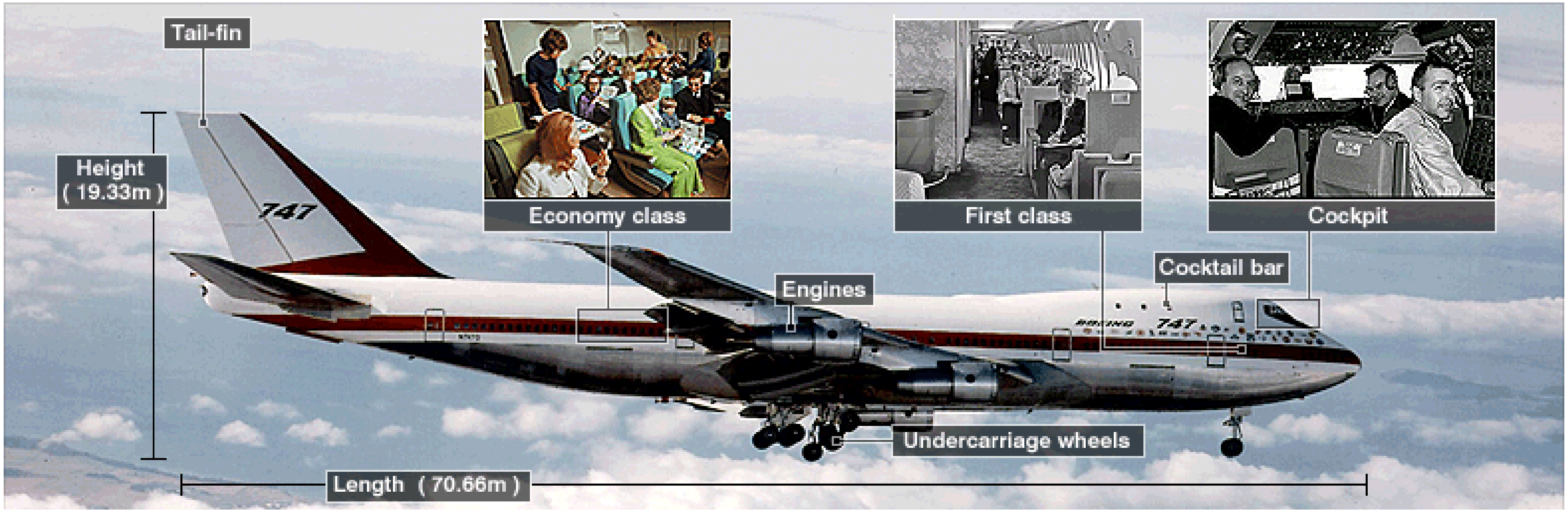
***Popular Mechanics,* September 1966**

<u>Above</u>: caption: "Concept Lockheed airliner from the 1970s – note the small 'children' airplanes attached to its wings"



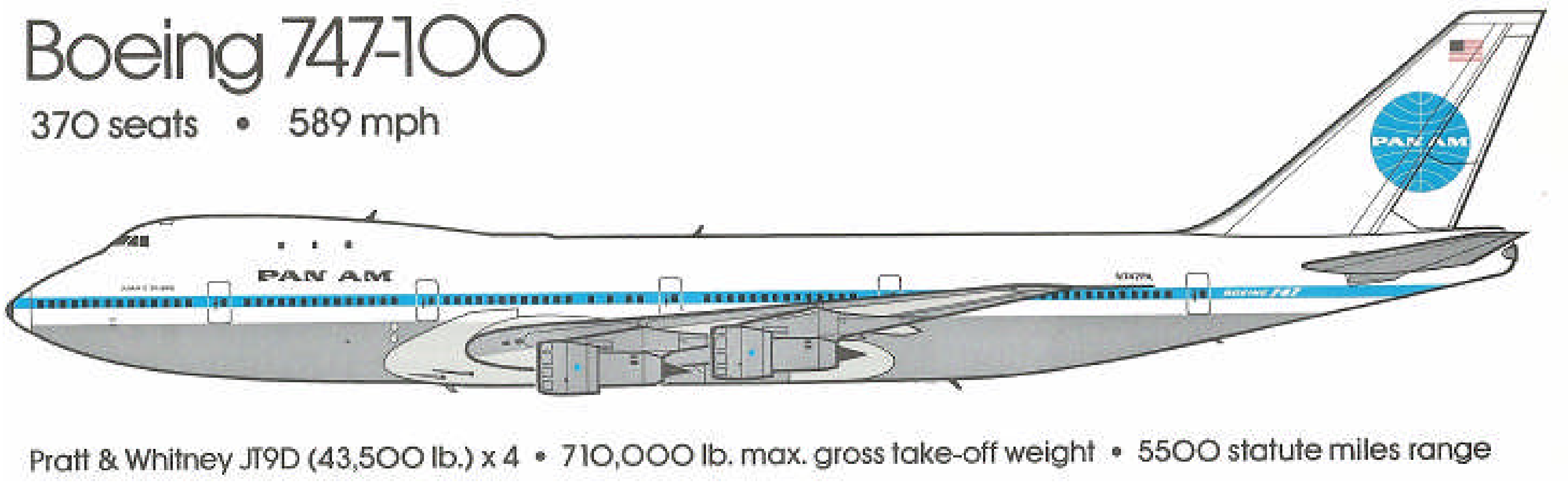
"…Trippe envisioned the 747 as a bridge aircraft which would carry the airlines through the adolescent years of the jet age until the supersonic transports, or SSTs, came along. He insisted on the double deck design for the jumbo, with the flight deck perched high above the main level, so that when the airplane had outlived its passenger-carrying days, it could readily be converted into a very economic cargo carrier. The nose cone would swing upward to reveal a nearly 200-foot straight-in main deck, accommodating cargo of a size and weight that would have been unthinkable just a few years earlier…"

Airways **magazine**



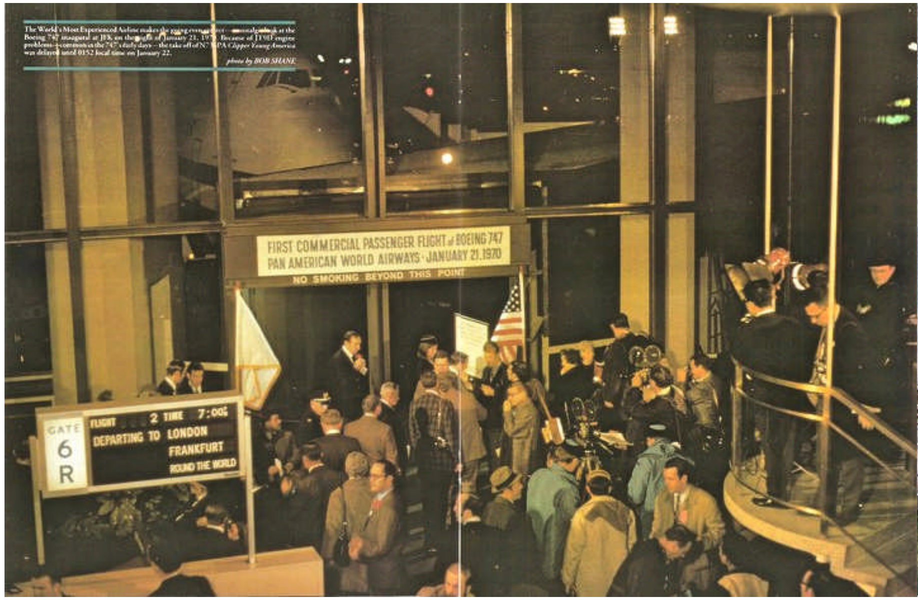
"…led the airline industry to a new generation of heavy duty transports…new standards of passenger comfort and convenience will be introduced. Simplified ticketing, computerized check-in and automated baggage handling will be provided. Pan Am's 747s will have two aisles and seat 366 passengers…"

RE: excerpt from PAA's 1967 Annual Report. The first 747-100s were built with six upper-deck windows (three per side). As airlines began to use the upper-deck for premium passenger seating instead of lounge space, Boeing offered a ten-window upper deck as an option. Some 747-100s were retrofitted with the new configuration.

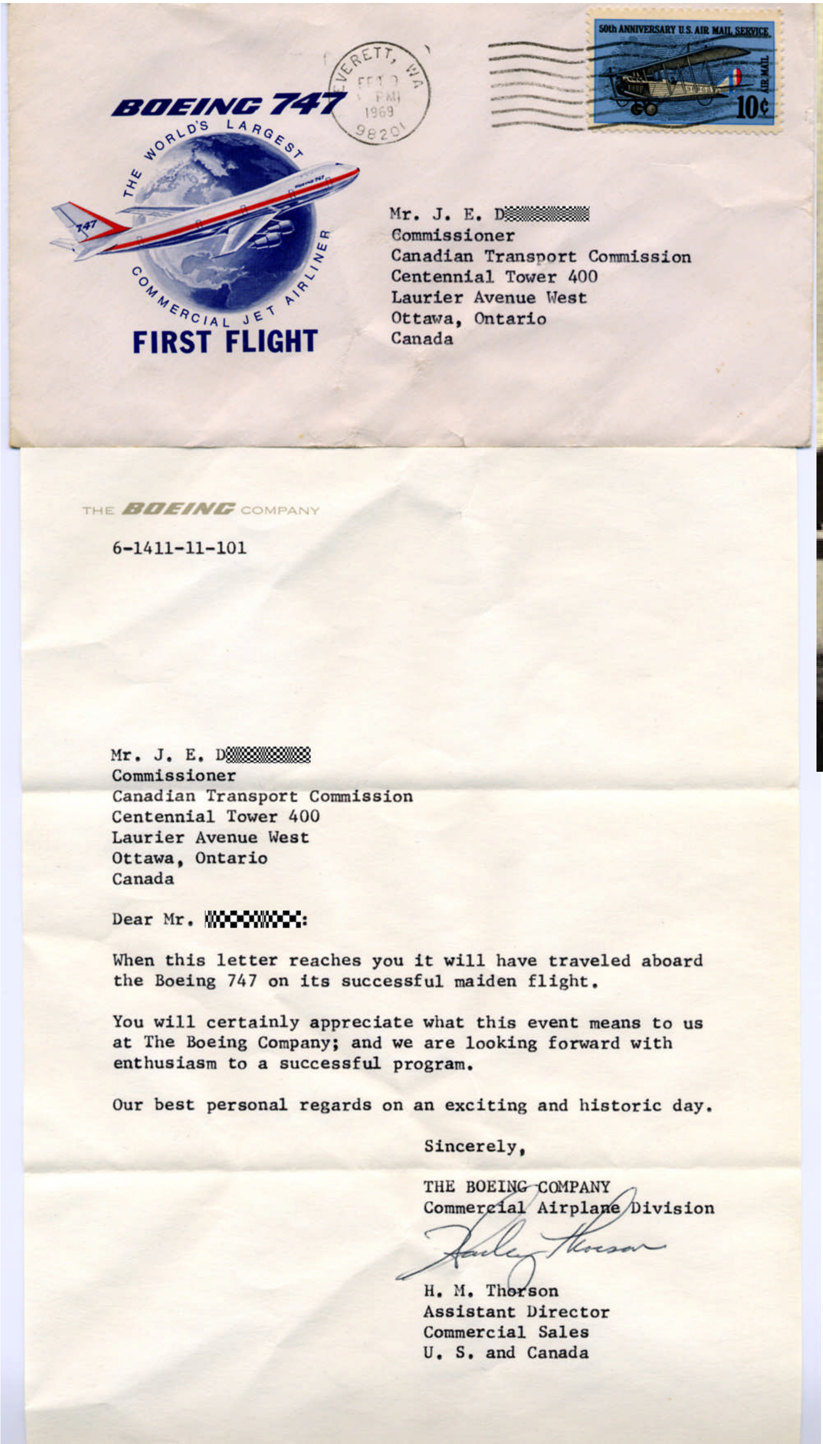


"…the year 1969 will mark the beginning of the second stage of the jet age - the time of the Boeing 747 and other wide-bodied, advance-technology jet transports. Pan Am again is the leader…Pan Am will be the first to put it into service to the major world markets we serve. Pan Am's fleet of thirty-three 747s will be the largest…Pan Am's operating and marketing plans for the 747 program have already been formulated. Ground facilities are also being prepared. The men and women of Pan Am at home and abroad will be ready to put the plane in service…"

RE: excerpt from PAA's 1968 Annual Report. The 747-100 was equipped with *Pratt & Whitney JT9D-3A* engines. No freighter version of this model was developed by Boeing. However, 747-100s have been converted to freighters. A total of 167 747-100s were built.



The first 747 was delivered on-time and was christened by First Lady *Pat Nixon* on January 15th 1970. Six days later - on January 21st 1970, the first commercial flight of a wide-body jet; *Pan American Airways Flight 2*, was scheduled for departure at 1900 hours for London Heathrow from New York JFK (left). The PAA Clipper *Young America* was assigned the honor of the first commercial flight of a 747. Unfortunately, an overheating engine delayed the departure, ultimately requiring that a stand-by air-craft (PAA's Clipper *Constitution*) make the first flight (right). Despite the delay, at 0152 hours on January 22nd 1970, the 747 departed NYC and arrived later that morning in London, completing the historic flight which opened the door to a new era of commercial aviation, making the Boeing 747 (with its distinctive "hump") one of the most recognizable aircraft in the world.



Mr. J. E. D[redacted]
Commissioner
Canadian Transport Commission
Centennial Tower 400
Laurier Avenue West
Ottawa, Ontario
Canada

THE BOEING COMPANY

6-1411-11-101

Mr. J. E. D[redacted]
Commissioner
Canadian Transport Commission
Centennial Tower 400
Laurier Avenue West
Ottawa, Ontario
Canada

Dear Mr. [redacted]:

When this letter reaches you it will have traveled aboard the Boeing 747 on its successful maiden flight.

You will certainly appreciate what this event means to us at The Boeing Company; and we are looking forward with enthusiasm to a successful program.

Our best personal regards on an exciting and historic day.

Sincerely,

THE BOEING COMPANY
Commercial Airplane Division

H. M. Thorson
Assistant Director
Commercial Sales
U. S. and Canada

"…When Pan Am's first 747 leaves Kennedy for London, passengers can rest assured that they are aboard the most thoroughly tested plane in the history of commercial aviation…

***Popular Mechanics,* December 1969**

<u>Left</u>: caption: "Boeing 747 'First Flight' letter"

"…The 747's maximum cruise speed is 625 mph, a 10 per-cent increase over the 575 mph of the 707. Thus, the flight time from New York to London will be reduced to five hours and forty-five minutes, slicing thirty minutes from current schedules. The 747 is rated for flying at 45,000 feet…"

***Popular Mechanics,* December 1969**

<u>Left</u>: caption: "The crew of a Pan Am Boeing 747 pose after it landed at London's Heathrow Airport"

ATLANTIC

Atlantic Services

U.S.A.
Austria
Belgium
Czechoslovakia
England

Germany
Iran
Ireland
Lebanon
Netherlands

Scotland
Turkey
Yugoslavia

1

Eastbound READ DOWN

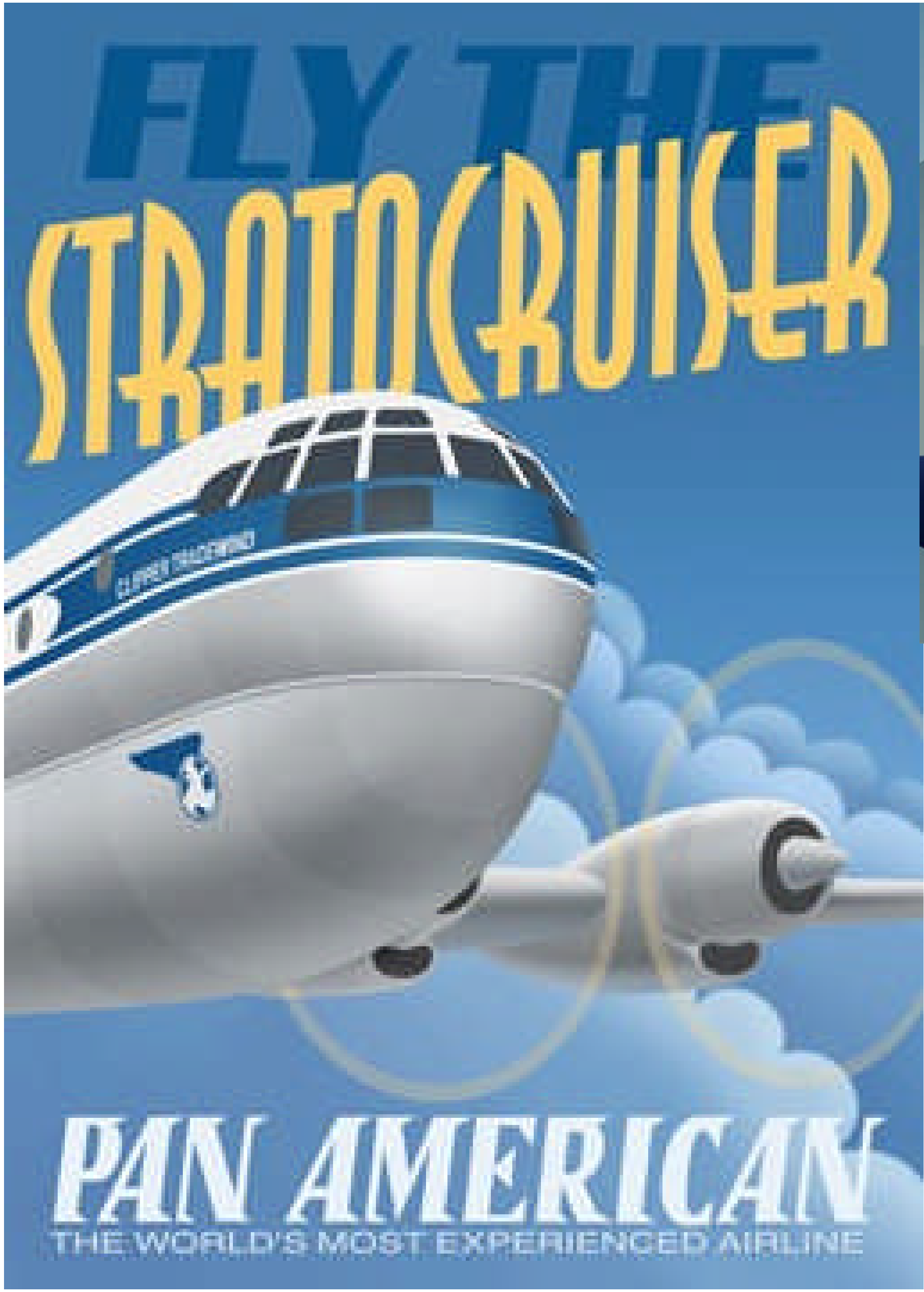
Hours from GMT														
	Class		FY	FY		FY		FY	FY	FY	FY	FY	FY	FY
	Flight No.		100	2		78		92	76	72	62	58	54	106
	Jet Aircraft		747	747		707		747	707	707	707	707	707	DC8
	Frequency		DAILY	DAILY MO WE FR	SU TU TH SA	TU	SA	DAILY	MO TH	DAILY	DAILY	DAILY	DAILY	DAILY
−6	Houston	LV	PAN AM'S 747									BN 13 00		
−6	Dallas	AR LV						PAN AM'S 747				13 45 14 30		
−6	New Orleans	LV		PAN AM'S 747										DL 13 20
−6	Chicago (O'Hare)	AR LV										16 30 PA 17 45		
−6	Minneapolis/St. Paul	LV											NW 14 15	
−5	Detroit (Metropolitan) (R)	AR LV											16 35 PA 17 30	
−5	Atlanta	AR LV												15 20 16 20
−5	Washington (Dulles)	AR LV												17 54 PA 18 45
−5	Baltimore (Friendship) (R)	LV									18 00			
−5	Philadelphia (R)	AR LV									18 45 19 45			
−5	NEW YORK (International)	LV	10 00	19 00	19 00	22 15	22 15	18 30	22 15	18 45				
−5	Boston (R)	AR LV							TU FR				19 10 20 00	
+1	Glasgow (Prestwick)	AR LV							10 40 11 30					
+1	Shannon	AR LV		TU TH	MO WE FR	WE 10 20 11 15	SU 10 20 11 15							
+1	London (Heathrow)	AR LV	22 40 23 40	SA 7 40 707 9 20	SU 7 40 707 9 20						8 30	8 25 9 45	8 35 9 35	7 55 8 55
+1	Amsterdam	AR LV						7 30 8 45					10 35	
+1	Brussels	AR						9 20						
+1	Hamburg	AR LV					13 15 14 15							
+1	Berlin (Tegel)	AR					15 00							
+1	Dusseldorf (Loh'sen) (i)	AR LV				13 00 14 00								
+1	Frankfurt (R)	AR LV	1 00	10 40 11 40	10 40 11 40					8 15 9 30		11 05		10 15
+1	Stuttgart	AR LV							13 30 14 30					
+1	Prague	AR				15 05								
+1	Munich (R)	AR LV								10 20 11 15				
+1	Vienna	AR								12 30				
+1	Belgrade	AR							16 00					
+2	Istanbul	AR LV		15 20 16 15	15 20 16 15									
+2	Beirut	AR LV		17 45 18 45	17 45									
+3½	Tehran	AR		23 00										

(R)—TRAFFIC RESTRICTIONS
Cities in U.S.A.—No wholly domestic traffic carried by PA between cities in the continental USA (except traffic between New York/Seattle/Portland and Alaska) and between cities served by PA on the East Coast of continental USA and Hawaii.
Frankfurt—Munich—No local or connecting traffic may be carried between Frankfurt and Munich.
All Flights operated by Pan American World Airways, Inc. PA/PAN AM unless otherwise indicated.

Jet—Boeing 747 Jet Clipper or Boeing 707 Intercontinental Jet Clipper or DC8 Jet Clipper.
FY—President Special—Rainbow Service (First-Economy Class). President Special provides the ultimate in First Class service.
BN—Houston—Dallas—Chicago portion operated by Braniff Airways.
DL—New Orleans—Atlanta—Washington portion operated by Delta Airlines.
NW—Minneapolis/St. Paul—Detroit portion operated by Northwest Airlines.
(i)—Dusseldorf also serves Cologne.
For explanation "How to use the Timetable" see page I.

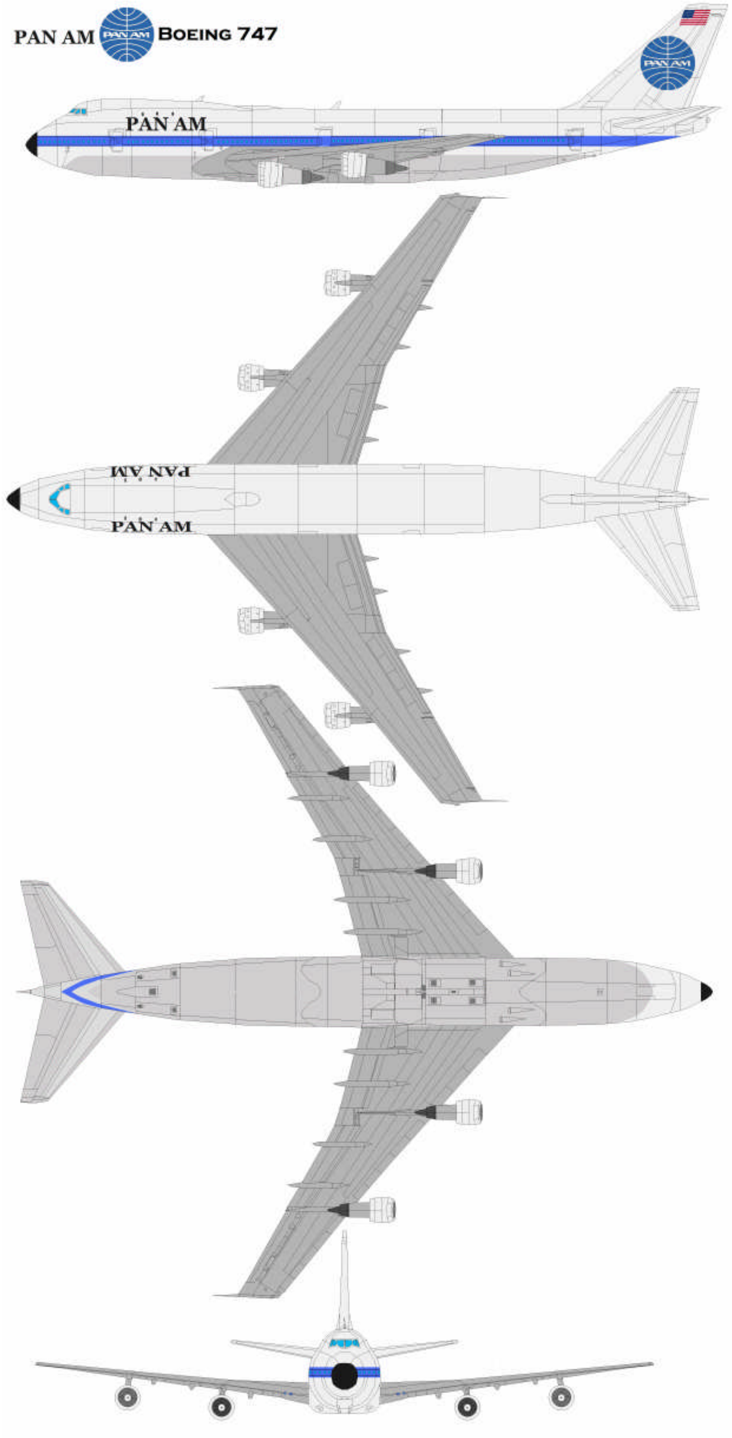

PAN AM

World’s Most Experienced Airline



"…And making great aircraft come true has been our way of life ever since the 1920s. Remember our China Clipper and our B-314 Flying Boats? Our B-377 Stratocruisers? Our 707 and DC-8 Jet Clippers were tremendous breakthroughs - and we've been in on many others. And look what's coming…"

RE: excerpt from a *Pan American Airways* advertisement (appearing in *LIFE* magazine in April 1967)



"...Take the Pan Am 747, for instance. Approximately two-thirds the length of a football field, it will make today's four-engine Jets look like baby brothers. The 747 will be 76 feet longer, 10 percent faster, twice as powerful. It will need almost 2,000 feet less runway on takeoff…"

RE: excerpt from a *Pan American Airways* advertisement (appearing in *LIFE* magazine in April 1967)

"…And when the day comes that you enter this elegant giant, you will rule out the word cabin. The interior will simply be too spacious for so small a word. And comfort will reign supreme. Our First-Class President Special section will consist of a lower deck with an honest-to-goodness bar and a spiral staircase leading to an upper deck…"

RE: excerpt from a *Pan American Airways* advertisement (appearing in *LIFE* magazine in April 1967)

The Plane That's a Ship

"…Our Rainbow Economy section will give you extra-wide seats for curling up, two extra-wide aisles for strolling about…"

RE: excerpt from a *Pan American Airways* advertisement (appearing in *LIFE* magazine in April 1967)

<u>Left</u>: caption: "Welcome to our first class section. Correction: Economy. It's not so easy to tell the difference in Pan Am's 747. The seats are wider, the leg room deeper, the ceilings higher. There are two aisles instead of one, with cabins as wide as most living rooms would like to be. There are even areas for non-smokers. And whether you want to watch a wide screen movie, listen to stereo music or just curl up and dream your way to Europe or the Caribbean or the Pacific or the Orient, you'll find an extra measure of service, all at no extra fare. Just ask a Pan Am Travel Agent to reserve you some space on the plane that's a ship…"

"…Surprisingly enough, the 747 will also be less expensive to operate. This will enable us to press for even lower fares than we have right now. And that will only be fitting, for without Pan Am's participation, there wouldn't be any 747s at all…"

RE: excerpt from a *Pan American Airways* advertisement (appearing in *LIFE* magazine in April 1967)

<u>Left</u>: caption: "Pan AM 747 art poster by Peter Max poster (1969)." PAA's advertisements of the era reflected the psychedelic (a/k/a "groovy") style of graphic art, then in vogue.

"…These, then, are the planes of tomorrow. We'll have more of them for you than any other airline. And they're all just over the horizon. World's most experienced airline. First on the Atlantic - First on the Pacific - First in Latin America - First 'Round the World."

RE: excerpt from a *Pan American Airways* advertisement (appearing in *LIFE* magazine in April 1967)

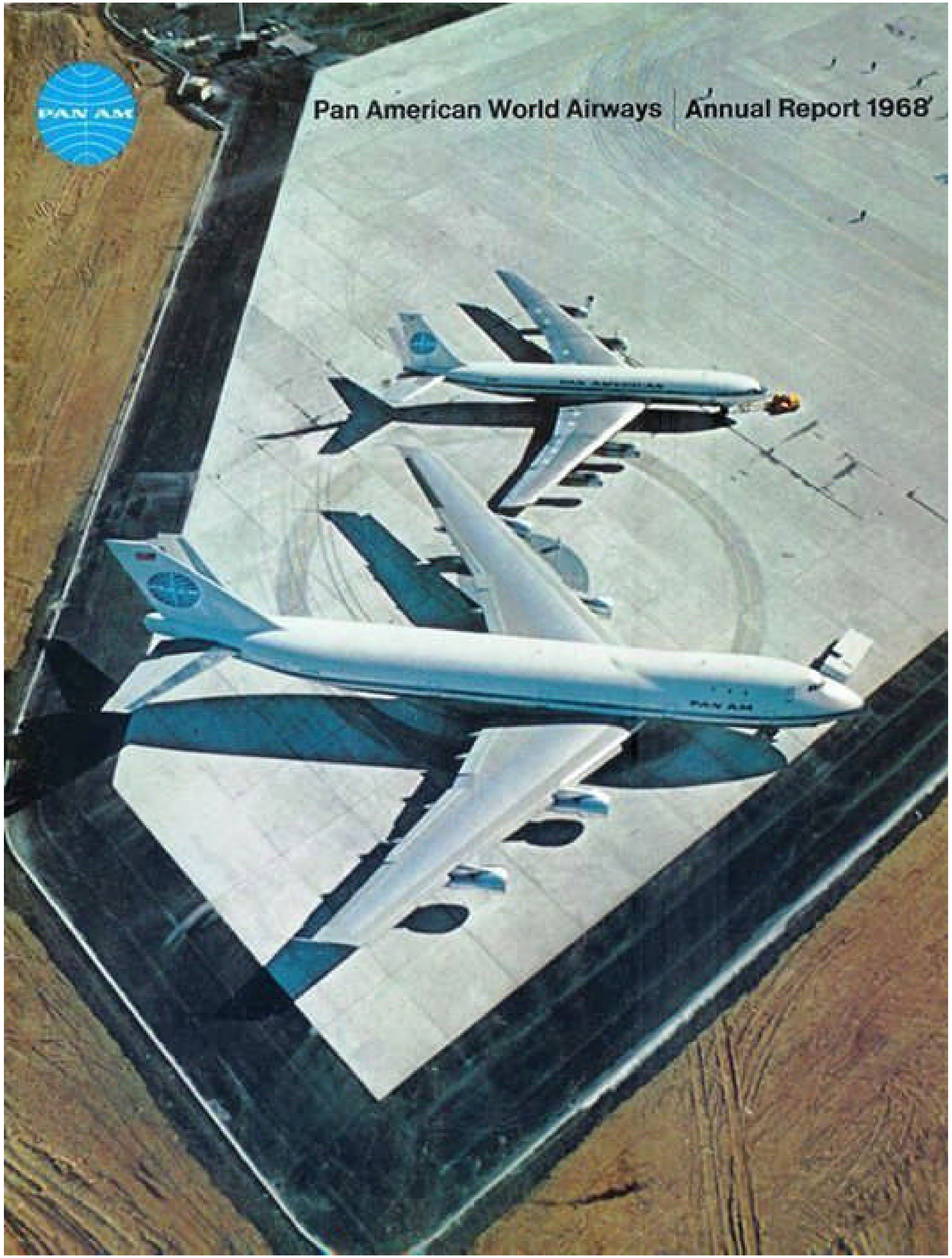
<u>Left</u>: caption: "Pan Am postcard with visual summary of their first fifty years"


Name
Tour Number
Pan Am's
World
747
747

Part 2

A Gee-Whiz Airplane

Registering Stupefaction



"Boeing engineers call their 747 the gee-whiz airplane. The reason: everyone who walks onto the assembly line at Everett, Wash., and sees his first 747 in shining aluminum is a cinch to utter at least one gee-whiz (or its equivalent) while registering stupefaction at the craft's size…"

Mechanix Illustrated, **November 1968**

RE: the *Boeing Company* didn't have a plant large enough to assemble the new 747 so they built an entirely new plant. Boeing considered locations in about fifty cities, eventually deciding to build the new plant about thirty miles north of Seattle, near Everett, WA.

<u>Left</u>: caption: "1968 Pan Am Annual Report - 747 and 707"

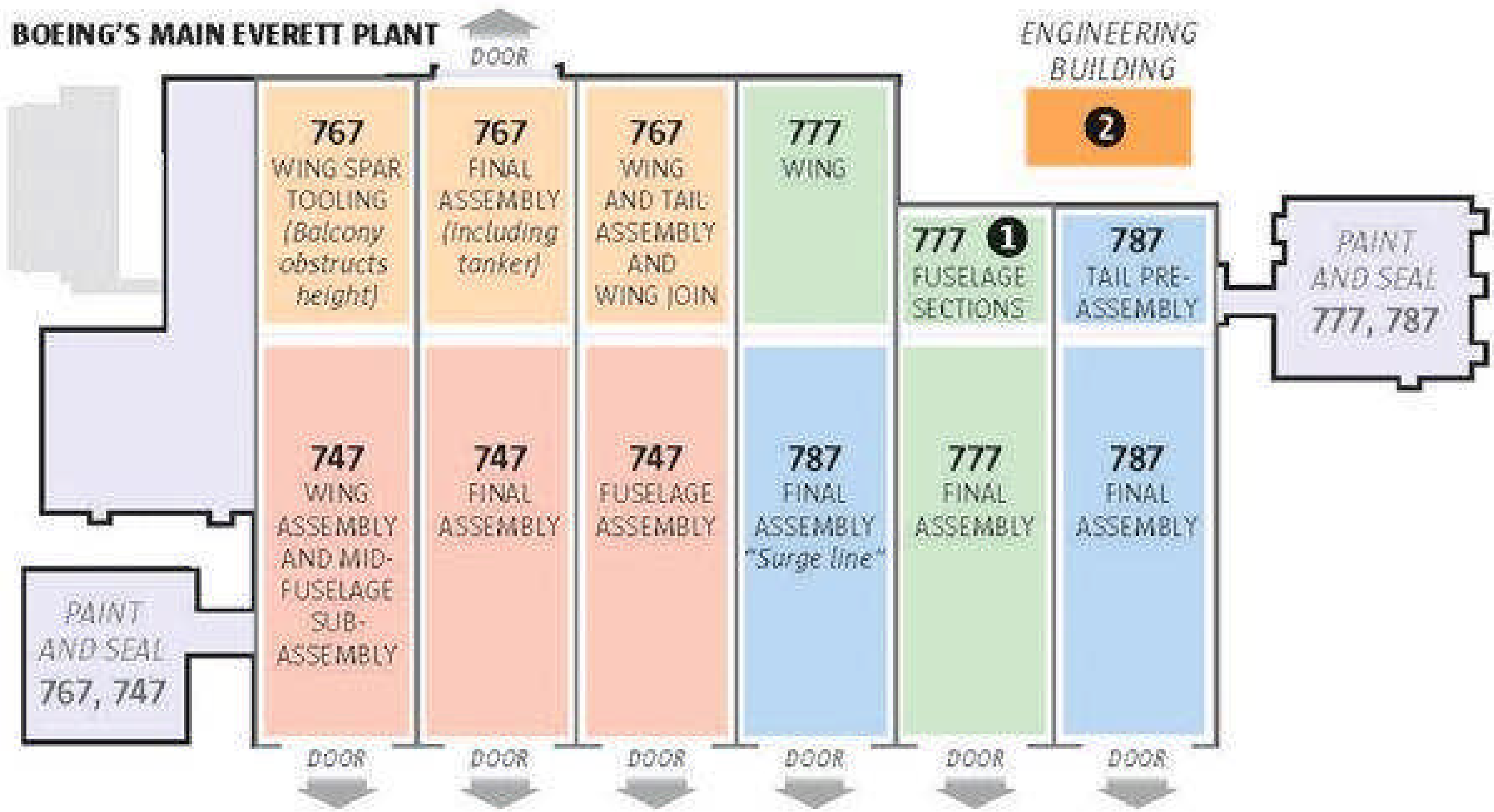
"…The introduction of the Boeing 747 represented a quantum leap in air transport technology and design. Twice as big as its predecessor the 707, the Jumbo not only dwarfed anything it might encounter on the world's airport ramps, but provided wonderful grist for anecdotal tales that were told among the airlines that were fortunate to have been at the head of the line to fly her…."

Airways **magazine**


Plans for the factory were first announced in 1966 for Everett to be the site for the construction of the 747 after Boeing was awarded a $525 million contract from *Pan American World Airways* to build twenty-five 747-100s. Boeing purchased 780 acres north of the then little-used *Paine Field*, which was operated by the U.S. Army during WWII (Boeing had a presence in Everett since 1943). Building the Everett assembly plant was nearly as challenging an undertaking as developing the airplane from scratch. To level the site, more than four million cubic yards of earth had to be moved. The plant remains the largest building (by volume) ever built, being substantially expanded several times to permit construction of later models of Boeing's wide-body commercial jets.

<u>Left</u>: caption: "Three 747s take shape at the Boeing Company plant at Everett, Wash."
<u>Right</u>: caption: "Workmen inspecting 747 are dwarfed by nose of aircraft and partly open door to baggage and cargo hold"

Twenty-two miles north of Seattle in suburban Everett, Wash., is Boeing's sprawling, ultra-modern airplane factory; massive, technologically sophisticated and vital to the world's aviation industry, What began as the birthplace of the world's first wide-body airliner, the iconic *Boeing 747* (appropriately named: "The City of Everett"), is now the site of where about 50% of the world's wide-body aircraft are produced. Nearly every Boeing wide-body airliner ever built; the 747, 767, 777 and 777, has been produced at Everett. It is recognized by the *Guinness Book of World Records* as the largest building in the world (by volume). Each factory door is the size of an NFL football field and seventy-five NFL regulation fields could fit within the footprint of the factory. Only the *Airbus* facility in Toulouse, France (where their wide-body planes such as the A380 are assembled) is comparable in size.


BOEING'S MAIN EVERETT PLANT
DOOR
ENGINEERING BUILDING
2
767 WING SPAR TOOLING (Balcony obstructs height)
767 FINAL ASSEMBLY (including tanker)
767 WING AND TAIL ASSEMBLY AND WING JOIN
777 WING
777 1 FUSELAGE SECTIONS
787 TAIL PRE-ASSEMBLY
PAINT AND SEAL 777, 787
747 WING ASSEMBLY AND MID-FUSELAGE SUB-ASSEMBLY
747 FINAL ASSEMBLY
747 FUSELAGE ASSEMBLY
787 FINAL ASSEMBLY "Surge line"
777 FINAL ASSEMBLY
787 FINAL ASSEMBLY
PAINT AND SEAL 767, 747
DOOR
DOOR
DOOR
DOOR
DOOR
DOOR


747
CITY OF EVERETT
RA001

At the time of its completion in 1968, the original *Boeing 747* factory at Everett - measuring 42.8 acres (1.9 million square-feet) and 205.6 million cubic-feet in volume, instantly became the world's largest building. Remarkably, the factory was so capacious, it began generating its own weather systems. A then state-of-the-art circulation system had to be installed because clouds (the product of accumulated warm air and moisture) were forming inside. Then as now, there is no climate control system for temperature. In the winter, machinery, body heat and residual heat from lights keep it warm while in the summer, the doors are opened to cool the building.

<u>Above</u>: caption: "A Boeing 747-200 on the assembly line (in 1972)"

<u>Top Left</u>: caption: Boeing Everett factory under construction, 1967"

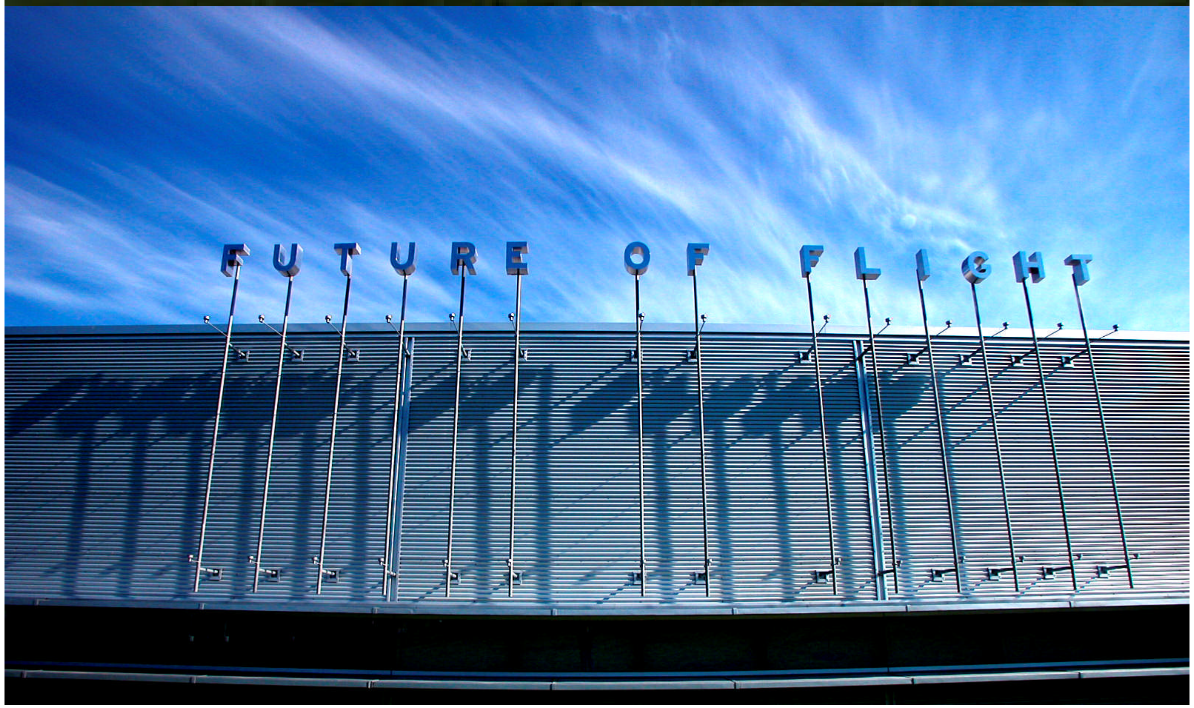
<u>Top Right</u>: caption: "Workers are dwarfed by the immensity of Boeing 747 jumbo jet nearing completion at the company's plant in Everett, Wash."

<u>Left</u>: caption: "The world's largest murals adorn the huge sliding Doors at the Everett plant"


BOEING


BOEING
WEST
EAST
Everett

<u>Left T&B</u>: Boeing's Everett, WA, facility is home to the 747, 767, 777 and 787 production lines. During the tour of the world's largest building by volume (472 million cubic-feet), visitors observe wide-body planes being built for Boeing's customers around the world. Unofficial tours began in mid-1967 and by the end of that year, 13K visitors had visited the still-under-construction plant. In response to the continuing demand, a *Boeing Tour Center* was established in 1968, thus beginning a tradition of offering free tours of the Everett factory complex. That year, 39,401 visitors came to see how Boeing was building the 747-100. The tour remains one of Washington State's most popular tourist attractions. The new *Future of Flight Aviation Center* and *Boeing Tour Complex* opened in 2005 (replacing an older facility built in the early 1980s to accommodate the nearly 110K visitors who visit each year). In 2007, Boeing welcomed the three-millionth visitor to the factory.


FUTURE OF FLIGHT


Rolls-Royce


TOURIST ACTIVITIES
Future of Flight
AVIATION CENTER
& BOEING TOUR

The Aluminum Avalanche

On January 3rd 1967, the first production workers reported to work at the new wide-body plant at Everett, WA. The idea was for the prototype to be built on the actual production assembly line (left). By May 1967, most tooling was complete and subcontracted parts arrived throughout the summer in what became known as "The Aluminum Avalanche." In September 1967, the wing skin-stringer riveting machine was loaded for the first time, marking the start of wing-build and the official beginning of the first ***Boeing 747-100*.**

Left: caption: "Body join on an early Boeing 747"

Roll-Out

On September 30th 1968, the first Boeing 747-100 was formally rolled out (top Left). Thousands of Boeing employees, the company's top brass and the world's press watched as flight attendant's (above, representing the 747's worldwide customers) christened the "City of Everett" in unison (sort of) with Champagne bottles (left). This first 747 weighed 710K pounds, well above the original (1966) estimate of 550K lbs.


747
BOEING 747


BOEING 747


BOEING
747

747


747
N7470

"…The following airlines will fly the Boeing Model 747:
- ***Pan American***
- ***Lufthansa***
- ***Japan***
- ***British Overseas***
- ***Trans World***
- ***Air France***
- ***Continental***
- ***American***
- ***Northwest***
- ***United***
- ***Alitalia***
- ***World***
- ***Irish***
- ***National***
- ***KLM***
- ***Air India***
- ***Eastern***
- ***Delta***
- ***Quantas***
- ***Swissair***
- ***SAS***
- ***Braniff***
- ***El Al***
- ***Air Canada***
- ***South African***
- ***Iberia***
- ***Sabena***
- ***Western***

RE: excerpt from a 1970 Boeing 747 brochure. Note the badges at the front of the fuselage (top) representing the airlines that had ordered the Jumbo up to that point in time.


Jack Waddell
Brien Wygle
Jesse Wallick
UNITED


AIR CANADA


British airways


Lufthansa


JAL
JAL


Alitalia
I-DEMA


AerLingus

THE RIGHT AIRCRAFT FOR THE FUTURE

The introduction of the Boeing 747 in 1971 was probably the most significant change in BOAC's operations since moving from flying boats to land planes. The aircraft was large by any measure needing not only a new Terminal 3 at Heathrow to handle large numbers of passengers but also the technical and engineering facilities to look after it. Commercially, it was a doubling of capacity compared to the 707 but BOAC was confident it could be operated profitably on its key routes, especially on the North Atlantic.

In April 1971 services began between London and New York quickly followed by services to Montreal and Toronto. Within six months results were above budget and twice the forecast operating surplus. There was no question that it was the right aircraft for the future.

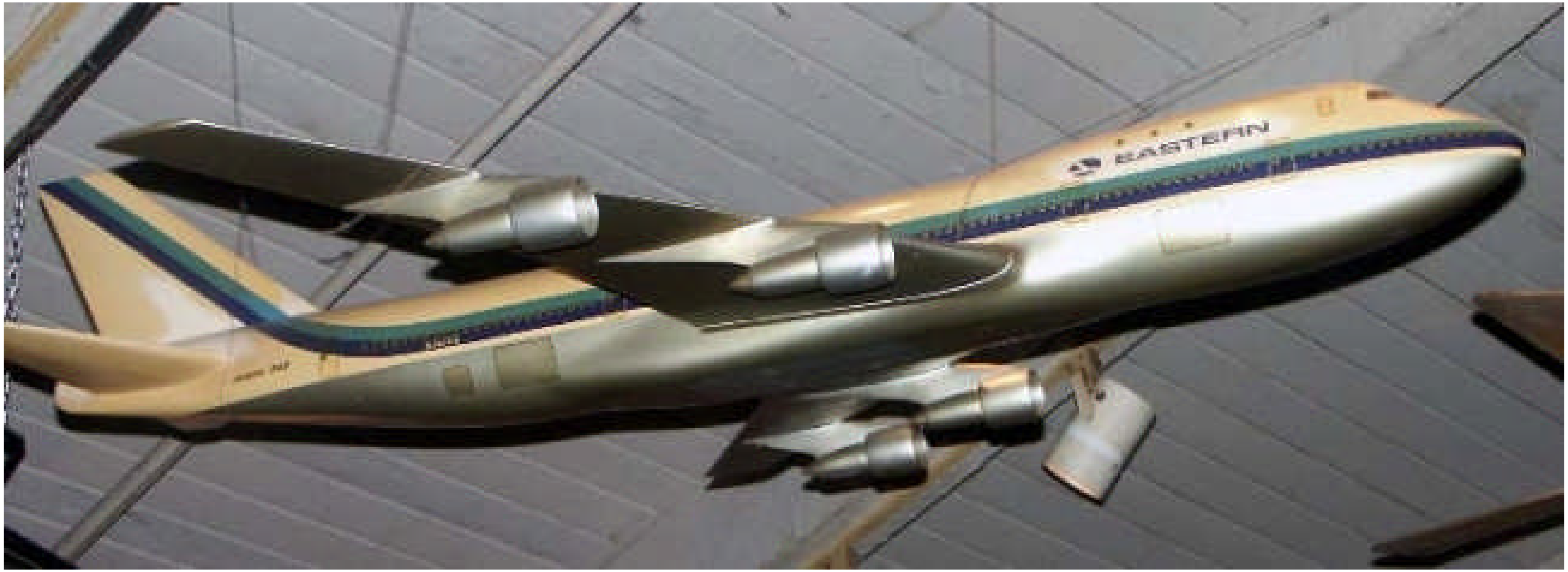
The 747 had introduced a reduction in unit costs that would become very important as competition with charter companies increased and the dividing line between scheduled and charter operations practically eliminated.


TWA
TWA


UNITED


DELTA
DELTA


AA
American



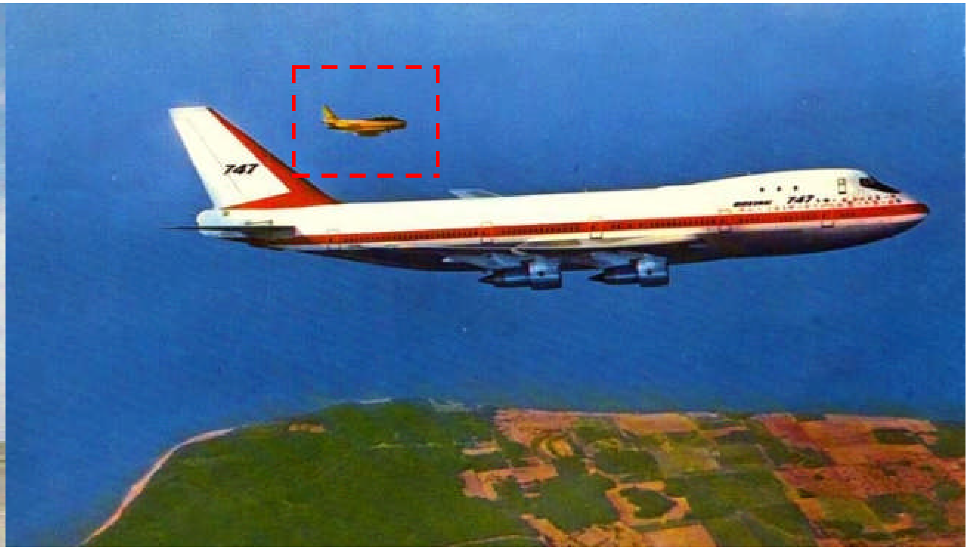
<u>Above</u>: caption: "Eastern Airlines Boeing 747 Model at Spirit Restaurant - Miami, Florida." EAL operated four 747-100s (leased from TWA) from 1970-73. The 747-100s were bought direct from Boeing, immediately sold to TWA and leased back to EAL. Like fellow Tri-Star launch customer Delta, EAL operated their 747s until the arrival of the delayed *Lockheed Tri-Star L-1011* in 1973. The EAL 747s mainly served the JFK-Miami and/or JFK-San Juan route/s.


EASTERN


CONTINENTAL


PAN AM

A Pilot's Dream



"The plane is ridiculously easy to fly, it almost lands itself...a pilot's dream"

***Jack Wadell,* 747 Project Pilot**

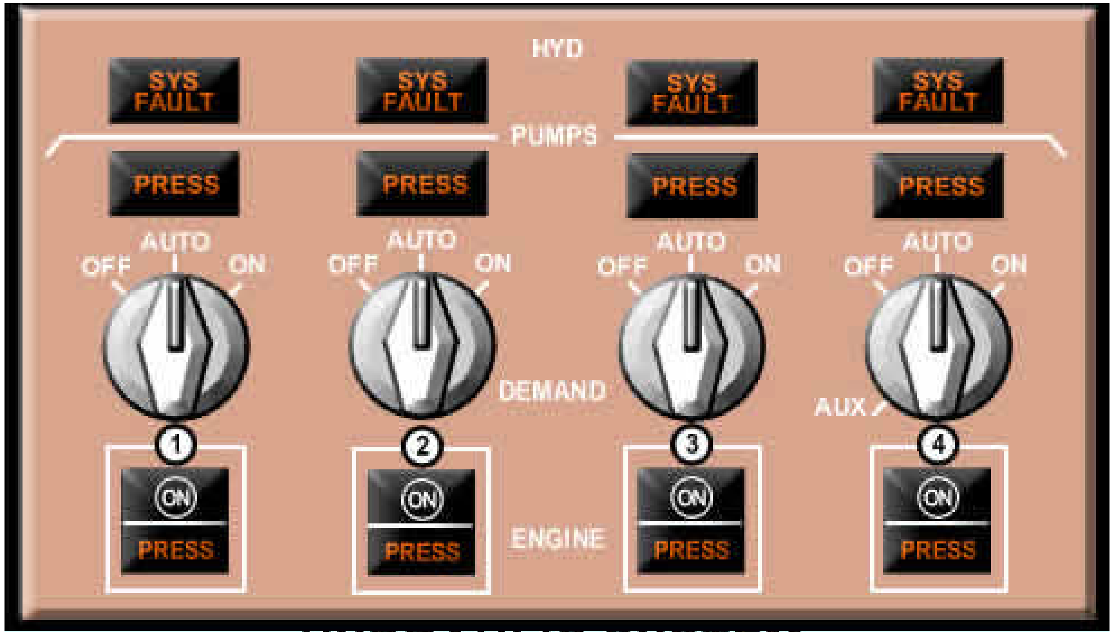
RE: comment made after first flight. At a length of 231-feet, some doubted whether the *City of Everett* prototype 747-100 would ever get off the ground. Even so, on February 9th 1969, with marginal weather and with test pilot/s *Jack Waddell* and *Brien Wygle* at the controls and *Jess Wallick* at the flight engineer's station, N7470 took off on the 747's first flight. Despite a minor problem with one of the flaps, the crew confirmed that the new Jumbo Jet handled extremely well, in fact it was a "pilot's dream" (according to Wadell). Production continued simultaneously with the flight-test program, though completion work on four of the original 747s happened in Renton, Washington (all completed before the end of 1969).

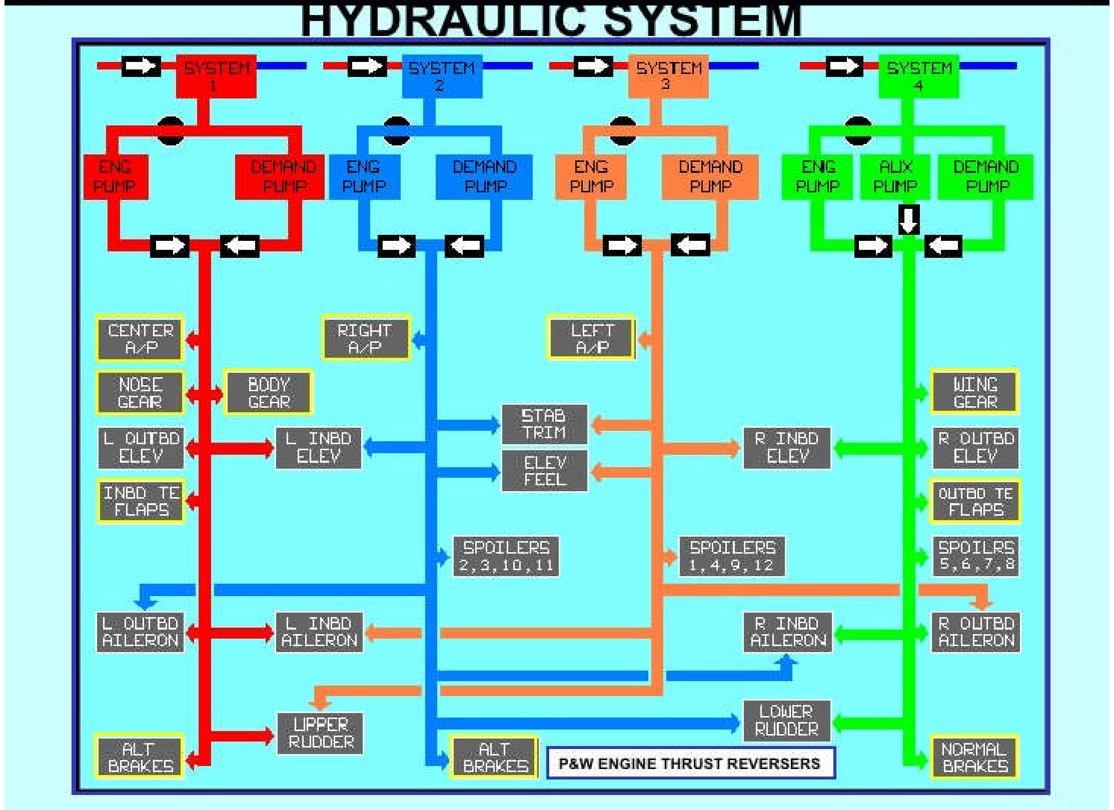
<u>Left</u>: caption: "Boeings experimental prototype 747 prepares for takeoff"

<u>Right</u>: caption: "The Boeing 747 prototype shadowed by Boeing's T-38 flies over the coast of Washington in 1969"

"It was a February day and there was snow on the edge of the runway, colder than hell. Nancy and Gabrielle went up with me to Everett and I had to go up to the radio room to listen to what the pilots were saying and so I took them out to the runway and I took them out to a position…and told Nancy, 'The airplane's wheels will leave the ground right here,' which they did."

Joe Sutter, **747 Project Chief Engineer**



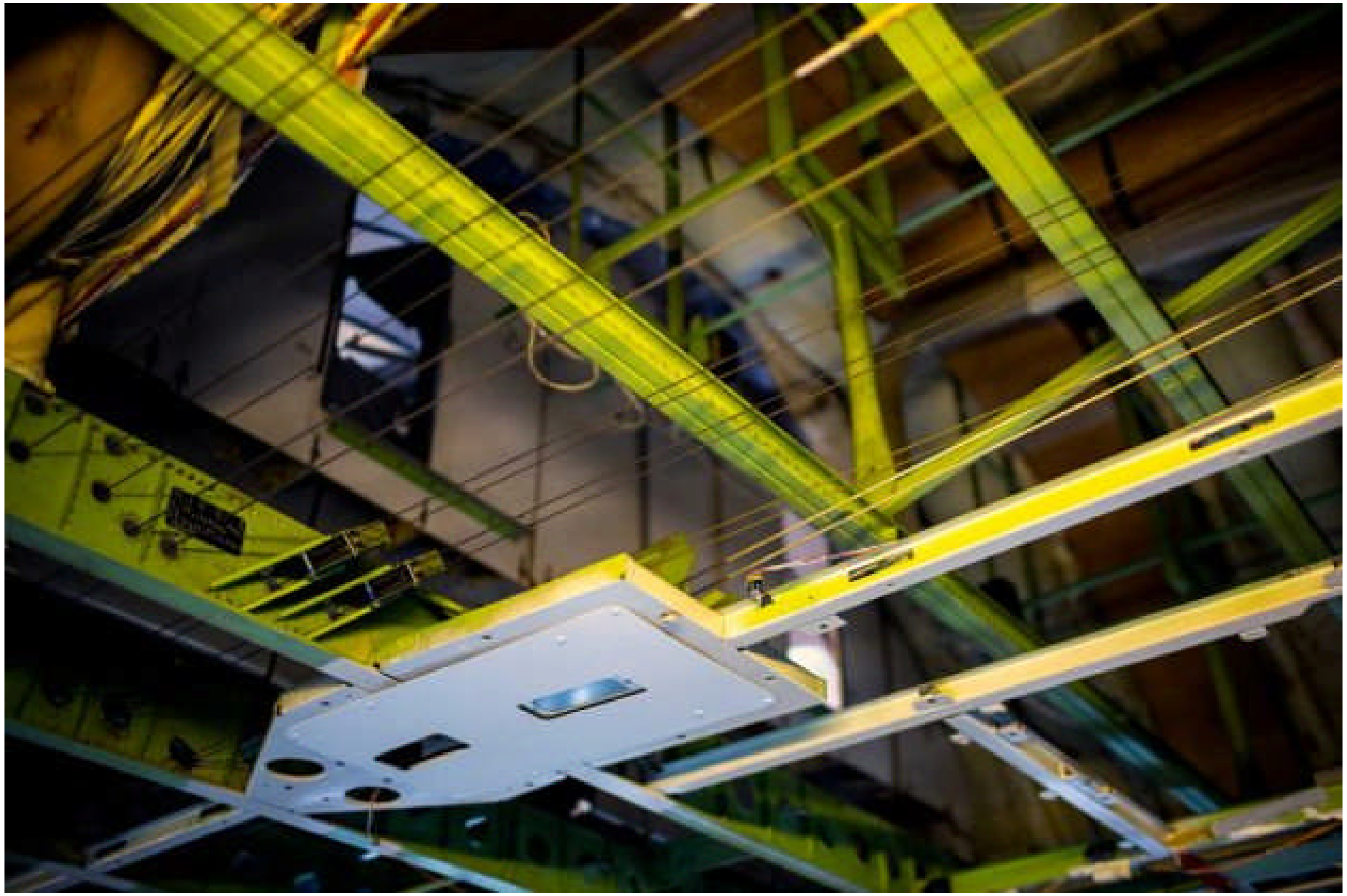


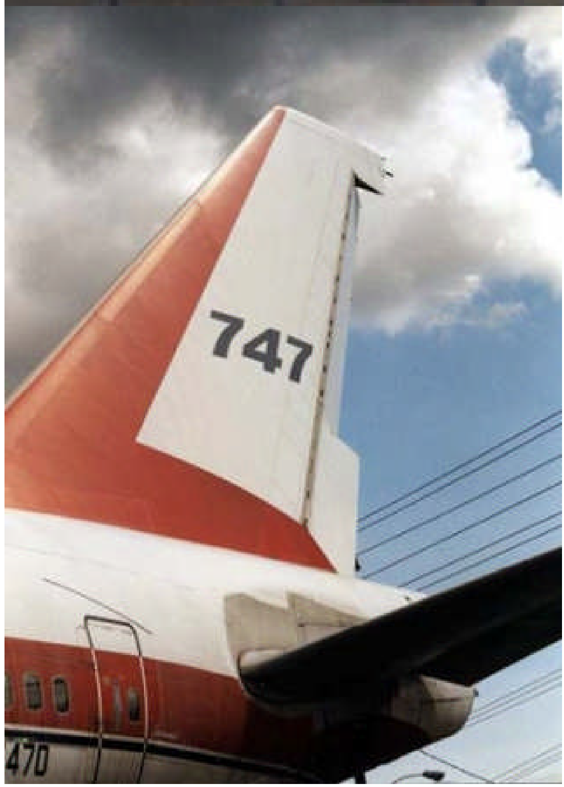
"…The 747 is simply too big to control manually. Since there are no manual controls to fall back on in the event of a power-assist system failure, Boeing has put in four independent hydraulic systems to actuate primary controls. In test flights, the plane has been flown with three of the systems shut-off…"

***Popular Mechanics*, Dec. 1969**

<u>Top</u>: caption: "B747-400 Hydraulic System Controls"

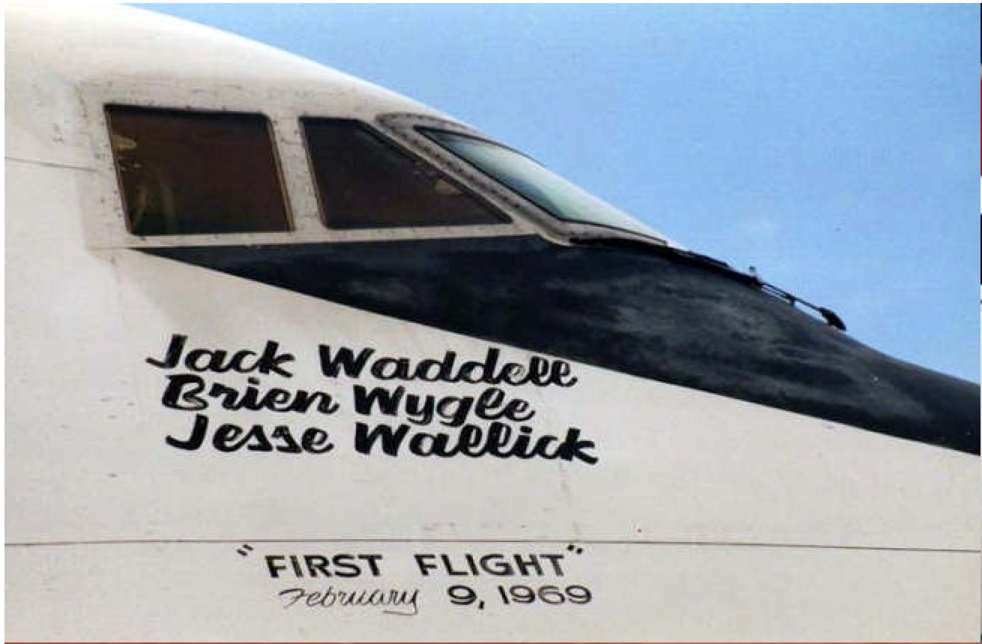
<u>Bottom</u>: caption: "B747-400 Hydraulic System Schematic"





<u>Above</u>: still wearing it's original color scheme, the first 747 can be found in a parking lot adjacent to the *Museum of Flight* at Seattle's *Boeing Field*. After the first flight on February 9th 1969 and subsequent flight-testing, N7470 never entered commercial service. Even after being donated to the Museum of Flight (in 1990), it was recalled into service twice (to serve as an engine test-bed for the 777 program). The original crews names are located on the fuselage just below the port and starboard flight-deck window/s.

<u>Left</u>: tail section of the N7470


Jack Waddell
Brien Wygle
Jesse Wallick
"FIRST FLIGHT"
February 9, 1969


N7470


Experimental

<u>Above</u>: caption: “A giant reel used for the trailing static cone system that would be deployed behind the first Boeing 747 in flight is shown board the jet at The Museum of Flight.”

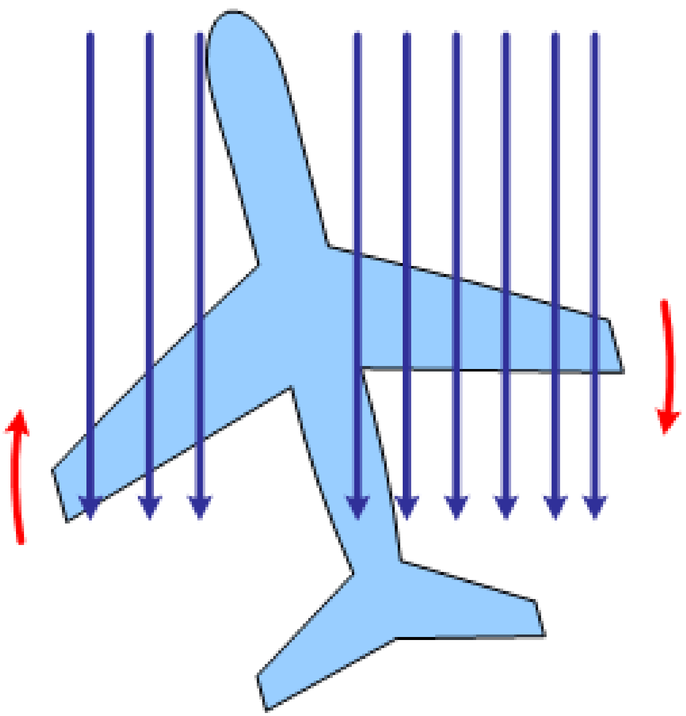
<u>Left</u>: caption: “This display in the forward section of the main cabin of the first Boeing 747 holds an early concept model of the 747 as a double-deck airliner”

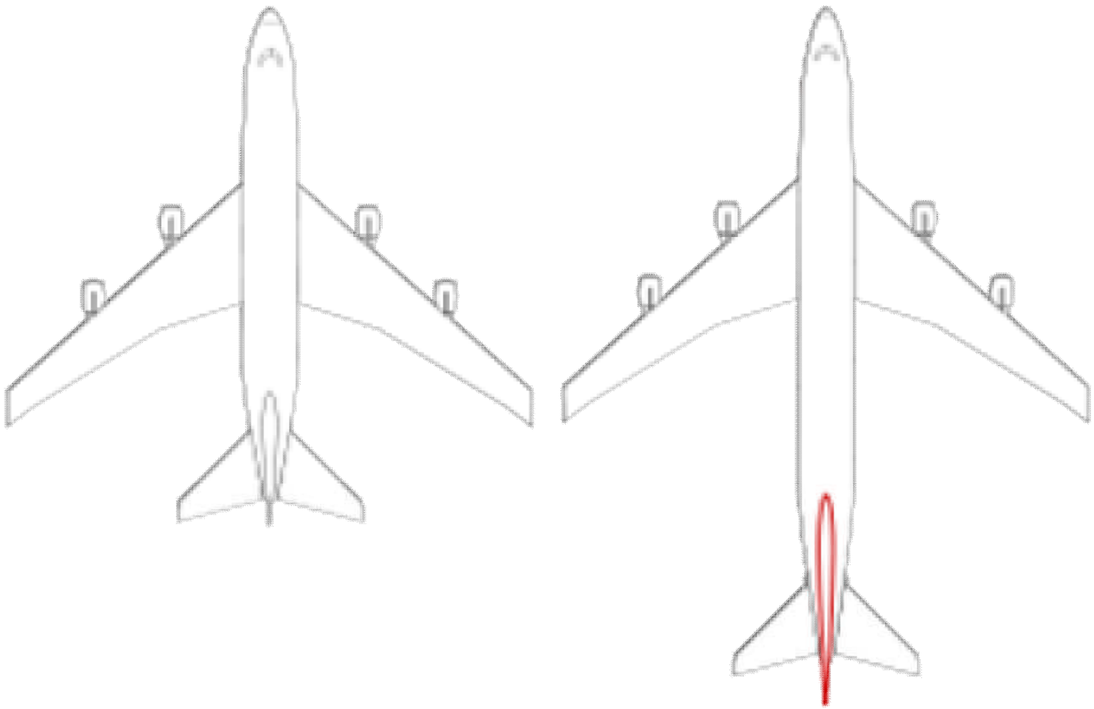
<u>Above</u>: the prototype Boeing 747 *City of Everett* (N7470) on display at *The Museum of Flight*, *Boeing Field*, Seattle, WA. Parked behind it are an *American Airlines Boeing 727-223* (N874AA) and the prototype *Boeing 737-130* (N73700), retired from NASA service. The three vertical fins of a *Lockheed L-1049G Super Constellation* (CF-TGE) are visible in the lower right corner.

"The question was whether a pilot could manage a plane this big with the same margins that he has had in past airplanes. Well, the evidence that we have gained from flying the 747 – and this includes our experience but that of the FAA, military and other non-Boeing pilots – is that it is as easy to operate as other planes. We've had nothing but good landings out of people on the very first try…" 130

***Jack Wadell,* 747 Project Pilot**

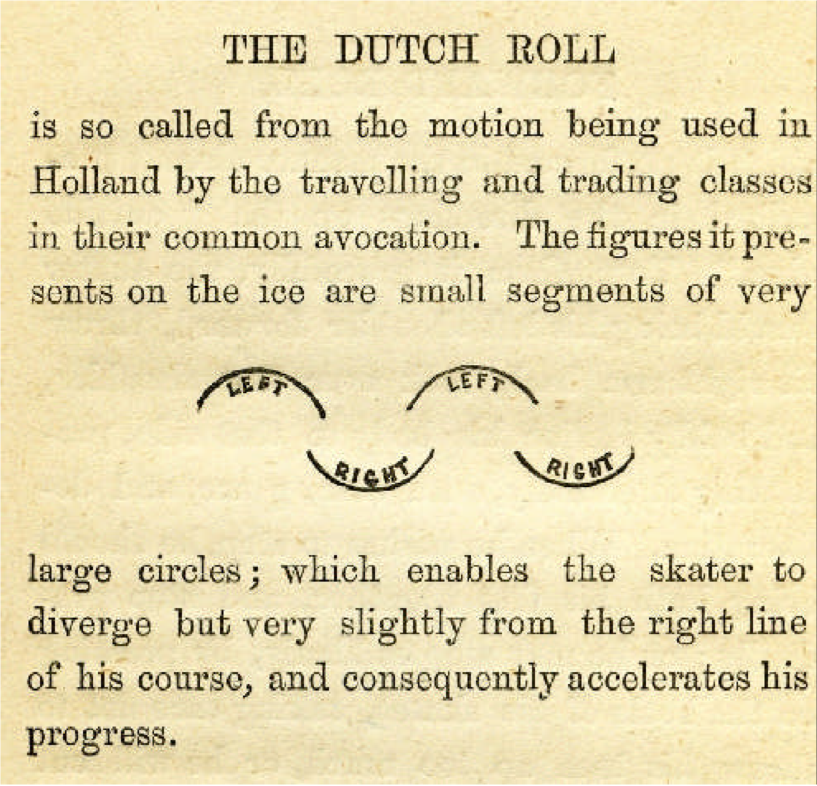
__Above__: **the *City of Everett* was rolled out of the Everett assembly plant on September 30th 1968, before the world's press and representatives of the twenty-six airlines that had ordered the unproven plane. Over the following months, preparations were made for the first flight. Despite a minor problem with one of the flaps, the first flight confirmed that the 747 handled extremely well. The giant airliner was found to be largely immune to "Dutch Roll," a phenomenon that had been a major hazard to the early swept-wing jets. Later, N7470 served as a test-bed for 747 systems improvements and new engine developments for other Boeing commercial jets. Its last flight was in the late 1990s.**





<u>Left</u>: caption: “As right wing migrates forward (yaw), sweptback design produces a simultaneous increase in lift. As the wing’s lift increases, induced drag increases, induced drag increases, resulting in wing returning rearward.” Most aircraft are designed with *swept* wings (both wings have a backwards sweep). This is the primary mechanism that gives the roll effect to an airplane that may only receive a yaw input. If a yaw is introduced to the aircraft (lateral motion), one wing will extend out more directly into the wind-stream, while the other wing will be even more swept back. This effectively makes one wing longer, and the other wing shorter. The longer wing will generate more lift and the shorter one will generate less lift and since there is unequal lift around the roll axis, the airplane will roll, and continue to roll. With more lift comes more drag which will counter the lift and pull the wing back causing an effect known as ‘Dutch Roll’ - a type of aircraft motion consisting of an out-of-phase combination of ‘tail-wagging’ and rocking from side-to-side. Many aircraft have a device called a ‘yaw damper’ to counter this motion.

<u>Right</u>: caption: “Left: low rate stability (directional stability); Right: high rate stability; Increasing the rate stability, by increasing the vertical tail (red) and/or extension of the rear fuselage. The wings are arranged in relation to the front length of the aircraft thus, the aerodynamic center-of-gravity moves relatively forward.”

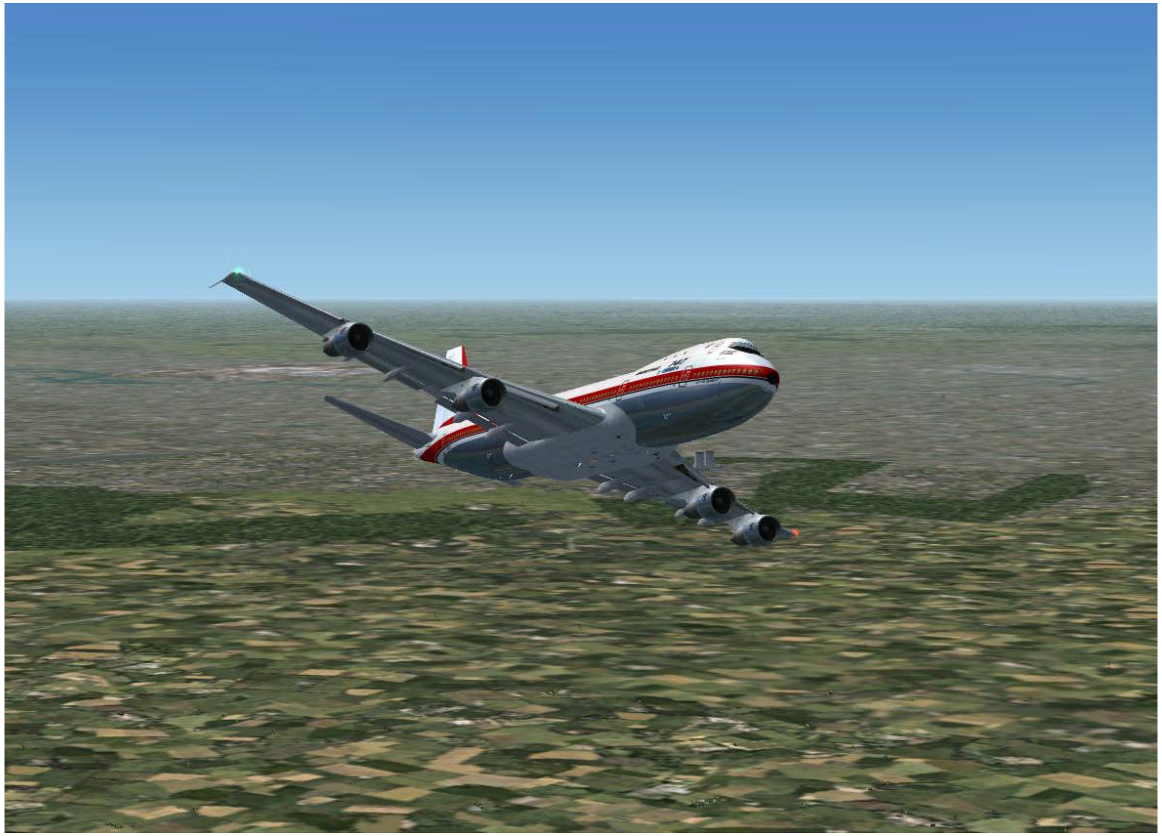

THE DUTCH ROLL

is so called from the motion being used in Holland by the travelling and trading classes in their common avocation. The figures it presents on the ice are small segments of very

LEFT LEFT
RIGHT RIGHT

large circles; which enables the skater to diverge but very slightly from the right line of his course, and consequently accelerates his progress.

<u>Left</u>: in 1916, "Dutch Roll" was the term used for skating repetitively to the right and left on the outer edge of one's skates. In 1916, aeronautical engineer *Jerome C. Hunsaker* published the following quote: *"Dutch roll - the third element in the lateral motion of an airplane is a yawing to the right and left, combined with rolling. The motion is oscillatory of period for 7 to 12 seconds, which may or may not be damped. The analogy to 'Dutch Roll' or 'Outer Edge' in ice skating is obvious."* The term thus became associated with aeronautical engineering to describe a lateral, asymmetric motion of an airplane from that time forward.
<u>Right</u>: the sweptback wings placed well above the center-of-mass of the *Boeing B-47 Stratojet* strategic bomber tended to increase the roll restoring force, therefore increasing its Dutch Roll tendencies



Part 3

The Superjet Era

The Boeing Hilton

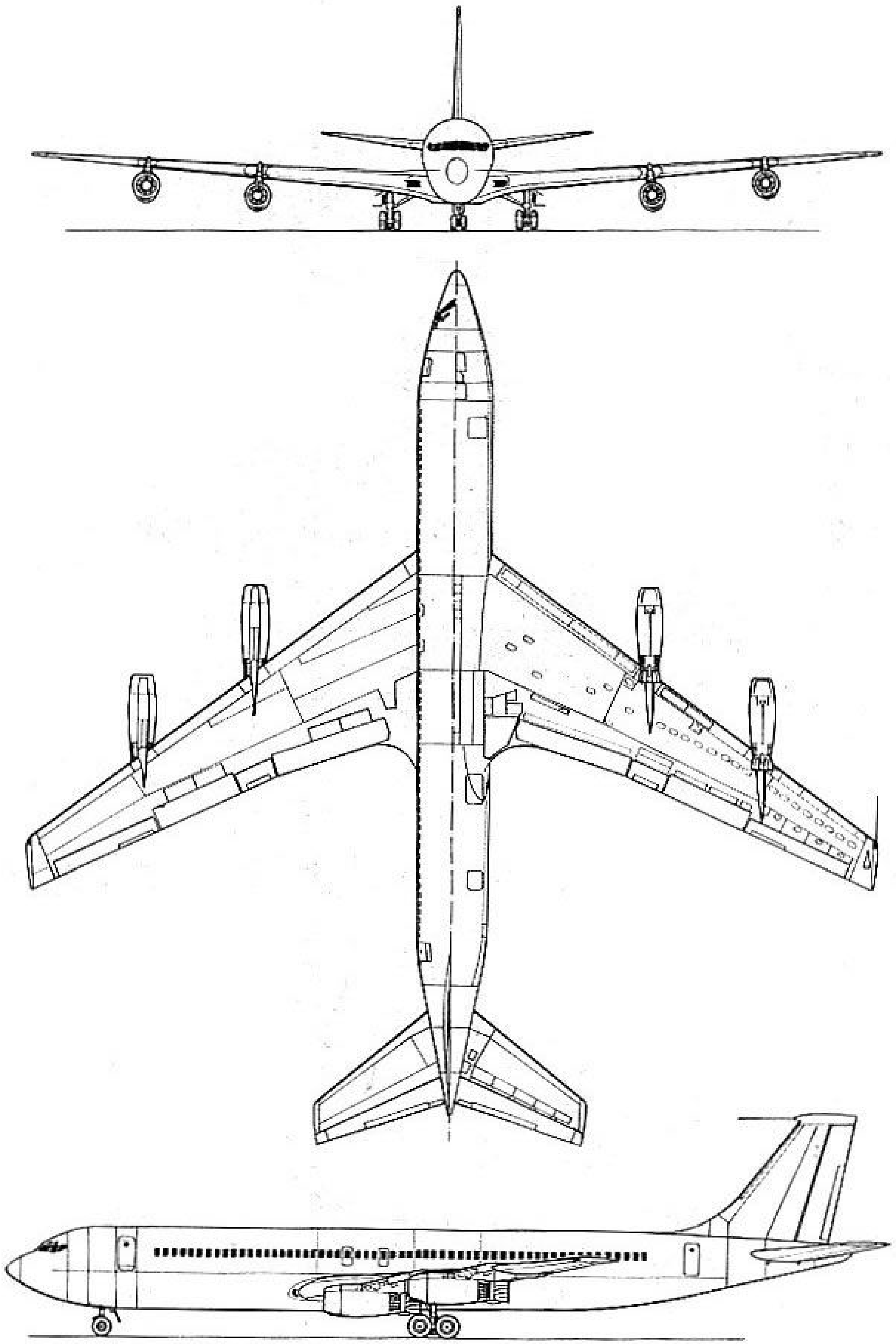
“They’re calling it the ‘Boeing Hilton,’ unofficially, because this enormous, new airliner will be able to carry 490 people, the capacity of a good-sized hotel. There’s room on board for private staterooms plus a big lounge up forward. ‘Economy’ seats will be large and luxurious. If an airline desires, the builder will install a separate motion picture area and even a special playroom for children!...”

***Popular Mechanics,* September 1966**

"…After being appropriately overwhelmed by the aircraft's size and technical virtues we can report with some authority on what flying will be like in the Superjet era almost upon us. It's closer than most folks realize. The 747 is scheduled to be airborne in test flights this month or next, and should open its doors to as many as 490 passengers per flight in scheduled service by late 1969…"

Mechanix Illustrated, **November 1968**

<u>Above</u>: caption: "Clipper America, the Boeing 707-121 that opened the commercial Jet Age. Christened by First Lady Mamie Eisenhower, October 1958"



<u>Above</u>: caption: "Boeing 707 cut-away diagram"
<u>Left</u>: caption: "Boeing 707 schematic diagram"

<u>Above</u>: the Boeing 707's interior
<u>Left</u>: Boeing 707 period ad (ca. 1958)

Dig It

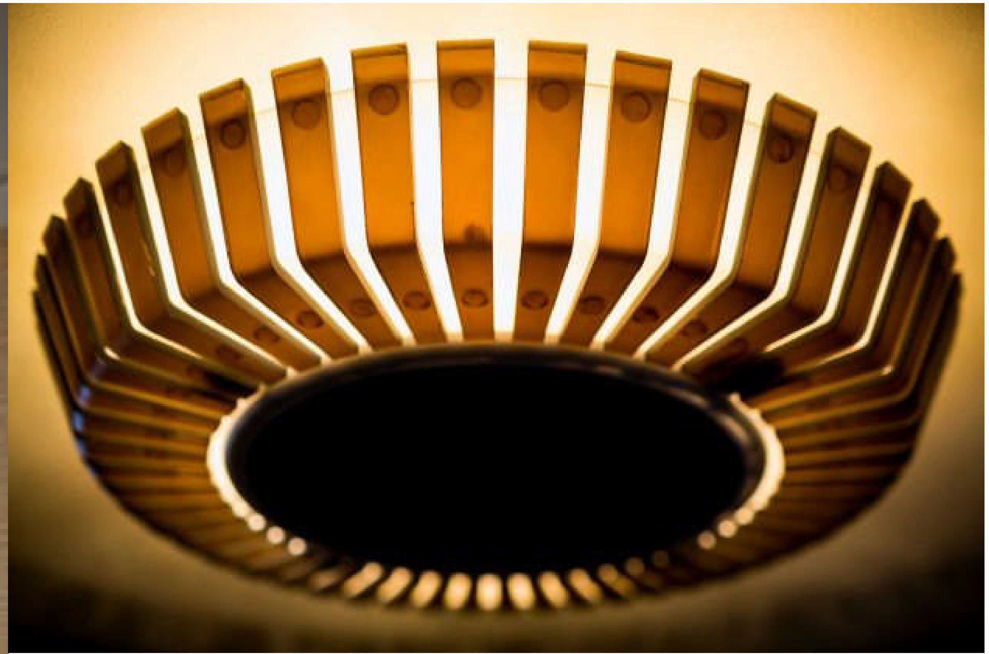
"…Boeing opened all the doors. What we saw was convincing evidence that air travelers will dig the 747. We wandered through interior mock-ups ranging from a swank, private club-like lounge through ten-abreast seating, climbed through the bowels of 747s in construction, scrambled along scaffolding under slender, graceful wings that seemed to go on forever, and climbed a ladder to the tip of the tail - the equivalent of a six-story building…"

Mechanix Illustrated, **November 1968**

<u>Above Left</u>: caption: "Full-scale mockup shows use of aisles to seat and serve passengers in economy class"

<u>Above Right</u>: caption: "First-class section has plenty of walking-around room in this tentative configurat-ion"

<u>Left</u>: caption: "Spiral staircase leads to first-class lounge"



The Museum of Flight **got Boeing to dig up a custom bulb for the unique circular chandelier (above) at the top of the spiral staircase (left) to the upper deck of the original Boeing 747 prototype now on display.**

A Celestial Cocktail Party

"…There were piano bars (an innovation that briefly came to pass with at least one jumbo operator) and movie amphitheaters, a Radio City in the sky. Passengers would be able to pass to and fro, as though attending a wonderful, celestial cocktail party…"

Airways **magazine**


Boeing 747 Coach
Lounge Piano



You won't believe you're on an airplane.
American Airlines New Coach Lounge.
American Airlines New 747 LuxuryLiner.
The plane with no competition.

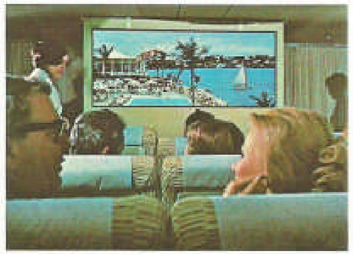
747 INTRODUCES NEW LOOK IN COMFORT AND SERVICE

When Pan Am places the first 362-passenger 747 in commercial service, air travel will enter a new phase in terms of service and speed, comfort and convenience. The 747 will be the largest, fastest and most luxurious airliner in the history of aviation. The interior of the 747 creates the atmosphere of a living room in the sky with roomy seats, extra-wide aisles, thick carpeting, high ceiling, six galleys, 12 rest rooms, six separate movie screens and an upper deck lounge.

Dome-shaped lounge on upper deck of 747 features swivel seats and banquettes

Circular stairway leads from First Class section to lounge on upper deck

Two 20-inch wide aisles run full length of Economy section

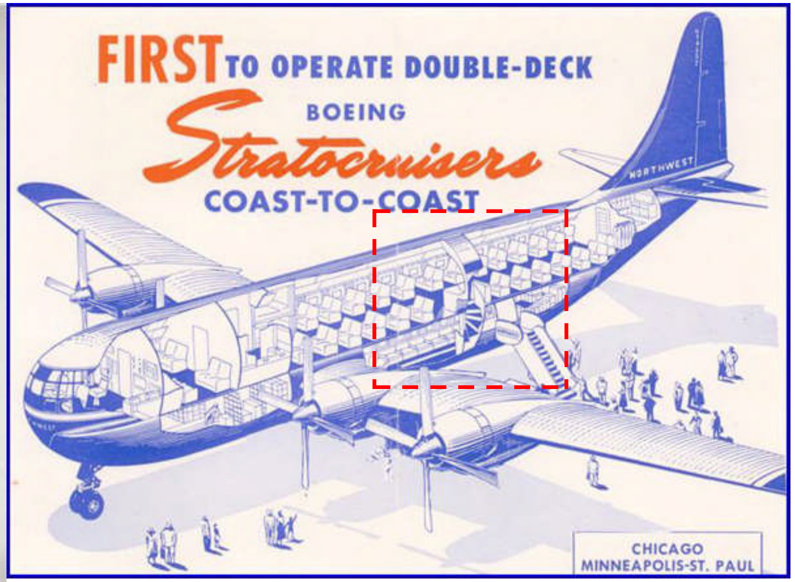


Pan Am's 747 Theater-in-the-Air has advanced large-screen color system

First Class in 747 resembles salon with service bar and roomy two-seat units

The 747 will provide economy passengers with greater comfort than ever before possible. Economy seats in 747 are 10 per cent wider than in 707

<u>Left</u>: caption: "747 Introduces New Look in Comfort and Service. When Pan Am places the first 362-passenger 747 in commercial service, air travel will enter a new phase in terms of service and speed, comfort and convenience. The 747 will be the largest, fastest and most luxurious airliner in the history of aviation. The interior of the 747 creates the atmosphere of a living room in the sky with roomy seats, extra-wide aisles, thick carpeting, high ceiling, six galleys, twelve rest rooms, six separate movie screens and an upper deck lounge."



Previously, Boeing used a spiral staircase in its *Model 377 Stratocruiser* (above & left). On the 747-100 and -200 models, a spiral staircase connected the main deck with the upper deck.

<u>Above</u>: caption: "First-class passengers being served in upstairs dining room on a Pan Am 747"

<u>Left</u>: caption: "Pan Am's big 747s have a first class dining room upstairs – the only one in the air. It's not just another restaurant but a very special place to dine, with the kind of food you'd expect among the stars. There's a full menu to choose from – the roast beef, freshly cooked, is carved at your table. And there is a selection of fine wines and liquers. Like all the best restaurants, you have to book early. So ask your Travel Agent to reserve your table when he books your flight across the Atlantic. It's all part of Pan Am's World."

The Spacious Age

"…In cold figures, basic dimensions are: wingspan 195 ft. 8 in., length 231 ft. 4 in., height 63 ft. 5 in. (compared to the 707, the 747 is 79 ft. longer, 21 ft. higher and has 50 ft. more wingspan). When we stood inside the main cabin and gazed along its full 185 ft. of interior length, the size began to sink in. Want a wild comparison? The Wright brothers could have made their first flight here - with plenty of room to spare…"

***Mechanix Illustrated,* November 1968**

<u>Left</u>: caption: "…Boeing's smallest jet, the 737, has a cabin as wide as the big 707 Intercontinental. And the latest family addition, the 747 superjet, is the most spacious, most comfortable jetliner ever built. When it enters service this winter the Boeing 747 will introduce The Spacious Age to air travelers."

<u>Above</u>: caption: “Plenty of room inside – all the riders that could be jammed into this fleet of cars arranged alongside the giant transport would find seats”

158

Fly Like an Eagle

"…This is going to be the heavyweight of air-planes. At 710,000 lbs. max. gross (more than double that of the 707) it seems incredible that it can get off the ground - let alone fly like an ea-gle…"

Mechanix Illustrated, **November 1968**

<u>Left</u>: caption: "747 production line. The depth of the Boeing 747's fuselage, from roof to belly, is almost 30 feet."

"…And we questioned its ability to operate from existing jetports, knowing that concrete runways have weight limitations. Boeing solved this problem by distributing the weight via 16 load-bearing wheels and a dual nose wheel…"

***Mechanix Illustrated*, November 1968**

<u>Left</u>: caption: "Eighteen landing wheels distribute 747's weight to permit operations from runways at airports capable of handling today's jets"

<u>Right</u>: caption: "Close-up of the 747 prototype's 16-wheel main landing gear"

"…As for getting it off the ground, the four Pratt & Whitney JT9D-3 turbofan engines develop 43,500 lbs. of takeoff thrust each - approximately twice the power of the largest commercial jet engines presently in use. Cruising speed will be Mach 0.84 to 0.90, or about 625 mph, ranging to 6,000 miles. Yet, with all this power the engines are designed to be quieter than those on current jet airliners…"

***Mechanix Illustrated,* November 1968**

RE: the technology that made the 747-100 possible was the *High-Bypass Turbofan Engine* - capable of delivering double the power of the earlier turbojets while using one-third less fuel (*General Electric* pioneered the concept for the *C-5 Galaxy*). *Pratt & Whitney* was working on the same principle. In late 1966, *Boeing,* PAA and P&W agreed to develop a new engine to power the 747, designating it the "JT9D."

<u>Above</u>: caption: "The Pratt & Whitney JT9D High-Bypass Turbofan Engine was developed for the 747"

"…Perhaps the biggest obstacle to the aircraft's designers was that of the engines. While Pratt & Whitney was working on the prototype of the huge JT-9D engine, it had yet to be tested, and it was far from certain that it would be ready in time to mate with the 747. Boeing had bitter memories of the B-29 bomber and its star-crossed marriage with the Wright Cyclone engines, which had a nasty habit of catching fire and burning off the wing. The giant JT-9D engine would be the first jet engine mated to an airframe that had not earned its stripes on the wing of a military airplane. It was an enormous gamble…"

Aviation **magazine**

Left: caption: "JT9D-3W engine"

"…The initial design specifications of the new airplane had the takeoff gross weight pegged at 550,000 pounds. As the 747 design grew and matured, it put on weight, the bane of every aeronautical engineer. A massive effort was directed at slimming-down the airplane, and eventually an all-up weight of 710,000 pounds became the final design target. Four engines, each producing 41,000 pounds of thrust, would be required to get the 747 airborne, and as the airframe design came closer to being finalized, Pratt was way behind the power curve. Engine development and production proceeded so slowly that the entire project threatened to sink under its own weight…"

***Aviation* magazine**

<u>Top</u>: caption: "P&W JT9D engine"

<u>Bottom</u>: caption: "B747 mock-up"

"…At one point there were so many engine-less airframes sitting on the ramp at the Everett production facility that their cost exceeded the net worth of the Boeing company…"

***Aviation* magazine**

Above: caption: "First Pan Am 747 rolls out at Boeing plant"

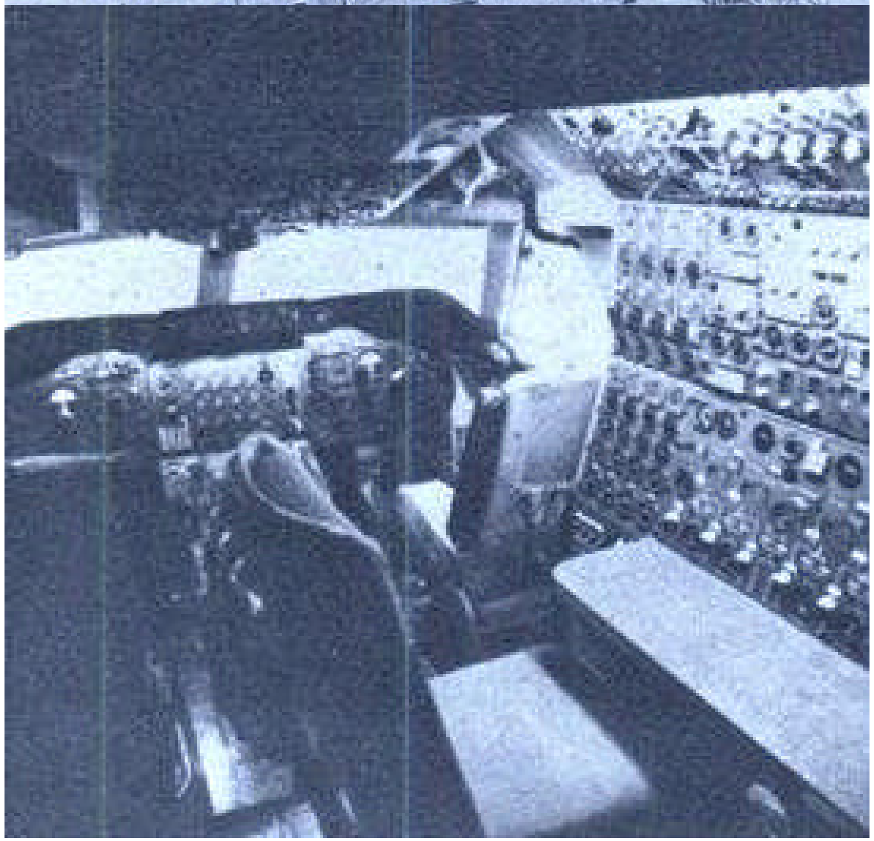
The Boeing 747's entry into service (on PAA's flagship New York JFK to London Heathrow route) on January 15th 1970 was somewhat ignominious. The six-hour late departure and equipment substitution was caused by an engine failure on the taxi-out to the runway. These engine failures would have enormous impacts 747 production almost immediately. The combination of the under-powered *Pratt & Whitney JT9D* engines that had to increase from 41K to 45K pounds of thrust (to lift an airframe that grew from 690K to 710K pounds) caused many engines to flame-out. Faced with engine redesigns, 747s were leaving the factory every three days, up to forty per month by March 1970 - an all time record, but without engines attached. Concrete blocks were hung on the engine pylons of the 747s scattered around the factory. *Paine Field* effectively became one big Jumbo Jet parking lot.

An Unround Situation

"…The early JT-9D-3 engines that powered the early model 747s were fraught with problems; they suffered from frequent compressor stalls, and would overtemp at the drop of a hat. It quickly became a procedure that once the engines were running, while the airplane was on the ground at least one of the three cockpit crewmembers had to constantly monitor the engine temperatures for overheat. Even the first scheduled passenger flight of the giant airplane was delayed several hours because of engine problems, severe enough to force an ignominious change to a backup aircraft. The sheer weight of the engine and nacelle resulted in a new, heretofore unknown phenomenon, the 'ovalizing' of the engine itself. Its weight was literally pulling the engine out of round. One of Boeing's engineers put the situation into cleverly-phrased perspective. 'We have an unround situation,' he said. Engineers devised a unique, space-age solution. It required that the largest amount of weight be placed in the smallest package, in the cowling of the engine itself. The result was the use of one of the densest metals known, spent uranium, which was embedded in the engine cowl. It solved the problem…"
Aviation **magazine**

"…Untold numbers of photos were snapped of comely stewardesses (still so-called in the early '70s) standing in the cowling of the huge Pratt JT-9 engines, surrounded by the great shroud that enclosed the big fans…"

Airways **magazine**



"…As we strolled through the plant, giving the first five planes under construction careful scrutiny, we began to look at the bird from the viewpoint of a pilot. The single- and twin-engine light airplanes we fly routinely are no match for a 747 but we were consumed with a strong desire to at least sit in the cushioned armchair reserved for the pilot, operate the controls and dream of glory on the flight deck for a few mom-ents. We did. It was lovely, even though the cockpit contained no real surprises. The rows and rows of gauges, switches and flight instruments, along with an engineer's station behind the pilot seats, reminded us that this was a jet, one which Boeing claims will be easy to fly…"

***Mechanix Illustrated,* November 1968**

<u>Top</u>: caption: "World's largest commercial jetliner takes shape inside Boeing's cavernous 747 plant at Everett, Wash., where major segments are mated"

<u>Bottom</u>: caption: "Instrumentation at engineer's and pilot's stations boggles the untutored eye"

"…Engineers say the Jumbo Jets will be so foolproof that it will be difficult for a pilot to make an error. In fact, for most routine operations the pilot will monitor the controls instead of handling them. Landings will be semiautomatic, with the radio landing system coupled to the automatic pilot. An automatic flare system will bring the plane into its landing attitude when 50 feet above the runway…

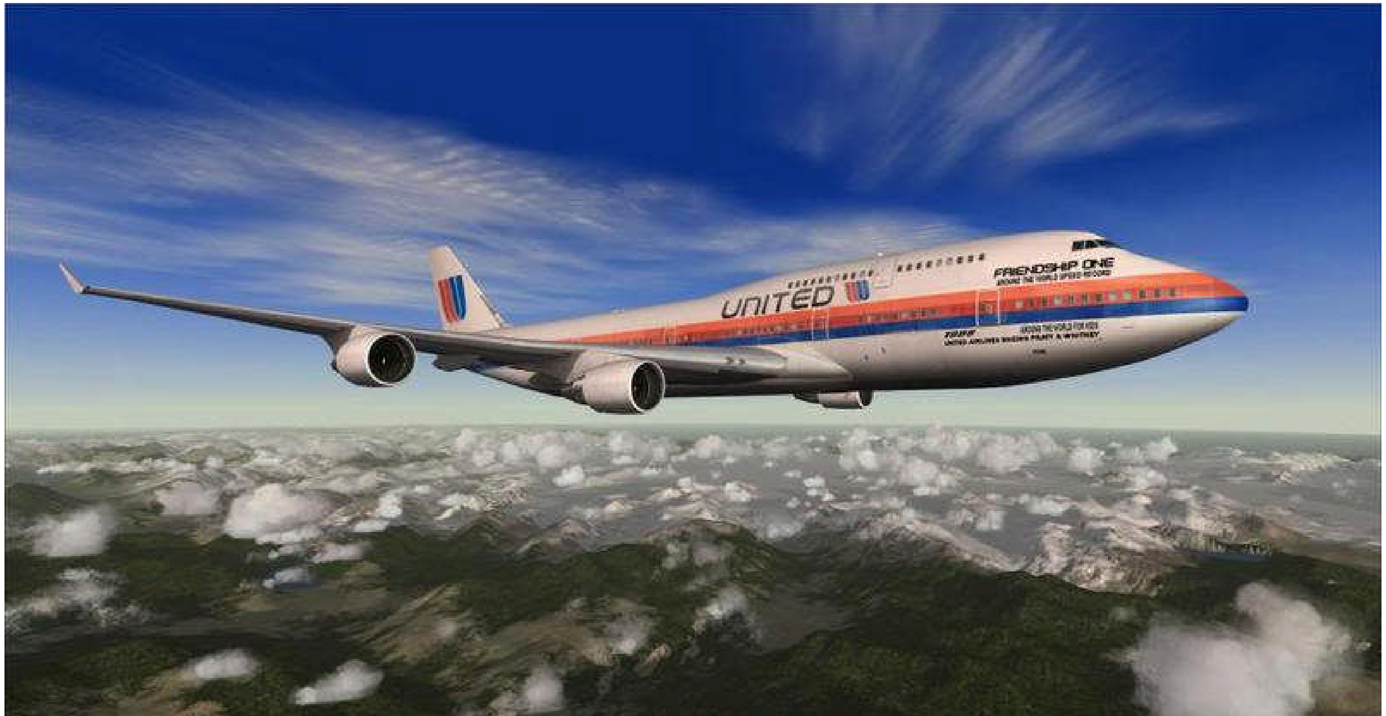
***Popular Mechanics,* September 1966**

Training Day

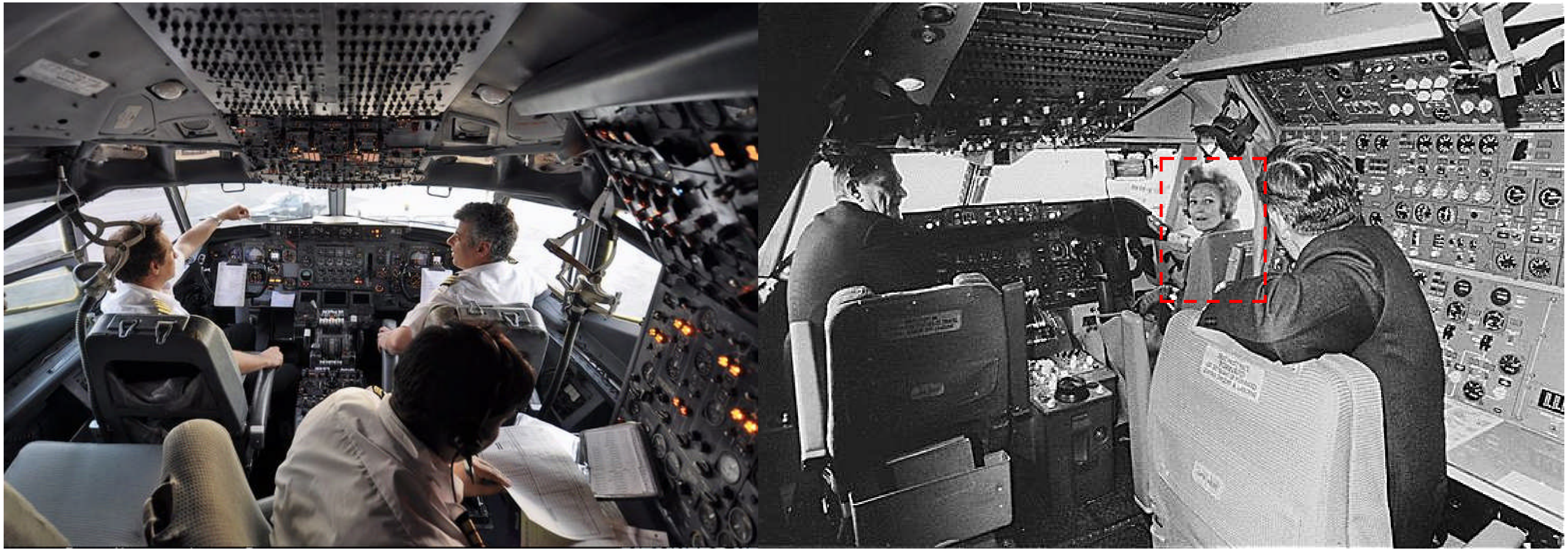
"…The typical 747 pilot will have had over five years or 5,000 hours on four-engine jets…"

***Popular Science,* December 1969**

<u>Left</u>: caption: "In 1988, Pilot Clay Lacy set the *Around the World Speed Record* in a United Air-lines 747 with the name of 'Friend-ship One'"


FRIENDSHIP ONE
UNITED

FRIENDSHIP ONE
UNITED

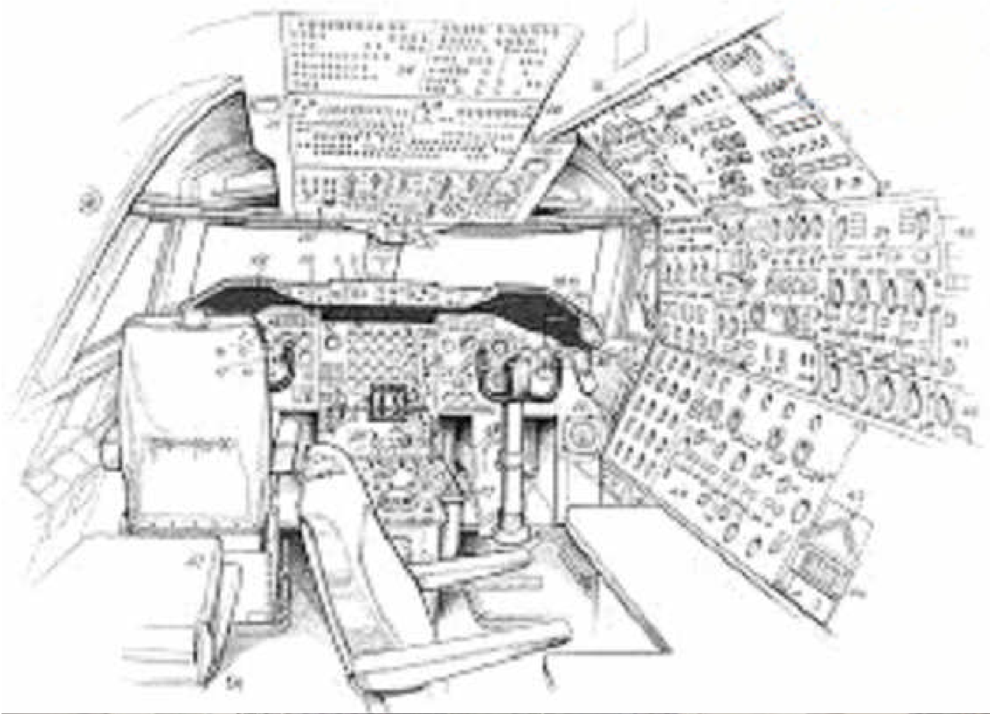


"… We found forward visibility to be somewhat restricted through narrow windows, a condition pretty nearly standard today. The fact is that at jet speeds the human eye isn't reliable as a collision-avoidance system, which is why the 747 will be a model in automatic guidance systems, mostly in duplicate for back-up protection. Super-advanced navigational systems will permit accurate flight to virtually anywhere in the world, pin-pointing the big bird to landings in near-zero visibility…".

***Mechanix Illustrated,* November 1968**

<u>Left</u>: caption: "Boeing 707 cockpit"

<u>Right</u>: caption: "First Lady Pat Nixon visits the cockpit of the first commercial 747 during the christening ceremony, January 15, 1970"



"…Lots of instruments. Lots of schooling – about 90 days of ground and flight instruction in the pilot school that starts at the Flight Operations and Crew Training Center at Boeing Field, Seattle. The ground-school course teaches crews only what they have to know to understand and operate the 747. It eliminates needless information about things they can't control…in the past, ground schools were actually handicapped with too much information. For example, a pilot and engineer need to know the <u>function</u> of a switch; but they don't really need to memorize the circuitry of the whole aircraft…"

Popular Science, **December 1969**

"…Each 747 system is taught as a teaching frame followed by instant quizzes for pilots and flight engineers. Students indicate answers by pressing a button on a response panel that is connected to the instructors' station. This avoids student aversion to verbal answers because of possible embarrassment before the whole class…"
***Popular Science,* December 1969**


LONGREACH

The Iron Bird

“…In another major phase of the test program, Boeing built a full-scale operating replica of the plane’s flight control systems. This ‘iron bird’ precisely duplicated the operation and responses of the 747’s controls, enabling engineers to refine the systems well ahead of installation in the first plane and giving test pilots a chance to get the ‘feel’ of the controls. Finally, five of the big jets were flight-tested for some 1,400 hours…”

***Popular Mechanics,* December 1969**

"…After 100 hours of ground school, pilots and engineers go to learn 'cockpit procedures.' For this, they work jointly in an aircraft computer-systems simulator made by Hawker Siddeley Dynamics. This is an actual aircraft cockpit that can be opened to instruct a small class. There are more hours in a flight simulator from Conductron or an elaborate Link trainer. These produce lateral, longitudinal, and yaw movements, as well as the pitch roll and vertical movements of earlier systems…"

***Popular Science,* December 1969**

"…There are more hours in a flight simulator from Conduct-ron or an elaborate Link trainer. These produce lateral, long-itudinal, and yaw movements, as well as the pitch roll and vertical movements of earlier systems…"

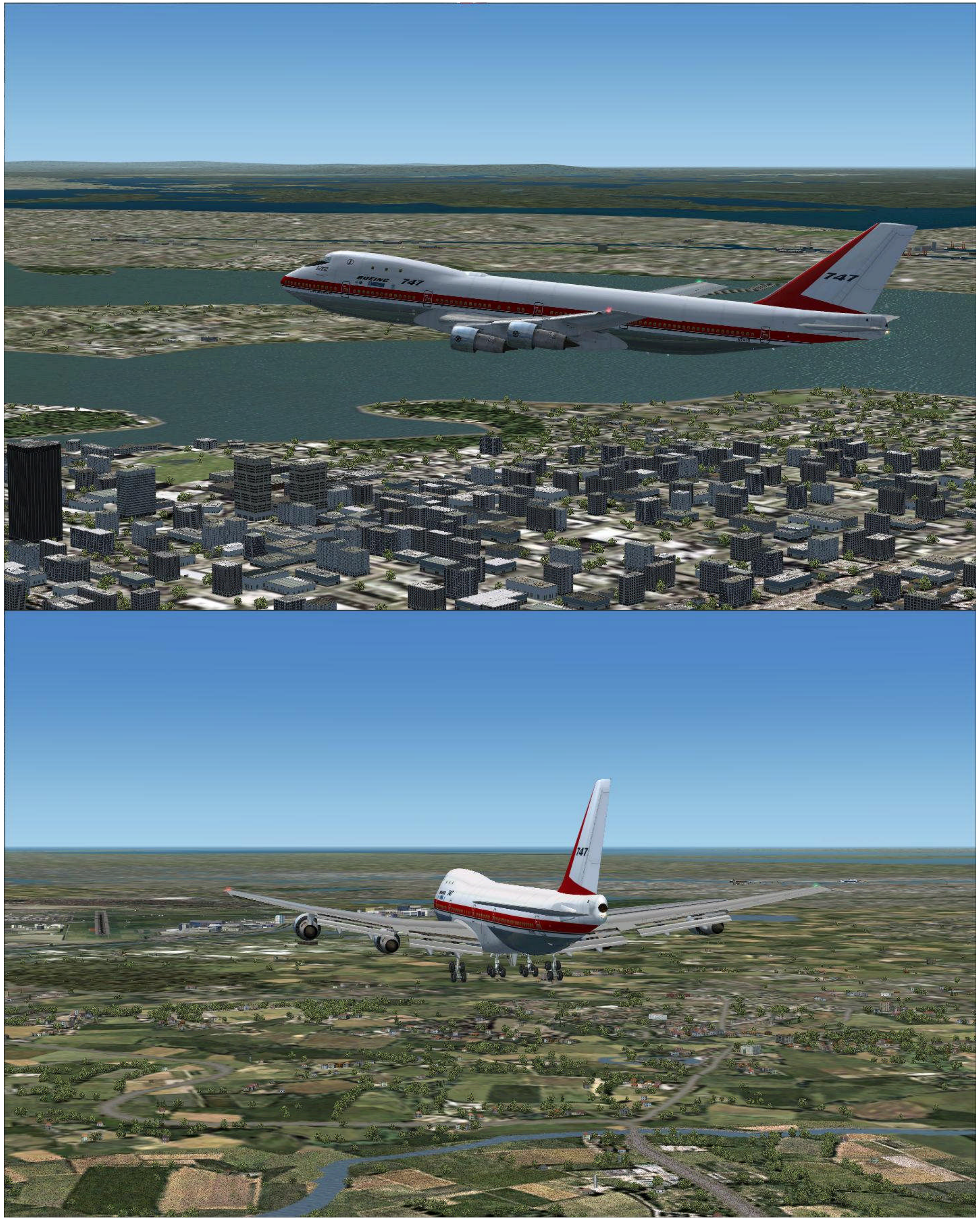
***Popular Science,* December 1969**

"…After ground training with a total of two weeks in flight and systems simulators, Pan Am pilots go to Roswell, N.M., for actual flight training. The pilots spend about twelve hours actually flying the 747…each pilot flies about two hours at a time, with an engineer taking training with him…"

***Popular Science*, December 1969**

<u>Left T&B</u>: 747-100 Flight Simulator

<u>Above</u>: caption: "At Roswell, N.M., Pan American Airways pilots undergo four to eight hours of flight time in the 747 before being rated on the aircraft by a FAA inspector"



"…When he has proved he can fly the 747 competently, the pilot goes through a route check. Crew scheduling assigns a check pilot who rides the assigned route with the pilot being evaluated. All told, twenty-five hours of line checking is involved. To qualify. The new pilot need not make a landing with the 747 at each airport on the route, but he must make an entry into the airport once every twelve months to remain qualified for that route…"

Popular Science, **December 1969**

<u>Left T&B</u>: flight simulated 747-100 airport landing app-roach

"…the feel of the 747 is somewhere between that of a four-engine 707 and a three-engine 727. The control responses are very good for a big plane, but cannot be compared to that of a small one…any pilot qualified and rated for flying big four-engine Boeings will have little difficulty making the transition to the 747…"

***Popular Science*, Dec. 1969**

<u>Above</u>: caption: "Aviation enthusiast John Travolta is a licensed pilot on many types including the 747-400 and the 707"

<u>Left</u>: caption: "John Travolta displays his wings showing he is qualified as 747 first officer after arriving at Heathrow Airport in London on August 19, 2002. Travolta, who is an enthusiastic pilot with eight licenses to his credit, has been flying his personal 707 on a 13 city 'Spirit Of Friendship' tour to promote aviation as Australian Airline Quantas' 'Ambassador-at-Large.'"

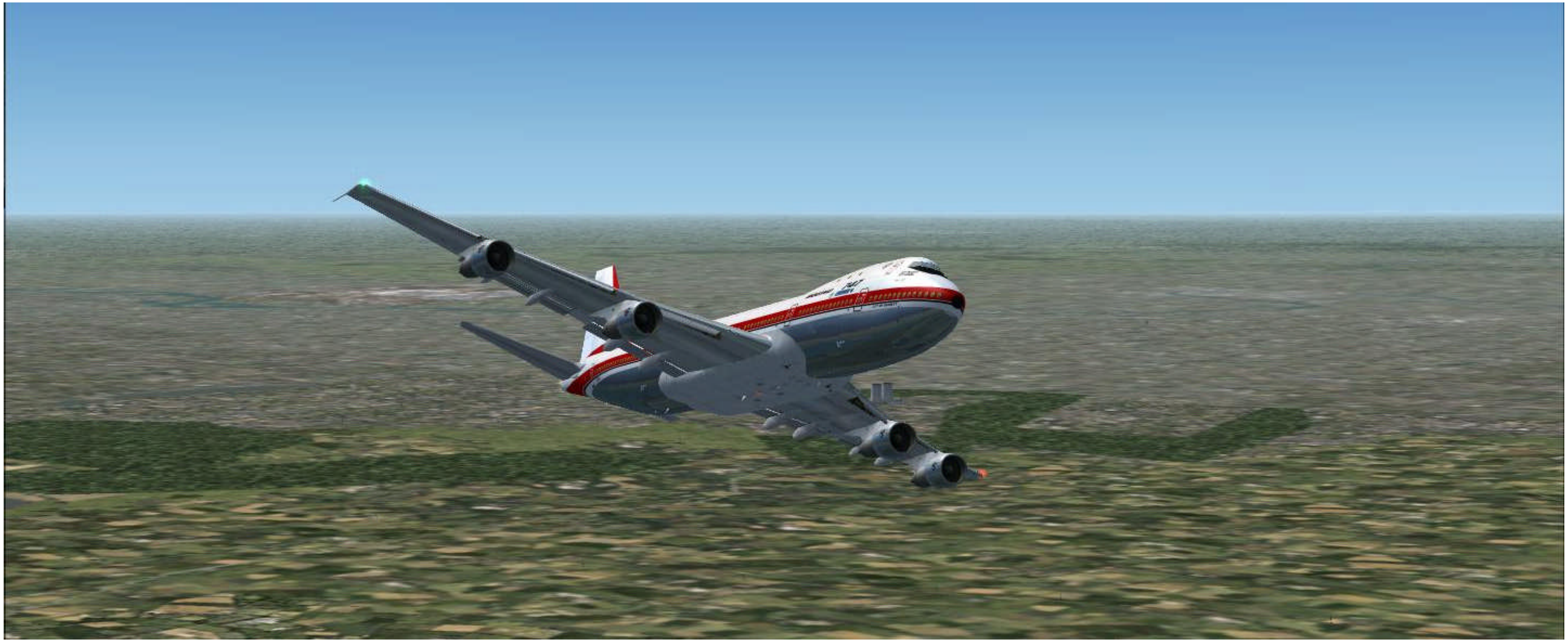

747

"…The speeds on landing and takeoff, and the runway distances required, will be about the same as for the present big 707's and stretched DC-8s. A pilot's eye level, however, will be quite a bit higher, and this will require some adjustment…Takeoff runs will be about the same as for the big 707 models. At sea-level and with a temperature of 80 degrees, both will need about two miles of runway, even though the 747 weighs twice as much as the 707-320. Landing will take just under 7,000 feet…"

Popular Science, **December 1969**

"…When the 747 is in its nose-up landing position, the pilot's eye level will be 37 to 39 feet above the wheel trucks. When the nosewheel is down on the ground, he will still be 28 feet or so above the ground, depending on how much the struts are extended. But these problems are not considered to be serious…"

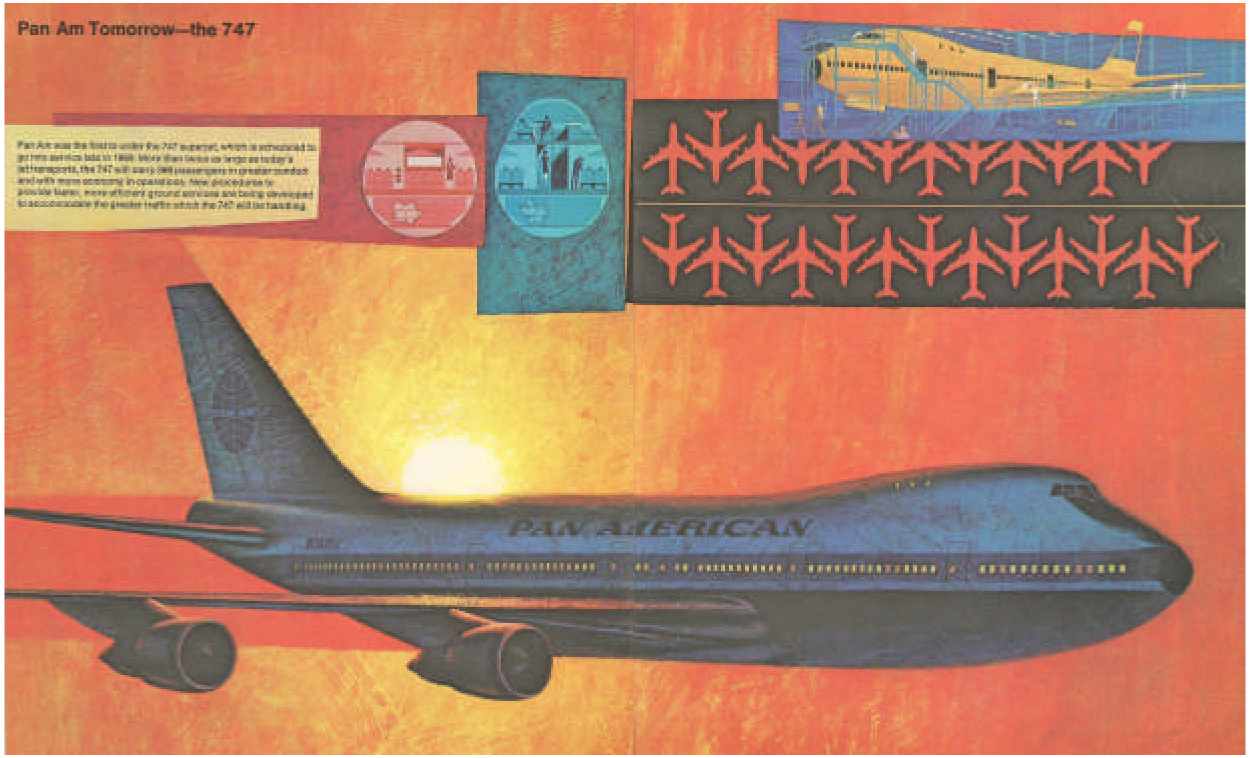
***Popular Science,* December 1969**



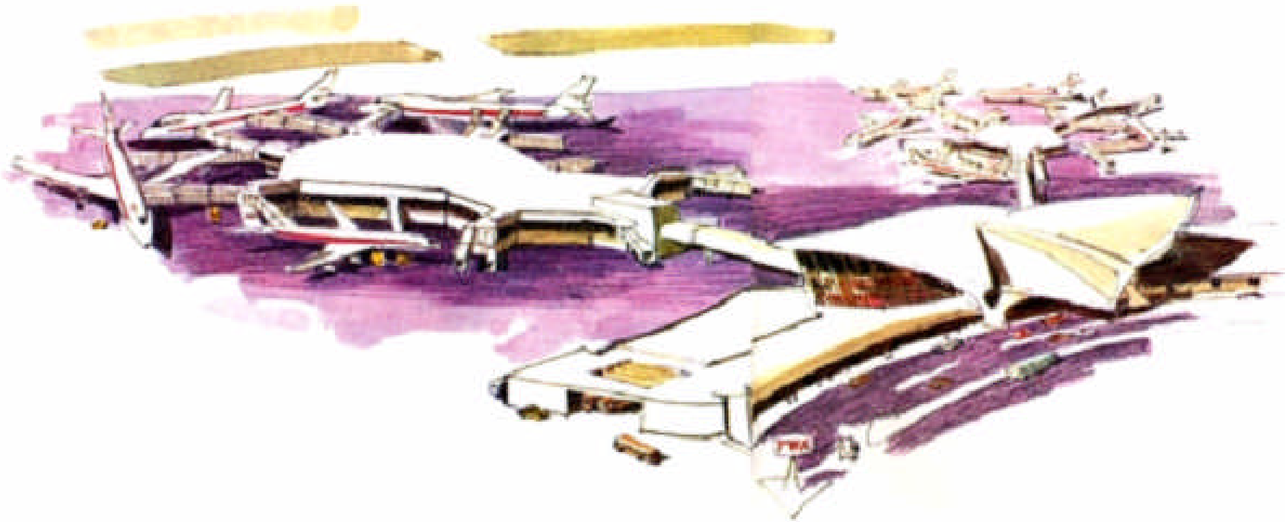
"…The engines, when started, will just barely be heard by passengers. In flight, the hum of the air conditioning will actually mask engine noise. Gear retraction will be so quiet and gentle passengers will hardly hear or feel it. The ride for pilots and passengers will be better because of the greater inertia of the 350-ton machine. There'll be less bounce from gusts, for example. But for the pilot, this greater inertia means he must plan his moves even farther ahead. It will take more time and longer distances for the plane to change direction even after the controls have changed its angle of attack to the air…"

***Popular Science,* December 1969**

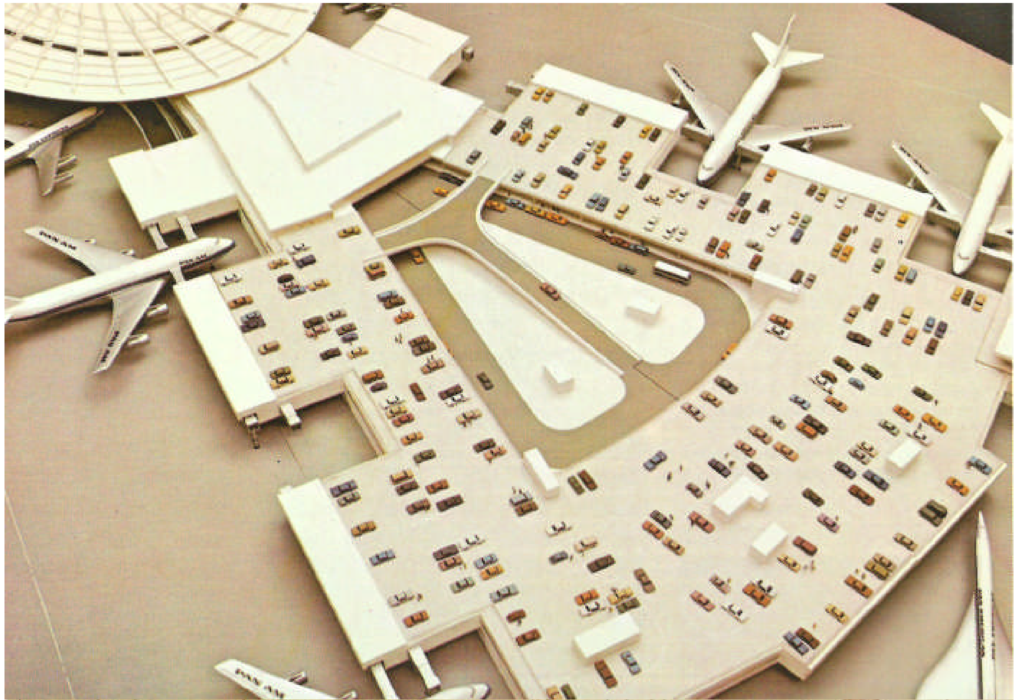
At Home on the Ground



"…'Artist's renderings' was a fanciful term applied to the surrealistic drawings of the new 747 that appeared in promotional material. The airplane was parked at a futuristic terminal, with a jetway conveniently nestled against each of her 8 main entry doors…"
***Airways* magazine**

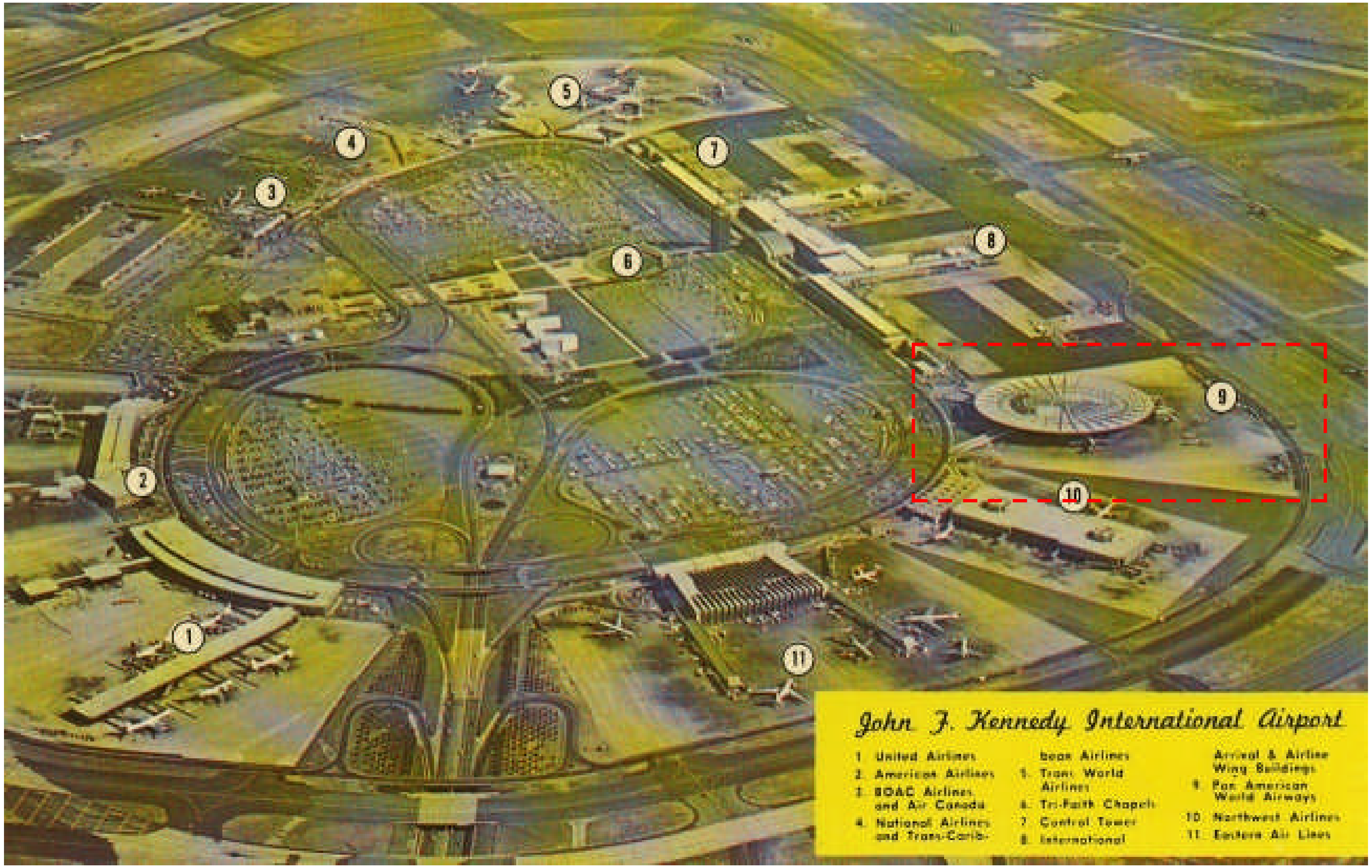



TWA



<u>Top</u>: caption: "Model of future four-level Pan AM terminal at Kennedy International Airport, New York, shows loading of 707 jets, 747s and supersonics. Parking for 500 cars will be available."

<u>Bottom</u>: caption: "Pan Am planners work with model of maintenance facility, now under construction at Kennedy International Airport, New York"



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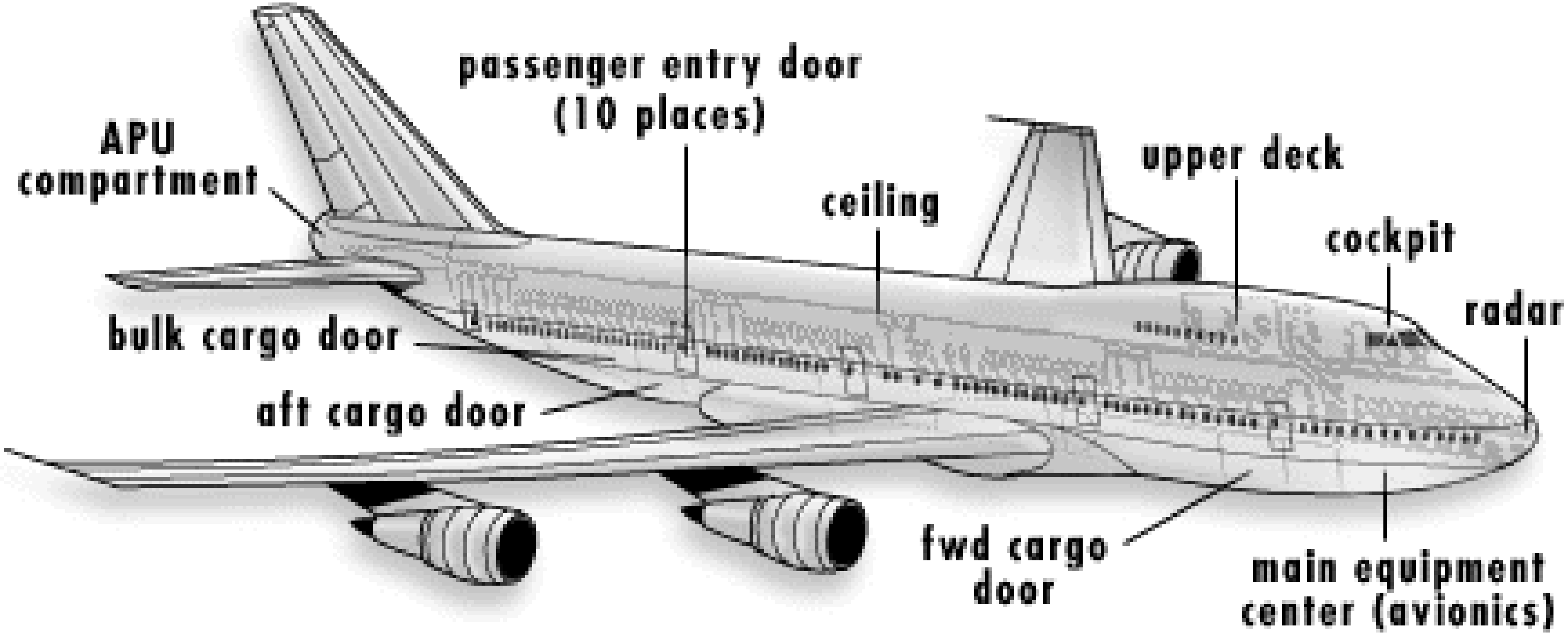
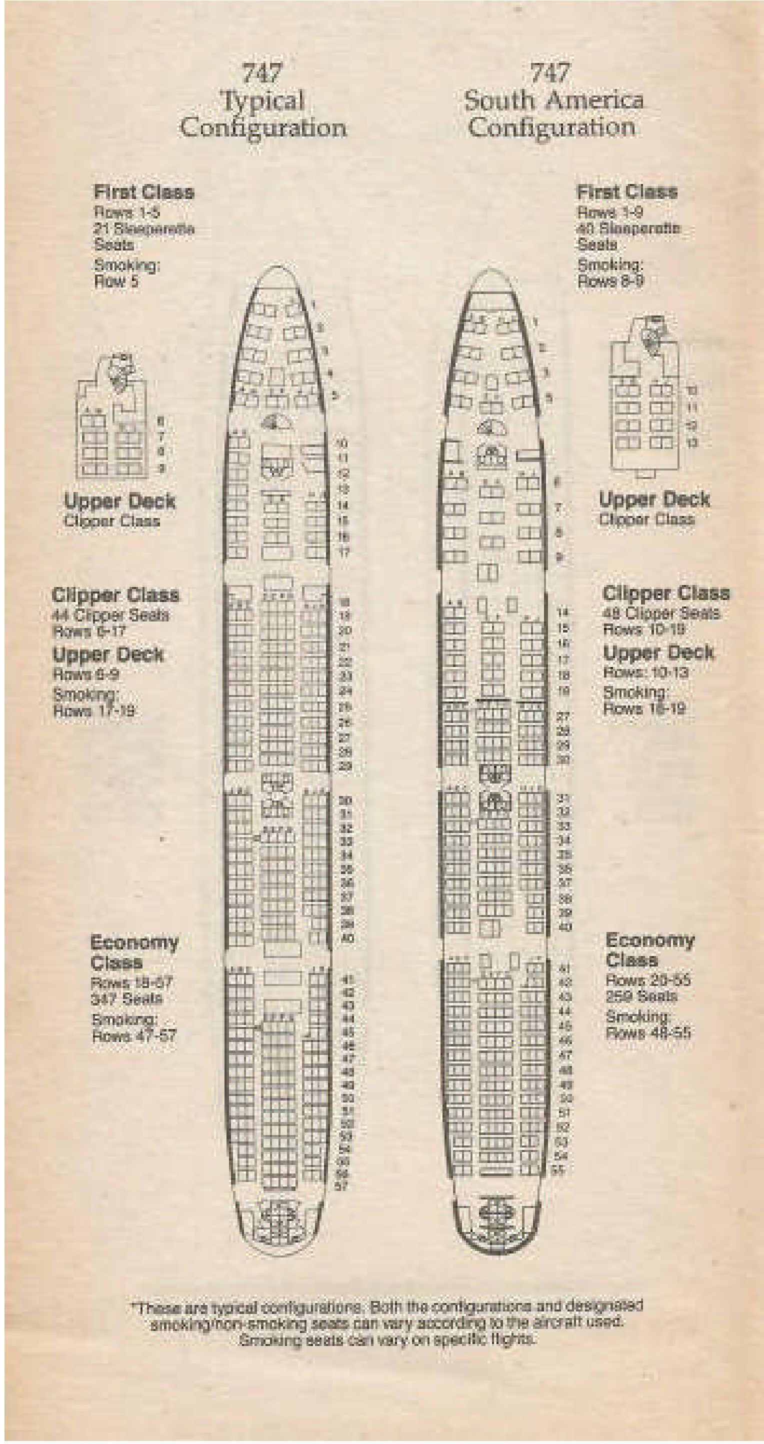
John F. Kennedy International Airport
1 United Airlines
2 American Airlines
3 BOAC Airlines and Air Canada
4 National Airlines and Trans-Carib-bean Airlines
5 Trans World Airlines
6 Tri-Faith Chapels
7 Control Tower
8 International Arrival & Airline Wing Buildings
9 Pan American World Airways
10 Northwest Airlines
11 Eastern Air Lines



"…The new airplane would carry up to 500 passengers; one of the early questions was, how do you evacuate 500 people from an airplane in just 90 seconds? The FAA, approached by Boeing to relax its 90-second evacuation criteria, dug in its heels and remained firm. Ninety seconds was the limit, or the airplane would not be certified…"

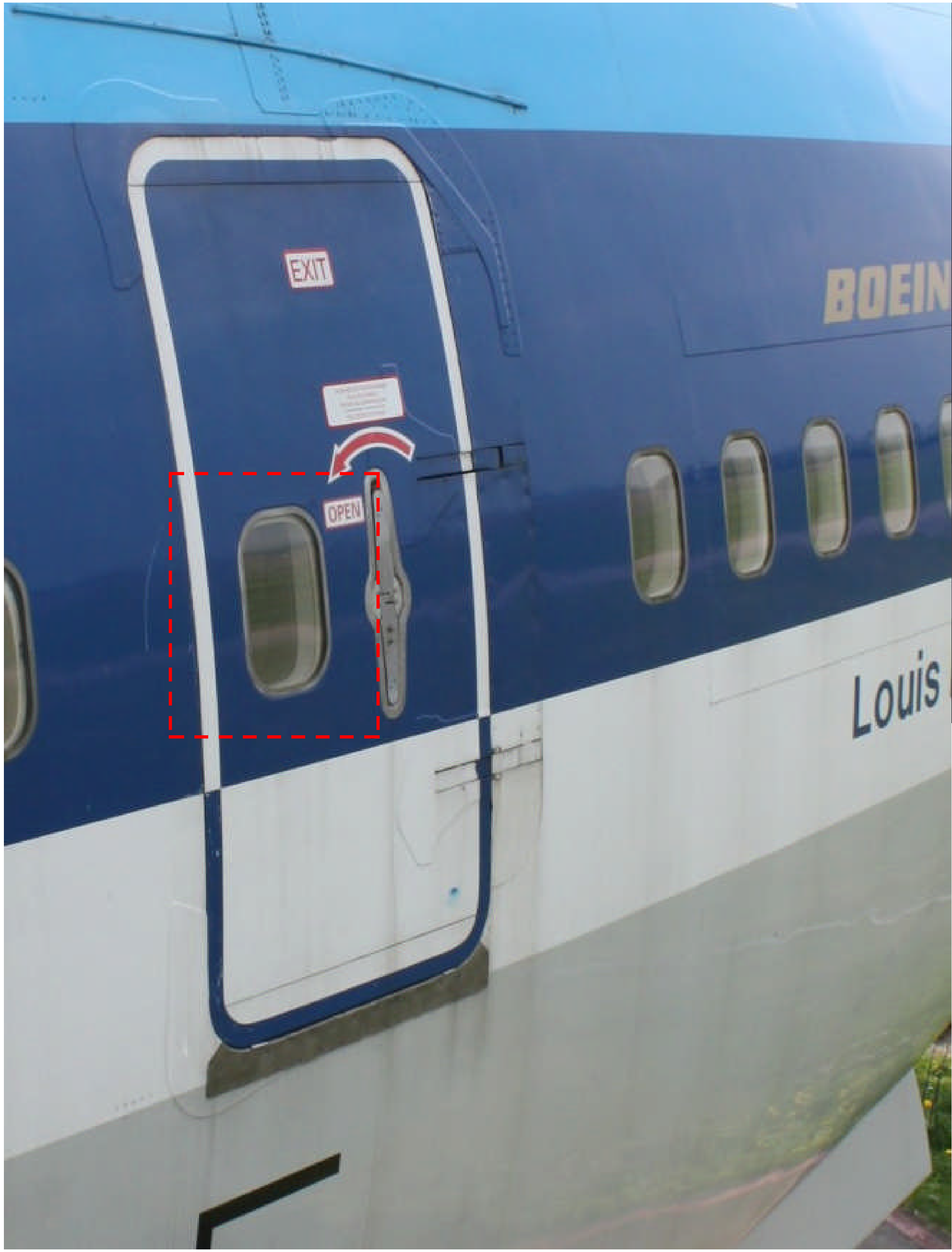
***Aviation* magazine**

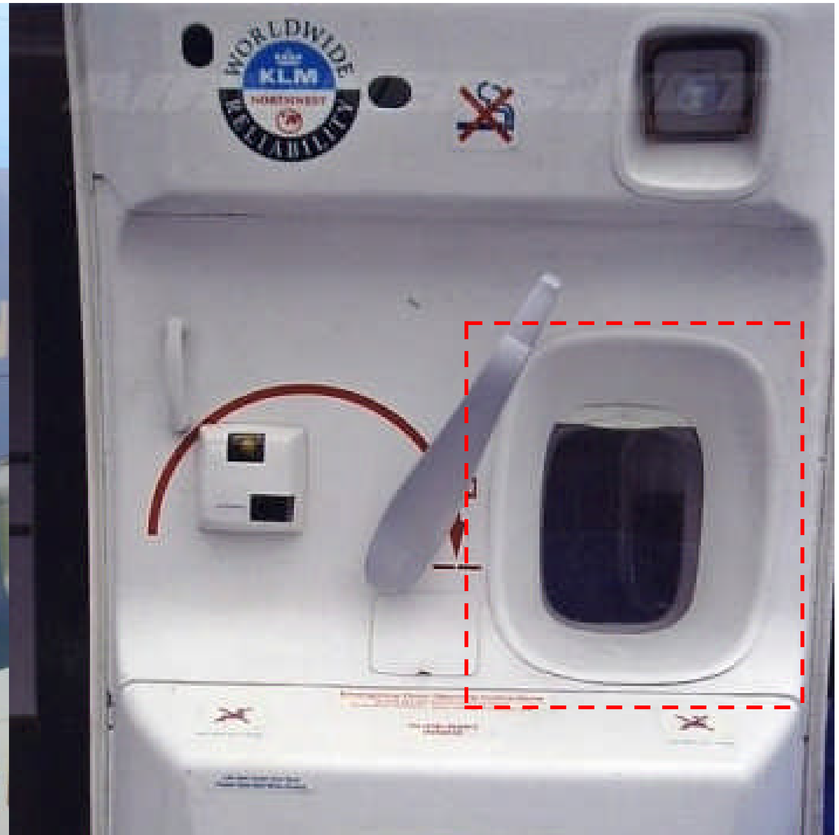


"…Engineers wrestled for days with the problem, and eventually redesigned the interior of the cabin to include not just one center aisle, but two, running the entire length of the airplane, with cross-aisles at each of the four main entry doors (there was an additional over-wing escape exit). The doors were redesigned to permit egress of a staggered two-abreast…"

***Aviation* magazine**

Left: caption: "Pan Am 747 Typical and South America Seat Configurations"





"Each of the cabin doors has a standard-size window. This is a vast improvement. Cabin crews can actually see out of the door, something that's very difficult with present generation jets."

***Susan Lea Limbaugh,* PAA Stewardess (ca. 1970)**


BOEING
747
CITY OF EVERETT
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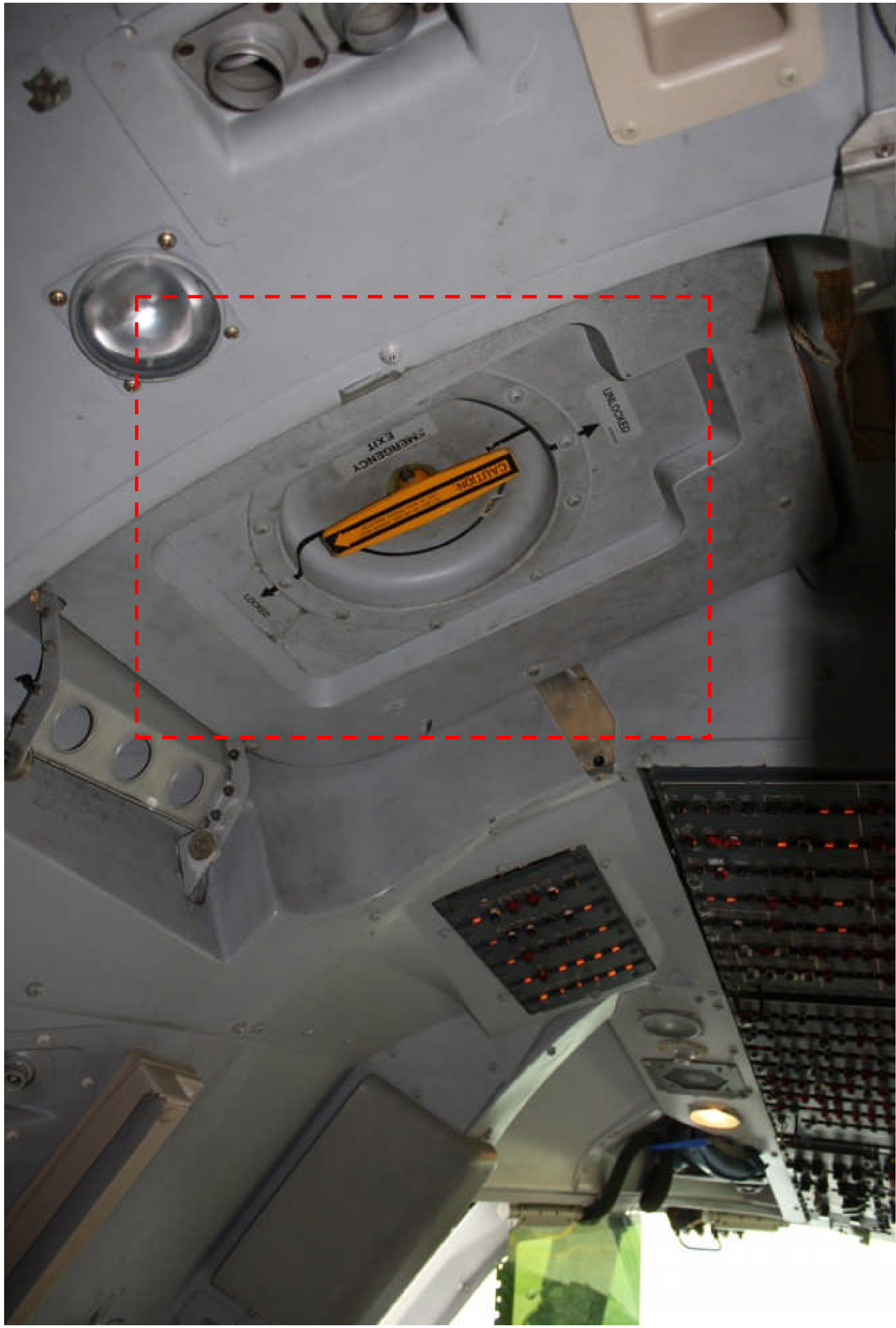
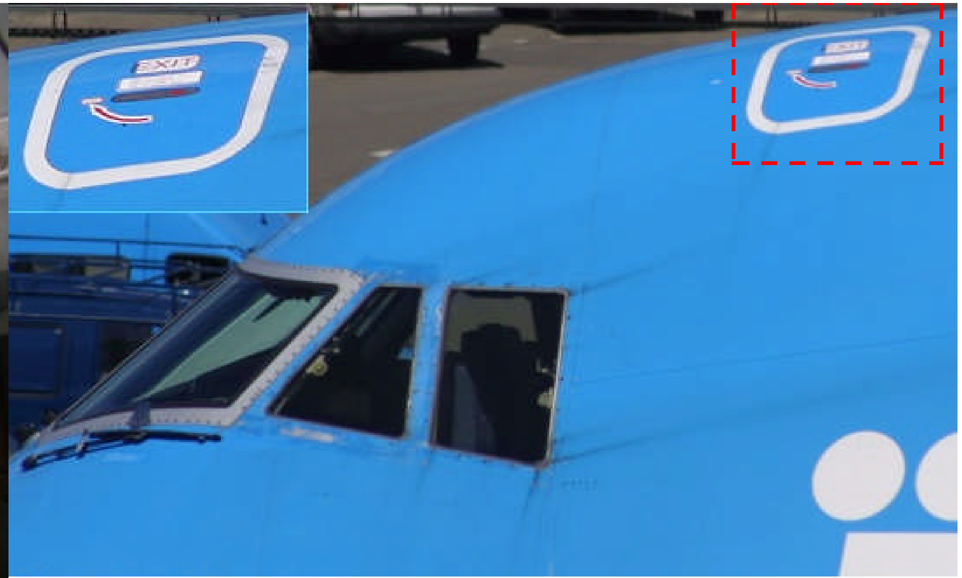
N7470





<u>Above</u>: **caption: “Boeing 747-300 cockpit emergency hatch (exterior view)”**

<u>Left</u>: **caption: “Boeing 747 flight deck escape hatch (interior view)”**


PAN AM

Part Four

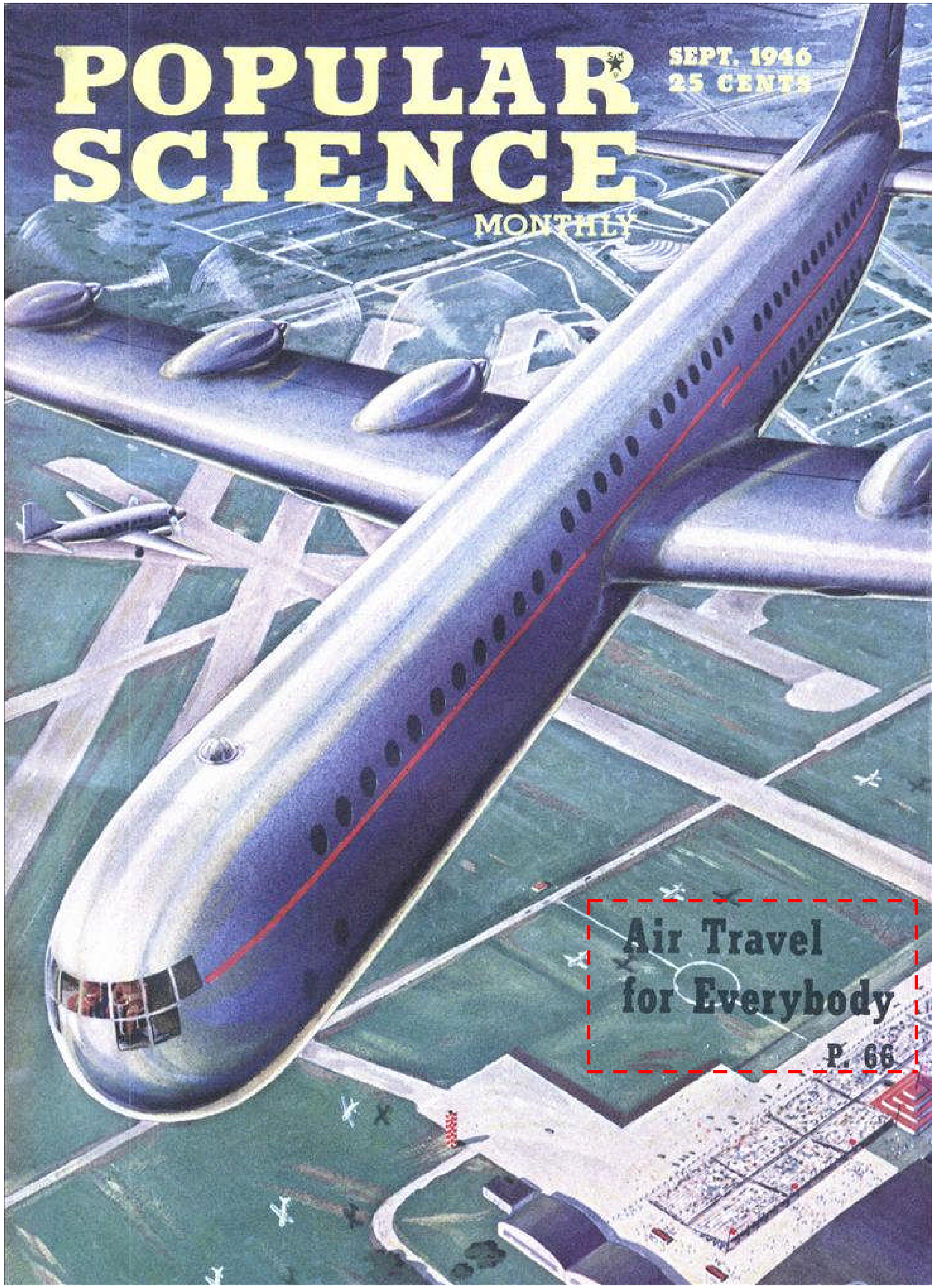
Air Travel for Everybody

"…Very few people live in a state of urgency that requires them to travel 500 miles an hour, and microscopic fractions of those who do can afford to trifle with the probability of being drastically late or set down in Framingham, Massachusetts, instead of Washington, D.C. The flying machine is tolerably safe, and that is taken for granted. It isn't at all reliable and it isn't comfortable."

RE: excerpt from a letter to a NYC newspaper (ca. 1947). After achieving a sterling war record, the airlines found themselves deluged with criticism. Air travelers, weary of delays and irritated by uncertain arrivals of planes, began to object, often vociferously. High fares, keeping passengers in airplanes for several hours waiting to take-off and/or the practice of "stacking" planes for long periods waiting to land was not wining many converts to air travel.

"…Slow takeoffs can be as exasperating as stacking. It often takes an hour to get a clear runway at crowded terminals. In the summer the passengers boil; in winter they freeze until the plane gets into the air…Reservations, flights without reservations, waiting time, 'no-shows,' ground transportation, meals aboard, terminal restaurants: these are still big problems…"

***Science Illustrated,* February 1947**



"In a half-dozen plants converted to peacetime pursuits, riveting hammers are pounding out air-craft to bring transportation by air to thousands of American hamlets at a price almost any traveler will be able to afford. Some of these air liners, built from design lessons learned dur-ing the war, will be able to cross the United States in less than seven hours. Some, engineered specifically for local flights on interurban schedules, will be only half that fast. All of them, for the first time in the history of the U.S. air transport, are being built for specific purposes…"

***Popular Science,* Sept. 1946**

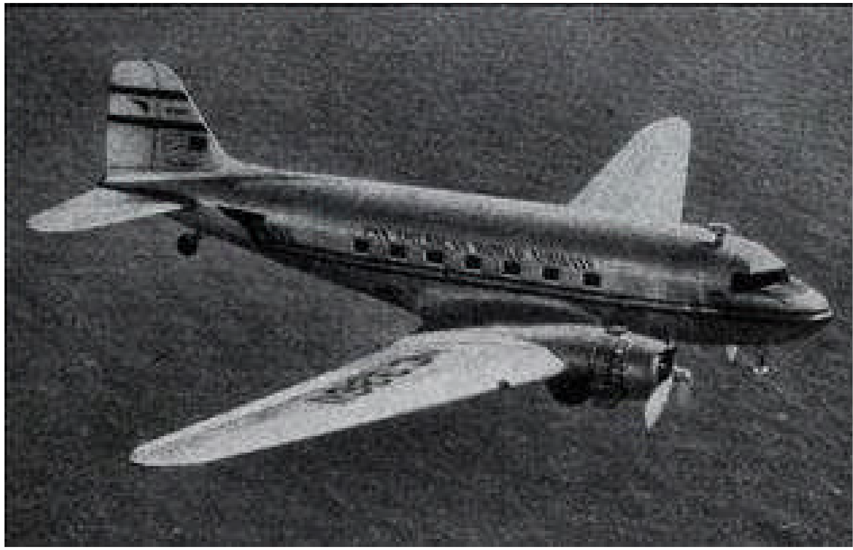
 

"…Conveniences for the traveler that these planes will provide reflect the public's criticisms of the air carriers for the last decade. They also provide a pretty good picture of what the public wants - and is going to get from the air lines in the next five years…"

***Popular Science,* September 1946**

<u>Left</u>: caption: "Eating from lap trays will be a thing of the past. Roomy tables will be available for meals or card playing. They will supplement lounges and buffets on the larger intercontinental transports."

<u>Right</u>: caption: "Telephone service will be available to passengers on the ground. This will be one of the conveniences for through travelers, who will no longer have to leave transports at intermediate points."



"…The 21-passenger DC-3 and the 42-passenger DC-4 that have served so nobly are going to be too slow, too antiquated, and too costly to run in a few years if the airlines are to live up to all the fine claims they're constantly making in advertisements and publicity releases. Major lines are writing every one of these planes off as fast as possible. In their time they've done yeoman duty. Yet some of these planes had been hopped up in seating capacity in 1946, with DC-3's carrying 28 passengers, DC-4's carrying 60. When you pack air passengers sardine fashion, they howl. They have every right to howl. Regardless of rates, people have been led to believe air transport is something special, as advanced in comfort as it is in speed…"

***Science Illustrated*, February 1947**

Left: caption: "Airlines workhorse, the DC-3, cruises 185 m.p.h., seats 21"

Right: caption: "The DC-4 has a range of 3,000 miles"

Fed Up

"…The public is fed up with traveling at 200 m.p.h. between terminals and then waiting 20 minutes or more to retrieve a traveling bag, laboriously unloaded from badly designed transports. So, presently, the air passenger will be able to carry his own bag aboard and stow it under his seat or in a rack over his head, or in a special baggage compartment at the plane's entryway…"

***Popular Science,* September 1946**

<u>Left</u>: caption: "Luggage space in the passenger compartment will obviate the need for tipping since travelers can carry their own bags aboard"

"…The public is fed up with all the hocus-pocus paper work, at reservation counters, airport terminals and even aboard the airplanes themselves, that takes passengers' time and delays departures. So, on shorter runs at least, a passenger presently will be able to walk up to an airport ticket desk, buy his passage, show it at the gate and go aboard without the bother of a reservation…"

***Popular Science*, September 1946**

"…The public is fed up with time wasted at stops. So in one type of transport the time spent on the ground will be cut by providing one door for boarding passengers and another for those getting off…"
Popular Science, **September 1946**

"…Everyone who travels regularly is having his trouble getting service anywhere. It's only human to think of your troubles, and to forget someone else's. When it became hard to buy a plane ticket, seasoned travelers simply said, 'To hell with it,' and tried the trains. Airline traffic slumped. Winter, the airlines' poorest season, set in and caused other set-backs. Under such circumstances, aviation stocks, good and bad, take a slide…"

***Science Illustrated*, February 1947**

What the Public Wants

"…The public wants airlines that go to a lot more places on the map. It wants to be able to travel by plane when the weather is stinko. It wants adequate ventilation in planes that are not too hot and too cold by spurts. It wants altitude conditioning on <u>all</u> transports, so a man's ears won't hurt as his plane descends to land. It also wants more speed for its dollar…"

***Popular Science*, September 1946**

"…All these it is going to get, plus a few more. By 1951, air transports and the airline pattern itself, both domestic and intercontinental, will confound the most extravagant predictions of the men who were nursing a few scrawny airlines to maturity in 1931. But for all the planning that is underway, the growth and character of airline service are bound to be somewhat hodgepodge for the next few years. The carriers themselves are guessing at exactly what's coming. They are in the midst of a tepid reenactment of the railroads' expansion three-quarters of a century ago. It is a tepid performance because the airlines are rigidly - some critics say too rigidly - controlled by the Government…"

***Popular Science*, September 1946**

What’s Best?

"…What's best - cheap transportation in economically run 'day coach' planes, or higher-cost transportation on plush seats? American Airlines, biggest U.S. carrier, favors low-cost travel for everybody. Many of its competitors are increasing, instead of cutting down, the plush. What's best - 200-m.p.h. planes at a cost to the passenger of three and a half cents a mile, or planes that will fly at 350 or 400 m.p.h. with considerably higher fares? That question is in a fair way to being answered. The slower planes will go on interurban runs, the faster ones on trans-ocean and one-stop and nonstop transcontinental runs. In-between planes will fly middle-distance runs. What's best - planes that sacrifice cruising speed for the ability to get into tiny airports, or faster planes that need more runway? That is the hardest question to answer. Good airports are few, and cities and towns are loath to put up money for better ones even if the Government chips in. What's best - 14-passenger planes that leave every hour, or 28-passenger planes that leave every two hours? Some aircraft manufacturers, hawking their wares among the airlines, are betting on the smaller plane…"

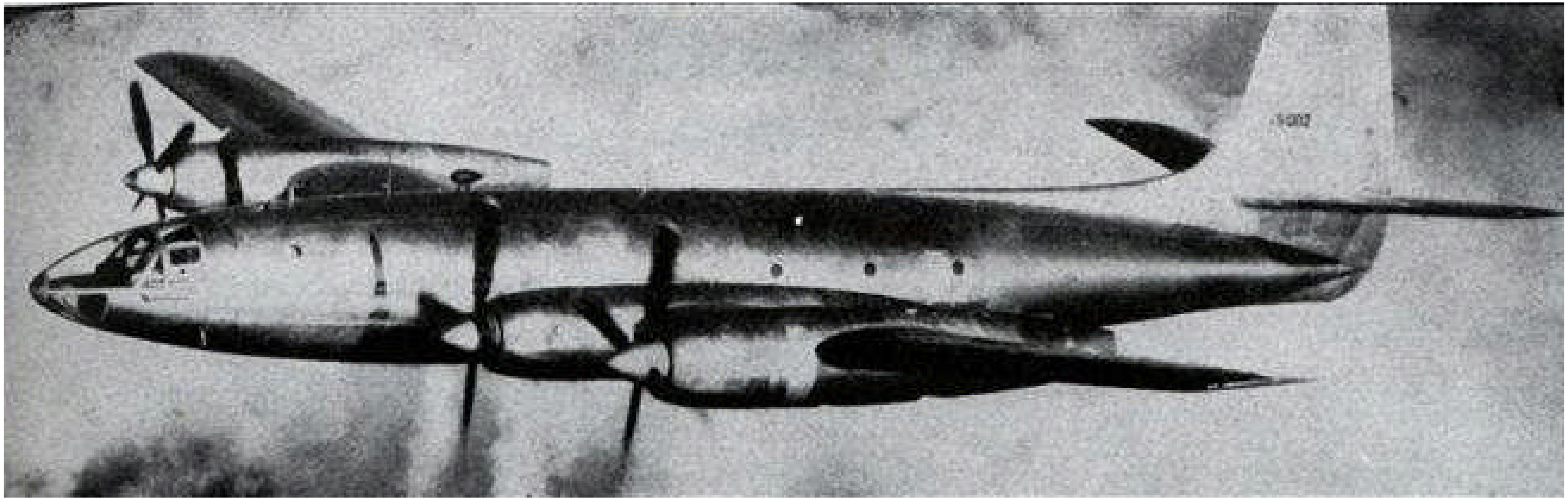
Popular Science, **September 1946**

"…One thing is certain: Faster, more efficient planes are coming. They will go farther on a gallon of gas, and that means lower fares. One manufacturer already is talking about the possibility of New York-to-San Francisco flights in less than eight hours for as little as $86. That compares with $118.30, tax extra, at present. The Pullman fare for the same trip is $127.13 (or 4.01 cents a mile); that by rail coach, $63.12; by bus, $45.25…"

***Popular Science,* September 1946**

"…The first half of this year domestic airlines alone carried 5,225,299 paying passengers, or 666,666 more than in all of 1944. Postwar traffic is 400 percent greater than wartime bookings. But the day of the 90-percent load factor is over. The airlines will have to be able to make money on normal load factors: somewhere between 65 and 75 percent…"

***Science Illustrated,* February 1947**



"…The Air Transport Association, the airline trade group, figures that average domestic fares in the next few years will drop to three and a half cents, and in its boundless and evidently warranted optimism forecasts flights made on 'trolley-car frequency,' with Wellwood Beall, Boeing's chief engineer, believes that long-distance flights at altitudes 'considerably in excess of 30,000 feet may soon be commonplace.' The Rainbow, in fact, is designed to climb to 40,000 feet, above the weather. Even combat planes seldom went that high during the war. Designed specifically for great altitude, the Rainbow costs less to operate at a height of almost eight miles…"

Popular Science, **September 1946**

Above: caption: "Republic Rainbow, sensational newcomer, has a 4,000-mile cruising range, carries 40 passengers at speeds of 400 to 450 m.p.h."

War Dividend

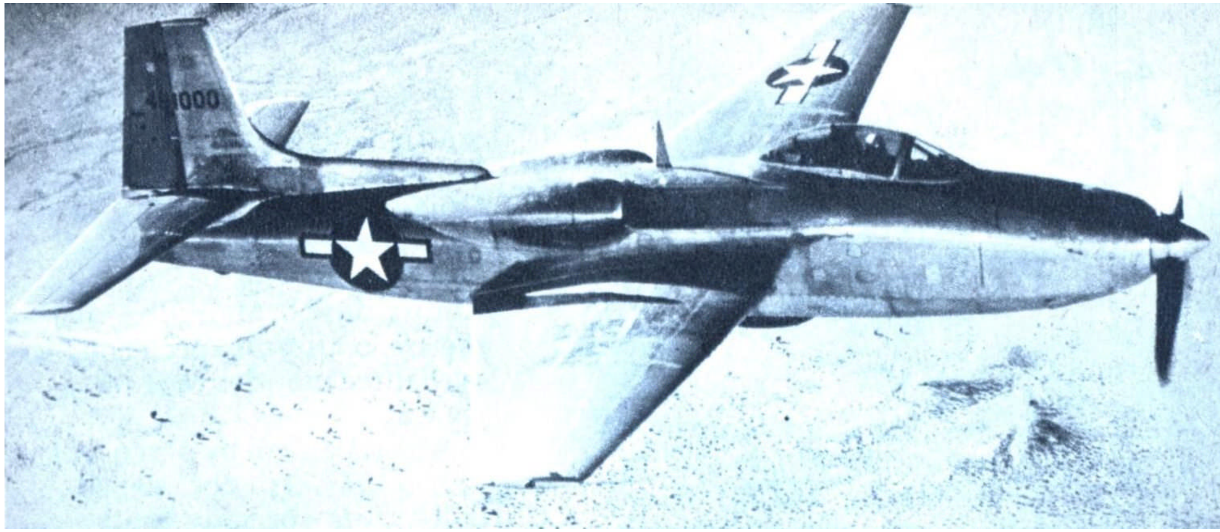
"…Planes with great improvements can be produced rapidly because it's relatively easy to convert warplane research to peaceplane progress…"
***Science Illustrated,* February 1947**

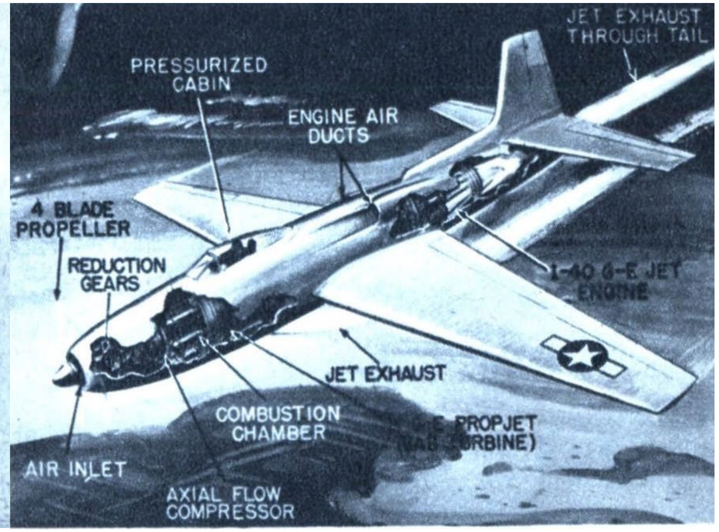
"…In five more years, and maybe less, the person who makes an air trip of considerable length will draw his final dividend from the war in comfortable flying…"

***Popular Science,* September 1946**

<u>Left</u>: caption: "Some of the individual conveniences in store for the air passenger of tomorrow. More personal comfort is the keynote."

<u>Right</u>: caption: "On long flights, electric stoves will permit preparation of varied meals aloft, in contrast to the vacuum-bottle menus that are served on air liners in use at present"





"…It was the war that accelerated work on the turbine as a power unit. Today the turbine, driving a conventional propeller and spewing burned gases from a jet pipe for supplemental thrust, is being installed in a version of the new Martin transport for experimental cargo work by United Air Lines. When it has proved its reliability, it will be fitted to passenger transports…"

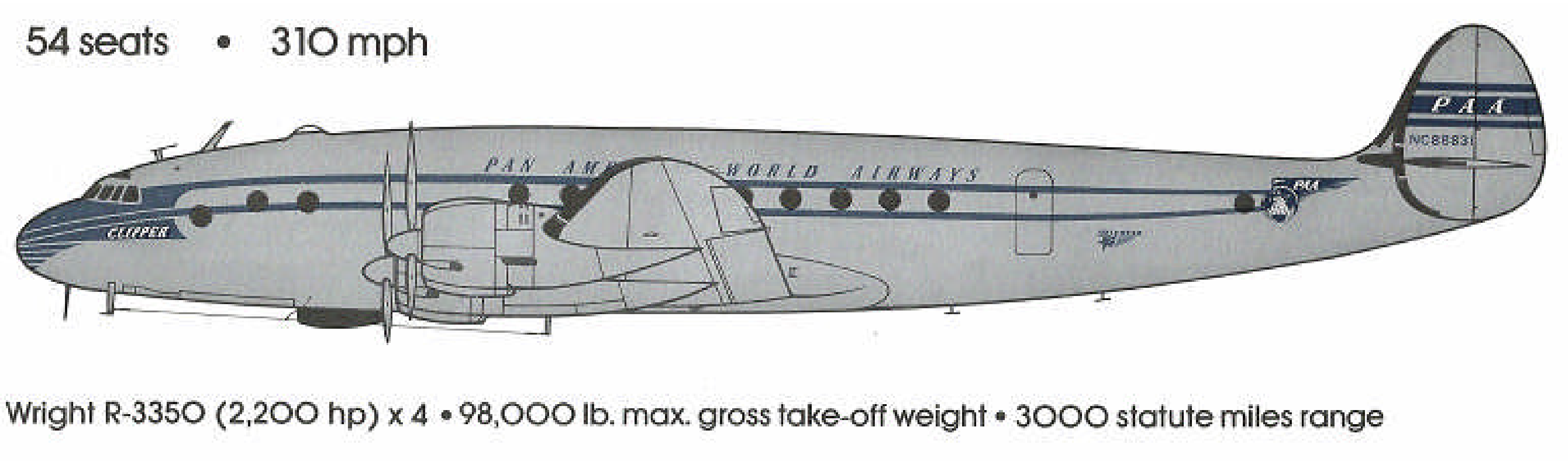
Popular Science, **September 1946**

<u>Above L&R</u>: caption: "Latest jet plane is this new Consolidated Vultee XP-81, the first plane ever to fly with a gas-turbine engine developed for propeller drive. Powered by a gas turbine engine in the nose and a jet engine in the tail, the sleek fighter will fly at a speed of more than 500 mph. At the right is a cut-away sketch showing the placement of the turbine and jet engine." (June 1946)

"…Turbine power, in contrast to that obtained from reciprocating gasoline engines, is practically vibrationless. Gone will be the aggravating, often nerve-wracking shaking that has always characterized powered flight. Because turbines produce more power per pound of weight, their adoption will mean even greater speeds; 400 m.p.h. will be no novelty. It will also mean bigger planes if the volume of passenger traffic calls for them…"

Popular Science, **September 1946**

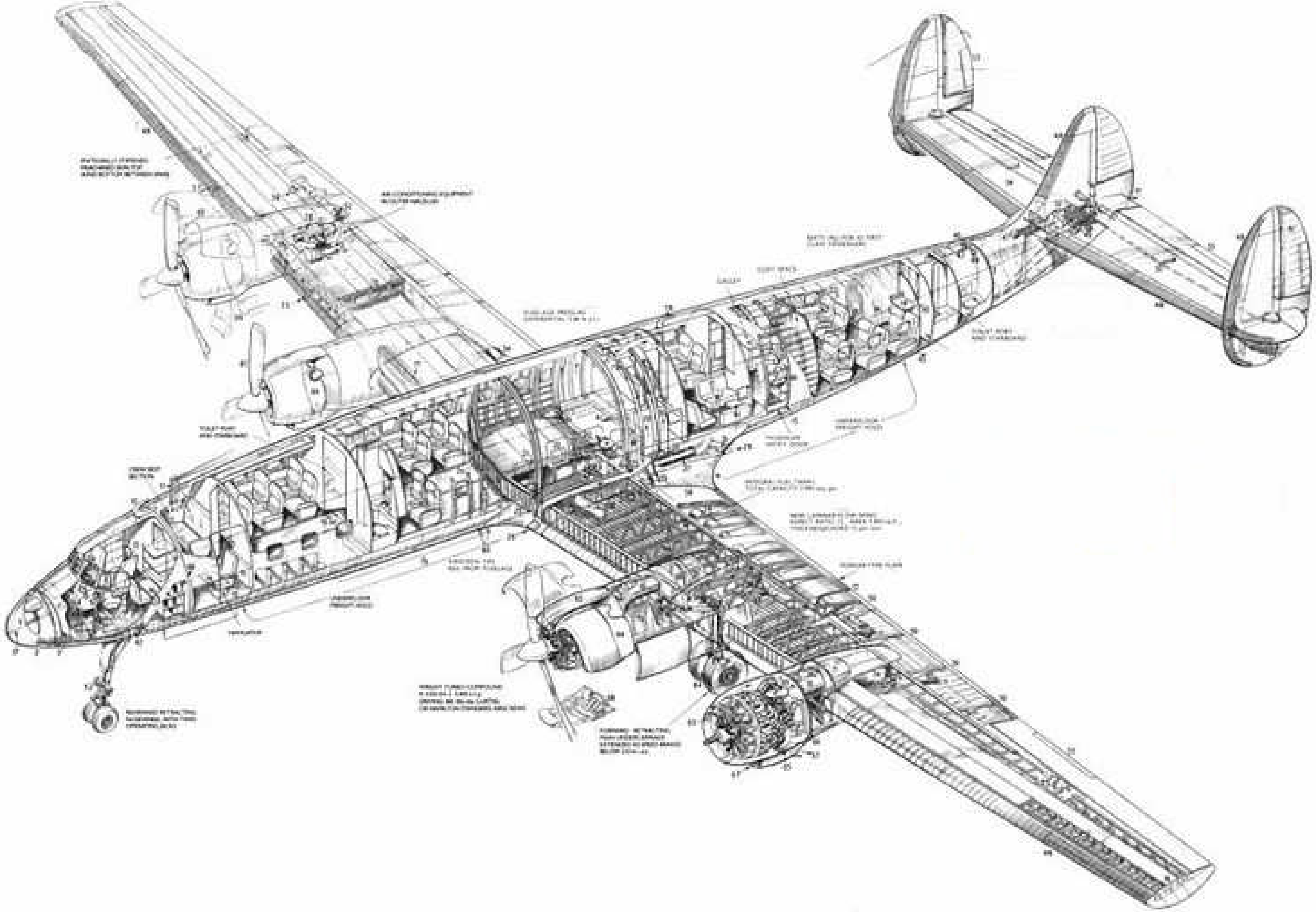
Shrinking the World



"New commercial transport planes, shrinking the United States to 1/200 the size of a century ago in terms of time, are incorporating a brand-new concept of comfort for the passenger. When airliners began operations in the late 1920s, the mechanics of operation were a primary consideration with designer and air-carrier companies. Today cushion-rubber chairs, modernistic lounges, and temperature controls are deemed as important as the navigational devices up front. To those are added speed; trans-continental flight in the Lockheed Constellation, for instance, is a matter of 10 hours, and crossing the Atlantic Ocean between Washington, D.C, and Paris, France, takes less than 13 hours…"

***Popular Science,* April 1946**

<u>Above</u>: caption: "PAA Lockheed 049 Constellation"



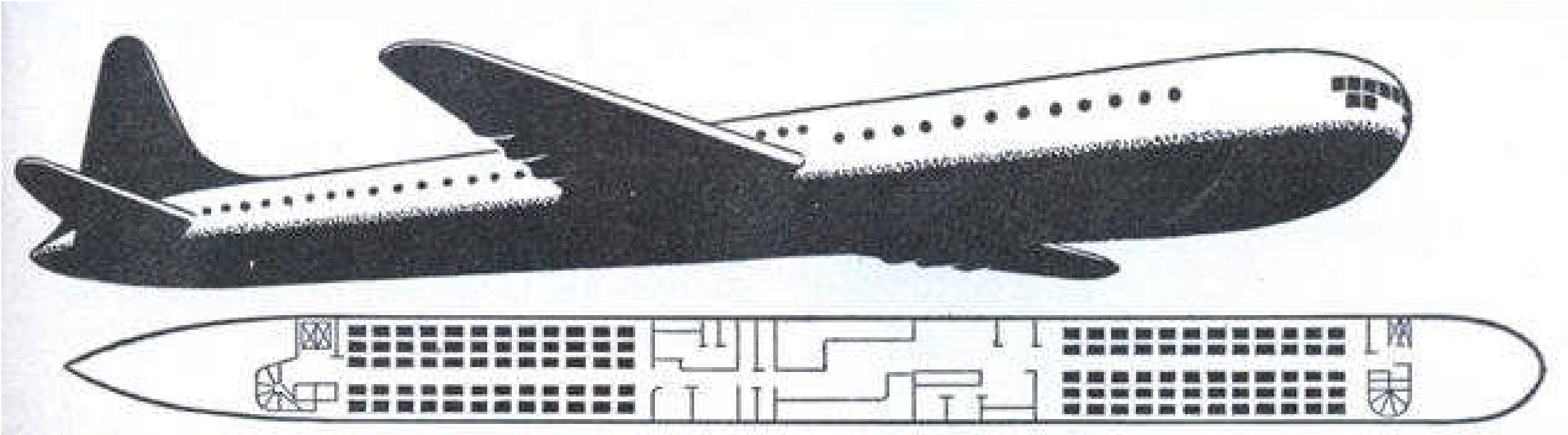
"…Constellations carry 57 passengers more than twice as fast as the familiar veteran, the 180-mile-an-hour DC-3. The fuselage in cross section is a perfect circle. Two super-chargers pour fresh air into the cabin to hold pressure at a simulated level of not more than 8,000 feet, and heating and refrigeration control the temperature. Circular windows en-able passengers to enjoy the unfolding view. More than 100 Constellations are being rushed to completion…"

Popular Science, **April 1946**

"…Designers and engineers are preparing other titans to speed the new era of air travel - Douglas' DC-6, the huge Stratocruiser by Boeing, and the gigantic Model 37, by Consolidated Vultee. Soon a passenger may breakfast in London, enjoy a late lunch in New York, and go to bed that evening in Los Angeles…"

***Popular Science,* April 1946**

<u>Above</u>: caption: "Here's the biggest airliner of the lot – Consolidated Vultee's Model 37. Weighing 320,000 pounds, it will be nearly twice as heavy as any land plane yet flown. Six gas-turbine engines will drive the giant."



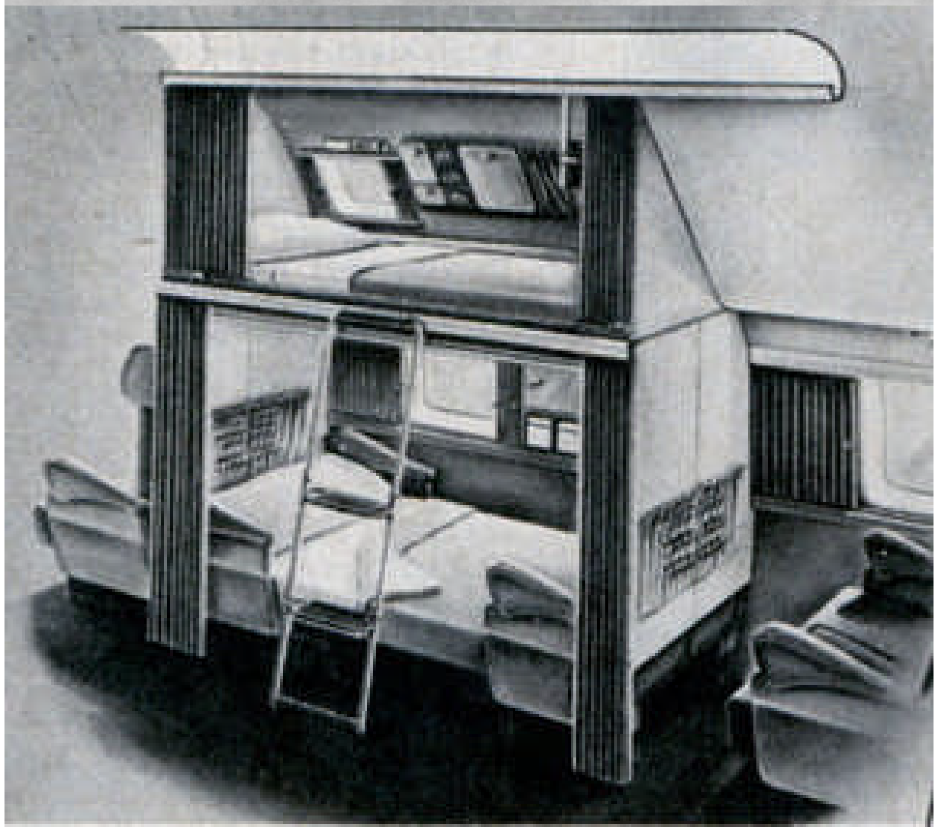
"…Consolidated Vultee's Model 37, developing 30,000 horsepower, will have a cruising speed of 342 m.p.h. This monster will be nearly twice as heavy as any land plane yet flown. On nonstop flights up to 4,200 miles, 204 passengers will enjoy the comfort of four cabins on two decks. These planes use plenty of gas. At takeoff, the Model 37's six big engines will consume fuel faster than you could bail it out of a barrel with a 10-quart pail, but they develop more power than 360 Ford V-8 engines. The electrical system would supply a town of 5,000…"

***Popular Science,* April 1946**

Above: caption: "When they enter commercial service, giants like the Convair Model 37, carrying up to 200 passengers at speeds in the 350-m.p.h. class, will handle intercontinental and express trans-continental traffic"

"…Consolidated-Vultee won't attempt to build a Model 37 until it can get turbines of 5,000 horsepower. The general adoption of turbines for long-range flying, incidentally, will make operation at high altitudes mandatory. Turbines work better higher up. Altitude flying will obviate the 'bumps' encountered in the turbulent air of storms, high winds and heat reflected from the earth…"

Popular Science, **September 1946**



"…When the DC-6 makes its appearance, it will be 80 inches longer than the DC-4 and will cruise at about 275 m.p.h. Passengers will enter this plane through a door aft of the wings. They will relax in cushion-rubber chairs, and stewardesses will serve meals from buffets near the door…"

Popular Science, **April 1946**

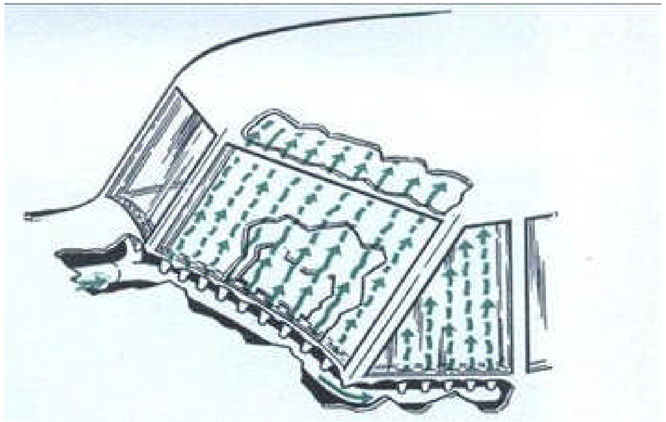
<u>Top</u>: caption: "UAL Douglas DC-6"

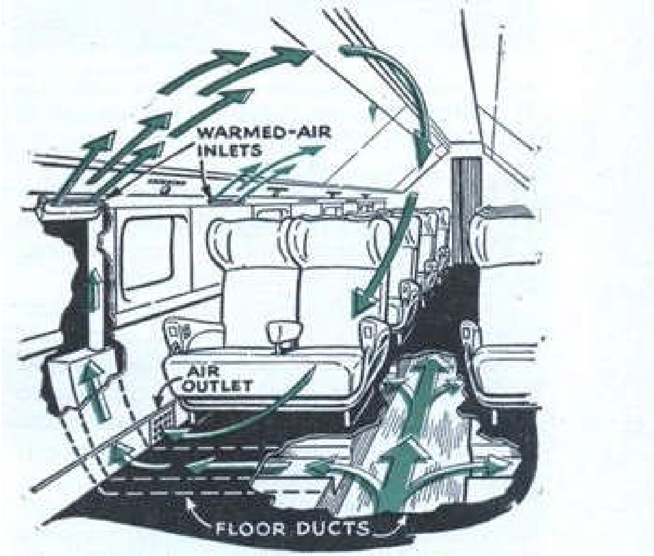
<u>Bottom</u>: caption: "Up to 70 passengers will be carried by day in the Douglas DC-6, while at night the capacity will be 26. Speed and comfort are stressed. Each berth of the DC-6 has an outside window. Lowers are 76-inches long, uppers 78-inches, both about 40-inches wide. Bedding and end panels are stored in upper berth."

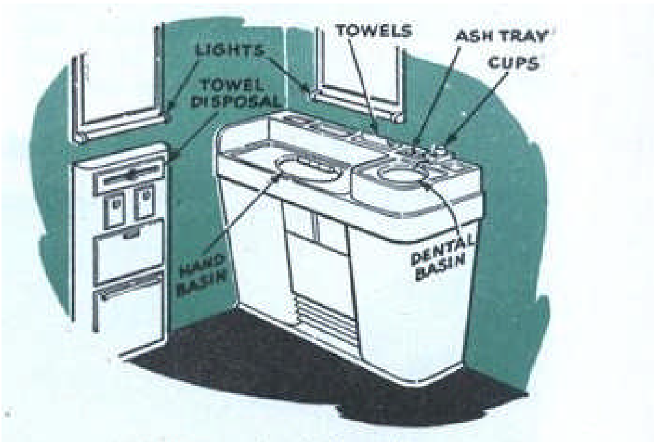
Shooting the Works

"…Give the aircraft manufacturers credit. Trying to keep their heads above water amid ruthless competition, they have done most of the work in the year since the war ended to make flying more enticing to the airline customer. The carriers themselves, spoiled by six years of more business than they could handle, too often have been characterized by the reservation clerk who is snippy over the telephone. The plane makers weren't blessed with that problem They had to go out and get business. To sell planes they had to build better ones, with more appeal. So they are shooting the works…"

***Popular Science*, September 1946**





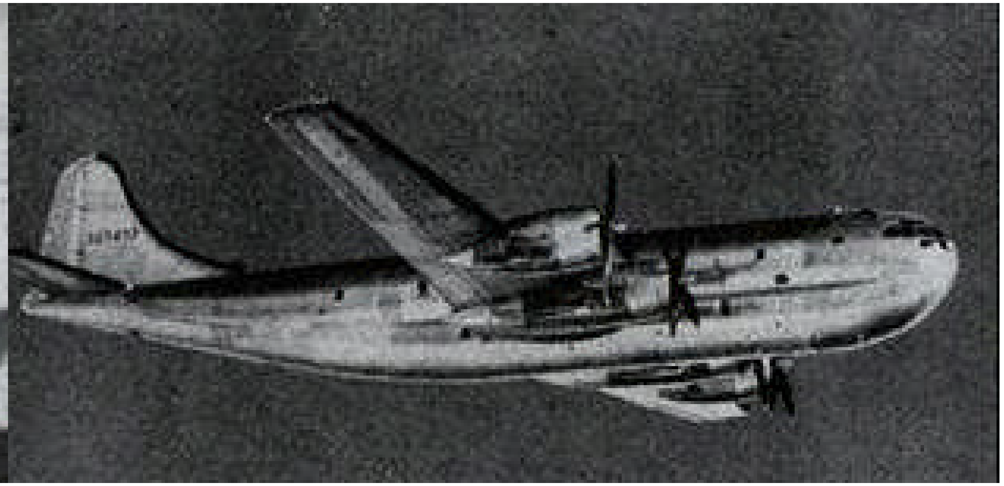


<u>Top Left</u>: caption: "The pilot's needs have not been forgotten. This windshield has two glass panels, with warm air flowing between them to prevent fogging on the inside and icing outside. Each panel is crash-proof, a safeguard against collisions with birds."

<u>Middle Left</u>: caption: "Automatic radiant heating for cabins will maintain perfect temperature control, eliminating the now-it's-too-hot, now-it's-too-cold complaints. Other comforts will include complete air conditioning and press-urized cabins in high-altitude craft."

<u>Bottom Left</u>: caption: "Improved facilities, such as the Pullman-type fixtures illustrated, will be among the features of more spacious powder rooms for women and lavatories for men on main-line planes."

Comfortwise & Courtesywise

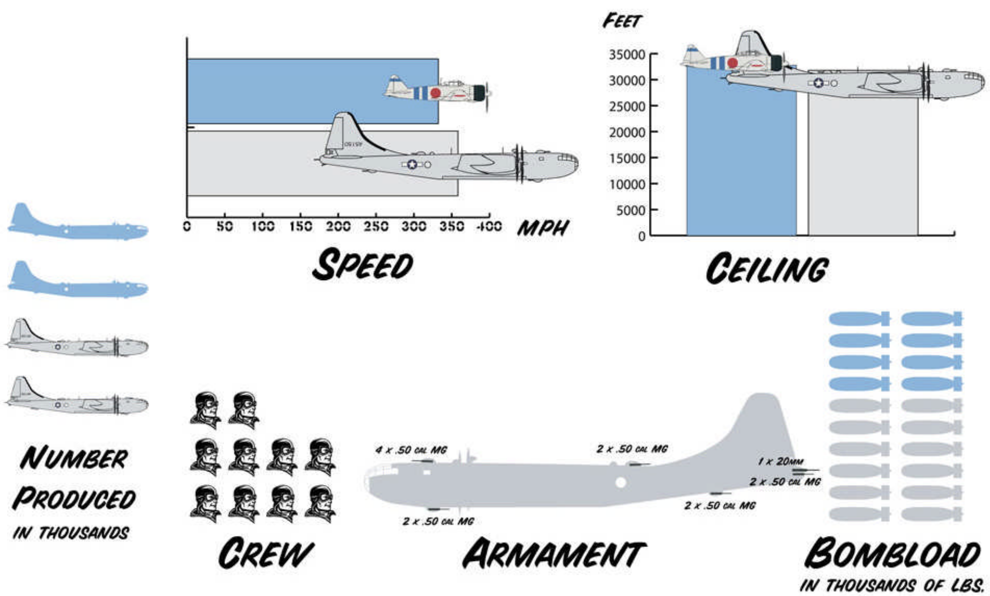
 

"…What planes will replace these old stalwarts that have been scientifically outmoded? On the shorter hops there will be planes like the twin-engined Martins, flying almost twice as fast as the still-standard DC-3s. They'll carry more passengers per plane, all the instruments and other safety devices, including thermal de-icing. This means wing edges will be heated to eliminate an old hazard, icing on the takeoff and in landing. For the longer coast-to-coast and trans-Pacific runs lines will be using big planes like the Boeing Stratocruiser, the commercial plane that grew out of the famed warborn B-29, the Superfortress that shattered the Japanese mainland. Cabins will be pressurized, speed will be doubled. All of these are improvements the airlines have to make. They have to move faster comfortwise and courtesywise than the railroads, because people expect more of the airlines than they do of the other carriers…"

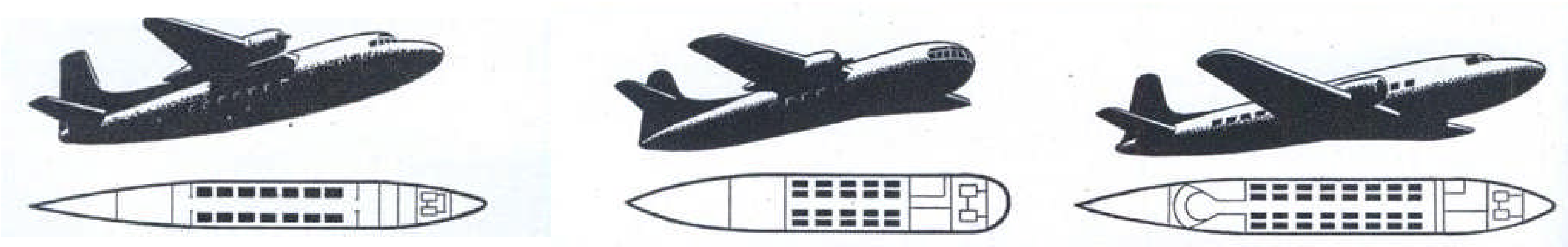
Science Illustrated, **February 1947**

Left: caption: "Martin 2-0-2 is a 40-passenger liner, cruises 270 m.p.h."

Right: caption: "Boeing Stratocruiser seats 100, flies at 340 to 400 m.p.h." The *Boeing Stratocruiser* was uneconomical to operate thus, Boeing only built 70 commercial models of the type.



Although the first specifications for the *B-29 Superfortress* were made in 1940, the first B-29 (built in Boeing's Renton, Wash. facility) was not delivered until 1943 (the B-29 did not reach full service until 1944). The B-29 was the most technologically advanced aircraft in the *U.S. Army Air Force* (USAAF) fleet during WWII. The U.S. government had asked Boeing to produce a long-range, accurate strategic bomber that could travel the long distances across the Pacific Ocean to Japan. Originally produced for the long-term bombing campaign planned for Japan, the B-29 was used to deliver the atomic bomb/s via the *Enola Gay* and *Boxcar* to Hiroshima and Nagasaki respectively. Later models of the B-29 were developed for use in weather programs and geological surveys. These B-29s were given the designation "F-13." The F-13 was responsible (from bases 1,500 miles away) for all the reconnaissance work which preceded the bombing of Japan. These models were in use until the early 1960s.



"…The A.T.A. believes that the current, frenzied purchase of new transports by the air lines to cash in on a war-born bonanza of patronage ultimately will create an orderly, stepped-down pattern of air-line equipment:

- ***Planes with 80 to 200 seats for intercontinental flights.***
- ***Planes with 40 to 60 seats for main trunk lines.***
- ***Planes with 20 to 25 seats for smaller trunk lines, such as those of considerable length over sparsely settled areas.***
- ***Planes with 10 to 15 seats for feeder lines serving communities with populations as small as 2,500.***

The main trunk lines also will have a certain number of 80- to 125-passenger planes for one-stop or nonstop coast-to-coast schedules. Some of these, in turn, will be fitted as sleepers…"

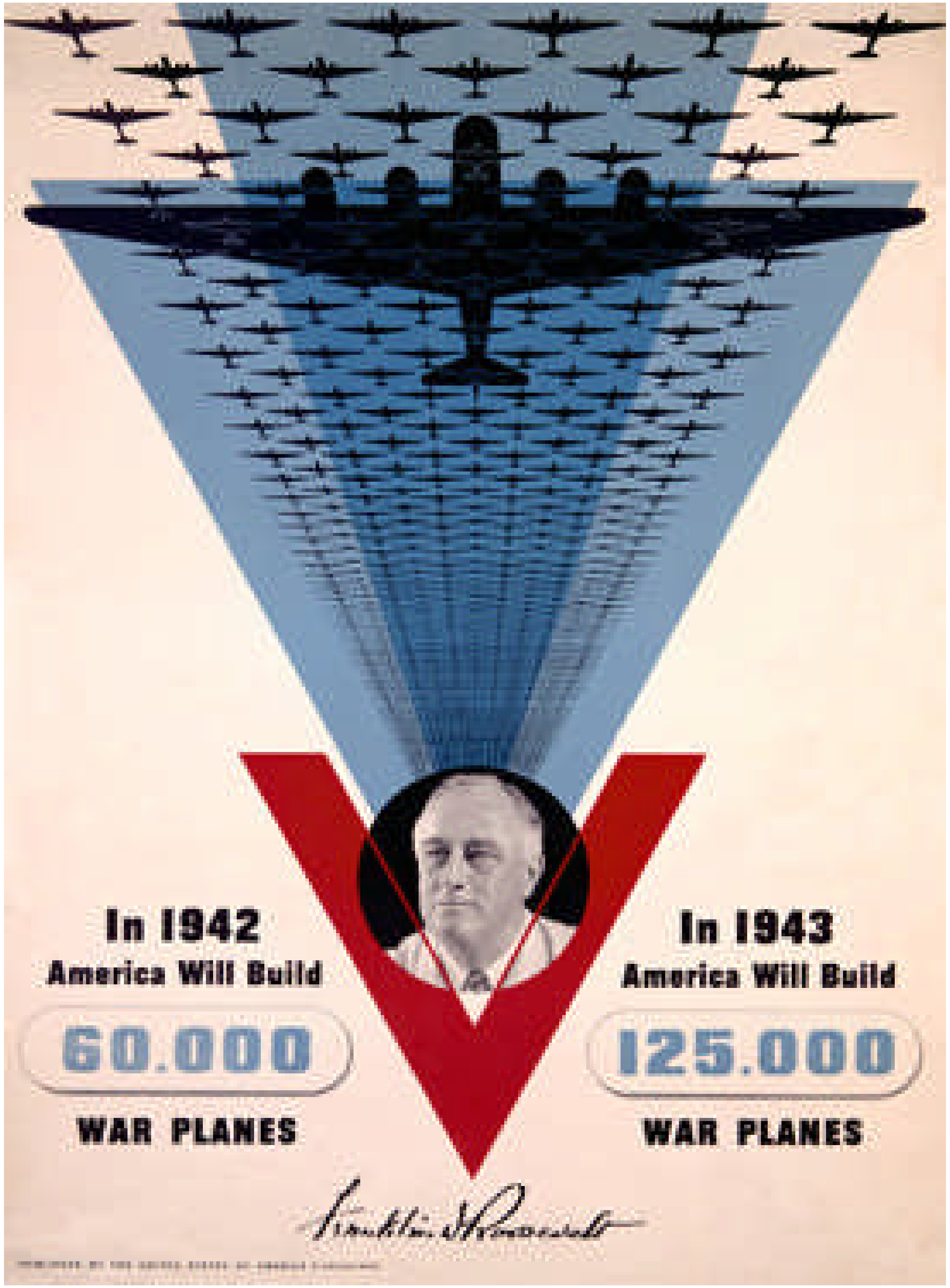
Popular Science, **September 1946**

<u>Left</u>: caption: "Planes with 10 to 15 seats will be used on feeder lines to bring even small communities into the U.S. air network"

<u>Middle</u>: caption: "Transports seating 20 to 25. cruising at 200 m.p.h., will step up present speeds on minor trunk lines"

<u>Right</u>: caption: "Faster runs on major trunk lines will be provided by 300 m.p.h. planes seating 40 to 60 passengers"

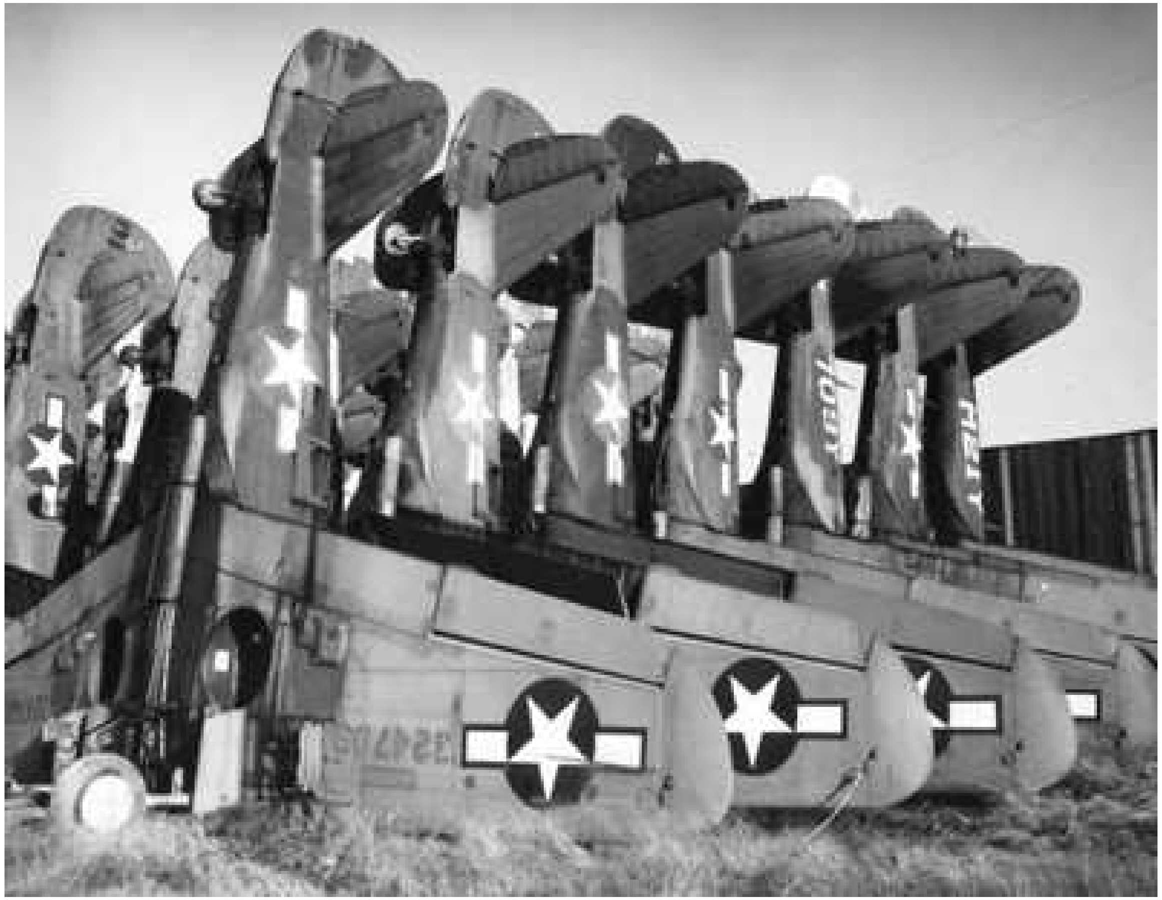
In a Dither



"…In their anxious, keep-up-with-the-Joneses buying of new transports - a windfall, by the way, to aircraft manufacturers who had billions in war orders canceled overnight – the airlines really deserve a little sympathy. They are in a dither. They are filthy rich in patronage but they want more…"

***Popular Science,* Sept. 1946**

Left: caption: "WWII Homefront Victory War Plane Production Poster"

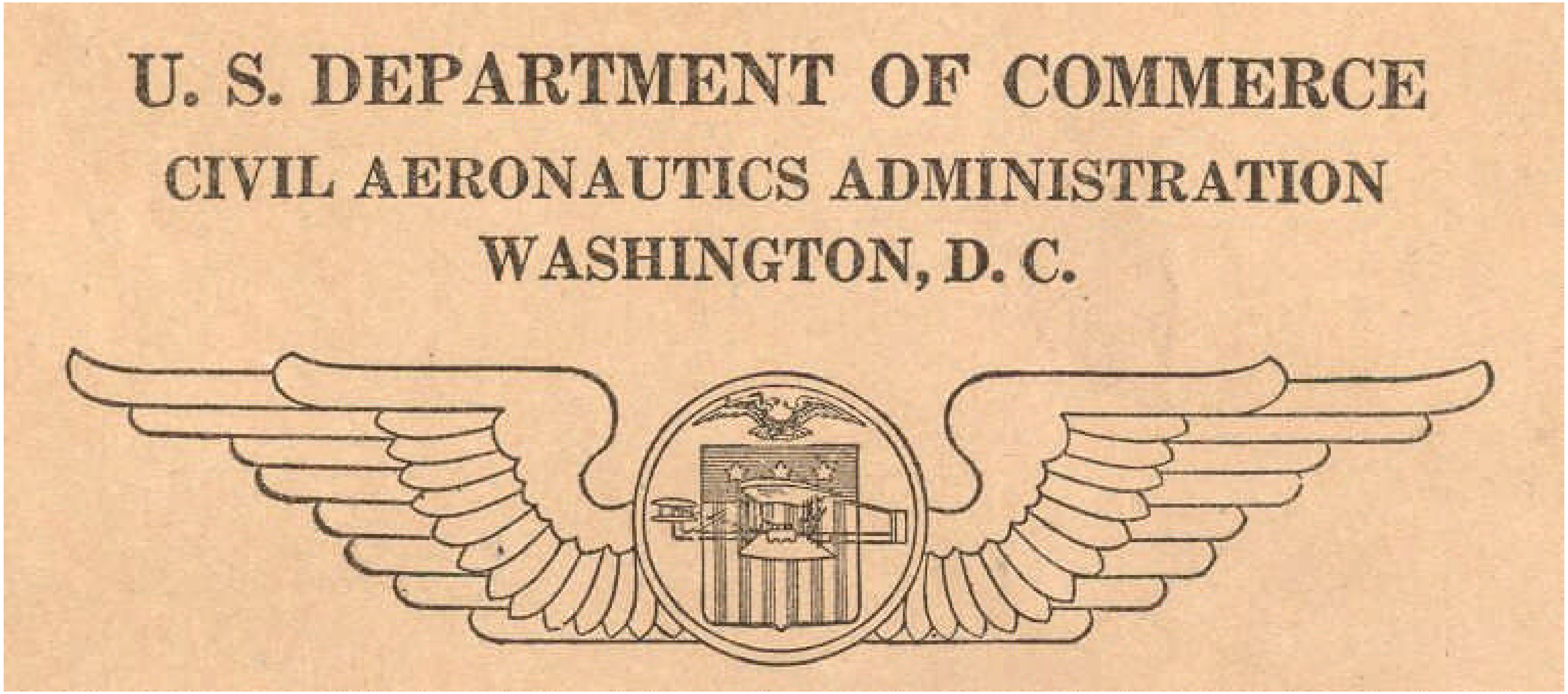


"…In casting around for answers, the only real truths the carriers can get their teeth into are those that can be proved on a slide rule. They know that the volumetric capacity of a conventional airplane varies as the cube of its linear dimension, while fuselage structure weight varies roughly only as the square. Put in plain language, that means the bigger the airplane, the more profit. As yet the theory of small planes for short runs is only a theory. People may begin using airplanes as they use buses. If the airlines buy big planes, which can be operated more economically per seat than small planes, they stand to lose their shirts if they don't carry good-sized loads. If they get timid and buy small planes of only fair speed in anticipation of modest patronage, they not only risk the larger profits on more expensively operated equipment but may lose customers as well to competitors with bigger, faster planes. They can't hook on a glider to take care of overflows as a railroad hooks on an extra car…"

***Popular Science,* September 1946**

"During the war, flying in zero-zero weather was no uncommon thing. Now the problem is to adapt equipment and methods to the commercial airlines, and get approval of the Civil Aeronautics Board. The adaptation is not too simple, will take time, but it will be worked out. This will mean that if an air traveler is scheduled to reach Shanghai, China, at 9 a.m. next Friday, he will be quite certain of getting there right on time."

Don King*, VP in charge of Orient routing for *Northwest Airlines



"…Whatever they buy, the public will benefit. More than 300 companies have filed applications with the Civil Aeronautics Board, the agency which rules the industry with an iron hand, to establish feeder routes. Right now only 61 of the nation's 665 communities with populations of 10,000 to 25,000 enjoy airline service. Almost half the nation's counties have no airports. Of the 678 points that feeder and trunk lines propose to add as stops, only 93 have satisfactory airports. That means a lot of heat is to be put on American cities and towns to build new airports or improve old ones. The more airports, the more places the airline customer can fly…"

Popular Science, **September 1946**

"…Some cities have their airport so close to the heart of town you can get to it in a cab in five minutes. But there are often some pretty high buildings in these cities. So at a 1,000-foot ceiling, the minimum for landing with safety under these close-proximity conditions, only 60 percent of the airport's actual facilities can be used. We'd all like downtown airports! Near by may be a city with even higher buildings, but with an airport so far out of town the buildings don't count. Approaches can be made at a 500-foot ceiling and 98 percent of the airport's facilities are utilized. Though everyone would like airports as close to the heart of town as possible, this isn't practical for most large cities. We ought to have airports where landings can be made at 1,000-foot ceilings, and almost 100 percent of the time. This means instrument flying, the safest flying there is. Many pilots will tell you they feel safer, and have less concern for safety of their passengers, when flying fully on instrument. But you can't get downtown in nothing flat, if you want a port with a 100-foot ceiling…"

***Science Illustrated*, February 1947**

"We are not masters of our own destiny insofar as airports are concerned"

Airline Executive (ca. 1947)

<u>Left</u>: caption: "Washington, D.C., had one of the most inadequate airports in America. Only way to improve facilities to meet current and future demands was to build the new municipal port pictured here. And yet this fine field, built as recently as 1941, already is approaching its capacity of 50 planes an hour. You are looking across the runways (from the passenger terminal interior) of what's currently the best airport in the U.S. The old field nearby is still usable for small planes, but not much more. New airports are badly needed throughout the U.S. New York's LaGuardia is out-of-date. Even with huge Idlewild, New York may need another big airport in three years. Chicago has to use Douglas Field (Douglas Aircraft) besides the field at Cicero. San Francisco, Philadelphia, Phoenix – all have big expansion plans. Building airports is a tremendous task and will require tremendous joint effort by all concerned."

Hurry-up and Wait

"…The big lines were a major part of the Air Transport Command, so they're all familiar with instrument flying. As an example, Northwest Airlines' planes, on their wartime run to Attu, were equipped with every safety instrument the Army, Navy, and the airlines were able to devise. Northwest's pilots on this run (notorious the world over for its bad weather) made a record that is something for Northwest to be proud of. Two round trips a day, day and night, almost always 'on instruments,' were routine. And yet, pilots on this difficult run turned in better operating results than were being maintained over continental United States. Why were they able to make such a record? You know the answer: instruments. Radar instruments and others, plus landing facilities…"

***Science Illustrated*, February 1947**

"…The war's over now, but the instruments are still there, and they are still doing the same marvelous job. The trouble is there aren't enough instruments and landing facilities to do the job the airlines would like. All lines and their pilots want the same facilities that helped on the Attu run, and others. They want them right away. But you want a new car . . . you want another apartment . . . you want a new coat of paint for your house. You can't get them. Neither can the airlines get the fields, approaches, instruments you think they should have for your speed, convenience, and safety. And they can't get them for the same reasons that you're on the waiting list…"

Science Illustrated, **February 1947**

Three-Miles-a-Minute Plus

"…In the next five years he will be flying faster, too. Yesterday's standard air-line speed of 170 m.p.h (advertised tongue-in-cheek as 'three miles a minute') is being boosted right now with transports, some of them re-modeled from the war, that do 200 to 275 m.p.h. Even short-haul trans-ports like the new 14-seat Lockheed Saturn will travel 200…"

***Popular Science,* September 1946**

RE: in late 1946, Lockheed announced that it had decided to temporarily shelve development of the *Saturn*, citing the lack of a reliable engine at the desired power rating. In February 1947, Lockheed announced a renewal of the Saturn project due to the availability of the *Wright Cyclone* engine (which were fitted to the first prototype, above). Though flight tested, the project came to an end late in 1947. Despite an earlier announcement of 500 possible orders, Lockheed de-clared that the market was not strong enough to support the $100K unit cost.

"…The 24-passenger Boeing 417, a pint-sized companion of the same company's Strato-cruiser, will fly at 196 m.p.h. The 40-passenger Martin 202 will make a bit less than 300; the 40-passenger Consolidated-Vultee 240 type, a full 300; the 52-passenger Douglas DC-6, a little more; the 80-passenger Stratocruiser, 340; the 200-passenger Consolidated-Vultee 37 model, 340, and the 46-passenger Republic Rainbow, 400…"

***Popular Science,* September 1946**

Above: Convair 240

Top Left: Boeing 417

Middle Left: Martin 202

Bottom Left: Republic Rainbow

"…All of these planes are on order. No deliveries to air lines will be made on any of them before the end of this year, and most of them won't be off the production lines until 1947 or 1948. The Convair 200-passenger job, commercial version of the U.S. Army's C-99, won't be flying before 1950…"

Popular Science, **September 1946**

RE: Convair briefly considered building a commercial version of the XC-99 but in the end, they built only one XC-99 (left).

The Sky's the Limit

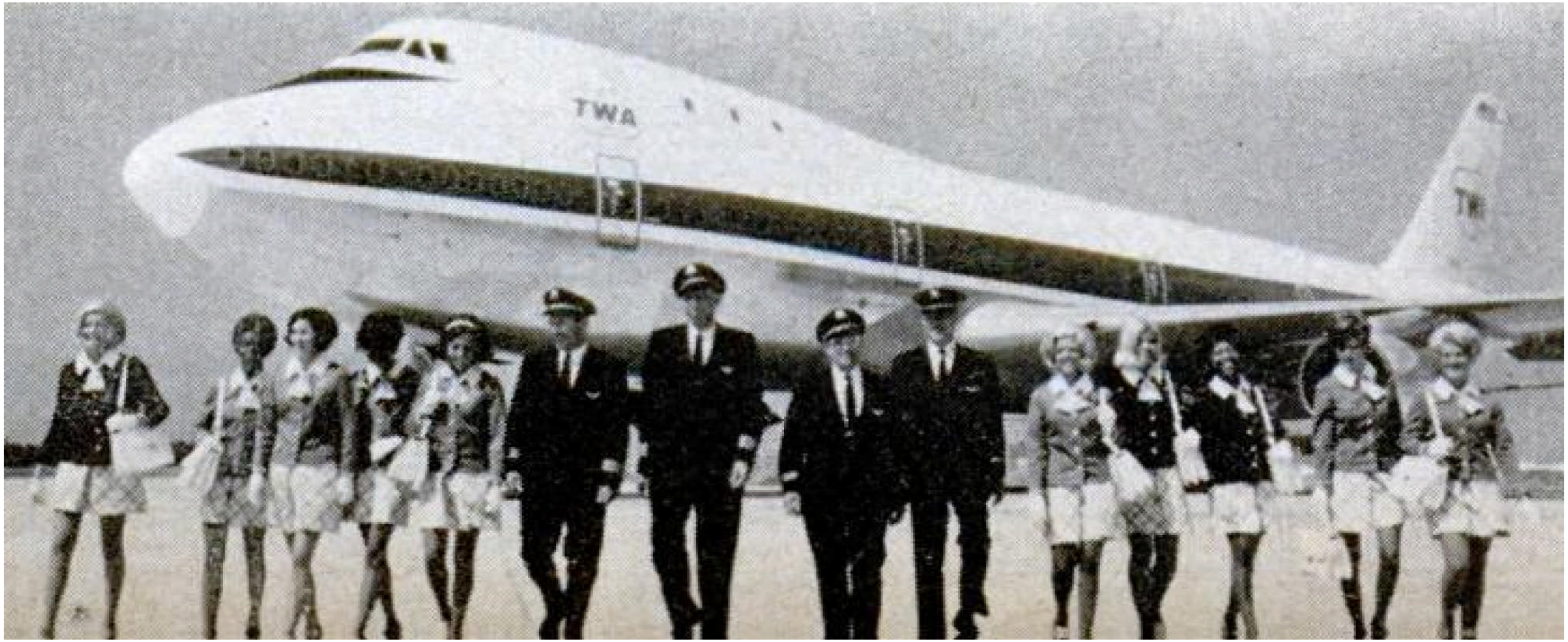
"…The airline customer may expect to fly higher. All the new transports except those devoted exclusively to short hauls will be pressurized for altitudes of at least four miles and new techniques will maintain sea-level pressure to as high as three miles."

***Popular Science,* September 1946**

Part 5

The Future is Now

A Reassuring Presence



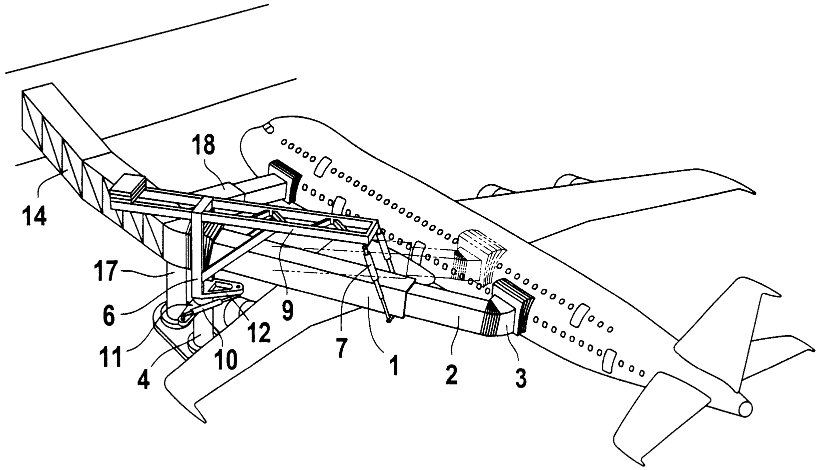
"…this 350-ton giant provides 362 passengers with more comfort, more speed, more security than any plane ever built. The 747 is over 90 feet longer, weighs more than twice as much on take-off, and carries a load three times greater than the original 707 does…The 747 requires a three-man flight crew…some airlines will have an additional male cabin attendant to repair minor things in flight in the large passenger compartments, and to serve as a reassuring presence…"

***Popular Science,* December 1969**

Above: caption: "Three-man flight crew is all that's needed to handle the 747, but 11 other crew members are needed to serve the 362 passengers"

"…After the imaginary flight it was time to become a potential passenger. Boeing showed us everything that will be available in terms of passenger comfort and convenience except for the 15 hostesses who will be on duty on each plane…"

Modern Mechanix, **Nov. 1968**



"…Here is how it will be for a paying customer: He'll board through one of the ten entry doors (five per side, each 8 in. wider than the two doors on a 707) arriving through one of several telescoping passageways which will deliver him from the terminal building directly to the position nearest his assigned seat. At some airports, portable boarding ramps still will be in use, but it will take at least three of them to accommodate the full passenger load…"

***Modern Mechanix,* November 1968**

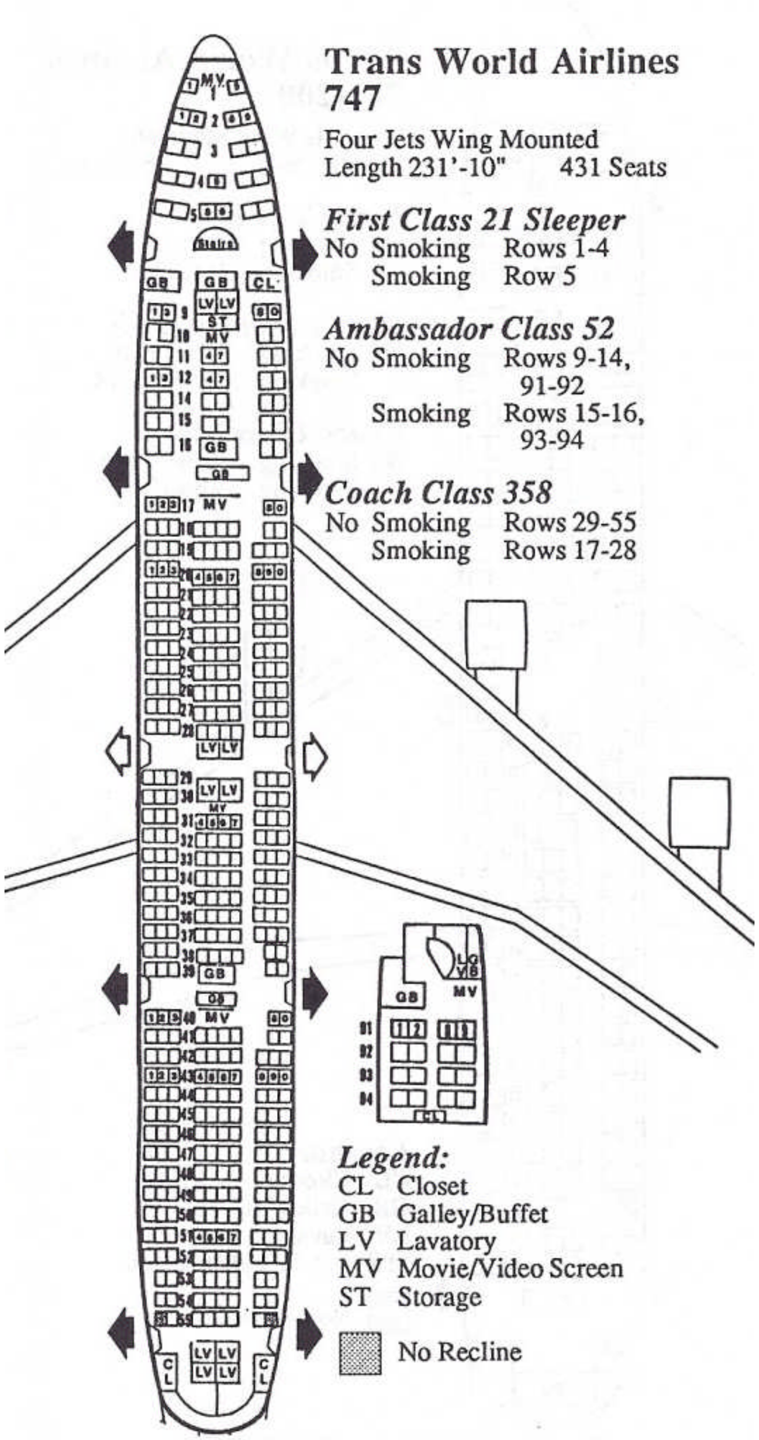
<u>Left T&B</u>: telescoping gangway patent drawing (top) and close-up view (bottom)


747
BOEING 747


B45

"…As our passenger heads for his seat he'll notice that there are two lengthwise aisles and five cross aisles. Both aisles and seats are at least 10 per cent wider than those on existing 707s. Ceiling height is 8 ft. and walls are near-vertical…"

***Modern Mechanix,* November 1968**

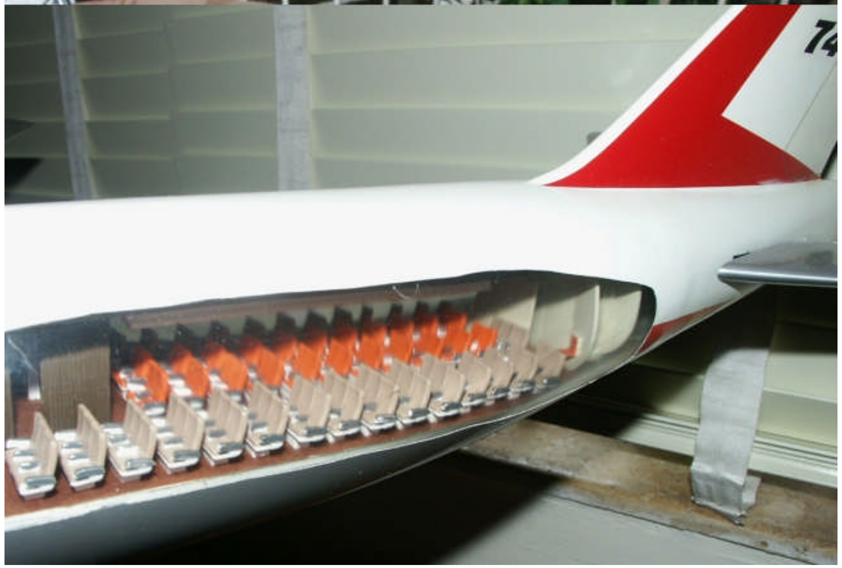


"…Passenger seating will vary according to airline requirements. Basic mixed class will be 58 first-class seats and 308 at lower fares, these latter nine abreast. In another version there will be 61 in first class and 336 arranged ten-abreast. One all-economy setup is 446 seats nine-abreast. Maximum is an all-economy, 490-seat, ten-abreast configuration…"

***Modern Mechanix,* November 1968**

<u>Left</u>: seating plan for a TWA Boeing 747-100 (ca. 1980s). Divided into three cabins, this workhorse of TWA's international operations seated 21 passengers in First Class, 52 in Ambassador Class (Business) and 359 in coach. The standard seating layout is 3 x 4 x 3 (Coach has several double-rows of Seating)





"…First-class passengers can look forward to using an upper lounge (just behind the flight deck) accessible via a spiral staircase from the main cabin…"

***Modern Mechanix,* November 1968**

THE BOEING 747 PASSENGER AIRPLANE

FLIGHT DECK

The control cabin and crew accommodations area comprise the flight deck. Its location above the main cabin enables the pilot to scan the field from an eye-height of 29 feet.

Crew accommodations are larger than those of previous jetliners and include generous storage space and a lavatory.

For ease of access, pilot seats move to the sides. Sidewall chart holders and work tables are additional features of the 747 that contribute to pilot comfort and efficiency.

Latest state-of-the-art flight controls are incorporated in a cockpit arrangement that allows good visibility.

FIRST CLASS SECTION

Passenger windows in the forward section of the airplane are now possible since the flight deck is placed on a higher level. Extra wide seats in this section are designed for luxurious comfort. The pleasing decor of this area is enhanced by the circular stairs leading to the flight deck and the passenger lounge. Provision is made for a service bar just forward of the stairway.

FIRST CLASS PASSENGER LOUNGE

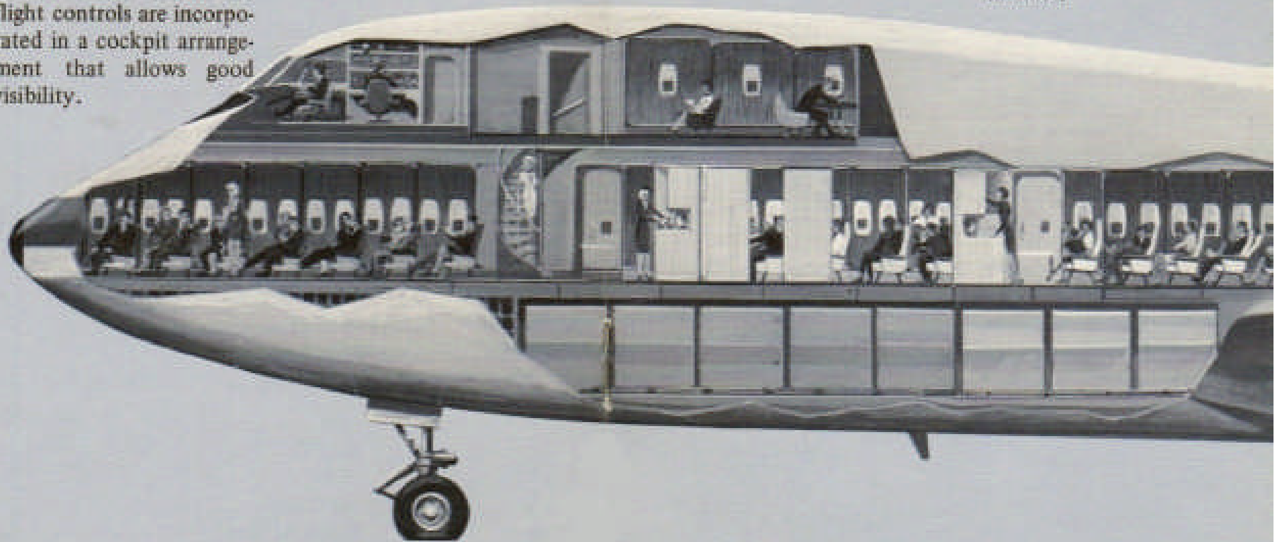
Located at the top of the stairway and behind the flight deck is a first class passenger lounge which is an optional feature of the 747. This lounge provides an appropriate atmosphere for conversation and refreshment.

A stateroom arrangement is offered as an alternate option to the lounge. Facilities can be provided for sleeping quarters, daytime seating or private conference rooms.

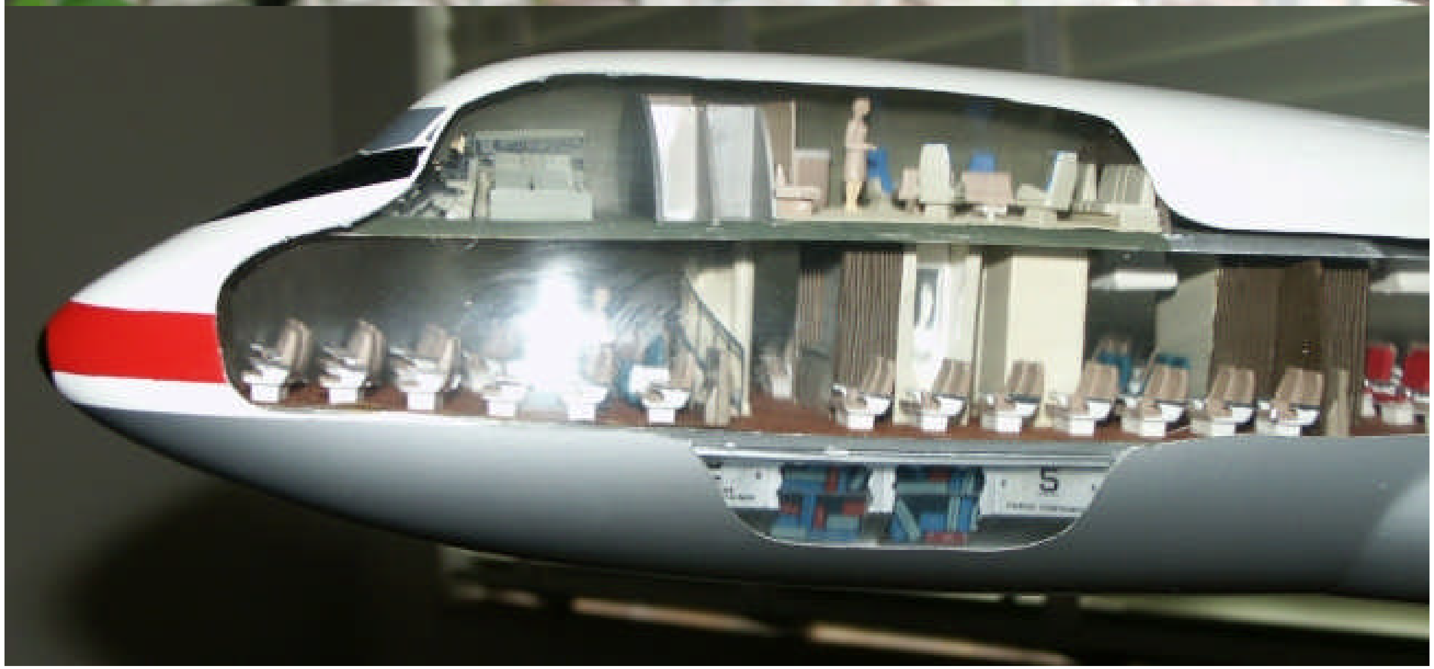
BOARDING AND BAGGAGE HANDLING

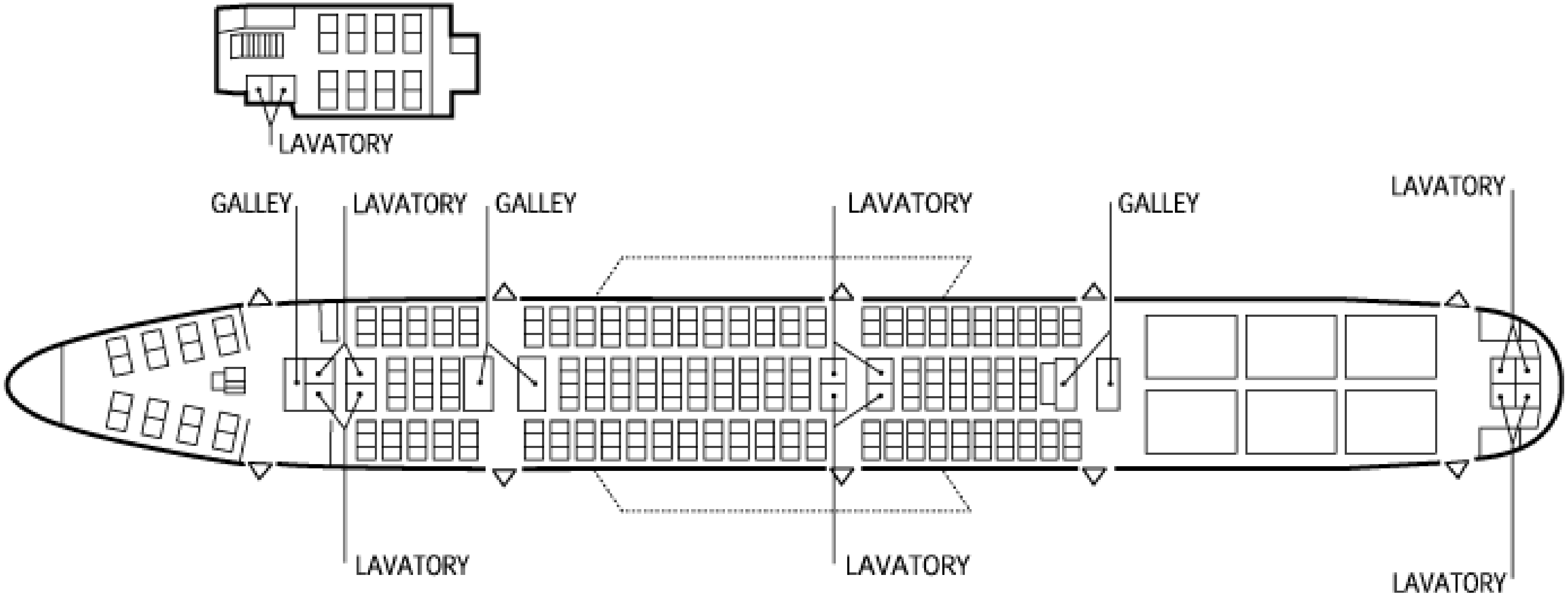
Three hundred and sixty passengers can easily board the 747 in six minutes when three of its ten doors, each wide enough for two people, are used.

For rapid handling of baggage, containers contoured to the dimensions of the lower compartments have been designed to be quickly loaded at the terminal and transferred to the airplane where a powered system will move them into their stowed position. At destination, unloading will be expedited in a similar manner.



Above: Boeing 747 brochure (ca. 1970)



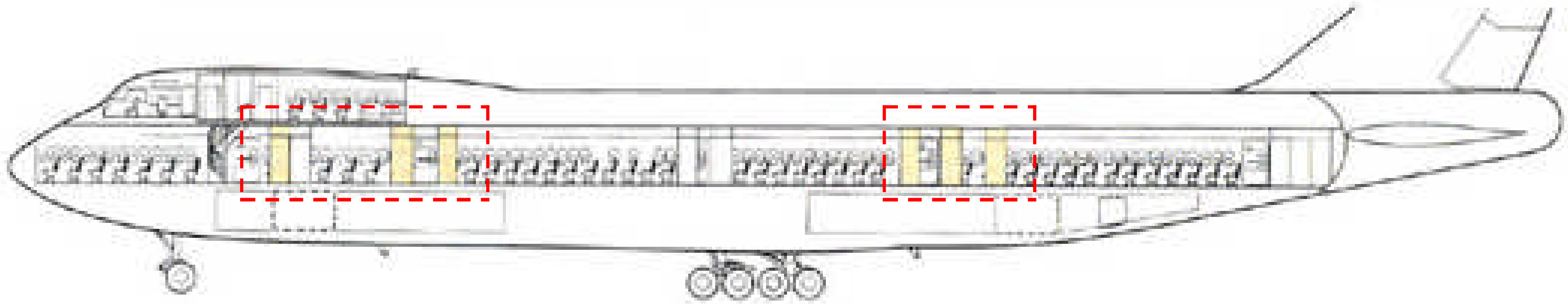


"…The 747 boasts five galley units and 15 lavatories. Something brand-new is the concept of overhead storage lockers. Hand luggage carried aboard will not be permitted under the seat…"

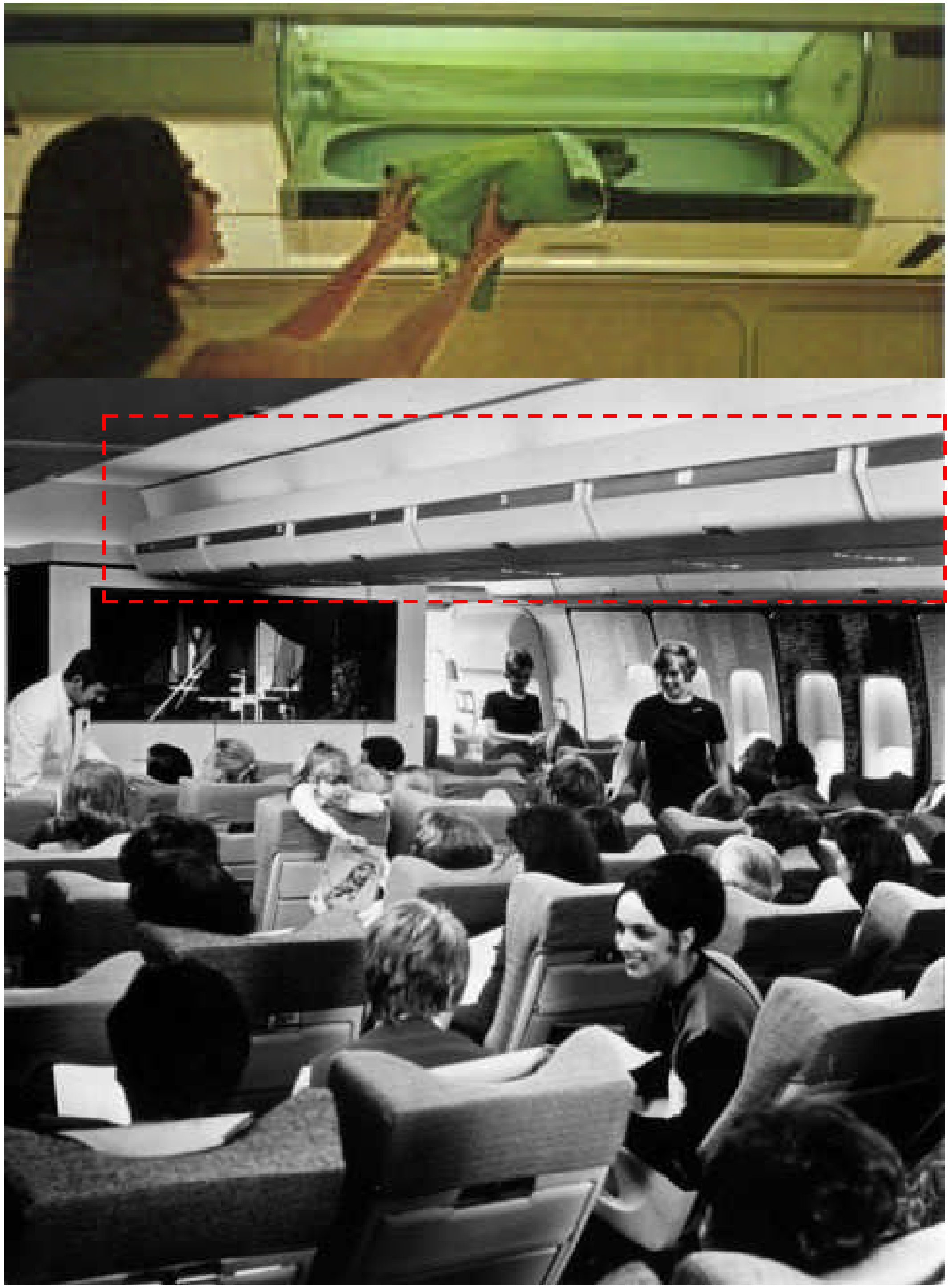
Modern Mechanix, **November 1968**

<u>Above</u>: caption: "Typical Cabin Configuration of Boeing 747-200"

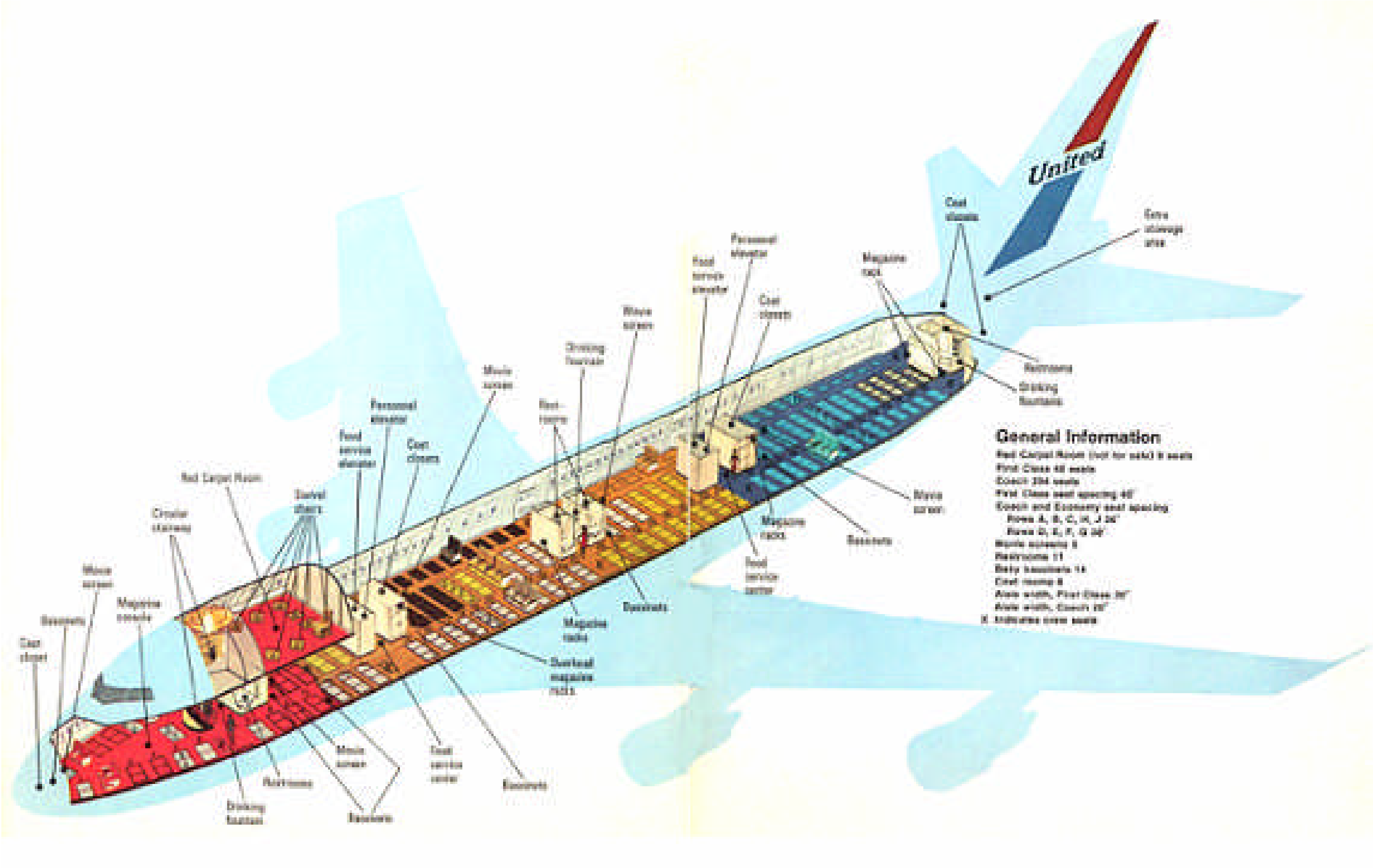
<u>Left</u>: caption: "Boeing 747 Galley"



<u>Above & Left</u>: caption: "Main Deck Galleys. Generous galley complexes can be located near doors 1, 2, and 4 as shown in the diagram. The galleys are 80 to 90 inches wide, offer large working surfaces and can include a walk-through area. However, specially planned complexes can be set up for service ranging from box lunches all the way to full-course meals. The large galley module allows attendants unequaled working space and serving convenience. Located in the open space between left-hand and right-hand door pairs, the galley can be serviced quickly from either side of the airplane."



<u>Left T&B</u>: caption: “Putting the galleys on the lower deck insures that passengers will enjoy the best meals in the sky, because, instead of six or eight stewardesses competing for oven space, all food will be prepared by one stewardess per galley. This means uniform and accurate cooking in our new convection ovens. The meals are delivered to the passenger deck by elevator in a special keep-it-hot cart that promises your steak will be sizzling hot…Coffee and beverages are served from the buffet serving areas located near all compartments…”



"…The fact is, the world's first 747s are flying the world's most experienced airline. To London, Paris, Hawaii, Tokyo, all over the world. And you're welcome to join in the fun on the big plane where the big thing is comfort. With two aisles throughout. A double-deck section up front, complete with upstairs lounge, that's in a First Class by itself. And three living room-size Economy sections. Each with its own galley, movie system, and full complement of stewardesses. And seats almost as big as First Class. And for all that, it won't cost a penny more than ordinary planes…"

RE: excerpt from a 1970 PAA magazine ad

<u>Above</u>: caption: "A cut-away view of a United Boeing 747-100" (ca. 1970)

<u>Above</u>: cutaways are the holy grail of airliner models. This superb 1960s-era 747 cutaway is an original factory sales demo, approximately three-feet in length, cutaway on both sides. The detail is superb right down to the spiral staircase and cargo level. The original 747 (which still exists in this livery scheme) never entered airline service.


747

747
BOEING 747

"…Of course, passenger entertainment has not been overlooked. Each chair will have an armrest-mounted control panel which will operate reading lamp, cabin attendant call and a dozen audio channels for music and/or movies…"

Modern Mechanix, **November 1968**

<u>Top</u>: caption: "Boeing 747 in-flight entertainment headset"

<u>Bottom</u>: caption: "Boeing 747 passengers enjoy an in-flight movie"

"…Those passengers seated in the center section might as well sit back and enjoy the music and movie time in the air, counting it an interlude between cities rather than flight at 45,000 ft. After takeoff they won't have much sensation of flight and, in any event, they won't be able to see much out of the distant cabin windows…"

***Modern Mechanix,* November 1968**

Profit Potential

"…To date, 26 airlines have ordered 150 of the 747s, and Pan American gets the first one about the end of 1969. At $20 million per copy, Boeing claims that the 747 will be an economy over the $7-million 707. For one thing, the seat-mile direct operating cost is 32 percent less for the 747 - about 0.8 cent per seat-mile. What makes the airplane even more attractive is the profit potential - three times greater than today's jets even though it costs twice as much to operate…"

***Modern Mechanix,* November 1968**

<u>Left</u>: caption: "Pan Am's 747s on the final assembly line, 1969"

<u>Right</u>: caption: "Pan Am fleet of series 100 and 200 B747s"


PAN AM

City of Despair

Besides production challenges, the deep recession of 1969-71 dealt a severe blow to Boeing's fortunes. The company only sold seven 747s in 1971. That same year, Congress cancelled the *Boeing 2707 SST,* causing a tremendous shock to the region and aviation industry. There was a modest economic recovery in 1972-73 as 747 orders increased (despite the fact that there wouldn't be any further U.S. domestic carrier orders during the same time frame). U.S. carriers (with the exception of TWA & PAA who flew the bulk of the long-haul routes) found they couldn't fill their 747s, replacing them with the new wide-body "tri-jets" (three-engine DC-10s and L-1011s). During this difficult period, Boeing cut more then 60K jobs and Seattle's unemployment rate soared to 13%, more than double the national average. Seattle became known as a "City of Despair" (as dubbed in the May 22nd 1971 issue of *The Economist*). Two real estate agents - *Bob McDonald* and *Jim Youngren*, purchased space on a billboard with the cynical message: "Will the last person leaving SEATTLE - Turn out the lights." The billboard was displayed for only fifteen days (in April of 1971), but the message struck a nerve. Opposition billboards sprung up as well. One said, "Who says the lights are out in Seattle…NOT US!" (the sponsor was *Sunny Jim* - a Seattle peanut-butter brand. McDonald and Youngren also got mail addressed to "The two idiots." Conditions began to improve in 1972; Boeing's employment increased to 45K, but was still well below the 1969 peak.


Will the last person
leaving SEATTLE -
Turn out the lights

The Most of Everything

"…One thing is certain: the 747 must revolutionize air travel if it is to be successful. It is estimated that only 15 percent of the population flies today. Many more will have to be enticed aboard in the coming years. The airlines even now are planning massive advertising campaigns to sell you some of those extra seats which soon will be available. Boeing predicts that air travel will grow from 175 billion revenue seat-miles (a paying passenger flying one mile is a seat-mile) today to 425 billion by 1975. If this happens the 747 will be right in there whooshing along. It really is the most of everything we have ever seen in aviation…"

***Modern Mechanix,* November 1968**

<u>Left</u>: caption: "According to the most recent survey by the Airline Passengers Association, an overwhelming majority of world travelers who answered chose the 747 as the plane they most preferred to fly. According to the same survey, Pan Am was the airline they most preferred to fly, when traveling abroad. Maybe it's that Pan Am flies more 747s to more places in the world than any other Airline." (1975 PAA ad)

The Arab Oil-Embargo crisis of 1973-74 and subsequent rampant inflation of the late 1970s further stifled 747 sales. Still, the 747 "Jumbo" jet had acquired iconic, pop culture status appearing in movies and changing the way the world traveled - raising the bar in luxury and lowering the cost for airline passengers to travel on a per-seat-mile basis. On the right routes, Bill Allen's "Stop-gap Airplane" had become a cash cow for the airlines operating it. In October 1975, the world-wide 747 fleet carried its 100 millionth passenger and on November 19th 1980, the five-hundredth 747 was rolled out at Everett for *Scandanavian Airlines* (SAS).


SAS
SCANDINAVIAN
500
DAN VIKING
BOEING
20th Ave. W.
EXIT 1/2 MI.
Paine Field
Airport Rd.

Part 6

A Parade of Progress

If It’s Not Boeing…

"To anyone familiar with aviation, the name Boeing calls to mind the engineering of a variety of aircraft from small fast pursuit ships to big four-engined 'flying fortress' bombers and commercial transports. A two-decked flying boat with a wing span of 152 feet, which will be capable of carrying as many as sixty passengers and a 107-foot span low-wing monoplane, designed for high altitude and substratosphere flying, are being developed by Boeing at this time…"

***Modern Mechanix,* March 1938**

Left: *William E. Boeing,* Founder

"…It's interesting to note that the founding of the Boeing organization was the result of an accident. Back in 1916, William E. Boeing, who had become interested in aviation as a hobby, and had learned to fly in California, had a crack-up with his plane. In contemplating the possibility that the damaged craft might be repaired in Seattle, he finally decided that an entire new plane should be built. Gathering a small group of interested men, he formed the Pacific Aero Products Company and in a small one room plant production was begun on the first Boeing ship, the B&W seaplane trainer of 1916. An unequal span twin-float biplane fitted with a 125 h.p. Hall-Scott motor, it had a cruising speed of some 60 m.p.h…"

Modern Mechanix, **March 1938**

<u>Left</u>: caption: "Men pulling B&W into Boeing Seaplane Hangar on Lake Union, Seattle"

"…In 1917 the name of the organization was changed to the Boeing Airplane Company and the plant continued to produce training planes in the hope that they might prove acceptable to the U.S. Navy. The following year the first sizeable order was received from the Navy for fifty training planes of the 'C' series. These two-place, twin-float biplanes were powered with A-7A Hall-Scott water-cooled engines…"

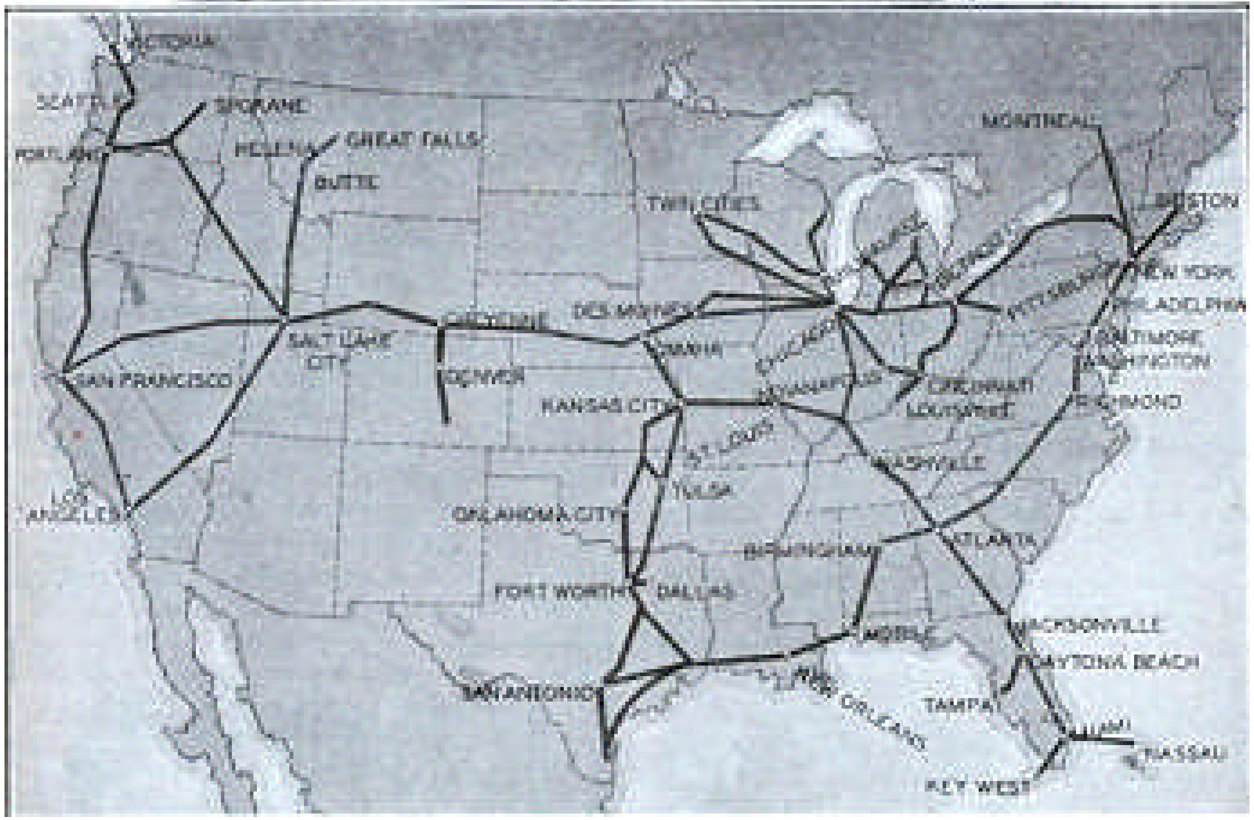
***Modern Mechanix,* March 1938**

Left: Boeing's original logo

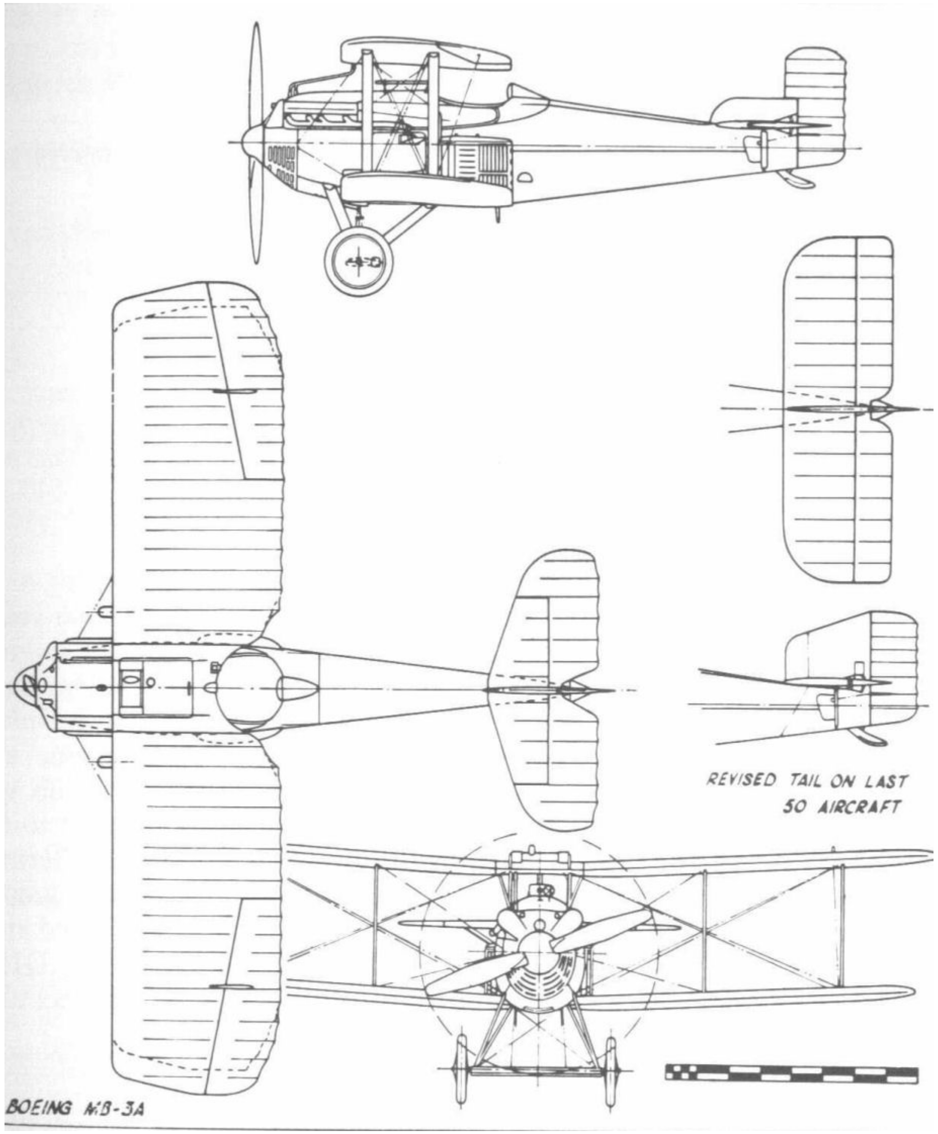
"…In 1928 Boeing began pioneering in the field of commercial aviation with the production of the B-l flying boat. This three-place job was constructed of spruce and ash framework with a two-ply cedar hull. Equipped with a 200 h.p. Hall-Scott, this flying boat had a top speed of approximately 95 m.p.h. It was with this boat that Edward Hubbard opened the nation's first privately contracted airmail service and the first international airmail service, between Seattle, Wash., and Victoria, B.C. By the time it was retired from active service, still airworthy, it had flown some 350,000 miles and had worn out six engines…"

***Modern Mechanix,* March 1938**

<u>Above</u>: caption: "The Boeing B-1 flying boat, a pioneer mail carrier, was built in 1919. Still airworthy, it was retired from service after flying approximately 150,000 miles and wearing out six engines"



<u>Left</u>: caption: "The first mail carrier – the N-ABNA – one of the Boeing flying boats, carried air mail on the Seattle-Victoria route. This was the first commercial air line. This ship, which is still frequently used, has covered more than a half-million miles. It has worn out six motors. The map graphically represents the air-mail network today. Many other lines will soon be in operation."
***Modern Mechanics*, July 1930**



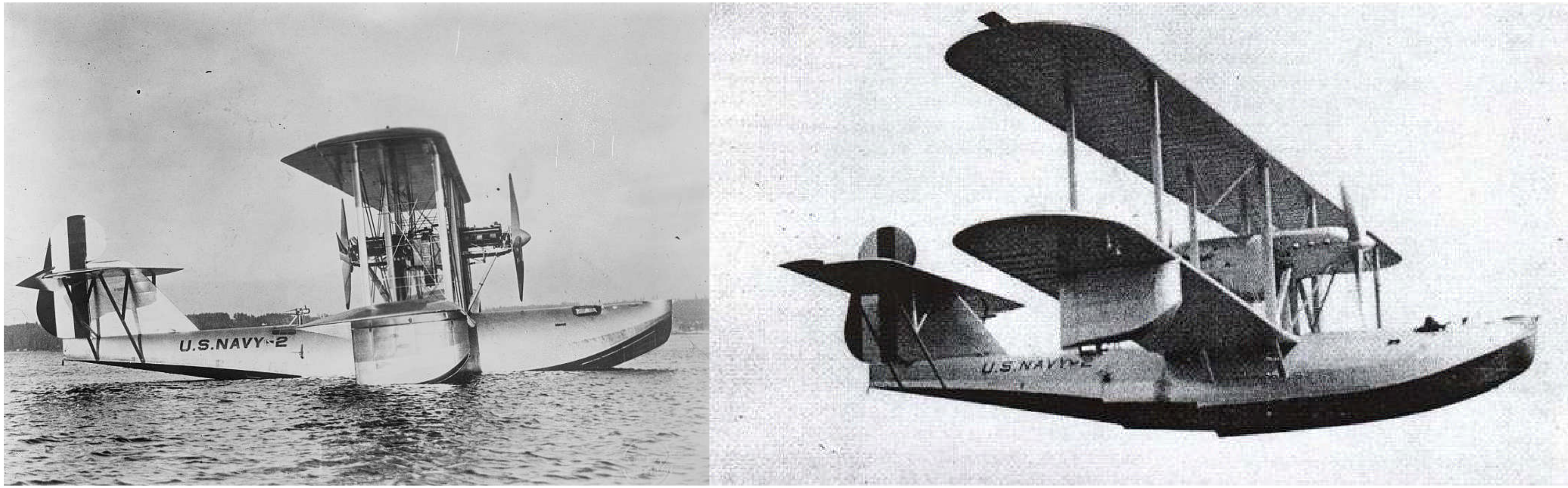
"…The first large Army order came to Boeing in 1921 when 200 MB-3A single-seater pursuit planes were contracted for. Of wood and fabric construction, they were powered with 300 h.p. Wright H-3 water-cooled engines and were built to a design furnished by the War Department. The MB-3A had a top speed of 140 m.p.h. and an absolute ceiling of about 21,200 feet…".

***Modern Mechanix,* March 1938**

"…Two years later Boeing began the production on the first pursuits built to their own design. These craft, known as PW-9's, were the first pursuits to be fitted with oleo shock absorbers. With a welded steel fuselage, fabric covered, and with wood and fabric wings, the PW-9 type was powered with the 425 h.p. D-12 Curtiss 12-cylinder engine which gave it a top speed of 160 m.p.h…"

Modern Mechanix, **March 1938**

Above: caption: "Boeing PW-9"



"…In 1925, Boeing developed the PB-1 patrol boat for the Navy. An interesting feature of this flying boat was the hull which was built of duraluminum up to the water line, above which it was built of plywood. This type of construction eliminated both weight and soakage danger. The PB-1 was one of the largest flying boats of the period and was powered with two 800 h.p. Packard engines mounted in tandem. It had a maximum speed of 112 m.p.h. and a range of more than 2,000 miles…"

***Modern Mechanix,* March 1938**

<u>Above L&R</u>: *Boeing PB-1* flying boat

"…In 1927 Boeing definitely entered the commercial field when the organization was awarded a contract to fly the mail between Chicago and San Francisco. The Boeing bid for this contract was but half that of the nearest competitor and financial observers called it frenzy, believing it could never be successful. However, in a period of but five months, Boeing designed, produced and placed in active service a fleet of 25 mail-passenger planes, known as the Model 40-A's. These craft were two-passenger biplanes powered with Pratt & Whitney Wasp engines and they helped to make the Boeing mail venture highly successful. The 40-A's were followed by the four-passenger P&W Wasp powered 40-B's and the four-passenger Hornet powered 40-B4's…".

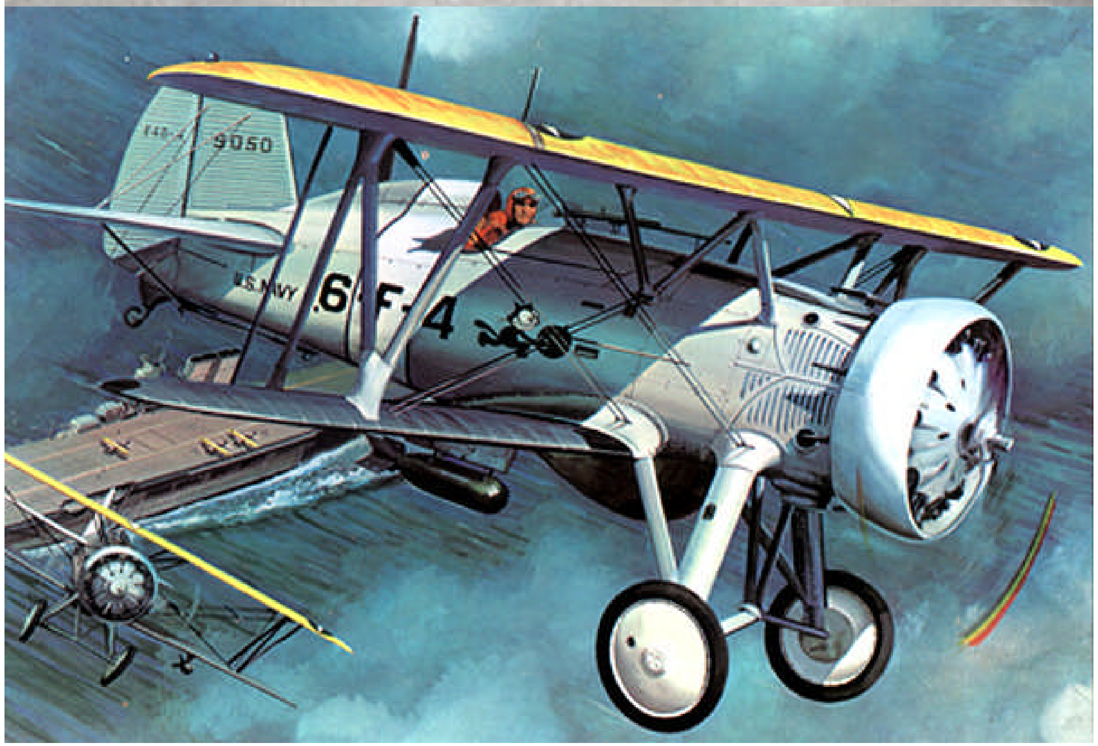
***Modern Mechanix,* March 1938**

<u>Above</u>: caption: "The Boeing 40-B-4 helped make history by flying pioneer air mail and passenger routes"

"…In 1928 the Model 80 tri-motored, 14-passenger biplane transport was introduced. With its three 525 horsepower P&W Hornets, the Model 80 had a top speed of 138 m.p.h. fully loaded and it brought a new degree of travel comfort to the airways. It was with planes of this type that United Air Lines established a 27-hour coast-to-coast service over the mid-continent route of their system…"

***Modern Mechanix*, March 1938**

Above: caption: "Boeing Model 80"



"…In 1929 the famous P-12 pursuits were produced and within a short time they became standard service equipment in the U.S. Army Air Corps. Later as F4B's they became standard with the Navy. Especially noted for their speed and maneuverability, these single-seater biplanes were powered with 450 h.p. Wasps and had a high speed well over 170 m.p.h. The Army version of this type was developed as the P-12A, P-12B, P-12C, P-12D, and P-12E, while the Navy edition was developed as far as the F4B-4, attesting to its ability…"

***Modern Mechanix,* March 1938**

<u>Top</u>: caption: "Produced in 1929, the P-12 single-seat, biplane pursuit plane became standard equipment with the Army Air Corps. Later, as the F4B, this plane also became a standard U.S. Navy fighter."

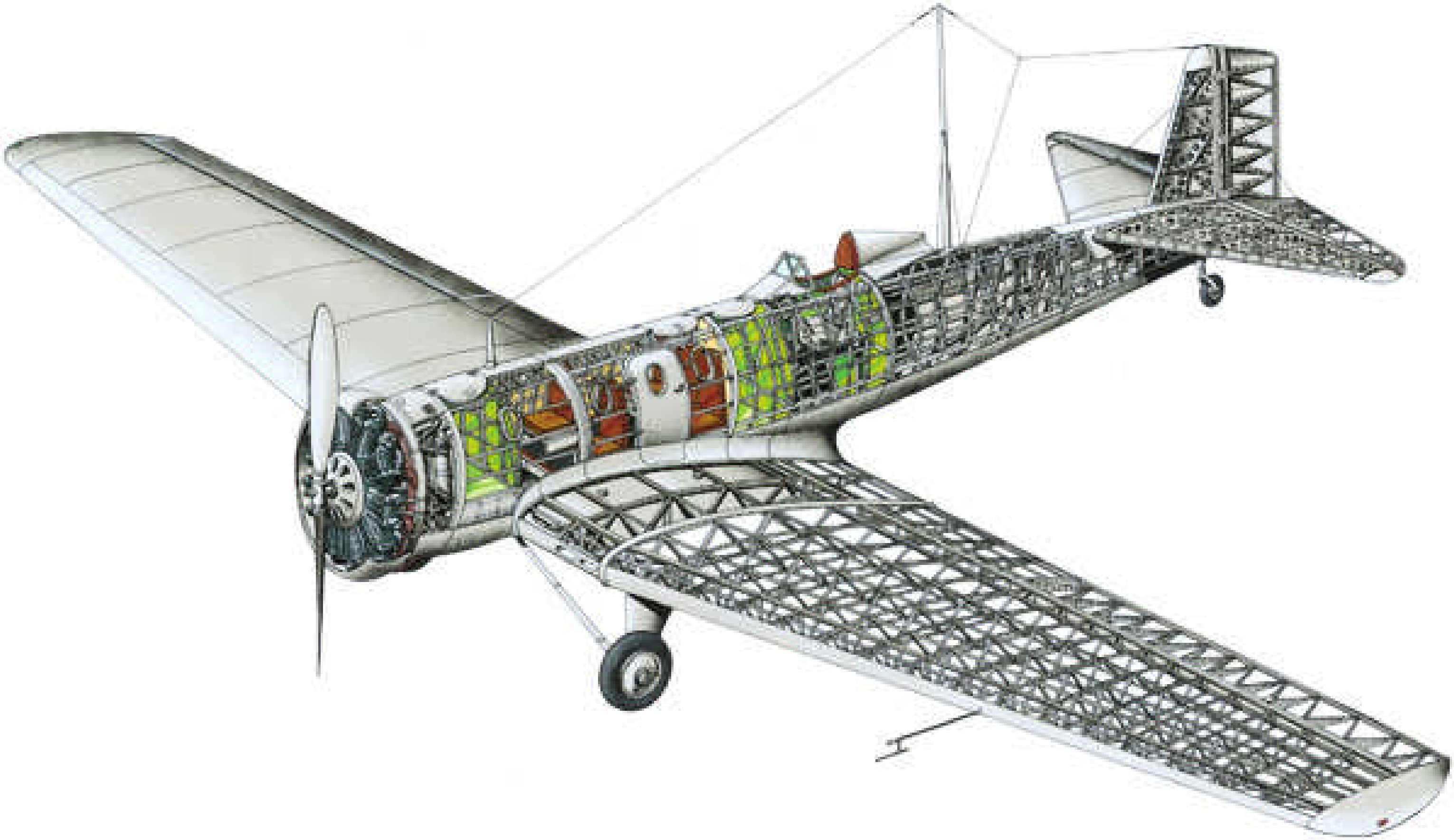
<u>Bottom</u>: caption: "Boeing F4B-4"

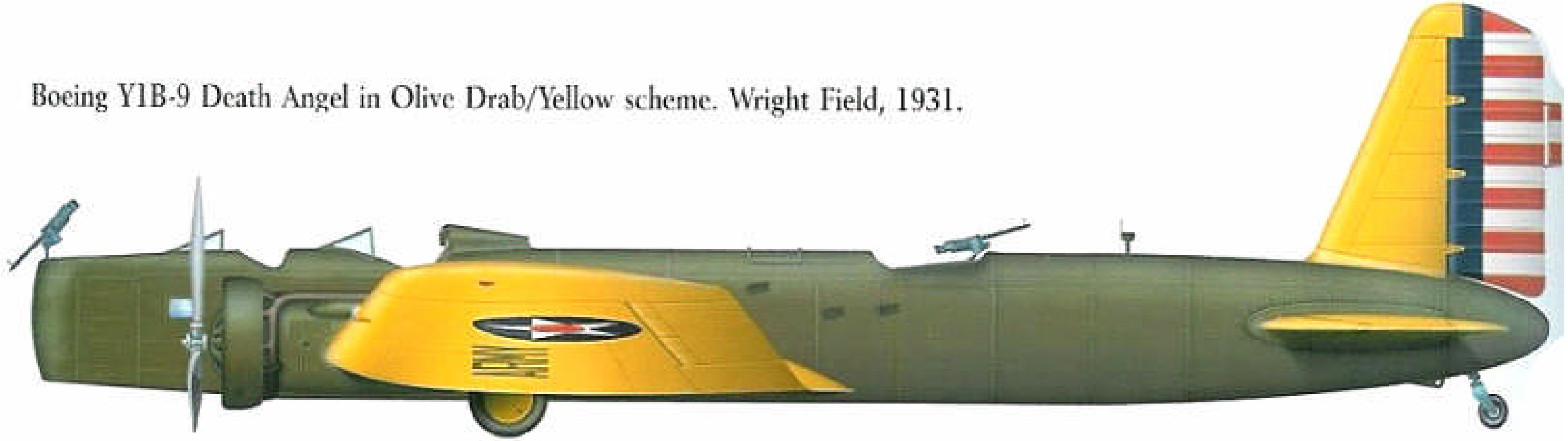

K-ADV-74

"…The year 1930 brought the introduction of the Monomail, the first successful American commercial smooth-skin, all-metal plane. This was also the first plane to be fitted with a retractable landing gear. It carried five passengers, their baggage, and 700 pounds of mail at a top speed of 160 m.p.h. This Hornet powered low-wing monoplane was the forerunner of the later big Boeing bombers and commercial trans-ports…"

***Modern Mechanix,* March 1938**

<u>Above</u>: caption: "Boeing Monomail 200"



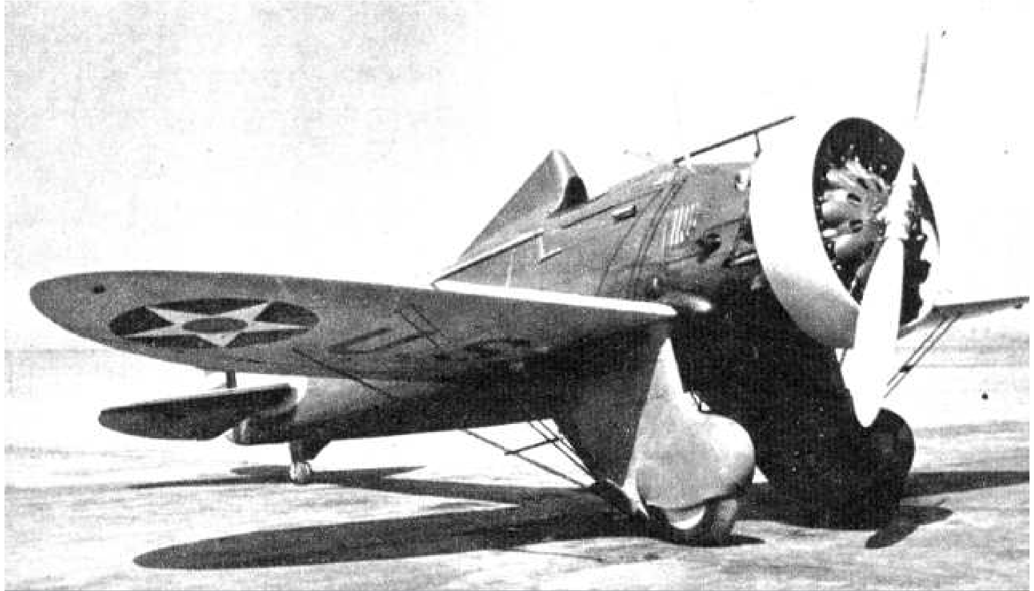


Boeing Y1B-9 Death Angel in Olive Drab/Yellow scheme. Wright Field, 1931.

"…The next year, the Boeing twin-engined bomber appeared and it at once established the present trend in bombardment aircraft. Known as the YIB-9, this all-metal low-wing monoplane was fitted with 600 h.p. air-cooled power plants, was streamlined throughout, and had a retractable landing gear…"

Modern Mechanix, **March 1938**

<u>Left</u>: caption: "Boeing Model 215 (YB-9) 'Flying Pencil' Model Airplane News cover art for September 1932"

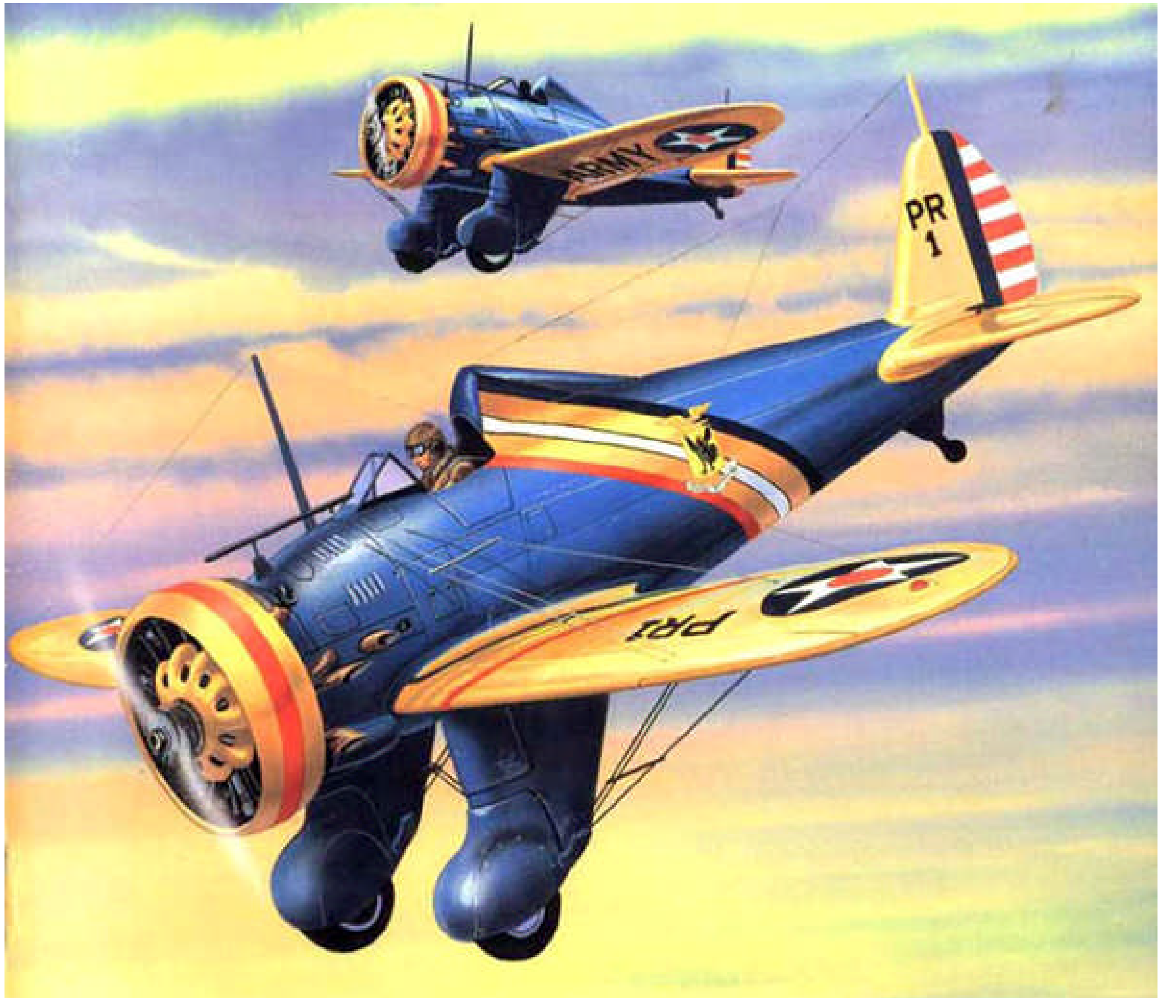


"…The famous P26 low-wing mono-plane pursuit was intro-duced in 1932 and it was quickly developed into the P26-A and became standard equipment with the Army Air Corps. With a top speed over 235 m.p.h. this single-seater was rated as the world's fastest one-place fighter…"

Modern Mechanix, **March 1938**

<u>Top</u>: caption: "The Boeing P-26A was the last of the small, open-cockpit single-seaters"

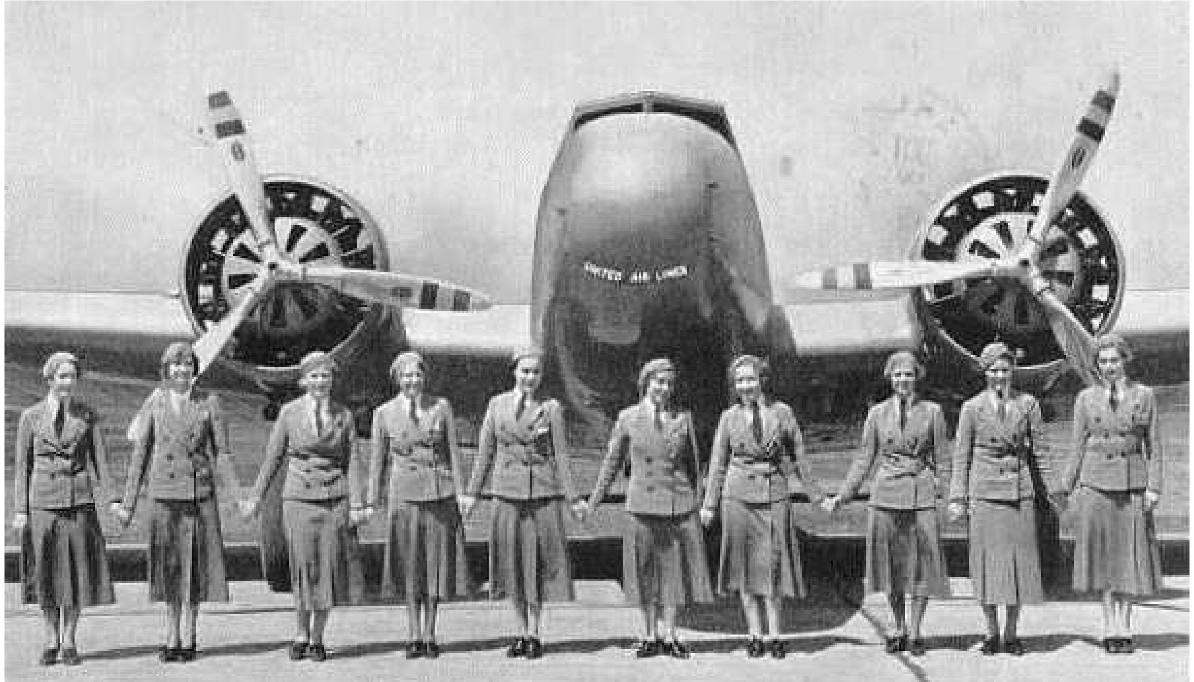
<u>Bottom</u>: caption: "A squadron of Boeing P26-A low-wing pursuit pla-nes in flight over Riverside, Calif-ornia. Introduced about 1932, these planes were regarded as the world's fastest single-seater fighting planes, having a speed of more than 235 m.p.h." (the P26-A was a/k/a "The Pea-Shooter")

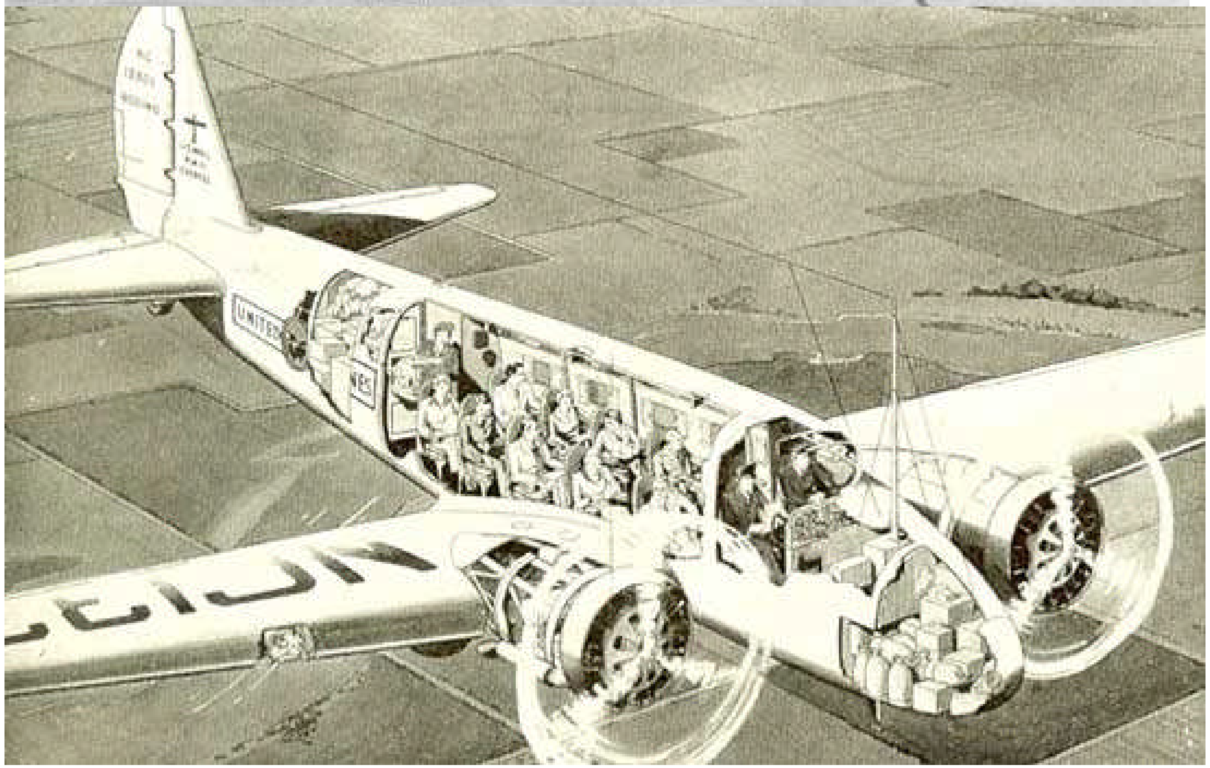

PR
1

"…The following year the well known model 247 twin-engined all-metal transports were brought out. A fleet of these low-wing monoplanes established overnight, coast to coast passenger and cargo schedules. With 550 h.p. engines these ships carried 10 passengers, pilot and co-pilot, stewardess, baggage, and cargo, at a high speed of 202 m.p.h. In 1934 these transports appeared as the Model 247-D and one of them was used by Roscoe Turner and Clyde Pangborn to place second in the London to Melbourne Air Race. Ships of this type were used by United Air Lines, Pennsylvania Airlines, Western Air Express, Wyoming Air Service, National Parks Airways, and Deutsche Lufthansa…"

***Modern Mechanix,* March 1938**

<u>Above</u>: caption: "United Airlines Boeing 247-D"


UNITED AIR LINES



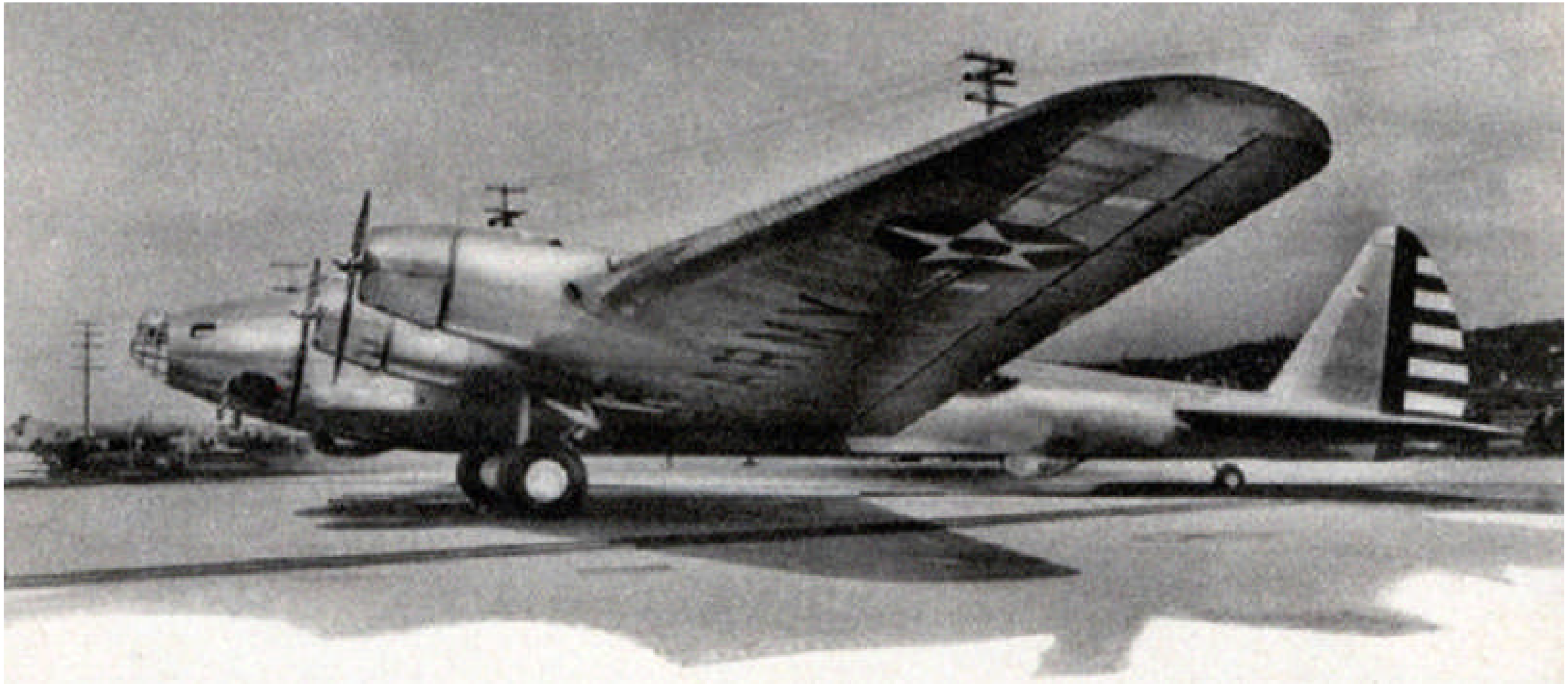

NC13304

Flying Fortress

"…In 1935 the Model 299 four-engined all-metal low-wing bombardment plane was brought out. This huge monoplane with a wingspan of 105 feet and a length of 70 feet weighs approximately 16 tons and its 1,000 h.p. Wright Series G Cyclone engines give it a maximum speed of over 200 m. p. h. The Model 299 became a focal point for the eyes of the world when it flew 2,100 miles non-stop from Seattle, Wash., to Dayton, Ohio, at an average speed of 232 m.p.h…"

***Modern Mechanix,* March 1938**

<u>**Above**</u>**: caption: "July 17th 1935 - Boeing Model 299 Roll-Out (Prototype B-17)"**



"…Popularly known as the 'flying fortress' this bomber ranked as the fastest and longest range bombardment craft in the world and the largest land plane in America until superseded by the XB-15, a four-engined bomber with a 150-foot wings span. Designated by the Army as the YB-17, thirteen of these giant planes were ordered by the Air Corps…"

***Modern Mechanix,* March 1938**

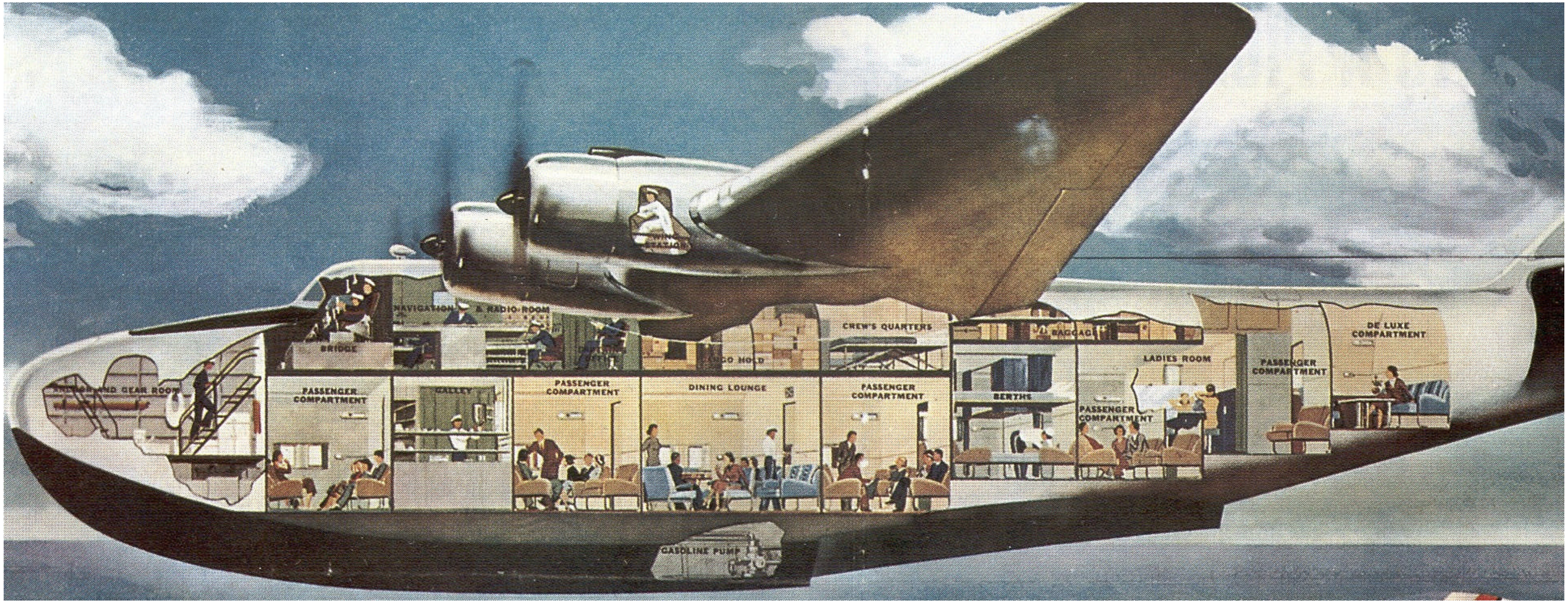
<u>Above</u>: caption: "Shown above is the Boeing XB-15, the 'Big Brother' of all four-engined bombers. The Air Corps' largest airplane, the XB-15 has a 150-foot wingspan, weighs more than 30 tons and is powered with four 1,000-horsepower engines. Because of its six machine guns, the gigantic bomber is known unofficially as the 'flying fortress.'"

A Helluva Boat

"…Brightest example of the worth of flying boats was the development of Pan American World Airways. Though one of Pan Am's early models caused a sailor to exclaim, 'That's a helluva way to carry a boat,' flying boats pioneered all the transoceanic routes of that system…"

Popular Science, **June 1963**

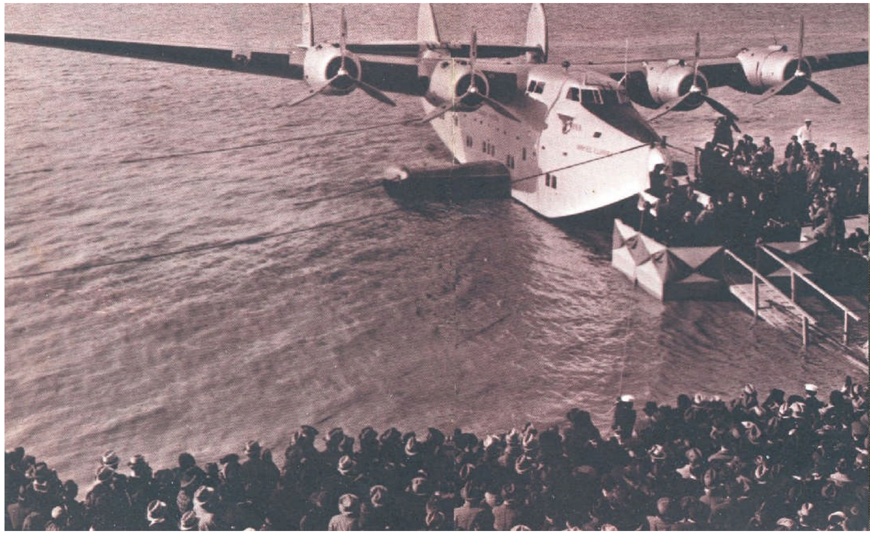
<u>Above</u>: caption: "PAA - Routes of the Flying Clipper Ships" (ca. 1940)

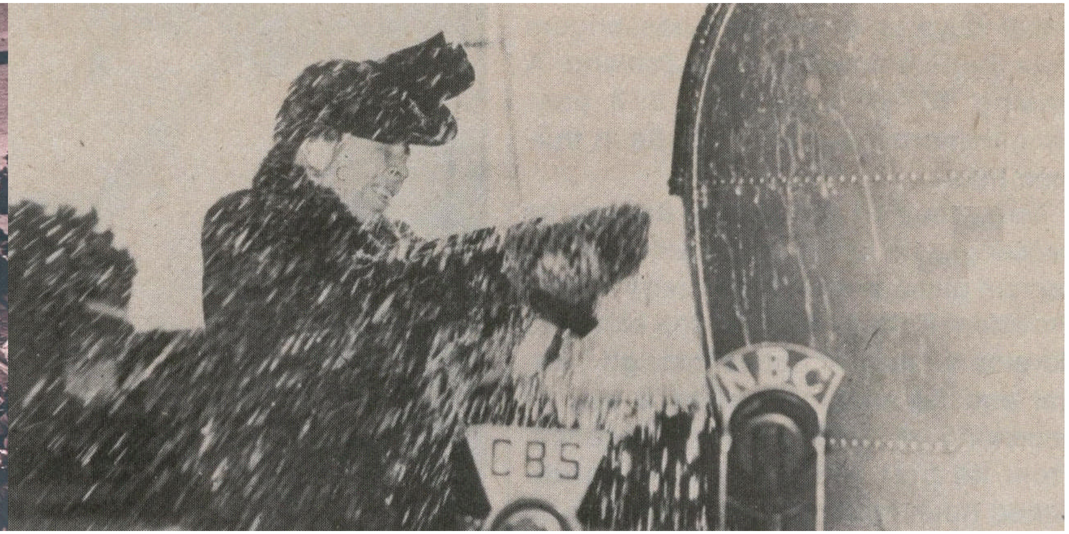


"…Boeing is now completing construction of six giant 'Clipper' flying boats for Pan American Airways. These boats will have a gross weight of more than 82,000 pounds and will be capable of carrying more than sixty passengers, with sleeping accommodations for forty. Embodying the most modern streamlined design, these ships will be internally braced high-wing monoplane types of all-metal construction and will have a high speed of around 200 m.p.h. The craft will ride the water during the takeoff and landing on short stub-wing hydro stabilizers instead of on the conventional wing tip floats…"

***Modern Mechanix,* March 1938**

<u>Above</u>: caption: "Cut-away view of the Boeing 314 flying boat"





"Pan American Airways 82,500-pound 'super-clipper' flying boat will soon lift from Long Island Sound on its initial passenger run to Europe. Built at the Boeing plant in Seattle, Wash., the new transatlantic sky boat – the first of a fleet of six – is the biggest airplane in the world. Its hull is 105 feet in length with a wingspan of 152 feet. A quartet of 1,500-horsepower Wright-Cyclone engines drags the boat through the air at more than 200 miles per hour. Catwalks through the wings enable mechanics to reach the engines and make repairs in flight."

***Popular Science Monthly,* June 1939**

Left: caption: "The first Boeing B314 'Yankee Clipper' being christened on March 3rd 1939 in Washington D.C."

Right: caption: "First Lady *Eleanor Roosevelt* officially christens the first Yankee Clipper (March 3rd 1939)"

“…Sometime this month, with spray glistening on its metal hull, the super-clipper will lift from the water off North Beach Airport, New York City, and head out over the ocean, taking the southern route to Europe. The coastline will drop behind the triple stabilizers at the tail; 2,422 miles of tossing water will slip beneath the wide-spread wings. Then, on a long slant, the ship will slide down, skim the waves, and wallow to a stop at the Azores. Charging away again in a cloud of spray, it will take to the air, winging on to Lisbon, Portugal, before the final, quick hop to its destination, Marseilles, France, or Southampton, England. Later in the summer, the great-circle route to Ireland and England, the path followed by Lindbergh, will be used by the super-clipper. The tentative fare for the transatlantic journey is $450. Mail and express will go for twenty-five cents a half ounce…”

Popular Mechanics, **June 1939**

P.A.A. Yankee Clipper (B314) In Flight
LaGuardia Field

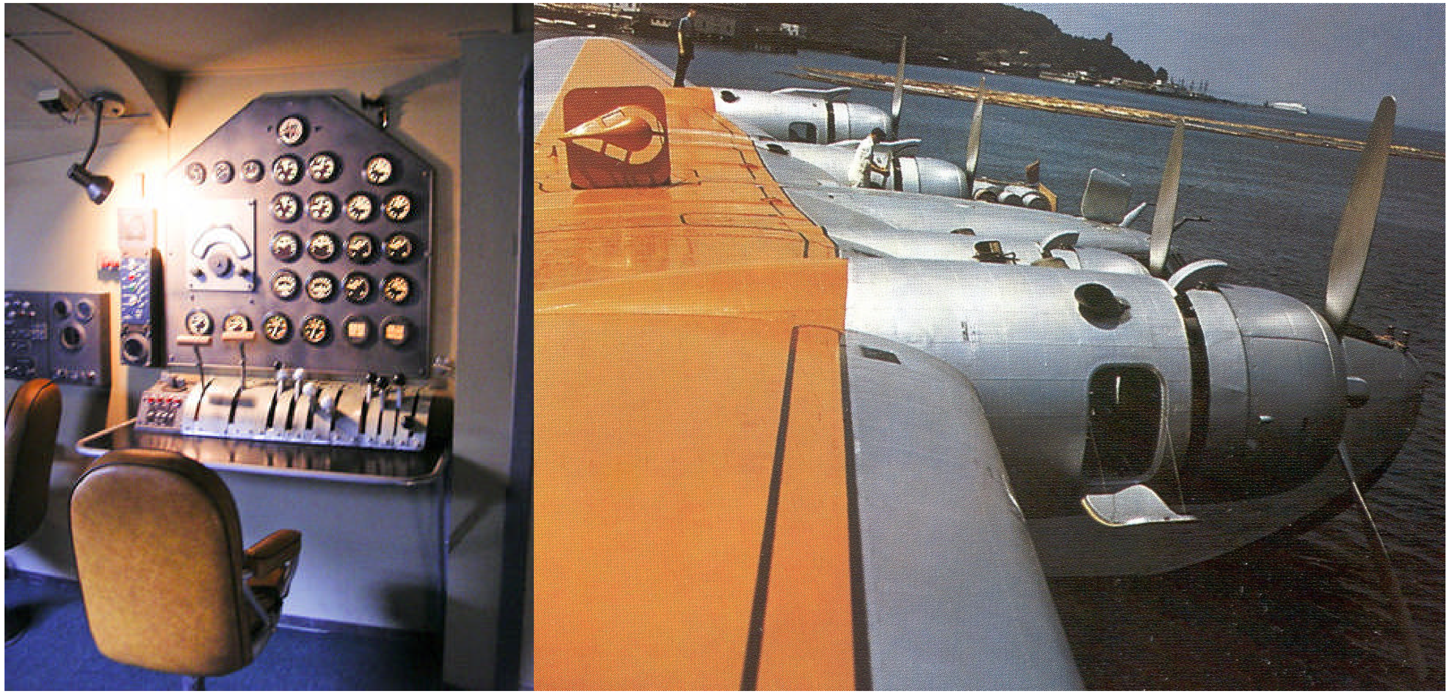
"…Scarcely will the first clipper roar eastward, within a few weeks, before a second ocean-going greyhound of the air will be hauled from a hangar at Baltimore, Md., and prepared for the start of the second scheduled voyage. Other sister clippers, now being constructed, will be added to Pan American's Atlantic fleet within a short time, enabling the company to offer service to Europe several times a week. While the clippers will be serviced at Baltimore, the takeoff terminal will be at North Beach on Long Island Sound or at Pan American's temporary base at Port Washington, N.Y. From there a northern route, which will be used in summer, is by Shediac, New Brunswick, to Botwood, Newfoundland, thence across a 1,996-mile over-water jump to Foynes, Ireland, and finally to Southampton, England. Passengers may reach London by air taxi or train. Flying time will be approximately twenty-four hours…"

***Popular Mechanics,* 1939**

"On wings sixty-two feet longer than the ship in which Columbus sailed to the New World, Pan American Airways' 82,500-pound 'super-clipper' flying boat will soon lift from Long Island Sound on its initial passenger run to Europe. In twenty-four hours, it will cross the sea on which Columbus's Santa Maria tossed for ninety-two days. Half a hundred passengers and a cargo of 5,000 pounds will ride in the great silver-colored hull of this aerial luxury liner. No other craft ever rode the air with as many aids to comfort and safety as the new machine will carry. Instruments so clever that they almost think will assist the pilots and protect the passengers. Throughout the flight, a delicate analyzing mechanism will suck air from all parts of the ship, flashing a red warning light if carbon monoxide gas or other impurities are present. Soundproofing will reduce the noise within the cabin to less than that of a railway coach. The whole interior will be air-conditioned and kept at a constant temperature. Five seven-room houses could be warmed by the plane's heating system…"

Popular Mechanics, **June 1939**

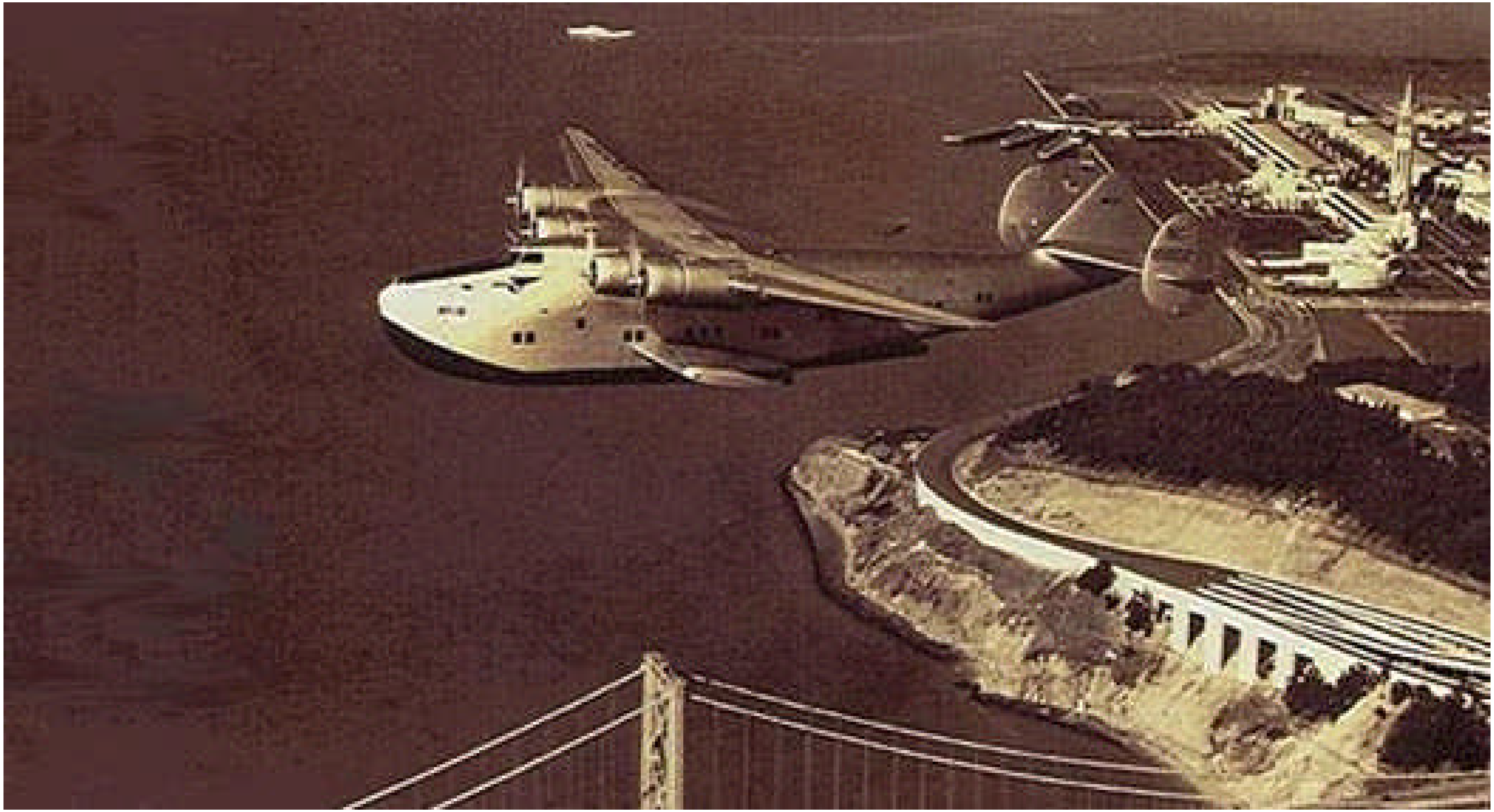
Above: ***caption:*** **"Boeing B314 'Atlantic Clipper' at Port Washington, NY (1939)"**



"…Built at the Boeing plant in Seattle, Wash., the new transatlantic sky boat - the first of a fleet of six - is the biggest airplane in the world. Its hull is 105 feet in length and its wings stretch 152 feet from tip to tip. With all four of its 1,500-horsepower Wright Cyclone engines thundering at full throttle, the all-metal craft can climb to 21,000 feet with a useful load greater than the weight of the ship itself. Spinning fourteen-foot, three-bladed steel propellers, the quartet of engines can drag the big boat through the air at a top speed of more than 200 miles an hour. At cruising speed, 150 miles an hour, one filling of the tanks will carry the transatlantic sky liner 4,275 miles. An average automobile could travel more than twice around the world on the 4,300 gallons of high-test fuel the tanks will hold…"

***Popular Mechanics,* June 1939**

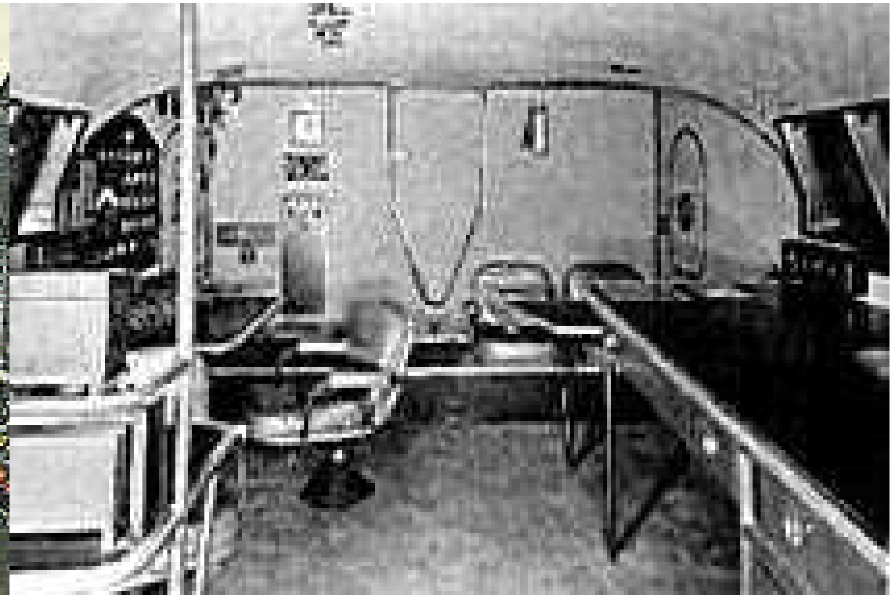
Above: flight engineer's station of a Boeing 314 Flying Boat (left). At right, Boeing 314 supper clipper under construction at the Boeing factory, Seattle, WA (1939)



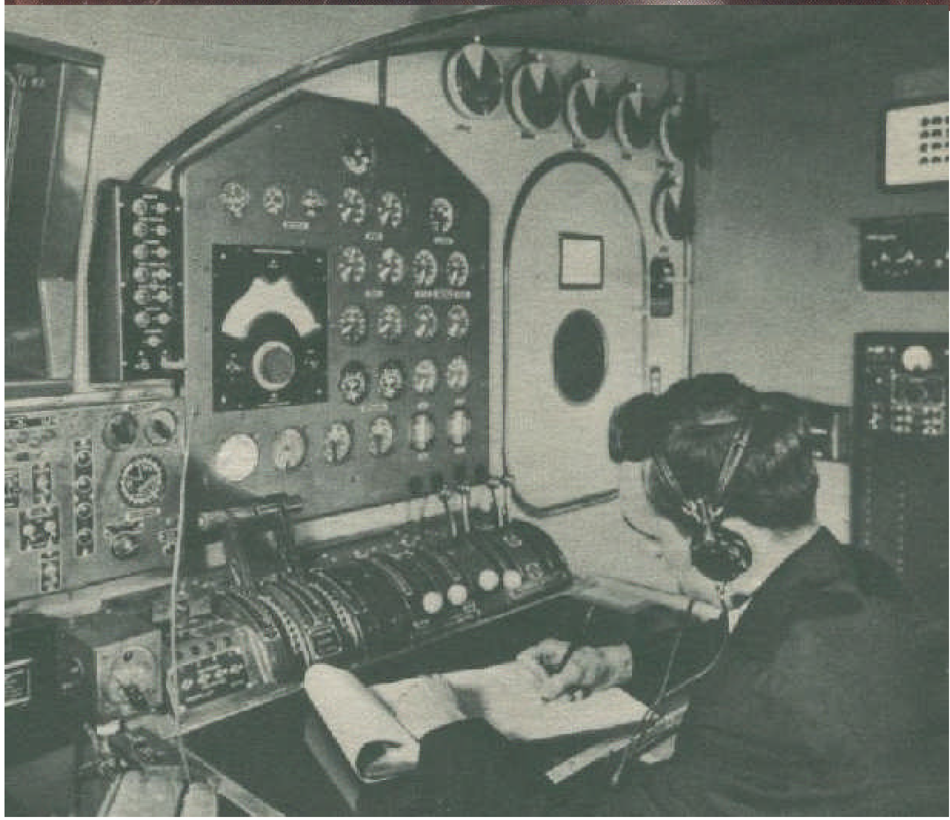
The *Boeing Model 314 Flying Boat* was a combination of the Wellwood E. Beall's design and the *Boeing XB-15 Bomber*. The aircraft first flew on June 7th 1938. A total of twelve were built with the last one retired in 1951. To the public, "China Clipper" became a generic name and originally was applied to all three of the Martin M-130's in PAA's fleet and, later, to the Boeing 314s.

"…The 42-ton flying boat, with four 1,500-hp engines, was very different from the Spirit of St. Louis. Its 152 foot wing was the same type that the huge B-29 Air Force bomber later used. Its double-decked hull was 109 feet long. The 'flight deck,' as it was called, was an eye-popping sight to the pilot of any lesser craft. It was nearly 22 feet long, 9&1/2 feet wide, and provide 6&1/2 foot headroom. It had wall-to-wall carp-eting. The flight officers sat at their controls or instrument panels in handsome leather-upholstered chairs…"

Popular Science, **June 1963**

<u>Above L&R</u>: the Boeing 314's flight-deck was one of the most luxurious ever made. Behind the cockpit was a complete flight operations room. Two heavy maroon curtains were drawn behind the pilots at night so as not to diminish their night vision. Between the pilots was a trap door leading into the bow compartment in the nose of the plane. On the port side was the navigator's 7-foot long chart table. Beyond that was a small conference table and an oval hatch leading to the crawlway inside the wing. The engines could be reached for simple maintenance or repairs during the flight, if necessary, through this crawlway. On the side, behind the cockpit, was a circular staircase that led down to the passenger compartment. Then came the radio operator's station and then the oval hatch that led to the starboard wing crawlway. Along the back wall of the flight deck was a doorway that led to the cargo holds.



Top Left: Boeing B-314 rear of cockpit. Left-to-right: navigator (extreme left), flight engineer (with headphones), reserve officers center-rear (at planning tables), Navigator (next to plotting table)

Top Right: navigator at work on plotting table (pilot and co-pilot beyond)

Left: flight engineers' control panel

Above: caption: "At this big panel, the flight engineer controls the motors. The door at right leads to a motor-inspection passageway."

Left: caption: "A view of the spacious cockpit, showing the station of the first pilot, second pilot, and the radio operator"

"Fifteen times as large as the cockpit of a modern twin-motor transport, the huge control room pictured on this page is the nerve center of a seventy-four-passenger clipper plane, one of a fleet of six being constructed at Seattle, Wash., for trans-oceanic service. In the photo-graph at the left, four of the six stations within the spacious cockpit are visible: the chief pilot's, the second pilot's, the navigator's, and the radio op-erator's. The ship's captain has a desk at the left rear of the cockpit, while the right rear section is occupied by the flight engineer, shown above con-trolling the operations of the four 1,500-h.p. motors."

Popular Science, **April 1939**

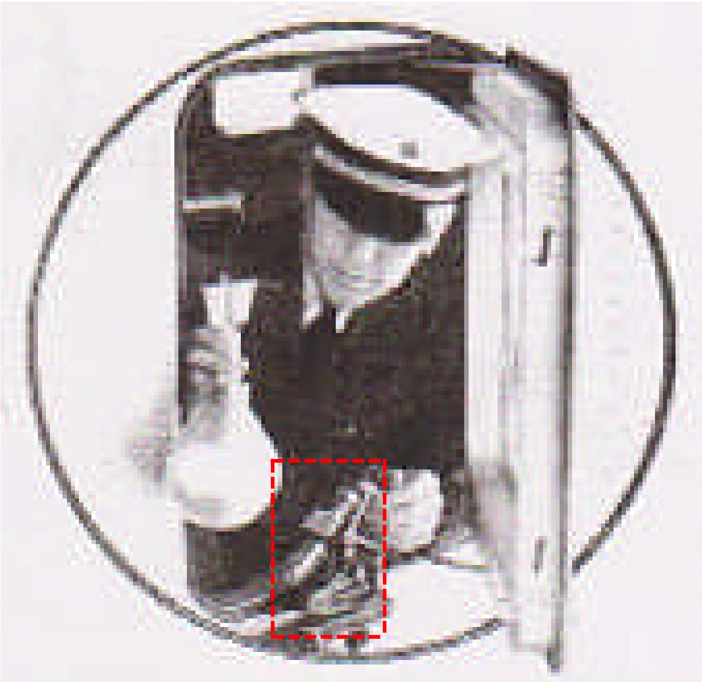
"…Pan American operates on the principle that when one of its clippers goes to sea it must take care of itself as ably as a big liner. The flying boat has to be both airworthy and sea-worthy, able to make a landfall without outside aid. The great clippers are navigated over the ocean exactly the same way as are surface vessels. The captain uses dead reckoning, celestial observations, radio bearings, and combinations of these methods for making his way across the sea. There is no flying the beam on the ocean. The clippers use the same basic principles of celestial navigation that were used in the old days of the sailing clippers, simplified for convenience in the air. The navigator often combines this art with radio in a number of ways, such as crossing a radio bearing with a sun line to get his position or by taking a radio bearing on a near-by ship whose position is known. If all radio communication should fail the clipper could make its way home…"

Popular Mechanics, **March 1939**

"…The navigator has just returned to the chart room on the lower deck after making a celestial observation. To do this he walked through the plane to the after companionway where he slid back the hatch and obtained a 'star fix' by sighting the star through the eyepiece of his octant and bringing it down to the level of his instrument's artificial horizon. The master compass and chronometer in the chart room, as well as air speed indicators and altimeters duplicating those on the bridge, will help him work out the problem…"

Popular Mechanics, **March 1939**

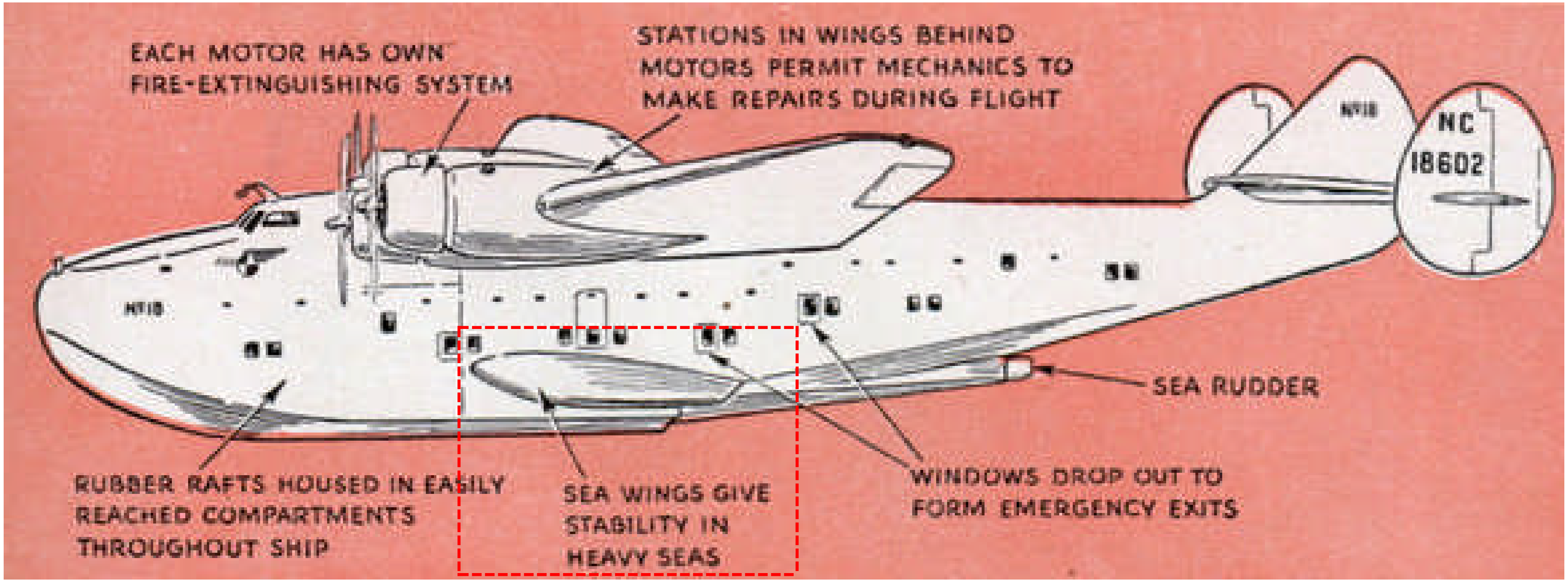
<u>Left</u>: caption: "Clipper navigator demonstrating use of octant"



"…If the navigator finds that a cross wind is setting him off course he tosses a glass bomb filled with aluminum powder out of a cabin window, shattering on the surface, the bomb spreads the light powder out into a shimmering spot and this can be followed by means of a drift indicator set up in the window. After dark a chemical that flames on the water, instead of aluminum powder, is used. When he has estimated his drift, the navigator can calculate a course that compensates for the cross wind…"

Popular Mechanics, **March 1939**

Left: caption: "Releasing aluminum powder bomb. Drift indicator on window (highlighted) is used to site the bright spot the powder makes on water"



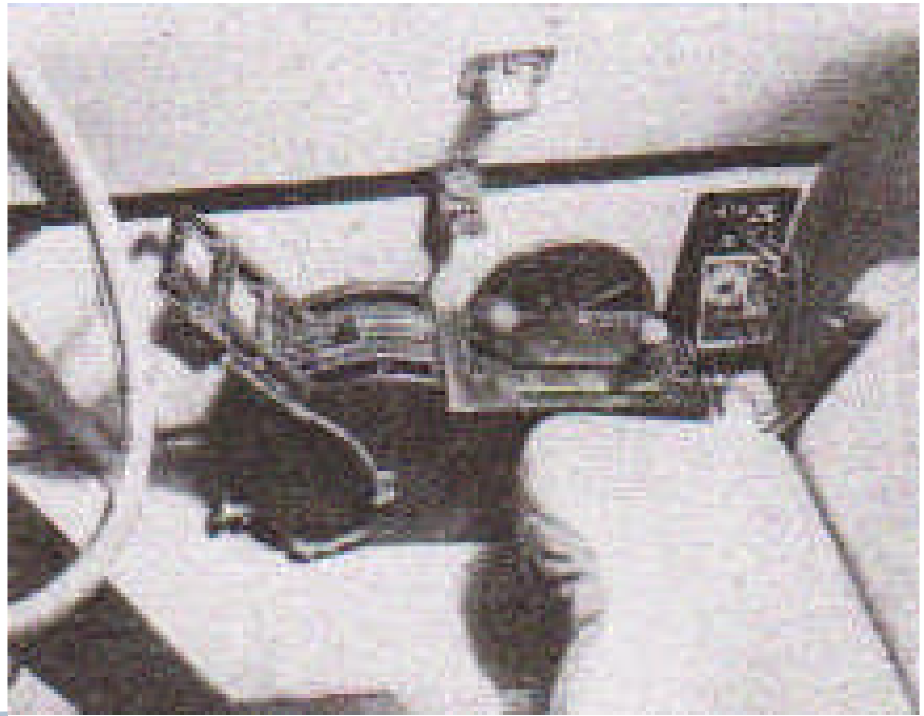
"…Two other innovations help control the boat on the water. To increase the ease of maneuvering about before a takeoff and after a landing, an underwater rudder operates in conjunction with the air rudders. 'Sea wings,' technically known as hydro-stabilizers, give the machine greater side-to-side stability, especially in heavy seas. These sturdy, wing-like floats jut out from either side of the hull…"

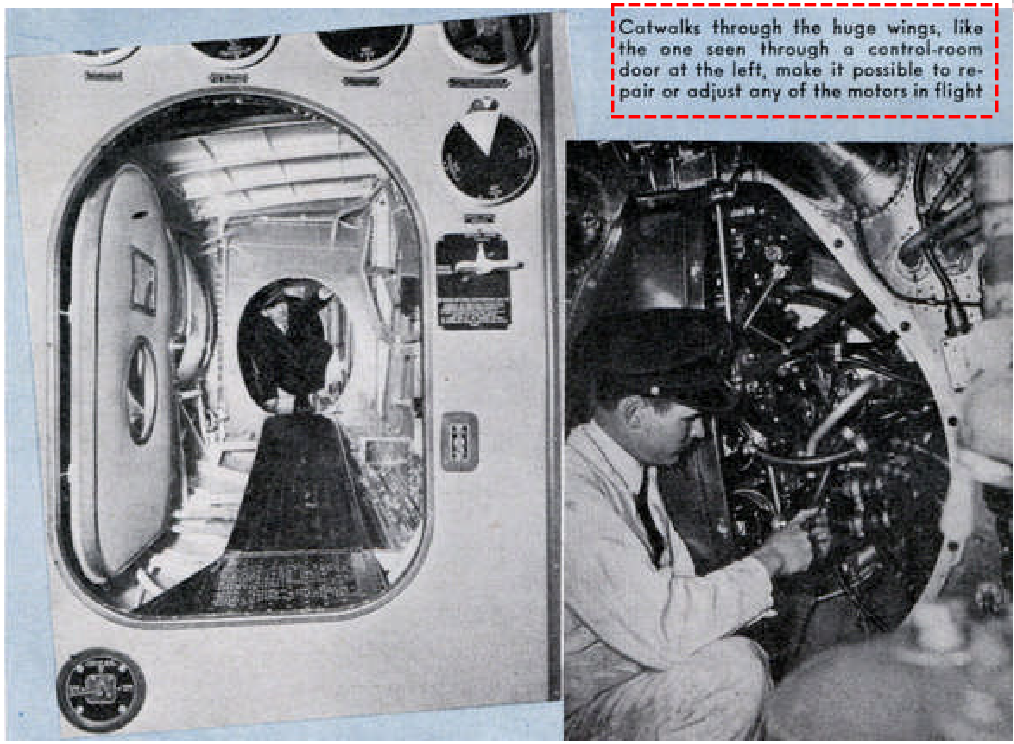
***Popular Mechanics,* June 1939**

"…Throughout the ocean voyage, instruments will show the temperature of each of the fifty-six cylinder heads in the air-cooled power plants. Every motor has its own fire extinguisher built into the wings of the plane, and catwalks through the interior of the great supporting surfaces enable mechanics to reach the engines and make adjustments and repairs in flight. With two of its four motors out of commission, the flying boat can still remain in the air…"

***Popular Mechanics,* June 1939**

Below: caption: "Catwalk through the huge wings, like the one seen through a control-room door at the left, make it possible to repair or adjust any of the motors in flight"





Above: caption: "All that the pilots need to look after; one of the control boxes in the pilots' compartment, with the throttle levers on the left and the trimming controls and indicators on the right, with master controls for the mixture and manifold pressures. On the extreme right is a remote-control panel for intercommunication and radio homing purposes."

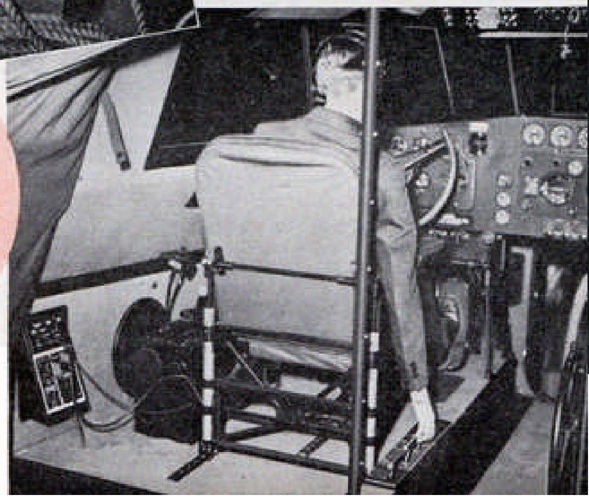
Above: caption: “Radio officer, left, and flight engineer at their stations. Dials show details of plane operation.”

Left: caption: “The Clipper’s Ears and Voice – the Radio Officer’s post. Every half hour these clicks to the guarding ground bases complete position and weather reports.”

Radio officer, left, and flight engineer at their stations. Dials show details of plane operation

Above: caption: "Radio officer, left, and flight engineer at their stations. Dials show details of plane operation."

IN AN EMERGENCY, the plane's heavy sea anchor, seen above, can be released through an opening in the side or from the bow hatch. At right, levers beside the pilots' seat operate the fuel dump valves

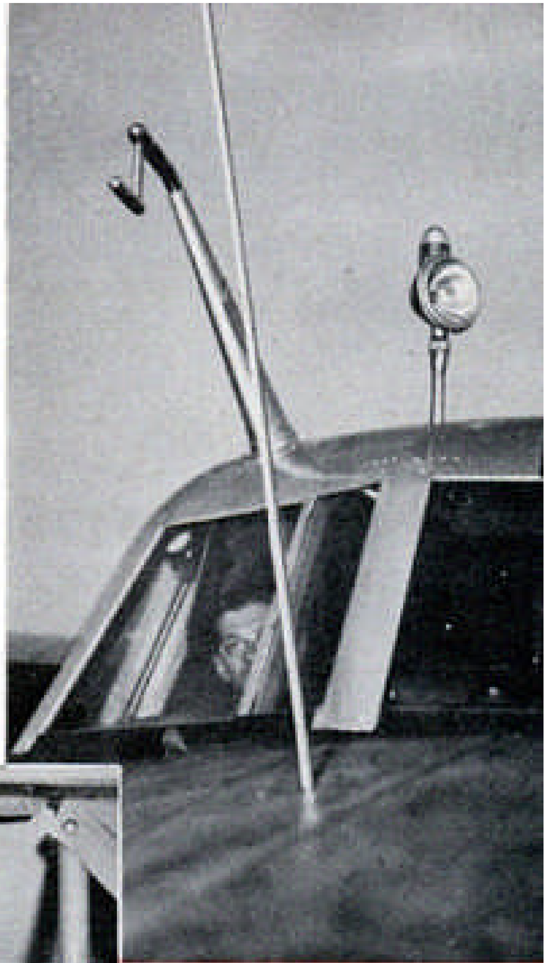


Above: caption: "In an emergency, the plane's heavy sea anchor, seen above, can be released from an opening in the side or from the bow hatch. At right, levers beside the pilots' seat operate the fuel dump valves."

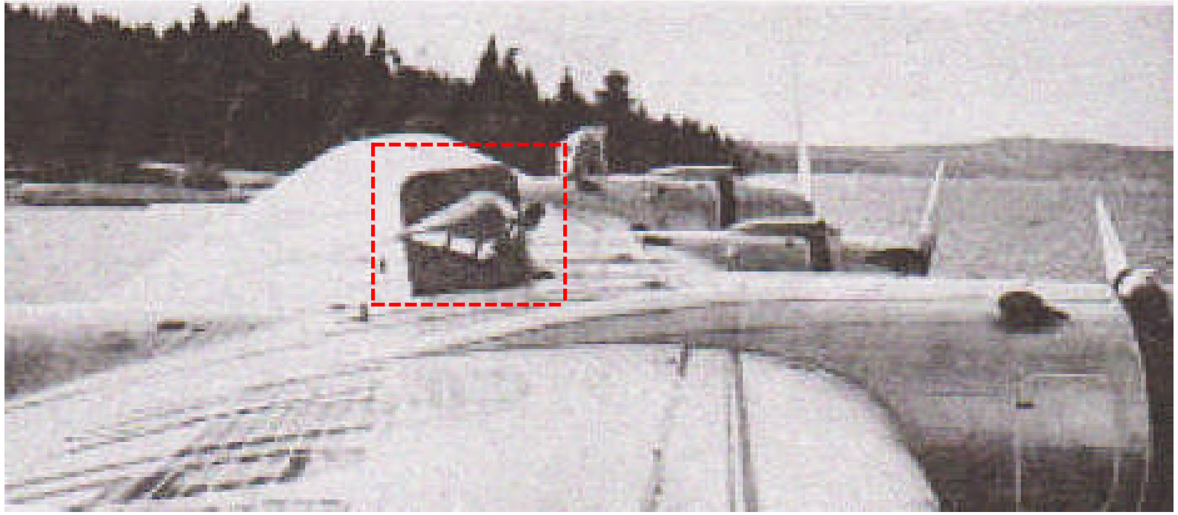
Above: caption: "Very pistol for emergency night signaling. The cartridge case beneath it contains red, green, and white flares."

"…To provide every possible convenience for the man who handles the controls, various innovations have been incorporated in the design of the new ship. A small button on the control wheel permits the pilot to illuminate the instrument panel without taking his hands from the controls. An automobile-type sun visor can be swung down when the machine is flying toward the rising or setting sun. By pulling down a lever overhead, the pilot can lift a powerful searchlight into position to aid in taxiing about after a night landing…"

***Popular Mechanics,* June 1939**



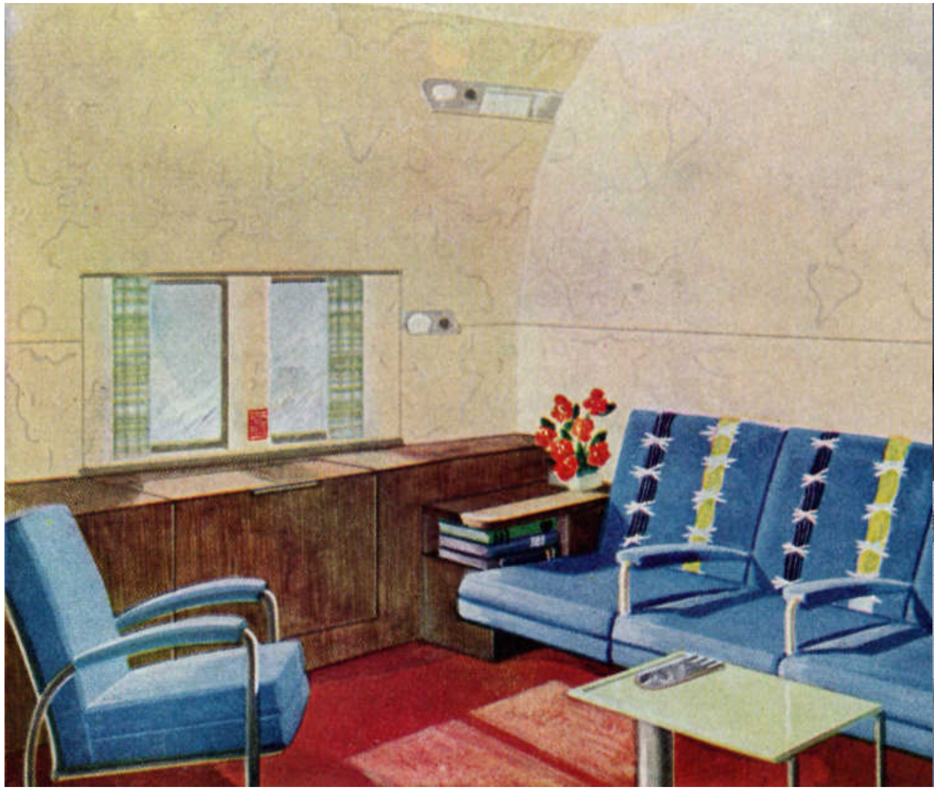
For night landings and taxiing, a powerful searchlight can be swung up out of a recess in the cabin roof by means of a lever, as at the left



"…This 'Queen Mary of the Air' is the first airplane with two decks connected by a spiral staircase. It has eighteen separate rooms within the hull proper, not counting the four 'engine rooms.' The ship measures 100 feet long and has a wing span of 152 feet, nearly one-half the length of a city block. The hull has an inside volume equal to that of a five-room house including basement, and the craft's thermostatically controlled system produces nearly five times as much heat as the heating plant of a modern seven-room house. Fuel tanks hold enough gasoline to drive an automobile two and one-half times around the world, 4,300 gallons, and the cargo holds have a capacity of 10,000 pounds of mail and air express. There are approximately 50,000 different parts in the clipper, assembled with 15,200 bolts and 1,000,000 rivets. The electrical system contains eleven and one-half miles of wiring, installed in 400 runs of conduit, and outlets for 160 light bulbs…"

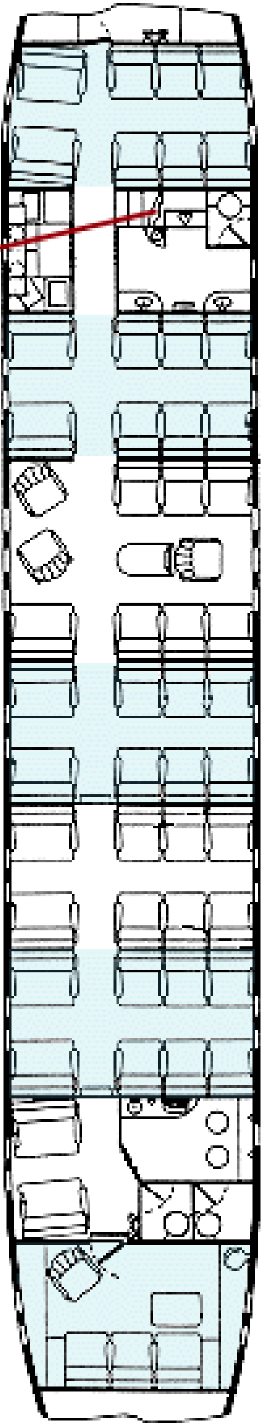
Popular Mechanics, **March 1939**

Above: view from the clippers starboard wing looking to port (note open hatch from fuselage)



"…Inside the double-decked metal hull, life during a transatlantic flight will be like life in an up-to-date hotel. A galley, complete with ice boxes and steam tables, will permit stewards to prepare food for ninety people. To conserve weight, special lightweight silverware will be used at meal-time. During the voyage, passengers will read, smoke, walk about from room to room. Different parts of the plane will be connected by telephone. There will be lounges, dressing rooms, smoking rooms, private compartments - even a honeymoon suite - on board the aerial leviathan…"

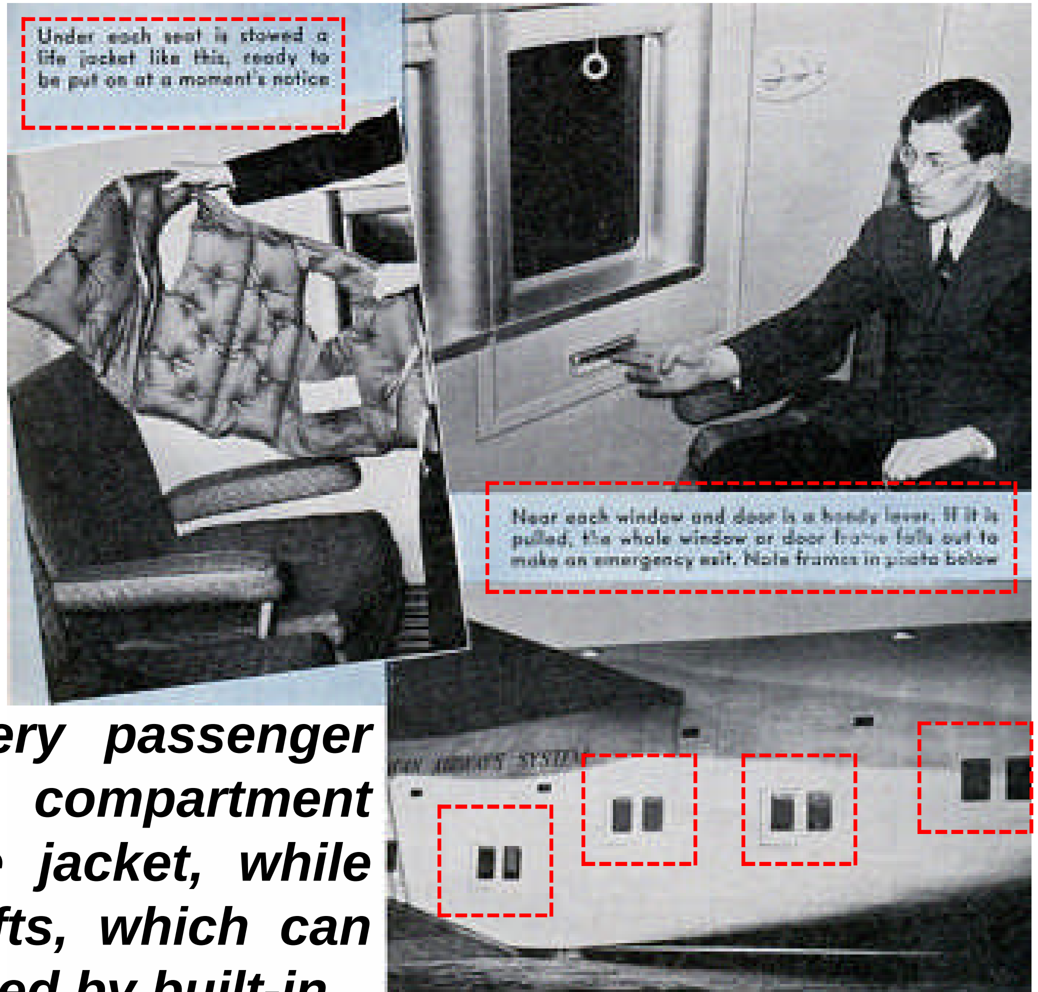
***Popular Mechanics*, June 1939**



"…Below, the passenger compartment was divided into 11 compartments. One was a dining room, seating 14 at 5 tables. On the early, pre-war flights, English passengers usually dressed for dinner. The cabin farthest aft was a luxurious bridal suite. The Yankee Clipper usually flew only 40 passengers on overnight flights, when its eight-foot berths were made up. By day, it could accommodate 74…"
Popular Science, **June 1963**

Left: passenger compartment plan. Passengers could expect to have all their needs catered to by the ever-attentive stewards. Food and drink were always available on demand. Curtained bunks were made up for the passengers at night. The thick carpeting, soft lighting, comfortable upholstery in soothing colors and the heavy soundproofing in the walls all helped to create a special world set apart from the weather and world rushing by outside the windows. The series of lounges were decorated in alternating color schemes; turquoise carpet with pale green walls or rust carpet with beige walls. The compartments could seat up to ten passengers each on a daytime flight, but overnight flights carried less as they could only sleep six passengers.

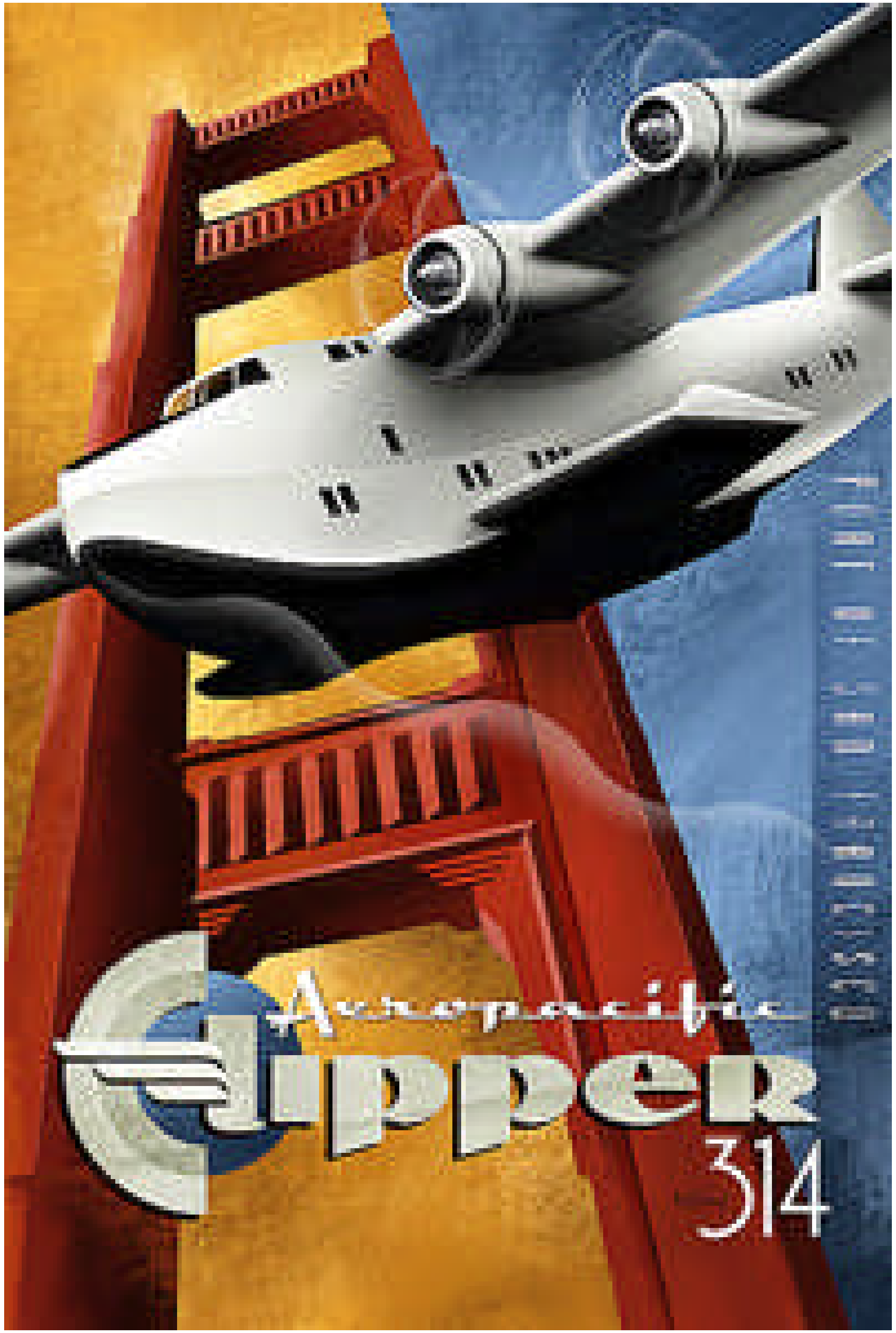
<u>Right</u>: caption: "Under each seat is stored a life jacket like this, ready to be put on at a moment's notice"



<u>Left</u>: caption: "Near each window and door is a handy lever. If it is pulled, the whole window or door frame falls out to make an emergency exit. Note frames in photo below."

"…Beneath every passenger seat, a special compartment will hold a life jacket, while ten-man life rafts, which can be quickly inflated by built-in gas cartridges, will be carried at strategic points within the hull. In a few seconds, thirty doors and windows can be converted into emergency exits. Jerking out a small lever nearby will cause the window or door, frame and all, to drop from its place…"

***Popular Mechanics*, June 1939**



"…These flying boats will be the first to have two full decks. The upper deck will house an elaborate control cabin, crew's quarters, and baggage compartment, while the lower deck will contain day and night passenger accommodations, lavatories, and dressing rooms. Passageways will extend through the wings to the engine nacelles to permit inspection and servicing of the engines during flight. Provision will be made for the highest degree of passenger comfort during long ocean flights…"

***Modern Mechanix,* March 1938**

<u>Left</u>: period poster featuring the Boeing 314 and one of the towers of the *Golden Gate Bridge* (completed in 1937). Both the B-314 and the bridge became icons of the era, representing innovation and human progress.

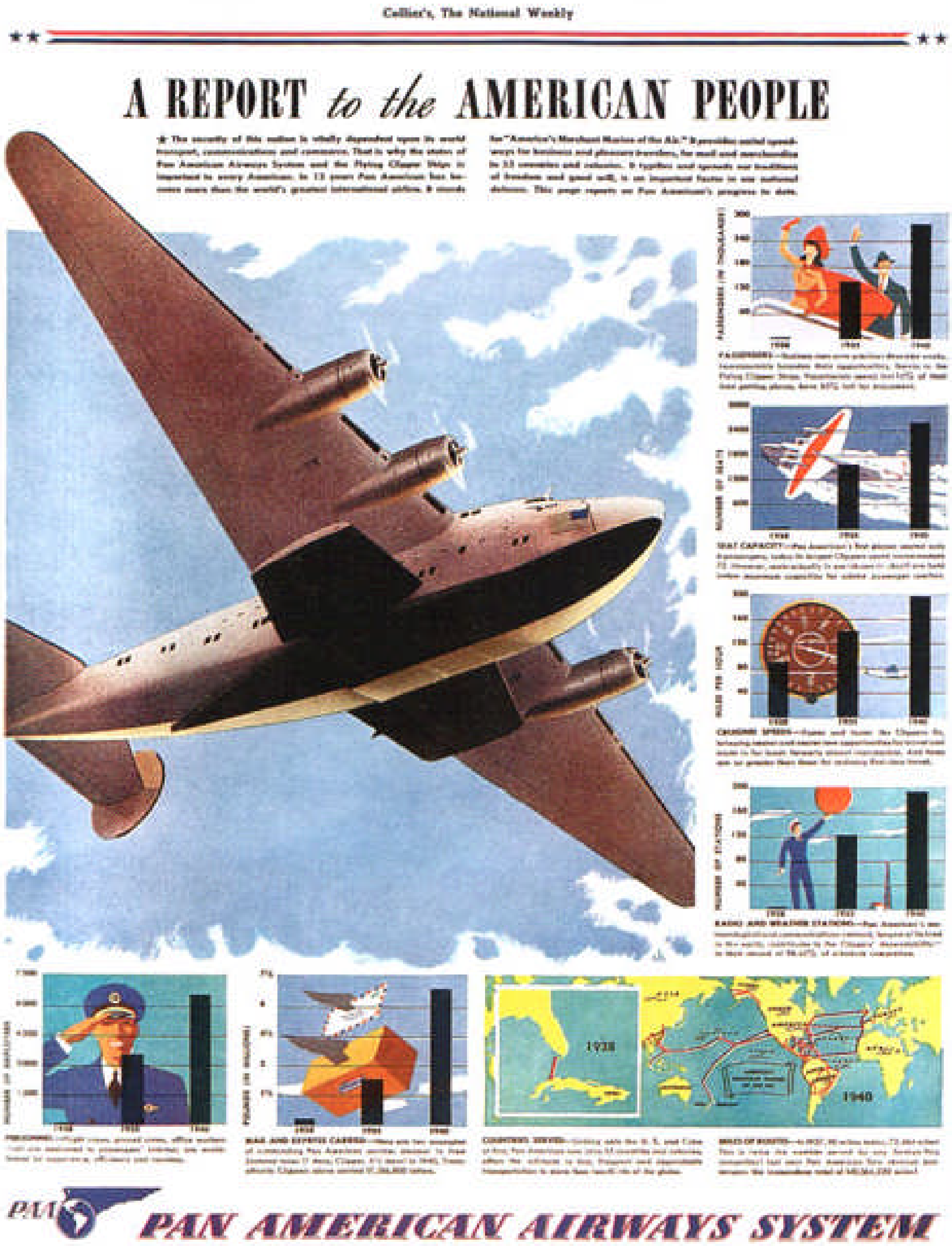
<u>Top Left</u>: PAA Chairman *Juan Trippe* consults a globe (ca. 1939)

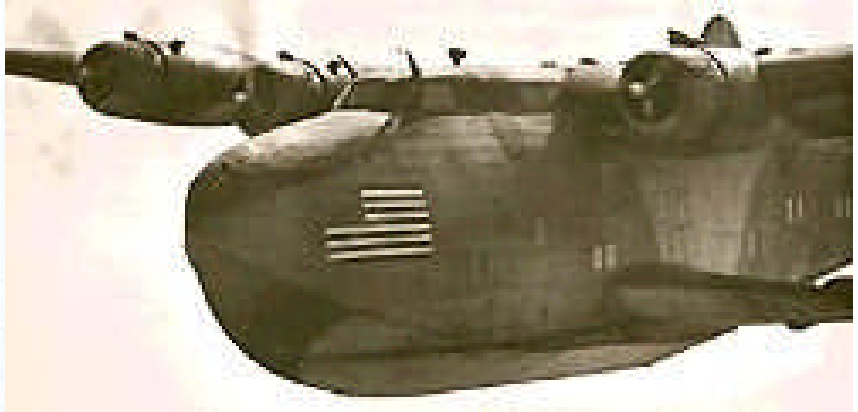
<u>Top Right</u>: PAA poster promoting Pacific travel via their Clipper flying boats

<u>Left</u>: a PAA Clipper above San Francisco. In 1939, a one-way ticket from San Francisco to Honolulu cost $278 and a one-way ticket to *Hong Kong* cost $1,368.

"…With the coming of war, all Clippers immediately joined the Navy, though keeping their civilian crews. The news of Pearl Harbor was flashed to the Philippine Clipper just after it had taken off from Wake Island, headed for Guam. It swung back to Wake, minutes ahead of the first Jap attack. Before it was ready for takeoff again, it was punctured by 97 bullets. Still, stripped of all furnishings and carrying 70 civilians, it managed to hobble safely to Midway and Honolulu…"

***Popular Science*, June 1963**





<u>Above</u>: wartime PAA *Boeing B-314*. The plush interiors of the flying boats were stripped to wartime austerity and priority cargo was packed into every available inch of space. The exteriors were camouflaged by painting them with drab sea-gray paint. The PAA crews wore khaki when under Army command and green when flying for the Navy

<u>Left</u>: 1941 PAA ad to communicate to the American public its role in the security of the country and its status as "America's Merchant Marine of the Air"

"…During World War II alone, they flew a total of more than 201 million miles, including nearly 18,500 ocean crossings…"

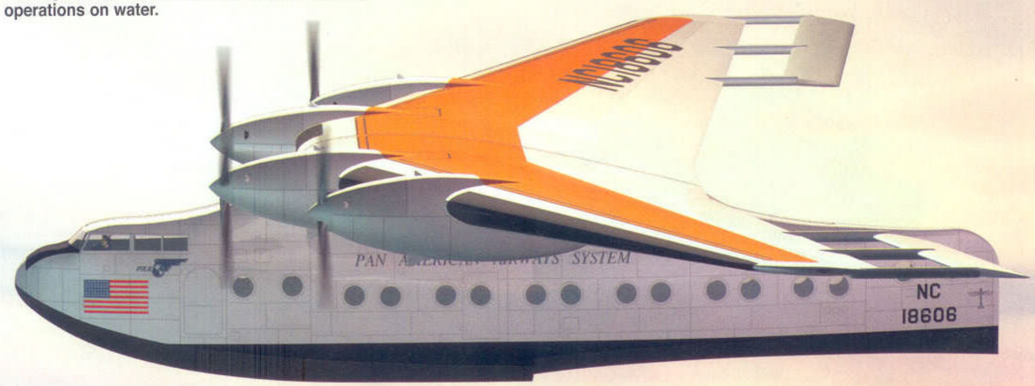
***Popular Science,* June 1963**

<u>Left</u>: advertising illustration from the *Saturday Evening Post* shows workers unloading much-needed engines for use on military planes. During the war years, PAA built some fifty airports in fifteen different countries, almost all of them in remote often hostile areas. As the largest air transport contractor to the army and the navy, PAA flew over 90 million aircraft miles for the government and made more than 18,000 ocean crossings. PAA also trained more than 5K military pilots and thousands of mechanics. More then two-hundred PAA employees lost their lives, an unknown number were imprisoned in enemy prison camps and at least a dozen aircraft were lost.

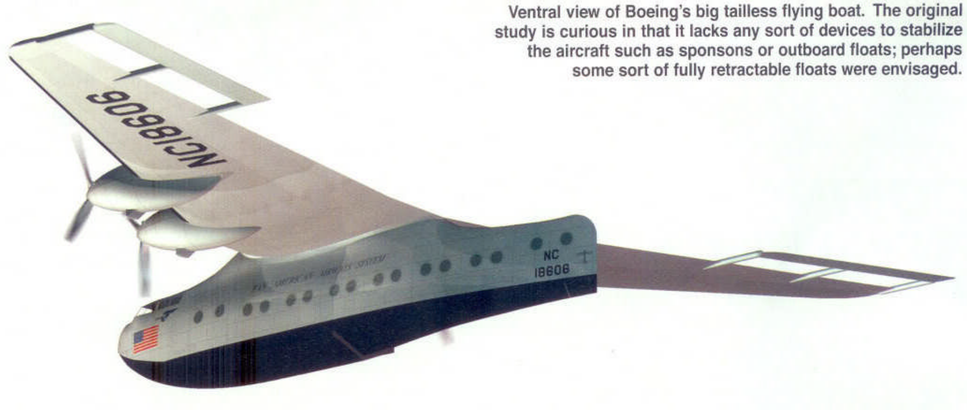
<u>Right</u>: military personnel aboard a PAA flying boat during WWII. In 1942 PAA Clippers made 1,219 Atlantic crossings. The amount of cargo carried increased sharply also; from 16,500 pounds in 1941 to over three million in 1942.

End of an Era

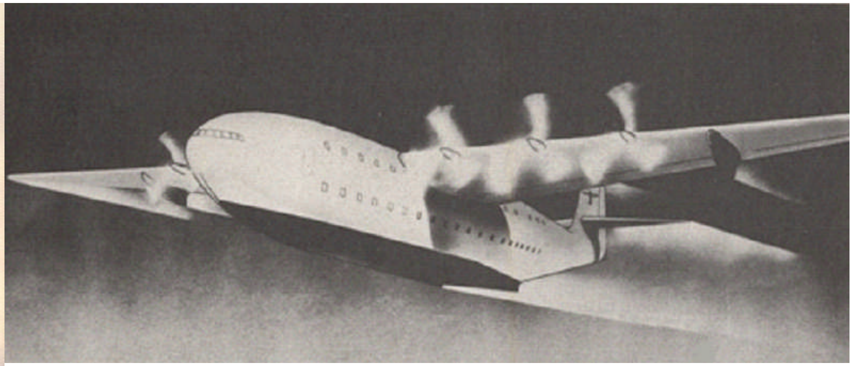
Model 306 flying boat in flight over the ocean. The shoulder wing was mounted very high to keep the engines well clear of the spray generated by operations on water.



Ventral view of Boeing's big tailless flying boat. The original study is curious in that it lacks any sort of devices to stabilize the aircraft such as sponsons or outboard floats; perhaps some sort of fully retractable floats were envisaged.



Model 306 commercial flying boat in a Pan Am color scheme, similar to that used on the famous B-314. Had it been constructed, it surely would have been the most distinctive clipper of the era.



<u>Above</u>: the Boeing "Super Clipper." This six-engine flying boat was designed for PAA as a follow-up to the successful *Boeing 314 Flying Boat*. The *Super Clipper* proposed to fly 100 passengers a distance of 5K-miles at a speed of 300 mph (it was never realized).

<u>Left</u>: various views of the proposed *Boeing Model 306 Flying Boat* (with PAA flying boat livery). Like the Super Clipper, it was never real-ized.

After the war, the government offered to sell the Clippers back to PAA, but the company declined. The war had brought many more airports around the world, and four-engine land planes could fly faster than the Clipper flying boats. DC-4s and Boeing 307s had begun to appear even before the war. Shortly after the war, PAA Lockheed Constellations, DC-5s and Boeing 377s took over the routes that the Clippers had pioneered. Other companies bought the remaining Clippers from the military, but in 1951, the last of the huge Boeing Clippers reached the end of its career. Sadly, none of these beautiful and historic aircraft remain. In many respects, the *Boeing 314* was the forerunner of the 747-100.

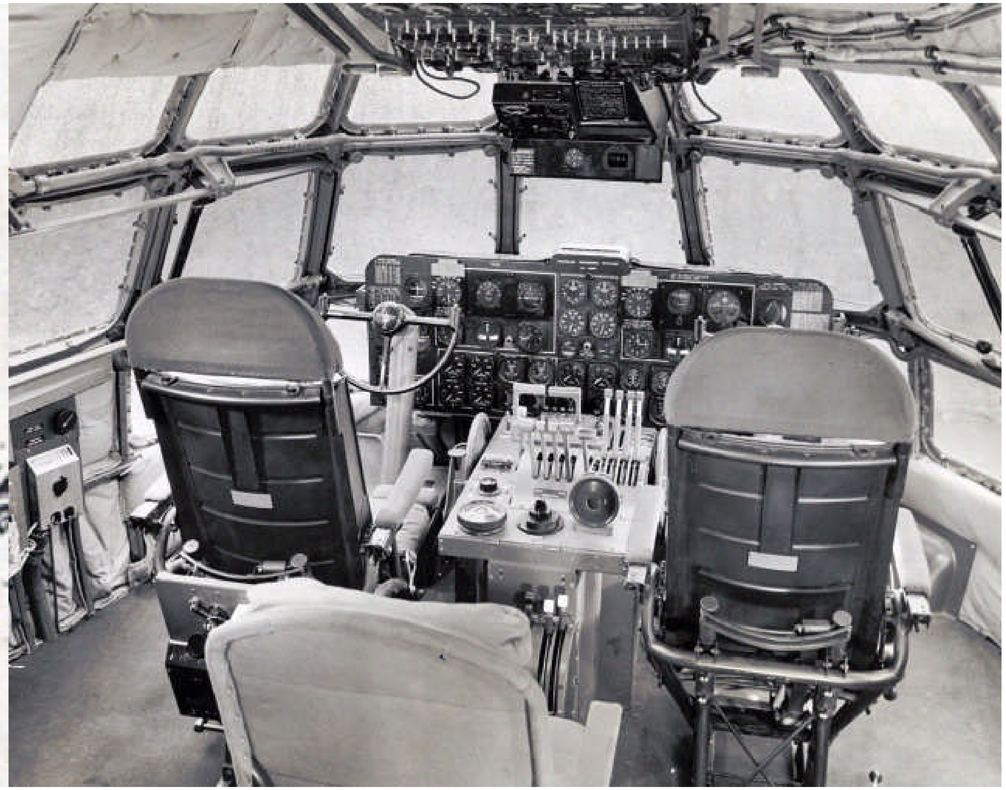
A Flier's Dream

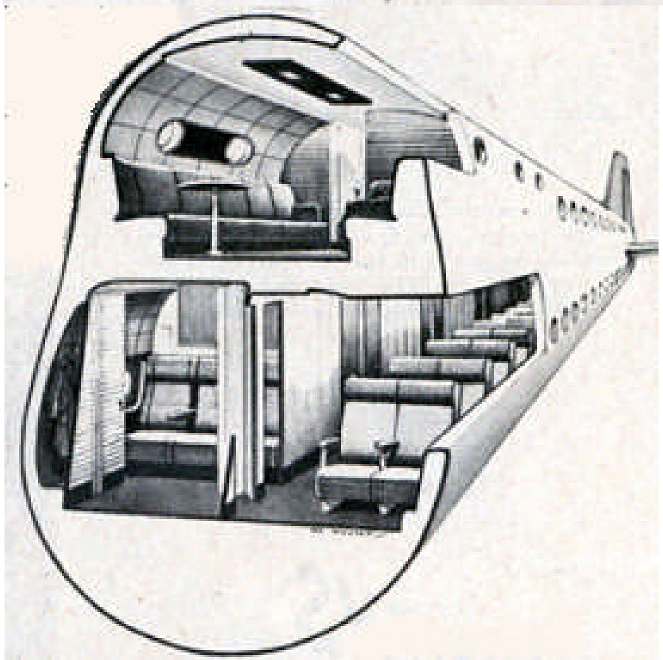
"…The two decks of the Strato-cruiser have been created by building one fuselage above the other. The bottom section is as wide as the Army's Superfortress. The upper is slightly larger…"

***Popular Science,* April 1946**

<u>Above</u>: caption: "Double-decked Boeing Stratocruiser has made a record of slightly over six hours from Seattle to Washington D.C. This comfortably upholstered airliner will carry up to 114 passengers or 39,000 pounds of cargo at speeds well over 300 m.p.h. Cabin is pressurized to the atmospheric equivalent of a 6,000-foot level."

<u>Left</u>: ca. 1950 *Northwest Airlines* ad featuring the *Boeing Stratocruiser* (above)



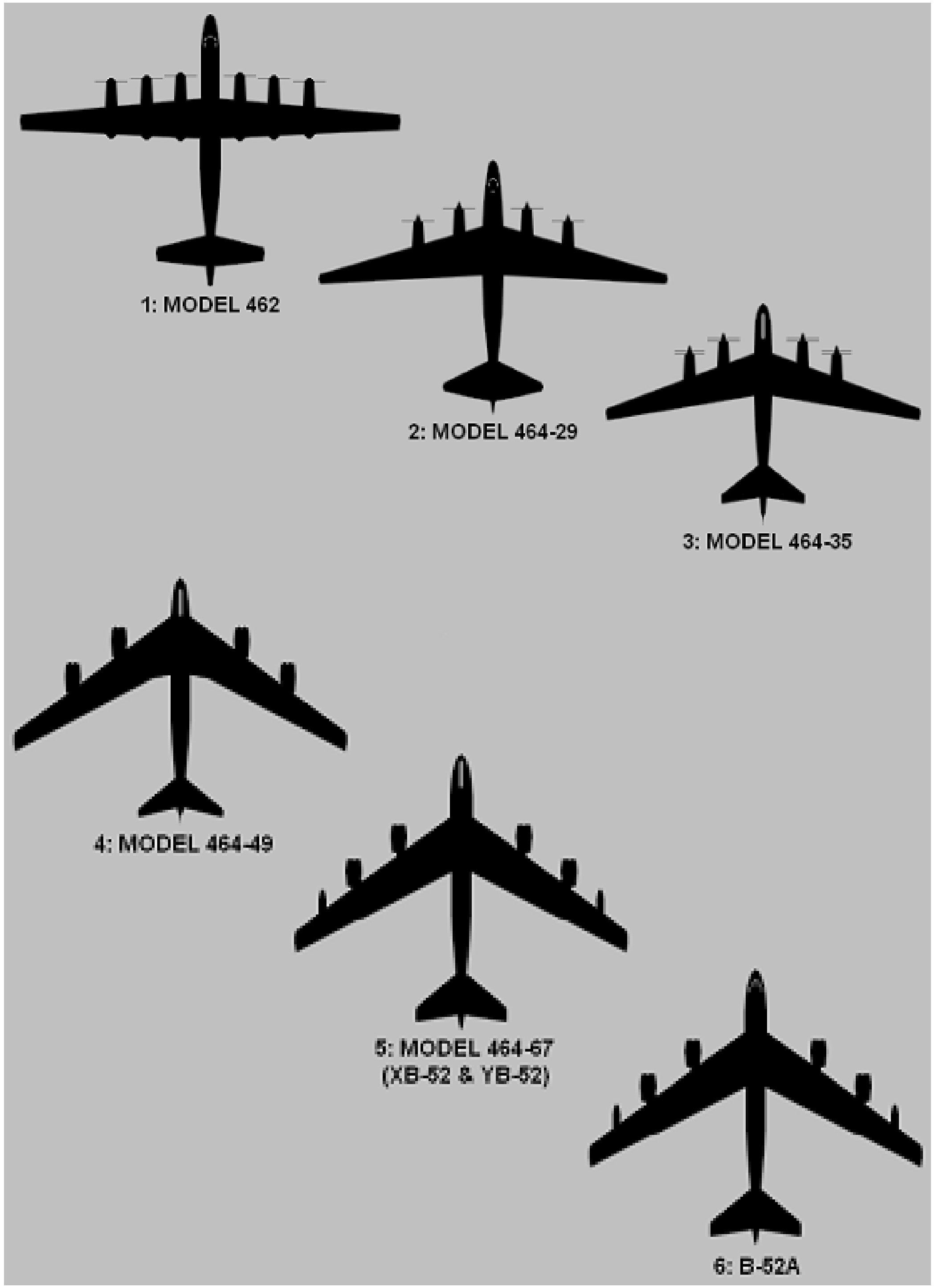


<u>Top Left</u>: caption: "The greater space and comfort provided for Stratocruiser pilots inspired Ernest Norling, Boeing designer, to draw this conception of a flier's dream"

<u>Top Right</u>: caption: "Stratocruiser Cockpit"

<u>Left</u>: caption: "A cross-section of proposed Pan American Clipper, showing the interior of the 204-passenger transport. Upper deck has lounge and rest rooms, lower has staterooms."

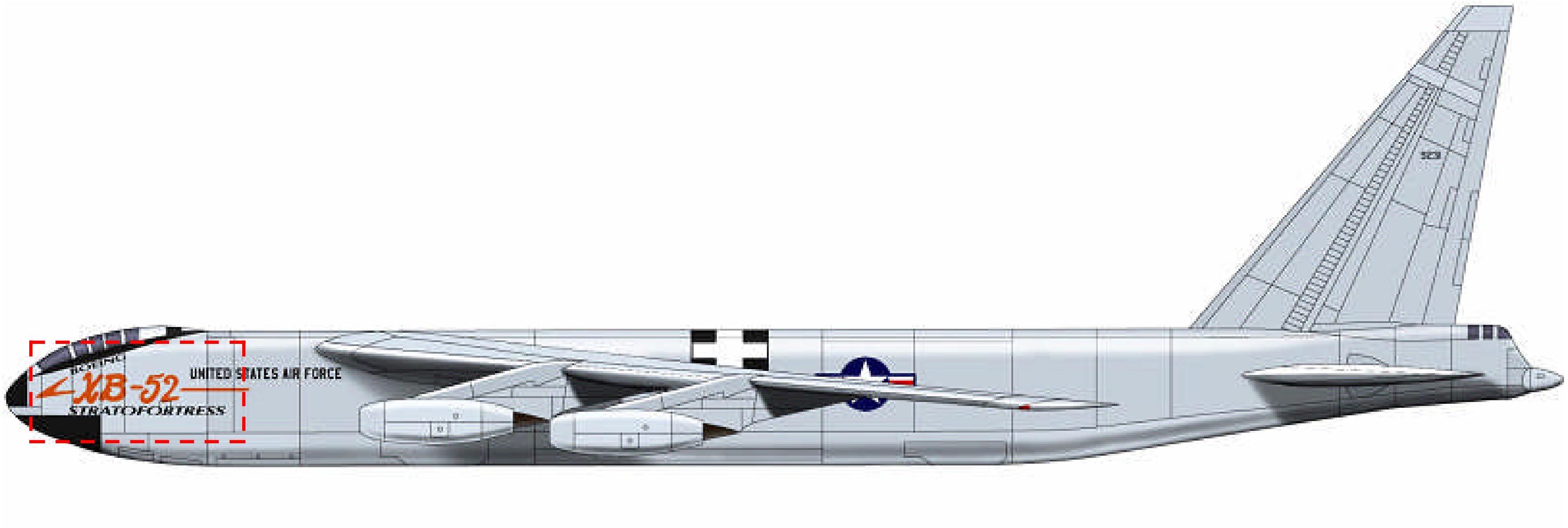
Stratofortress



The original XB-52 design, selected by the USAAF in 1946, was for a straight-wing, six-engine, propeller-powered heavy bomber. On October 21st 1948, Boeing Chief Engineer *Ed Wells* and his design team were in Dayton, Ohio, when the USAAF's Chief of Bomber Development told them to scrap the propellers and come up with an all-jet bomber. In a Dayton hotel room over the following weekend, the Boeing team designed a new eight-engine jet bomber (still referred to as the "B-52"), making a scale model out of balsa wood and preparing a 33-page report. This effort impressed the USAAF's *Air Materiel Command* and the design was approved.

<u>Top</u>: caption: "B-52 Evolution 1: Models 462 (1946) to 464-35 (1948)"

<u>Bottom</u>: caption: "B-52 Evolution 2: Models 464-49 (1949) to B-52A (1952)"



The two prototype aircraft: *XB-52* (above) and *YB-52* (left), rapidly took shape in a classified area of Boeing's "Plant No. 2" in Seattle. The two planes were basically identical (YB-52 was instrumented for flutter tests). YB-52 rolled-out on March 15th 1952 and made the first flight of the B-52 series on April 15th 1952 (XB-52 was damaged during a full-pressure test of its pneumatic system). XB-52 made its first flight on October 2nd 1952.

"This was it. The tremendous roar of the engines grew louder and louder as the plane gained speed. It raced down the runway with deceptive speed, past the other bombers that had made history taking off from here: the smaller B-47s, the B-50s, the B-29s and an old but proud B-17, nearly two decades of history-making bombers. The huge crowd that had gathered to watch the takeoff let out a spontaneous cheer."

Boeing News, **April 17th 1952**

Left: caption: "Shrouded in tarpaulins and a veil of secrecy, the XB-52 is rolled out and moved quickly through the rainy night to the flight-test hangar"

Right: caption: "The YB-52 prototype makes its first flight on April 15, 1952, from Boeing Field in Seattle"


USAF
9231

The general layout of the two B-52 prototypes was similar to that of the B-47. Boeing engineers retained the 35-degree swept wing, pylon-mounted engines, braking parachute, bubble canopy and bicycle-type landing gear. A notable difference was the use of four separate and steerable landing-gear units. This interesting capability allowed B-52 pilots to align the landing gear with the center of the runway while "crabbing" the aircraft into the wind (during crosswind landings). Another innovation was the use of a completely moveable horizontal tail (instead of conventional elevators for pitch control). This system was standard for jet fighters of the period, but had never been used on jet bombers.

Above: Boeing *B-52 Stratofortress* (left) & *B-47 Stratojet* (right) bomber/s


BOEING
XB-47


2335
U.S. AIR FORCE
U.S. AIR FORCE

By the time the B-52A made its first flight in 1954, a more traditional cockpit with side-by-side seating had replaced the prototypes' bubble canopy. The B-52A was followed by the B-52B, with increased gross weight and larger jet engines. The B-52B was the first production version of the *Stratofortress* because the three B-52As were primarily used as flight-test aircraft. The B-52B entered service with the U.S. Air Force's *Strategic Air Command* (SAC) on June 29th 1955, with the 93rd Bomb Wing at Castle Air Force Base, California. With photographic reconnaissance or electronic capsules installed in their bomb bays, 27 of the 50 B-52Bs built were designated RB-52Bs.

<u>Left</u>: caption: "Boeing shows off its first production B-52A in 1954"

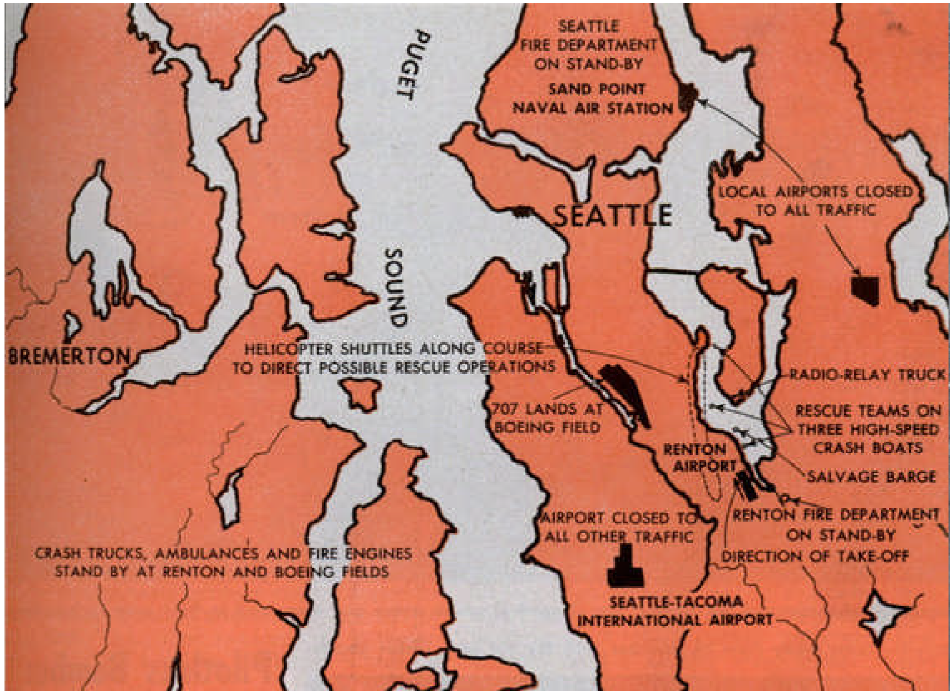
<u>Right</u>: caption: "Three B-52Bs of the 93rd Bomb Wing (ca. 1957)"

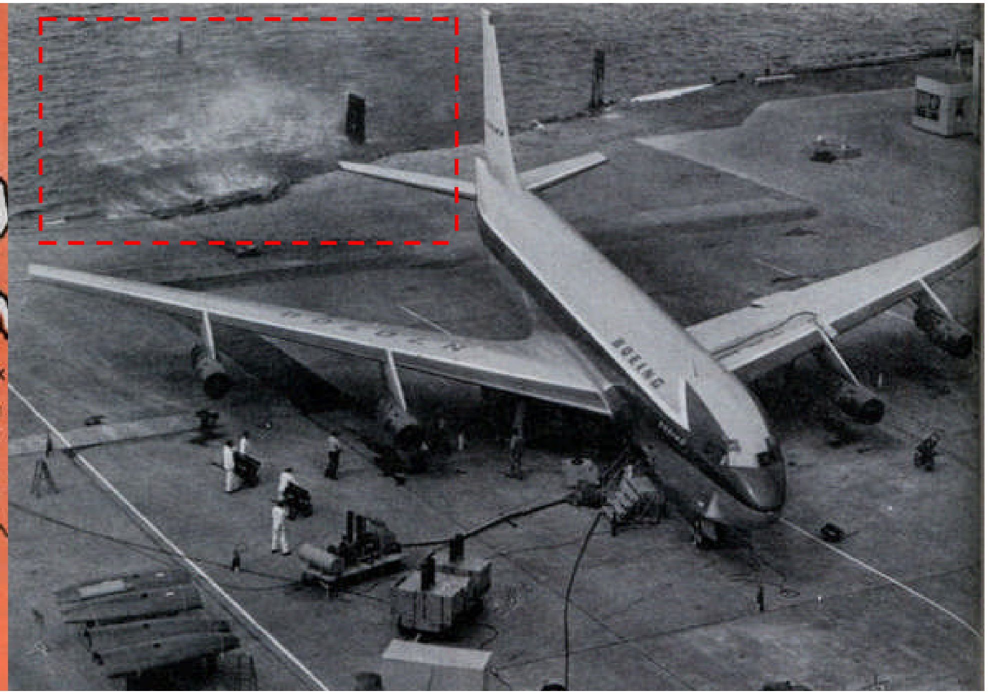
Next off the production line were B-52Cs (further improvements resulted in a higher gross weight of 450K pounds and un-refueled range extended by a total fuel capacity of 41,700 gallons). The B-52D made its first flight in 1956 (the B-52D was essentially the B-52C without the alternative reconnaissance capsule feature). The Es and Fs were exclusively long-range, heavy bombers. Equipped with the Boeing-developed flying boom system for in-flight refueling, they had virtually unlimited range. With improved bombing, navigation and electronic systems, the B-52E first flew in 1957 (it was the least expensive of the B-52 series, costing slightly more than $6 million per copy). The B-52F, the last model before the B-52 went through a major redesign, used 13,750 pound-thrust *Pratt & Whitney J57-43W* turbojet engines.

Left: period Boeing ad featuring the B-52 prototype

Seattle production of B-52s ended in 1958 when the last B-52F rolled off the assembly line (B-52Fs were also produced in Wichita, where the substantially improved G and H models were also built). While B-52Cs and Es were phased out during the early 1970s and the Fs in the late 1970s, B-52Ds remained in service until 1983. The B-52G and B-52H looked very similar to earlier *Strartofortress* models, but they were substantially different and capable of a variety of new missions. The B-52G (which made its first flight in 1958) was the first variant to introduce major innovations to the original design. It had a redesigned wing and a shorter vertical fin. Its internal fuel capacity was increased to 46K gallons (by using built-in wing tanks rather than the flexible bladders of earlier versions). This gave the B-52Gs a range almost 2K miles greater than the first B-52. They remained in service until 1994. The B-52H first flew in March 1961, incorporating all of the B-52G's improvements. One major advancement was the switch to *Pratt & Whitney TF33* turbofan engines. With more than 17K pounds of thrust, the turbofans were much more powerful than the G's turbojets. With each variant, the B-52 increased in range, power and capability. In all, 744 B-52s were produced by the Seattle and Wichita plants between 1952 and 1962. Only the B-52H remains in service.

A Calculated Risk





"'Crash boats are standing by off Mercer Island! All airports in vicinity of Seattle are closed to normal traffic! Rescue helicopter now on patrol off Seward Park! Fire fighters standing by! Your chase plane is airborne!' Reports like these were part of the pre-flight preparations in July when copilot 'Dix' Loesch and I prepared to streak down the concrete runway at Renton Airport and lift the prototype of America's first jetliner into the air on its initial test flight. Boeing's 707 'Jet Stratotanker-Stratoliner' is considered the safest passenger transport ever built, yet Dix and I were happy about the elaborate precautions to rescue us if anything went wrong. All our recent preflight and ground tests had been perfect. We were expecting a normal routine ride on the first flight, but there's always a chance that the unexpected can happen…"

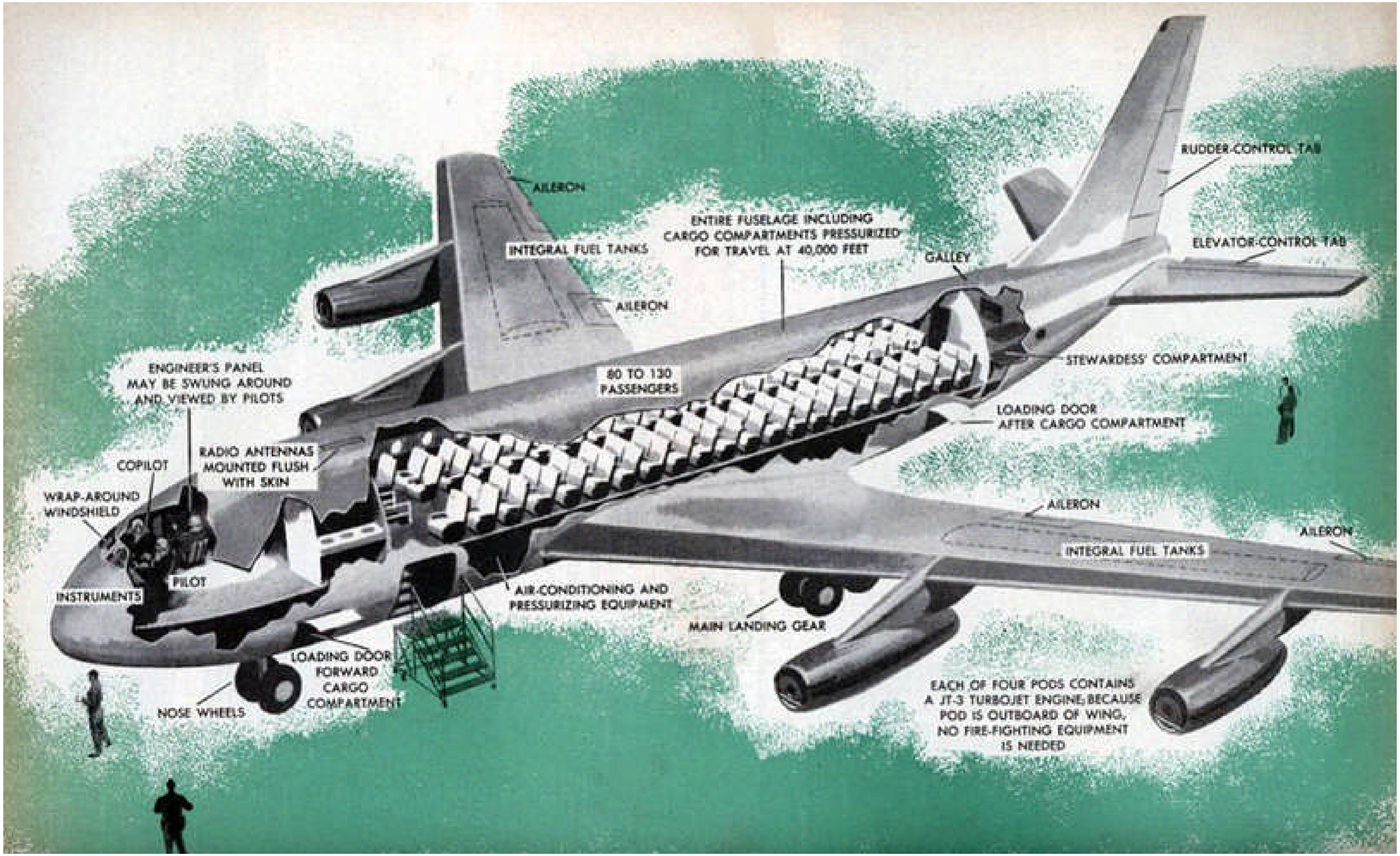
A.M. "Tex" Johnston **- Chief of Flight Testing for the** ***Boeing 707*** **(August 1954)**

Left: caption: "Map of the Seattle area shows some of the preparations made for the first flight test of the new jetliner"

Right: caption: "Technicians check thrust of one of the four powerful engines. Exhaust kicks up miniature storm in water."

"…And the unexpected did happen during an early taxi test. A landing gear strut unexpectedly folded up. The plane skidded along the runway on one wing for a few feet and the whole test program was delayed during repairs. For the first flight test, it was comforting to know that the crash boats carried diagrams of the fuselage with 'Chop Here' information, and that fire fighters were standing by even though we wouldn't need their help. We had landing priority at any airport within 50 miles and, as a final precaution, we were wearing parachutes…"

***A.M. "Tex" Johnston* - Chief of Flight Testing for the *Boeing 707* (August 1954)**


AILERON
RUDDER-CONTROL TAB
ENTIRE FUSELAGE INCLUDING CARGO COMPARTMENTS PRESSURIZED FOR TRAVEL AT 40,000 FEET
INTEGRAL FUEL TANKS
GALLEY
ELEVATOR-CONTROL TAB
AILERON
STEWARDESS' COMPARTMENT
ENGINEER'S PANEL MAY BE SWUNG AROUND AND VIEWED BY PILOTS
80 TO 130 PASSENGERS
LOADING DOOR AFTER CARGO COMPARTMENT
COPILOT
RADIO ANTENNAS MOUNTED FLUSH WITH SKIN
WRAP-AROUND WINDSHIELD
AILERON
AILERON
INTEGRAL FUEL TANKS
PILOT
INSTRUMENTS
AIR-CONDITIONING AND PRESSURIZING EQUIPMENT
MAIN LANDING GEAR
LOADING DOOR FORWARD CARGO COMPARTMENT
NOSE WHEELS
EACH OF FOUR PODS CONTAINS A JT-3 TURBOJET ENGINE; BECAUSE POD IS OUTBOARD OF WING, NO FIRE-FIGHTING EQUIPMENT IS NEEDED

"…All of this is routine procedure at Boeing when a new design is being flown for the first time. In this case the pre-cautions were more complete than usual, if possible, for our new plane is the pioneer American aircraft in the jet-powered passenger-transport field. Including engineering and re-search man-hours, this prototype was built at a cost of $15,000,000…"

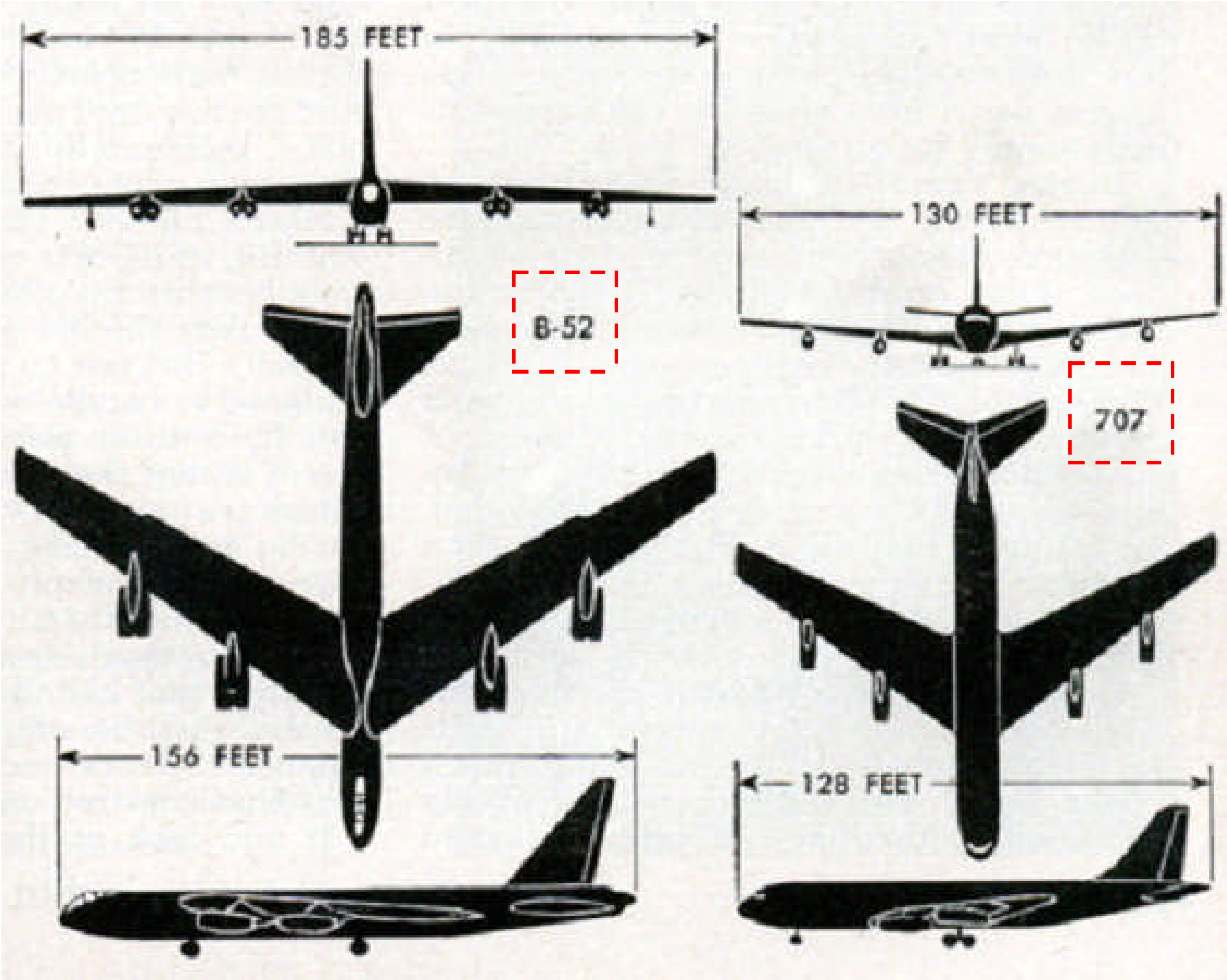
A.M. "Tex" Johnston **- Chief of Flight Testing for the** ***Boeing 707*** **(August 1954)**

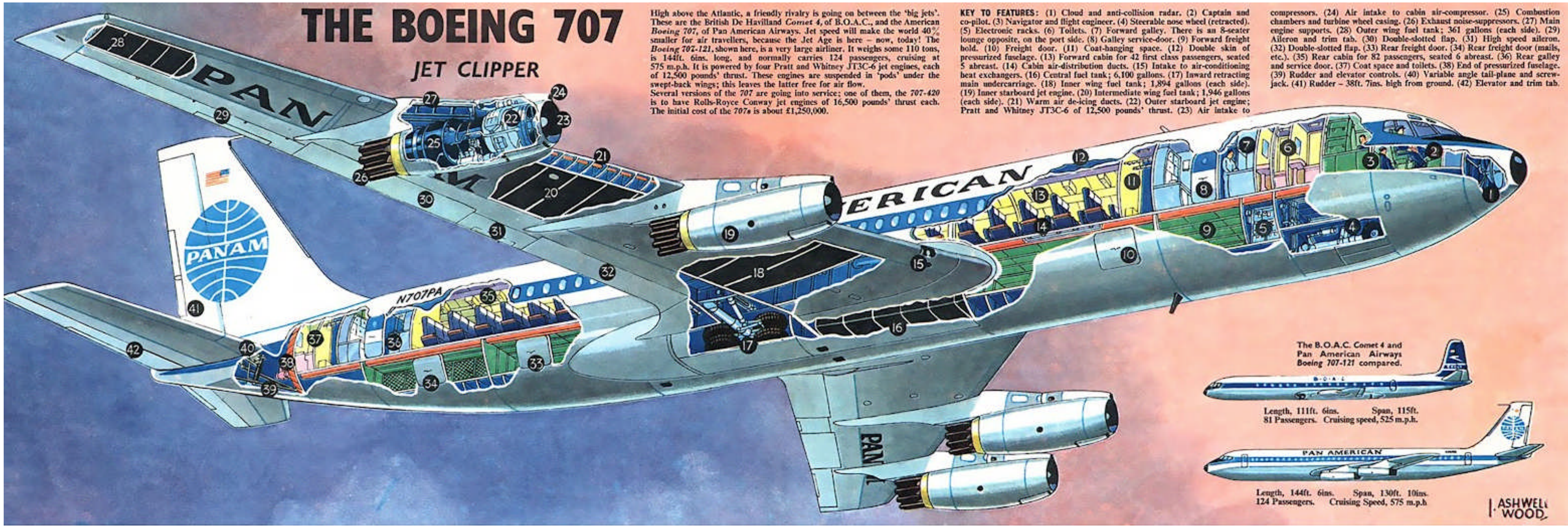
"…The 707 has a wingspan of 130 feet and is 128 feet long. It is smaller than a B-52 bomber and is larger, heavier and faster than the British Comet. It is a brand-new design with a striking sweptback wing. We are offering it to two different markets - to the Air Force as a jet-refueling tanker or for transport, and to the airlines as America's first and the world's best jet passenger transport…"

A.M. "Tex" Johnston **- Chief of Flight Testing for the *Boeing 707* (August 1954)**

<u>Top Left</u>: caption: "BOAC De Havilland Comet in-flight"

<u>Top Right</u>: caption: "Flight line at Renton in late 1957, with the first production 707 (Pan Am No. 1) in the foreground, a line of KC-135's behind it"


185 FEET
B-52
156 FEET
130 FEET
707
128 FEET



"…As an airliner it will cruise at 40,000 feet at about 550 miles per hour, carrying you across the United States in about five hours. Westbound you'll almost keep pace with the sun. Eastbound you'll go from ocean to ocean in three hours if the pilot catches a lift on the high-speed jet stream high in the air. The galley can be smaller than usual since there won't be time to serve more than one meal per flight. Depending on seating arrangements, it will carry 80 to 130 passengers…"

A.M. "Tex" Johnston **- Chief of Flight Testing for the *Boeing 707***

<u>Above</u>: caption: "The Boeing 707 Jet Clipper 1959"

Now! only on BRANIFF

WORLD'S FASTEST JETLINER!

Fastest between New York or Chicago and Texas

exclusively on Braniff
the Different and Superior
BOEING 707 · 227
...the JET with the BIG engines

El Dorado Super Jet

FASTEST--cruises over 600 m.p.h.
POWER PLUS--20% to 40% more
ON-TIME--the most power in reserve
EPICURE MEALS--Braniff's famed service
ELEGANT LUXURY--decor exclusively Braniff's
(Both first class and tourist.)

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South America
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jetliner!

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Call any Braniff office or your travel agent. General Offices: Dallas, Texas.

A new age of TRAVEL

Previewing the luxury which will feature your jet flight

[illegible]

"…The Jet Stratoliner is designed to combine the best features of both jet and piston-engine aircraft, something that seemed impossible in the past. It has the high speed and altitude capabilities of a jet plane and still has the good low-speed performance of piston-engine aircraft. It can climb out of a field as fast as most transports can cruise. It can make a steep, slow approach for a landing, then brake to a minimum stop…"

A.M. "Tex" Johnston **- Chief of Flight Testing for the** ***Boeing 707*** **(August 1954)**

"…During the rest of this summer Dix Loesch and I will complete its Phase I testing. Among other things, this involves proving its performance, stability and altitude capabilities. We will find out how closely it meets the specifications to which it was designed. Takeoff and landing distances will be measured, as will its Mach number and indicated air-speed limitations. We'll check flutter characteristics, if any, in all speed ranges and under all conditions of loading and centers of gravity. Fuel consumption under all conditions will be measured…"

A.M. "Tex" Johnston **- Chief of Flight Testing for the *Boeing 707* (August 1954)**

<u>Above</u>: caption: "Here is the Model 707 outside the Boeing Flight Test Center at Boeing Field. The center's facilities include laboratories, radio transmitters and offices."

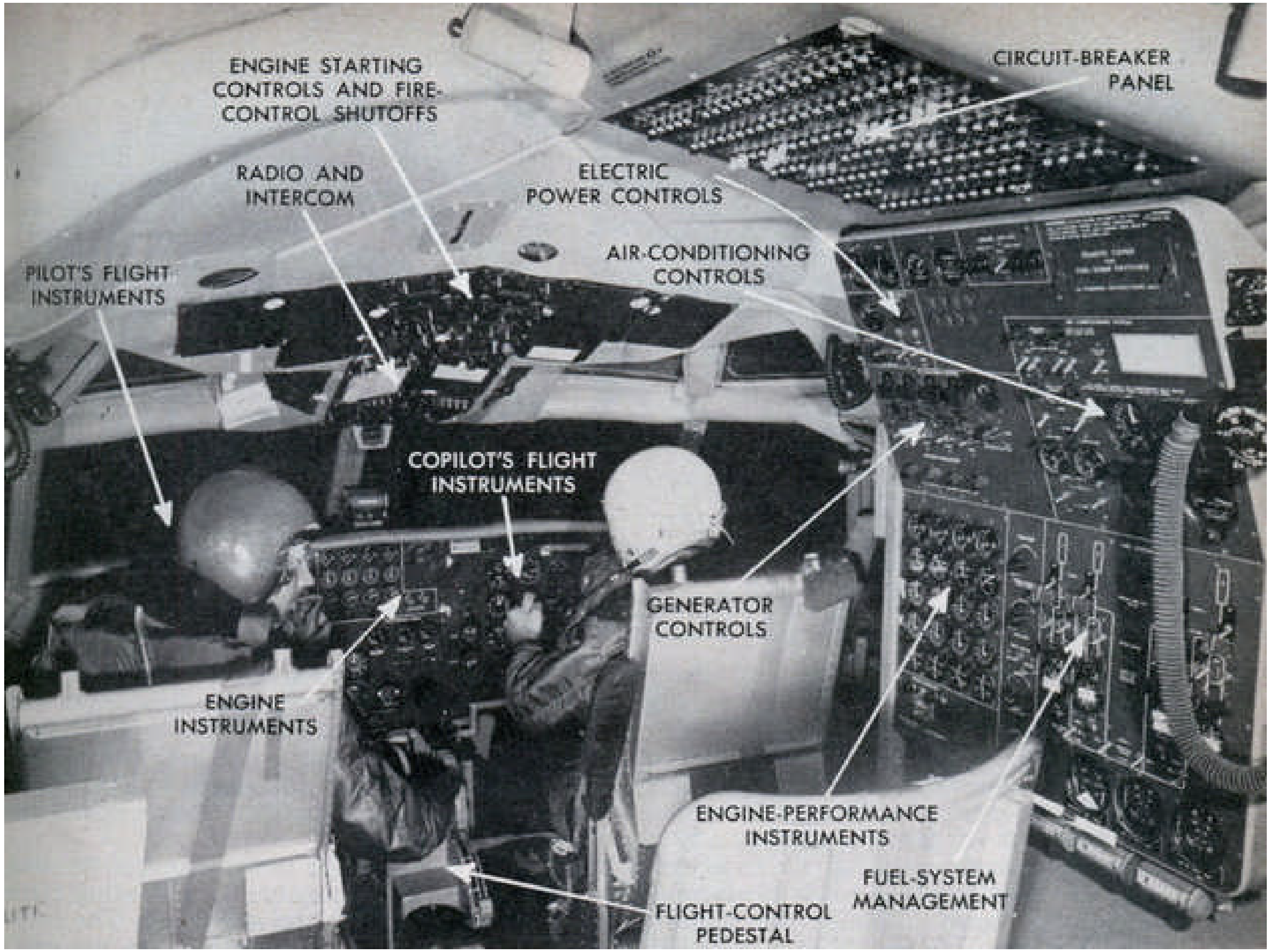
"…Probably we'll find a few minor faults that are expected with any new design. We don't anticipate any major troubles. In fact, part of our job is to prevent any major trouble from developing. An emergency in the air usually has a small beginning that multiplies itself. Finally the plane is in real trouble. It's up to us to prevent any minor malfunction from building up into an emergency. We've worked up cockpit procedures for stopping or eliminating any adverse condition almost as soon as it starts…"

A.M. "Tex" Johnston **- Chief of Flight Testing for the *Boeing 707* (August 1954)**

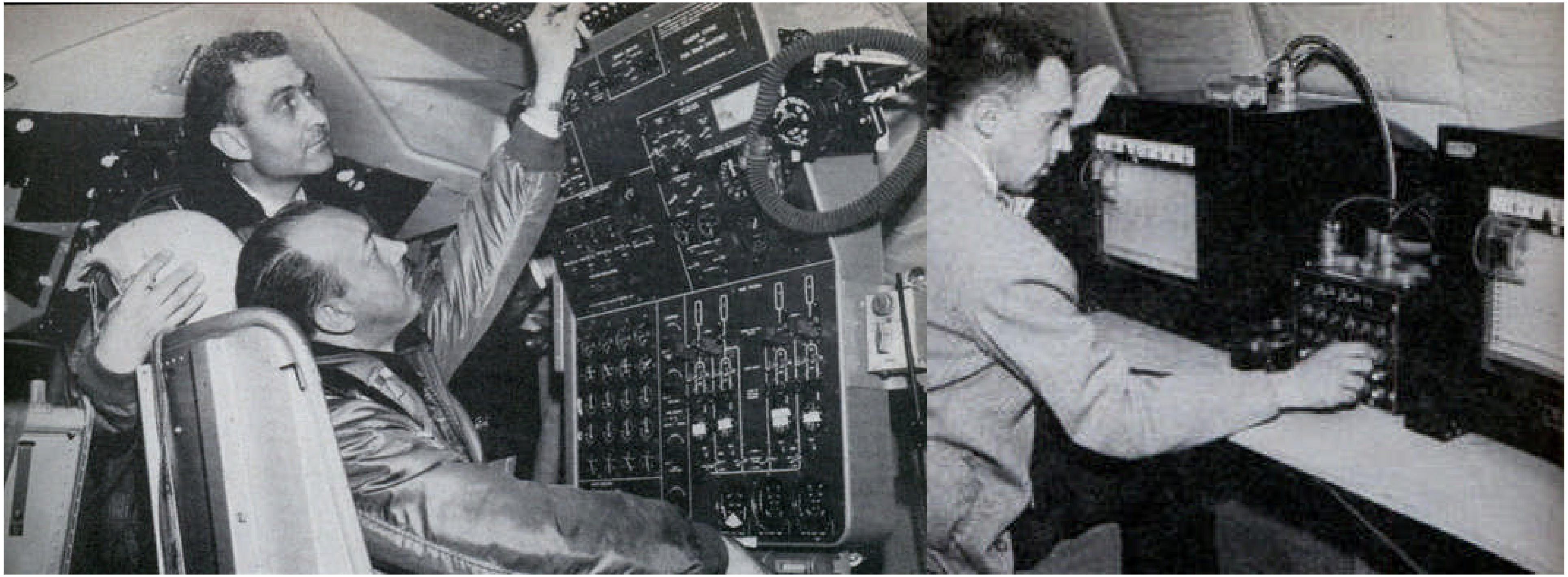
<u>Left</u>: caption: "By pulling a single switch the co-pilot can cut-off all fuel, oil and electricity to a burning engine"

"…Loesch and I spent more than 10 hours in the cockpit before the plane was first taxied. Part of the time we rehearsed the ordinary handling of the aircraft and the rest of the time was devoted to practicing emergency procedures. Normally, an engineer sits behind us at his panel. He's part of the flight crew, but on the first flight we left him on the ground and swung his hinged panel around so we could read its dials simply by turning our heads...One of the reasons why the 707 is regarded as the safest transport ever built is its extreme simplicity. For one thing, much of the heavy, complicated and potentially dangerous apparatus that must be lugged around with piston engines is unnecessary with jets. We don't have propellers and their complicated controls, we don't need superchargers. All in all, our cockpit has about half as many controls and indicators as has a current piston-engine passenger liner…"

A.M. "Tex" Johnston **- Chief of Flight Testing for the** ***Boeing 707*** **(August 1954)**



ENGINE STARTING CONTROLS AND FIRE-CONTROL SHUTOFFS
CIRCUIT-BREAKER PANEL
RADIO AND INTERCOM
ELECTRIC POWER CONTROLS
PILOT'S FLIGHT INSTRUMENTS
AIR-CONDITIONING CONTROLS
COPILOT'S FLIGHT INSTRUMENTS
GENERATOR CONTROLS
ENGINE INSTRUMENTS
ENGINE-PERFORMANCE INSTRUMENTS
FUEL-SYSTEM MANAGEMENT
FLIGHT-CONTROL PEDESTAL

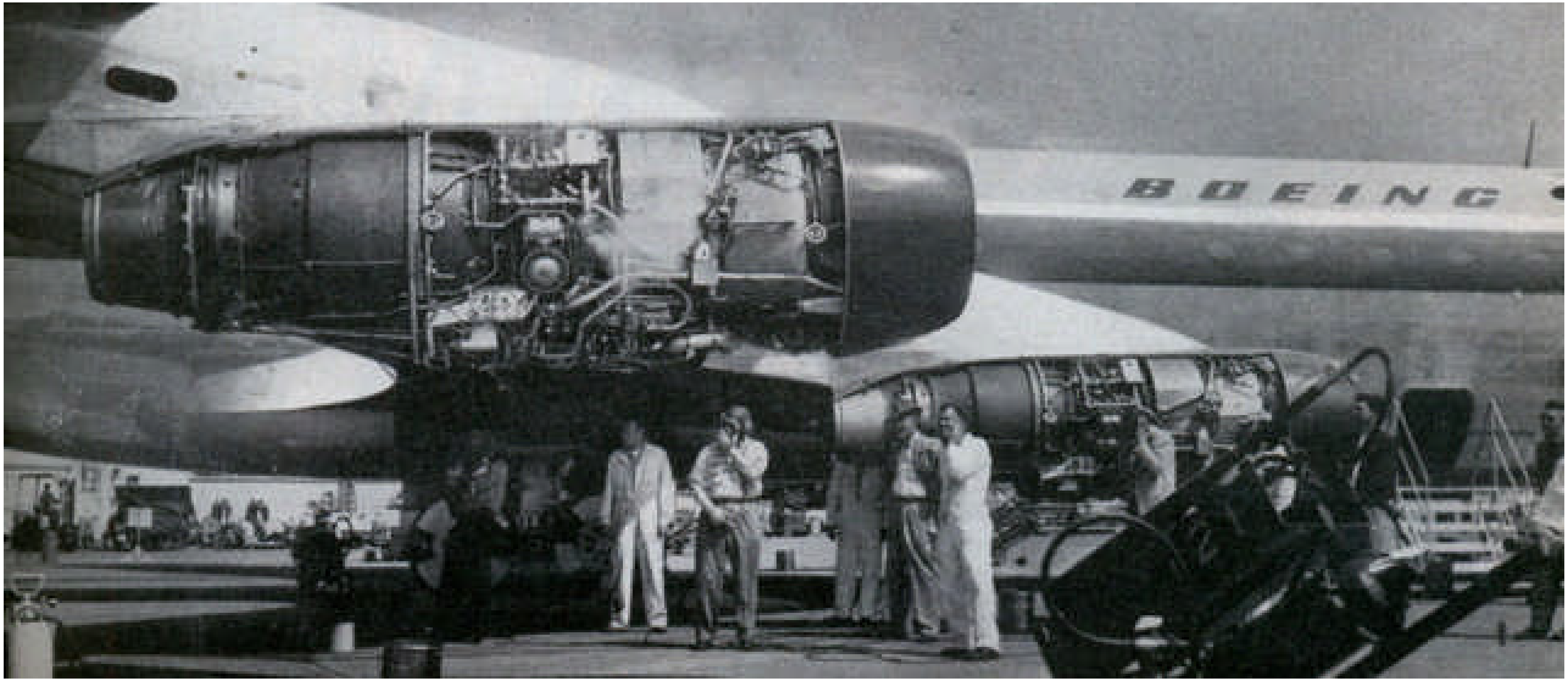


"…During Phase I the aircraft carries a lot of instruments that automatically measure pressures, temperatures and other conditions at numerous locations. This information is transmitted to automatic recorders and cameras mounted in the fuselage. Phase II of the test program, which we'll enter during the fall, is a development phase in which any changes that seem indicated are made and tested. We may find, for instance, that the rudder is larger than necessary. That would mean we are carrying weight that we don't need so, during Phase II, a small rudder would be tested…"

A.M. "Tex" Johnston **- Chief of Flight Testing for the** ***Boeing 707*** **(August 1954)**

Left: caption: "Author (foreground) and co-pilot Loesch spent hours practicing emergency procedures and use of instruments"

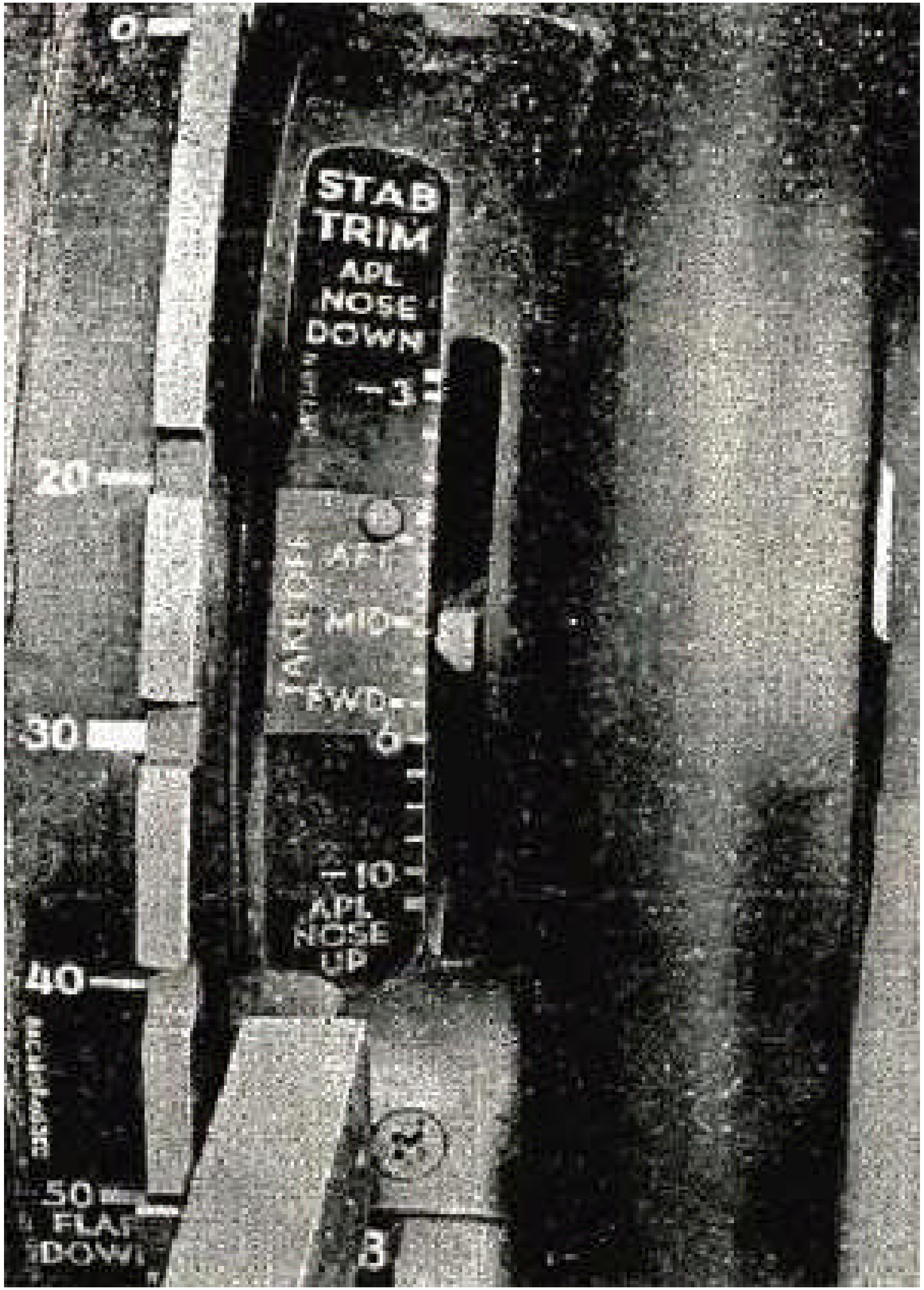
Right: caption: "Inside main cabin, an engineer starts instrument which will record plane's characteristics during flight"



"…Nor does the 707 require an independent pressurizing apparatus or a heating plant for cabin warmth and anti-icing. The needed hot air is bled directly from the compressors of a couple of the engines. It comes off at 700 degrees, in fact, and has to be cooled by a reduction turbine before it can be used. Another thing we don't need (and this may surprise you) is any fire-extinguishing apparatus for the engines. Each engine is carried in its own pod away from the wing. If an engine fire occurs, it takes less than a second to shut off the fuel, oil, hydraulic fluid and electricity. Then the fire blows itself out. It can't keep on burning for there's nothing left to support combustion. And the fire can't get up into the wing. This plane, incidentally, can maintain altitude, loaded, on only two of its four power plants…"

A.M. "Tex" Johnston **- Chief of Flight Testing for the *Boeing 707* (August 1954)**

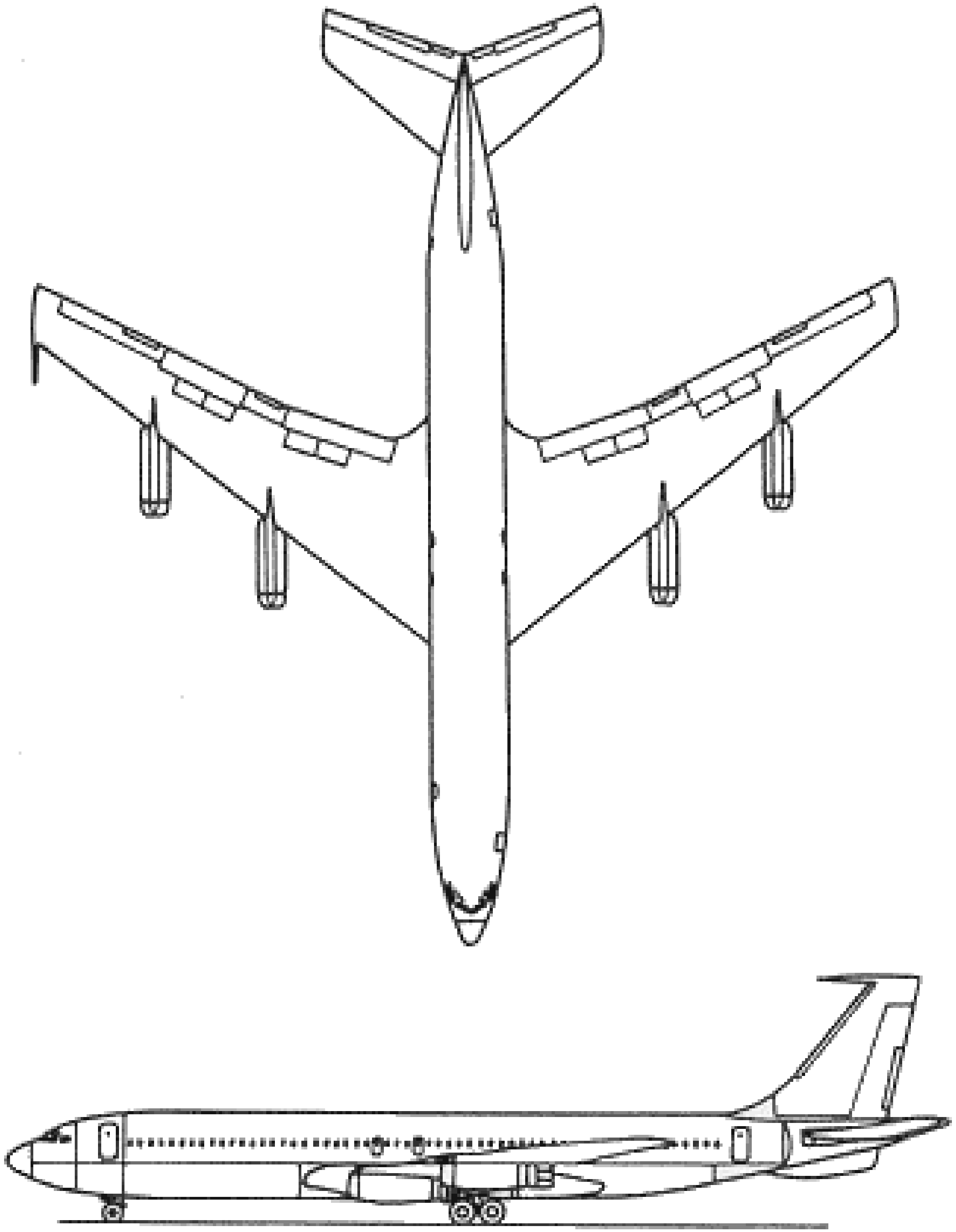
<u>Above</u>: caption: "One of the engines is given a ground test prior to first taxi test. Each engine develops 10,000-pound thrust"



"…Here's another thing that will surprise you. Big transports use power-boosted controls because no pilot is strong enough to manipulate the big control surfaces all by himself. But not on the 707. The plane is designed to handle with the same ease that you fly a three-place job manually. The secret is that the ailerons, rudder and elevators are equipped with small control tabs, similar to trim tabs, built into the trailing edges. The cockpit controls operate the tabs and the tabs in turn force the control surfaces in the desired direction. It's an old principle that hadn't been refined until recently, when the engineers learned how to balance the tabs and eliminate the flutter that characterized earlier designs…"

A.M. "Tex" Johnston **- Chief of Flight Testing for the *Boeing 707* (August 1954)**

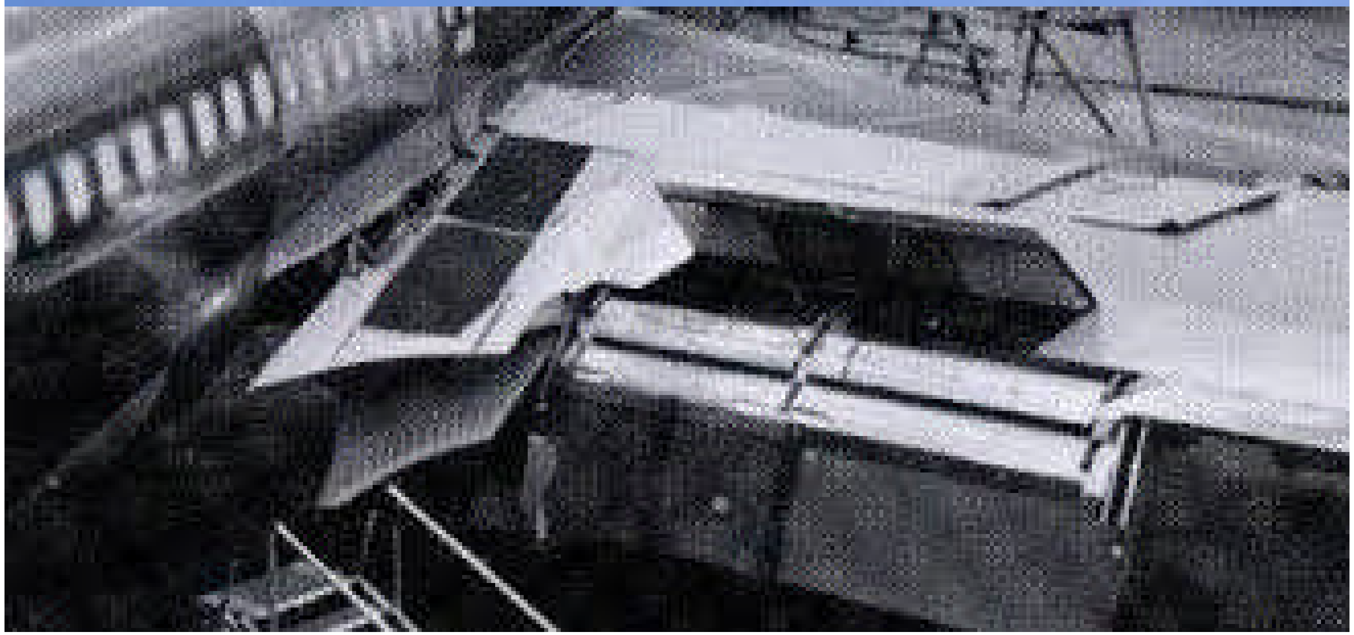
<u>Left</u>: caption: "707 Cockpit Trim Indicator"

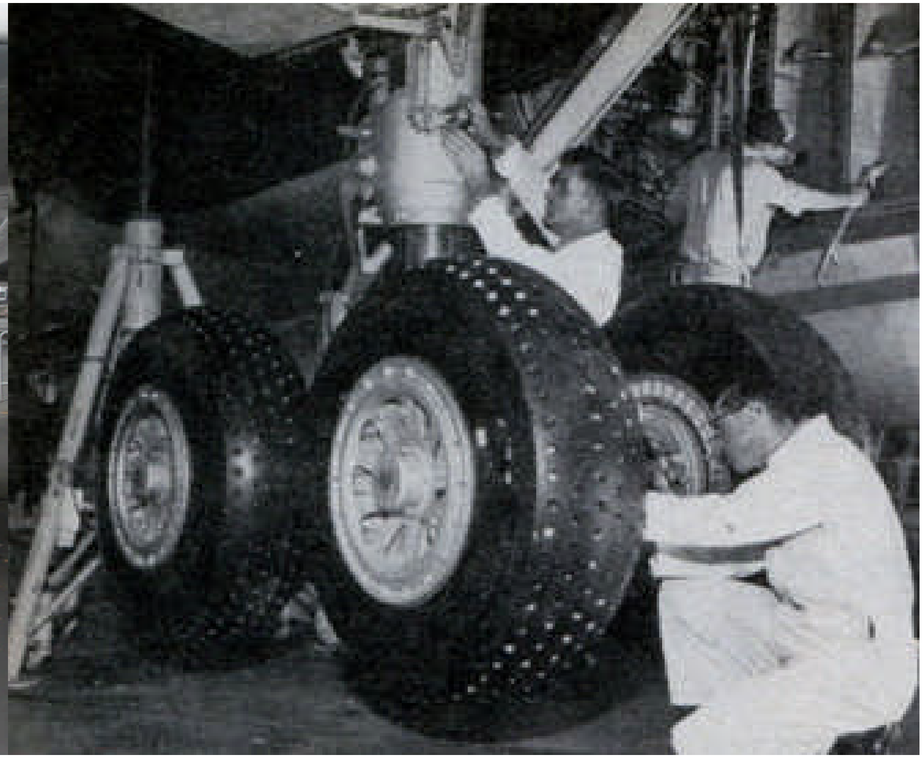


"…If you look at the 707 wing you'll see that the trailing edge has various control surfaces instead of simple ailerons and landing flaps. How these surfaces are used is still a company secret. They are part of the reason why we have takeoff and approach performance that compares with piston-engine aircraft…"

***A.M. "Tex" Johnston* - Chief of Flight Testing for the *Boeing 707* (August 1954)**

<u>Left</u>: caption: "Boeing 707 side (Bottom) and overhead (top) views"





"…The 707 won't need a drag chute to serve as a brake when landing, partly because its tricycle landing gear permits normal wheel braking as compared to the bicycle landing gear on our jet bombers. Each main gear has four rubber tires and the nose gear has two. giving a lot of 'footprint' area that makes for good braking and distributes our heavy load so well that we can use existing airports…"

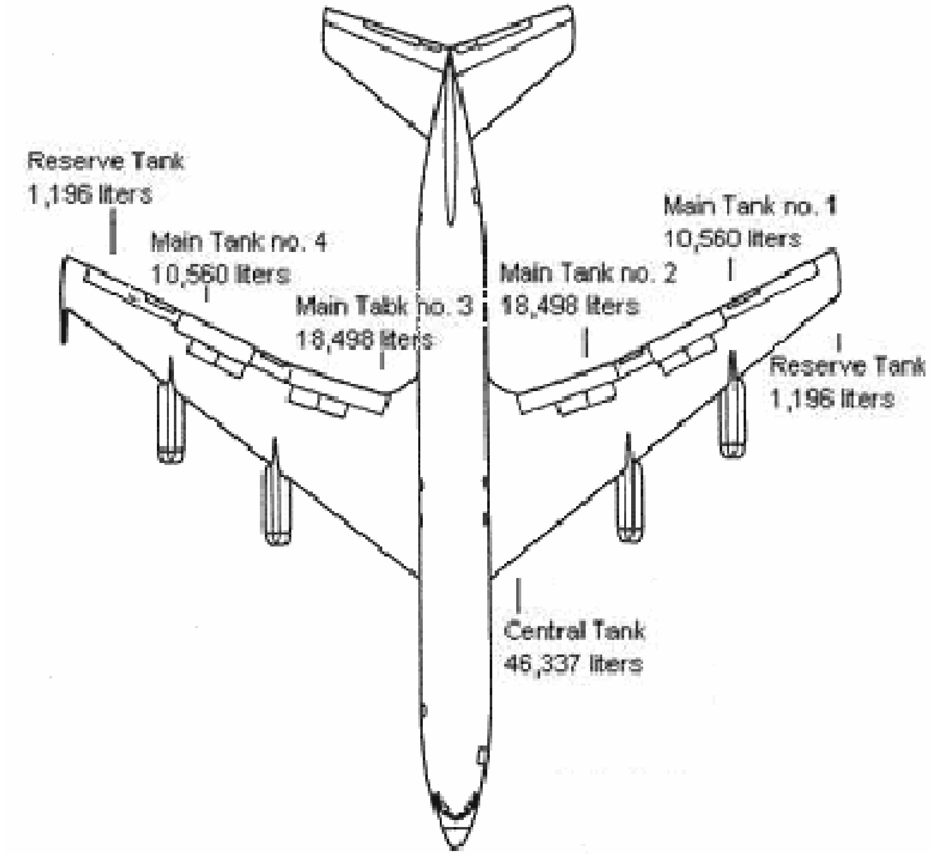
A.M. "Tex" Johnston **- Chief of Flight Testing for the** ***Boeing 707*** **(August 1954)**

Left: caption: "The four-wheel landing gear bogies on a 707–120"

Right: caption: "Jetliner has two main landing gears with four huge tires on each, giving pilot plenty of braking area"

"…Some air disasters have occurred in the past because of improper fuel-tank venting. Explosive fumes collected inside a wing structure and then were ignited when an adjacent electric switch produced an arc. A fire or explosion was bound to happen. Authorities suspect that this has caused a number of unexplained crashes. This hazard is completely eliminated in the 707. You might say that the whole plane was built around its fuel tanks and their venting systems. Complete safety was the first stipulation…"

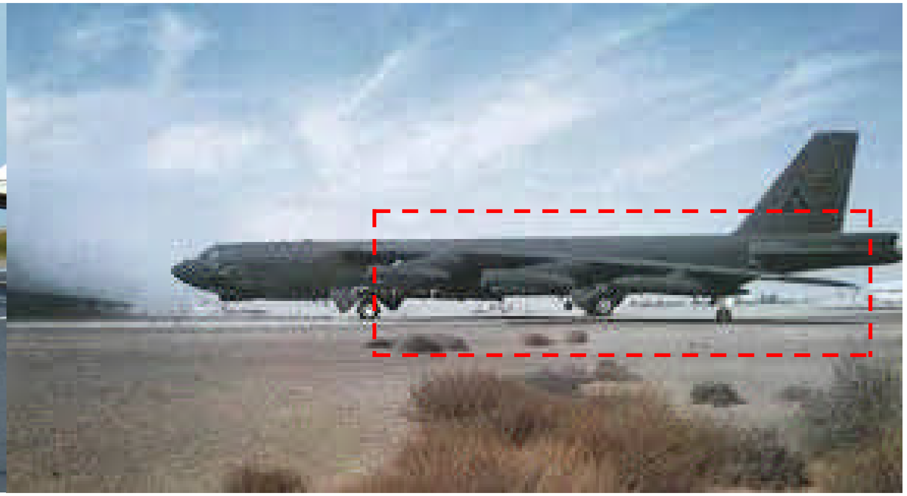
A.M. "Tex" Johnston **- Chief of Flight Testing for the** ***Boeing 707*** **(August 1954)**



"…The main tanks are in the wings, integral with the structure. They are semi-pressurized with ram air to prevent the fuel from boiling during fast ascents to high altitudes. Vents are in the trailing edges, out near the wing tips. Wiring and all electrical apparatus are confined to a different zone in the wing, separated from the fuel-system areas…"
A.M. "Tex" Johnston **- Chief of Flight Testing for the *Boeing 707* (August 1954)**
<u>Left</u>: caption: "Fuel tanks of the Boeing 707"

"…Boeing has built more than 600 jet bombers, and all the experience gained in their construction is in the background of the new tanker-transport. But this is not a 'warmed over' B-47 or B-52. Aside from its stock instruments and its crew seats and rudder pedals, every part of the 707 is new both in design and construction…"

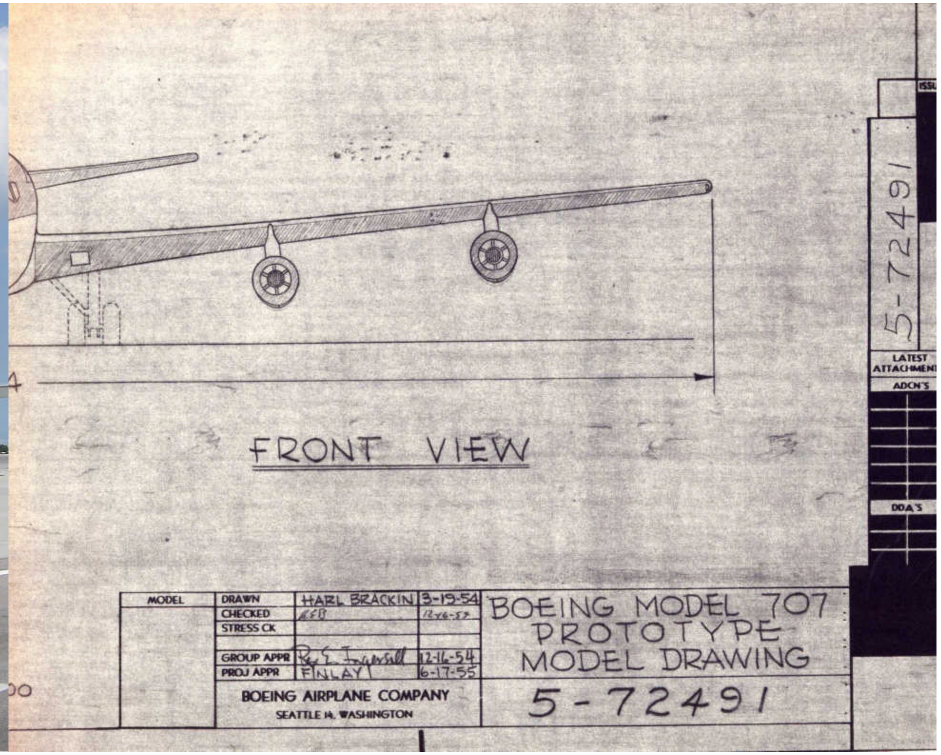
A.M. "Tex" Johnston **- Chief of Flight Testing for the *Boeing 707* (August 1954)**

"…One trend evidenced by the 707 is its relatively stiff wing. Its tips come up only about a foot in flight, as compared to five or six times that deflection in our jet bombers. Perhaps you've noticed that the wings of a B-52 appear to droop while on the ground. They do, because of their flexibility. The wings become level when airborne. The stiffer 707 has a slight amount of positive dihedral, though this isn't apparent on the ground…"

A.M. "Tex" Johnston **- Chief of Flight Testing for the** ***Boeing 707*** **(August 1954)**

<u>Above L&R</u>: frontal (left) and side (right) view/s of the flexible "droop wings" of the B-52 (when on the ground)



"…Another trend found in the 707 is that its wing skin is quite highly stressed. The skin is thick and carries much of the load, while the spars inside are very light. We are approaching the time when internal spars will serve primarily as bracers to hold the upper and lower surfaces of the wing apart…"

A.M. "Tex" Johnston **- Chief of Flight Testing for the** ***Boeing 707*** **(August 1954)**

<u>Above L&R</u>: frontal view/s of the Boeing 707's wings

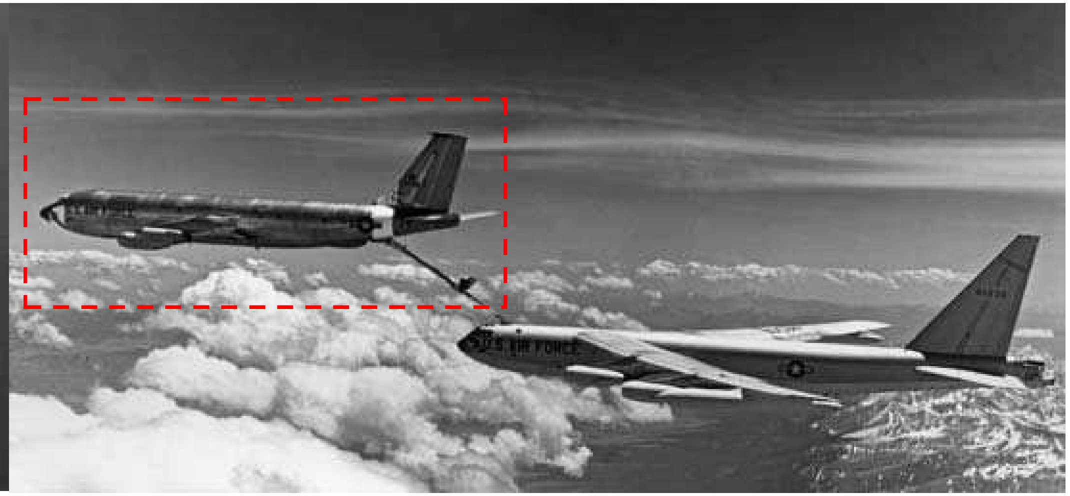
"…The 707 is designed to operate from present airports and to meet all present regulations governing civil air transport. It is expected to be as easy to maintain as our present airliners and imposes much less noise and vibration on its passengers. It will carry passengers at the same cost per seat-mile as do our present-day air transports. This is the kind of airliner you'll be riding in the future!"

A.M. "Tex" Johnston **- Chief of Flight Testing for the** ***Boeing 707*** **(August 1954)**

<u>Left</u>: caption: "The Boeing 367-80, known as the 'Dash 80' rolls-out of the Renton, Wash., plant in May 1954. Boeing took a calculated risk with this airplane, but this bet paid off." All told, 1,010 commercial and military 707/720s were ordered and delivered (production ended in mid-1991). *Boeing Military Airplane* offers tanker/transport conversions of ex-airline 707s; 707/720 conversions are also offered by *Israel Aircraft Industries* and *Comtran Ltd., USA.*

The 7-7 Formula

A frequently asked question posed to the *Boeing Company* is: “How did they come up with the 7-7 name for its commercial jets?” As one of the most famous brands in history, there are many myths about the Boeing 7-7 name. Some are certain that “707” was chosen because it is the sine of the angle of wing sweep on a 707 jet. Not so (the wing sweep is 35 degrees rather than 45). Others lean toward superstition and feel that the positive connotation of the number seven was the reason it was selected. Truth be told, Boeing has assigned sequential model numbers to its designs for decades (as have most aircraft manufacturers). Boeing commercial aircraft use their model number as their popular name, for example: *Model 40, Model 80, Model 247, Model 307 Stratoliner* and *Model 377 Stratocruiser*. On the other hand, Boeing planes built for the military are best remembered by their military designations, such as the *B-17 Flying Fortress* or the *B-52 Stratofortress*. These airplanes also had Boeing model numbers assigned to them (the B-17 was the *Boeing Model 299* and the B-52 was the *Boeing Model 454*).

After WWII, Boeing was a military airplane company. Company president *Bill Allen* decided that the company needed to expand back into the commercial market and pursue the new fields of missiles and spacecraft. To support this diversification strategy, the engineering department divided the model numbers into blocks of 100 for each of the new product areas. Thus, 300s and 400s continued to represent aircraft, 500s would be used on turbine engines, 600s for rockets and missiles and 700s were set aside for jet transport aircraft. Boeing developed the world's first large swept-wing jet; the *B-47 Stratojet* bomber. That aircraft sparked interest with some of the airlines, in particular, PAA which asked Boeing to determine its feasibility as a commercial jet transport. At the same time, Boeing began studies on converting the propeller-driven *Model 367 Stratotanker* (better known as the KC-97, at left) into a jet-powered tanker that would be able to keep pace with the B-52 during in-flight refueling. Boeing product development went through several renditions of the Model 367 and finally a version designated "367-80" was selected. It was soon nicknamed the "Dash 80." This design would lead to the 707 passenger jet and the KC-135 tanker (right).

Since both offspring of the *Dash 80* would be jet transports, the model number system called for a number in the 700s to identify the two new planes. The marketing department decided that "Model 700" didn't have the right ring for the company's first commercial jet, so they decided to skip ahead to "Model 707" (because it simply sounded better). Following that pattern, the other offspring of the Dash 80 (the USAF tanker) was given the model number "717." Since it was a USAF plane, it was also given the military designation: "KC-135." After 717 was assigned to the KC-135, the marketing department made the decision that all remaining model numbers that began and or ended in "7" would be reserved exclusively for commercial jets. After the *Boeing-McDonnell Douglas* merger in the late 1990s, the model number 717 was reused to identify the MD-95 (above) as part of the Boeing commercial jet family (left).

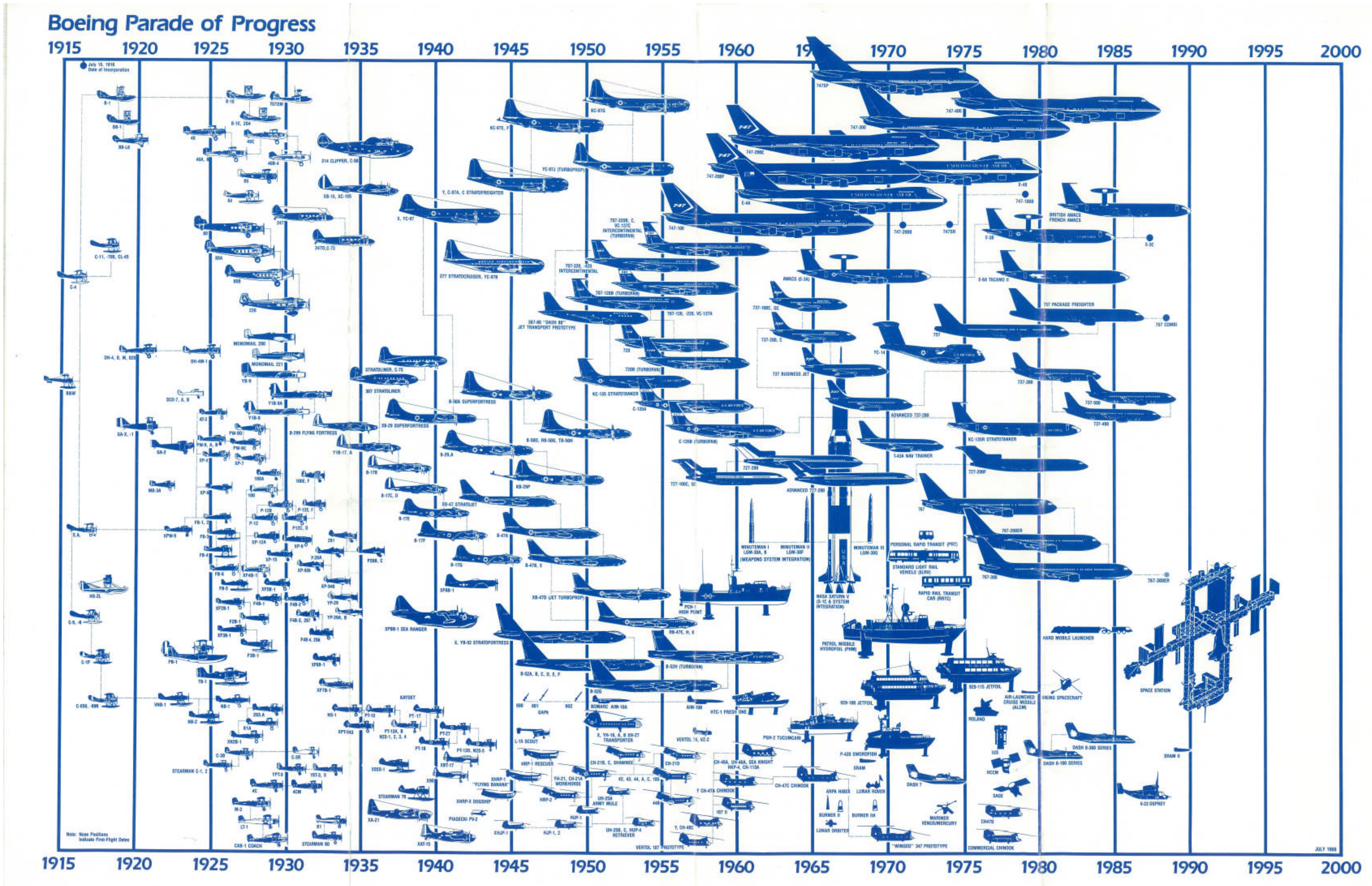
Other than the 717, the only anomaly to the Boeing commercial jet numbering system was the Boeing *Model 720*. The 720 was a short-range, high-performance version of the 707 and was first marketed to the airlines as the "Model 707-020." *United Airlines* was very interested in the 707-020 but had previously decided to go with *Douglas Aircraft* and their DC-8. To help UAL avoid any negative public relations for going back to the 707, Boeing changed the name of the 707-020 to the 720. Since the naming of the initial 717, all Boeing commercial jets have been named in succession based on the 7-7 formula (i.e. 727, 737, 747, 767, 777 etc.)

<u>Above</u>: caption: "The complete line of Boeing 7-Series aircraft (from B-707 to B-777)

Above & Left: the ***B*oeing *B*usiness *J*et** (BBJ) series are variants of Boeing jet airliners for the lucrative corporate jet market (initially only the 737 series airliners were BBJs). This type of aircraft usually seats between 25 and 50 passengers within a luxurious configuration. This may include a master bedroom, a washroom with showers, a conference/dining area, and a living area. The Boeing Business Jet is a 50/50 partnership between *Boeing Commercial Airplanes* and *General Electric*. The latest versions of BBJs include configurations based on the *Boeing 777 and 747-8 Intercontinental*.


BOEING

…I'm Not Going!


Boeing Parade of Progress
1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000

Part 7

The Incredibles

A History of Problem Solving

"…The history of the 747 is also a history of meeting and solving big problems. One hurdle had to be faced immediately: where to build the monsters. Boeing bought 780 acres in Everett, thirty miles north of Seattle, and built a $200-million manufacturing facility that incl-udes the world's largest building, even more spacious than the huge Saturn assembly building at Kennedy Space Center. Used as a manufacturing and assembly fac-ility, the building includes 160 million cubic feet. It is so vast that some workers use bikes to get around…"

***Popular Mechanics,* Dec. 1969**

747 Manufacturing Opened for Business This Week

The massive 747 assembly building at the Everett Branch opened for business Monday. Those present recalled the area was a sea of mud less than a year ago and marveled at the speed of construction taking place at the site. But while others marveled, 'pioneer' employees - vanguard of more to follow - donned hard hats and began setting up wing-panel jigs…and plugging in the machines in the 40-31 bay of the huge manufacturing building.

Boeing News, **May 1967**

RE: the opening of the Boeing facility in Everett, WA, (to support 747 manufacturing) was announced with little fanfare, at the time. The first group of Boeing employees to work in the complex of buildings were called: "The Incredibles." The nickname recognized their efforts to develop the 747; the world's first "Jumbo Jet," despite numerous technical challenges and an aggressive 29-month concept-to-production schedule.

"The main risk was the tremendous amount of money required to develop an airplane of that size, with all that new technology. Boeing's investment in research and development, tooling, manpower, and an entirely new manufacturing site at Everett totaled more than $1 billion by the time of roll-out, a sum greater than the company's net worth."

Bill Allen, **Boeing Company CEO**

<u>Top</u>: caption: "Legendary Boeing CEO Bill Allen's 'Incredibles' Everett Factory Hard-Hat at Boeing Corporate Archives." ***Bill Allen*** **was the President of the Boeing Company from 1945 until 1968. He also served as Chairman from 1968 through 1972. While he was president of the company, he made the famous decision (in 1952) to "bet the company" when he authorized the building of the** ***Boeing 367-80*** **(bottom), which led to the development of the 707. He again risked all when he commissioned the launch of the 747. Allen also participated in launching other legendary Boeing planes such as the 727 and 737.**

"…But before the plant could be put up, Boeing had to build a three-mile rail spur to the site. The spur climbs a 5.6 percent grade, making it the second steepest stretch of standard-gauge track in the country…"

***Popular Mechanics*, December 1969**

<u>Top</u>: caption: "The Mount Baker Terminal"

<u>Bottom</u>: caption: "Fuselage section arrives via rail spur from Mt. Baker Terminal"

"…Structural parts of the plane are manufactured in many sections of the country and shipped to Seattle for assembly. This operation was hampered in the beginning because the parts were so huge. Standard-sized freight cars could not carry the larger parts, so special oversized cars had to be made. And even loading these jumbo cars is tricky. Tolerances are so fine that laser beams are used to make sure that long parts go in straight. Crooked loading could result in damage…"

***Popular Mechanics,* December 1969**

<u>Top Left</u>: caption: "Containerized parts are barged from across the Pacific Rim, primarily Japan, and offloaded onto flatcars by the traveling gantry crane at Mount Baker Terminal. The containers are oversize, and the contents are of very high value. A pair of GP38-2 locomotives is needed to transport them to the Everett plant."

<u>Top Right</u>: caption: "To get from the container terminal (left background) to the Boeing spur (right), Boeing trains have to cross over several tracks, including the BNSF main line."

<u>Left</u>: caption: "Arrival at Paine Field and the Boeing yard (main assembly building in background)

Left: an *Aero Spacelines* artists' concept (ca. 1968) depicting a six-engine variant of their "Super Guppy," modified to transport 747 components from the Wichita, KS facility to the Everett, WA facility. While never realized, in the 1990s Boeing modified 747s to carry 787 "Dreamliner" components.

"We were the fourth guys in line for resources, and that included facilities"

***Joe Sutter*, 747 Project Chief Engineer**

RE: in the early-mid 1960s, Boeing was working on the *Supersonic Transport* (SST) and developing both the 737 and an improved 727. They were also bidding on the USAF contract for the CX-HLS (Heavy Logistic System) which it lost to Lockheed (their design becoming the *C-5 Galaxy*). Initially, the site Boeing chose would have to have been large enough for both 747 and CX-HLS production. In March 1966, the 747 was given an official green-light by Boeing's Board of Directors after PAA's Chairman *Juan Trippe* signed an order for twenty-five 747s (valued at $25 million each). Design work on the 747 began in a variety of borrowed and improvised locations, most of them along Seattle's Duwamish River. Boeing concluded that the final assembly facilities at Renton and/or *Boeing Field* were much too small and busy to accommodate a project of such logistical stature as the 747.

Boeing considered several locations for 747 production facilities elsewhere including Colorado and Georgia as well as:
- **a site near *Paine Field* in Snohomish County, WA;**
- **a site adjacent to *McChord Air Force Base* in Pierce County, WA (south of Seattle);**
- ***Moses Lake* (in eastern Washington State), and;**
- **Walnut Creek, CA (near San Francisco)**

Despite the political advantages of California and the lower-cost labor to be found in both Colorado and Georgia, Everett held the advantage in both Bill Allen's heart and head (despite the fact that the rural and difficult-to-access Everett site initially did not even place in the top five). Everett offered access to rail service and maritime shipping, as well as an airfield. Also, under a tight schedule, it was important to have a site near Boeing's Northwest-based manufacturing and engineering facilities and aerospace-skilled workforce.

"In 1967, it was like mudflat alley getting here every day from Renton, where I lived. It took me more than four hours to drive one-way to Everett."

***Millie Hughes*, Senior Blueprint Clerk**

RE: her recollections during the 40th Anniversary celebration (in May 2007) of Boeing's Everett facilities. Construction of the Everett plant took place under the direction of *Bayne Lamb*, 747 Program Director of Facilities, and *Malcolm Stamper* (left), President and General Manager of the 747 Division. Building the plant was a monumental task, with drainage being a particular problem because of the constant rain.

Paine Field **(a/k/a "Snohomish County Airport") meant Boeing would not have to build its flying infrastructure completely from scratch (Paine Field just happened to have a 9,100 foot-long runway that is still used today for most Boeing test flights and deliveries). During WWII, Boeing operated two facilities in Everett (to provide subassembly support for the B-17s being built in Renton) including work on bulkheads and the radio operator's section. In 1956, the B-52 and KC-135 jigs and shipment fixtures were moved to Everett. Two-hundred-eighty-three employees from Seattle's** ***Boeing Field*** **and Renton plants were transferred to Everett along with seventy new employees hired locally. These original manufacturing facilities were located at the** ***Everett-Pacific Shipyard*****. In 1957, Boeing was honored with a celebration entitled: "Boeing Week." As part of the celebration, Boeing President** ***William M. Allen*** **attended a special "Boeing Week Banquet," which made a lasting impression.**

Above: caption: "Boeing's Everett Facility at Paine Field photographed from the air in 2009 with runway 16R/34L on the left side"

In June 1966, Boeing purchased 750 acres on the northeast side of *Paine Field*. This was not without its challenges as many long-time rural landholders did not want to leave at any price. Others became opportunistic when real estate agents representing Boeing appeared with blank checks. Reportedly, one small, run-down property appraised at $4,700 was finally sold for $50K. Almost immediately, an army of construction workers descended on the area, clearing the heavily wooded and rolling land. They blasted hillsides and filled in valleys. Most impressively, a spur of railway was hacked through the dense forest from the *Great Northern Railroad*. More than 1.25 million cubic yards of dirt were moved to create the track bed, which climbed from 20-feet above sea-level to the western edge of the Everett site at 540-feet, making it the second steepest standard-gauge railroad track in the U.S. In the following months, more than 2,800 workers and 250 subcontractors withstood windstorms, mudslides, 67 straight days of rain and snowstorms. The three main 300-by-1K-foot assembly bays began to take shape in the fall of 1966 and by November 1966, the roof of the mammoth structure was complete.

First of Many

EVERETT HERALD

Haiti Invasion Squelched by Exiles' Arrest

Jack Ruby Succumbs To Cancer

Defections By Cong Set Record

Today's Most Active N.Y. Stocks

500 Due in Month

First Boeing Team On Job in Everett

Pope Paul to Meet With Soviet Leader

Thompson Named To Liquor Board

Loses $20,500-a-Year Job

Solons Order Powell's Wife Fired

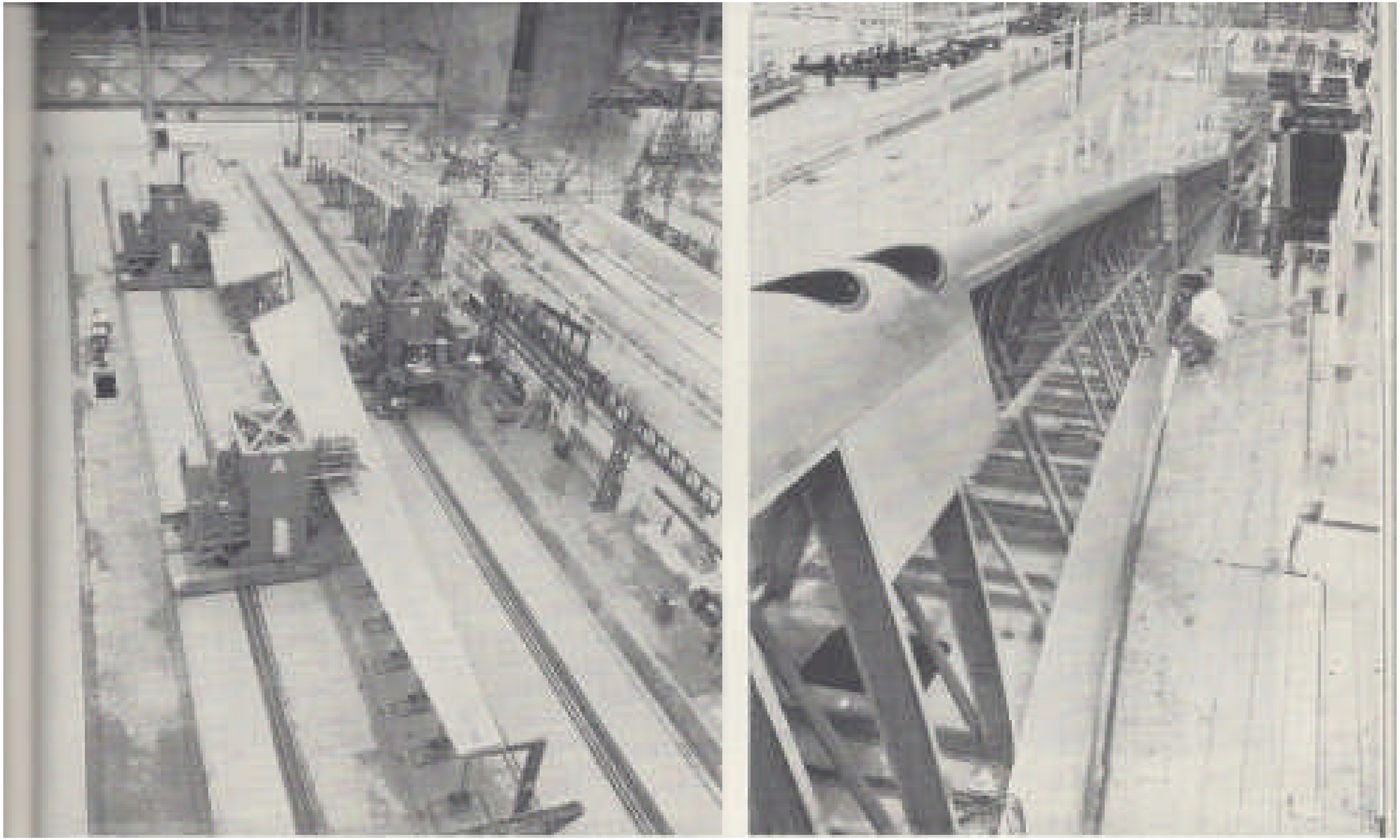
Cascade

"The first 113 of a potential 15,000 Boeing employees went to work today at Everett's still a'building 747 jet assembly plant. Speeches and coffee opened their working day. The forerunner of the thousands yet to come were called 'the incredibles' by a Boeing official who welcomed them to the huge plant. 'The inconveniences are going to be many,' Bayne Lamb, director of Boeing's Everett facilities, cautioned the first 113. 'You'll be wearing hard hats and overcoats for some time.' Preparations for transfer of the 747 jet mockup from Renton to Everett will be made by this first work force. That transfer is expected to start – with the mockup moved in sections – by the middle of this month. Stamper told the first workers at the new plant that 'if we could look 20 to 50 years ahead it would be interesting to see what kind of products we'll roll across these floors.'"

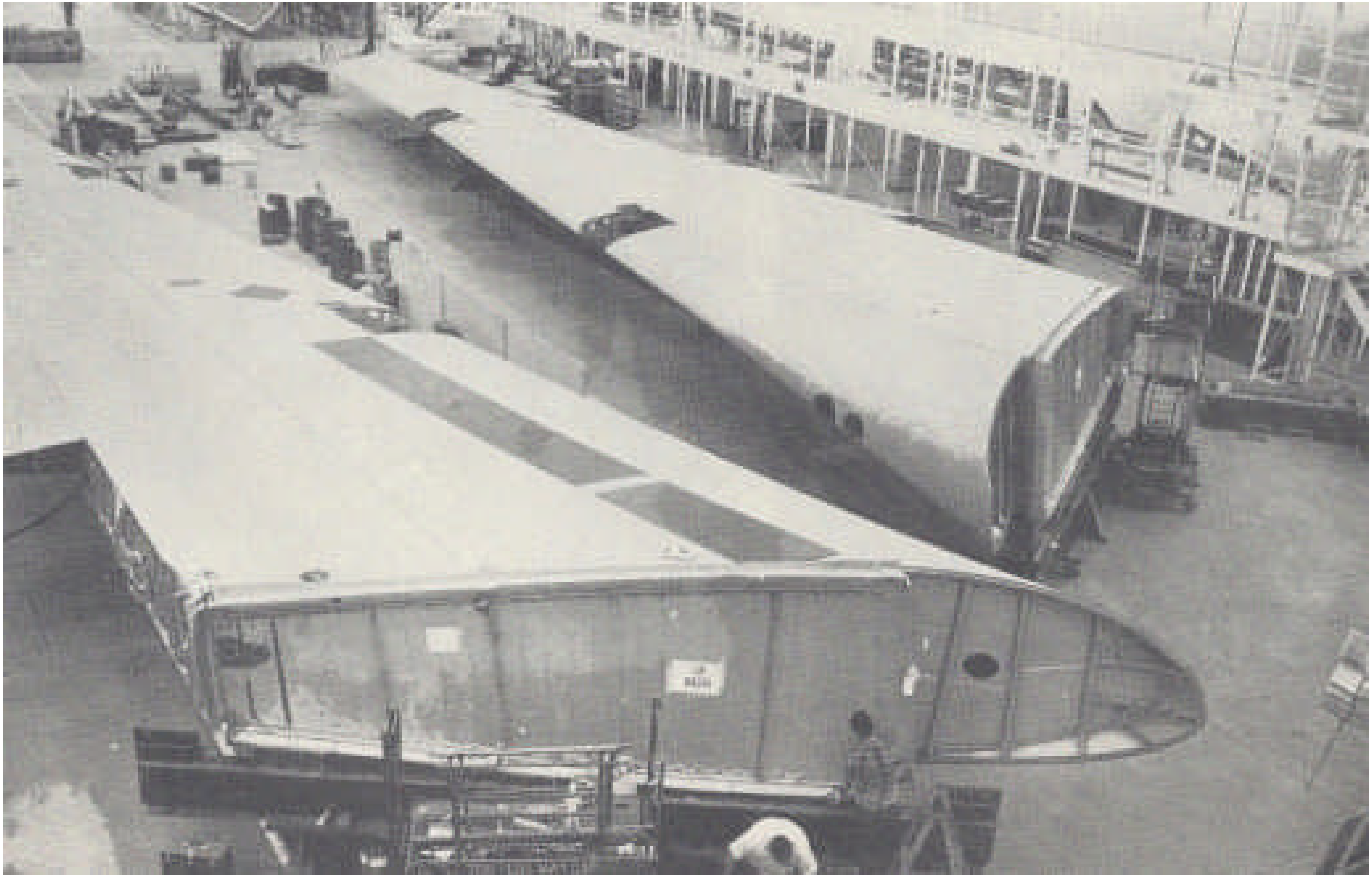
***Everett Herald*, January 3rd 1967**

Getting Busy

<u>Left</u>: **the April 28th 1969 issue of *Aviation Week & Space Technology* carried an eleven-page special photo report detailing the *Boeing 747* assembly process, with photos of the second and third aircraft on the production line at Everett (as well as photos of the first 747-100 being inspected after its first flight)**



Above L&R: caption: “Buildup of 747 wings at Boeing’s Everett, Wash., assembly plant begins with riveting stiffeners to spanwise skin panels using numerically controlled machines (left) and progresses into two-level main wing jig lay-up (right). There, spars, stiffeners and multiple panels are fastened together to form each wing.

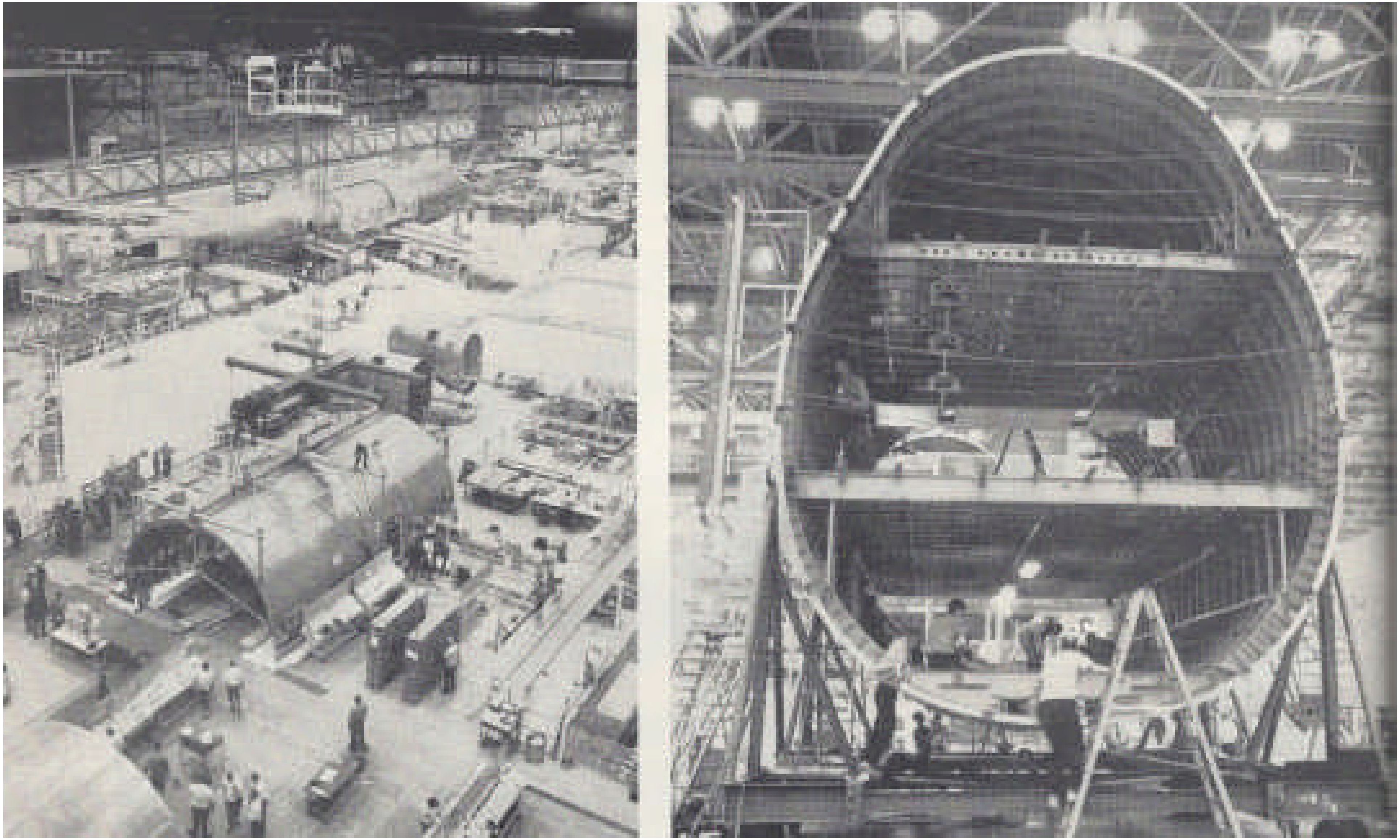


<u>Above</u>: caption: “Each wing, weighing approximately 28,000 lb., then is placed on supports for easier access to finishing. Wing thickness at the root is over 6 ft. Holes in wing leading edges at upper right are for landing lights.”

"…Additional scaffolding with tool crib and parts bin at each level were installed when women riveters became dizzy from the height, and older production workers began wheezing from repeated climbs and descents of two or three levels…"

***Aviation Week & Space Technology*, February 17th 1969**

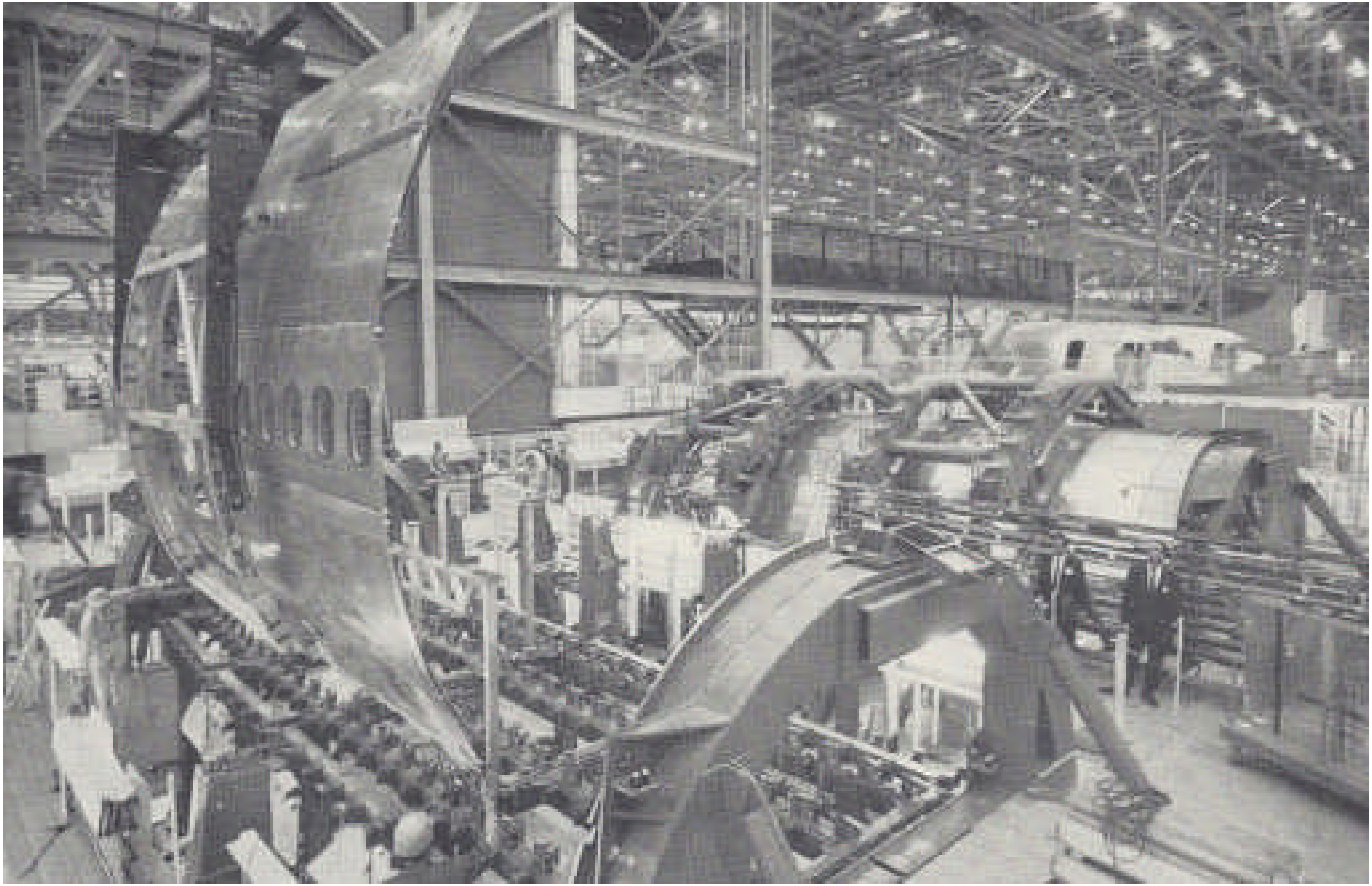
Above: caption: "Cab sections made in Boeing's Wichita plant have bulk of wiring, tubing, insulation and the like installed prior to mating with the main fuselage. Work platform level is at the same height as the main floor of the cab."



<u>Above L&R</u>: caption: “Following completion of panel assembly, the overwing body section 44 (left) is lifted by crane to the wing assembly area for mating. Three-level section 42 on dolly (right) will be mated to cab section 41 at one end and overwing body section at other. Note safety chains stretched across open ends.”

"…The size of the 747 was somewhat responsible for difficulties encountered in adapting manufacturing techniques long used in producing 727, 737 and 707 aircraft. Almost all main elements of the 747, such as body panels, have to be handled by overhead crane. This meant adapting new procedures and building handling fixtures…"

***Aviation Week & Space Technology*, February 17th 1969**

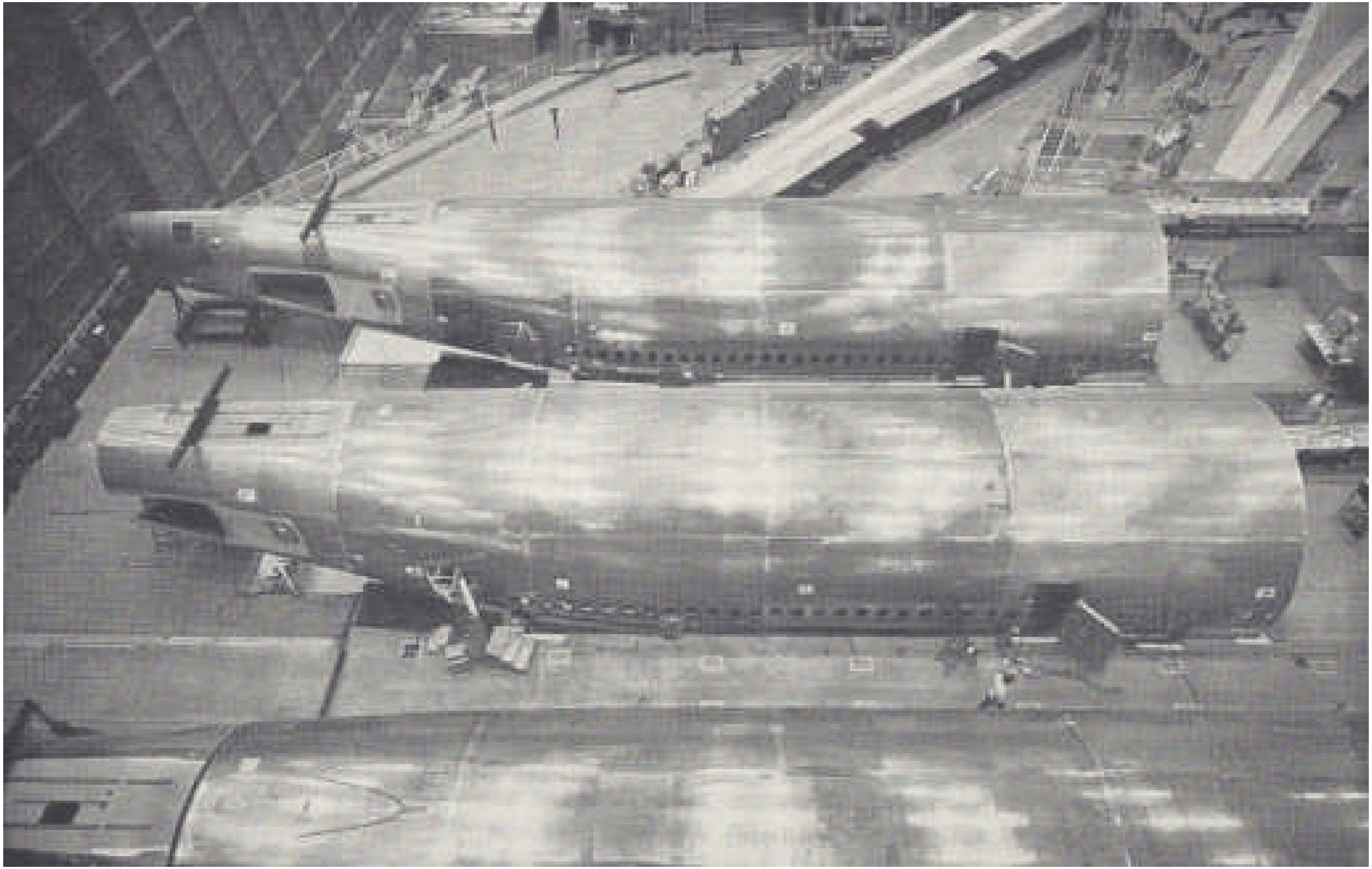


<u>Above</u>: caption: "Fuselage panel made by Northrop Corp. is eased into section 44 build-up fixture using crane. This is typical of the way all fuselage sections are assembled. Large size of 747 components has required greater use of overhead cranes than anticipated."

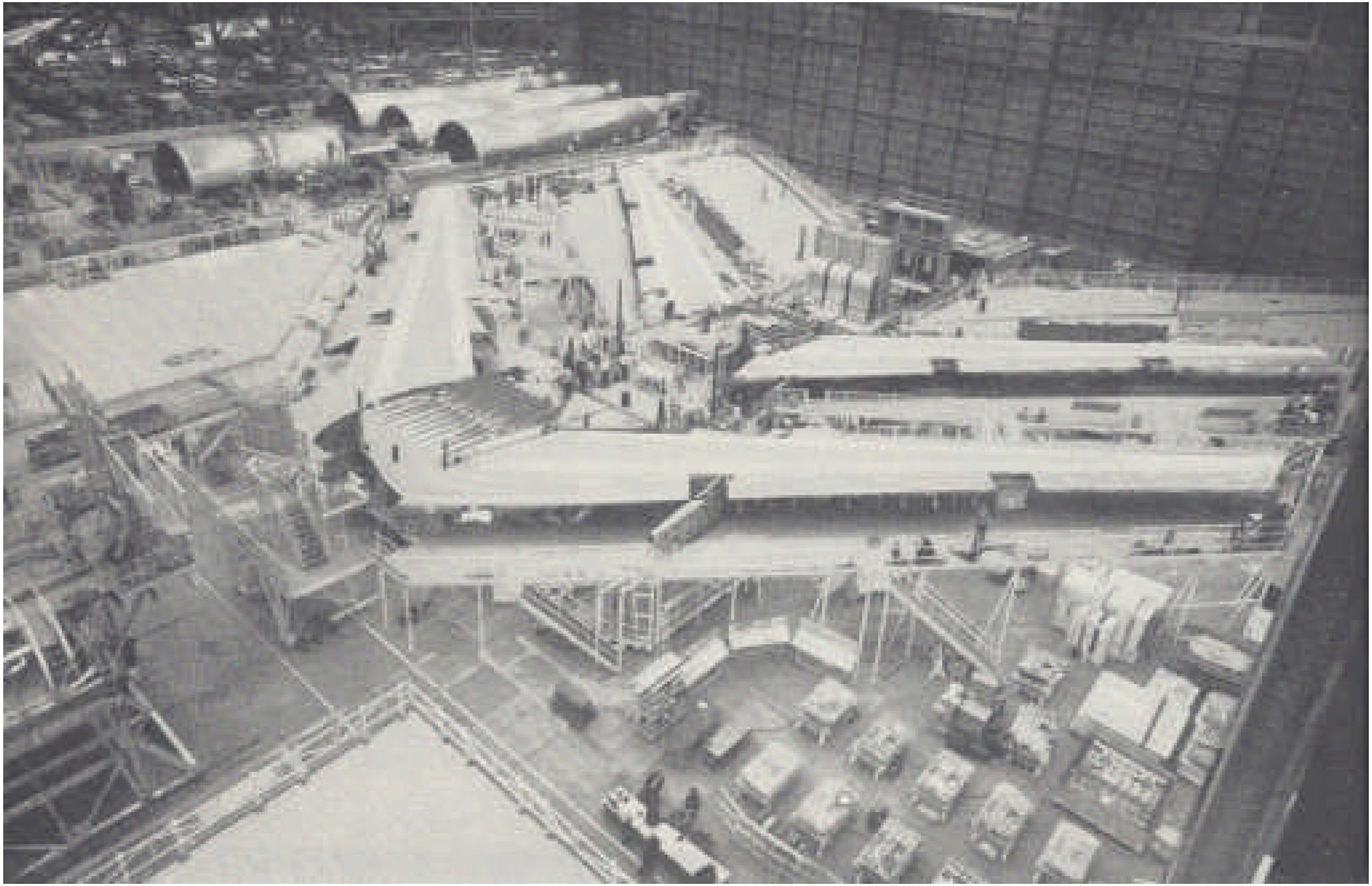
Strong Point

"…One of the strong points of 747 manufacturing has been the exceptional fits of the variety of parts supplied from firms throughout the country, Boeing said. The fuselage consists of five main sections, each built up of smaller panels at Everett. The No. 1 fuselage, for example, was joined in only five days, with little or no mismatch in the large cylindrical sections. The 10 major suppliers of 747 components ship to Boeing via a fleet of 137 rail cars, and all are on schedule…"

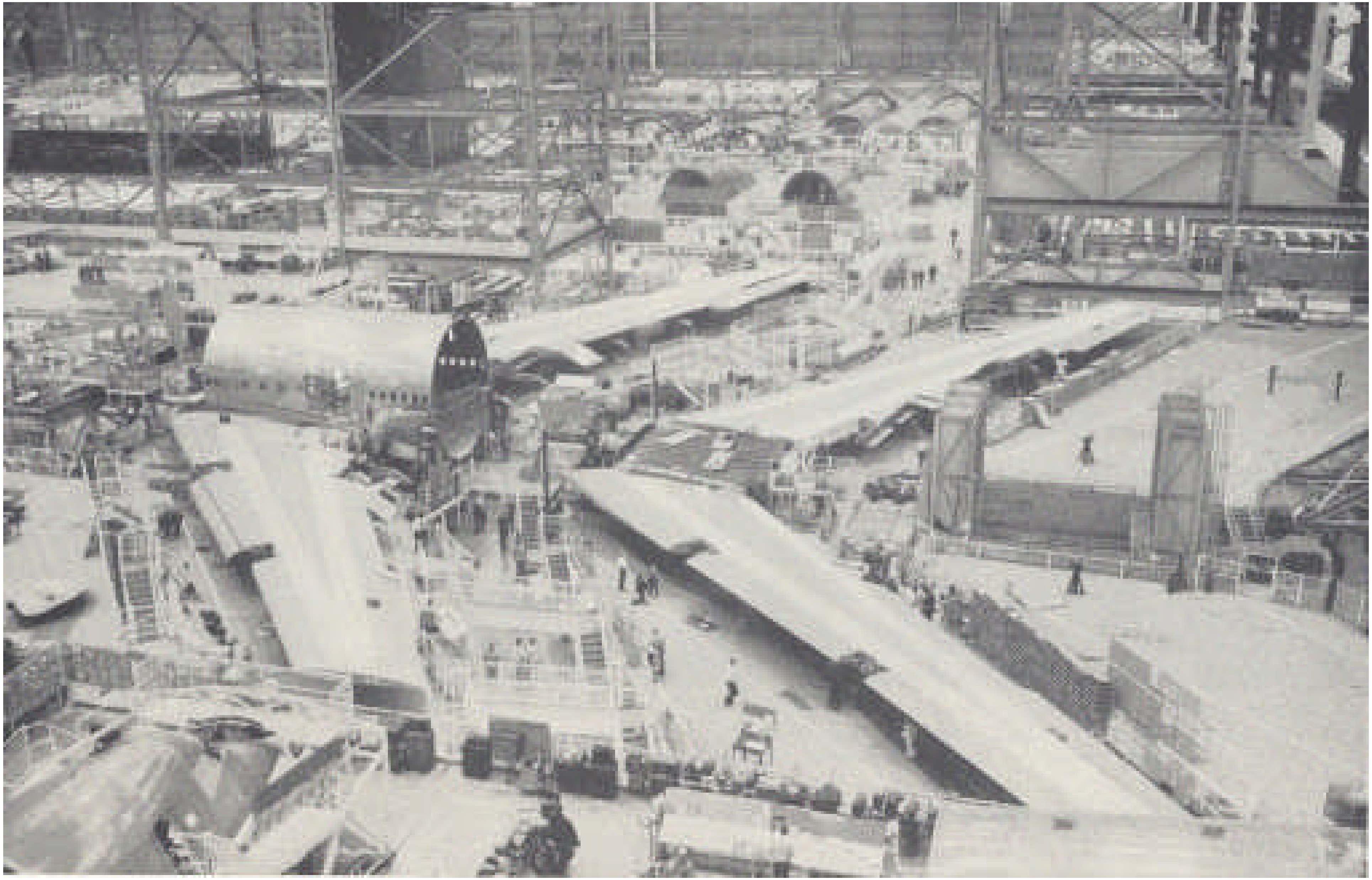
***Aviation Week & Space Technology*, February 17th 1969**



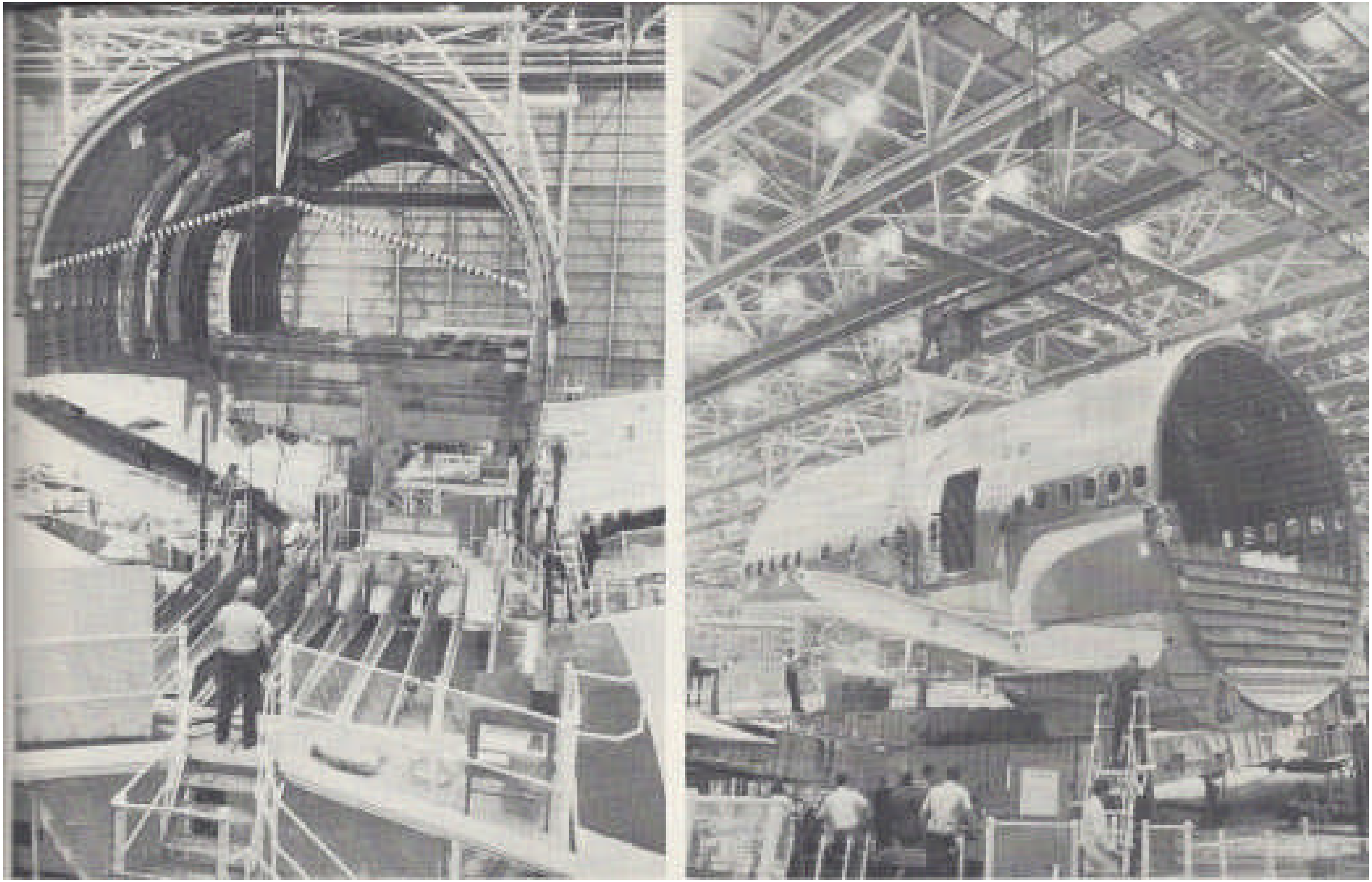
Above: caption: "Aft fuselage consists of Northrop section 46 and LTV section 48. Section 48 comprises the forward two-thirds portion and section 46 the tapered rearward part. Each section is assembled from panels from subcontractors into one tube section in jigs. 444 **Outline of individual panels can be seen."**



<u>Above</u>: caption: "Assembly of the two wings to the carry-through section is done prior to mating with fuselage. Third station behind the two sets of wings being joined is a clean, seal and test area and is next in sequence."

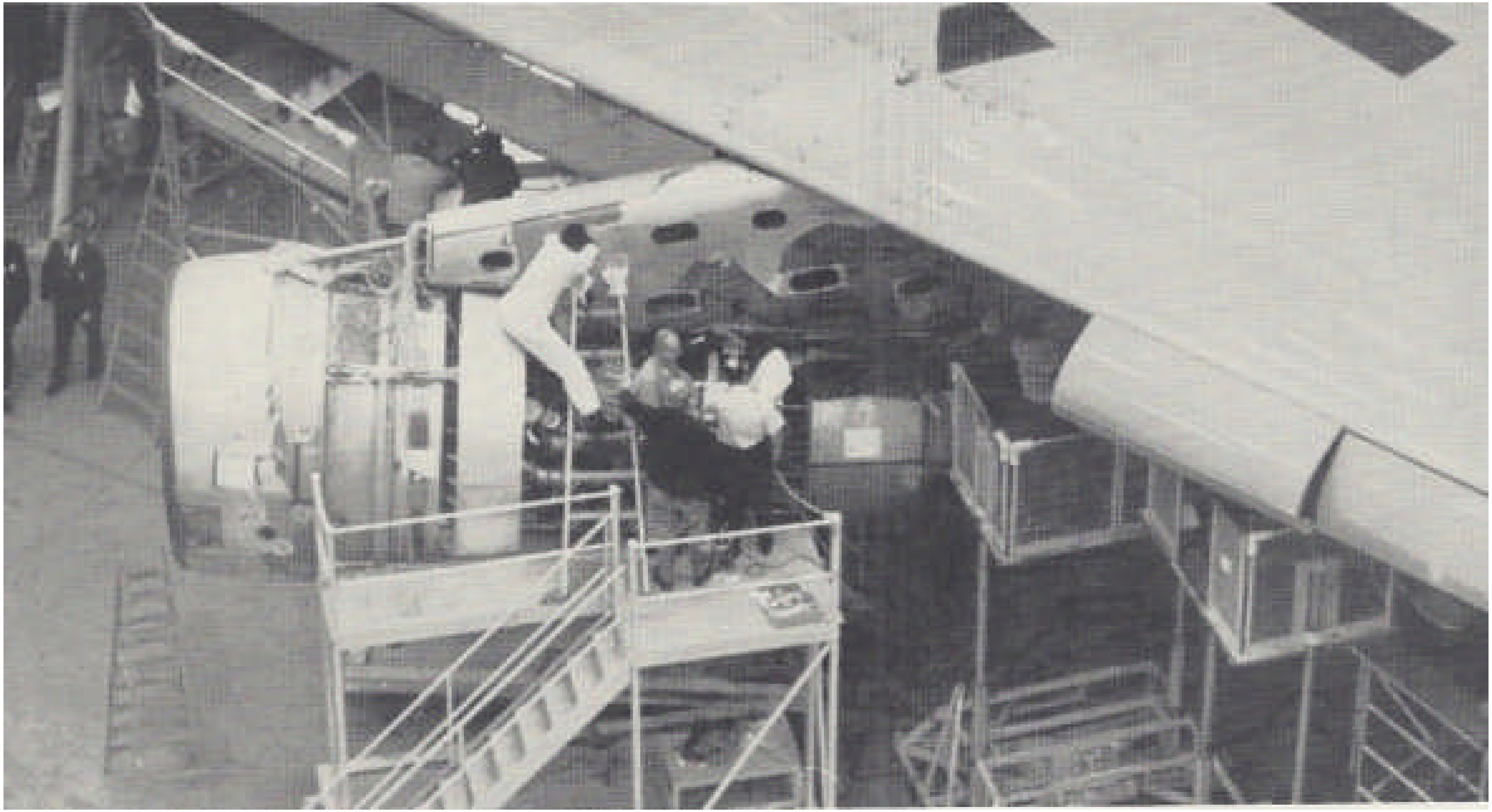


<u>Above</u>: caption: "Wing-body join station precedes joining of the three main fuselage sections at the next station. Station shown is in one of two final assembly bays in use. A third bay is used for subassembly work."

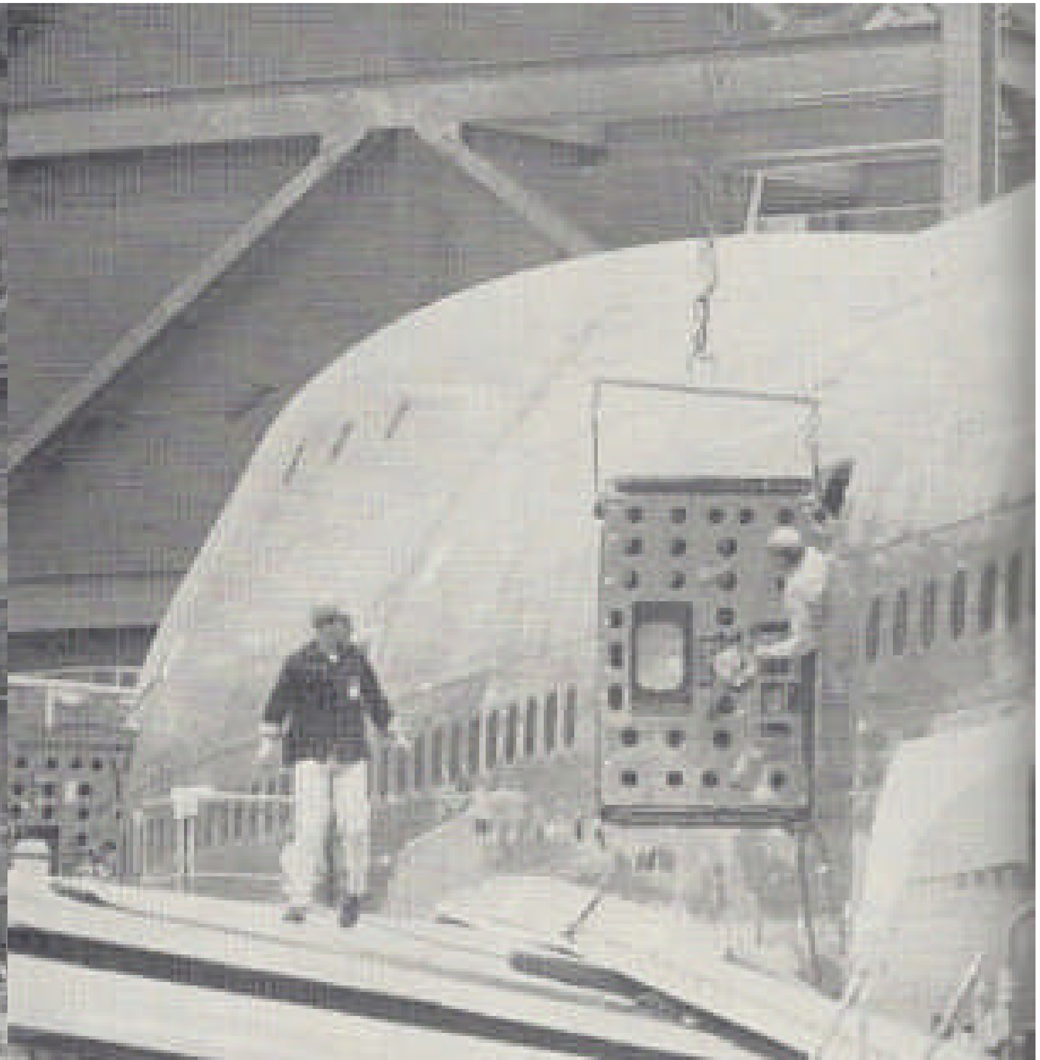


<u>Above L&R</u>: caption: “Wing-fuselage mating has been simplified by using only a short fuselage section. Section 44 is placed atop the wing carry-through section and bolted in place (left). Landing gear support is I-beam extending from fuselage (right).”

<u>Above</u>: caption: "Final body join position, where three major sections are fastened together, is located forward of the wing-stub join area. Landing gear and tail also are installed here."

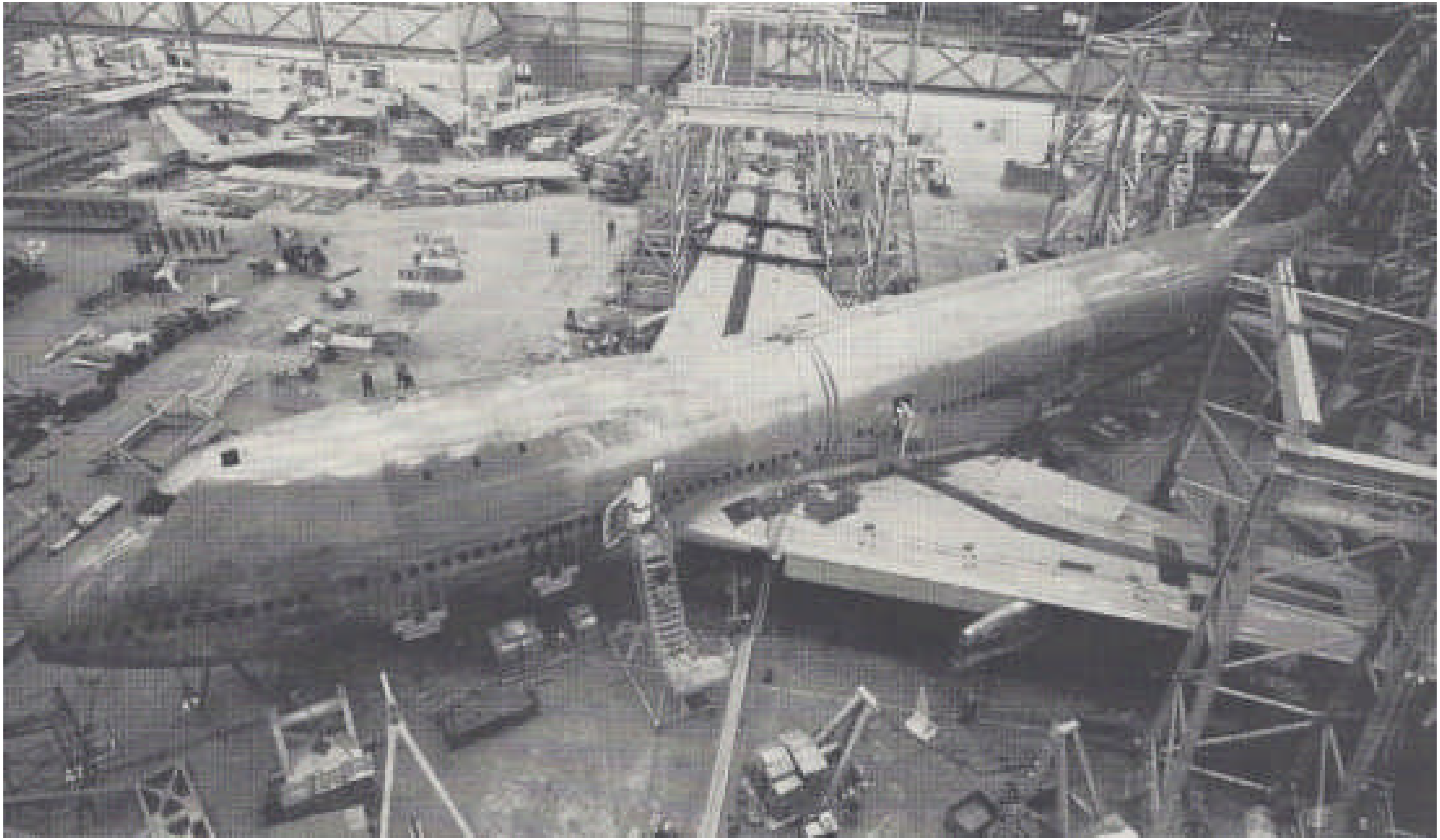


<u>Above</u>: caption: “Workmen check controls of Pratt & Whitney JT9D engine at final assembly and installation position number three on second flight test aircraft. This third final assembly position is last prior to rollout from the factory to the paint hanger. Variable-camber leading edge flaps are at lower right.”



<u>Left</u>: caption: "Access doors for Garrett auxiliary power unit are on underside of tail. Lower halves of split rudder and elevators have not been installed."
<u>Above</u>: caption: "Crane is used to place door in position for attachment. Although basic assembly techniques developed in earlier programs are used on the 747, substantially greater use is made of multi-level scaffolding and overhead cranes."

<u>Above</u>: caption: “Horizontal tail is built much the same as the main wing, with each stabilizer attached to a carry-through section to form a single unit. Elevators are installed after stabilizers are mounted to rear fuselage.

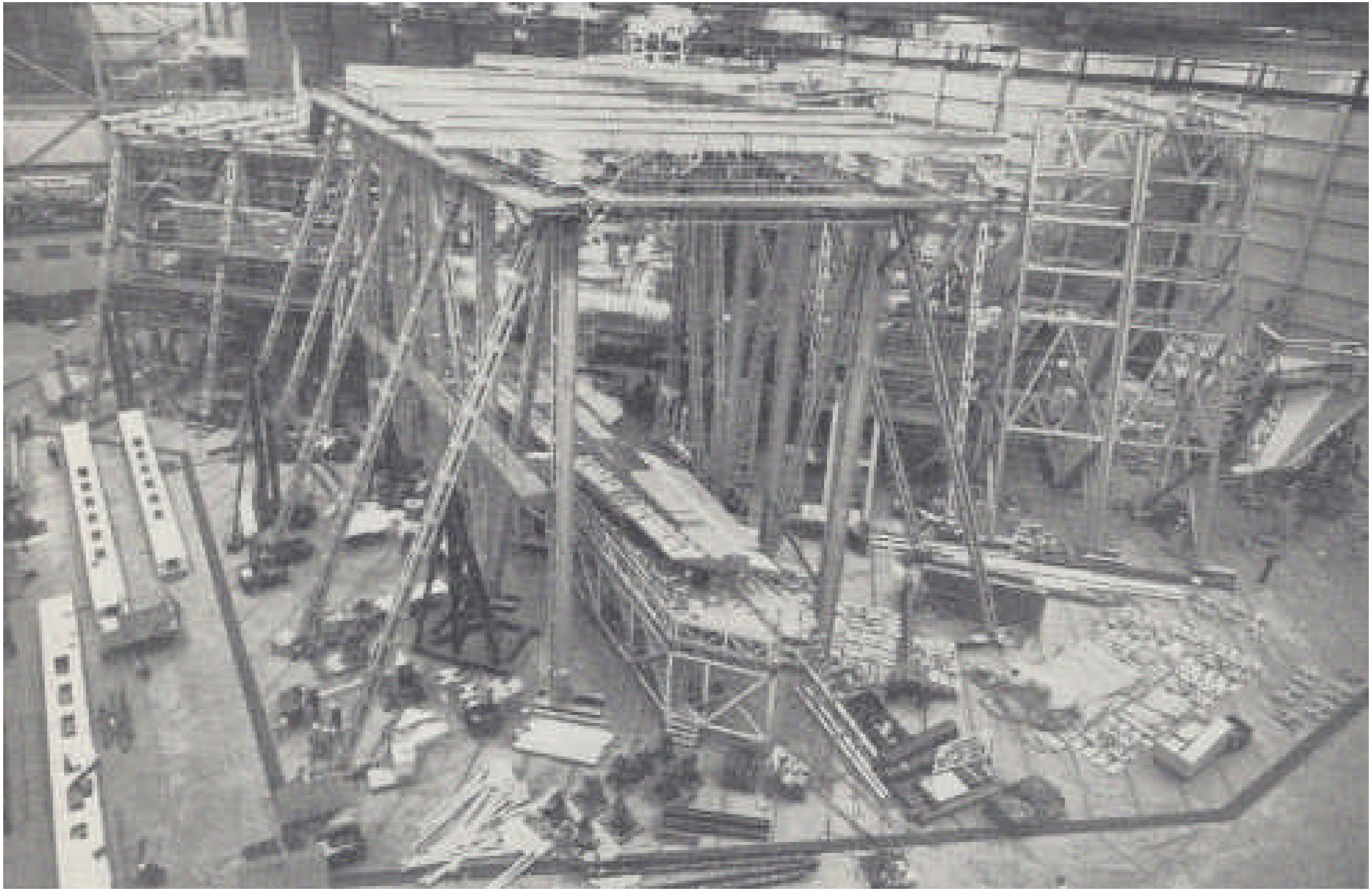


Above: caption: “Flight loads survey aircraft which is expected to roll-out soon is number three aircraft off the line. It is shown during an early calibration of on-board instrumentation.

<u>Left</u>: caption: “Overview of final assembly bay shows number two flight test aircraft in last of three assembly and installation positions. Second position was not occupied. Aircraft at top is in final body join. Canting in three final assembly positions helps to utilize space. They are moved on their own landing gear, which can be swiveled.”

"…In addition to laboratory tests of separate parts and components, two complete airframes were used for static and fatigue tests. In the static tests the airframe was subjected to stresses and loads far in excess of those experienced in airline service. In the fatigue testing program, the airframe was subjected to repeated operation of its flight controls and cabin pressurization systems. The equivalent of years of operation was compressed into months. The goal of these programs was to prove an airframe life of 60,000 hours - the equivalent of fifteen years of normal operation…"

***Popular Mechanics,* December 1969**

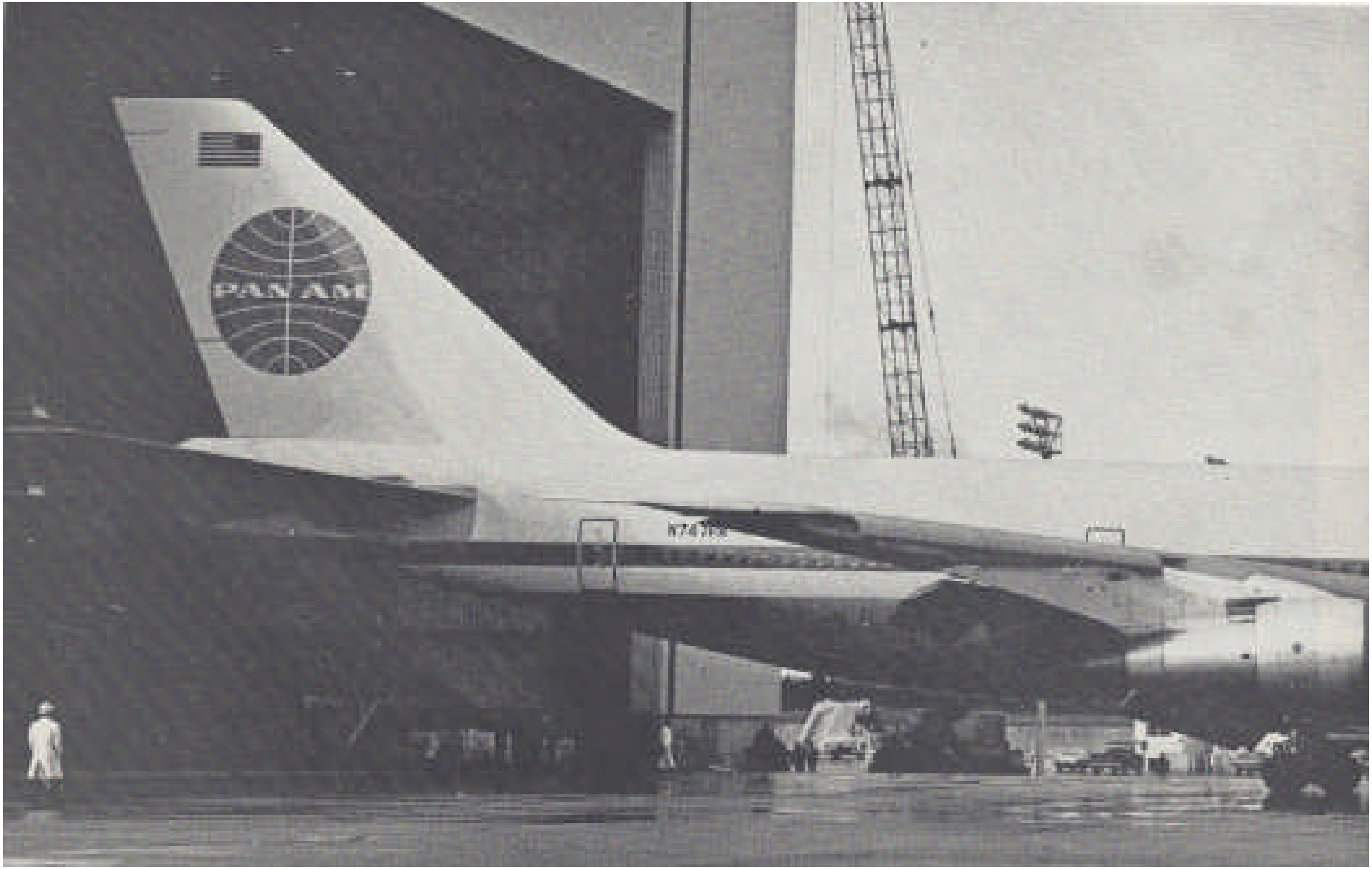


<u>Above</u>: caption: "Static test framework surrounds structurally complete test aircraft. Static tests, including proof pressurization checks began in March. Horizontal stabilizer is tested separately at far right."

Learning Curve

"…The factory now is operating with two parallel final assembly lines. The No. 2 aircraft is scheduled for rollout Feb. 25. The following three test 747s will be finished at monthly intervals stretching into May. The learning-curve is starting to descend now as startup difficulties are largely overcome, according to George D. Nibble, director of Everett Branch operations…"

Aviation Week & Space Technology, **February 17th 1969**



<u>Above</u>: caption; "Production rate is building to an 8.5 units-per-month rate by early 1971. First two flight test aircraft now are flying from Boeing Field, Seattle, but initial flights were at Paine Field near the plant. The number three flight loads survey aircraft is expected to roll out in early May."

"…By the end of 1970, Boeing plans to have completed 95 of the giant jets. The first 747B passenger version is expected to be completed in early 1971. It will be fitted with 45,500-lb.-thrust JT9D-7 engines and will have a maximum gross take-off weight of 775,000 lbs. Following the passenger version of the 747B in succession will be convertible and freighter versions at 2-3-month intervals…"

***Aviation Week & Space Technology*, February 17th 1969**

<u>Above</u>: caption: "Ground view of number two 747 in final assembly shows radome swung aside. Aircraft at this point, just prior to rolling out the door, is being subjected to final proof testing of all systems and a structural shakedown of the entire aircraft."

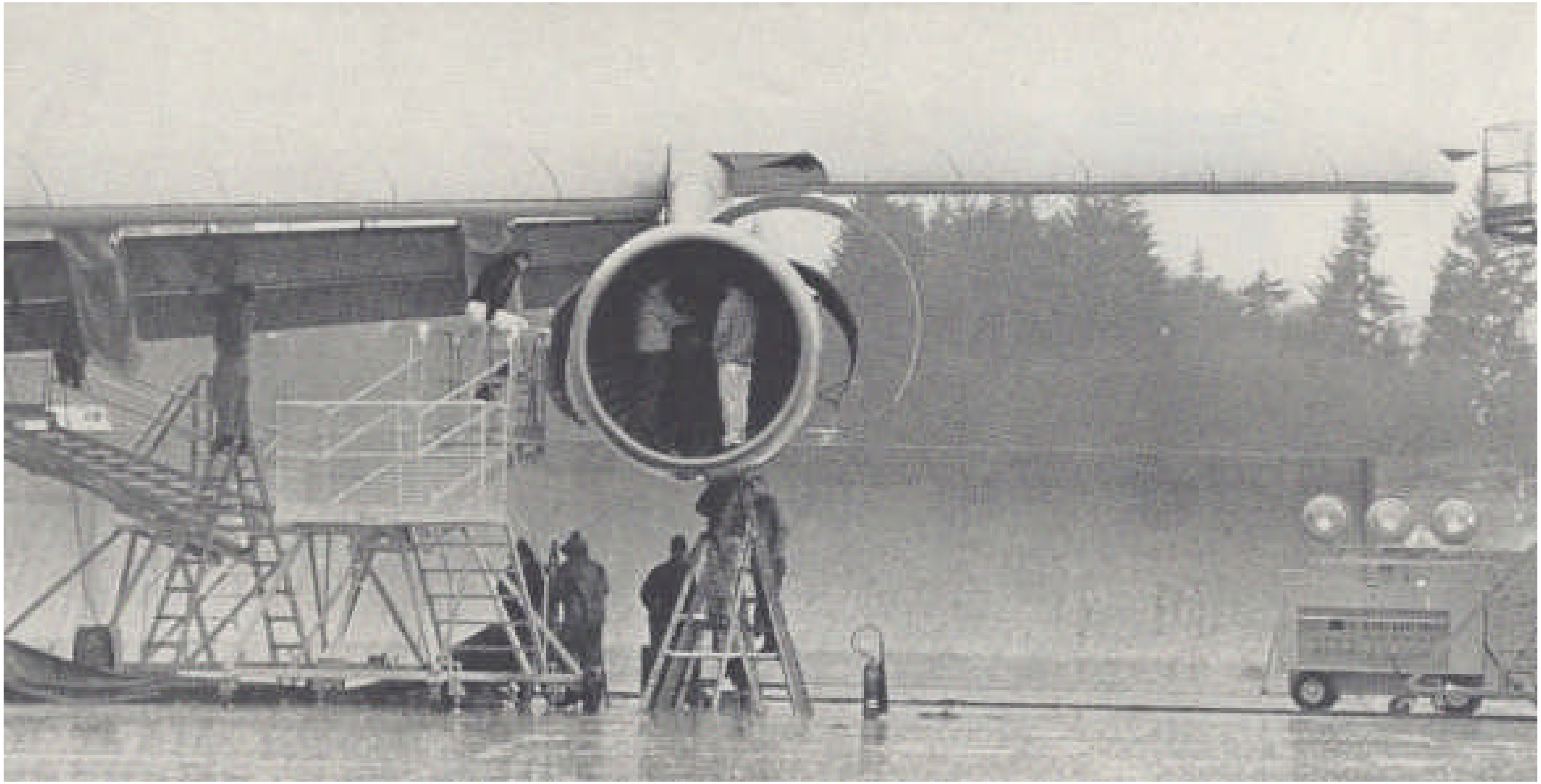
"…operating empty weight of the basic 747 will be 353,398 lbs., while the 747B will weigh 365,802 lbs., according to latest Boeing projections. The 747 convertible in a passenger version will have an operating weight empty of 378,404 lbs., and in the cargo version 353,975 lbs. The freighter will be lightest of all at 330,742 lbs. if pallets are used on the main deck and containers in the lower cargo bays…"

***Aviation Week & Space Technology*, February 17th 1969**

<u>Above</u>: caption: "Number two flight test aircraft in Pan American colors is towed from paint hangar to flight test line. By mid-April, the number one 747, owned by Boeing, which flew in February, had accumulated 63.5 hrs."

“…Maximum gross takeoff weight of all the advanced 747s will be greater than the basic 710,000 lbs. Passenger aircraft will be 775,000 lbs…”

***Aviation Week & Space Technology*, February 17th 1969**



<u>Above</u>: caption: “Ground crewmen give No. 1 Boeing 747 transport prototype Pratt & Whitney JT9D-1 turbofan engine a thorough check at Paine Field, Everett, Wash,. after aircraft’s first flight. Note size of men in 96-inch-diameter duct.”

"…Interest in all-cargo versions of the 747 never has re-surged to the heights apparent at the start of the program nearly three years ago. Boeing has sold three 747 con-vertibles but so far has announced no freighter orders. Total 747 orders are 167, including two 747Bs…"

***Aviation Week & Space Technology*, February 17th 1969**

<u>Left</u>: caption: “Overwing access panel has been opened for inspection of hydraulic and electrical lines. Plastic engine inlet plugs installed in No. 3 and No. 4 engine inlets keep out dust and debris while aircraft sits on ground. Krueger flaps inboard and variable-camber flaps outboard are extended.”
<u>Above</u>: caption: “Vertical tail is inspected with aid of special truck-mounted hoist”

Certificating

"Everett, Wash. - Boeing Co. faces a major challenge in certificating the 747 giant jet transport by the end of November. The No. 1 aircraft made its maiden flight here Feb. 9, opening the flight test program 7½ weeks behind schedule. If the November certification target is not met, Boeing faces possible problems with contractual obligations to its first 747 customer, Pan American World Airways…"

***Aviation Week & Space Technology*, February 17th 1969**

"…Also a potential problem area if certification is delayed is an inventory of 30 aircraft scheduled to have been rolled-out by that time, This figure includes the five flight test models. But the Boeing investment in the remaining 25 is estimated at $200-250 million, assuming roughly 50% progress payments. Although all of the slack built into the 747 manufacturing and flight test schedule has been used up, top Boeing officials believe that deliveries will be made on time…"

***Aviation Week & Space Technology*, February 17th 1969**

"…The first provisional training aircraft, the sixth production model, completed wing-body mating last week and is scheduled for delivery to Pan American in September. By the end of November, Pan American is scheduled to receive two certificated 747s…"

***Aviation Week & Space Technology,* February 17th 1969**

<u>Above</u>: caption: "Boeing executives Malcolm Stamper, left, and Joe Sutter show-off the first Boeing 747"

"…Boeing officials were encouraged that the flight test program would proceed smoothly, based on the 1-hr. 16-min initial flight. The project pilot, Jack Waddell, was pleased with responsiveness and basic stability…"

***Aviation Week & Space Technology,* February 17th 1969**

<u>Top</u>: caption: "The prototype Boeing 747, N7470, City of Everett, takes off at Paine Field, 9 February 1969"

<u>Bottom</u>: caption: "Brien Wygle was the co-pilot on Feb. 9, 1969, for the maiden flight of the Boeing 747"

"…A problem was encountered with flap misalignment when Wadell shifted from a 25-deg. Intermediate setting to a landing setting of 30-deg. At this point, the forward segment of the inboard three-segment, trailing-edge flap on each side of the aircraft twisted. Waddell returned to the 25-deg. Setting, an alternate for landing, to make the approach and touchdown. Inspection later determined that a sequential locking mechanism on the segment had not functioned properly. The device was adjusted, inspected and tested for a second flight last week…"

***Aviation Week & Space Technology*, February 17th 1969**

"…The misalignment was noticed by the flight engineer, Jess Wallick, from the cockpit, and by F. Paul Bennett, pilot of the Boeing-owned Canadair Sabre Mk. 5 chase aircraft. Waddell elected to discontinue the flight then, instead of continuing for the scheduled 2-2½ hrs…"

Aviation Week & Space Technology, **February 17th 1969**

<u>Above</u>: caption: "Canadair CL-13 Sabre Mk.5, N8686F, The Boeing Company, Seattle, Washington." Originally delivered to the *Royal Canadian Air Force* in February 1954, the aircraft was modified to act as a chase, calibration, and photography platform. It was delivered to Boeing in late 1962.

Experimental
N8686F
BOEING

“…The 7½-week first flight delay was not caused by any single subsystem or component problem, officials said. An unusually heavy snowfall contributed to the delay. But it was primarily the magnitude of ground checking the 747’s systems that led to the lengthy interval between rollout and first flight. The decision last fall to retain the December first flight established several years previously is typical of the tough program goals set by Boeing management. This first flight date had been established several years earlier. After roll-out last September, there were 2,500 open items to be closed before flight. Program managers elected to adhere to the original first flight date on the basis of closing a proportionate number of items daily. This daily schedule was kept, but in the process, an equally large number of open items had to be added…”

***Aviation Week & Space Technology*, February 17th 1969**

"…At present, there are no main-gear steering provisions, and considerable scrubbing friction is encountered during turning. Boeing will evaluate the necessity for adding steering mechanism to the rear trucks during flight tests…"

Aviation Week & Space Technology, **February 17th 1969**

Above: caption: "First flight crew: (left-to-right) Pilot Jack Waddell, Co-Pilot Brien Wygle and Flight Engineer Jess Wallick"

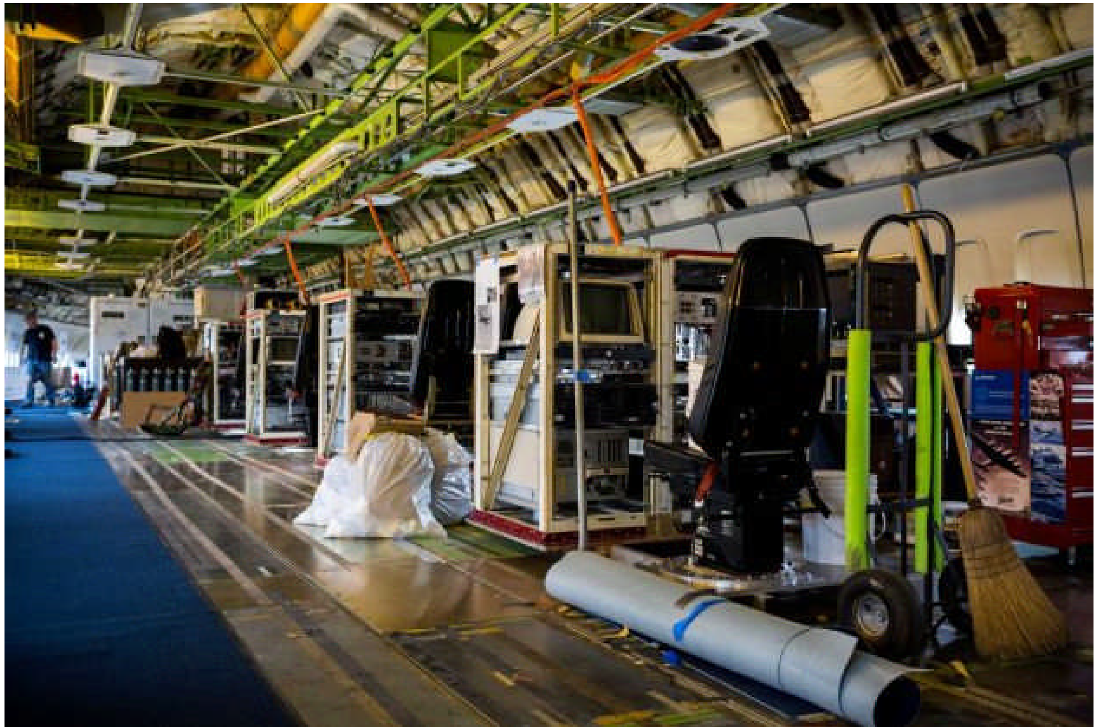
Double Trouble

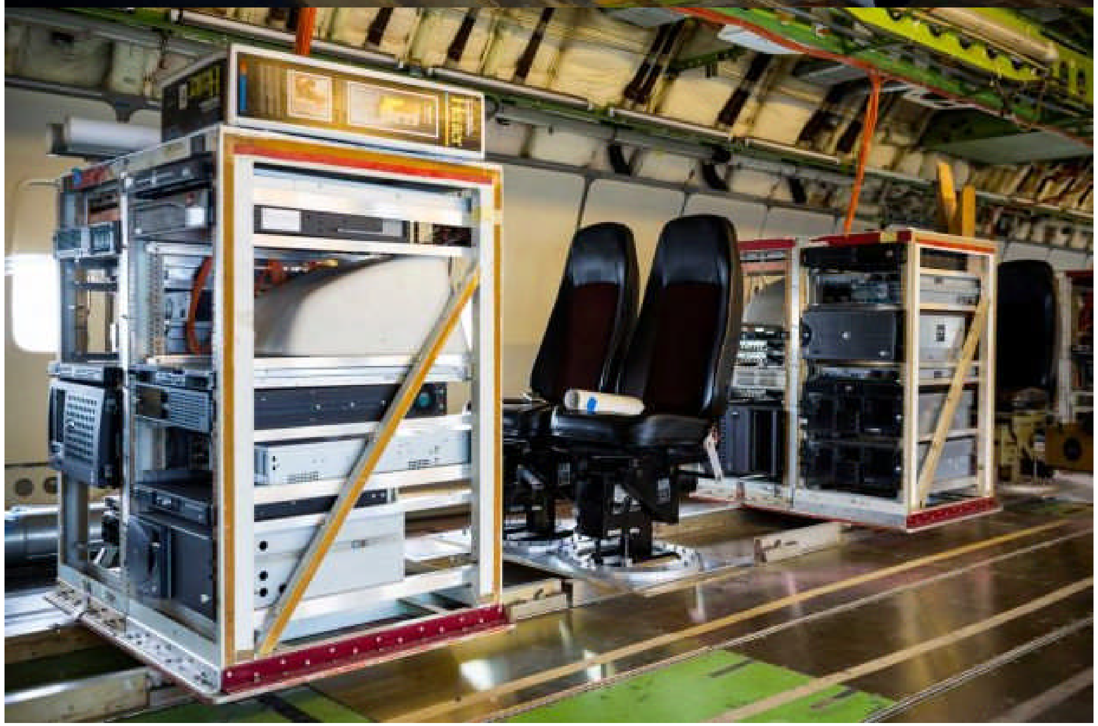
"…A particularly important element of the test program will be proving, concurrently, both a new airframe and a new engine. Completion of flight tests within the framework of the schedule would be tough enough with a production engine, but with a new engine – in two different sizes – problems are expected…"

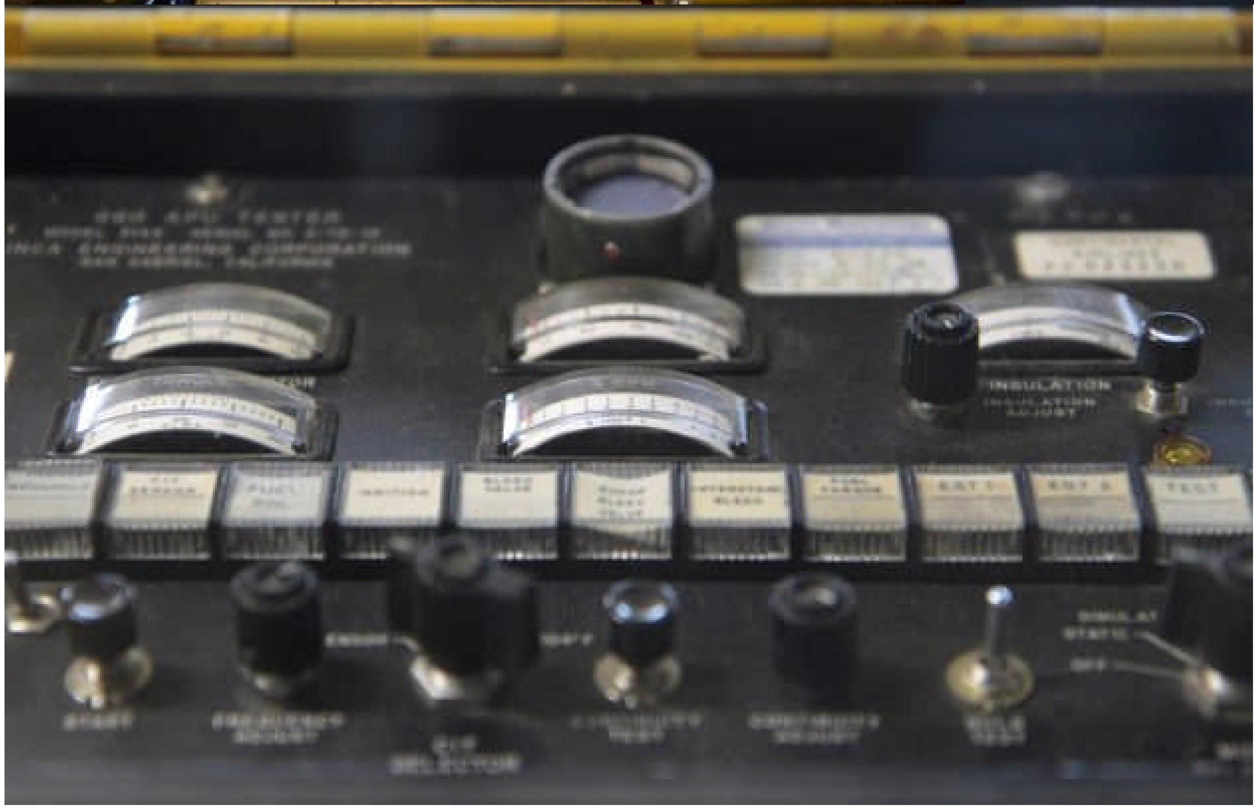
***Aviation Week & Space Technology*, February 17th 1969**

<u>Left</u>: caption: "Lines of flight equipment within the original Boeing 747 prototype"

<u>Right</u>: caption: "Flight test data stations in the main cabin of the first Boeing 747"





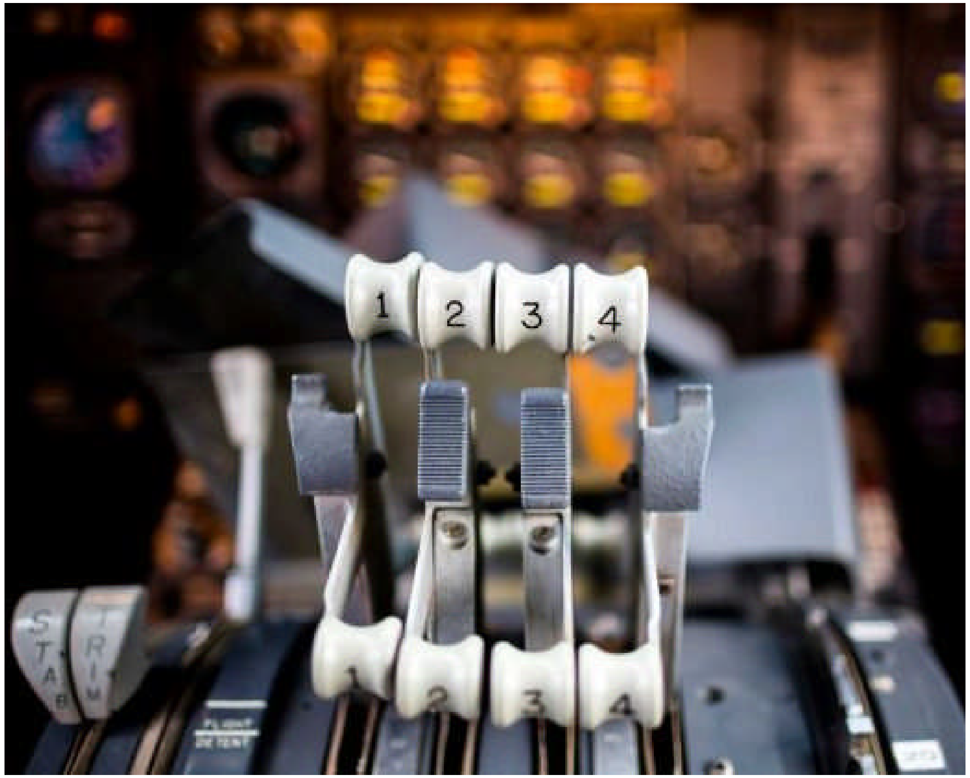


<u>Top L&R</u>: caption: "Water ballast barrels within the original Boeing 747 prototype"
<u>Left</u>: caption: "An APU tester on the first Boeing 747"

"…Pratt & Whitney JT9D-1 powerplants are fitted to the early test aircraft and will be replaced next summer by high thrust JT9D-3 engines, which will be on all production aircraft. Rated sea-level thrust of the JT9D-1 is 41,000 lbs., and that of the JT9D-3 is 43,500 lbs. The higher-thrust engines will require a complete new inlet air flow pattern survey as well as duplication of much of the other basic test work. Boeing is studying the advantage of adding a sixth aircraft to the flight test program. A sixth test aircraft also would be useful for continued testing when the No. 1 Boeing-owned 747 is laid up for several months in early 1970 to be retrofitted for 747B testing…"

Aviation Week & Space Technology, **February 17th 1969**

Left: caption: "Port (left)-side Engine Nos. 1&2 – B747 prototype"



"…On the first test flight, Waddell used a rolling takeoff – setting the power at 1,444 engine power ratio after the air-craft was moving. Maximum predicted engine thrust was 39,000 lbs. The JT9D-1 engines fitted to the No. 1 test aircraft are flat-rated at 41,000 lbs. thrust at 38F. Above this temperature, thrust decrea-ses. The No. 1 engine, which ran hotter by 20-30C than the other three, was throttled back to remain within temp-erature limits…"

***Aviation Week & Space Technology*, February 17th 1969**

"…As the aircraft reached midfield, it was rotated at approximately 131 kt. and lifted off after a roll of 4,800-5,000 ft. This was somewhat longer than the predicted 4,300 ft., but was believed due to a carefully controlled rotation. As the 747 passed by observers standing several hundred feet to one side of the runway, the noise appeared to be less than expected for such a large aircraft…"

Aviation Week & Space Technology, **February 17th 1969**

Above: caption: "February 9, 1969 – the first Boeing 747 takes-off as spectators watch nearby"

"…After takeoff, Waddell kept the four-post landing gear extended and retained flaps at 20-deg. Take-off setting throughout a series of gentle tests of roll, pitch and yaw response. Still characteristics were checked, and at 114 kt., a slight stall warning shudder was felt. Airspeed was allowed to decrease further to 110 kt. Before speed was increased. Maximum speed reached was 180 kt. Due to the 'dirty' configuration retained throughout the flight, although a Mach-0.65 top speed had been planned…Takeoff weight of the 747 was 480,000 lbs. and landing weight was 440,000 lbs…"

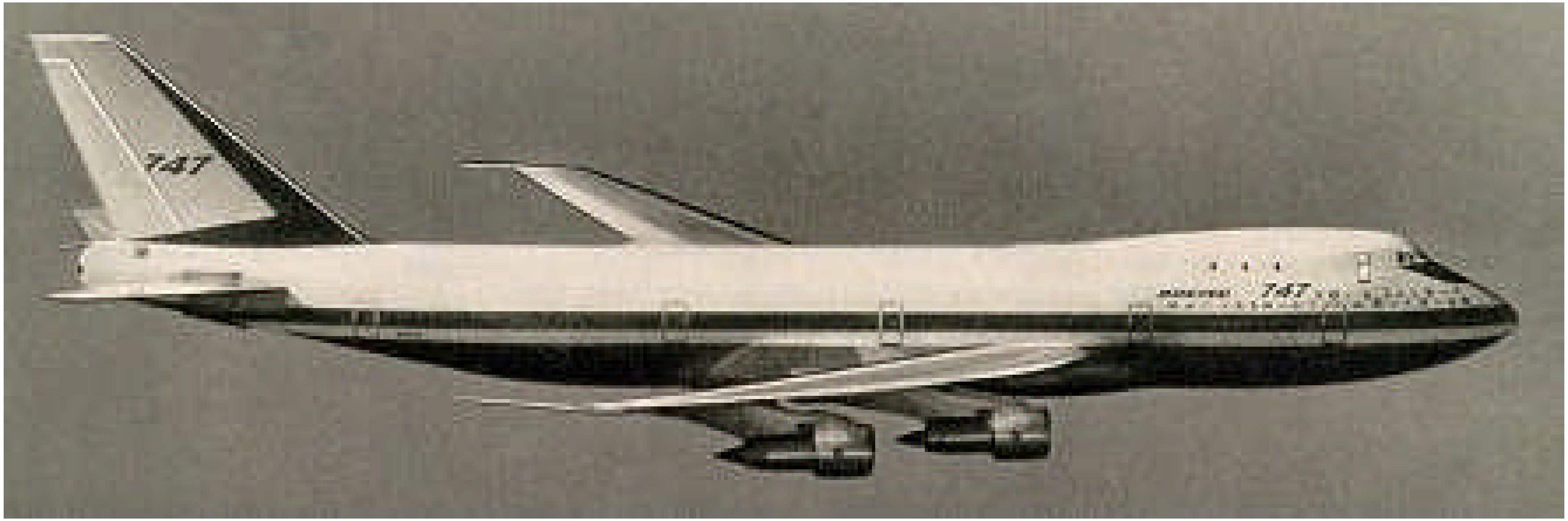
Aviation Week & Space Technology, **Feb. 17th 1969**

"…Waddell and co-pilot Brien Wygle both were pleased with the mild response of the aircraft to light and moderate turbulence. During the landing approach, Waddell reported exceptional yaw and speed stability. Height of the pilots above the ground did not seem a problem, Waddell reported, either during taxi or on landing…"

***Aviation Week & Space Technology,* February 17th 1969**

Left: caption: "The test pilots who flew the first Boeing 747: Left-to-right, Brien Wygle, Jack Waddell and Jess Wallick"

Key Concern



"…Noise is a key concern in the 747 program because the current anticipated regulations have been written to include aircraft with high-bypass ratio engines such as the 747. If the noise legislation is enacted later this year, Boeing would have to demonstrate acceptability of the 747 to obtain cert-ification. Since the only way to improve noise with a current aircraft is to offload payload at the rate of 20,000-30,000 lbs. per decibel of improvement, Boeing and the airlines both are uneasy…"

***Aviation Week & Space Technology*, February 17th 1969**

"…One characteristic of the aircraft found during taxi tests is the low engine noise level in the cockpit. Without noise cues, and with a larger volume of air being moved through the engines, care in monitoring engine instruments will be needed to avoid damage to other aircraft or airport installations in ground operations…"

Aviation Week & Space Technology, **February 17th 1969**

<u>Left T&B</u>: "There are 971 switches, dials and lights in the cockpit of the Boeing 747 prototype"

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION FEDERALAVIATION ADMINISTRATION

STANDARD AIRWORTHINESS CERTIFICATE

1. NATIONALITY AND REGISTRATION MARKS	2. MANUFACTURER AND MODEL	3. AIRCRAFT SERIAL NUMBER	4. CATEGORY
N12345	**Boeing 747-400**	**197142**	**Transport**

5. AUTHORITY AND BASIS FOR ISSUE

This airworthiness certificate is issued pursuant to the Federal Aviation Act of 1958 and certifies that as of the date of issuance, the aircraft to which issued has been inspected and found to conform to the type certificate, therefor, to be in condition for safe operation, and has been shown to meet the requirements of the applicable comprehensive and detailed airworthiness code as provided by Annex 8 to the Convention on International Civil Aviation, except as noted herein:

EXEMPTION NO. 1013A FAR 25.471(b): Allows lateral displacement of C.G. from airplane centerline.

6. TERMS AND CONDITIONS

Unless sooner surrendered, suspended, revoked, or a termination date is otherwise established by the Administrator, this airworthiness certificate is effective as long as the maintenance, preventive maintenance, and alterations are performed in accordance with Parts 21, 43, and 91 of the Federal Aviation Regulations, as appropriate, and the aircraft is registered in the United States.

DATE OF ISSUANCE	FAA REPRESENTATIVE	DESIGNATION NUMBER
11/29/92	*John Q. Publican* John Q. Publican	**DMIR ANM 1234**

Any alteration, reproduction, or misuse of this certificate may be punishable by a fine not exceeding $1,000, or imprisonment not exceeding 3 years, or both. THIS CERTIFICATE MUST BE DISPLAYED IN THE AIRCRAFT IN ACCORDANCE WITH APPLICABLE FEDERAL AVIATION REGULATIONS.

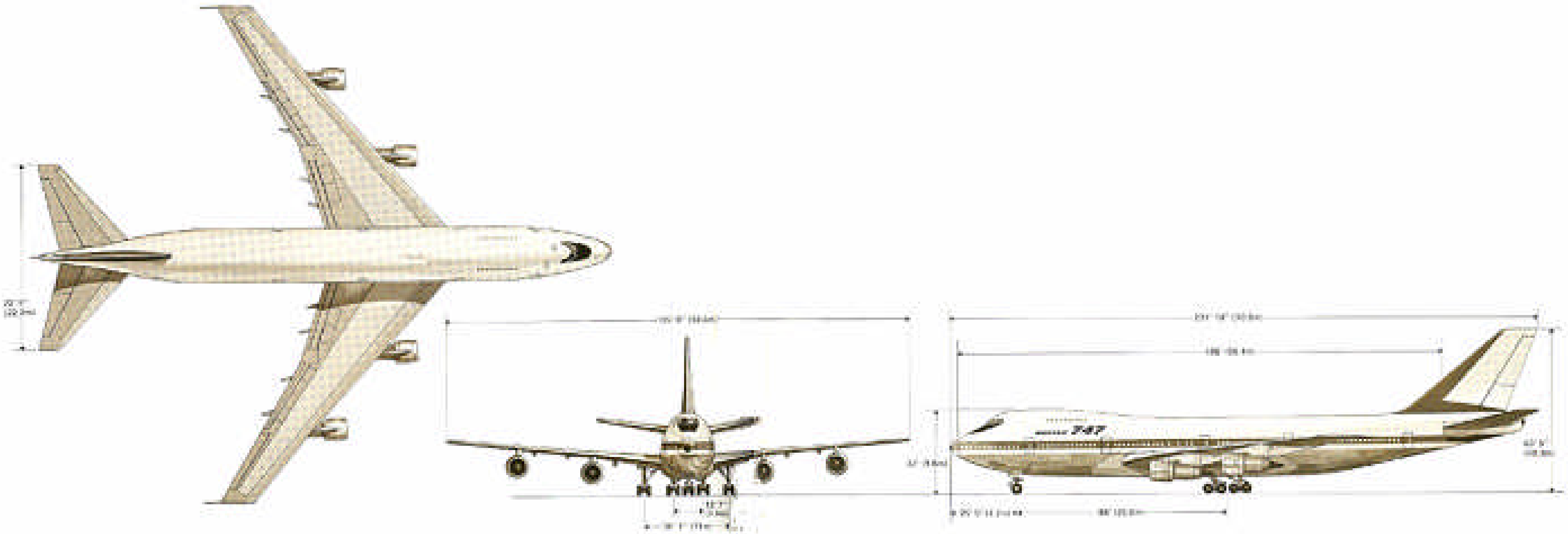
FAA Form 8100-2

Part 8

Under the Hood

General Description
(747-100/-200B/SR Passenger Airplanes)
(excerpts from a 1971 Boeing sales brochure)

general arrangement



747-100 AND 747-200B CHARACTERISTICS

	747-100		747-200B				
	STANDARD	IMPROVED					
ENGINE	JT9D-7A	JT9D-7A	JT9D-7AW	JT9D-7FW*	CF6-50E*	JT9D-70A*	RB211-524B*
THRUST (LB)	46 950	46 950	48 570	50 000	52 500	53 000	50 100
MAXIMUM TAXI WEIGHT (LB)	713 000	738 000	778 000(1)	808 000*	808 000*	808 000*	808 000*
MAXIMUM BRAKE RELEASE WEIGHT (LB)	710 000	733 000	775 000	805 000	800 000	800 000	800 000
DESIGN LANDING WEIGHT (LB)	564 000	564 000	564 000	564 000	564 000	564 000	564 000
MAXIMUM ZERO FUEL WEIGHT (LB)	576 500	526 500	526 500	526 500	526 500	526 500	526 500
OPERATING EMPTY WEIGHT (LB)(2)	356 900	357 100	365 800	366 000	369 900	373 900	375 100
PAYLOAD							
MAX STRUCTURAL (LB)	169 600	169 400	160 700	160 500	156 600	152 600	150 400
CARGO/BAGGAGE VOLUME (CU FT)	6 190	6 190	6 190	6 190	6 190	6 190	6 190
FUEL CAPACITY (LB—AT 6.7 LB/GAL)	316 300	316 300	344 580	344 580	342 300	342 300	344 580

*Option

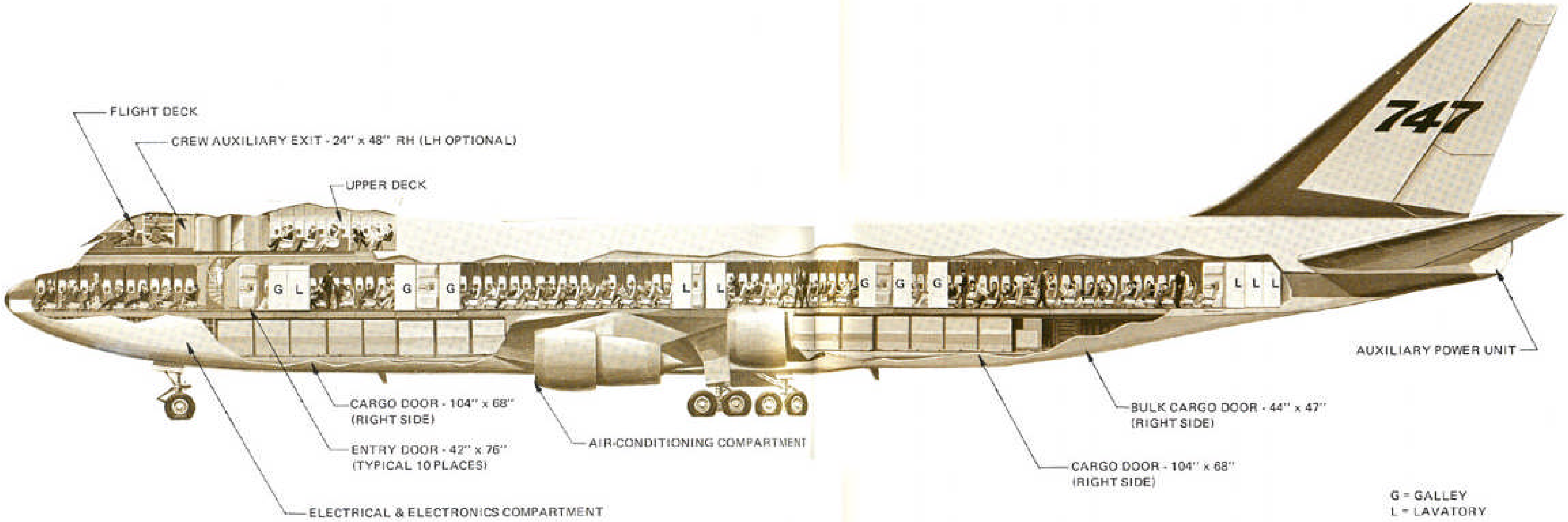
(1) 788 000-lb maximum taxi weight available
(2) Typical seating capacity—385 passengers: 48 first class: 337 tourist class

747SR CHARACTERISTICS

ENGINE	JT9D-7A	JT9D-7A	JT9D-7A
THRUST (LB)	46 950	46 950	46 950
MAXIMUM TAXI WEIGHT (LB)	523 000	603 000*	713 000(1)*
MAXIMUM BRAKE RELEASE WEIGHT (LB)	520 000	600 000	710 000
DESIGN LANDING WEIGHT (LB)	505 000	525 000	564 000
MAXIMUM ZERO FUEL WEIGHT (LB)	475 000	485 000	526 500
OPERATING EMPTY WEIGHT (LB)(2)	345 000	345 000	345 000
PAYLOAD			
MAX STRUCTURAL (LB)	130 000	140 000	181 500
CARGO/BAGGAGE VOLUME (CU FT)	6 190	6 190	6 190
FUEL CAPACITY (LB—AT 6.7 LB/GAL)	316 300	316 300	316 300

*Option

(1) 738 000-lb maximum taxi weight available
(2) Typical seating capacity—600 economy class



INBOARD PROFILE

Passengers can enter the airplane through any of 10 doors (5 on either side), all wide enough for two people to walk in together. Whichever side is selected to suit boarding facilities at the air terminal, the opposite set of doors can be used to service galleys at the same time. This dual setup quickens turnaround time.

Interior variability is one of the outstanding features of the 747. For a basic passenger layout, it is convenient to subdivide the main deck into five easily manageable zones or areas, each separated by either a lavatory or galley service center. A spiral stairway leads to the upper deck, which can be set apart for regular seating, lounge, dining room, or other specialty use. This upper deck can have its own galley and lavatory facilities. The control cabin is on the same deck directly ahead of this passenger area.

Below the main deck, in the lower lobe of the fuselage, are wheel wells for landing gear, compartments for electronic equipment and air conditioning, and three large compartments for cargo. Part of this cargo area can be reserved for a galley and made accessible to the main deck by adding a service/personnel elevator.

INTERIOR ARRANGEMENTS

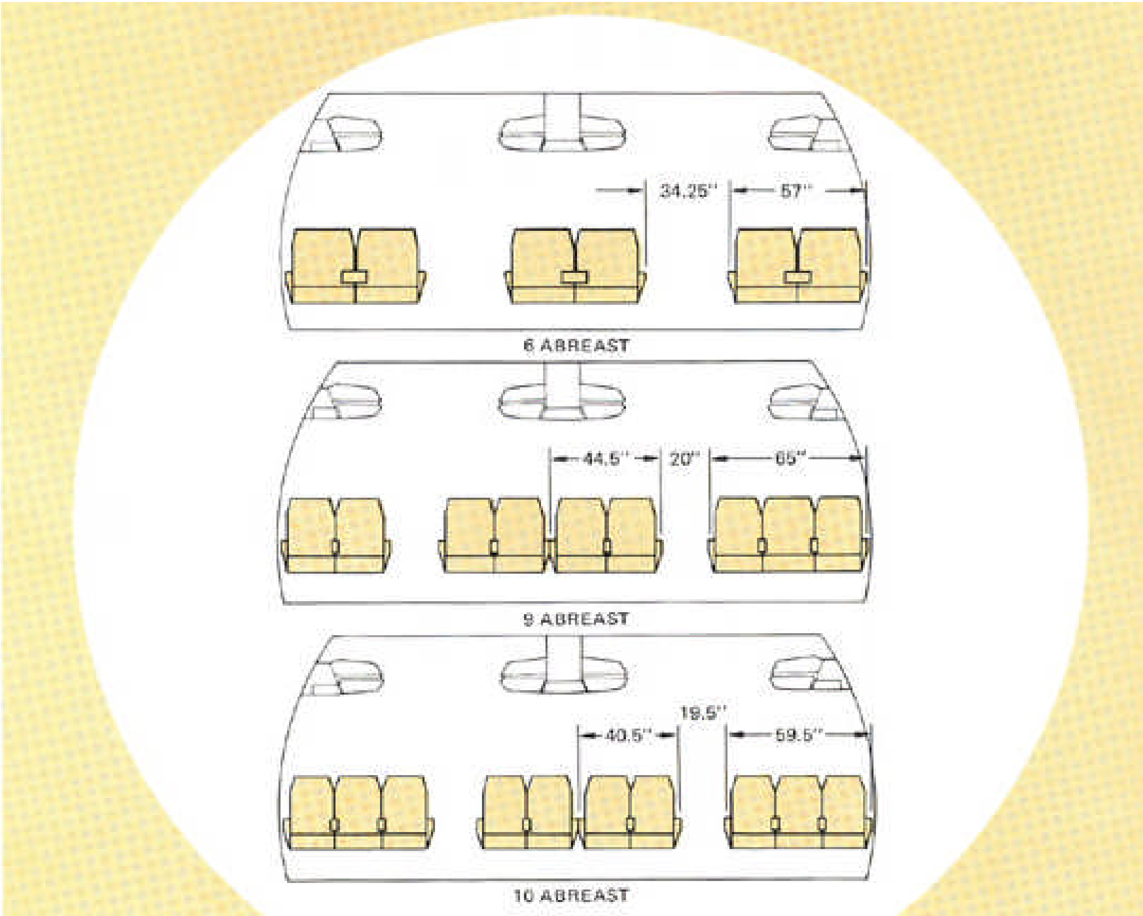
The wide body of the 747 permits a main passenger deck with nearly vertical walls, 8-foot ceiling, and 20-foot floor width. When professionally appointed with carpeting, upholstered seating, and decorative dividers, each passenger zone takes on a well-furnished roomlike atmosphere.

Easily accommodated by the wide body, nine-abreast seating is 10 percent wider than 707 economy seating and is popularly used on long-range schedules. Ten-abreast 747 economy seats are equivalent to 707 six abreast. Seating in the upper or main deck lounges is usually more informal, giving an added element of relaxation to high-density travel. Passengers affirm a sense of personal freedom about the 747 and they enjoy the lower sound level.

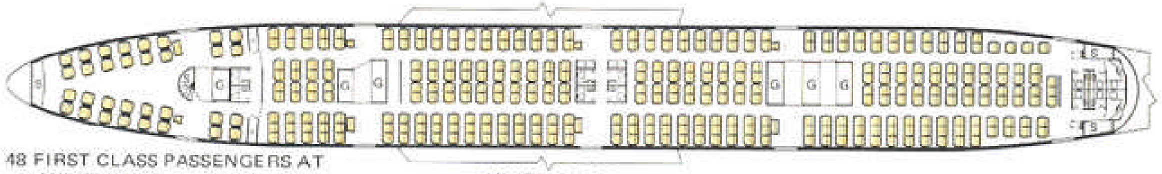
Modular design is the key to arranging the interior for any desired combination of service classes. The same tracks that hold seats in groups of twos and threes, as suggested below, also hold galleys, lavatories, service counters, storage units, or simple dividers. This flexibility lends itself to creating a special area for first-class service and for a refreshing change of surroundings on long flights.

In-flight entertainment has taken on new dimensions in the 747 with the introduction of several motion picture screens and private stereo listening. The large size and high position of these screens make the pictures visible regardless of passengers or attendants walking in the aisles. Each passenger seat has stethoscope earphones for selection from many channels of stereo music or movie sound.

Overhead stowage gives travelers a place for as much as 40 pounds of "hard goods" per area with no need to put parcels underfoot or under the seats.

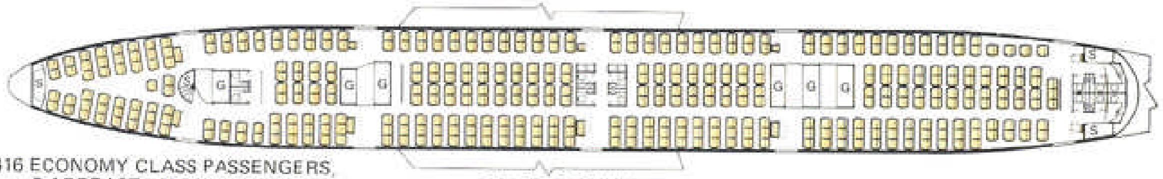

34.25''
57''
6 ABREAST
44.5''
20''
65''
9 ABREAST
19.5''
40.5''
59.5''
10 ABREAST

TYPICAL INTERIOR ARRANGEMENTS



48 FIRST CLASS PASSENGERS AT 41" SPACING*
337 ECONOMY CLASS PASSENGERS, 9 ABREAST AT 34" SPACING
385 TOTAL PASSENGERS

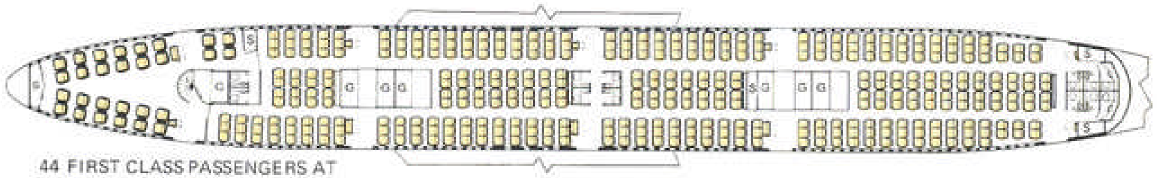
MIXED CLASS



416 ECONOMY CLASS PASSENGERS, 9 ABREAST AT 34" SPACING*

ALL ECONOMY

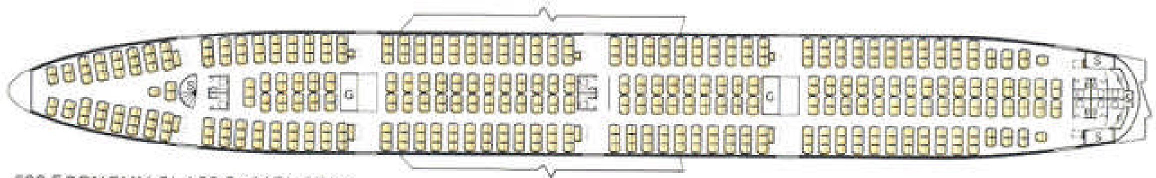
ALTERNATE INTERIOR ARRANGEMENTS



44 FIRST CLASS PASSENGERS AT 41" SPACING *
379 ECONOMY CLASS PASSENGERS, 10 ABREAST AT 34" SPACING
423 TOTAL PASSENGERS

MIXED CLASS

G = GALLEY
S = STOWAGE
E = ELEVATOR



500 ECONOMY CLASS PASSENGERS, 10 ABREAST AT 34" SPACING*

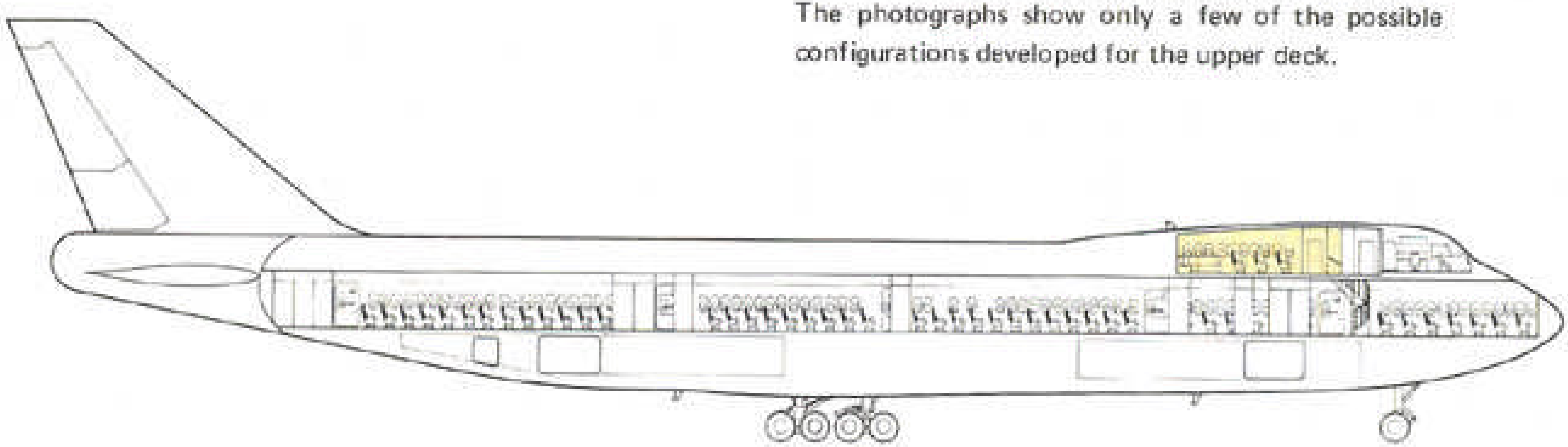
MAIN DECK GALLEYS
MINIMUM SERVICE

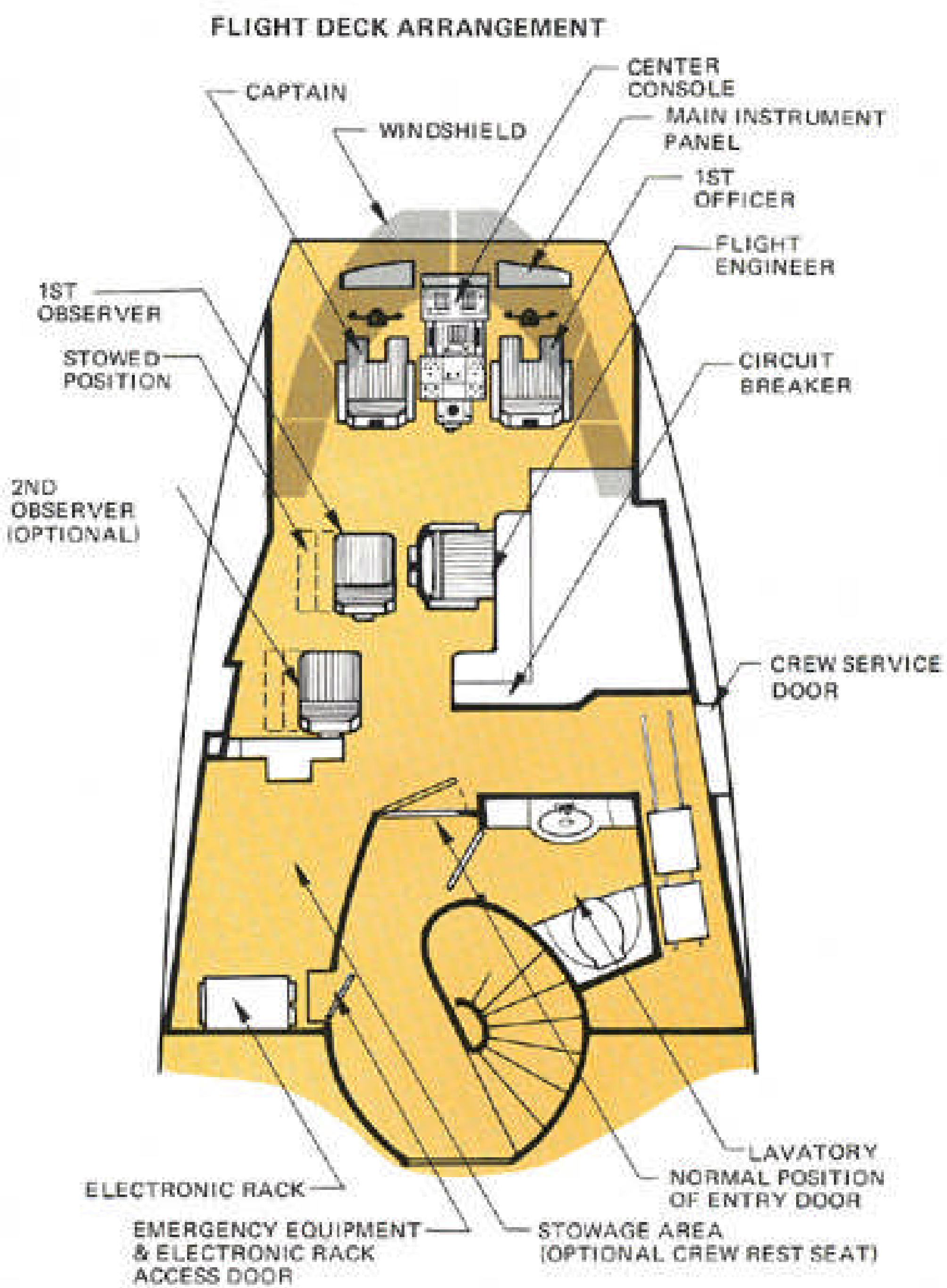
* INCLUDES 16 SALABLE SEATS ON UPPER DECK

UPPER DECK

The upper deck offers a unique passenger attraction available only in the 747. This 747 "penthouse," reached by spiral staircase from the main deck, offers luxurious privacy to a group of travelers. Treatment of this area by different airlines has provided most unusual and attractive arrangements ranging from cocktail lounges to staterooms.

The upper deck is certified up to a capacity of 16 salable seats. With the installation of the optional upper deck door, certification can be received for seating arrangements for up to 32 salable seats on the upper deck. One lavatory is located on the upper deck with provisions for a second and third lavatory, and galley or bar. Galley service is also available from the main deck through use of an optional food service lift. The photographs show only a few of the possible configurations developed for the upper deck.





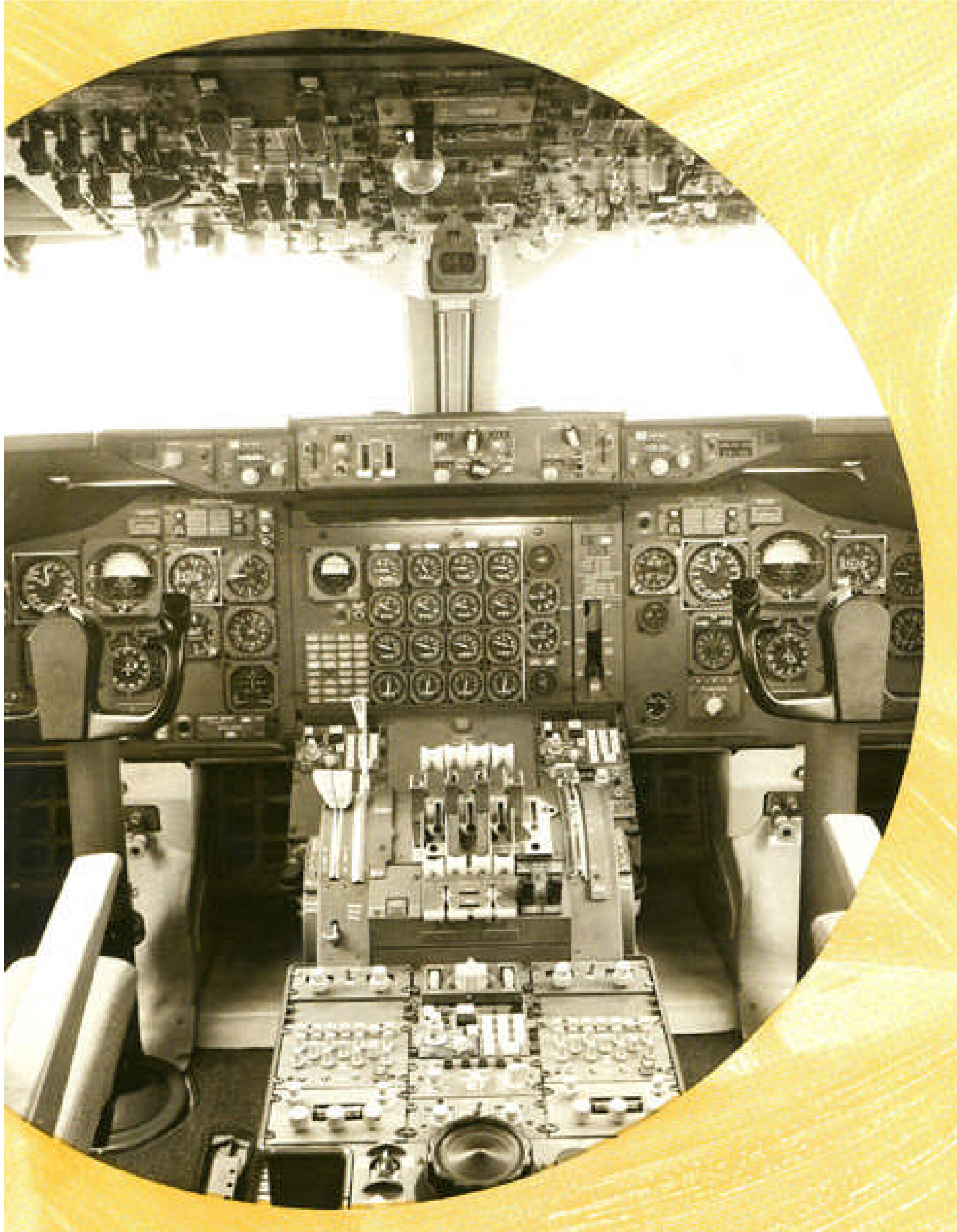
FLIGHT DECK

The 747 is designed for operation by a captain, first officer, and flight engineer. All seats have fore, aft, and vertical adjustments for optimum position. Powered seat operation is available as an option. In addition, the engineer's seat swivels. Outboard travel of the pilot's seat and folding of the inboard armrests give adequate clearance for easy entry and exit. One observer's seat and provisions for a second are installed.

The crew stowage area, containing sections for emergency equipment, crew clothing, and luggage, provides much more storage space than in previous jetliners. A lavatory accessible to the crew is a basic installation on the upper deck.

The control cabin is entered through either the lockable door atop the spiral stairway leading up from the main cabin or through the exterior 24- by 48-inch door on the flight deck. An overhead hatch with structurally attached inertia reels provides additional emergency egress.

Among the special features of the control cabin are high ventilation rates and excellent temperature control. Each crew station has an individual conditioned-air outlet, with variable direction and volume control.



INSTRUMENT PANELS

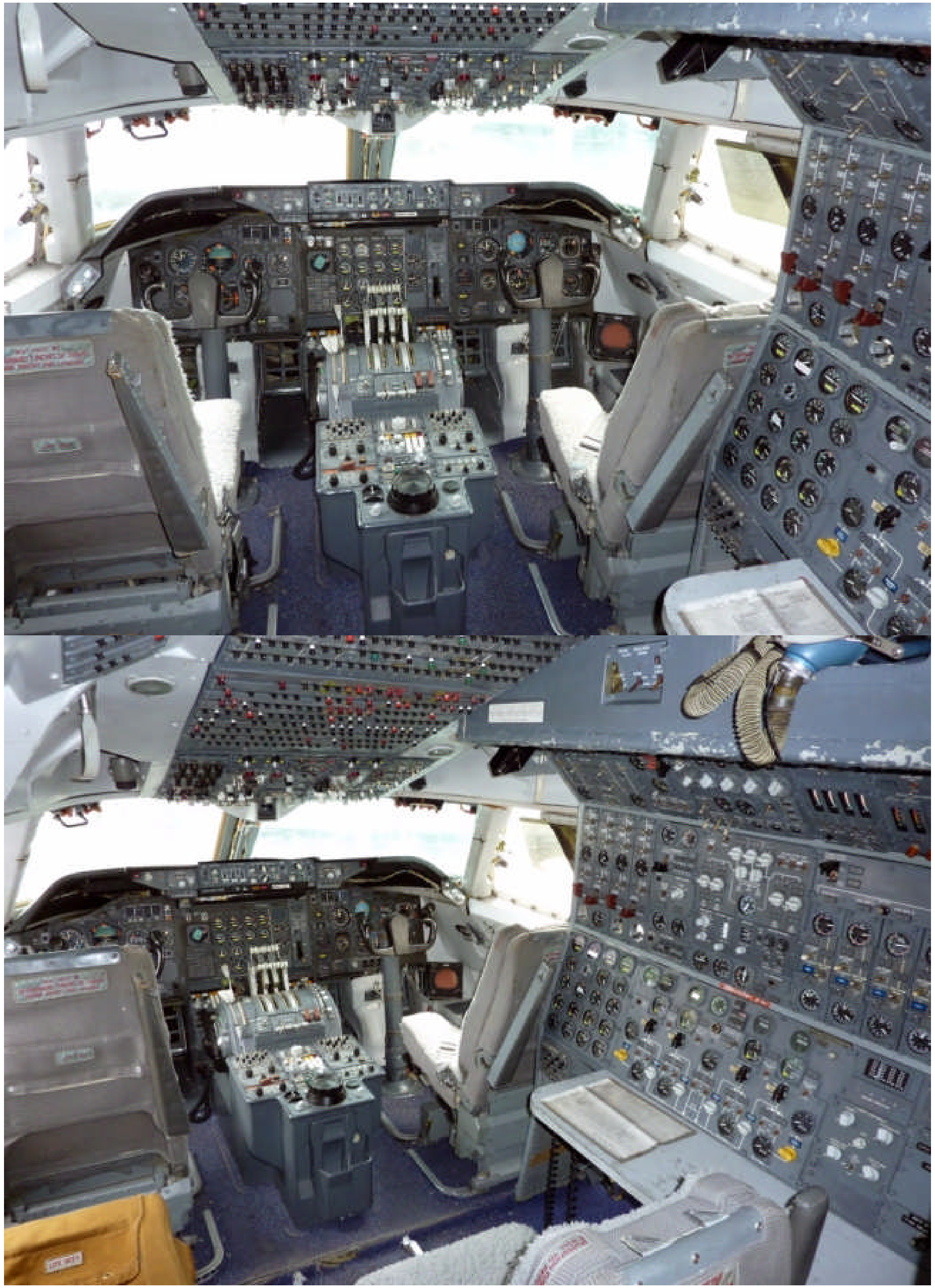
The basic flight instruments provide dual independent displays of critical parameters. Numerous advances are incorporated. These include:

- Larger instruments with expanded scales for improved readability and accuracy
- Increased use of digital readouts
- Increased sensor switching and instrument cross-checking
- Integration of flight instruments with the inertial navigation system and autopilot

The attitude director indicators and horizontal situation indicators have face diameters of 5 inches for increased accuracy and readability. Attitude, navigation, and flight director data source switches on both pilots' panels permit choice of alternate signal sources if the normal one fails or becomes suspect. Detailed switching configurations are a customer option.

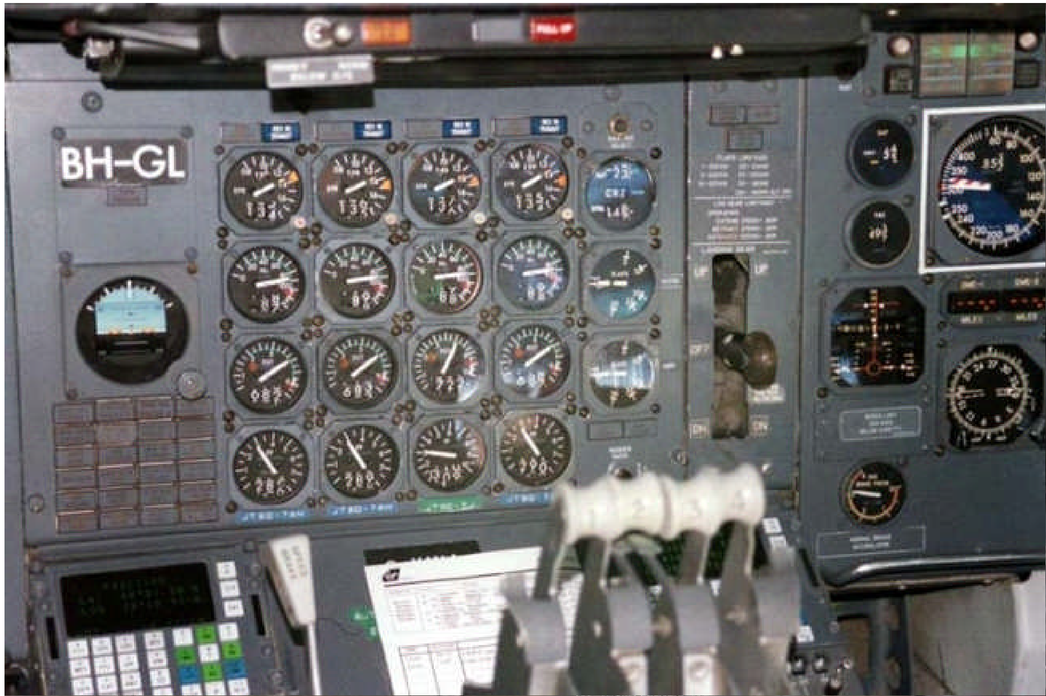
All instruments can be removed from the face of the panels without disturbing the associated control module. Module replacement is speeded by such features as quick-release captive fasteners and adjacent electrical and pneumatic disconnects.

The panels shown represent a typical basic arrangement that can be modified to specific customer configuration.



"…The new plane has more automation in flight controls and pressurization systems, and thus is better able to reduce pilot work loads. These advantages will offset the additional pilot work of monitoring some of the new systems…"

***Popular Science*, December 1969**

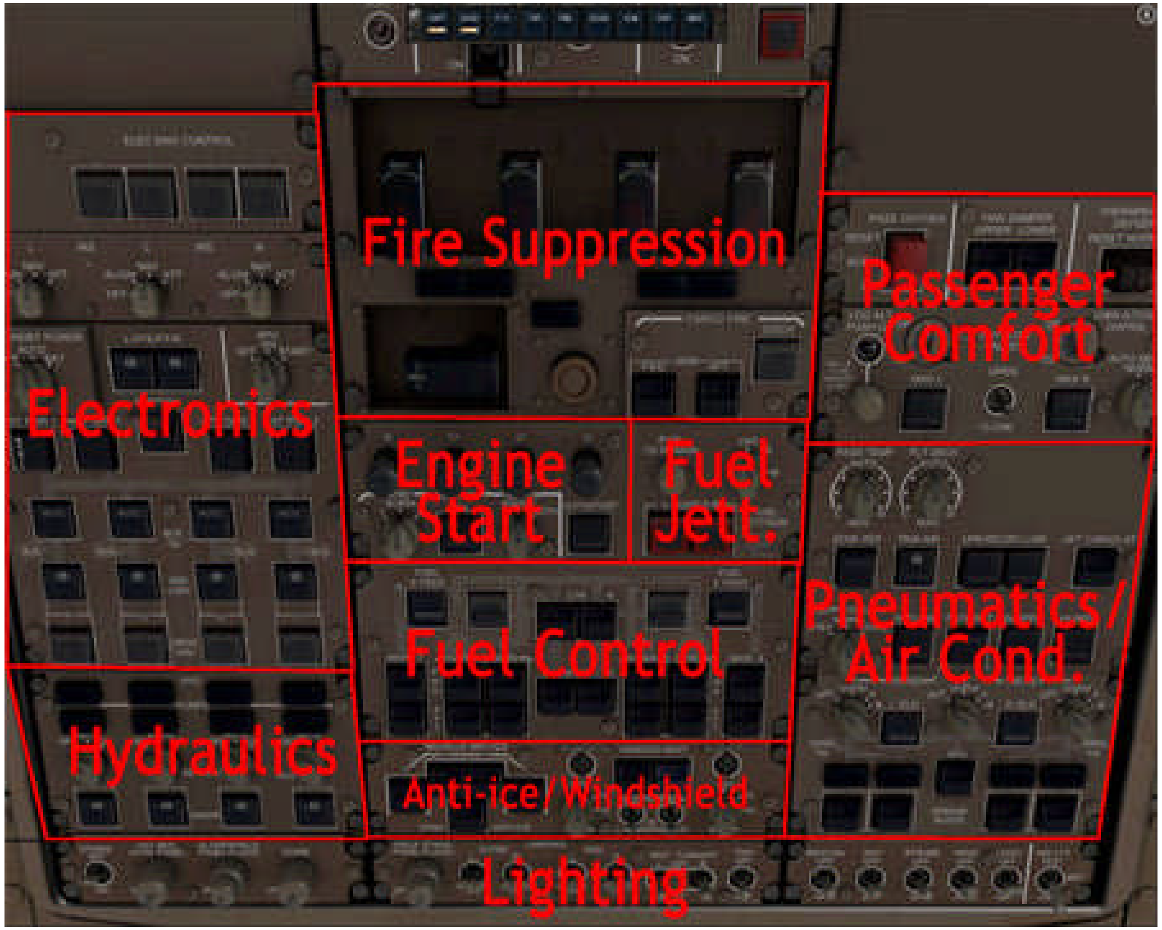


"…Some computers pre-select altitudes and hold them. The autopilot can operate in a turbulence mode, which will fly the plane with control adjustments to give an optimum ride…"

***Popular Science,* Dec. 1969**

"…Control inputs are reduced to about half those ordinarily used, so that the autopilot maintains control during bumps and yet stays within structural load limits of the plane. This is an important safety factor in case the plane encounters severe turbulence…"

***Popular Science,* December 1969**


Fire Suppression
Electronics
Passenger Comfort
Engine Start
Fuel Jett.
Fuel Control
Pneumatics/ Air Cond.
Hydraulics
Anti-ice/Windshield
Lighting

POWER PLANT

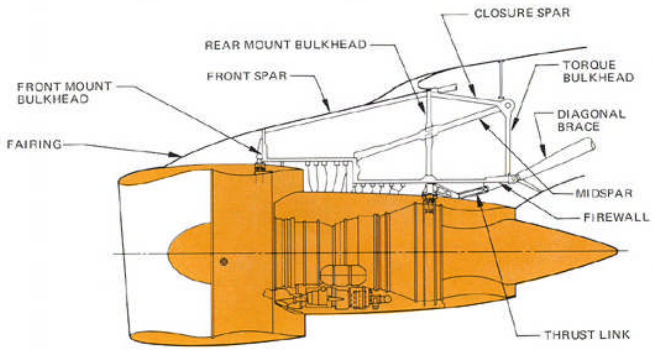
The 747 airplane is powered with JT9D-7A engines; JT9D-7F, JT9D-70A, RB211-524B, and CF6-50E engines are optional. The JT9D-7A and JT9D-7F powered airplanes can incorporate water injection, if desired, to provide greater takeoff thrust.

The engines are pod-mounted below the wing through the use of multiple lugs, flanges, and bolts. This pod-to-strut attachment is designed with sufficient strength such that if one of the items fails, the remaining items are capable of carrying the design loads. In addition, safety links and bolts are incorporated that normally carry no load but will do so after a failure of certain mount components.

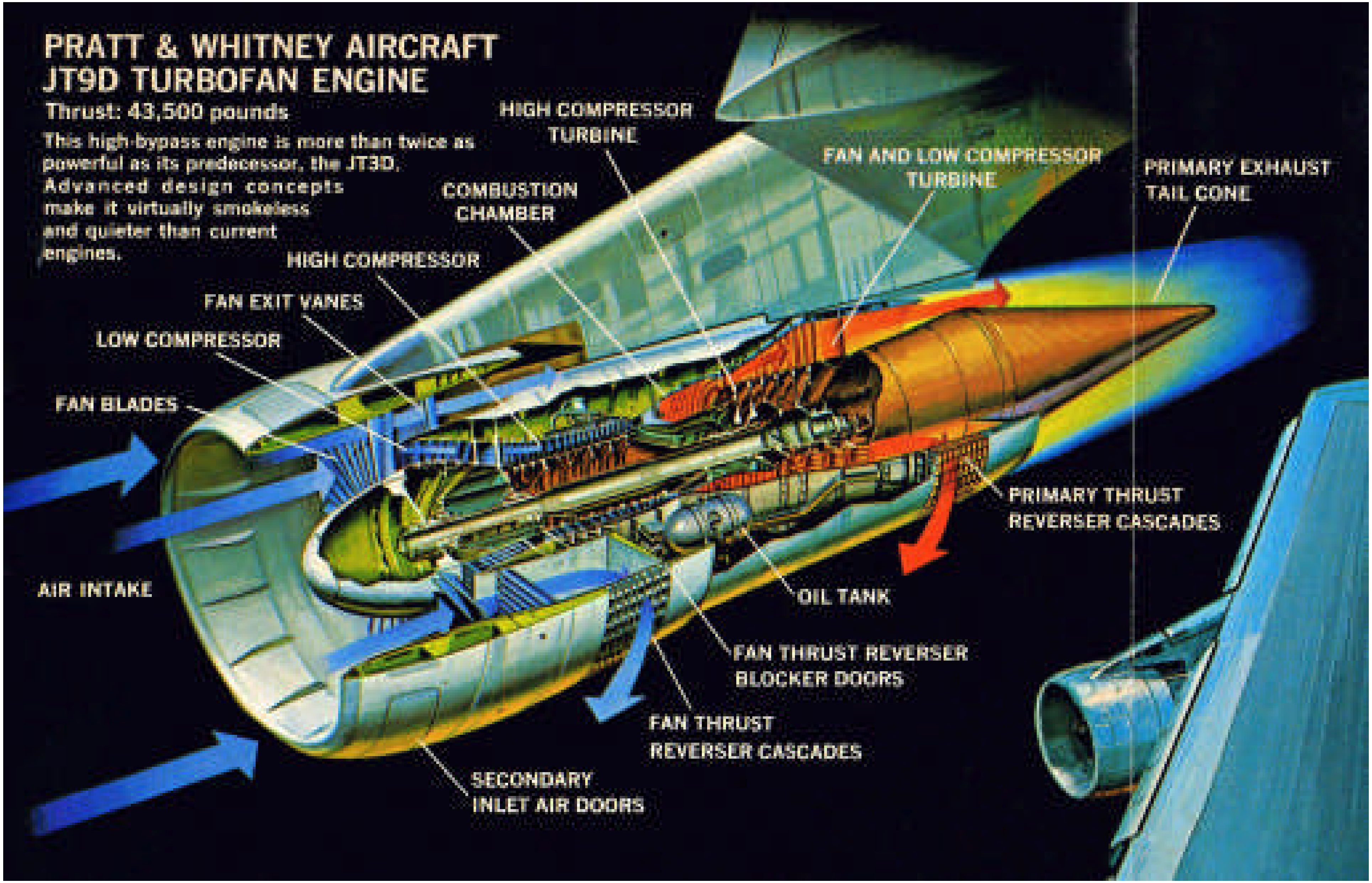
Engine change is accomplished by the use of hoisting components, which can be attached to the strut. This permits engine replacement without a requirement for commercial hoisting equipment. The only fasteners involved in an engine change are four bolts at the rear mount and a two-bolt connection at the front mount. All fuel, hydraulic, pneumatic, and electrical disconnects are conveniently placed at the strut firewall.

Installed on each engine are a constant-speed drive, generator, hydraulic pump, and pneumatic components to provide the necessary services to the airplane. The installation of these components is configured for ease of maintenance. Access to the engine and its accessories is obtained by opening large cowl panels, which are hinged on each side of the pylon and are latched at the bottom centerline. Hold-open rods are provided to maintain the cowl panel in an open position while maintenance work is being done on and around the engine.

The engines have been designed to reduce the generation of noise. In addition, noise attenuating material is incorporated in the inlets and fan and turbine exit nozzles to further reduce the noise.



JT9D-7 ENGINE INSTALLATION


PRATT & WHITNEY AIRCRAFT
JT9D TURBOFAN ENGINE
Thrust: 43,500 pounds
This high-bypass engine is more than twice as powerful as its predecessor, the JT3D. Advanced design concepts make it virtually smokeless and quieter than current engines.
HIGH COMPRESSOR TURBINE
FAN AND LOW COMPRESSOR TURBINE
PRIMARY EXHAUST TAIL CONE
COMBUSTION CHAMBER
HIGH COMPRESSOR
FAN EXIT VANES
LOW COMPRESSOR
FAN BLADES
PRIMARY THRUST REVERSER CASCADES
AIR INTAKE
OIL TANK
FAN THRUST REVERSER BLOCKER DOORS
FAN THRUST REVERSER CASCADES
SECONDARY INLET AIR DOORS

JET ENGINES

The Boeing 747 is powered by four Pratt and Whitney JT 9D-3 two-spool turbofans with a high by-pass ratio. Each jet is housed in a pod made of drawn aluminum alloy 0.059” thick, riveted on to a conventional structure of frames and stringers. The front fan is protected by a fairing 7’ 11” in diameter made of metal honeycombed sandwich panels.

Total weight of each engine: 8,470 lbs.

Thrust at takeoff: 4 x 43,500 lbs.

The thrust of the engine is transmitted to the structure through rear trunnions made of Inconel 718, an alloy which is highly resistant to heat and corrosion and needs no external protection.

The very large diameter fan on this jet engine can handle five times the volume of air handled by previous turbofans, and because of its low circumferential speed it reduces noise level by 4 decibels. The insulating materials upstream and downstream from the fan channel also contribute to a reduction in noise level. The 747 will be no more noisy than the Boeing 707, despite the fact that it is a much more powerful aircraft.

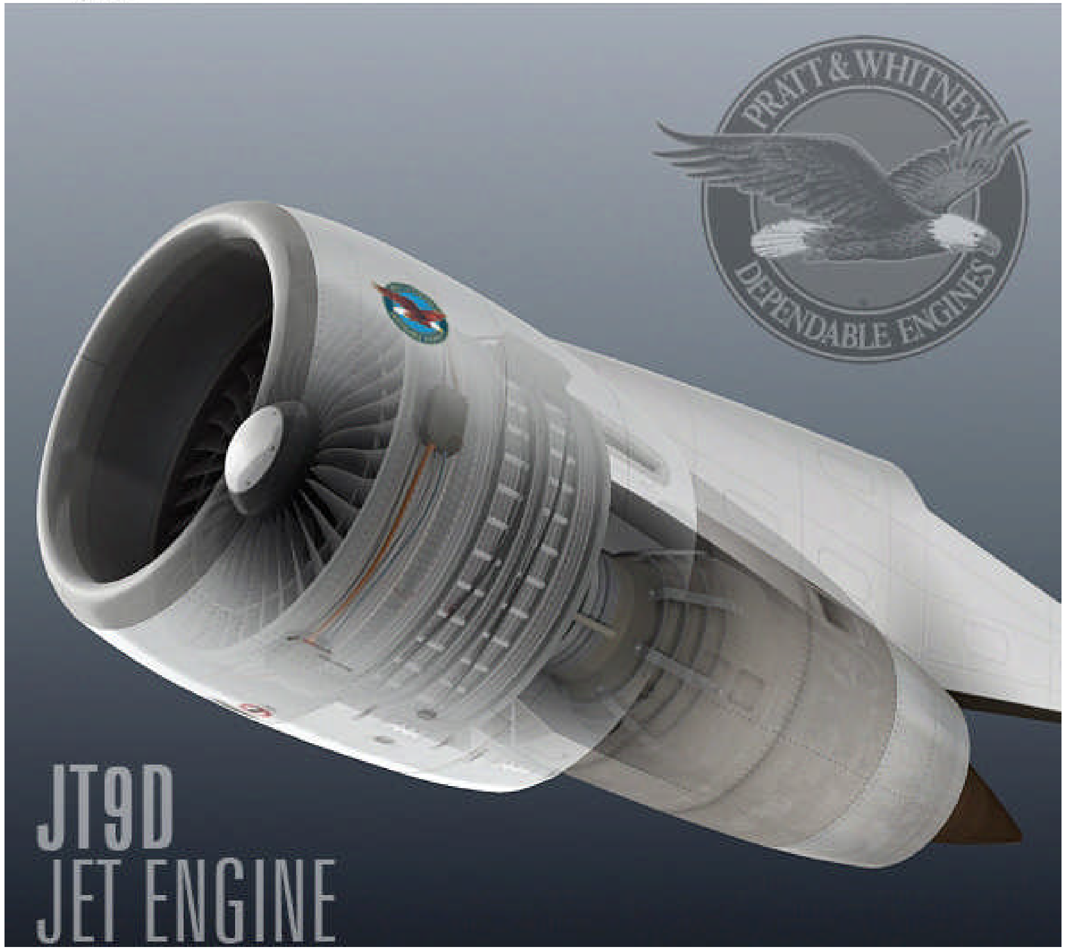
"…look into the engine intakes eight feet in diameter, more than big enough to permit Wilt Chamberlain to stand inside wearing a top hot…"

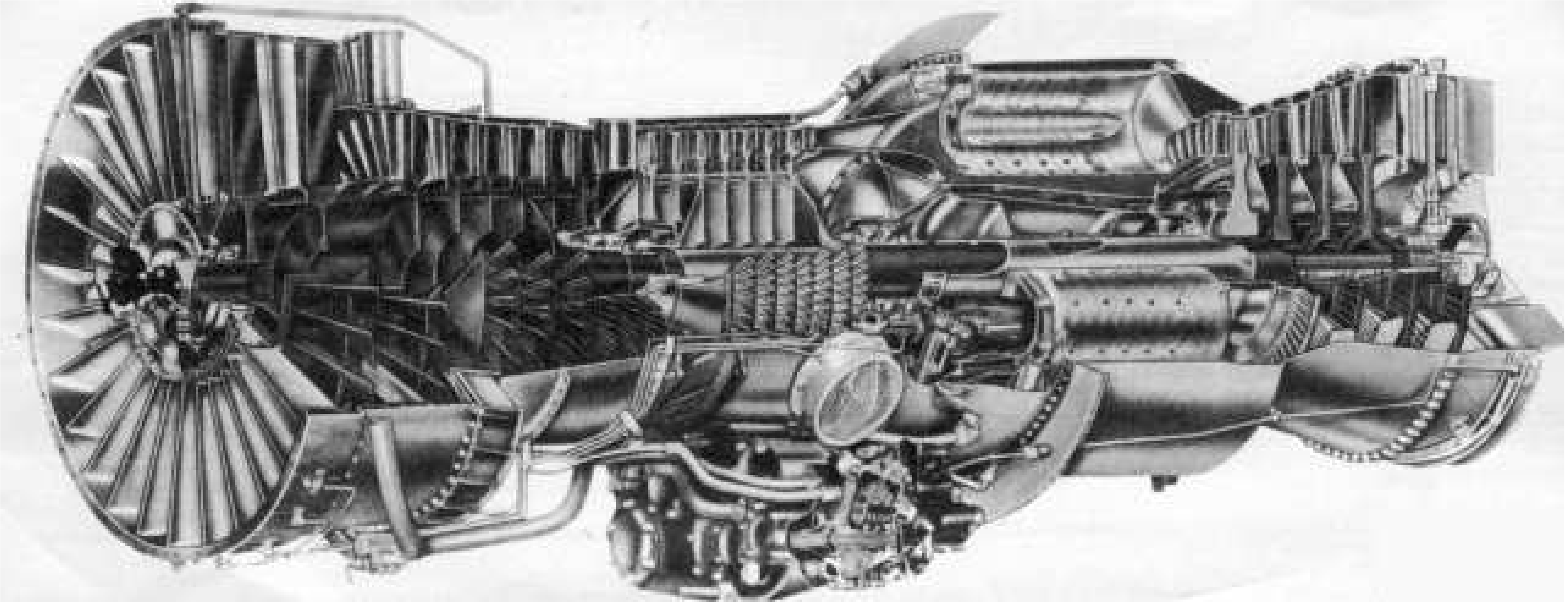
Popular Mechanics, **December 1969**

ENGINE CHARACTERISTICS

	P&WA JT9D-7A	P&WA JT9D-7A (WET)	P&WA* JT9D-7F	P&WA* JT9D-7F (WET)	GE* CF6-50E	P&WA* JT9D-70A	RR RB211-524B
TAKEOFF THRUST (LB, S.L.S.– FLAT RATED TEMPERATURE)	46 950 (TO 80°F)	48 570 (TO 86°F)	48 000 (TO 80°F)	50 000 (TO 86°F)	52 500 (TO 78°F)	53 000 (TO 86°F)	50 100 (TO 84°F)
BYPASS RATIO	5.15	5.15	5.15	5.15	4.3	4.9	4.35
THRUST/WEIGHT RATIO	5.28	5.44	5.38	5.57	6.14	5.71	5.09
PRIMARY AIRFLOW (LB/SEC)	250	253	255	259	280	271	273
TOTAL AIRFLOW (LB/SEC)	1 541	1 559	1 567	1 592	1 485	1 600	1 464
CRUISE THRUST AT 35 000 FT, STD +10°C, M_n = 0.85	10 670	10 670	11 050	11 050	11 650	11 950	11 085
WEIGHT (LB)	8 885	8 925	8 930	8 970	8 520	9 110	9 844
FAN DIAMETER (IN.)	93.0	93.0	93.0	93.0	86.4	93.6	85.5
WATER FLOW RATE (LB/HR)	—	26 000 TO 30 000	—	26 000 TO 30 000	—	—	—

*OPTION



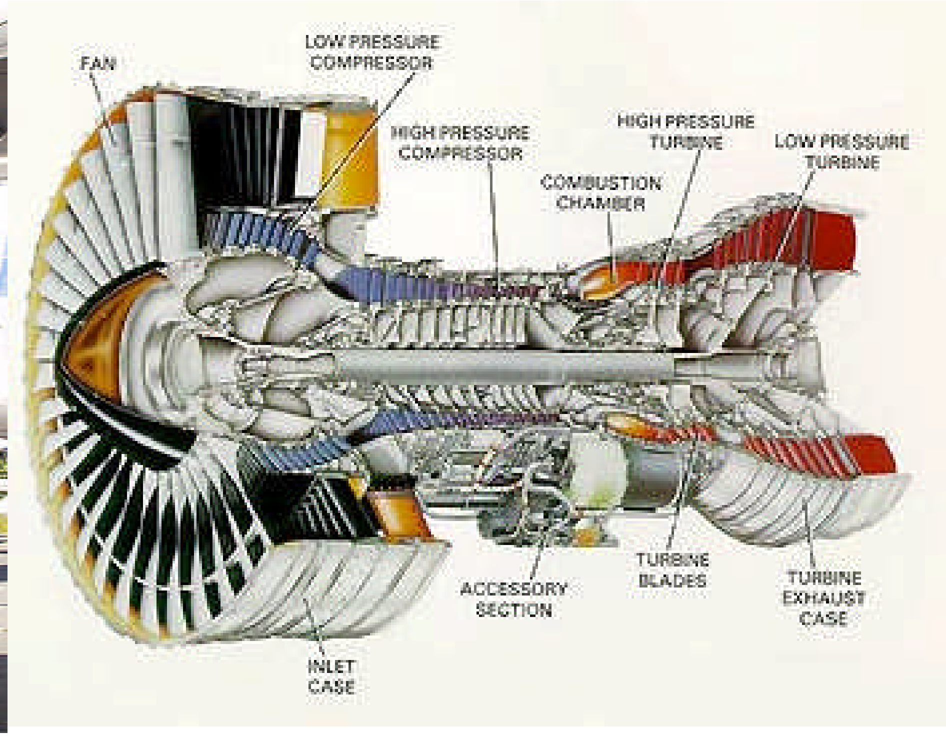


"…The big bird has four Pratt & Whitney JT9D turbofan units that are each capable of producing 43,500 pounds thrust, more than double that of the JT3D on the 707. Though the JT9D has an intake almost twice the diameter of the JT3D, it is six inches shorter than the latter and more efficient…"

Popular Mechanics, **December 1969**

<u>Above</u>: caption: "JT3D cut-away"

<u>Left</u>: caption: "JT3D (J57) Low-Bypass Turbofan"



"…Design advances in the combustion and compressor stages, for example, produce higher pressures than achieved in earlier models, fewer such stages are needed. Growth versions of the engine, with thrusts up to 47,000 pounds, are in the works…"

***Popular Mechanics,* December 1969**

<u>Left</u>: caption: "Pratt & Whitney JT9D, Prototype Boeing 747 'City of Everett' N7470"

<u>Right</u>: caption: "Pratt & Whitney turbofan engine cut-away view"

"…Research has also achieved a quieter engine. By lowering jet exhaust velocity, engine roar was lessened; the elimination of inlet guide vanes (stationary inlet struts) and a reduction in the speed of the fan at the front of the engine minimized the ear-splitting siren sound that is characteristic of turbofan engines. In addition, sound absorbent material was installed in the engine cowling, ahead of and behind the fan…"
Popular Mechanics, **December 1969**

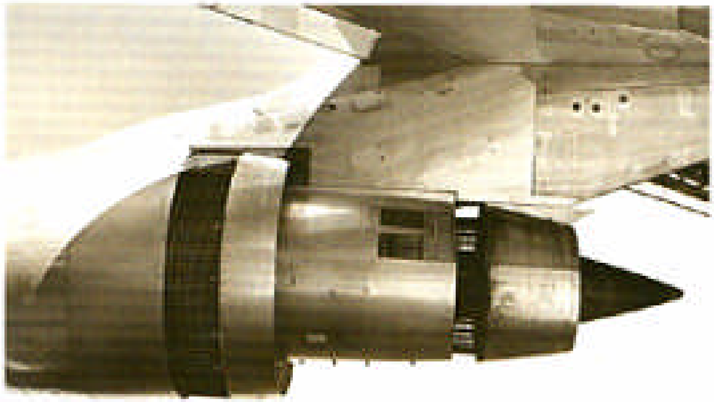
"There you sit, one of the lucky first passengers on Pan Am's inaugural 747 flight from New York to London. For almost 100 feet to each side of you, the monster wings spread out and back. Slung beneath them are the four most powerful turbo-fan engines ever mounted on a passenger plane. They total 180,000 pounds of thrust. Yet, as you glide down the runway on the takeoff run you are aware of their power more from the hefty push at the back of your seat than from the engine roar…"

***Popular Science,* December 1969**

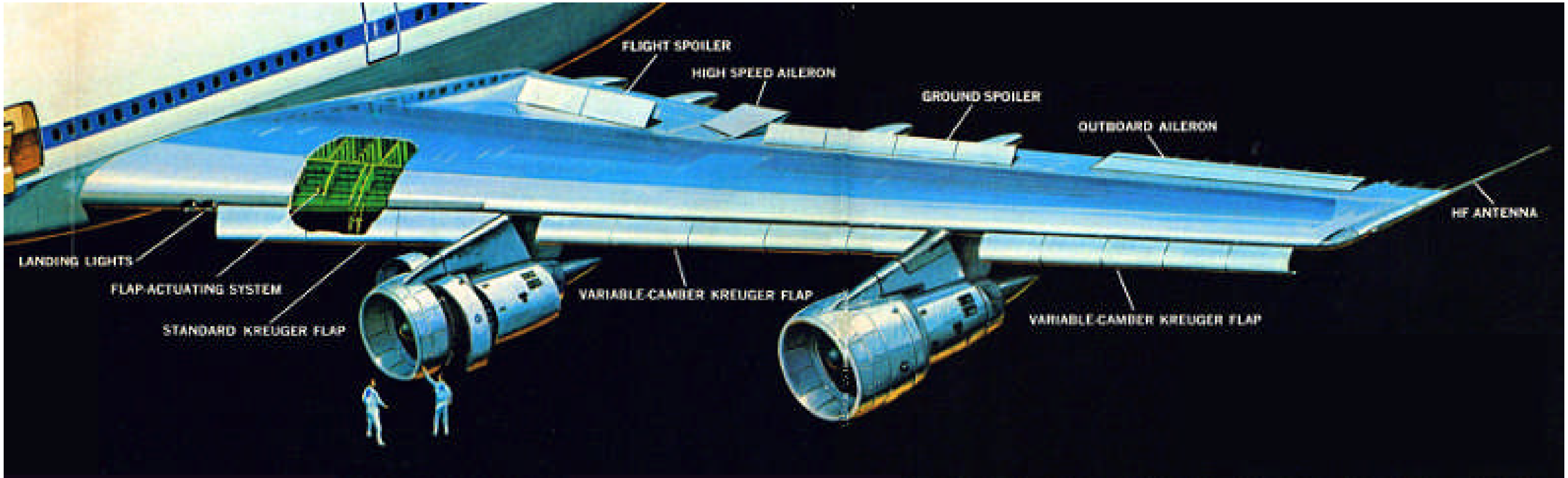
THRUST REVERSERS

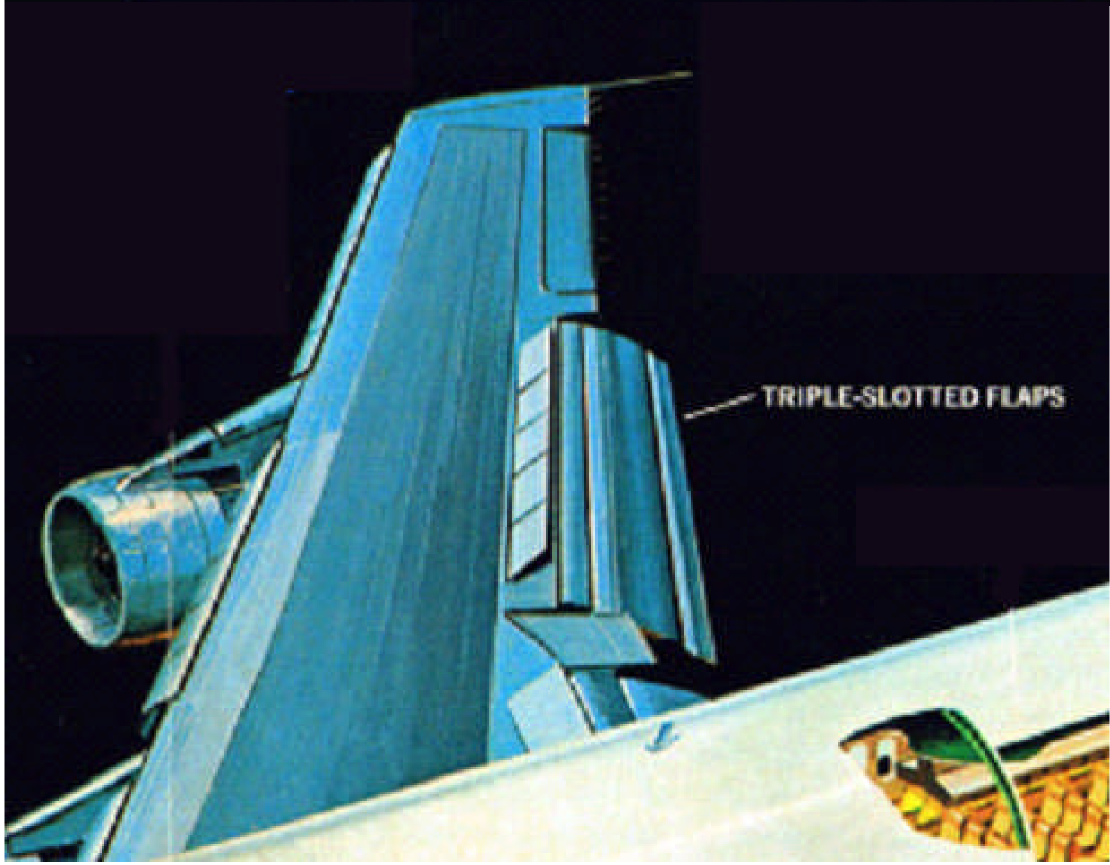
To reduce aerodynamic drag and maximize net forward thrust, the fan and turbine exhausts exit separately through annular nozzles. A thrust reverser is installed for each fan section. In the operation of the reverser, a sleeve that forms the outer wall of the forward-thrust nozzle moves aft to uncover peripheral cascade vanes. Closure of the normal exhaust path is accomplished by blocker doors hinged to the translating sleeve. The cascade vanes direct the exhaust outward and forward. At the customer's option, the turbine reverser can be installed on the Pratt & Whitney powered airplanes. It is installed with the CF6-50E option.

JT9D-7 THRUST REVERSER – CLOSED



JT9D-7 THRUST REVERSER – OPEN
(TURBINE REVERSER OPTIONAL)





"…The 747 can operate from runways used by the 707 and DC-8. This capability is due, partly, to high-lift devices in the wings. Flaps on leading and trailing edges add to wing area and direct the flow of air as to give the plane increased lift as it speeds down the runway…"

***Popular Mechanics,* December 1969**

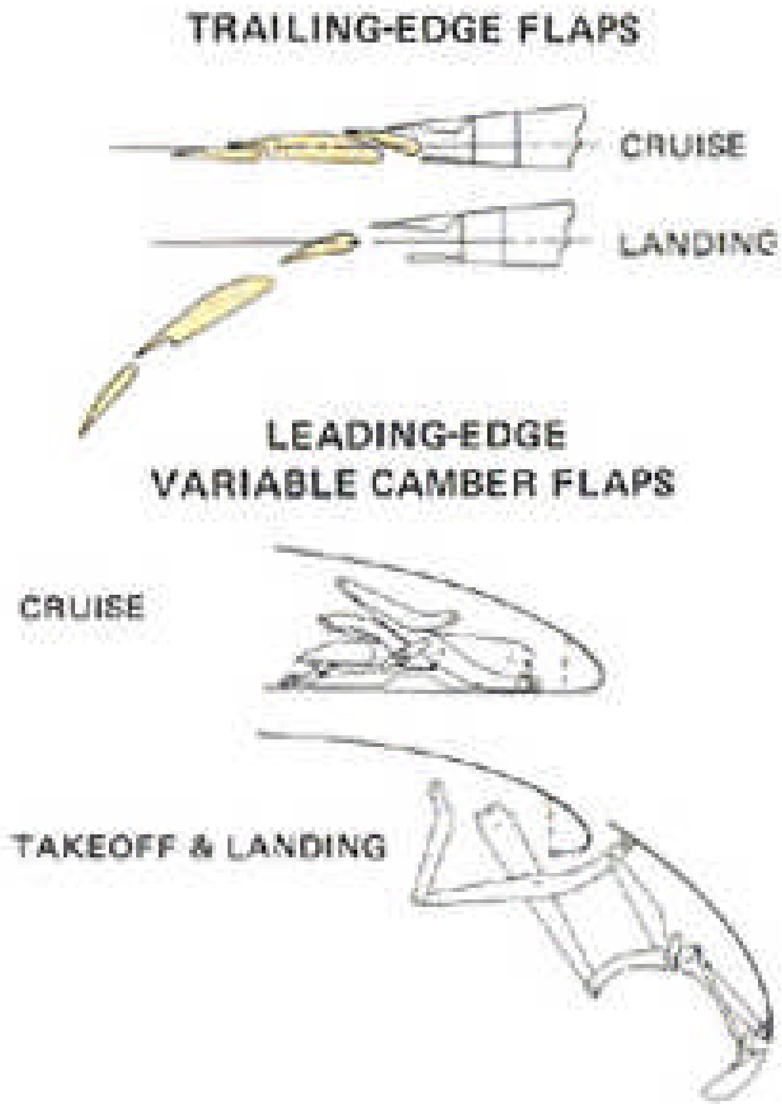
FLIGHT CONTROL

In the 747, all flight control surfaces are power actuated. Multiplicity of power sources, command paths, power actuators, and control surfaces have permitted manual reversion to be eliminated.

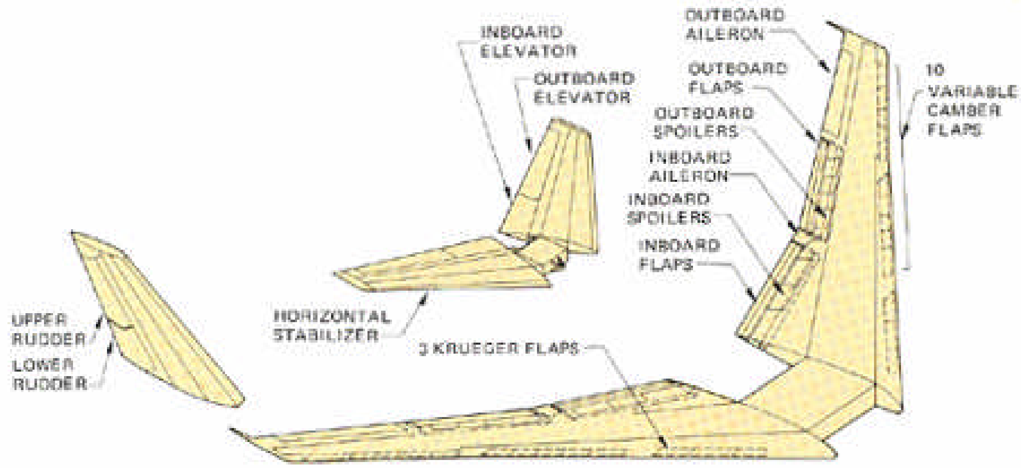
The primary flight controls consist of four ailerons, four elevators, two rudders, and a horizontal stabilizer. In addition, a system of leading-edge and trailing-edge high-lift devices and a spoiler system are provided. The normal type of actuation power is pneumatic pressure for the leading-edge flaps and hydraulic pressure for all the other surfaces.

Each aileron, inboard elevator, and rudder is driven by two independent hydraulic sources. The assignment of these power sources varies from surface to surface to maximize redundancy pressure and is chosen from four different pairings of the airplane's four hydraulic systems. Outboard elevators and spoilers are driven by single hydraulic sources. As a result of this variety of energy sources, airplane control for each of the three attitude axes (roll, pitch, and yaw) is powered by all four hydraulic systems.

In normal operation, hydraulic systems 2 and 3 have no assignment other than flight control. They are, in that sense, the basic flight control energy suppliers. However, even if both of these primary systems were to fail, the source redundancy is such that all of the aileron, elevator, and rudder sections would still be provided with power.




EVERGREEN

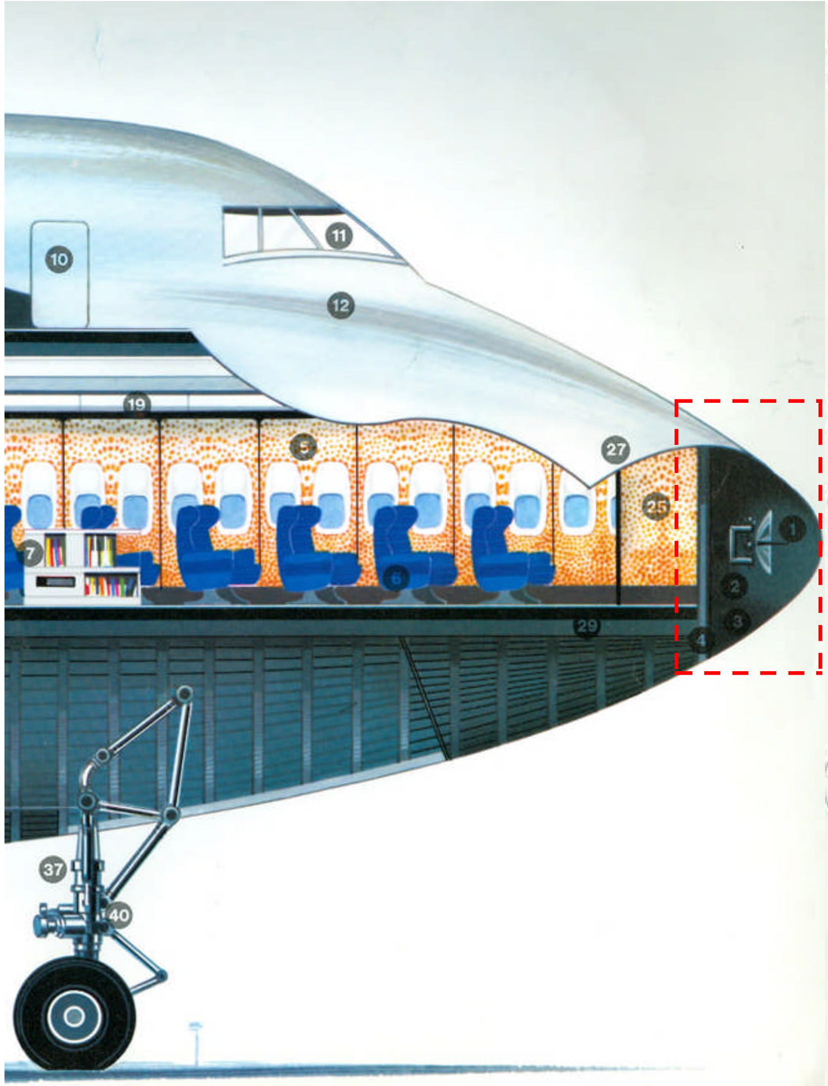


The 747 has a 37° sweep angle at the 25-percent chord which, with the lower wing thickness ratio, improves cruise speed. Yet it can operate fully loaded from existing airports used by 707-type aircraft. This performance is made possible by an advanced high-lift system.

Triple-segmented, triple-slotted flaps are installed on the wing trailing edge. Fixed and variable camber flaps are installed on the leading edge. Retracted, the leading-edge flaps fair with the underwing surface. During extension, the 20 outboard leading-edge flaps alter in shape, flexing from flat to curved. The resulting camber guides the airstream smoothly along the greater curvature path required for increased lift. Maximum extension of all flaps increases wing area by approximately 21 percent and lift by approximately 90 percent.

L’Anatomie Du Geant

<u>Above</u>: Air France's *Boeing 747-128 (*F-BPVJ) was delivered in October 1972 to *Air France* In 2000, Air France donated the Jumbo Jet to the *France Museum of Air and Space*. There, a very unique display can be seen whereby numerous sections of the cabin, seating and cargo deck have been cut-away, revealing the inner workings of the giant airliner.



1 WEATHER RADAR

RCA AVQ 30 weather radar system of an entirely new design, operating on a wavelength of 3 centimetres. This equipment makes use of the latest applications in the field of semiconductors and ferrites. *It receives echos from cloud formations 335 miles ahead of the aircraft, as compared with 170 miles with previous systems.*
This gives the pilot more time to change course if necessary. The system also gives a better image definition.

2 ILS ANTENNA (plane of descent)

3 ILS ANTENNA (localizer)

ILS (Instrument Landing Systems), one of which is an emergency standby, are designed to give lateral and vertical guidance to the aircraft during approach and landing.

4 FORWARD AND REAR BULKHEADS

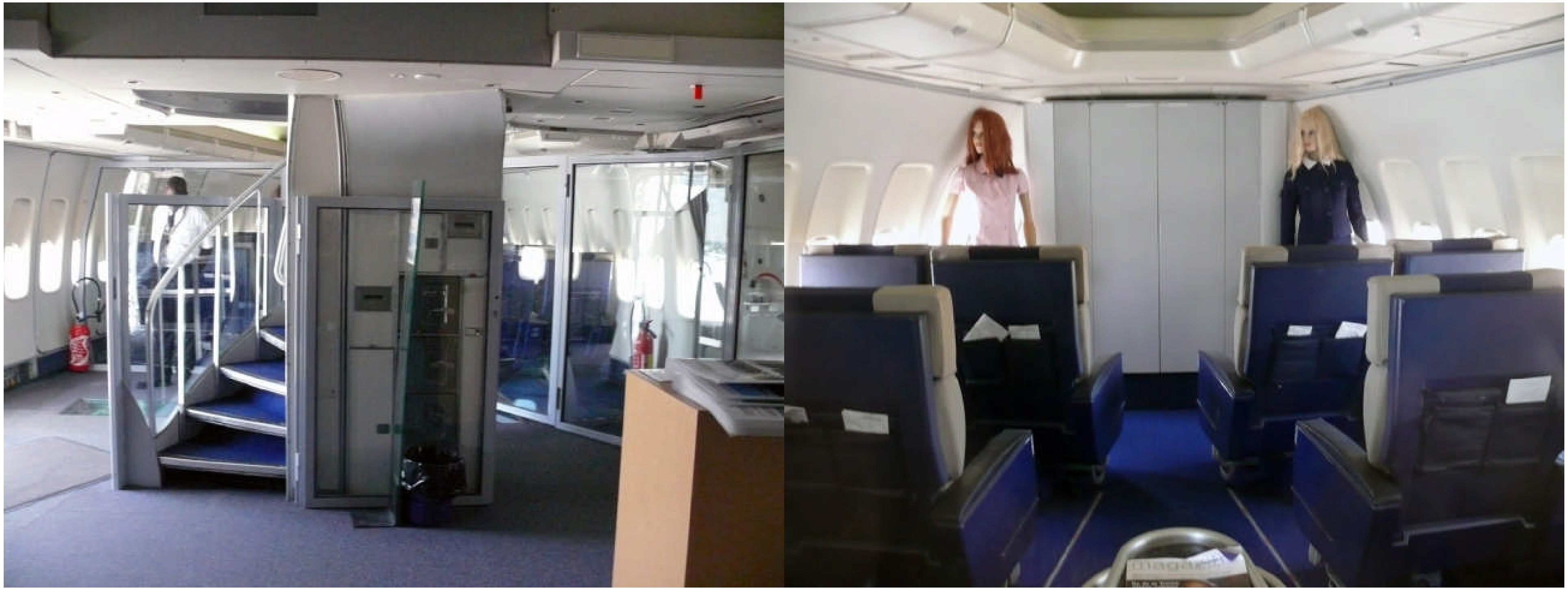
These two bulkheads enclose the front and rear extremities of the pressurized fuselage. The B 747's normal cruising altitude is around 35,000 feet, and the fuselage is designed for external pressures corresponding to 45,000 feet.
Whatever the plane's altitude, the pressure inside the passenger cabin always remains constant at the equivalent of about 5,000 feet altitude, and is permanently checked.

5) FIRST CLASS PASSENGER SALON (BLUE SALON)

A cloakroom is located at the forward end of this salon.
The movie screen is covered by a painting when not in use.
24 seats (equipped to receive movie soundtracks and music programs).
A spiral staircase leads to the Lounge Bar on the upper deck.
A galley unit serves First Class Passengers.
Twelve seats are placed to the rear of the First Class salon.

"…If you're in the most forward compartment under the pilot's, you are getting an unprecedented view. The 747 is the first plane in which some passengers can look ahead and to one side, although they still won't get the pilot's full head-on view…"

***Popular Science*, December 1969**

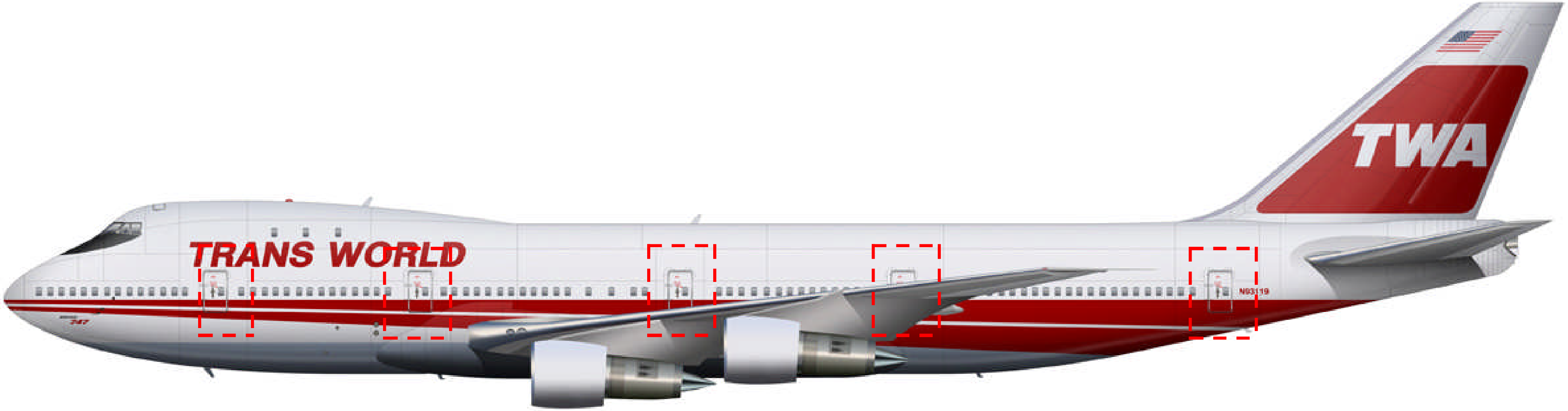


6) FIRST CLASS SEATS

Because the fuselage of the B747 tapers toward the nose, the seating configuration of the forward section is quite original. Seats are arranged two by two on each side of the central aisle, in front of the spiral stairway leading to the lounge bar.
There are 36 spacious and comfortable seats in First Class, all of them arranged in pairs.

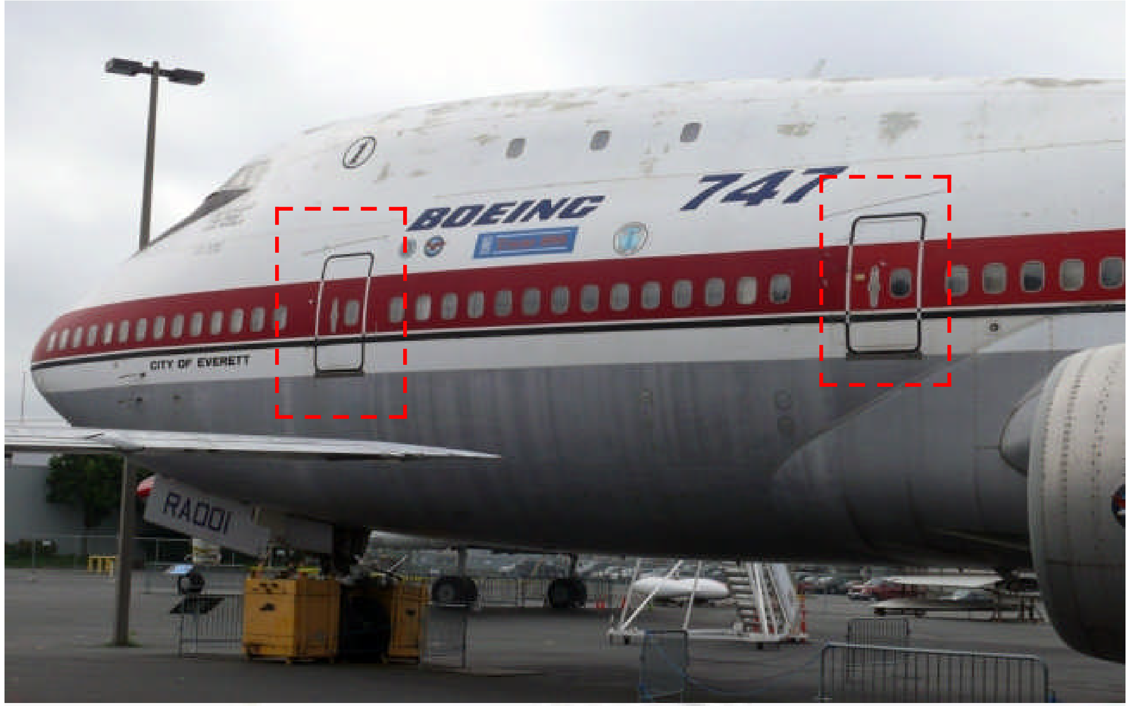
"…To speed loading, passengers will assemble in four waiting rooms instead of one and will enter the cabin through four double-width doors. Baggage will be routed from the plane to the claims area on high-speed conveyor systems…"

***Popular Mechanics,* September 1966**



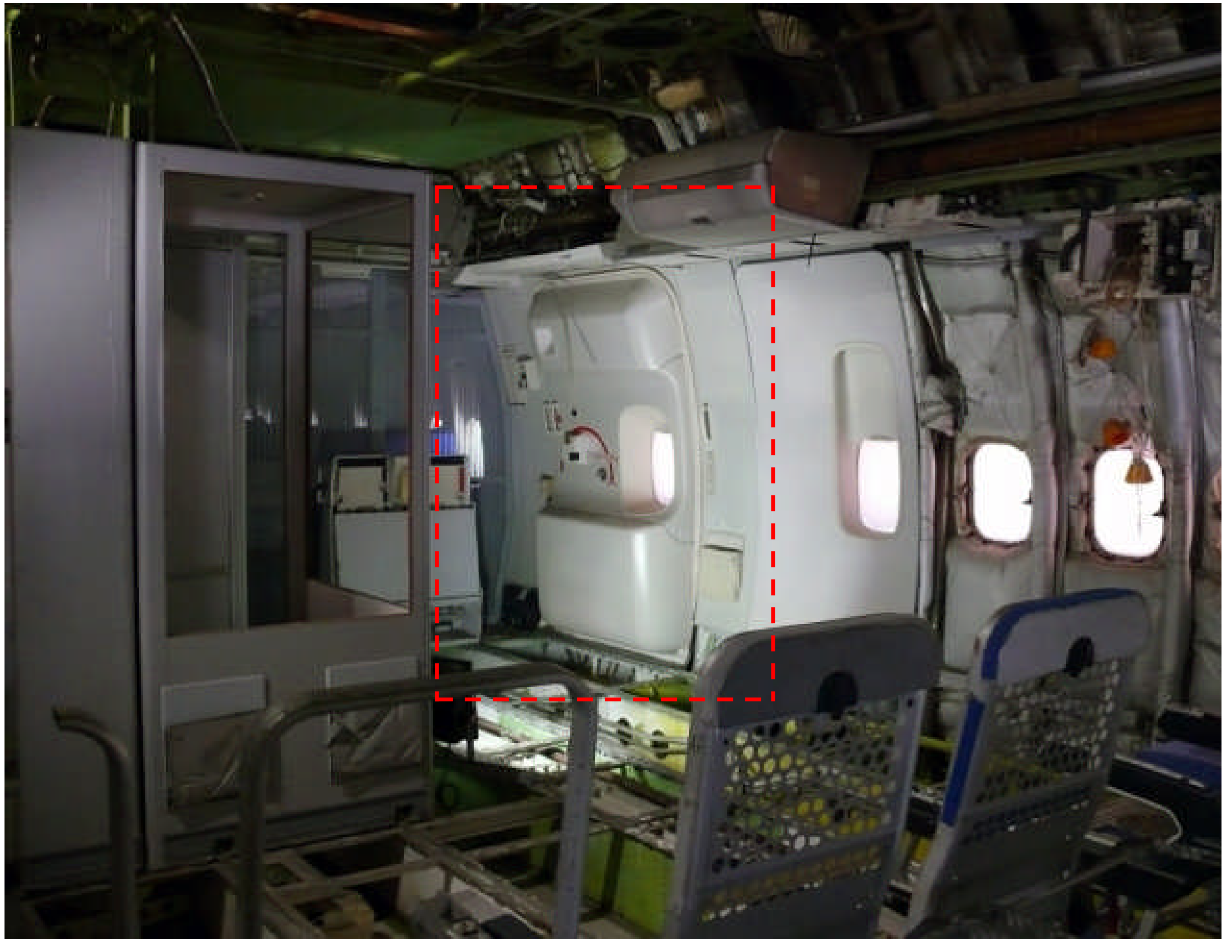
9 ENTRY DOORS

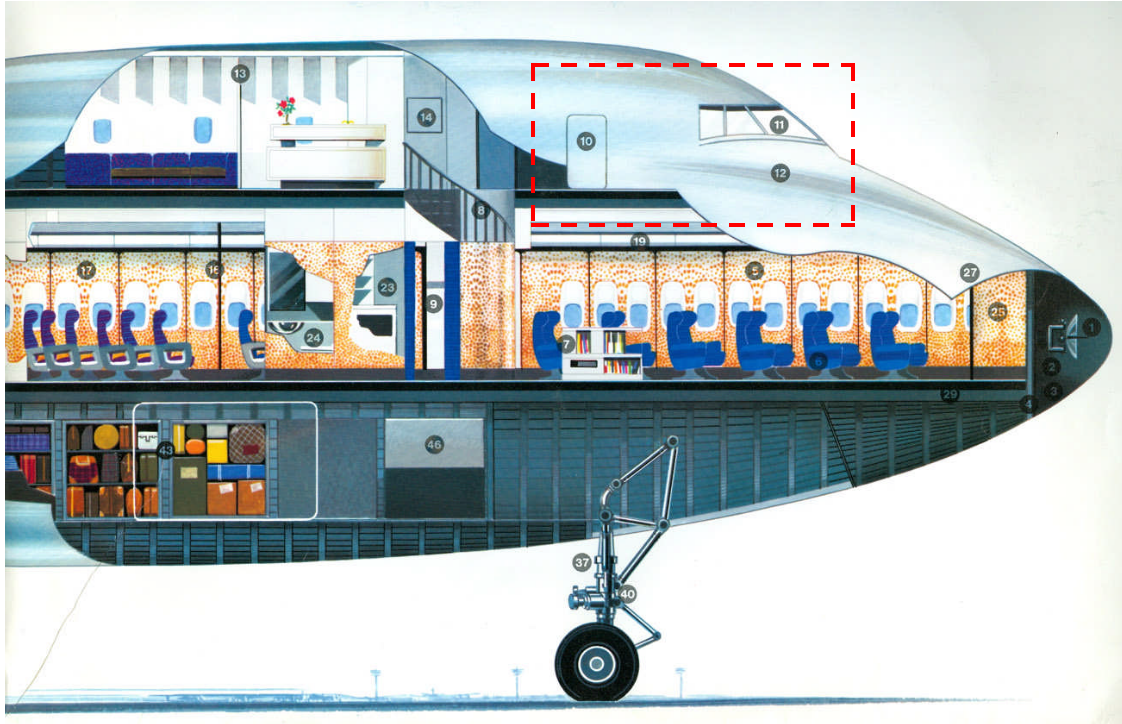
There are ten entry doors, five on each side of the fuselage. They are wide and high, allowing two passengers to enter abreast without lowering their heads.
Dimensions: width 5′6″, height 6′3″.
They are 17′6″ above the ground.


BOEING
747
CITY OF EVERETT
RA001


N7470


BOEING 747
HS-VGB
PAN AM





(10) CREW DOOR

This door gives access to the flight deck, and is 27′5″ above the ground.

(11) FLIGHT DECK

Flight crew stations.
Main instrument panel.
Other instrument panels on the sides and ceiling of the flight deck.
All the flight controls are actuated through irreversible hydraulic servo-mechanisms.
Control of all hydraulic, electric and electronic equipment.
Two Bendix central air data systems provide information on altitude, static temperature, airspeed and mach number (the Boeing 747 is not a supersonic aircraft; it flies at mach 0.90).

(12) INERTIAL NAVIGATION SYSTEM


BOEING
747
CITY OF EVERETT

747
Trent 890
CITY OF EVERETT

12) INERTIAL NAVIGATION SYSTEM

Newton's first law of motion states that every body will continue its state of rest, or of uniform motion in a straight line, unless it is compelled by the action of external force to change that state. Inertial navigation makes use of highly advanced technology, directly derived from space science. In very simplified terms, the inertial navigation platform is a device which calculates the latitude and longitude of the aircraft *ten times each second*, in other words it provides a permanent "fix." This system was used for the first time aboard American atomic submarines, which can remain submerged for a very long time, during which they have no other method of determining their position.
Since velocity is the differential coefficient of distance with respect to time, and acceleration is the differential coefficient of velocity with respect to time, it is possible, by integrating twice, to deduce from the aircraft's acceleration (measured accurately) its speed and its distance from a given point – the point of departure on the airport runway.
To perform this operation, accelerations must be measured to an accuracy of one millionth of a G. The measuring instrument aboard the plane must be completely insulated from all forces and effects such as pitching, rolling, banking and vibrations, as well as from external gravitational forces.
To this end, it is mounted on a platform which is stabilized by means of costly, high-precision gyroscopes, which remain pointing in the same direction relative to interstellar space and not relative to the earth.
The axes of these gyros rotate on air bearings; their system is also immersed in a fluorine liquid, which further reduces friction. Whereas conventional gyros have a drift of one degree an hour, these tolerate only one hundredth of a degree.

(continued…)

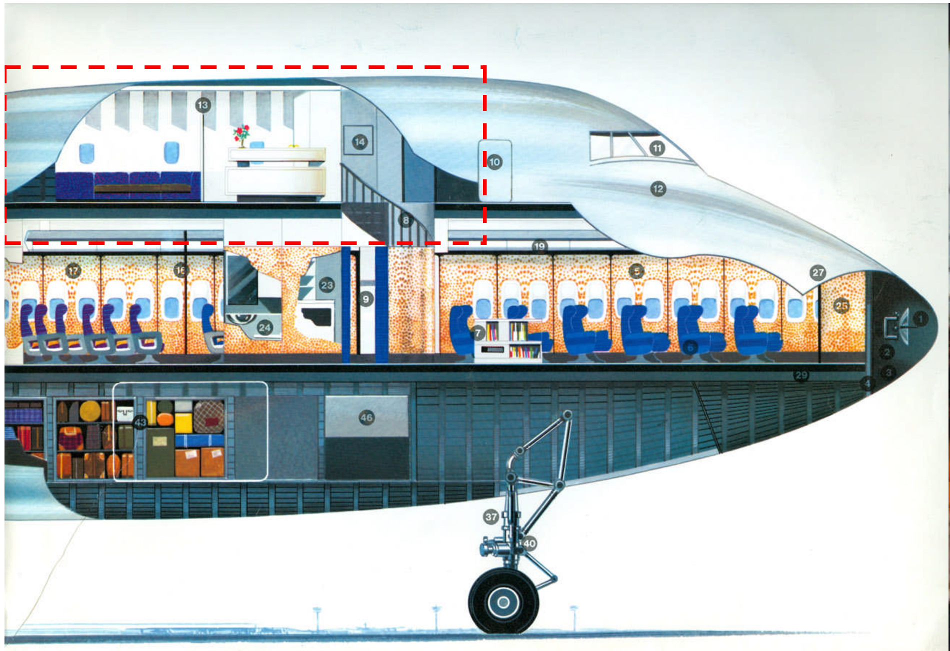
12) INERTIAL NAVIGATION SYSTEM (cont'd.)

This is the first time that a commercial aircraft has had this system of navigation built-in by the manufacturer.
A number of Air France's Boeing 707's are equipped with these inertial navigation platforms, but they were fitted subsequent to delivery.
Air France's Boeing 747's are equipped with three Carousel IV inertial navigation systems, designed and built-in as part of the aircraft's instrumentation by AC Electronics, a division of General Motors Corporation of Milwaukee.
Weight: 50 x 3 lbs.
Cost: $100,000 each, total 3 x 100,000 = 300,000 dollars.
Each of Air France's eight Boeing 747's is equipped with these three completely independent inertial systems. They are located on the flight deck, one on the left for the use of the Flight Captain, the other on the right for the use of the pilot; and the third as an emergency reserve which can be brought into service immediately if need be.
They are the "brain" of the aircraft.
The system keeps the crew informed of the latitude and longitude of the aircraft, its position in relation to a section of the great circle route which is part of the predetermined flight plan, its ground speed and drift, geographical course, true course, and wind force and direction.
The data provided by the accelerometers is processed by electronic computers which correct any errors which may be introduced by the earth's rotation or by the fact that the earth is slightly flattened at the Poles. They finally indicate the exact position of the aircraft, its distance to the next way-point, the time necessary to reach that point, and the course to follow.
These units give the directional and vertical gyroscopic references which are used by the flight instruments and by the two Sperry compass couplers.

(continued…)

12) INERTIAL NAVIGATION SYSTEM (cont’d.)

The system also gives steering signals to the automatic pilot to enable the aircraft to follow a predetermined route.
Each internal navigation platform has to be adjusted or aligned every time the aircraft takes off. This operation requires a quarter of an hour. The pilot enters the coordinates of the point of departure and of future way-points. The platform is coupled to a computer into which this program is fed.
The flight program can be modified if necessary.

13) LOUNGE BAR (Upper Deck)

Located above the First Class cabin, from which it is reached by an internal staircase, this vaulted lounge bar is a pleasant spot for First Class passengers to chat and drink. Around the walls, recesses containing contemporary-style seats alternate with low tables. The floor and seats are covered with a thick, plum-colored carpet, while the bar itself and the cushions are in light genuine leather.
Indirect lighting provides a soft, restful atmosphere.
Additional light comes through six large windows, three on each side.

14) CREW TOILETS

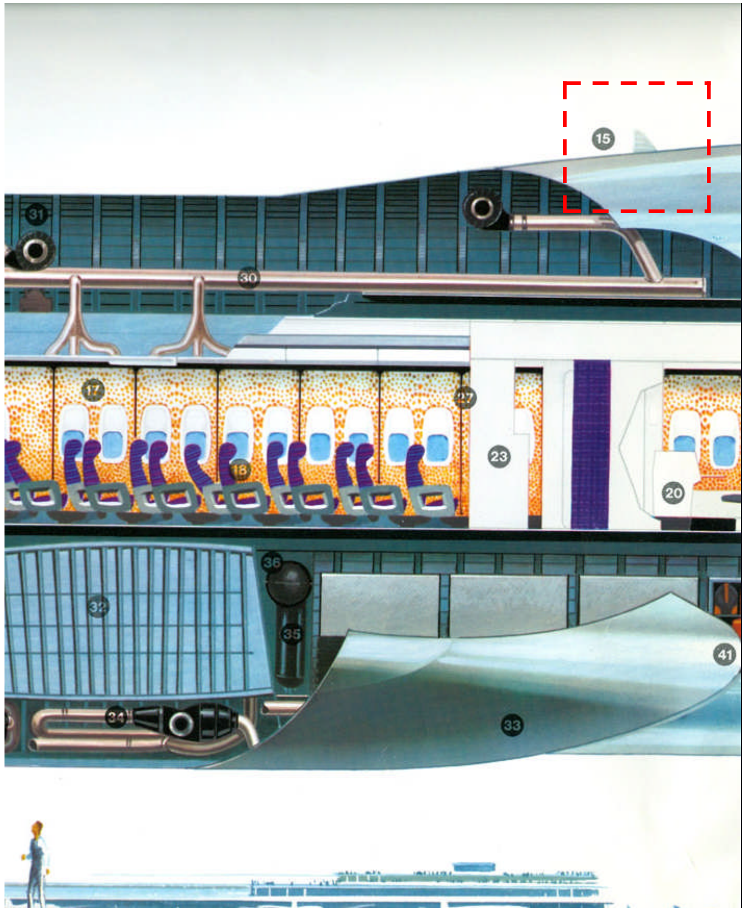
Located on the Upper Deck, between the Flight Deck and the Lounge Bar, these toilets are for the priority use of the crew.
But they are also available to First Class passengers using the Lounge Bar.

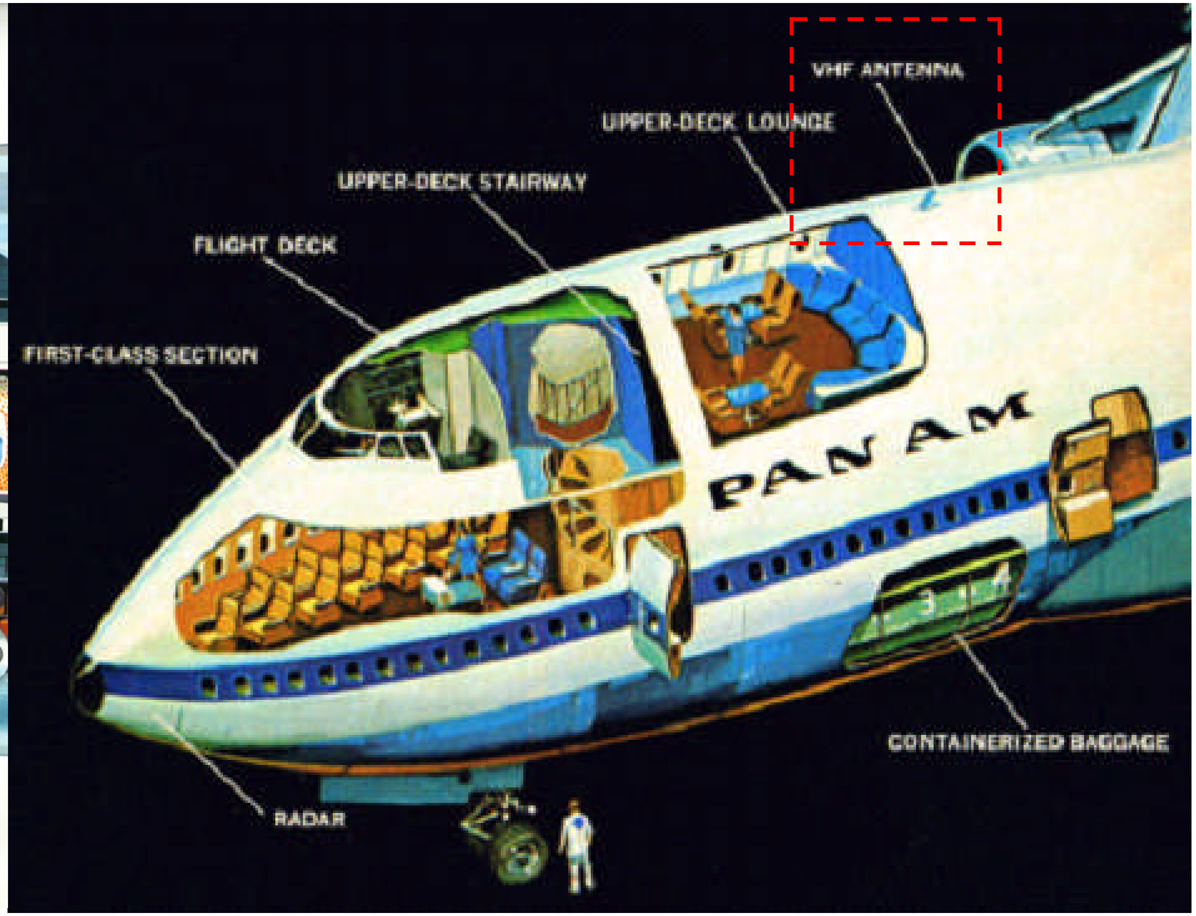
<u>Above</u>: *Braniff International Airways* (BIA) operated a lone *Boeing 747-100* from 1971 to 1978. When the 747 was introduced (during an economic recession), passenger capacity exceeded demand. Also, the Upper Deck was not initially certified to carry passengers during takeoffs and/or landings. Thus, airlines used them as premium lounges (*Continental* and *American Airline/s* even added pubs and organs in theirs). Braniff's lounge was intimately stylish, very much of its era.

<u>Above</u>: model of Braniff's famous 747-100 (a/k/a "The Great Pumpkin" and/or "Big Orange"). This 747 flew from Dallas-Fort Worth to Honolulu daily and had the distinction of being the most utilized Boeing 747 in the world. Until service to London commenced, it was the defunct airline's only 747. Big Orange flew the last BIA scheduled flight (before it went bankrupt in May 1982).

"…Trips from New York to London will be about an hour shorter than in the 707 or DC-8. Along the route, the pilots will never be out of touch with VHF ground stations. Eventually, they will bounce direct-voice communications via satellites in parked orbits 22,000 miles in space…"

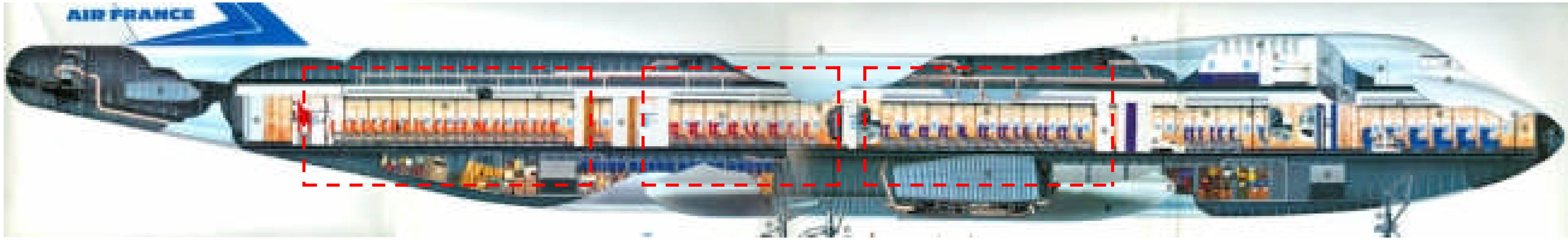
***Popular Science,* December 1969**

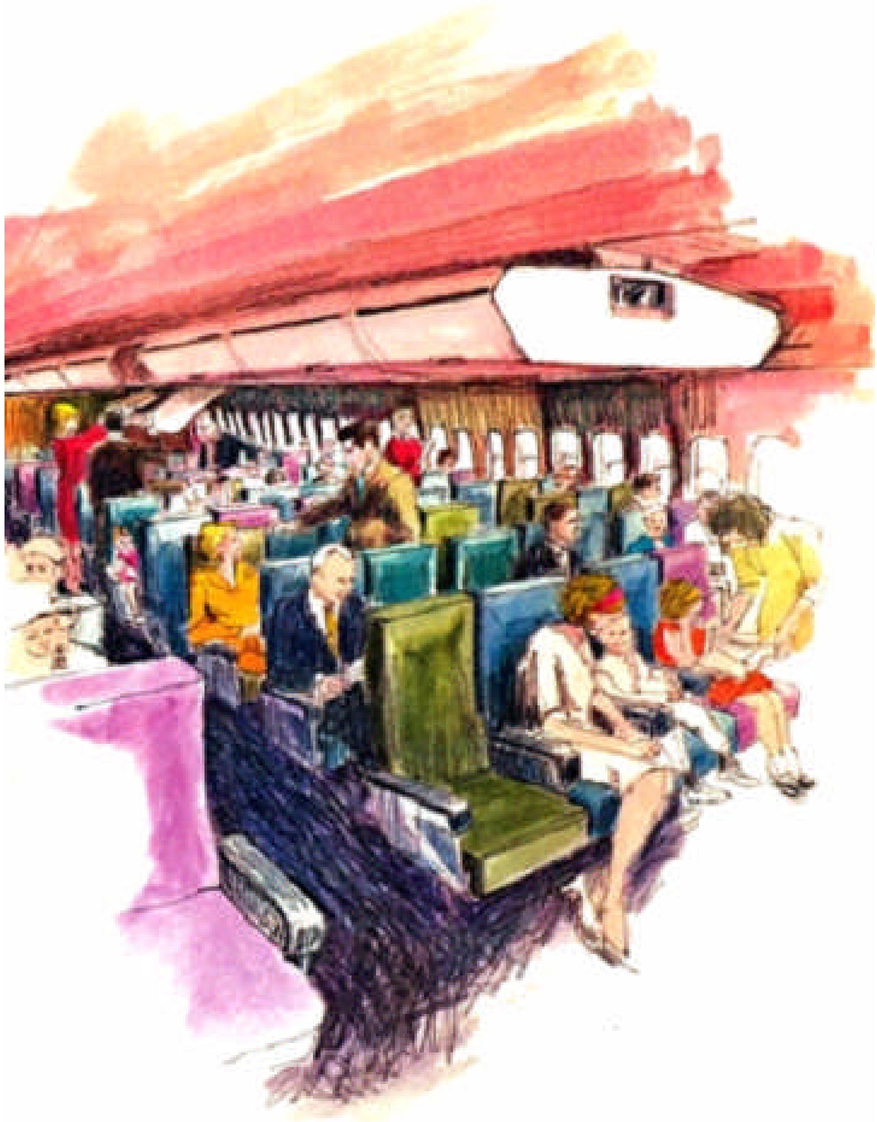




13) VHF ANTENNAE

For long- and short-distance communication purposes, the Boeing 747 possesses a particularly comprehensive and well-designed set of equipment.
In addition to conventional telecommunications systems (HF and VHF transmitters and receivers), the aircraft may subsequently be fitted with electronic equipment to allow communications via satellites high above the earth.
The Boeing 747 has three VOR receivers (very high frequency omni-directional radio-range) which pick-up signals from radio range beacons transmitting at very high frequency.





17) VIOLET SALON

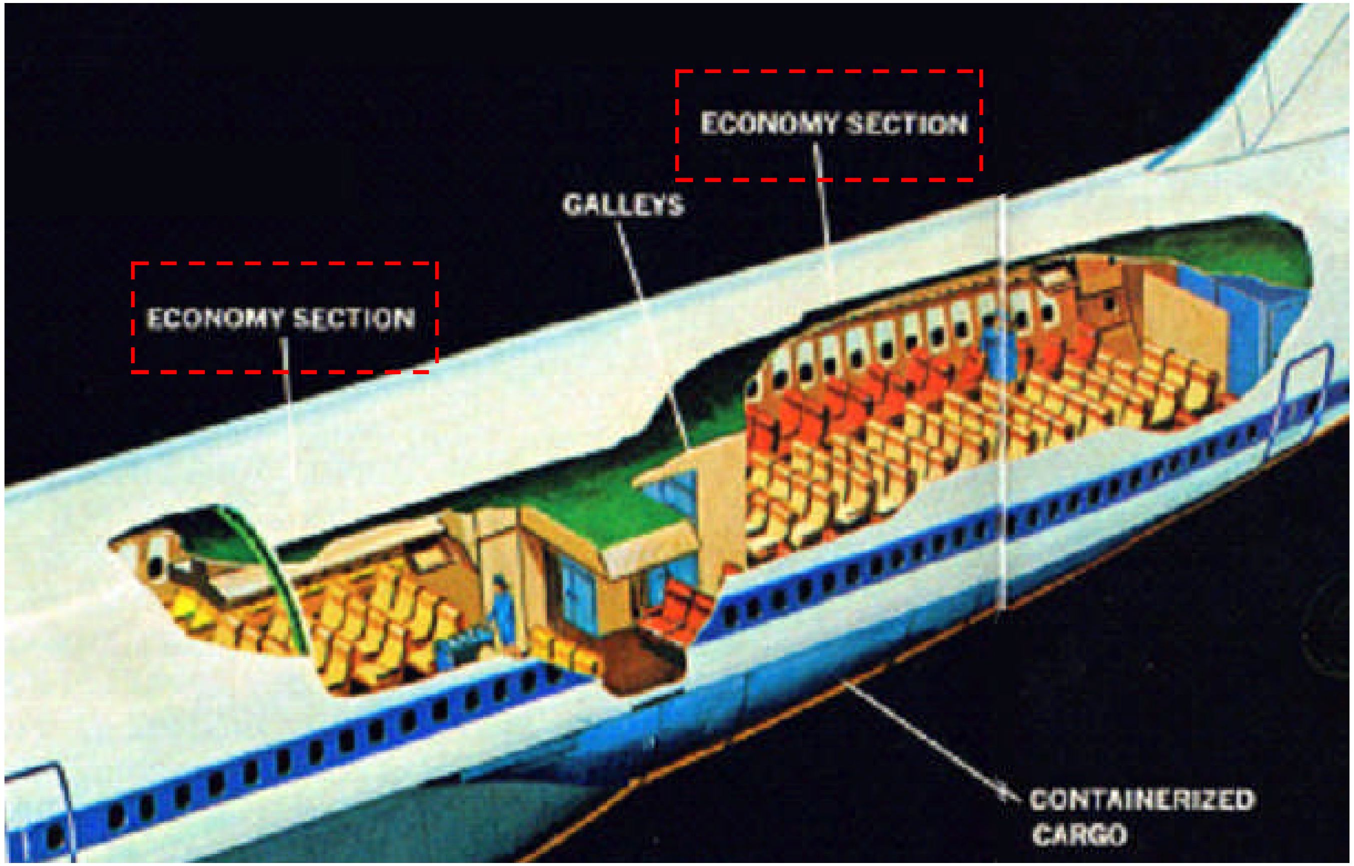
There are three different salons in Economy Class.
The Violet Salon is the largest of them. It can accommodate 28 passengers in the forward section, the area reserved for those who do not wish to watch in-flight movies. This section also includes the Chief Steward's station, and the extensive galley complex adjacent to the No. 2 doors.
The rest of the Violet Salon lies behind this compartment: it can accommodate 100 passengers, in seats arranged nine-abreast.

21) RED SALON

Located between doors 3 and 4, this salon can accommodate 82 passengers in nine-abreast seating.
It is approximately in the middle of the Economy Class Section of the aircraft.

22) YELLOW SALON

This salon is at the rear of the plane, and can accommodate 114 passengers in nine-abreast seating, plus seven additional seats.
This is the most spacious salon of all. The free space between the cabin wall and the rear side seats are specially equipped to receive babies' cradles, conveniently near cloakrooms and toilets. Here too is the rear Economy Class galley complex. For all these reasons, the rear section of the cabin will doubtless be preferred by passengers traveling with young children.


ECONOMY SECTION
GALLEYS
ECONOMY SECTION
CONTAINERIZED
CARGO


18 ECONOMY CLASS SEATING

Each row of two or three seats has only two legs, made of high-strength aluminium alloy. These new seats are wider than those aboard the Boeing 707 (an additional 6 inches for each row of three). The armrest between the seats can be raised; in the front section of each armrest are housed the individual selector knobs for selecting music and movie channels.
The seat and back of each armchair are upholstered in foam polyester.
The seat and back are hinged, so that when the back is reclined the seat moves forward.
There are side-rests for the head on each side of the back.
The back of each seat incorporates a table and a pouch for books, newspapers, etc. Under each seat is an easily accessible life-jacket. Every seat also has its safety belt, ashtray, reading lamp switch, and service push-button.
The Boeing 747 can carry 490 passengers, but the Air France version has only 360 seats, 36 in 1st Class and 324 in Economy Class.

(19) INDIVIDUAL HAND-BAGGAGE HOLDERS

Hand-baggage is stowed in individual pull-down holders above passengers' heads, 6'2" above the floor.
They are high enough to allow passengers to stand up without bending.
They are arranged in four parallel rows, one on each side and two in the middle of the cabin, on either side of the ceiling lights.
A low step allows easy access to these holders.

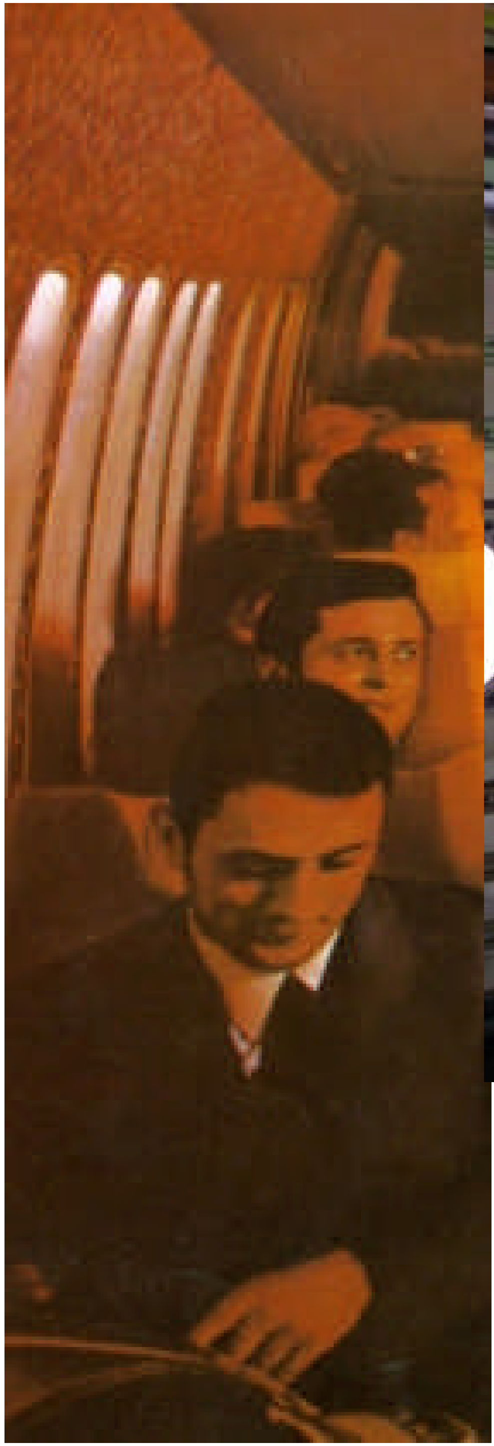
23 GALLEY UNITS

The Boeing 747 has three galley units. One of them, in the forward section of the plane, is reserved for 1st Class passengers. The two others are in Economy Class, adjacent to doors no. 2 and 4, to facilitate the loading and unloading of catering supplies and equipment. They are high-capacity units, incorporating fats-heating electric ovens, refrigerators, hot water boilers, dish distributors, and cupboards for trays and crockery.

To facilitate service, these galleys are accessible from both ends.

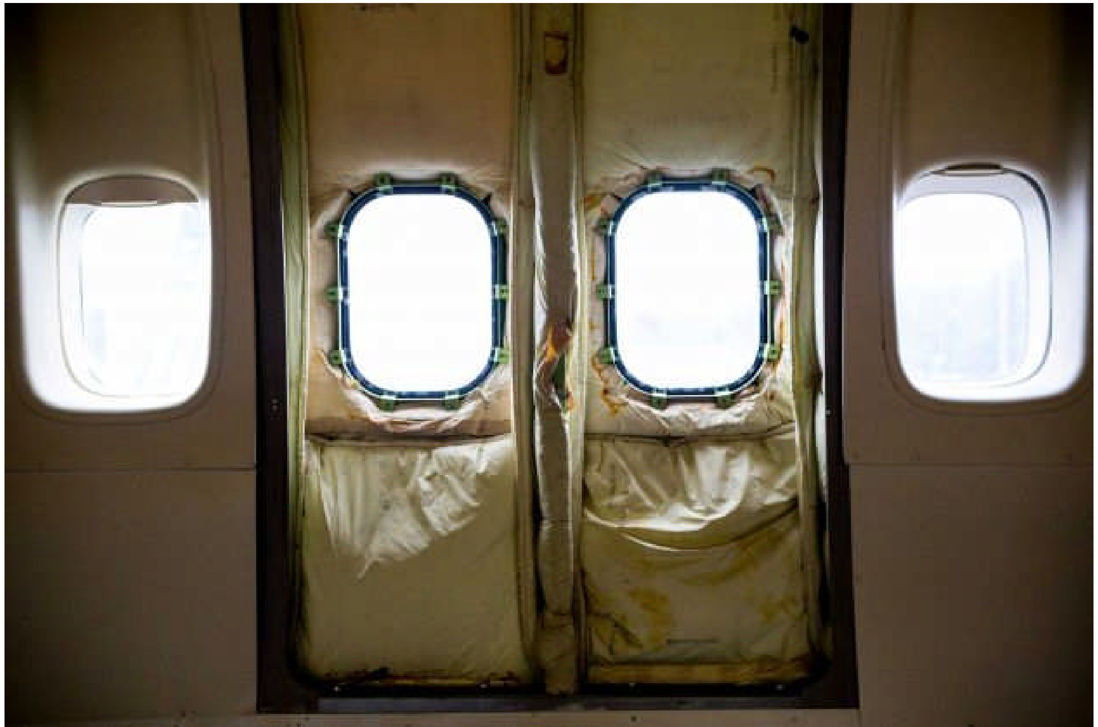
24 THIRTEEN TOILETS

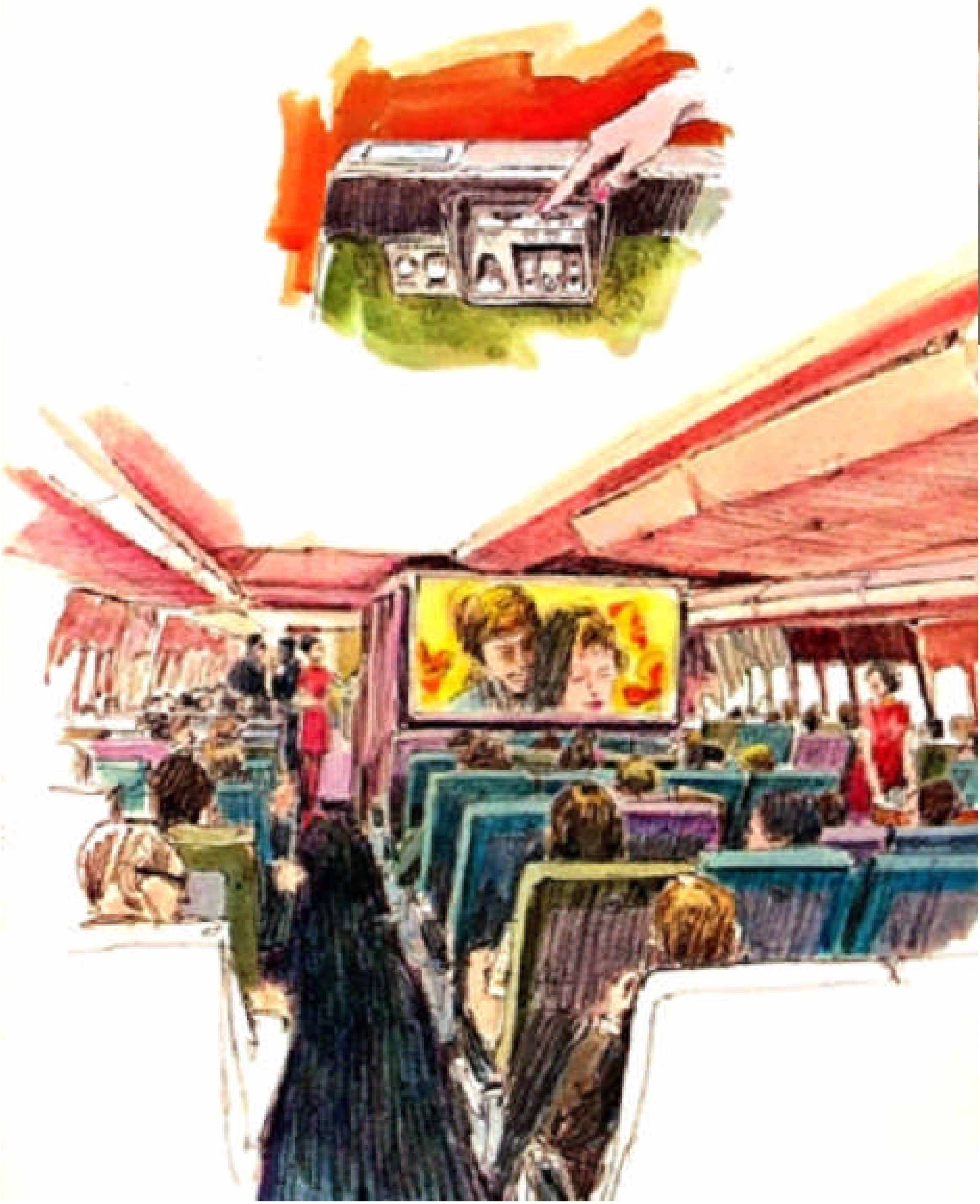
Thirteen toilets are at the disposal of passengers aboard the Boeing 747: one on the upper deck, two in the forward section, four in the centre section, and six in the rear.



26 WINDOWS

The windows are in tinted plexiglass, filtering out ultra-violet and infra-red rays at high altitudes.
They are double-glazed, with reinforced frames riveted to the sides of the fuselage.
The Boeing 747 has 181 windows altogether.





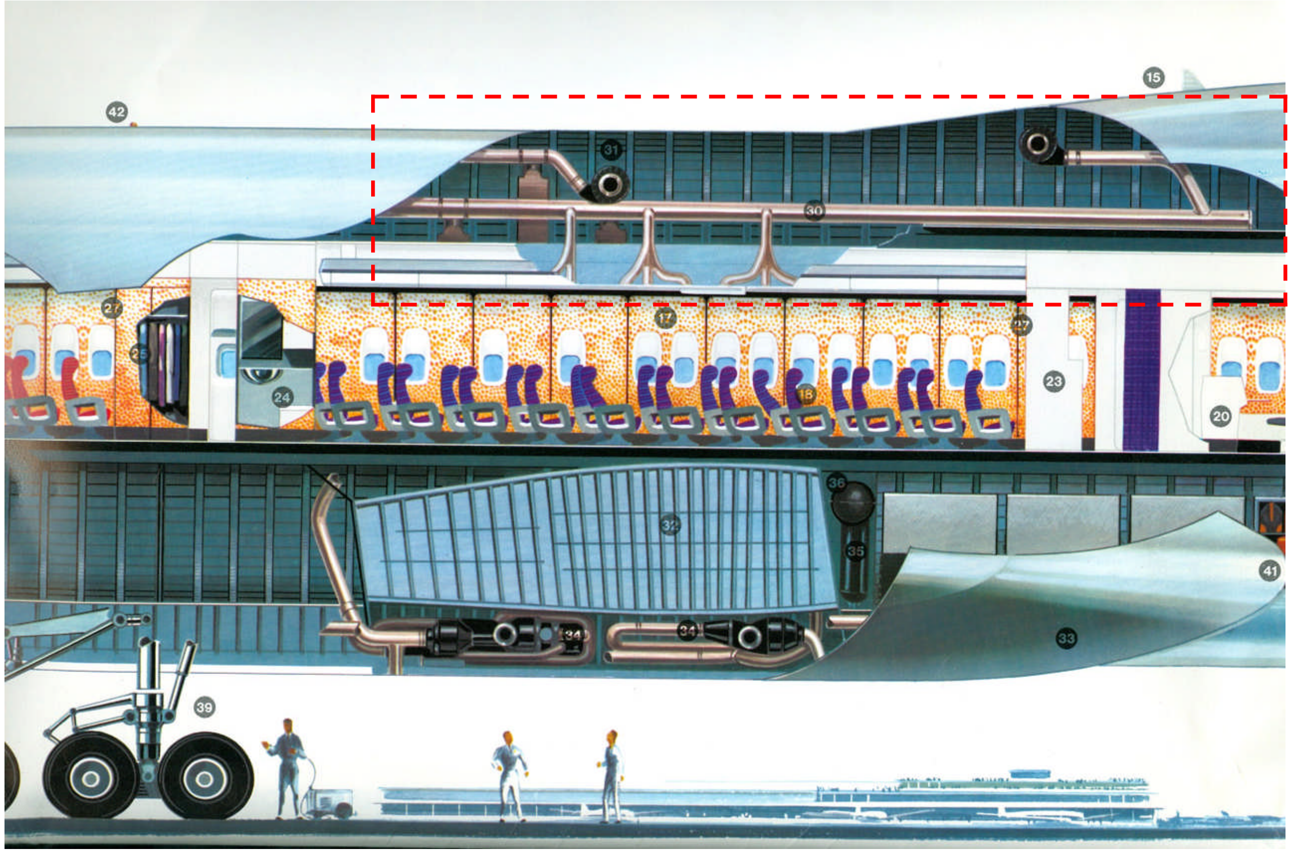
27) Movie Screens

The passenger cabin may be converted into four motion picture theatres, comprising four different screens and four individual projectors built into the ceilings. The same program (Inflight Motion Pictures, Inc.) is screened in all four salons: a feature film in color on a wide screen. Selector knobs for film soundtracks and music programs (the sound comes through individual headsets) are incorporated in the seat armrests.
A slight extra charge is made for the use of individual headsets.


FLY PAN AM
PAN AM
With our compliments
for your inflight enjoyment
and
as a souvenir of
your travels with us
PAN AM

29) CABIN FLOOR

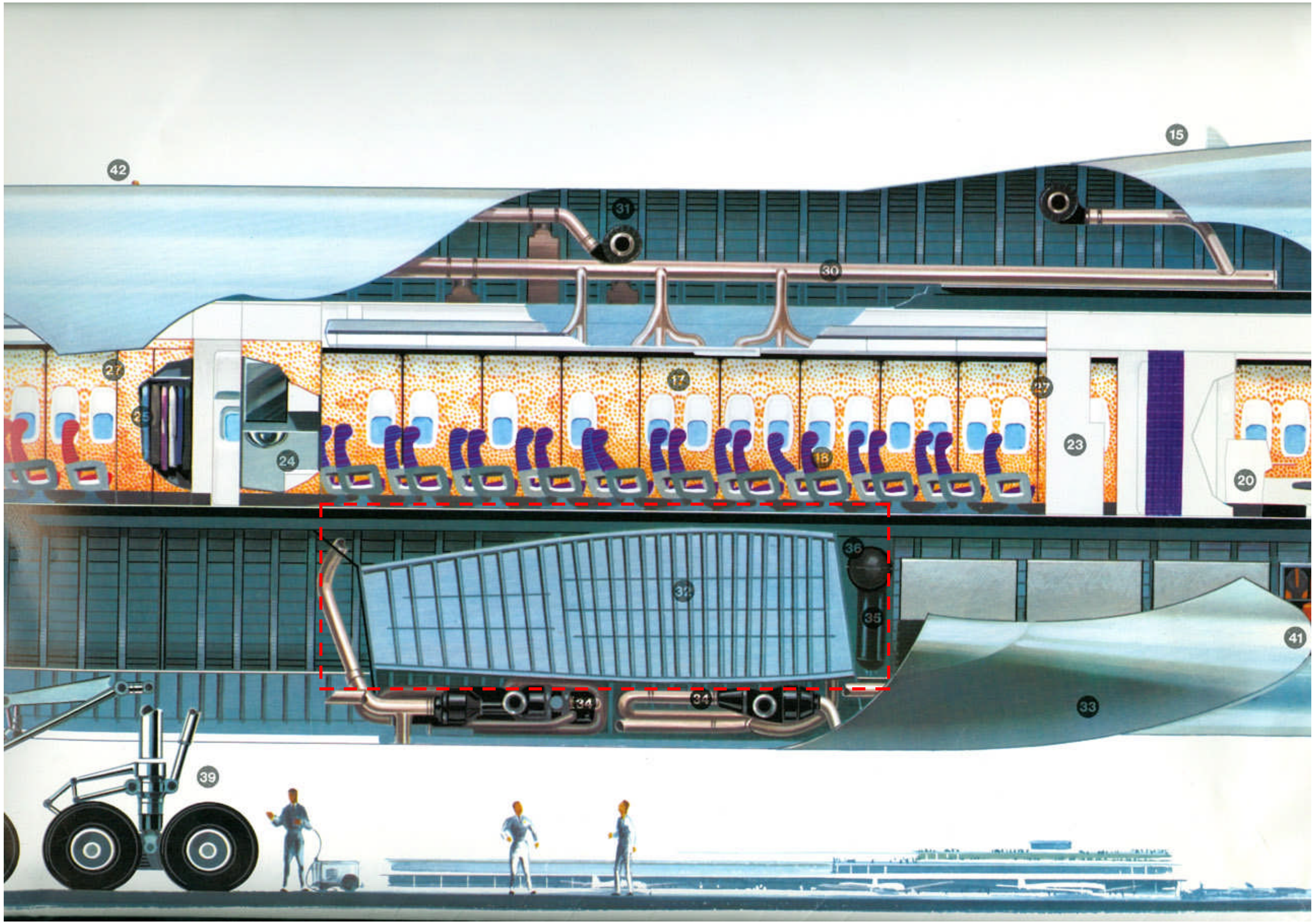
The cabin floor consists of sandwich-type panels, 4’ x 12’, 4” thick, with a core consisting of expanded polyvinyl between two sheets of titanium 0.001” and 0.0047” thick.
The panels weigh 0.6 lbs. per square foot.
Total floor area: 3,240 square feet.



30) AIR-CONDITIONING DUCTS

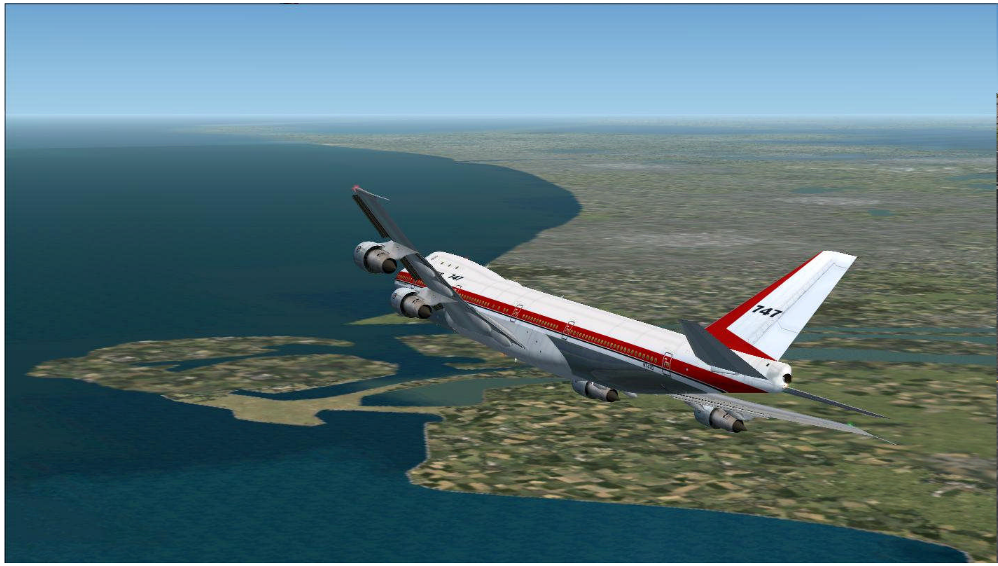
Ducts of various diameters carry fresh, heated and pressurized air to all parts of the passenger cabin (ceiling, walls, floor), as well as to the holds.
The flight deck is also air-conditioned.
The air temperature (average 23-degrees C, 75-degrees F) is controlled either automatically or manually in each zone. Fresh air is supplied at the minimum rate of 20 cubic feet per passenger per minute.

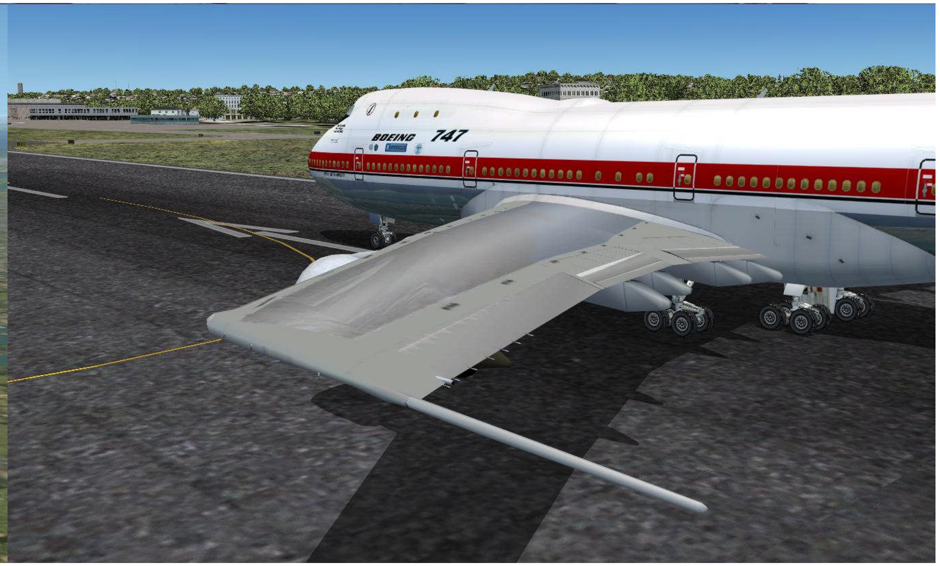
31) RECIRCULATION FANS



32) MAIN CENTER-SECTION SPAR BOX

This spar box weighs ten tons. The stabilizer measures 72’ by 32’ 10” and weighs 4 tons. The tail fin is in one piece, 560 square feet in area, and weighs 2 tons. Each jet engine weighs 6 tons.





WING

The wingspan is 195’ 8”, with a sweepback (one-quarter-chord) of 37.5 degrees.
This new wing design, developed by Boeing, required 9,000 hours of wind tunnel testing.
The wing elements are adjusted to a tolerance of 0.05 mm by means of a laser device. They are riveted by two giant 60 ton machines, digitally controlled, capable of driving in 12 mm rivets at the rate of seven a minute.
The wing is a three spar structure with a constant section box extending through the fuselage.
The wing is made of special high-strength aluminum alloys. Some of the 188 panels which make up the wing surface measure up to 100 feet in length.
The core of the median mid-spar is continuous, and the ribs are made up of several elements. 28 of the 108 ribs are solid, and form the sides of the wing fuel tanks.

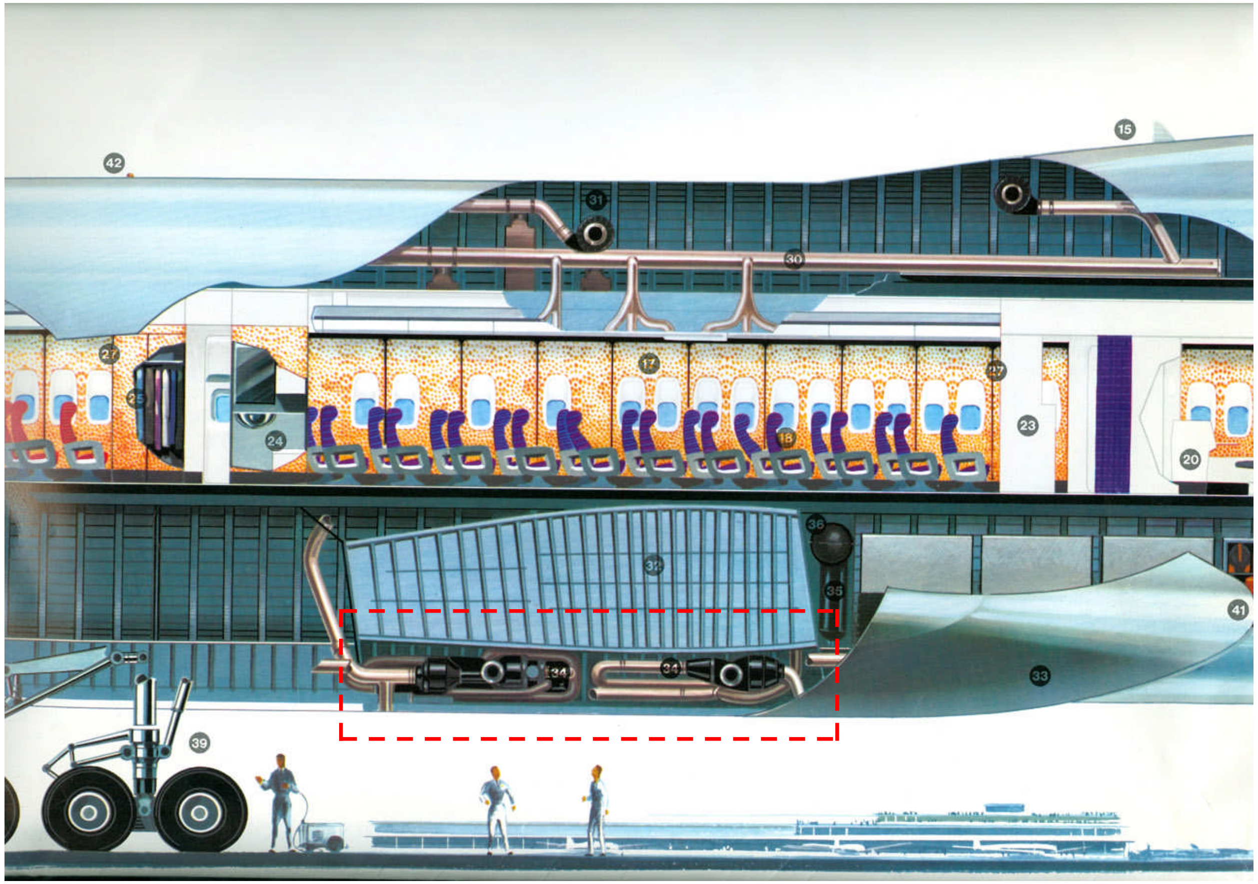
"…The craft is so big and solid-looking that you wonder how it can be supported by anything as insubstantial as air. But fly it does, and very well…"

***Popular Mechanics,* December 1969**

33 PNEUMATIC MOTOR ACTUATING WING FLAPS

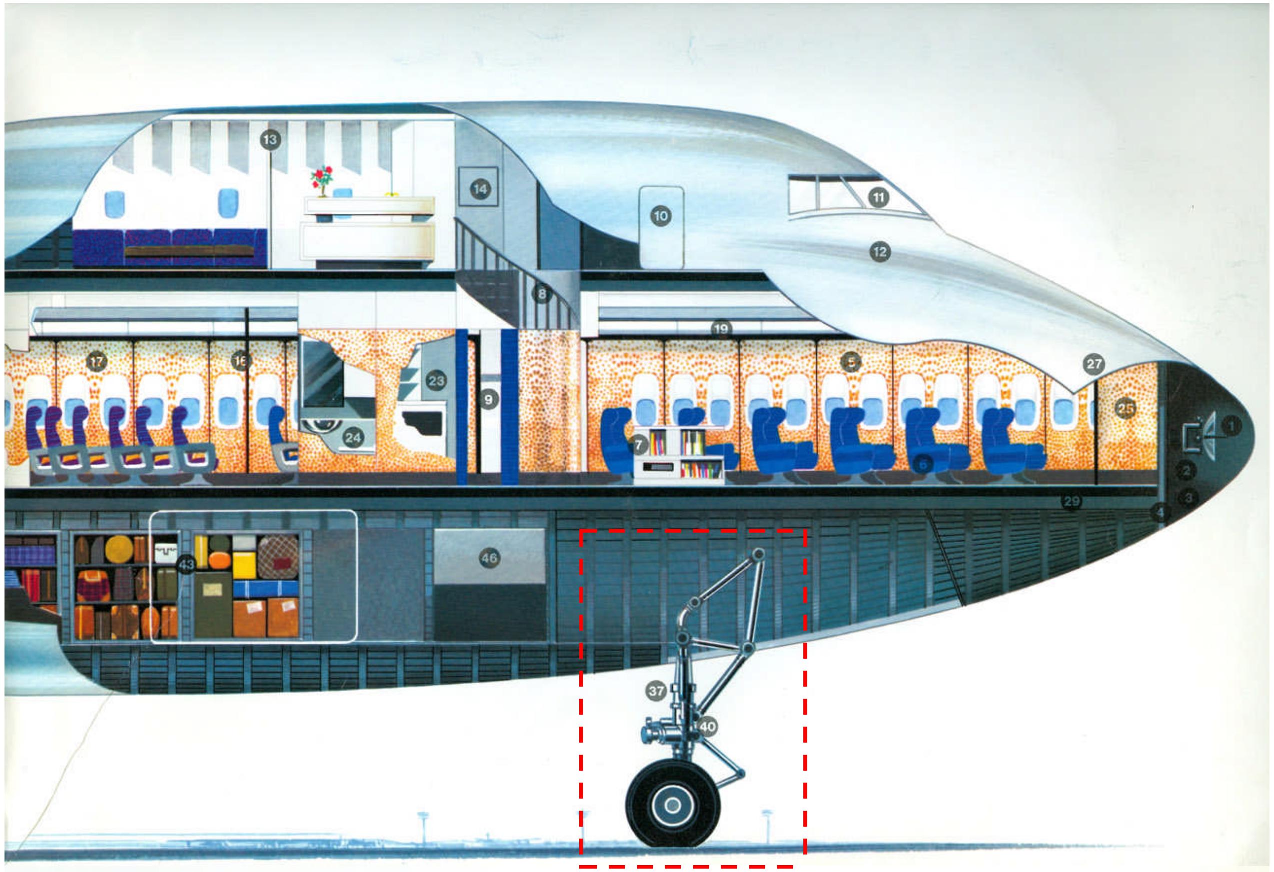
The wing flaps (not visible here) are actuated by a pneumatic circuit; this is an additional safety factor, for it avoids the presence of hydraulic ducts along the titanium de-icing system on the leading edge of the wing.
The inboard and outboard flaps on each wing are controlled by two screw jacks driven through transmission shafts by two motors. The flaps are retracted by eight guide rods (two for each flap) made of forged steel, fixed to the wing spar box by means of titanium bolts.


747
BOEING
747



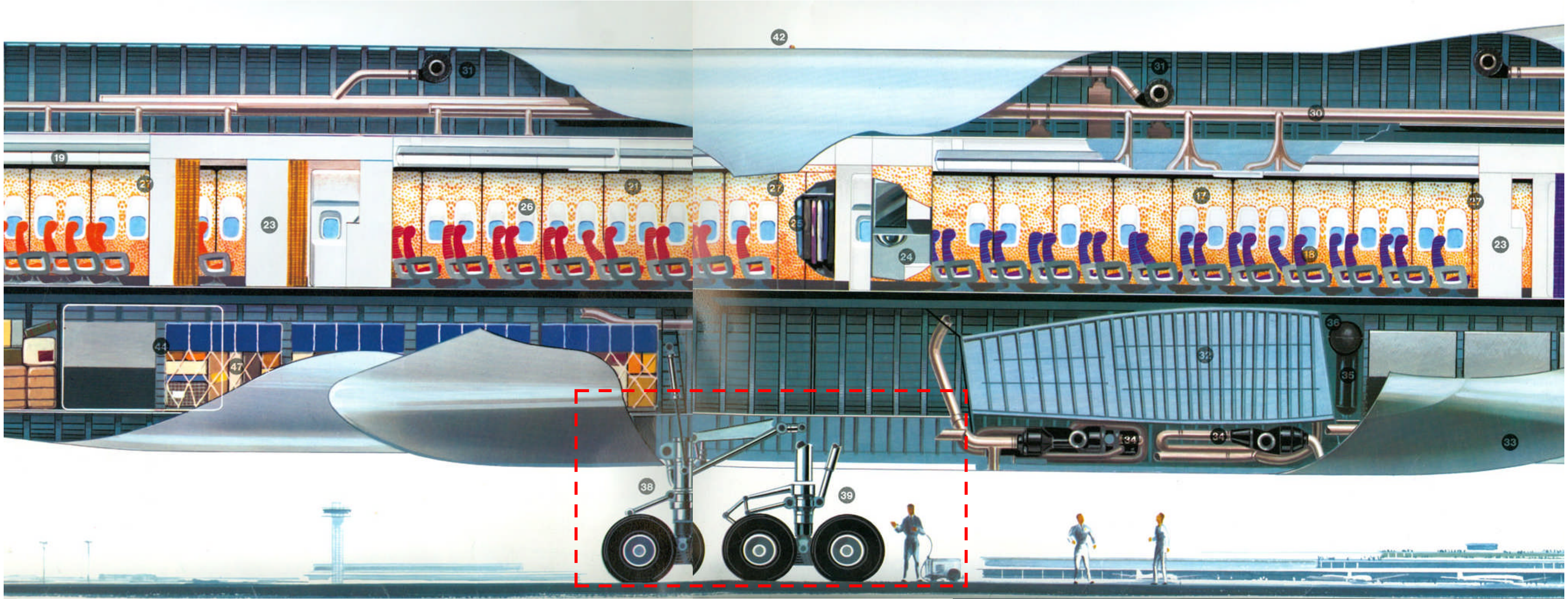
34 AIR-CONDITIONING UNITS

Three identical air conditioning systems are installed to provide ventilation, air temperature control and pressurization.
Hot air extracted from each engine compressor goes through a primary heat exchanger, where it is precooled and then is distributed to the three systems.
Each of them includes a secondary heat exchanger, an air cycle machine (bootstrap), mixing valves and a water separator.
The three systems feed a command manifold which distributes air into the four cabin zones and the cockpit.
Outflow and safety relief valves provide normal cabin pressure regulation and pressure relief. Cabin pressure is automatically controlled.



37 NOSE LANDING GEAR

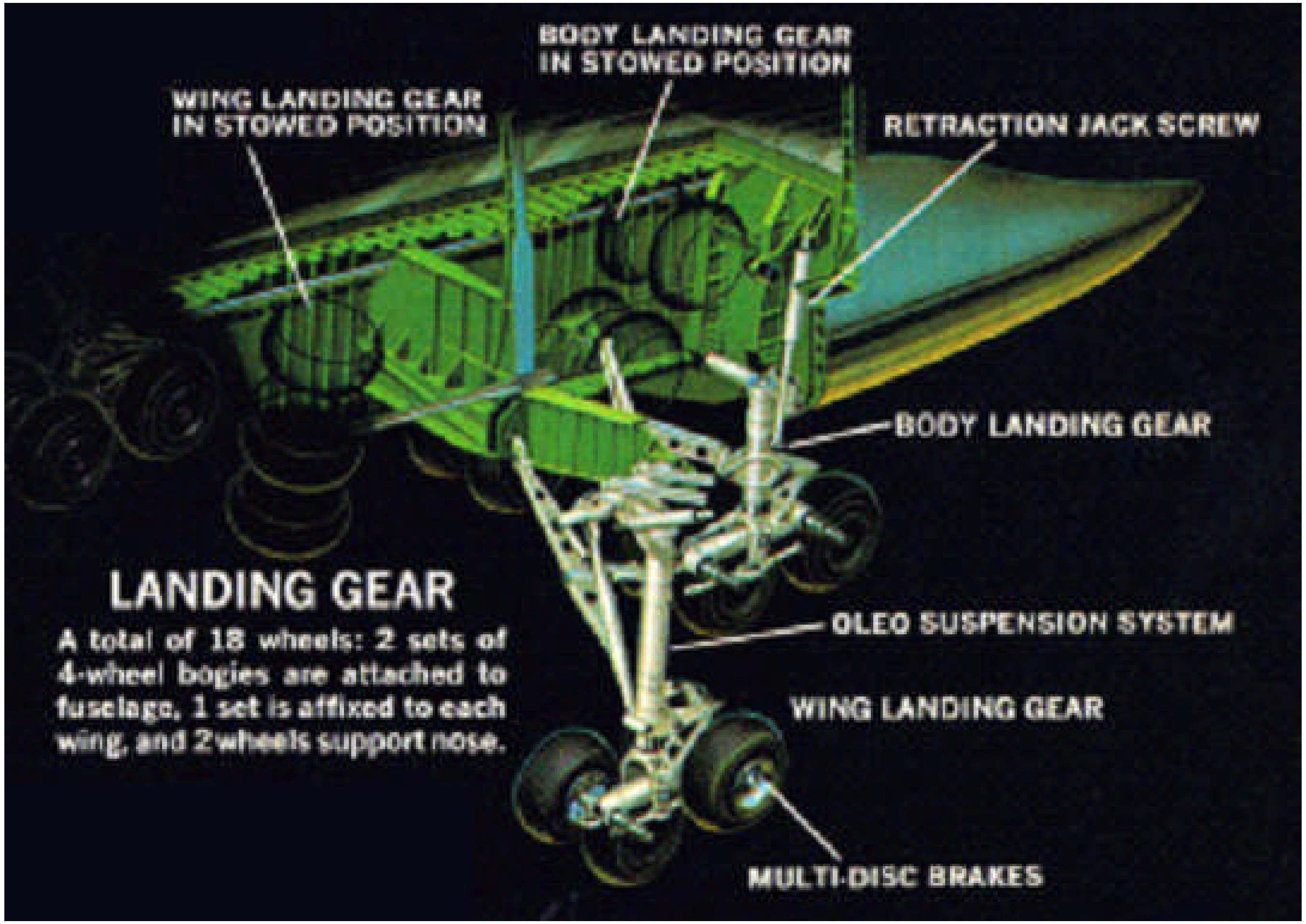
The nose landing gear is conventional, with an oleo-pneumatic shock strut and dual wheels mounted on a vertical common axle. Nose wheel steering is controlled from the flight deck, and the gear retracts forward into a housing enclosed by two doors.
A system of dynamometers or strain gauges on the axles of the main and nose landing gear wheels make it possible to check the weight of the aircraft and the distribution of its load. Data provided by the dynamometers appears on the Flight Engineer's instrument panel.
There are 18 undercarriage wheels altogether (two in the nose landing gear and 16 in the main undercarriage); all of them are identical.



38 - 39 MAIN LANDING GEAR

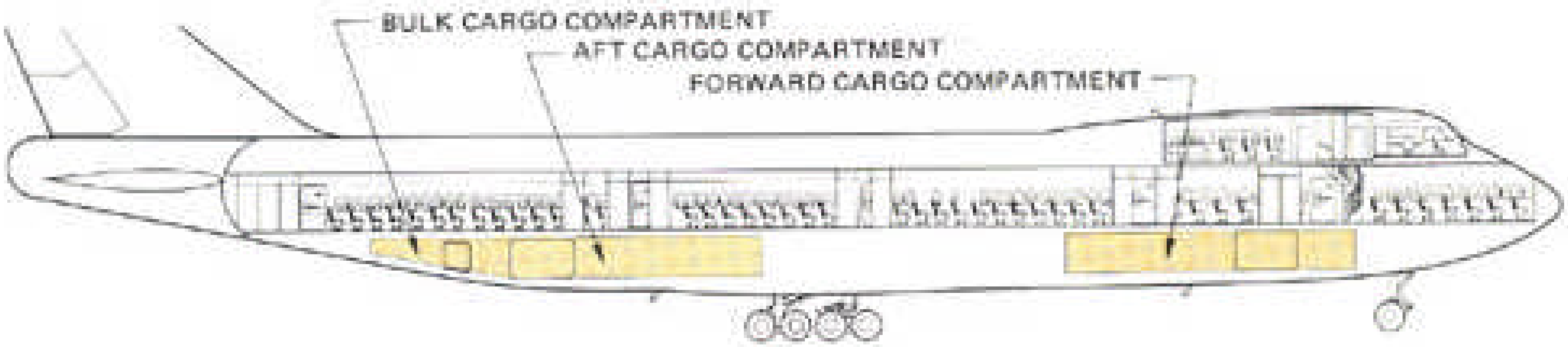
This landing gear is of the tricycle type, and is retractable by means of hydraulic jacks.

It has four bogies, each with four wheels. Two of the bogies are mounted under the wing, and the two others under the fuselage, slightly to the rear.
The distance from the nose gear to the wing gear is 78′11″, and from the nose gear to the body gear 89′5″.
This long wheelbase provides excellent stability for taxiing on the ground.
On landing, the body undercarriage makes contact with the ground first; the wing undercarriage makes contact only when the oleo-pneumatic shock absorbers are compressed.
Thanks to advanced aerodynamic design (more effective flaps, improved braking and anti-skid systems) the Boeing 747 will require a slightly shorter runway than the Boeing 707.
Which means that an aircraft carrying two-and-a-half times as many passengers as the 707 can use the same runways as the latter.


BODY LANDING GEAR
IN STOWED POSITION
WING LANDING GEAR
IN STOWED POSITION
RETRACTION JACK SCREW
BODY LANDING GEAR
LANDING GEAR
A total of 18 wheels: 2 sets of 4-wheel bogies are attached to fuselage, 1 set is affixed to each wing, and 2 wheels support nose.
OLEO SUSPENSION SYSTEM
WING LANDING GEAR
MULTI-DISC BRAKES

CARGO COMPARTMENTS

The Boeing 747 has three holds, all of them pressurized, ventilated, heated, pesticized and protected from fire by an automatic extinguisher system.
With a usable volume of 5,322 cubic feet, the hold capacity of the Boeing 747 is four times that of the Boeing 707.
In addition to the baggage of 360 passengers, 18 to 22 tons of cargo can be carried.
The forward and centre compartments have a constant cross-section and can accomodate containers or pallets.
These two holds have very wide doors for easy and rapid loading and unloading. The doors are on the righthand side of the plane, and have the same dimensions as those of the Pelican jet freighter (8′7″ × 5′6″).
Pallets can enter lengthwise. The floor is fitted with roller bearings to facilitate the movement of cargo. The width of the roller bearing floor can be adjusted according to whether containers or pallets are being handled.
When the cargo has entered the hold, it can be moved in the longitudinal direction. For this purpose, the floor is fitted with a system of rollers driven by small electric motors which facilitate stowage.



FORWARD HOLD

16 half-containers, capacity 2,610 cubic feet.

CENTER HOLD

In the Air France arrangement, this can take 4 pallets (1384 cubic feet) and 2 half-containers (328 cubic feet).

REAR HOLD

The aft compartment is located in the rear of the plane. Because of its tapered shape, it can take only bulk consignments.
Capacity: 1,000 cubic feet.
Maximum load: 14,000 lbs.
The hold is 20 feet long; the height varies from 5′7″ to 2′4″, and the width varies from 13′6″ to 10′4″ in the upper part; the floor is the same width, 9′2″, throughout its length.
The door of this hold is also on the righthand side of the plane, and is 3′7″ wide × 3′10″ high.
This is the warmest of the three holds, with the temperature maintained at between 18° and 27 °C. (64°F. to 80°F.); this is advantageous for the transport of live animals.
It is fitted with nets to hold crates and packages in place.

CONTAINERS

Air France has preferred to use half-width containers, which are easier to handle and more convenient to use than the full-width containers previously planned. Two half-containers occupy the same space as one large container.

Dimensions: Depth 5′. Height 5′3″. Width at top 7′7″.
Width at base 5′1″.

A half-container can hold 55 items of baggage, or about one ton of freight.

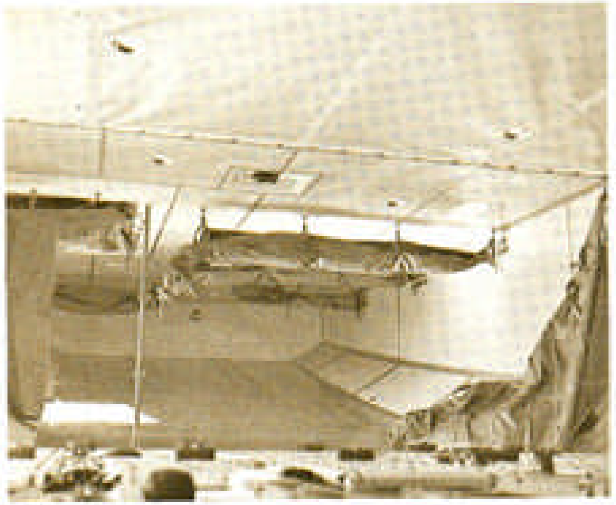
Each half-container, whose standard dimensions have been adopted by all European airlines, has a volume of 162 cubic feet and fits the shape of the hold neatly.

To cover the first two years of operation, Air France has ordered 300 containers of this type.

PALLETS

The floor width allows the same pallets to be used as aboard the Pelican jet freighter. This gives great flexibility of use and transfer between the Boeing 707 and the Boeing 747.

Dimensions: 7′3″ × 10′5″ × 5′3″ high.


Bulk compartment


Aft compartment


Forward compartment


Container loading

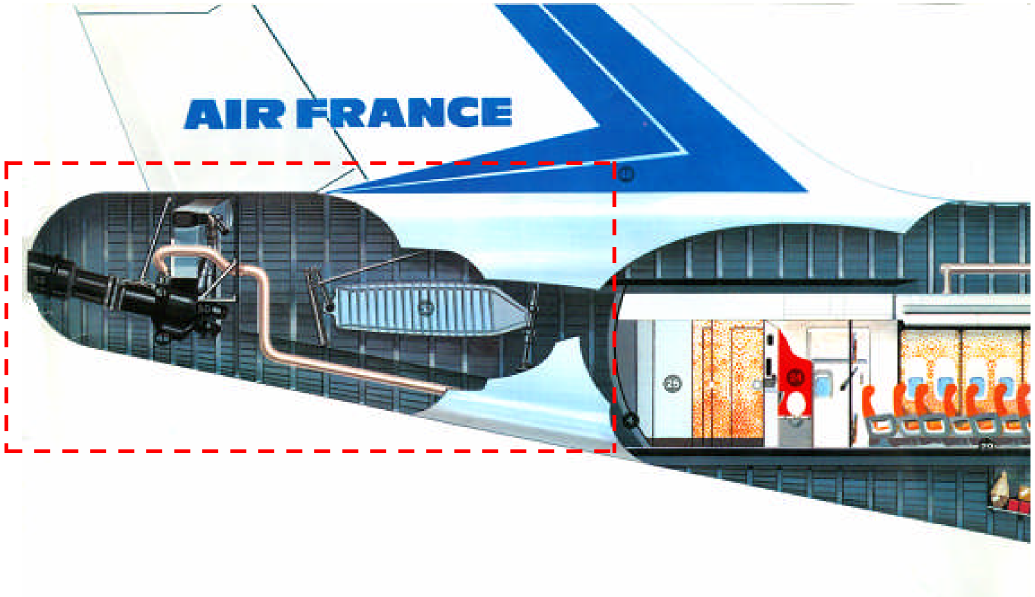

TWA

48) TAIL FIN

The tail fin is 63’ 4” high (23 feet higher than the Boeing 707), equivalent to the height of a five-story building.
This height has necessitated the construction of special wide and high hangars.


PANAM

"…They will be completely self-contained, with their own auxiliary power plants to handle electrical requirements while on the ground during loading and unloading…"
Popular Mechanics, **September 1966**



49 GARRETT AIR RESEARCH AUXILIARY POWER UNIT

Behind the bulkhead at the rear of the passenger cabin is a 1,100 hp Garrett Air Research auxiliary power unit. While the airplane is on the ground, the auxiliary power unit provides pneumatic and electric power, and also operates the air-conditioning system in the aircraft.

50 POWER SYSTEM

Four 60 kVA engine driven generators supply alternating current for the various items of equipment on board.

51 AIR-CONDITIONING EXCHANGER AND AIR DUCTS

52 CENTRAL TAILPLANE SPAR BOX

53 TURBINE GAS EXHAUST


AIRESEARCH GT-CP 660
AUXILIARY POWER UNIT
Equivalent to 2000 HP
On ground, it provides power
for all airplane systems.
AIR INLET
TURBINE
COMPRESSOR
GENERATORS
AUXILIARY POWER UNIT
PAN AM

Part 9

Commercial Inertial

Absolutely Fantastic!

"Much has been said about the Boeing 747 – that it occupies nearly the space of a football field, that its engine nacelles are of greater diameter than a B-17's fuselage, that when fully loaded it weighs more than 140 Cadillacs. But one of the giant's most intriguing features is an electronic unit that occupies a cubic foot and weighs slightly more than an electric typewriter. It is the Carousel IV, the inertial navigation system (INS) that tells a 747 pilot where he is and how to get to where he wishes to go. The INS provides this and much more navigational data instantly and with far more accuracy than any gear previously used by airlines. 'Absolutely Fantastic!' is a typical reaction when a veteran pilot first sees it work…"

***Popular Mechanics,* October 1971**

"…A brainchild of General Motor's Delco Electronics Div. at Milwaukee, the Carousel IV is a by-product of 20 years' work with inertial guidance technology. Navigators similar in concept were used to guide the Thor and Titan missiles, and the command and lunar modules on the Apollo moon missions…"

***Popular Mechanics,* October 1971**

<u>Above</u>: caption: "Volume production of AChiever guidance systems at AC Milwaukee plant. Here the gimbal assemblies get final checkouts before going into pre-flight testing."

<u>Left</u>: caption: "Thor missile, 1958"

Super-Sophisticated

"…Pan Am pilots will be guided by a new super-sophisticated AC electronics inertial navigation system that will give them their position in space without any outside radio beams. It uses the same techniques that were used to guide Apollo astronauts to the moon and back. Once set, it provides the position of the aircraft regardless of wind shifts and changes in direction or attitude of the plane…"

Popular Science, **December 1969**

"…The cockpit, which occupies part of a short top deck, bristles with electronic gear, about $1 million worth (a complete plane, if you're in the market, costs about $20 million). In addition to such more familiar equipment as radar scope, radio compass, autopilot, altimeter and so on, the 747 is the first plane to have an inertial guidance system (INS) as standard equipment…"

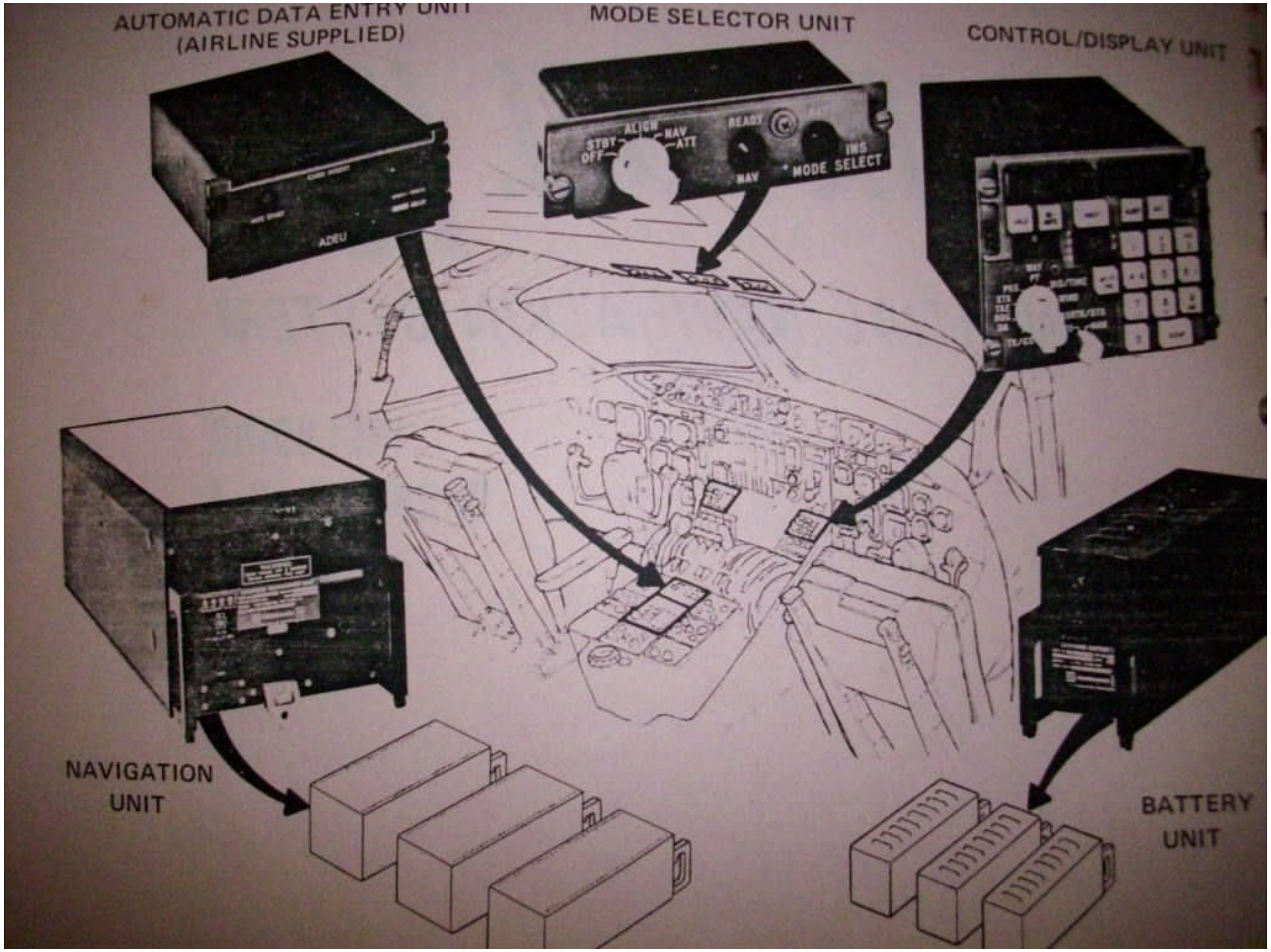
***Popular Mechanics*, December 1969**

<u>Left</u>: caption: "Flight deck displays seen in the Boeing 747 during its Paris Show visit gave little evidence of radically new position display techniques. Control panels and readouts for the Carousel inertial system are situated on the console, while DME readouts are on the left of the co-pilot's panel."

<u>Right</u>: caption: "Co-pilot adjusts the INS mode selector in flight"

"…The INS is similar to that used on Polaris submarines and the Saturn moon rockets. One of its main advantages is that it needs no outside signals. Key elements in the system, a piece of hardware no larger than a standard file drawer, are a precision inertial reference unit and a digital computer. In the reference unit, gyros and accelerometers are mounted on a platform set with gimbals that allow it to turn in any direction. Spinning at 24,000 rpm, the gyros stabilize the platform to a known, fixed reference, such as the latitude and longitude of an airport. Whenever the plane strays off course, the gyros give off an error signal. The starting point and a series of waypoints are fed into the INS before takeoff. The system's computer calculates the shortest course from waypoint to waypoint, and finally to the destination. When connected to the autopilot, the INS actually flies the plane, leaving the pilot free to monitor a continuously updated control and display unit…"

Popular Mechanics, **December 1969**


AUTOMATIC DATA ENTRY UNIT
(AIRLINE SUPPLIED)
ADEU
MODE SELECTOR UNIT
STBY
OFF
ALIGN
NAV
ATT
READY
NAV
INS
MODE SELECT
CONTROL/DISPLAY UNIT
NAVIGATION
UNIT
BATTERY
UNIT

Going Inertial

“Reliability technology learned in our missile and space programs has enabled us to build quality, reliability and maintainability in the Carousel IV considerably greater than ever before offered in equipment of similar complexity. Carousel IV is really AC Electronics’ first major venture into the commercial avionics business - our first ‘commercial inertial’ system. Even though the 747 is a brand new aircraft, and Carousel IV is a brand new navigation system, we’ll have accumulated over 100,000 system flight hours on the C-IV before the 747 goes into service later this year.”

***Paul Larson,* C-IV Program Director**

RE: unlike earlier inertial navigation platforms (developed for military and/or space uses), C-IV was the first *Inertial Navigation System* (INS) designed and built as an integral part of a commercial aircraft. Conceived and built by the *AC Electronics Division of General Motors,* the C-IV’s three separate platforms provided operators of the 747 with high precision, fully automatic all-weather navigation.

<u>Left</u>: **caption: "AC Electronics 50th production Carousel IV inertial system was sold to Japan Air Lines. Examining the unit with Carousel program director Paul Larson (center), were Capt. Hitoshi Koyano (left), pointing to the mode selector, and Capt. Takoaki Nomo, holding the central and display unit. The two JAL pilots were at the General Motors division plant in Milwaukee for training on the new system. BOAC is testing the C-IV in a VC-10."**

Flight testing was done by Boeing on their prototype 747 and by 747 customers who received the C-IV units ahead of time (for evaluation and training purposes using existing aircraft such as the 707 and/or DC-8). The system was also sold to airlines for retrofit on aircraft already in service and for newer versions of in-service types. *AC Electronics* highlighted to its customers the greater accuracy of inertial navigation as well as its other advantages. For example, by holding the aircraft more precisely to its desired course (especially on long over-water flights), the C-IV system reduced flying time resulting in significant fuel savings.

"…The accuracy of Carousel IV has been demonstrated in approximately 10,000 hrs. of flight testing to date. Recent testing by Pan American on trans-oceanic flights has shown accuracies well within FAA requirements. That is, in a ten-hour flight, the system brings the aircraft within 25 miles along track and 20 miles cross-track of its destination. This is within normal VHF and radar range of the terminal airport…"

FLIGHT International, **September 4th 1969**

<u>Above L&R & Left</u>: the C-IV system included four basic components. At its heart was/is the *Precision Reference Unit* (PRU), comprising a digital computer, electronic and heat-control elements, and a power supply. The PRU weighs about 50 pounds and is less than one cubic-foot in volume.

"…Present flight rules require a human navigator or suitable replacement on overseas flights. With certification of inertial navigation for commercial use, the specialist navigator will no longer be required. Possibly more important to the airlines and their next-generation passengers is the potential narrowing of separation standards over the oceans. Routes over the North Atlantic are fixed by international agreement at 120-mile spacing at the moment. Aircraft are required to stay within their assigned lane and at their assigned altitude. Inertial navigation will make it possible, says AC electronics, safely to narrow these lanes to, for example, 60 miles, enabling twice as many aircraft to fly in the same airspace…"

FLIGHT International, **September 4th 1969**

In an inertial guidance system, highly sensitive gyroscopes and accelerometers are mounted on a stable platform, set within 'rings,' called gimbals, which are free to turn in any direction. The instruments measure changes in position and velocity, and feed them to the computer which continually calculates new information on heading and speed. It does not rely on radio or radar contact with the ground, and cannot be affected by any kind of communication interference (one reason why this type of system was chosen to guide missiles).

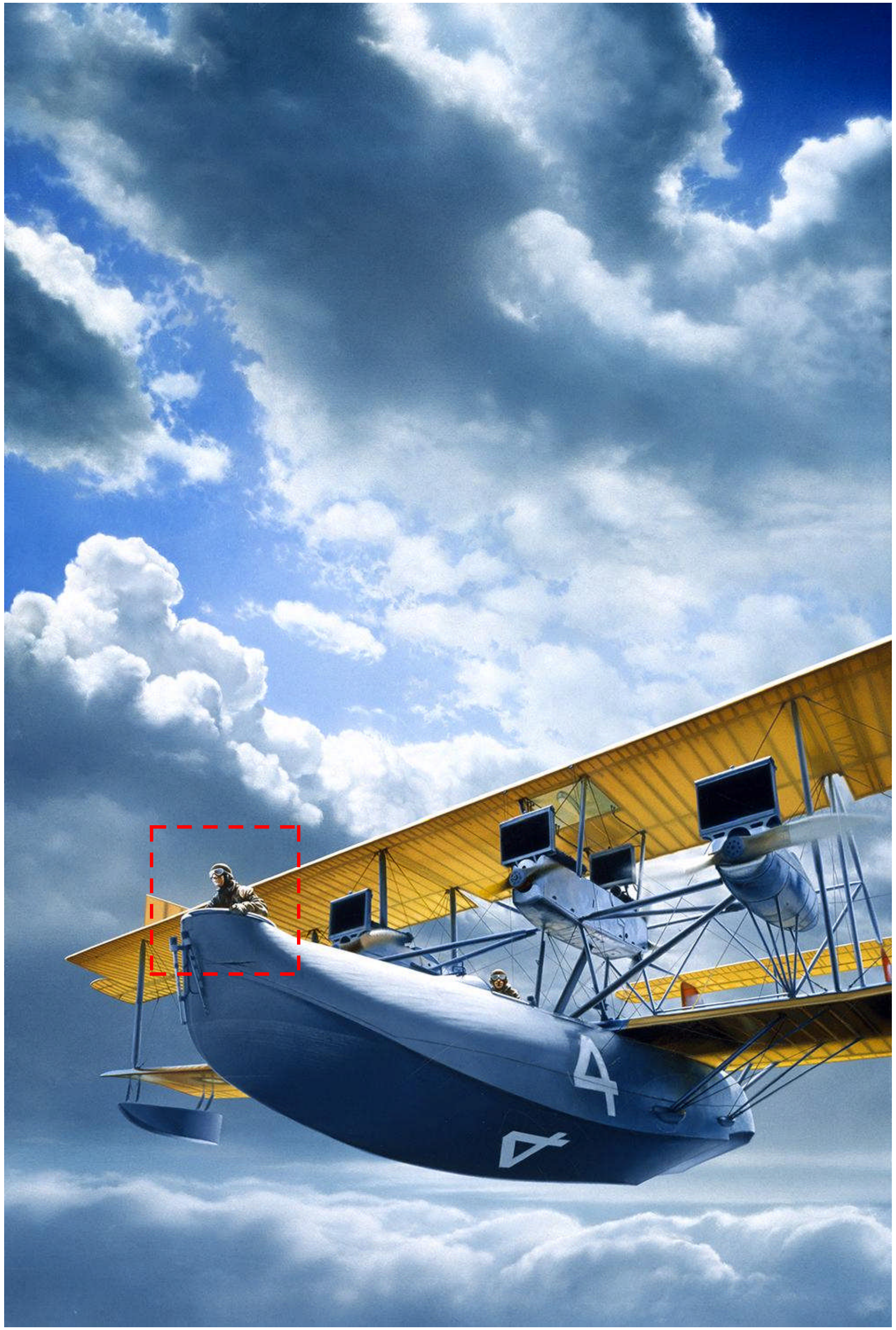
Left: caption: "A production assembler at Delco Electronics, inspects inertial reference unit gimbals (ca. mid-1970s). The gimbals are used in the Carousel IV navigation system on military and commercial aircraft. The system eliminated human navigators and was based on the inertial guidance/navigation for ballistic missiles."

Avigation

"Precise navigation of long-range aircraft requires careful co-ordination of all three methods of navigation: celestial for position fixes, dead reckoning for flight between the fixes, and radio direction finding for getting into the airport on the nose and for radio bearings when the sky is not visible."

***Harry Connor*, navigator on Howard Hughes' 1938 around-the-world flight**

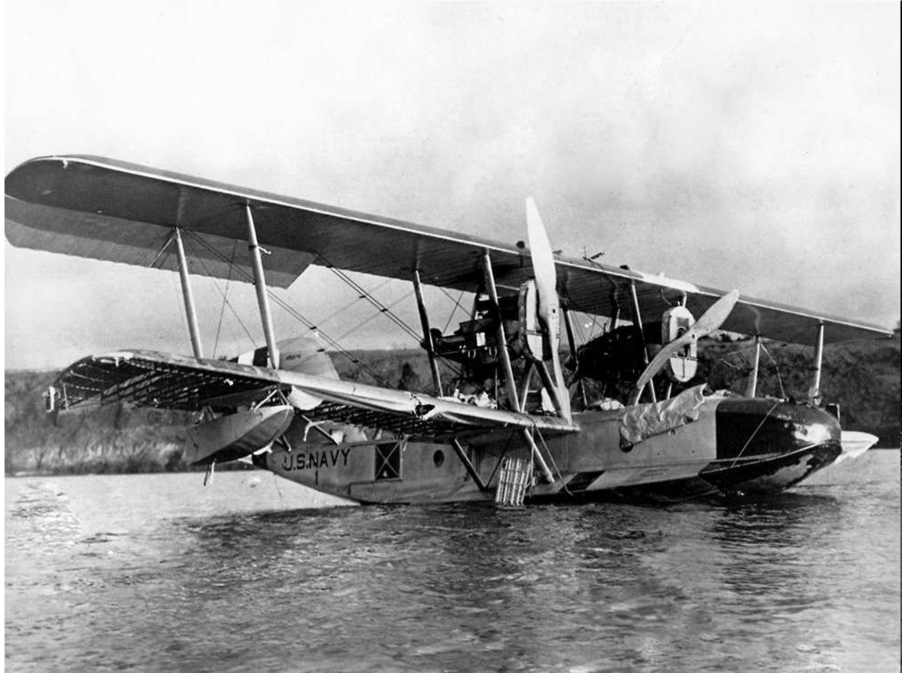
RE: "Dead Reckoning" is the simplest means of navigating, but the least accurate over long distances. "Radio Navigation" became the main method of navigation because of its precision and ease of use. Before global radio navigation systems, "Celestial Navigation" was preferred, but it's now rarely used.



"…In the early days, trans-ocean flying was accomplished by dead reckoning and celestial navigation. A pilot held a compass course which had been adjusted for variation, deviation and whatever wind information was available. En route, his navigator pinpointed actual position with sun or star shots, provided clouds did not obscure the sky. Drift was measured by dropping a smoke marker or flare onto the water and lining up the receding target with the grid lines of a drift sight. The crew which found itself 'on solid instruments,' a common situation over the North Atlantic in mid-winter, could only maintain flight plan headings and hope for a break in the clouds prior to landfall…"

***Popular Mechanics,* October 1971**

Left: the U.S. Navy's Curtiss NC-4 flying boat made the first crossing of the Atlantic by air in 1919. On most early bombers and flying boats, the navigator made sightings from the nose, where his view would not be obstructed by the biplanes wings and struts. He had no protection from the elements. The force of the wind made his sextant difficult to handle. Though it worked anywhere the sky could be seen, it required a clear line-of-sight to celestial bodies and a high degree of skill on the part of the navigator.



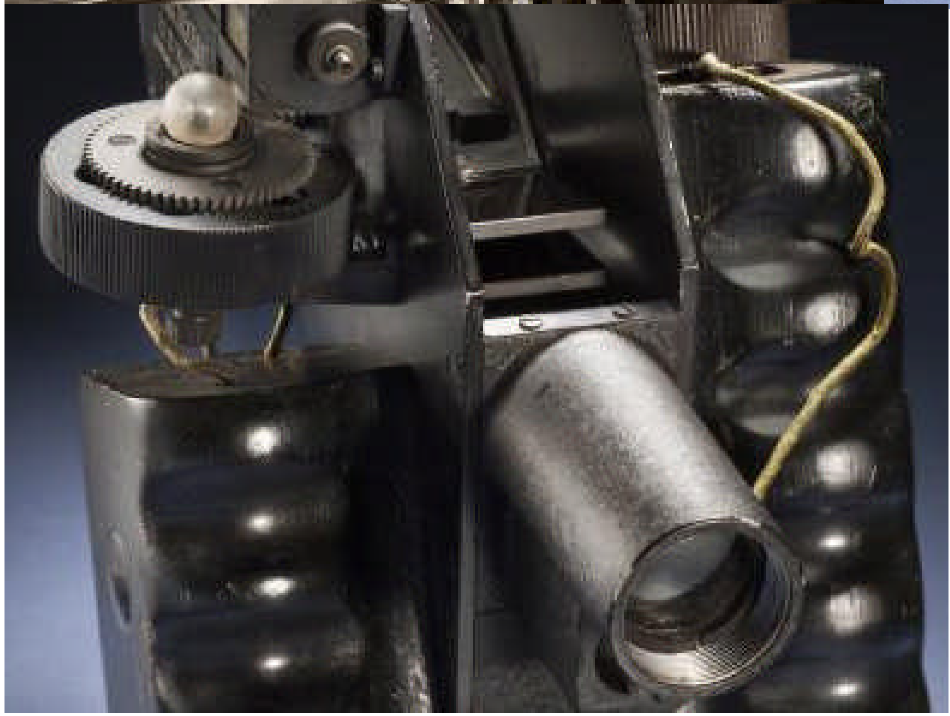
Although land-based airplanes and dirigibles had the range to cross the world's oceans, explorers, airlines and military aircrews often preferred flying boats. With runways few and far between in the pre-WWII era, flying boats could land in almost any sheltered stretch of water. They also made in-flight emergencies over the open ocean much more survivable. Still, navigating across an ocean in any type of aircraft was difficult and perilous. Between the World Wars, the U.S. and many European countries competed for national prestige by setting transoceanic records, establishing overseas airline service, connecting colonial possessions and demonstrating their military prowess. In the summer of 1925, USN Cmdr. *John Rodgers* and his crew spent nine days adrift at sea in their PN-9 flying boat (left) after failing to rendezvous with a refueling ship. They successfully "sailed" PN-9 to Hawaii thereafter. Note the navigator's compartment in the nose (highlighted in the scale model, at right).

Shooting the Stars

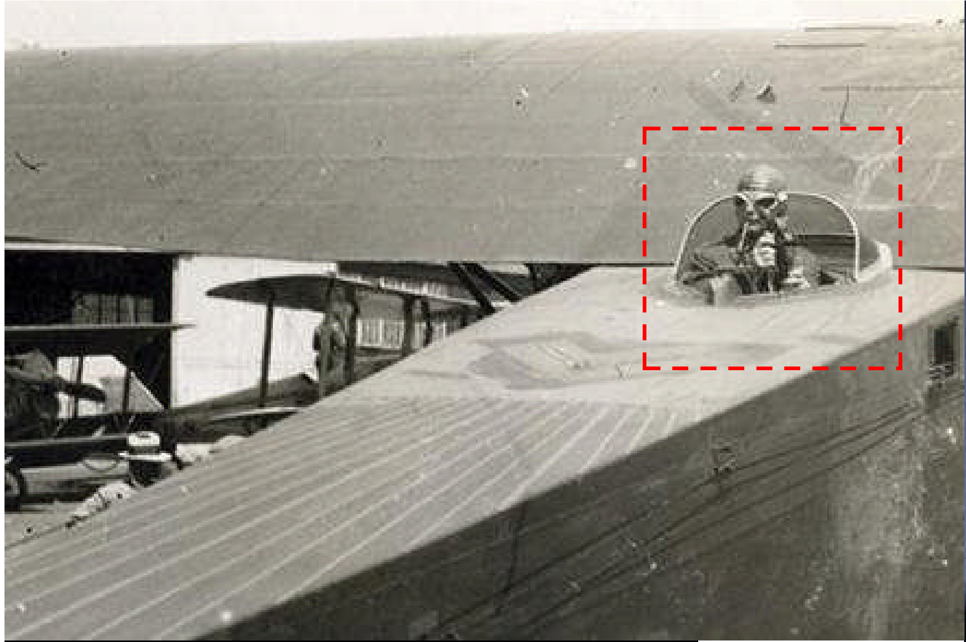
Early aviators on long flights often faced great danger because they could not figure out exactly where they were. "Fixing" position over water, in the dark and/or in poor weather was difficult and the consequences of getting lost could be fatal to man and machine:

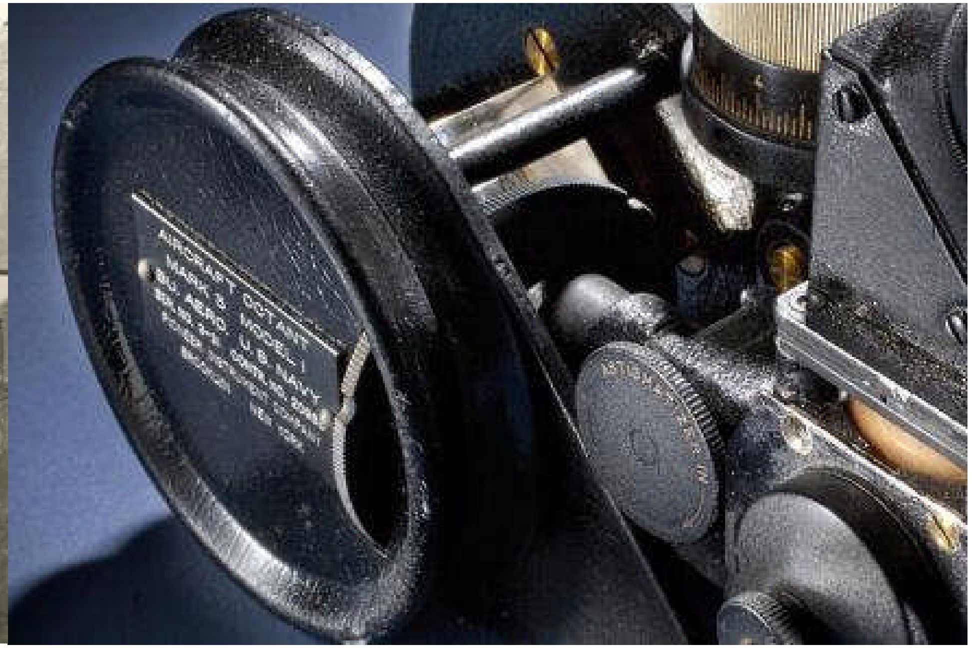
- **<u>Speed</u> - since airplanes move much faster than ships, aerial navigators had to work fast to fix their position. Even minor miscalculations could result in much greater errors;**
- **<u>Instability</u> - the natural roll of the airplane and/or air turbulence made taking accurate sightings and readings challenging, to say the least;**
- **<u>Weather</u> - haze often obscured the horizon line needed for sextant sightings. Clouds could keep navigators from sighting the sun/stars and/or determining wind drift;**
- **<u>Cockpit Environment</u> - cramped open cockpits, low temperatures and wind speeds over 100 mph made air navigation very difficult. Heavy gloves (or frozen fingers) made sighting with a sextant, determining drift and making calculations nearly impossible;**
- **<u>Equipment</u> - celestial navigation tools used by mariners did not work as well in the air.**

Thus, aviators required new equipment and techniques to meet the challenge of transoceanic aerial navigation. Air navigation pioneers sought to distinguish themselves (from maritime navigators) by calling it "Avigation" and air navigators "Avigators" (it didn't take).



Top Left: caption: “Max Pruss, Graf Zeppelin Navigator. Using a sextant to find a Sun line of position.”
Top Right: caption: “A maritime sextant with a special bubble attachment to the eyepiece to aid in establishing a horizon in aero-nautical use, circa 1919.”
Left: caption: “Second-generation aeronautical sextants were much more aerodynamic, lightweight, and easy to handle”

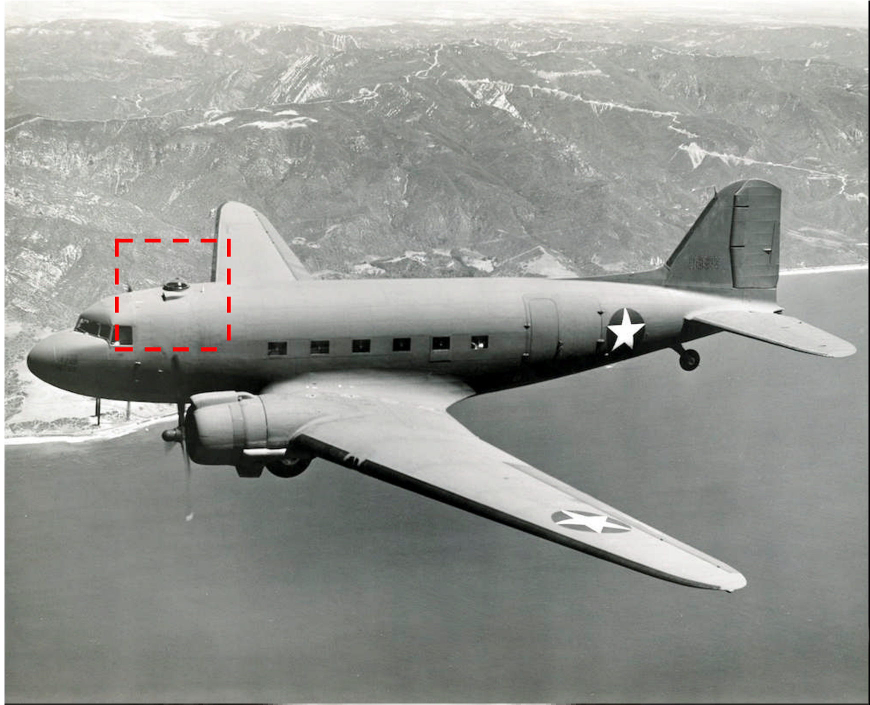


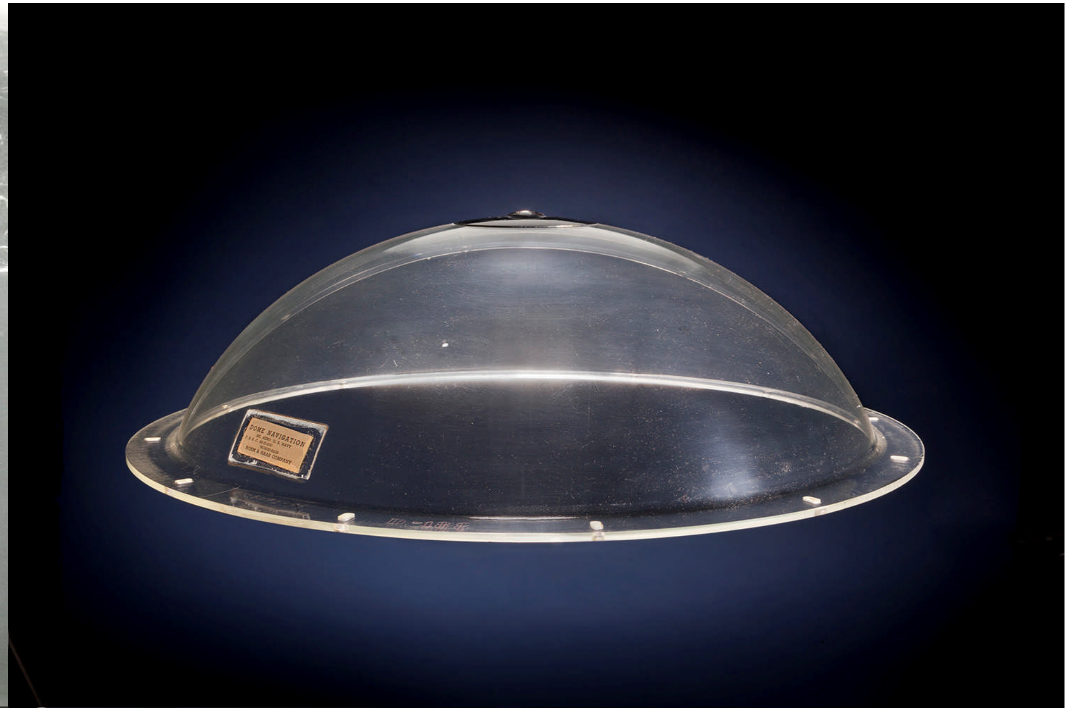


<u>Top Left</u>: caption: “Albert Hegenberger in the Bird of Paradise’s Celestial Sighting Station.” In 1927, the U.S. Army Air Corps’ Fokker C-2 *Bird of Paradise* became the first airplane to fly from the U.S. mainland to Hawaii. Navigator *Albert Hegenberger* had the new luxury of facing rear and behind a semi-protective windscreen while making his celestial sightings.

<u>Top Right</u>: caption: “Pioneer Mark 3 Model 1 Aircraft Octant.” *Charles Lindbergh* made daytime celestial observations with this octant while his wife Anne flew the *Tingmissartoq* from the rear seat. The bubble level was problematic and leaked during their flight.

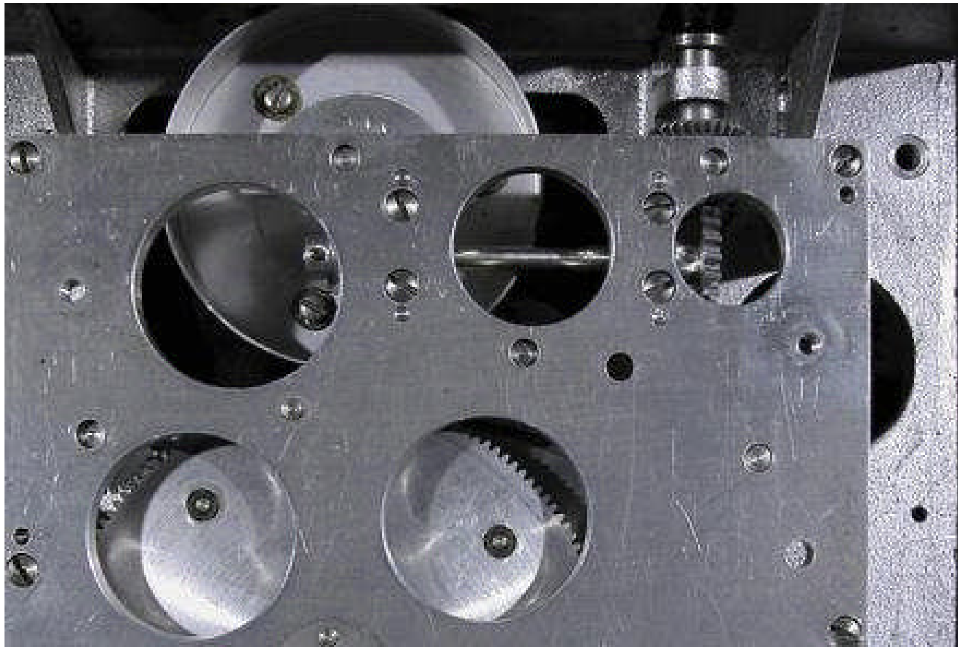
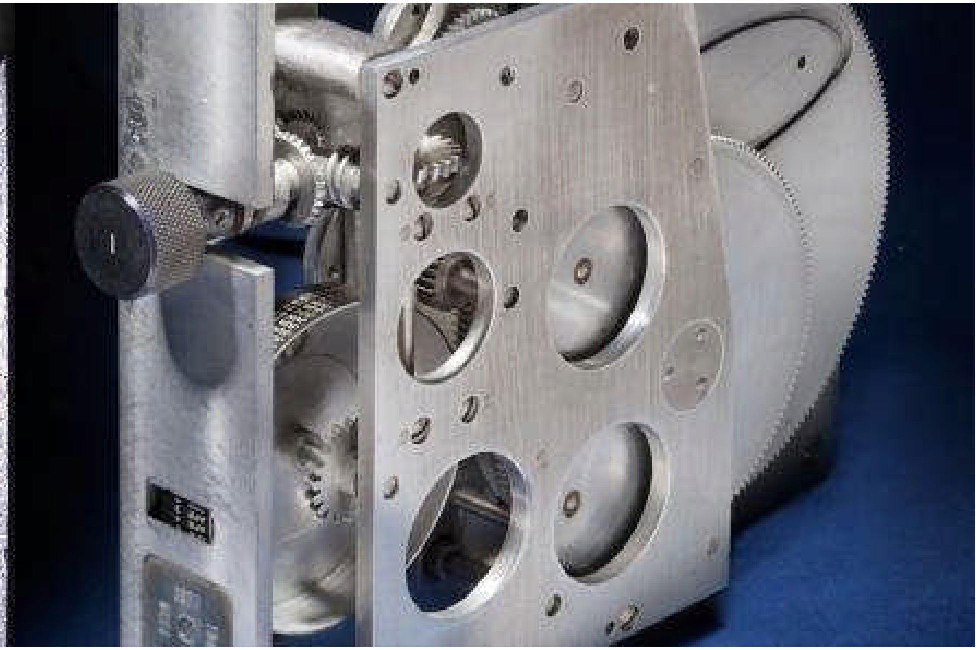
<u>Left</u>: caption: “Interwar Flying Helmet and Mask.” Aviation in the interwar years made complex tasks like navigation problematic and tested human endurance.





<u>Top Left</u>: a 1940s transport, such as this *Douglas C-47* (ca. 1944) could fly more than 200 mph and reach altitudes where the temperature fell well below freezing.

<u>Top Right</u>: the astrodome was a technological marvel for its time. Not until the eve of World War II were manufacturers able to shape Plexiglas (a rugged transparent plastic) into a dome shape. An astrodome provided an enclosed area from which a navigator could take celestial sightings (left). The black disc at the top is a hanging point for a sextant (so navigators would not have to hold the heavy military models).

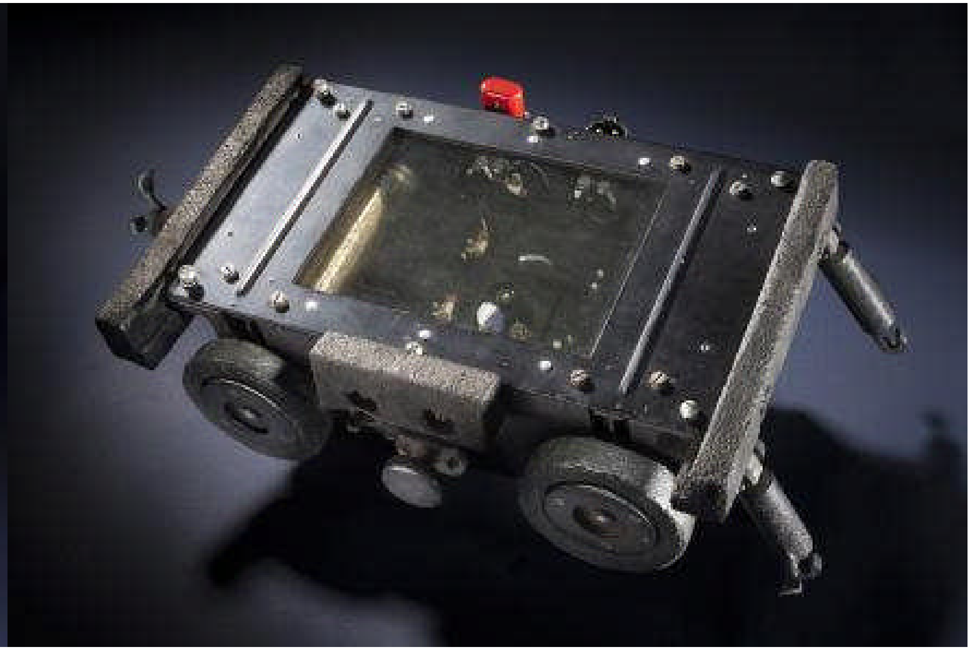



<u>Left</u>: caption: “Fairchild-Maxson Mark I Line of Position Computer.” This 1938 mechanical computer was a remarkable attempt to automate complex navigational processes. Instead of spending minutes making manual calculations, navigators could simply input sextant observations and accurate time readings. It was too expensive and heavy for regular use. Only several dozen were made for the Air Corps and Navy.
<u>Right</u>: caption: “Cassette for Fairchild-Maxson Line of Position Computer.” One of the cleverest features of this instrument was its use of “diskettes” with their own gears and cams “coded” with the data from a set of celestial tables.

Left: caption: "Link A-12 Sextant." The A-12 sextant was designed with Navy Commander Weems' assistance just before WWII and manufactured by *Ed Link* (of "Link Trainer" fame). It represented a new generation of "averaging" sextants that compensated for "Dutch Roll" in airplanes by taking multiple sightings and computing an average without manual calculations.

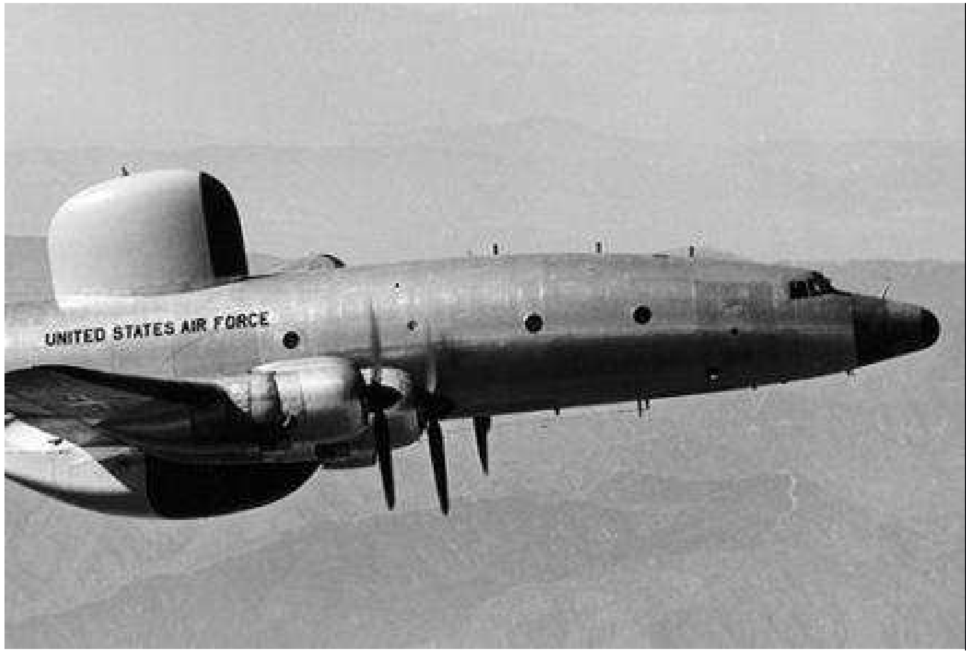
Right: caption: "AN 5740 Master Navigation Chronometer." Many USAAF navigators in WWII carried a chronometer set to *Greenwich Civil Time* (later *Greenwich Mean Time*) and mounted in a special hardened case with shock absorbing springs.

<u>Left</u>: caption: "A-10A Sextant." The compact A-10 was one of the most commonly used sextants in the USAAF. Tens of thousands were made during World War II and many remained in service with the USAF through the 1950s. Key features include a lighted bubble and a recording disk to determine averages.

<u>Right</u>: caption: "Mark IB Astrograph." The British-invented astrograph helped navigators determine the altitude curves of principal stars by projecting reels of film corresponding to certain latitudes. Suspended above the chart table in medium and heavy American bombers, the astrograph quickly fell out of favor because it was heavy and unreliable.

Left: caption: “Mark V Sextant.” This averaging sextant was reliable and accurate but heavy (used mainly by the Navy). The hook allowed the navigator to hang the bulky sextant from the top of an astrodome for more precise readings.
Right: caption: “Astrocompass Mark II.” The astrocompass was mainly used to determine magnetic variation in the angular difference between an aircraft’s bearing to the magnetic North Pole and the geographic North Pole. *Charles Blair* used this one on the first trans-polar solo flight in 1951.



Left: caption: “Lockheed RC-121D.” Navigators on civilian airliners and long-range military aircraft, such as the *Lockheed RC-121D*, began using retractable periscopic sextants in the late 1940s. They eliminated the risk of astrodome blowouts in pressurized aircraft and produced less drag. But their narrow field of view made finding a particular star more difficult.
Right: caption: “Kollsmann D-1 Periscopic Sextant.” The retractable periscopic sextant eliminated the need for astrodomes in pressurized aircraft. But their narrow field of view made finding a particular star much more difficult.

An Educated Guess

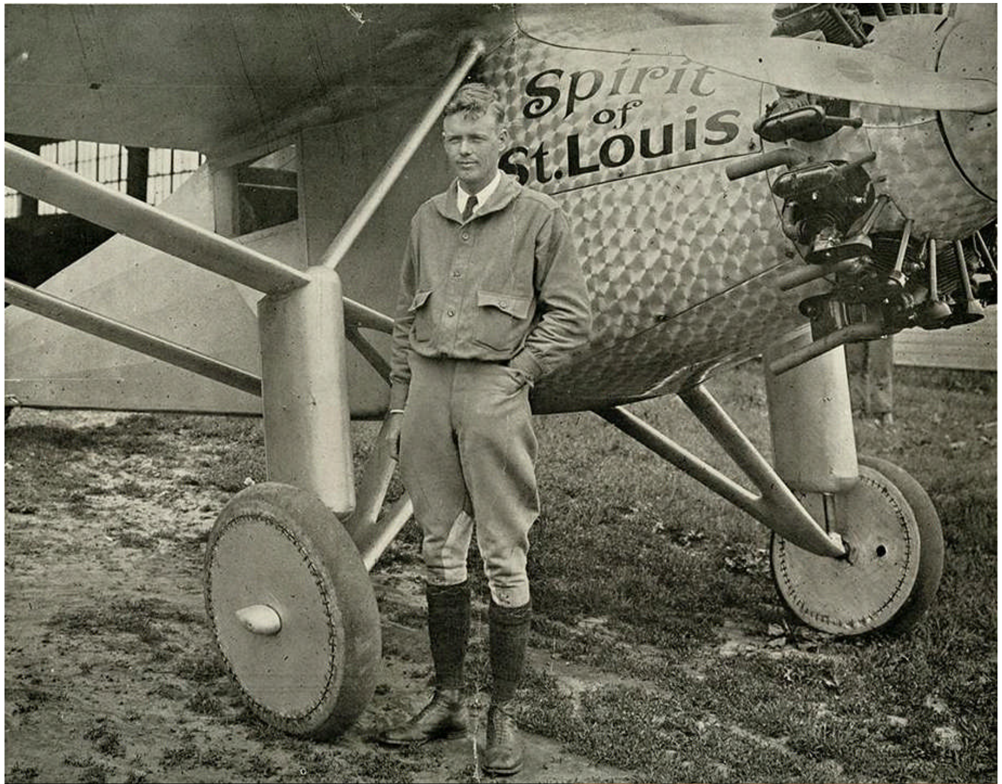
Before the advent of automated positioning systems (such as later versions of LORAN-C, GPS and/or the Astroinertial Navigation System that continuously computed positions), aviators and/or air navigators determined "fixes" by verifying position using known features on the surface, using computed positions from celestial observations or by bearings and lines of position from radio navigation stations. Between these fixes, aviators had to depend on a "best guess" in the form of a calculated position known as "dead reckoning." The process of dead reckoning depends on determining wind drift through observations or estimates and predicting the movement of the aircraft based on heading and speed. Though it works when out-of-sight of the sky and/or ground, dead reckoning requires complicated and heavy equipment in the aircraft and a complex array of ground and/or space-based equipment/infrastructure.

Lucky Lindy

"It will be news to millions that Colonel Lindbergh needs to be taught navigation…If the Colonel doesn't know how to navigate, who knows anything about anything?"

***New York Times*, 1928**

RE: in spite of all the obstacles, *Charles Lindbergh* made landfall in Ireland within three miles of his intended site, an extraordinary feat. His skill in maintaining a heading while exhausted is an indisputable achievement, but the *National Aero-nautic Association* (NAA) observer for the flight; *John Heinmuller*, also noted that the pressure distribution over the Atlantic on the two days of the flight was such that the net wind drift was zero: *"the first time such unusual weather conditions have been recorded by weather experts."* The magnitude of Lindbergh's accomp-lishment led many to believe that transoceanic air navigation was simply a matter of will and determination. In fact, he relied entirely on "dead reckoning" – cal-culating his position from point-to-point by tracking his airspeed. He used a clock and compass just as he had between checkpoints while flying airmail. Through the rest of 1927, at least fifteen people died in ocean-crossing attempts leading to calls for federal regulation. While inexperience played a role in many of these accidents, inadequate navigation technology had let nearly everyone down, cau-sing everything from inconvenience to fatalities.



Charles Lindbergh **navigated the** ***Spirit of St. Louis*** **(left T&B) on his 1927 trans-atlantic flight with an earth inductor compass, drift sight, speed timer (a stopwatch for the drift sight) and an eight-day clock. Despite weather deviations and extreme fatigue, Lindbergh reached the coast of Ireland within three miles of his intended great circle course. Even so, he knew that chance - not skill or equipment - had allowed such accuracy (prophetically, winds during his flight had caused no significant drift). Because he lacked any means for fixing position, his flight also illustrated that, until better navigational tools and techniques were developed, this type of flying could be fatal. Besides being uncertain of his position at times on his trans-Atlantic flight, Lindbergh found himself lost several times on his Caribbean and Latin American tour/s. In each case, faulty equipment let him down. Lindbergh realized he had to find better ways of fixing position if he was going to continue to make long-range flights and promote safe long-distance air travel.**

"Over the Straits of Florida my magnetic compass rotated without stopping…I had no notion whether I was flying north, south, east, or west. A few stars directly overhead were dimly visible through haze, but they formed no constellation I could recognize. I started climbing toward the clear sky that had to exist somewhere above me. If I could see Polaris, that northern point of light, I could navigate by it with reasonable accuracy. But haze thickened as my altitude increased…Nothing on my map of Florida corresponded with the earth's features I had seen…where could I be? I unfolded my hydrographic chart (a topographic map of water with coastlines, reefs, wrecks and other structures)…I had flown at almost a right angle to my proper heading and it put me close to three hundred miles off route!"

Charles Lindbergh

RE: in 1928 Lindbergh, once again piloting the *Spirit of St. Louis*, lost his way somewhere between Havana, Cuba and the southwest coast of Florida. It happened in the middle of the night and it alarmed Lindbergh enough that years later he recalled the incident in his memoir: "The Autobiography of Values." However, his nearly tragic Caribbean trip turned out to be a critical moment in time, not only for Lindbergh's understanding of navigation but also for the advancement of the practice for all aviators. It may be hard to believe Lindbergh didn't learn to navigate until the year after his nonstop New York-to-Paris flight, but in 1927 the practice was still more art than science. Aviators had attempted to cross the Atlantic with various degrees of success since 1919, but they were still using tools and methods designed for seafaring and those were proving unsuitable for the third dimension.

"It was a lot of fun 'shooting the sun' with the Memphis sextant. I was fortunate enough to hit it with a fair degree of accuracy."

Charles Lindbergh

RE: Lindbergh watched in anguish as others attempting his feat disappeared at sea. After finishing his Latin America and Caribbean tour with the *Spirit of St. Louis* in early 1928, he was eager to find better equipment and procedures for future flights. Though he had dismissed celestial navigation for his 1927 trip to Paris (fixing position with sun and star sextant sightings), he resolved to learn the skill. Upon his return, Lindbergh began planning an around-the-world flight, scheduled to kick-off a few months later in a *Ford Tri-motor* provided by *Henry Ford* and copiloted by his close friend; *Thomas Lanphier*. That April, he went to observe air operations aboard the *U.S.S. Langley* – the U.S. Navy's experimental aircraft carrier, where he encountered an enthusiastic Navy Lieutenant Commander; *Philip Van Horn Weems*, who was conducting navigation experiments for carrier-based aircraft. Weems demonstrated several of his innovations to Lindbergh including a bubble sextant that he was helping the *National Bureau of Standards* (NBS) to improve and his prototype "Second-Setting Watch" - the first true aviator "hack" watch that could be set precisely to the second. Later, the U.S. military realized the benefit of this precision and began to synchronize multiple watches for field operations, thus making famous the line: "Gentleman, synchronize your watches."

Several weeks later, after donating the *Spirit of St. Louis* to the *Smithsonian Institution*, Lindbergh decided he would set out from Washington D.C. for Detroit to finalize his plans with *Henry Ford* and Lanphier. He felt the trip would be an ideal time to learn "Avigation" - a popular term used in the 1920s and '30s to differentiate air navigation from maritime practice. He asked polar explorer *Lincoln Ellsworth* for suitable tutors. Ellsworth recommended Weems. Weems approached Lindbergh's training with items from his bag of tricks, including his hack watch. Previous chronometers could be set only to the minute; this was an acceptable error for nineteenth century mariners who might go weeks or more before stopping and making an adjustment, but not for twentieth century pilots who could use radio broadcasts to synchronize their timepieces. A watch error of thirty seconds could throw-off a position calculation as much as seven miles, so Weems' innovation was significant. Weems used most of the lessons to teach Lindbergh how to find his position by shooting the sun with a very rare sextant. It was a 1924 *Bausch & Lomb* model (of which only six were made) and Weems believed it was still the best model available in the U.S. Bubble sextants had been around for more than a decade, but because so little attention had been paid to aerial navigation, their design had not advanced much. During his sessions with Lindbergh, Weems carefully studied the sextant's deficiencies, later taking his notes to the NBS, which worked with Bausch & Lomb to produce an improved version that saw wide service in the 1930s.

Teaching "Lindy" Navigation

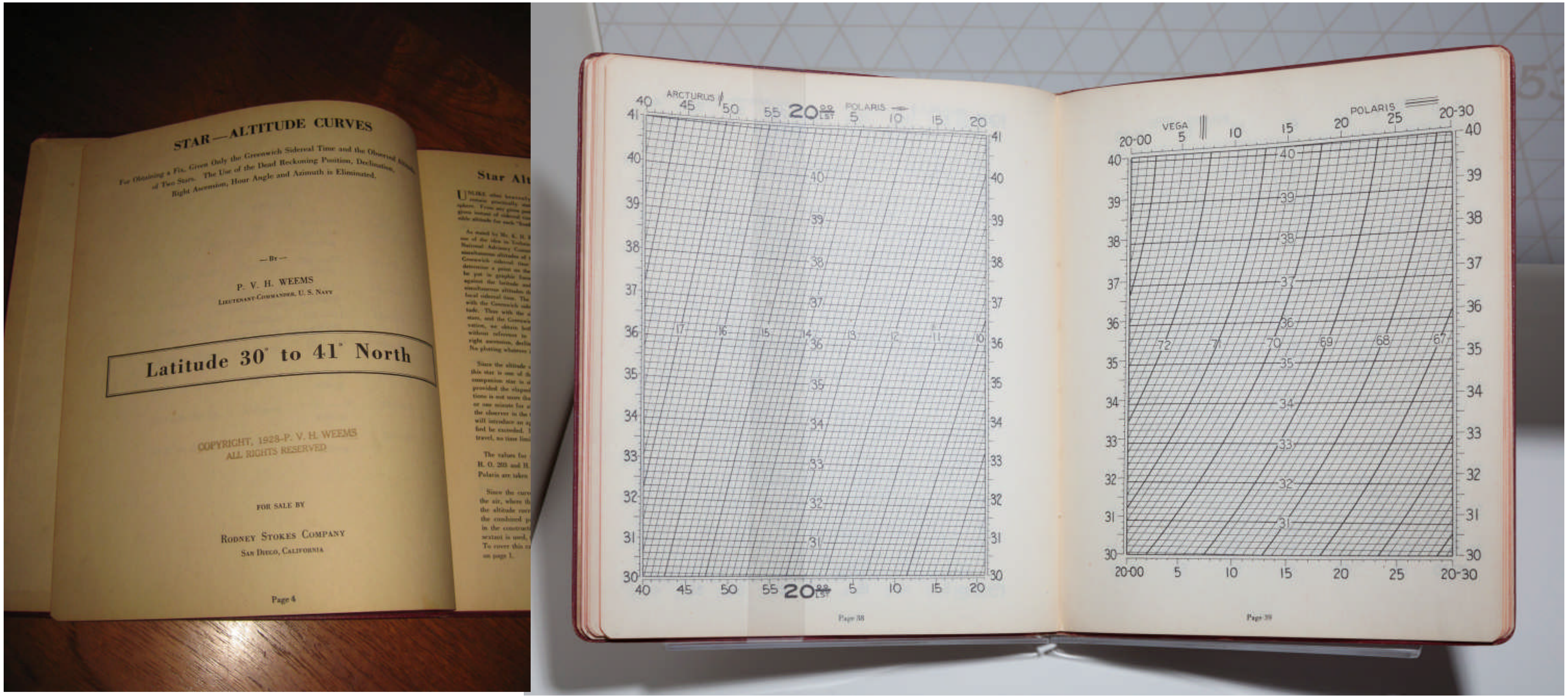
Why the World's Greatest Pilot Is Learning from a Tutor the A B C's of the Science of Finding His Way

"…toiled cheerfully for days over head-splitting mathematics...Lindbergh makes a fine student. He studies till twelve or one o'clock and does not get 'fussed' or rushed…didn't really do much instructing…was brilliant and caught on quickly. He instructed himself."

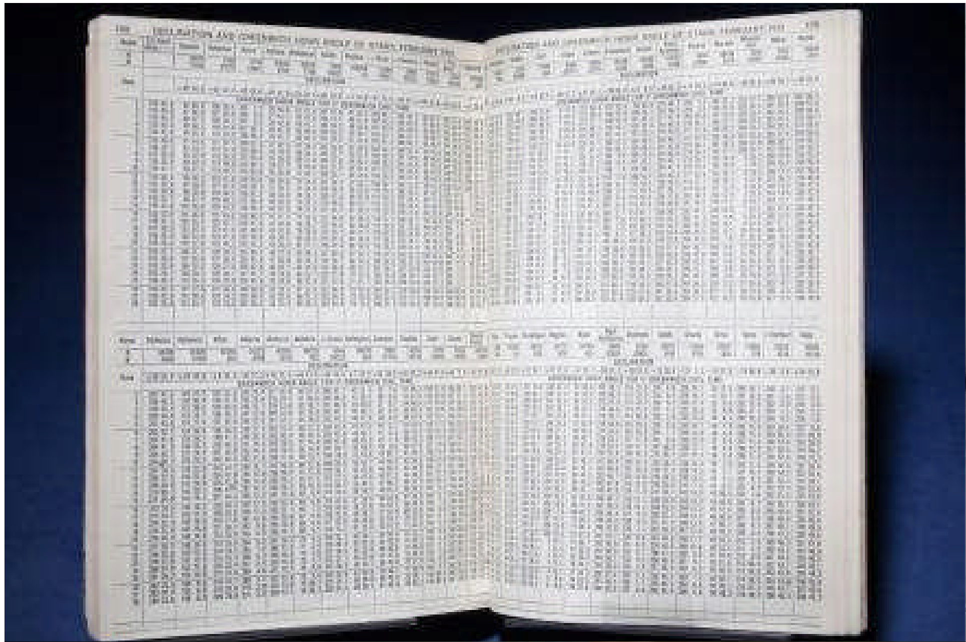
Philip Van Horn Weems

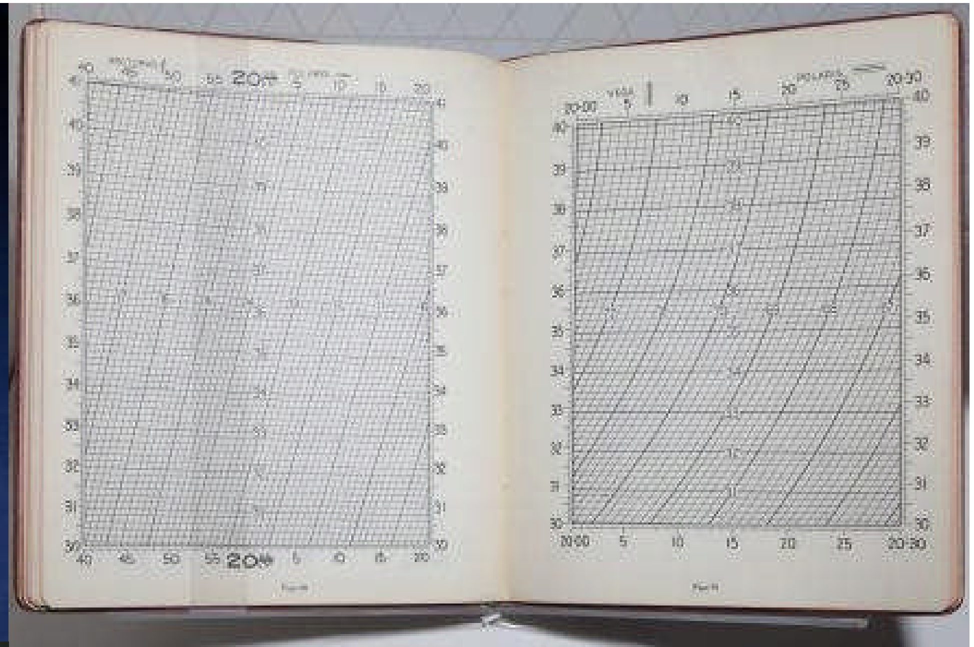
Right: caption: "Lindbergh's tutor in the science of navigation, Lieutenant Commander Philip V.W. Weems, U.S.N., demonstrates the simplest method of taking bearings, using a sextant and the wrist watch seen on his left arm."

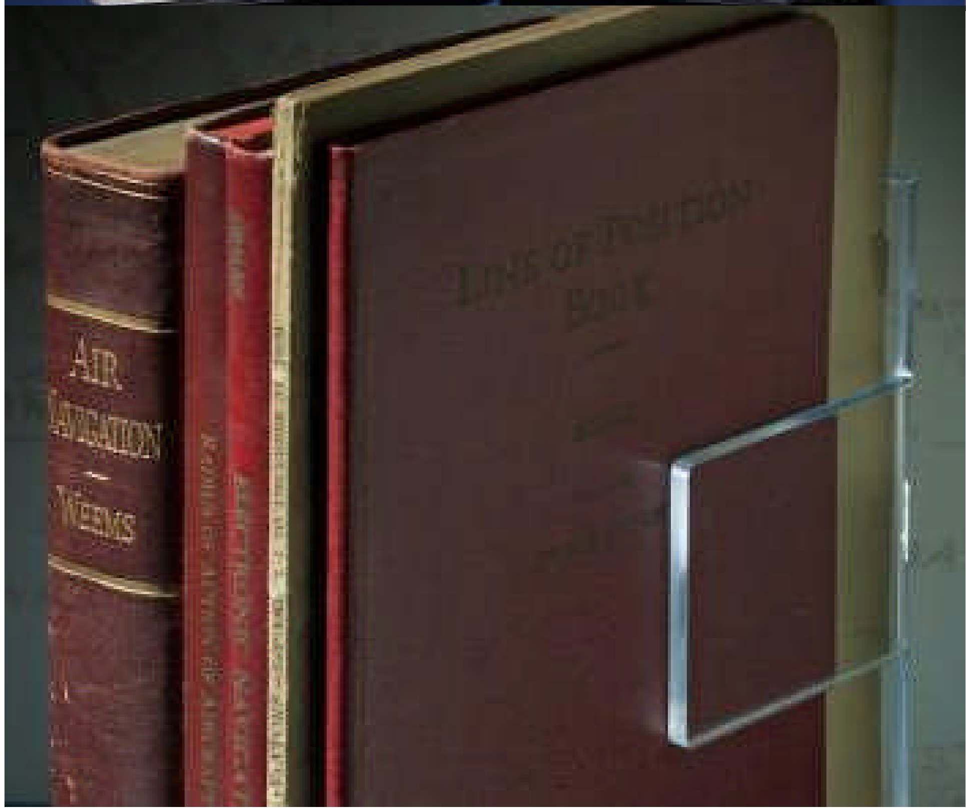
Lindbergh's tutor in the science of navigation, Lieutenant Commander Philip V. W. Weems, U.S.N., demonstrates the simplest method of taking bearings, using a sextant and the wrist watch seen on his left arm.



Another Weems innovation used in Lindbergh's training was his "Star Altitude Curves" (above); a revolutionary set of charts that let a navigator find his position using two stars (one was usually the north star; *Polaris*). The graphs helped cut the calculation time from fifteen minutes to forty seconds. During the day, instead of triangulating position using two stars, a navigator could use the sun to determine a line of position. By measuring the angle between the horizon and the location of the sun on its daily path, a navigator could draw a line on the globe and be assured that his position was a point somewhere on that line.
In "Line of Position," Weems published a comprehensive guide for this more difficult calculation.





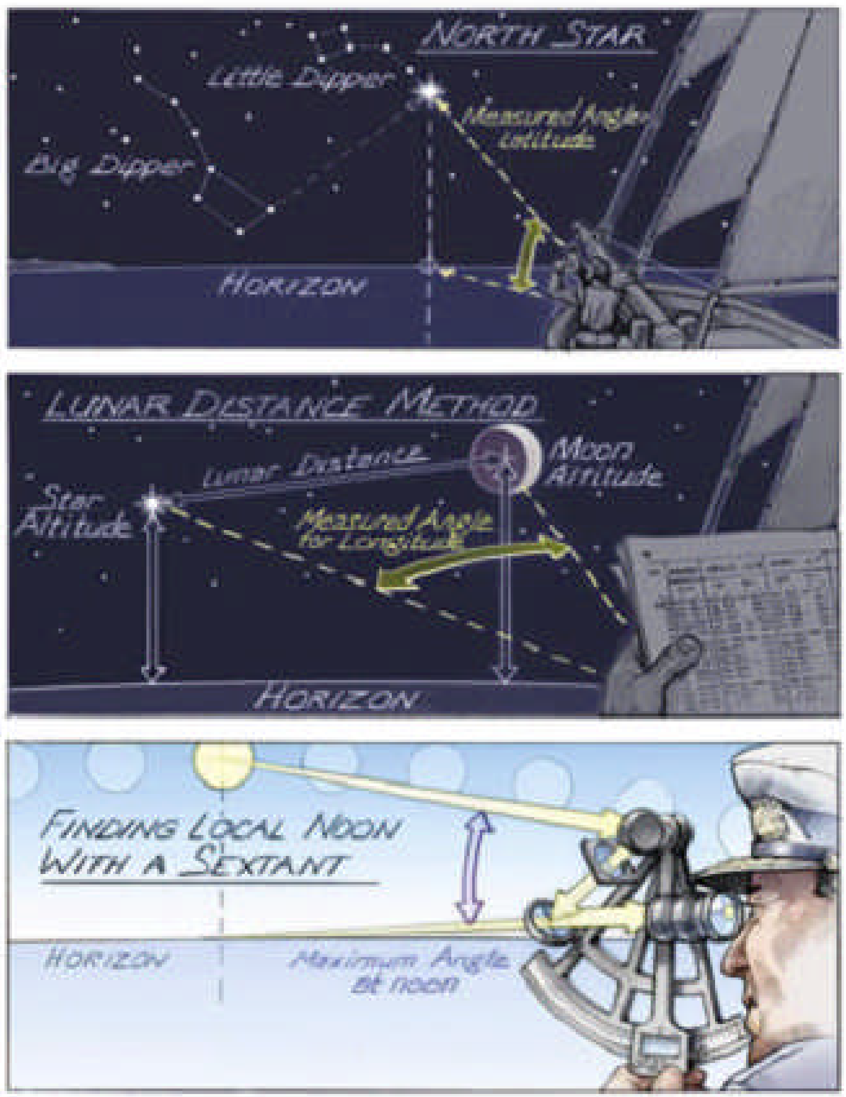


<u>Top Left</u>: caption: "The Air Almanac." In 1932, Weems devised an almanac that greatly reduced the time needed for computing position based on celestial sightings. The U.S. Naval Observatory showed little interest in it at first, but the Royal Observatory in Greenwich began publishing it in time for World War II, when it proved invaluable.

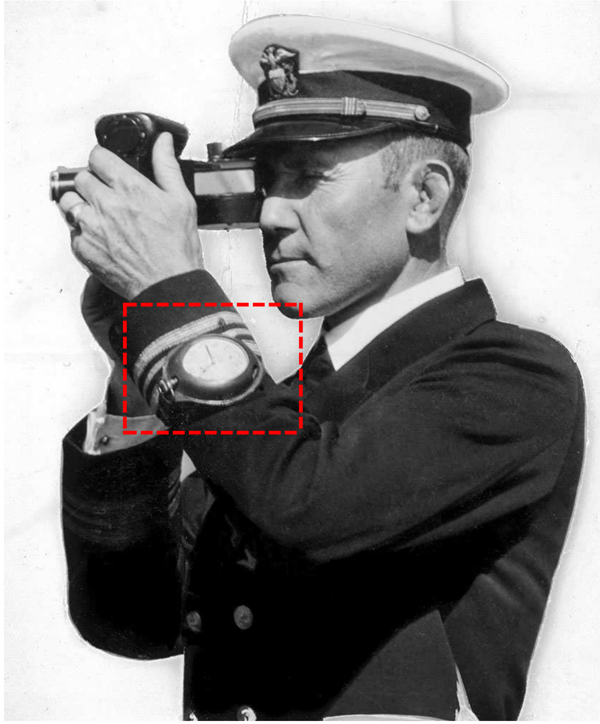
<u>Top Right</u>: caption: "Star Altitude Curves." This book of graphical solutions provided nighttime celestial calculations five times faster than other techniques. It required the sighting of Polaris and at least one other well-known navigational star.

<u>Left</u>: caption: "The Air Navigation Library." Weems developed, authored, or encouraged the writing of dozens of books and articles on advancements in air navigation. Air Navigation was a standard text for several decades.

Celestial Navigation at Sea

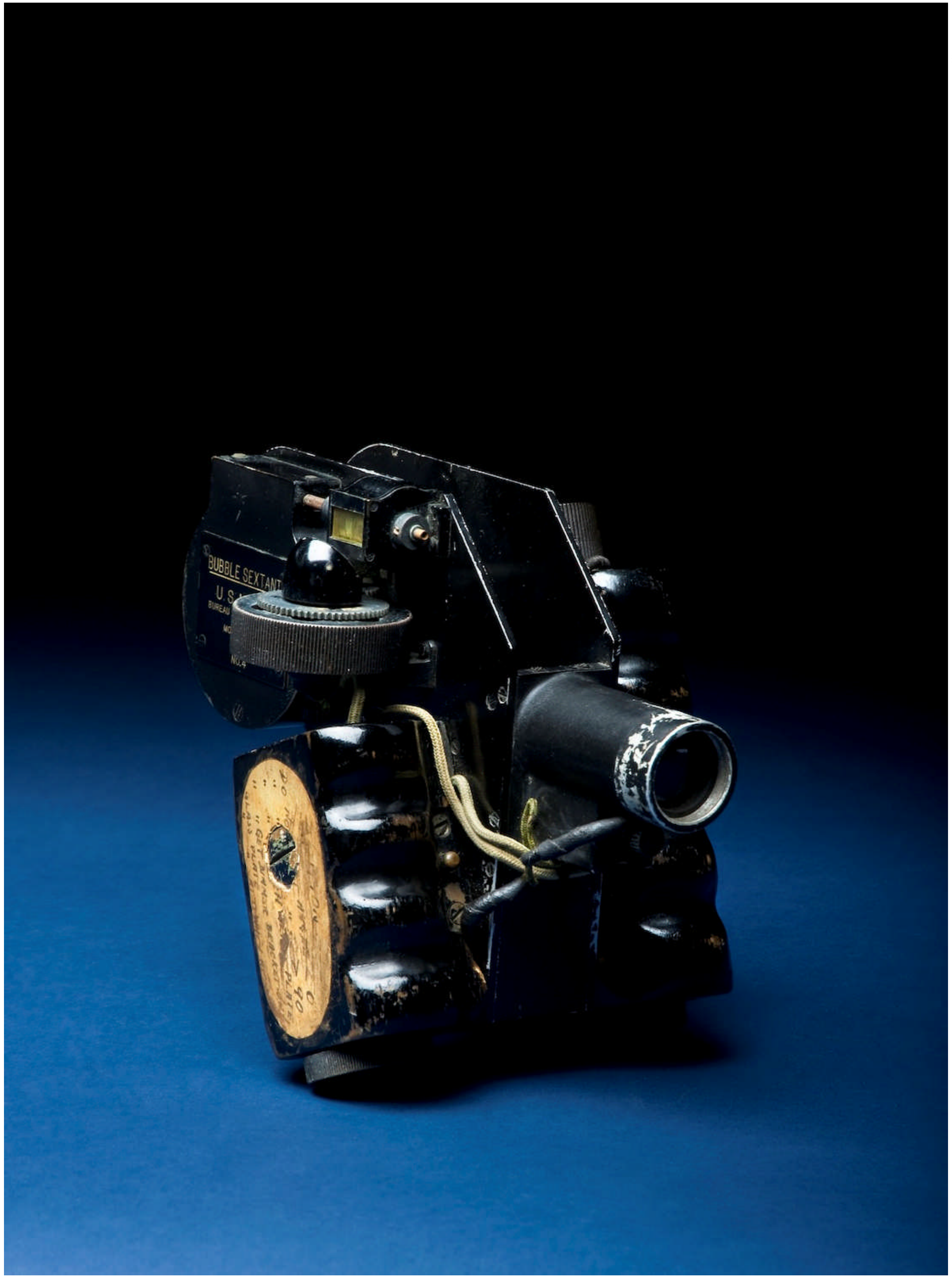


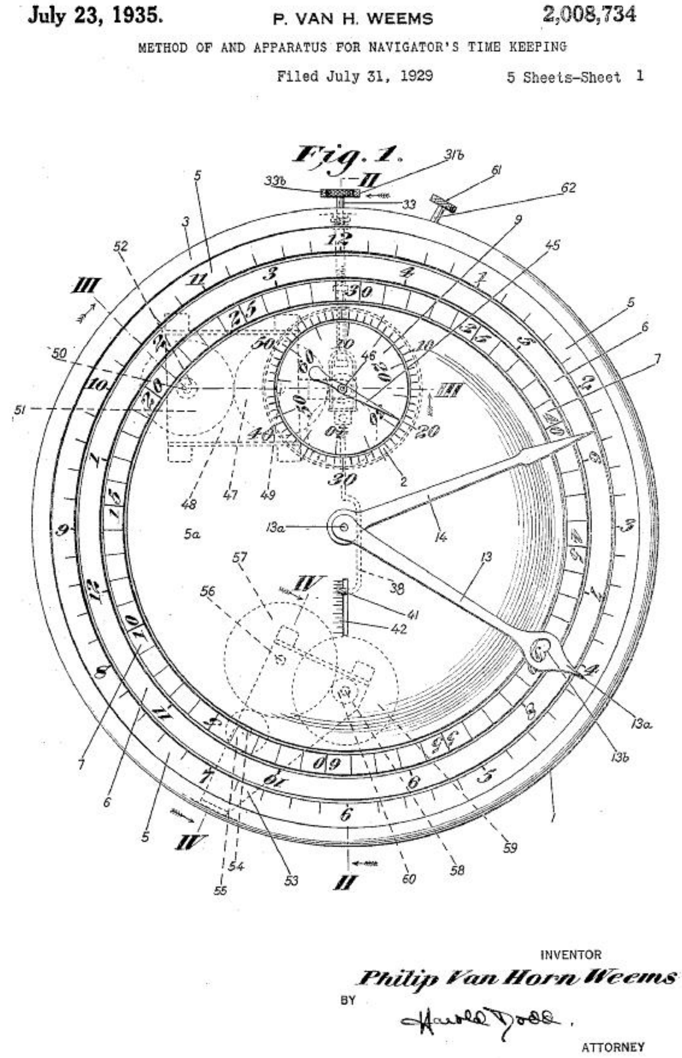
To locate themselves on the open ocean, navigators can determine their position by observing the Sun, Moon, stars, or planets.



<u>Above</u>: Weems using a bubble sextant. Note the large "Second-Setting Watch" on his arm.

<u>Left</u>: caption: "Sailors can find their locations by using a sextant to observe the angle of the sun, moon or stars off the horizon, then using this measurement to calculate their line of position. Aviators can do this with a bubble sextant, which gives them an artificial horizon at altitude."





<u>Above</u>: U.S. Patent drawing for Weems' "Hack" watch

<u>Left</u>: Weems used this sextant in training *Charles Lindbergh* and *Lincoln Ellsworth*. The NBS designed it for the USN in 1924 and *Bausch & Lomb* manufactured it.

<u>**Left**</u>**: caption: “Longines-Wittnauer Weems Second-Setting Watch Sidereal Model.” Before 1927, watches used with sextants for celestial sightings could only be set to the minute. A watch error of 30 seconds caused a navigational error of up to 7 miles. In 1927, P.V.H. Weems devised a watch with an adjustable second hand that could be set using radio time signals. These examples were his personal navigation watches.**

<u>**Right**</u>**: caption: “Longines Lindbergh Hour Angle Watch.” In the mid-1930s, the *Longines-Wittnauer Watch Company* marketed a line of watches designed in collaboration with *Charles Lindbergh* and *P.V.H. Weems*. The “Hour Angle Watch” sped computations for determining celestial lines of position. Its bezel and dial allowed navigators to read off the hour angle of a celestial object at Greenwich, eliminating a simple but troublesome calculation.**

<u>Left</u>: the "Lindbergh Hour Angle Watch" was a popular item during the height of Lindbergh's celebrity

"Lindbergh flew his ship with one hand and took a sextant altitude of the sun with the other! I am confident that this was the first time in history such a thing had ever been done."

Philip Van Horn Weems

RE: Weems' system was still a work-in-progress. He noted that Lindbergh's accuracy could be off by as much as fifteen or twenty miles. Shooting the sun next to the pilot, however, Weems was eventually able to fix position to an accuracy of within three miles - a margin of error unacceptable today, but the position was certainly good enough to put a pilot within sight of an island. Although Lindbergh never made the around-the-world flight, his lessons were not in vain. He helped establish cross-country air routes for *Trans-continental Air Transport* - known as the "Lindbergh Line" and later as *Trans World Airlines* (TWA) and was also courted by *Juan Trippe* of PAA to establish trans-Atlantic air routes. Because the continental United States was covered by a network of radio beacons, celestial navigation had little application over land, but the method became essential for the overseas routes that PAA was considering. With Lindbergh as its first disciple, the "Weems System of Navigation" quickly attracted a broad range of aviators who were eager to learn the latest techniques. Armed with a set of tools including the bubble sextant, the second-setting watch and celestial plotting forms for making calculations from the *Star Altitude Curves* and *Line of Position* books (and, by the mid-1930's, an *Air Almanac*, *Lunar Ephemeris for Aviators*, and a *Mark II plotter* - which every student pilot still receives), Weems' pupils now had everything they needed to find their position while in flight.

Weems hired Australian navigator *Harold Gatty* as chief instructor at his new school in San Diego, California; the first dedicated to aerial navigation. The two collaborated on numerous advances in navigation, including the *Gatty Drift Meter* (used to measure an aircraft's drift from a track). Gatty taught *Anne Morrow Lindbergh* the Weems system. When Lindbergh took *Juan Trippe* up on his offer and began planning overseas survey flights for PAA, he realized that his wife Anne would have to assist with navigation. These flights were textbook examples of the Weems System. In fact, Weems became the Lindberghs' official chronicler for the 1933 airline survey flight and used it as a case study for his "Air Navigation" textbook. Lindbergh and Gatty spread the Weems System through much of the aviation community in the U.S. and elsewhere (Gatty persuaded Lindbergh to bring PAA on as a client for the Weems System). *American Airlines* and TWA also adopted the Weems System in the late 1930s as they began considering trans-Atlantic routes. Paradoxically, the only entity not heavily influenced by Weems was his own branch of the service - the *U.S. Navy*. Focused on carrier-based aviation, the service largely ignored the needs of its long-range patrol squadrons until the late 1930s when it had to race to catch up. The military services lacked enough instructors to train cadets during WWII so PAA's school served as a leading source of navigators for the USAAF and *Royal Air Force* (RAF) at the start of the war.

The Immutable Law of Averages

“No less than 11 trans-Atlantic flights, carrying 28 passengers, are being planned for this summer. Cold mathematics, based on a record of past performances, prove that 40% of these flights will fail and that upwards of 11 persons will die in them - unless recent advances in airplane construction afford this season’s pilots new factors of safety. Despite the fact that the immutable law of averages decrees certain death for several of their number, more than two dozen pilots and passengers and 11 airplanes are going ahead with preparations to fly the Atlantic this summer. Some of the flyers are making the trans-Atlantic flight for scientific reasons; others frankly have no regard for science, but look on the matter as a joy flight and a sporting proposition; others are probably thirsty for the newspaper fame which will surround them with a halo of national glory if they succeed. But, regardless of their purposes, every man and woman who heads out to sea in an airplane is fighting the law of averages which says that 40% of the flyers who have attempted Atlantic crossings have landed in watery graves. Grim and inexorable is the law of averages. It can’t he repealed. It is about as amenable to flattery, bribery, coaxing and persuasion as an Egyptian Sphinx. Its personality is as friendly as a set of multiplication tables from an arithmetic book. When it says something, it means it. And it says - make no mistake about it - that 11 trans-Atlantic flyers are going to die if they carry out their plans. Maybe you don’t believe it. Maybe the trans-Atlantic flyers don’t believe it. But the law of averages doesn’t care. It will simply produce some such piece of irrefutable logic as this: Nine trans-Atlantic flights have failed, bringing death to pilots and passengers. Twenty-one persons perished on these expeditions. At the same time, 15 similar flights succeeded. Out of 24 attempts, therefore, 9 failed - slightly less than 40%. Applying this 40% average to the forthcoming flights, therefore, it is easy to predict that 4 or 5 flights will fail and that 40% of the 28 passengers - about 11 - will perish…”

Popular Mechanics, **August 1931**

15 Flights Succeeded to 9 That Failed

Atlantic Flights Cost These Lives:

- Capt. Charles Nungesser and Francois Coli, May, 1927.
- Princess Loewenstein-Wertheim, Capt. Leslie Hamilton and Colonel F. F. Minchen, August, 1927.
- Lloyd Bertaud, James DeWitt Hill and Philip Payne, 1927.
- Capt. Terry Tully and Lieut. James Medcalf, September, 1927.
- Mrs. Frances Wilson Grayson, Brice Goldsborough, Lieut. Oskar Omdal and Fred Koehler, Dec., 1927.
- Capt. Walter Hinchcliffe and Hon. Elsie Mackay, March, 1928.
- Major Leon Idezikowski, July, 1929.
- Oscar Kaiser, Kurt Luescher and Alfred Tschopp, Aug., 1929.
- Urban F. Diteman, October, 1929.

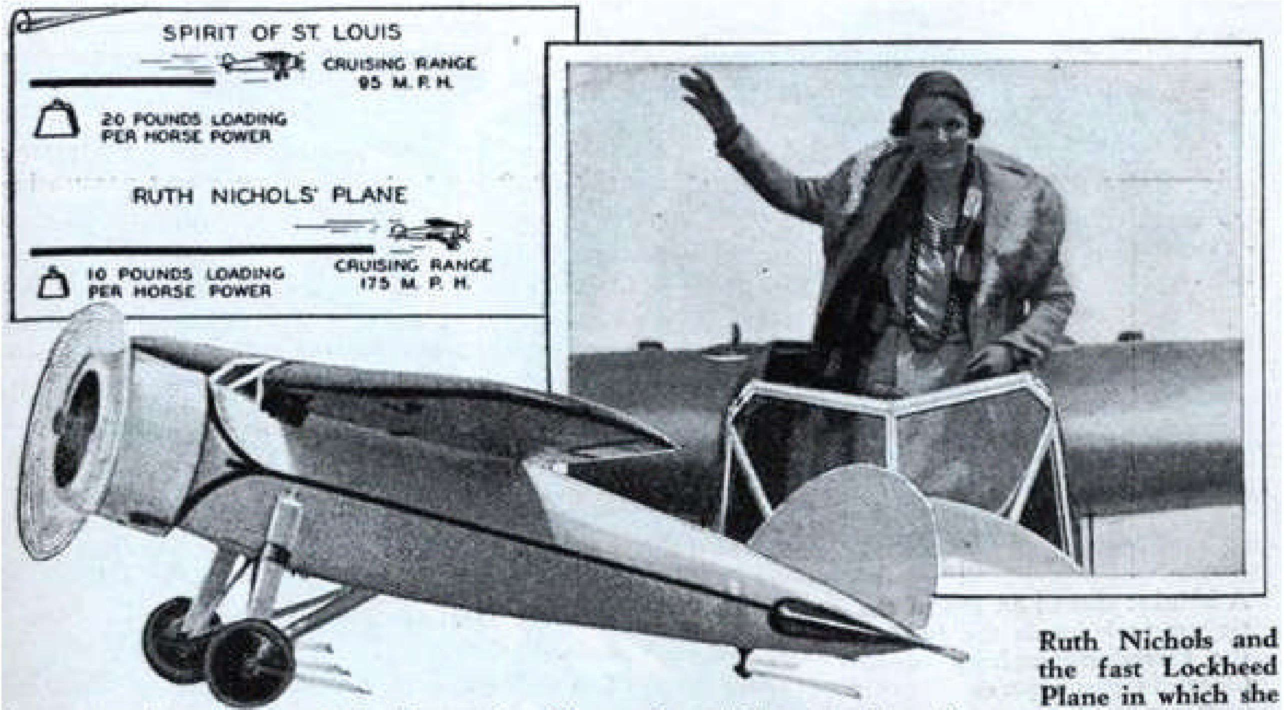
These Trans-Atlantic Flights Succeeded:

- Alcock and Brown, 1919.
- Navy NC-4, 1920.
- Army round-the-world flight, 1924.
- Charles A. Lindbergh, 1927.
- Chamberlin and Levine, 1927.
- Byrd, Neville, Acosta and Balchen, 1927.
- Brock and Schlee, 1927.
- Amelia Earhart, Wilmer Stultz and Louis Gordon, 1928.
- Koehl, Fitzmaurice and von Huenefeld, 1928.
- Assolant, Lefevre and Lotti, 1929.
- Williams and Yancey, 1929.
- Boyd and O'Conner, 1930.
- Kingsford-Smith, 1930.
- Wolfgang von Gronau, 1930.
- Coste and Bellonte, 1930.

<u>Above</u>: list of previous trans-Atlantic flight/s fatalities and successes

<u>Left</u>: caption: "Composite map of the trans-Atlantic and round-the-world flights planned for this summer. Note how time to travel around globe has shortened."

(*Popular Mechanics,* August 1931)



Ruth Nichols and the fast Lockheed Plane in which she hopes to make a 13-hour Atlantic crossing. Comparison of her plane's performance with Lindbergh's Spirit of St. Louis, shown graphically in the corner drawing, indicates how improved plane design has bettered the chances of ocean flyers by increasing the speeds and reliability of their machines.

"…There is a slight joker concealed in this statement, however, which you may have ferreted out for yourself. It is this: These averages were compiled on planes which made their trips, mostly, between 1927 and 1930. There is a vast difference between Lindbergh's Spirit of St. Louis, for instance, and the Lockheed plane which Ruth Nichols hopes to pilot to Paris. Lindbergh's ship had a 225 horsepower motor and a cruising speed of 95 miles per hour. The trans-Atlantic Lockheed has a 660 horsepower motor - almost three times as powerful as Lindbergh's. The motor itself is slightly larger than Lindbergh's, but most of the increase in horsepower is attributable to supercharging. With a cruising speed of 175 miles an hour, therefore, the hazards of an Atlantic crossing are considerably lessened. And there are other improvements, which will be mentioned a little later, that give the 1931 crop of flyers an advantage over their pioneering brothers…"

Popular Mechanics, **August 1931**

“…to a coldly scientific mind, a successful flight by Ruth Nichols to Paris would not be deserving of the same acclaim which greeted Lindbergh, may be found in the fact that the Lockheed plane which Miss Nichols flies has a cruising speed 80 miles an hour faster than Lindbergh’s; it has an engine three times as powerful which is extremely unlikely to fail in the air; it has a variable pitch propeller which enables a heavily loaded ship to takeoff easily, changing back to high speed pitch when in the air; it has a Sperry artificial horizon, which tells the position of the plane in fog or snow - that is, whether it is climbing, diving, or whether one wing is low; it has three compasses to warn of deviation from the course; it has warning instruments to indicate when ice is forming on the wings, giving the pilot a chance to climb to a stratum of air where ice cannot form. What Miss Nichols’ flight may prove, therefore, is not that she is a feminine runner-up to Lindbergh, but that a modern airplane is too well powered and so well equipped that much of the danger of an ocean flight has been eliminated. Miss Nichols, in other words, is all set to start the law of averages working again on a new set of facts…”

Popular Mechanics, **August 1931**

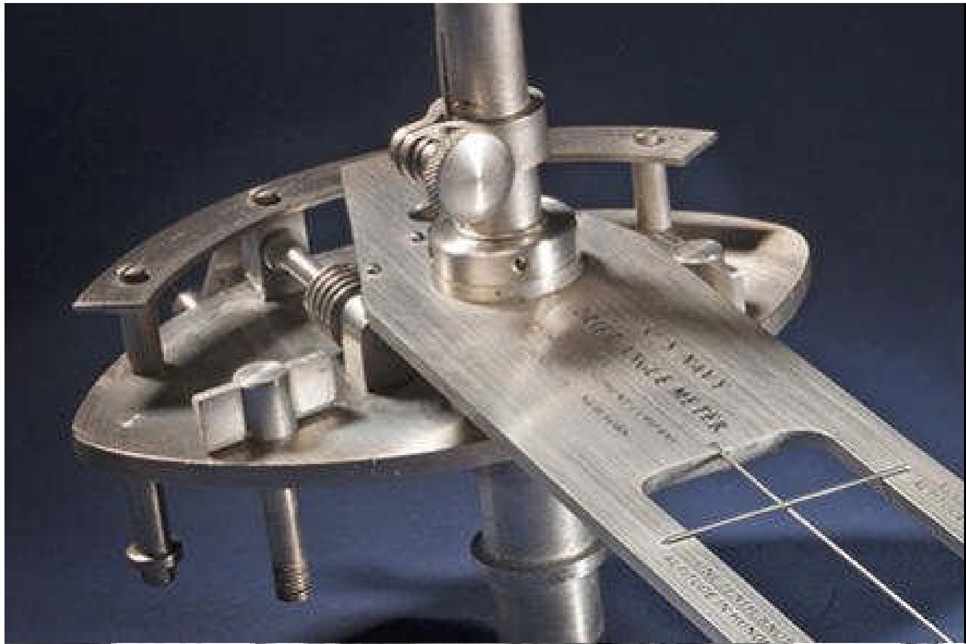
"…Every trans-Atlantic pilot, it is safe to say, has all sorts of confidence in his ability to carry out his plans successfully. The United States government, however, as semi-officially represented by its weather bureau, doesn't share this enthusiasm. In fact, it frowns upon these flights as suicidal, purposeless from a scientific point of view, and inspired by a desire for notoriety. It issues weather forecasts to flyers because it has done so in the past, but it does so grudgingly, realizing that it would be in for considerable criticism if a flight failed because of adverse weather conditions which the bureau failed to warn against. Without mentioning any names, it frowns also on the 'sex competition' which the projected solo flights of women have injected into the trans-Atlantic game. Being the first woman to fly the Atlantic, or to reach a certain altitude, or to do a dozen outside loops, doesn't mean a thing to the coldly scientific bureau except that the women concerned have snatched a laurel wreath which may temporarily decorate their brows until some other woman snatches it off. When men have set and held all maximum air records, there is little scientific glory left for the woman who comes closest to matching the marks, in the view of the weather bureau, however much human interest there may be in her feat…"

Popular Mechanics, **August 1931**

Tools of the Trade

__Left__: **caption: “Pioneer Earth Inductor Compass.” The earth inductor compass was popular in the U.S. for long distance flights in the period 1924-1934. *Charles Lindbergh* relied on this type of compass on his 1927 New York to Paris flight to maintain course until it mal-functioned. It’s primary attraction was that it was far more stable than liquid-filled “whiskey” magnetic compasses and featured a controller that could dial in a heading that could be followed with a left/right indicator similar to that used for VOR navigation decades later. This made is far easier to hold a heading over long periods, particularly when fatigued. It used a wind-driven generator to create an induction field that created variable current as it interacted with the Earth’s magnetic field. Less reliable than a liquid compass, it fell out of favor by the mid-1930s, replaced by gyroscopic heading indicators.**

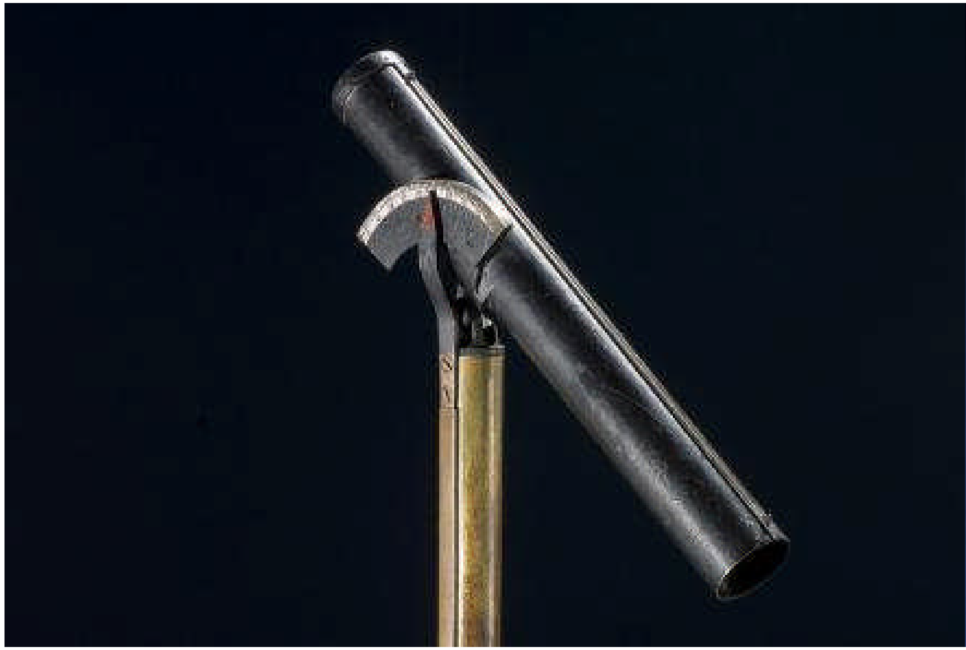
__Right__: **caption: “Waltham Eight-Day Clock.” Lindbergh brought this clock with him on his transatlantic flight in the Spirit of St. Louis. His simple dead reckoning approach to navig-ation did not require an accurate clock. “Eight-day” refers to how long the clock would run on a full winding.**



<u>Top Left</u>: caption: "Pioneer Drift Meter." Lindbergh carried a Navy drift meter like this one to measure wind drift. He never used it because it was too difficult to mount and operate outside the window while flying and still manage to control the aircraft safely.

<u>Top Right</u>: caption: "Louis Levin B-2 Drift Indicator." Celestial navigation innovator and instructor *P.V.H. Weems* and *Harold Gatty* worked together to develop this new drift indicator. It could determine drift and ground speed without a cumbersome apparatus deployed outside the aircraft.

<u>Left</u>: *Harold Gatty* instructs a USAAF officer in the use of his drift indicator.

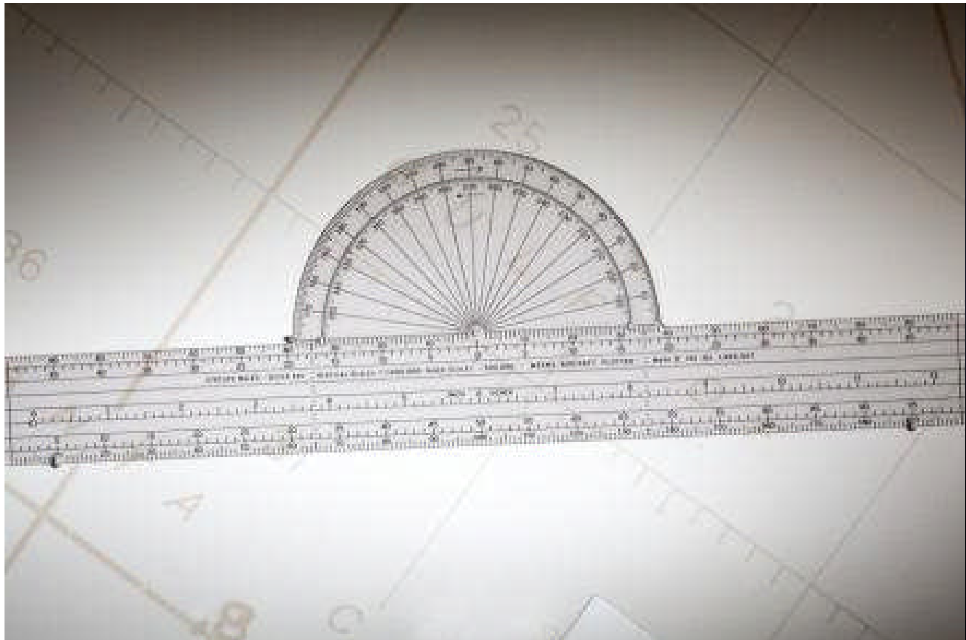


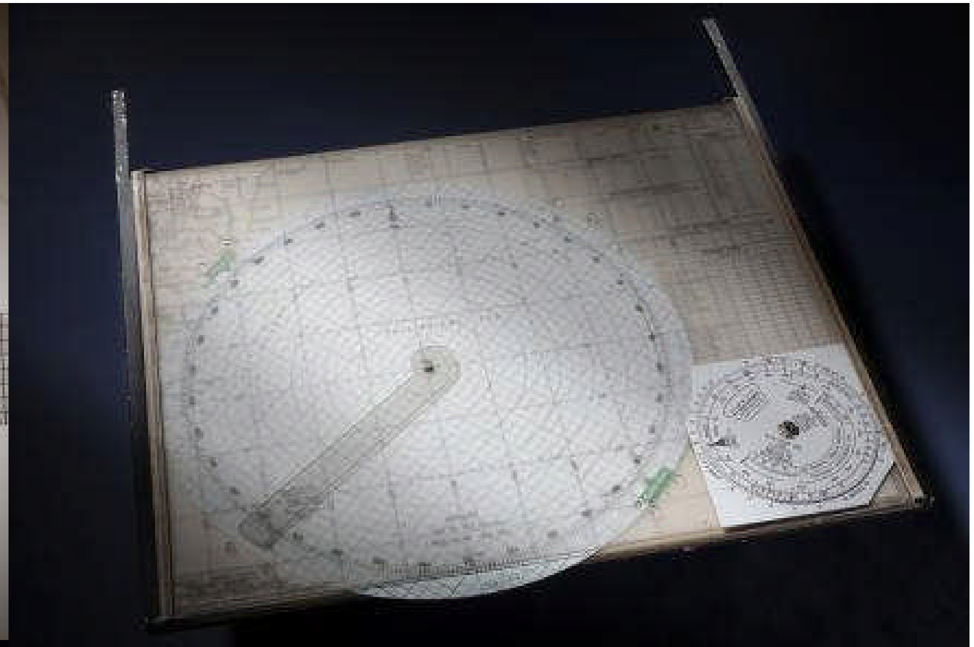
<u>Left</u>: caption: “Mark IIB Pelorus Drift Sight.” A Gatty-style drift sight was complex, heavy, and less effective for over-water flying. The Pelorus drift sight was smaller and lighter but required more manual calculation and the use of flares or smoke bombs in certain conditions.

<u>Right</u>: caption: “Mark IV Aircraft Float Light.” The float light was a smoke-producing flare designed to be dropped by an aircraft over open water for drift sighting during the day or night. This type would have been used from the late 1930s through WWII.

<u>Above</u>: caption: "Air Position Indicator." The Air Position Indicator (API) was a remarkable electromechanical system of dead reckoning. It took inputs from airspeed sensors and gyro magnetic compasses and continuously computed latitude and longitude. This system became standard on the *Boeing B-29*. The API foreshadowed the future importance of computing in navigation.

<u>Left</u>: caption: "B-3 Drift Meter." The B-3 was used on bombers and transports when ground or water could be clearly seen. It evolved from the earlier Gatty drift meters.





<u>Top Left</u>: caption: "Weems Mark II Plotter." Weems developed this simple but effective plotter for aeronautical charts in 1935. It remains the most popular aviation plotter in the United States. Richard Byrd used this one on his Antarctic expeditions.

<u>Top Right</u>: caption: "Mark 3A Plotting Board." The crews of carrier-based aircraft had to keep track of their own position as well as that of their aircraft carrier. This type of plotting board allowed them to track the movements of each and plot a return course.

<u>Left</u>: caption: "Dividers and Compass." Used to measure distances on charts.

The Grand Old Man of Navigation

For many decades, the *Weems System of Navigation* was the principal means of fixing position in over-water navigation for the U.S. military and airlines, along with many of the famed record setters and endurance fliers. In 1937, the transpolar flights that the Soviet Union achieved in Tupolev ANT-25s were made by aviators who were using the Weems System. U.S. observers noted that the Soviet aircraft had a hand-copied version of Weems' *Star Altitude Curves* on board. Weems created a community of aerial navigation experts and practitioners where none had existed before. Weems continued to be fascinated by navigational problems throughout his life. He began to adapt his aerial navigation techniques for the unique challenges of orbital mechanics and the adaptations were put to use in the *Apollo* program. Weems also founded the *Institute of Navigation*, which is still the leading professional society devoted to the advancement of navigation.

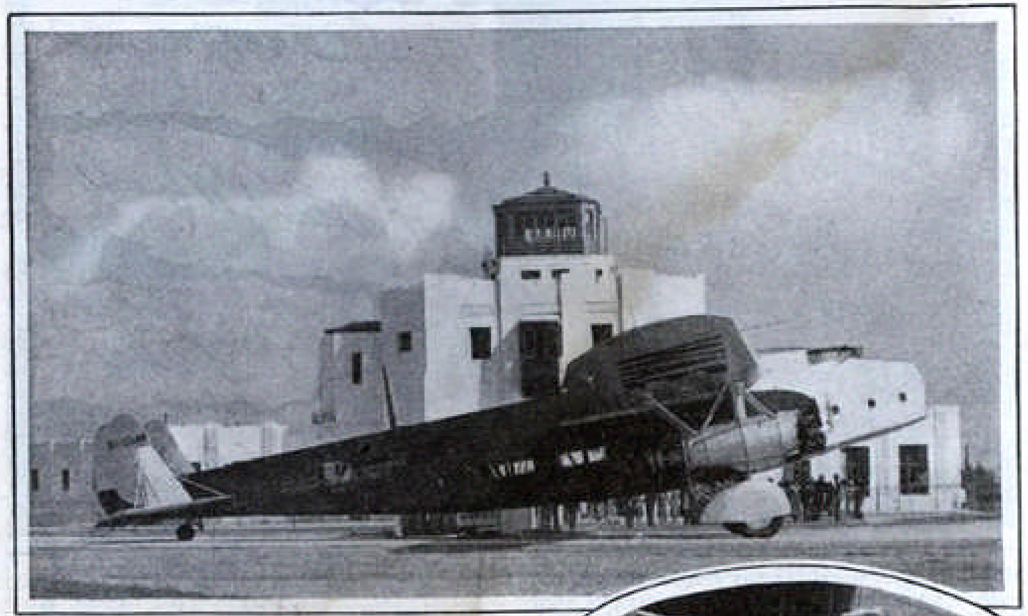
<u>Left</u>: *Philip Van Horn Weems* (1889-1979)

Flying the Beam

"…Radio took much guesswork out of it, at least for an aircraft within 300 miles of land. The fixed loop antenna enabled a pilot fly a selected track to or from a transmitter; later, the rotating loop enabled his navigator to zero-in on two or more stations, plot them and come up with a reasonably accurate fix. Coastal direction-finding stations picked up a plane's signals and radioed their fix to its pilot. Then came the radio range which radiated a beam seaward so the inbound airman could ride home on it. Just before World War II the automatic direction finder came into use. This god-send's needle automatically pointed to any station and seemed, at the time, everything the over-water crew could desire…"

Popular Mechanics, **October 1971**

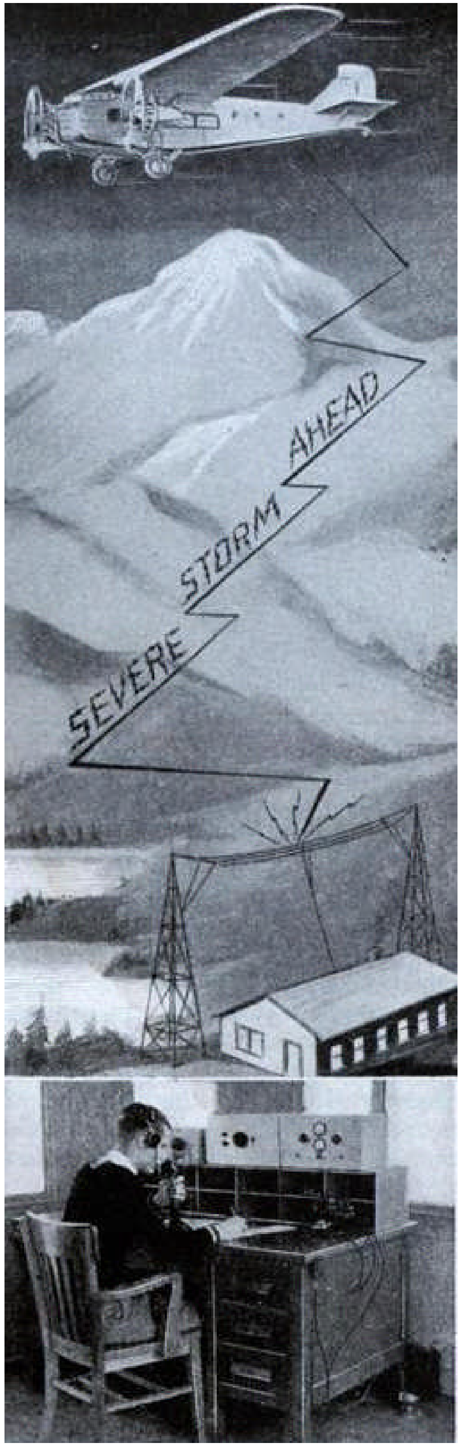
"…Herbert Hoover, Jr., son of the nation's chief executive, is chief engineer of the Western Air Express radio service, and is directly in charge of communications. For the past year he and his staff of radio-trained assistants have been at work conducting a series of experiments that have made radio and aviation history. As a result of his labors every plane of the Western Air Express is now equipped with two-way radio telephones. The whereabouts of every airplane in the company's vast network of western air lines is known during every minute of their flights. Every pilot of the various lines, while in the air, is constantly within 'speaking distance' of his home airport, of weather stations, and of terminals, and intermediate fields. If another plane of the Western Air Express is ever forced down, every office of the entire system would know about it almost instantly. They would know almost the exact spot at which such a ship makes contact with the ground. Gone are the days of the 'needle-in-the-hay-stack-hunts' for aviators 'down in the rough,' as in the case of Maurice Graham, famous mail pilot…"



A 32-passenger air liner of the Western Air Express in front of the Alhambra Station. Note aerial strung from the wings to the fuselage mast.

Dr. Lee DeForest and Herbert Hoover, Jr., who are literally father and son of the present system of radio telephony used in commercial aviation.

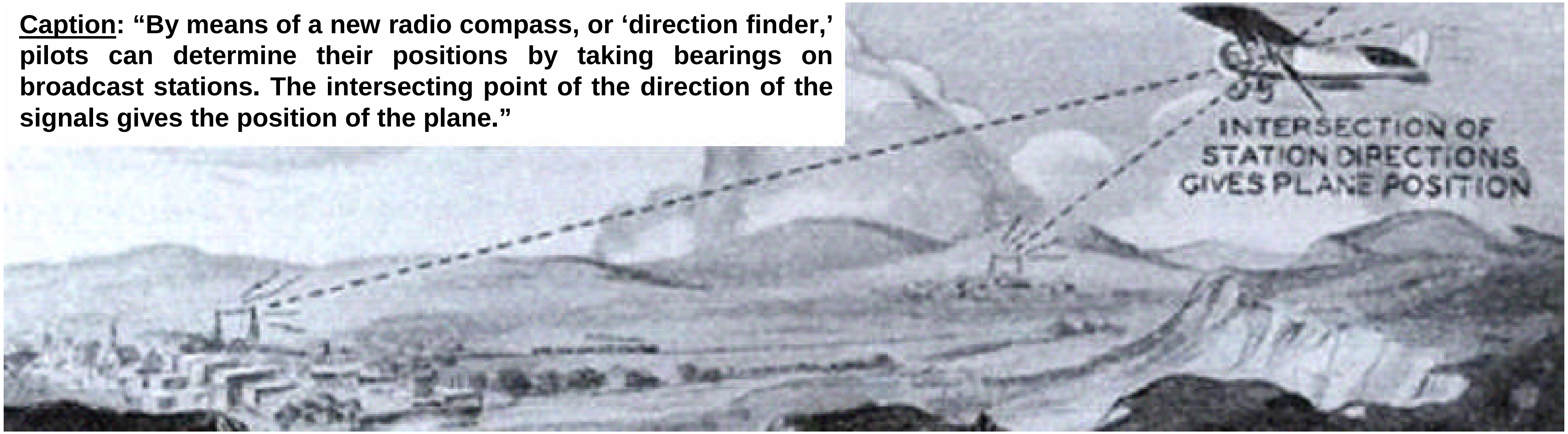
***Modern Mechanics,* June 1931**



"…Finding and rendering assistance to the radio telephone-equipped airplane is placed in the class with answering the 'S. 0. S.' call of an ocean ship, with her latitude and longitude known to the rescue ships. Radio telephony gives aviation an entirely new set of values for weather science. The danger of collision between airplanes in the air is virtually eliminated. Pilots are no longer forced to rely wholly upon their own judgment, and aerial passengers are given a new sense of security in the safety and reliability of modern air line service. A transport pilot has plenty to occupy his time and attention when in the air. Thus, out of necessity, conversations with the dispatcher are rendered in the simplest possible terms. The pilot, in reporting his position as 'L-9,' is using a code language developed for the purpose. The maps of the air routes are all divided up into squares, and these squares are designated in the manner of a city map. Alphabetic letters indicate distances on the map north and south, and the numbers represent distances east and west. Thus, when a pilot reports his position as 'K-4,' 'G-2.' 'B-14,' or whatever the designation may be, the location is as definite to the dispatcher as if the pilot were present, and pointing out a location on a map on the wall. The beacon lights are all designated by number, and flash their own identifications to pilots in the air. This gives a very definite location when a pilot reports in to say that he is five miles north of beacon 27…"

***Modern Mechanics,* June 1931**

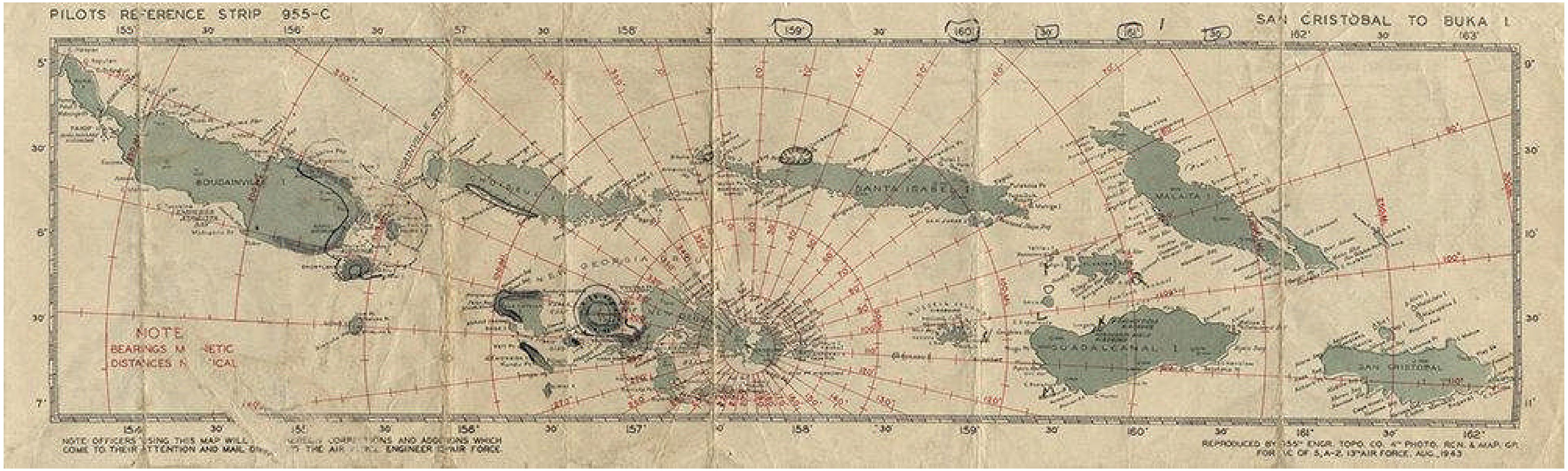
Left: caption: "Sitting at his desk before a microphone, the operator can warn passenger or mail plane pilot of severe storms or direct landing operations. The above drawing shows the hookup with which signals are transmitted to and received from the pilot."



<u>Caption</u>: “By means of a new radio compass, or ‘direction finder,’ pilots can determine their positions by taking bearings on broadcast stations. The intersecting point of the direction of the signals gives the position of the plane.”

“…Radio compass and radio beacon experiments are now also going forward at the Alhambra airport. A radio beacon is already in operation to inform pilots when they’re over the field, even during conditions of obscured visibility. Aviators approaching the field come within its sphere of influence twenty miles away. The beacon impulses are recorded by an instrument with an oscillating pendulum. These impulses become stronger as the field is approached, and turn on a colored light on the pilot’s instrument board when the plane gets over the field. A radio compass has now been developed with which the pilot can take bearings on any station transmitting any kind of signals, either broadcast or code. By determining the directions of two or more broadcast stations, the pilot can chart out his own position, which will be at the point of intersection of the directions from which the signals come…”

***Modern Mechanics,* June 1931**



Before WWII, radio navigation could only provide a course or a bearing to a station. The invention of timekeeping technologies led to a new era of systems that could fix position accurately and were easier to use. Each system of radio navigation uses time in a slightly different way and each requires its own type of navigational charting. On the eve of WWII, a web of air navigation radio stations and beacons connected by "airways" began to cover the globe. When the war broke out, new military equipment revolutionized air navigation. This allowed less experienced users to achieve the same results as highly trained celestial navigators and eventually decreased the need for professional navigators.

<u>Above</u>: caption: "Chart, Pilots Reference Strip 955-C, San Cristobal to Buka Island, 1943." Charts like this were used by Navy pilots throughout the Pacific during WWII.

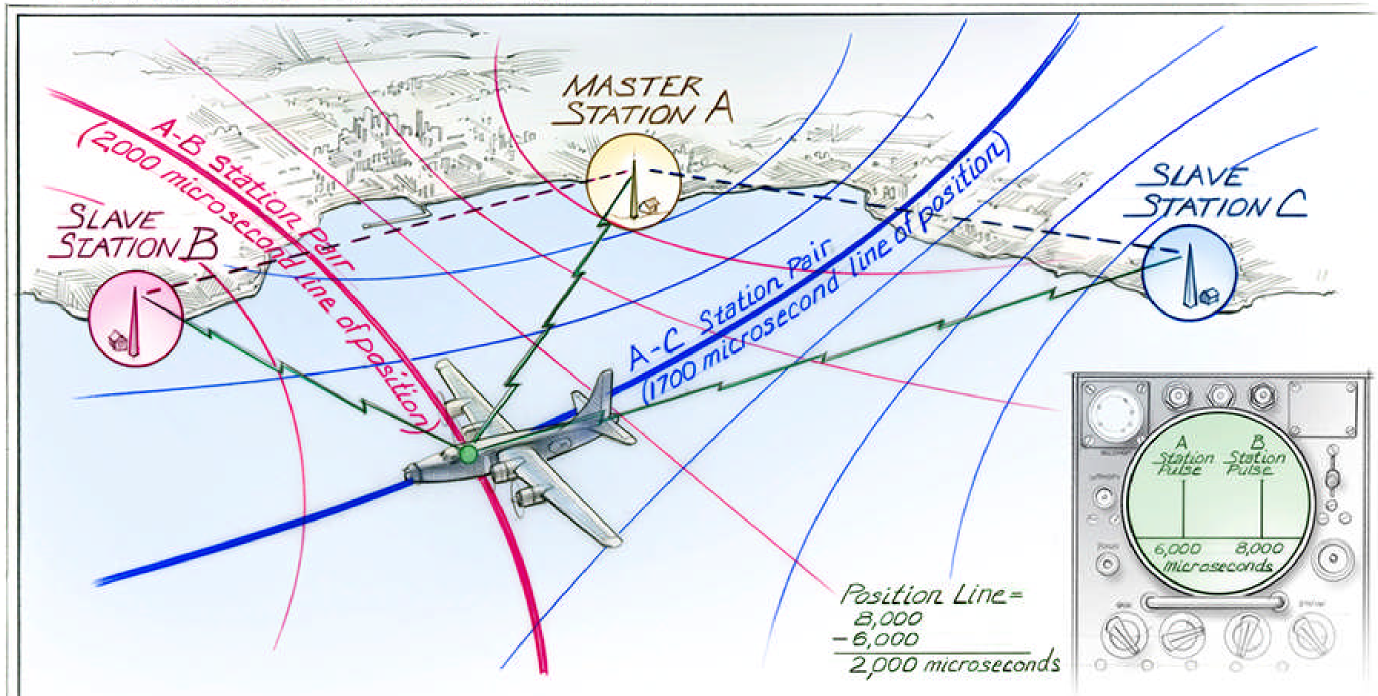
<u>Top Left</u>: caption: "Westport Radio Compass Receiver." Wiley Post used this radio compass for a nonstop stratospheric transcontinental flight attempt in his Lockheed Vega Winnie Mae. He had to position the square antenna "loop" manually to home in on commercial broadcast radio stations.

<u>Top Right</u>: caption: "Westport Radio Compass Indicator"

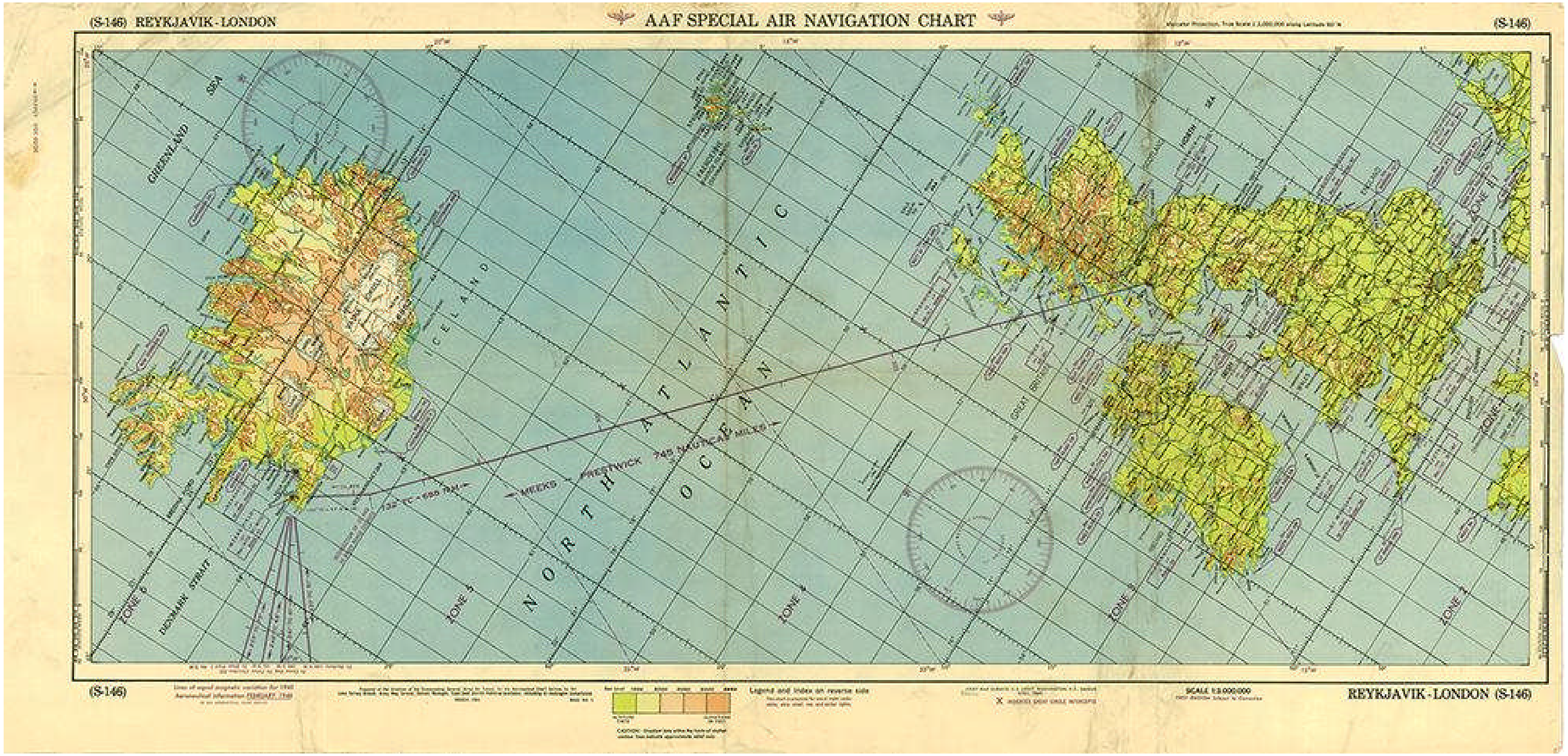
<u>Left</u>: caption: "Westport Radio Compass Loop Antenna"

Celestial navigation was not well suited for use in all-weather military operations or by the thousands of inexperienced young navigators entering military service. To remedy this situation, Great Britain and the United States created complex radio navigation systems that used advances in timing technologies and electronic computing. These systems revolutionized navigation. In 1940, British scientists and engineers developed "GEE" - a practical medium-range (up to several hundred miles) system of radio navigation based on measuring the time-delay between sets of radio signals. The U.S. built on this effort and created a longer-range system called LORAN (<u>LO</u>ng-<u>RA</u>nge <u>N</u>avigation) to provide oceanic coverage for ships and aircraft. Although initially no more accurate than celestial navigation, LORAN had a big advantage: it worked when the sky was clouded over. During the day, when sextant "sun shots" could only provide a line of position, LORAN gave a precise fix.

Hyperbolic System



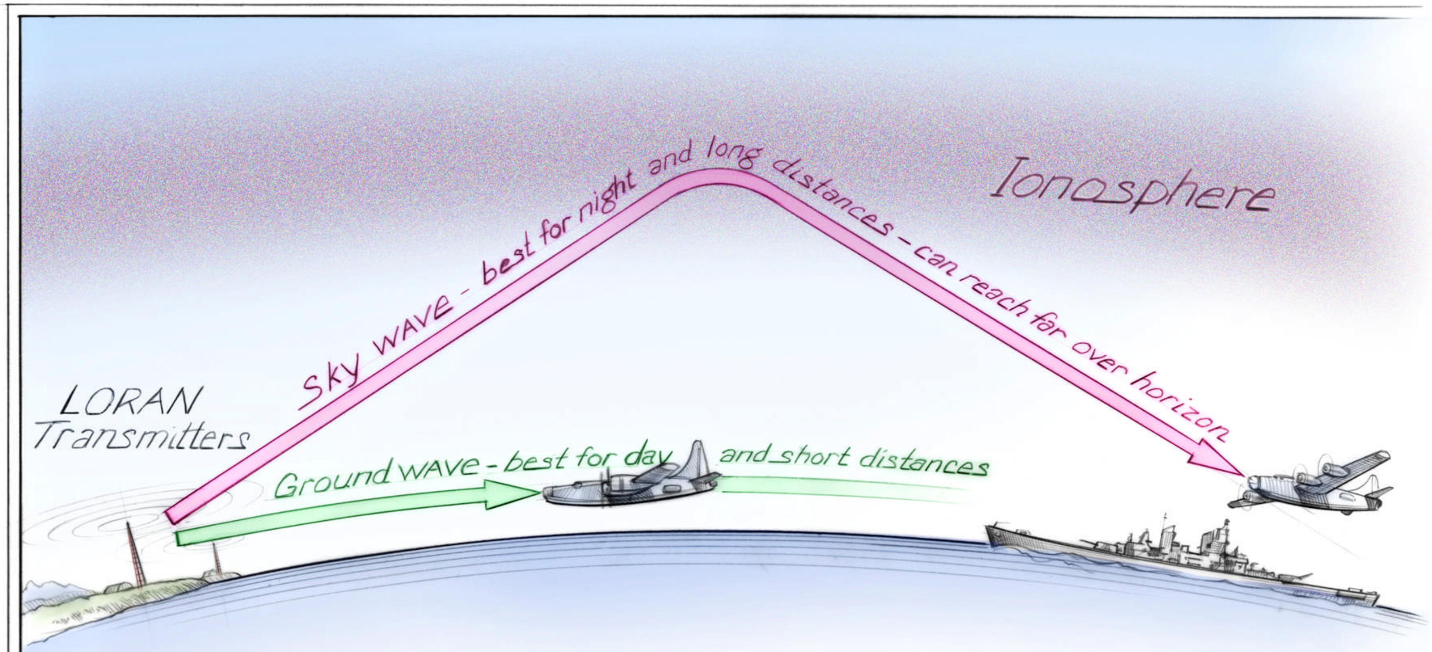
In a hyperbolic system like LORAN, a receiver on an aircraft or ship picks up radio signals broadcast by one or more pairs of radio stations spaced hundreds of miles apart. The system works by measuring the time difference between signals from the two stations. By tuning in different pairs, the navigator could plot lines of position in the form of hyperbolas (arcs) that intersect to give a precise location.



By 1943, Allied pilots in Europe were using the medium-range GEE hyperbolic system for all-weather navigation. But its limited range did not extend far into the North Atlantic, where ships and aircraft on anti-submarine patrol desperately needed it. In the Pacific, Navy patrol bombers like the ***Consolidated PB4Y-2 Privateer***, B-29 bombers attacking Japan and other aircraft also needed a long-range, all-weather navigation system.

<u>Above</u>: caption: "USAAF Special Air Navigation Chart (S-145), Stephenville to Reykjavik, 1946, Scale 1:3,000,000"

PUTTING THE LONG RANGE IN LORAN

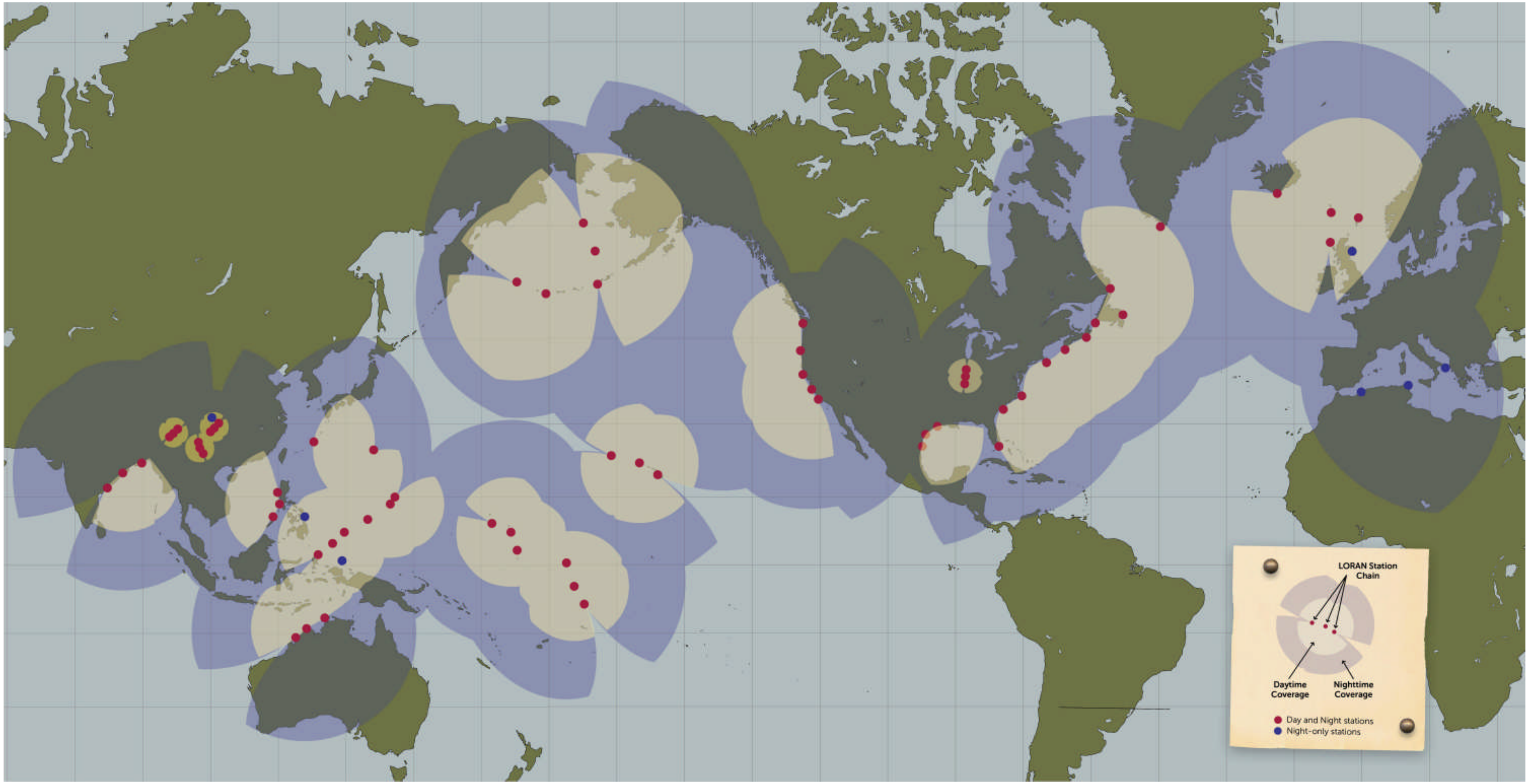


LORAN receivers picked up signals that were either broadcast directly from stations as "ground waves" or reflected as "sky waves". Sky waves could travel three times farther than ground waves because they reflect off the ionosphere, the layers of charged particles in Earth's upper atmosphere.

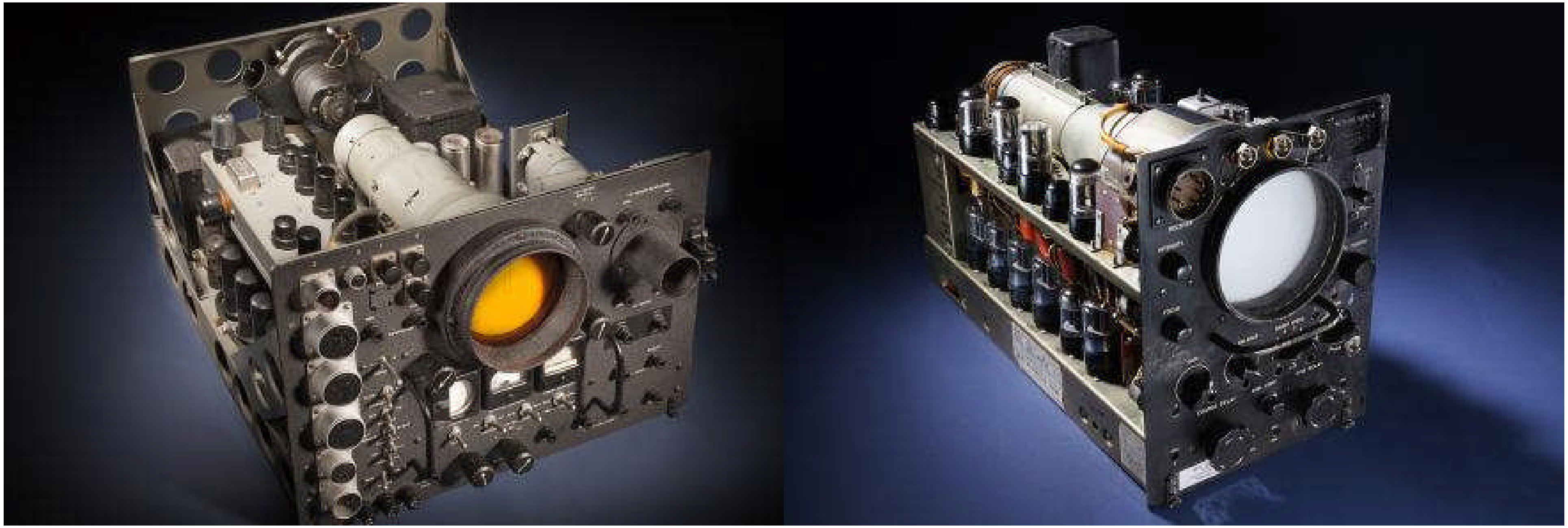
<u>Left</u>: caption: "RCA AVR-15A Radio Range Receiver." This is a typical radio range receiver used in the late 1930s on private airplanes.

<u>Right</u>: caption: "Type 62A GEE Mark II Indicator Unit." The RAF and the USAAF's *Eighth Air Force* relied extensively on the GEE hyperbolic system in their bombing campaigns over Europe, where it was essential in the overcast skies. Late in the war, GEE combined with a system of radar beacons (known as "GEE-H") allowed the bomber crews to attack their targets without seeing them.

Mechanical clocks and watches that referenced a standardized time became less important to navigation because electronic systems such as LORAN could accurately calculate a relative position with their own internal time. This achievement was only possible through massive national investments in developing and combining the technologies of radio transmission and timing. At LORAN's heart was its timing unit - a crystal oscillator that allowed a receiver on an aircraft, ship or submarine to measure the difference between "master" and "slave" radio pulses. Early LORAN equipment was sensitive and operators had to monitor it carefully, especially in areas with salt air and high humidity which rapidly corroded components. Many LORAN stations were in remote, inhospitable places. They required extensive infrastructure; personnel quarters, water and fuel tanks, communications equipment and electrical generators (such as the one in Adak, Alaska).



<u>Above</u>: **by the end of WWII, LORAN chains consisting of seventy-two operable stations provided navigation over 30% of the globe (mostly in the northern hemisphere). More than 70K receivers for aircraft, ships and submarines had been built. By the height of the Cold War, coverage had extended to 70% of the Earth's surface. The ionosphere and terrain limited daytime coverage, thus LORAN was far more effective at night.**



<u>Left</u>: "Western Electric AN/APS-2E Radar Plan Position Indicator." This Navy radar scope would have been used on long-range patrol aircraft, such as the Consolidated PB4Y, late in WWII and during the early Cold War. U.S. bombers during WWII used radar for short-range navigation (under 50 miles) and for bombing through clouds and at night (but less accurately than conventional bombsights). The system was only effective in locating cities and shorelines.
<u>Right</u>: caption: "AN/APN-4 LORAN Set." The APN-4 was the first LORAN set for aircraft to enter service. It had a separate receiver and display unit. The navigator had a leather hood to put over the oscilloscope's cathode ray tube so he could clearly see it in daylight. LORAN was most valuable when the skies couldn't be seen for celestial navigation and when coastlines couldn't be picked up by radar. It required a skilled operator.

Left: caption: "ZB-1 Radio Homing Adapter and Security Cover." A significant wartime innovation for naval aviators was the YE-ZB radio system, which enabled aviators to find their aircraft carrier without giving away its position. The ship broadcast Morse Code letters in 30-degree arcs. The aircrew flew a heading assigned to the letter. The signals were modulated so they would sound like static if heard without the ZB-1.

Right: caption: "Narco VHT-2 Superhomer VOR Receiver." This mid-1950s era VOR receiver helped usher in a new era of all-weather navigation capability for light aircraft at moderate cost. After WWII, "Very-high frequency Omni Range" (VOR) technology merged highly accurate crystal oscillators (timers), based in remotely operated ground stations, with high-frequency transmissions. VORs were much more accurate, reliable and easier to use than the earlier radio range system.

Achilles Heel

"…All of these aids operated at low frequency, and this was their drawback. Weather and other factors rendered their information unreliable when it was most needed. Communications with direction-finding stations and range beams were drowned out buy static; ADF needles were attracted by thunderstorms as well a shore stations; at dawn, and again at sunset, low frequency transmissions would skip over an aircraft 100 miles at sea but would be clearly received by pilots 5,000 miles away. Early radio was an aid rather than a solution…The visual omni range (VOR) and radar afforded highly accurate close-in navigation and traffic separation but, while immune to most interference, suffered from a lack of range. VHF and UHF signals – like those from a TV station – follow a 'line-of-sight,' not the earth's curvature. Even when it flies at the highest legal altitude, an airliner operating between San Francisco and Honolulu is beyond the range of VHF signals for 80 percent of its schedule…"

***Popular Mechanics,* October 1971**

Post-War

"…Radar, radio altimetry, LORAN (Long Range Navigation) and very high frequency (VHF) came out of the Second World War and were put to airline use – bringing a bit closer the day of precision over-water navigation…"

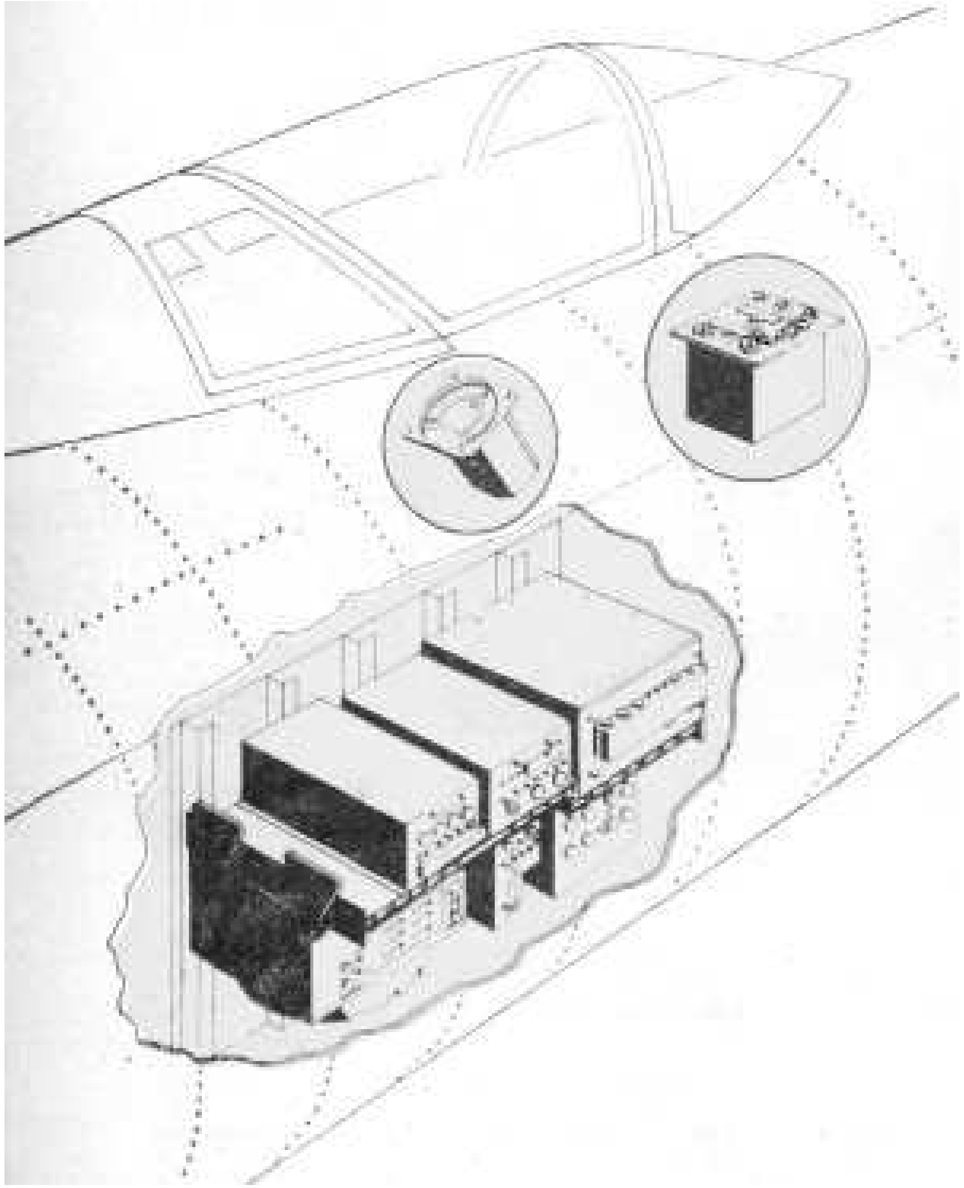
***Popular Mechanics,* October 1971**

RE: LORAN was one of the most widely used over-water navigation systems in the post-WWII era. It depended on a number of transmitters scattered around the world which sent out arc-shaped signals. A plane received these signals as distinctive blips on a radar-type scope. With the help of special charts, the intersecting blips from neighboring LORAN transmitters were interpreted by a trained navigator. Thus, it was possible for the navigator to locate their plane on an intersection and determine the direction of flight. By timing the flying time from one intersection to another, the navigator could also compute their true surface speed. Obviously, this procedure took time, time in which errors could pile up – particularly at jet speeds. Correcting an error also took time and whenever the wind changed, the navigator had to start from scratch. A radio beacon served as a check-point, but it was useless unless a plane flies over or very near to it. The various ranges tell whether a plane is on or off-course (provided the course and range coincide) and give some idea of the degree of error. However, even when a range was available, a certain amount of calculating was involved.

"…The rapid expansion of transatlantic airline service in the late 1940s made precision a necessity. While half a dozen aircraft could zigzag between New York and London without endangering each other, this would not be acceptable for 30 flights, much less 60…"

***Popular Mechanics,* October 1971**

<u>Left</u>: period *American Airlines* ad (ca. 1950) highlighting the fact that in just eight years, AA had made 20K trans-Atlantic flights

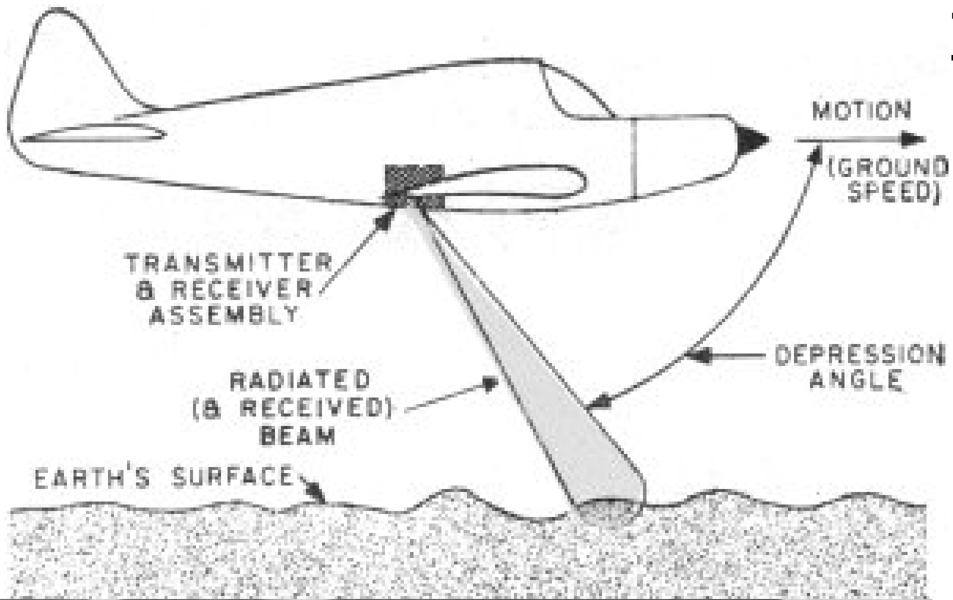


"…Today, most international air carrier flights navigate using Doppler equipment. The Doppler relies on four continuous radar signals between aircraft and water, providing ground speed and drift readings. This equipment will lead a flight across 3,000 miles of water with great accuracy. Two entirely separate Dopplers are minimum equipment – one unit is checked against the other en route…"

***Popular Mechanics,* October 1971**

<u>Left</u>: caption: "Sample Layout for Jet Plane. The combined antenna-transceiver-computer package is mounted in plane's belly, while ground-speed and drift-angle indicator (circular dial) and control panel are in cockpit. Control panel indicates plane's exact longitude and latitude."

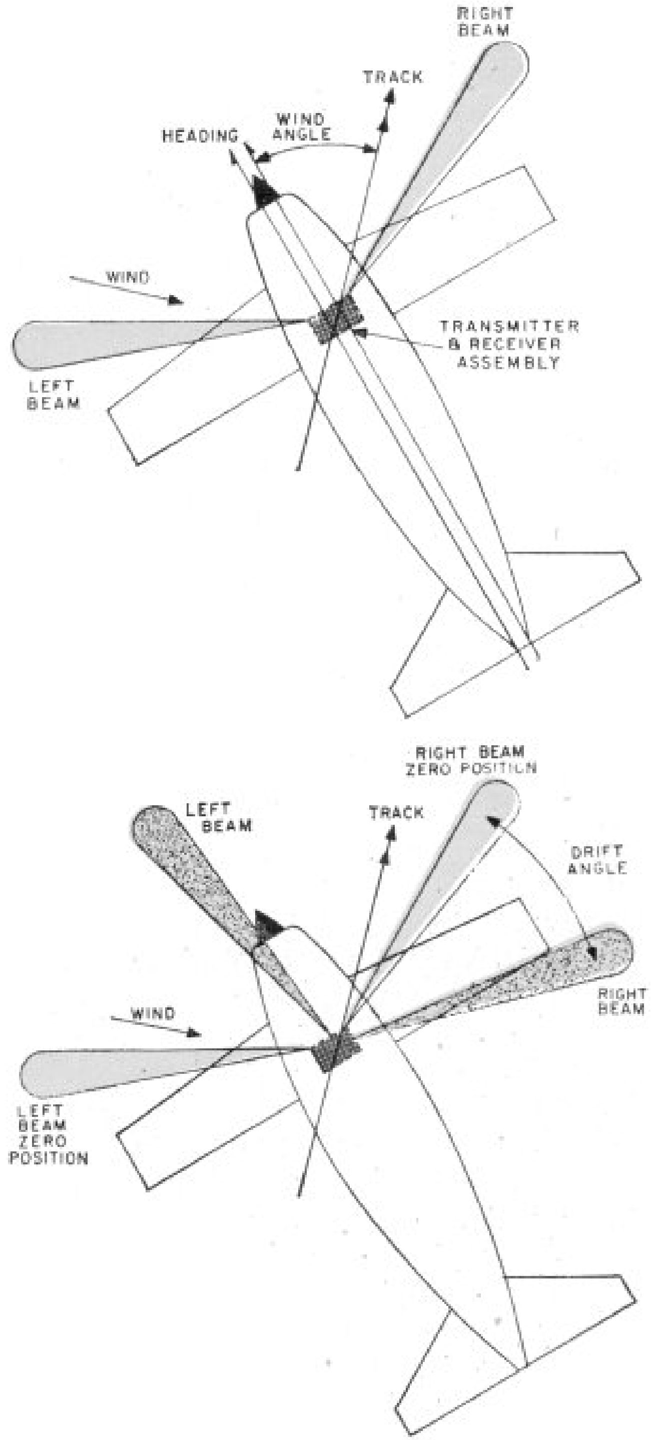
Before Doppler radar was developed, a pilot had no way of knowing his exact ground speed and angle of drift (the pilot did know his approximate air-speed, which is literally the speed of the air moving past his airplane). If the air were dead calm, an airspeed indication would give him a reasonably good idea of how fast he was actually going. But the air is never completely still. It is, in reality, an ocean of gas with currents flowing in many different directions at varying speeds, capable of changes in speed and direction in an instant. Drift was the second great problem in aerial navigation. Suppose an airplane is pointed due north and flying at a fair speed. Now suppose a strong wind is blowing from the west. Obviously, the wind will tend to push the plane sideways. Thus, the plane's true course over the earth will be roughly northeast. The difference between the true course and the direction in which the plane is heading is the "Angle of Drift." If a pilot or navigator knows the exact direction and speed of the wind, they can compute their ground speed and path (a/k/a "track") across the earth with some accuracy. But when either the speed or the direction of the wind changes, their calculations were completely thrown-off.



<u>Top</u>: caption: "Determining Speed. Signal is beamed at ground ahead of plane. Reflected signal is then received. Ground speed is a function of shift between frequencies of beamed and received signals, together with depression angle. Measurement of reflected Signal's Doppler shift gives ground speed."

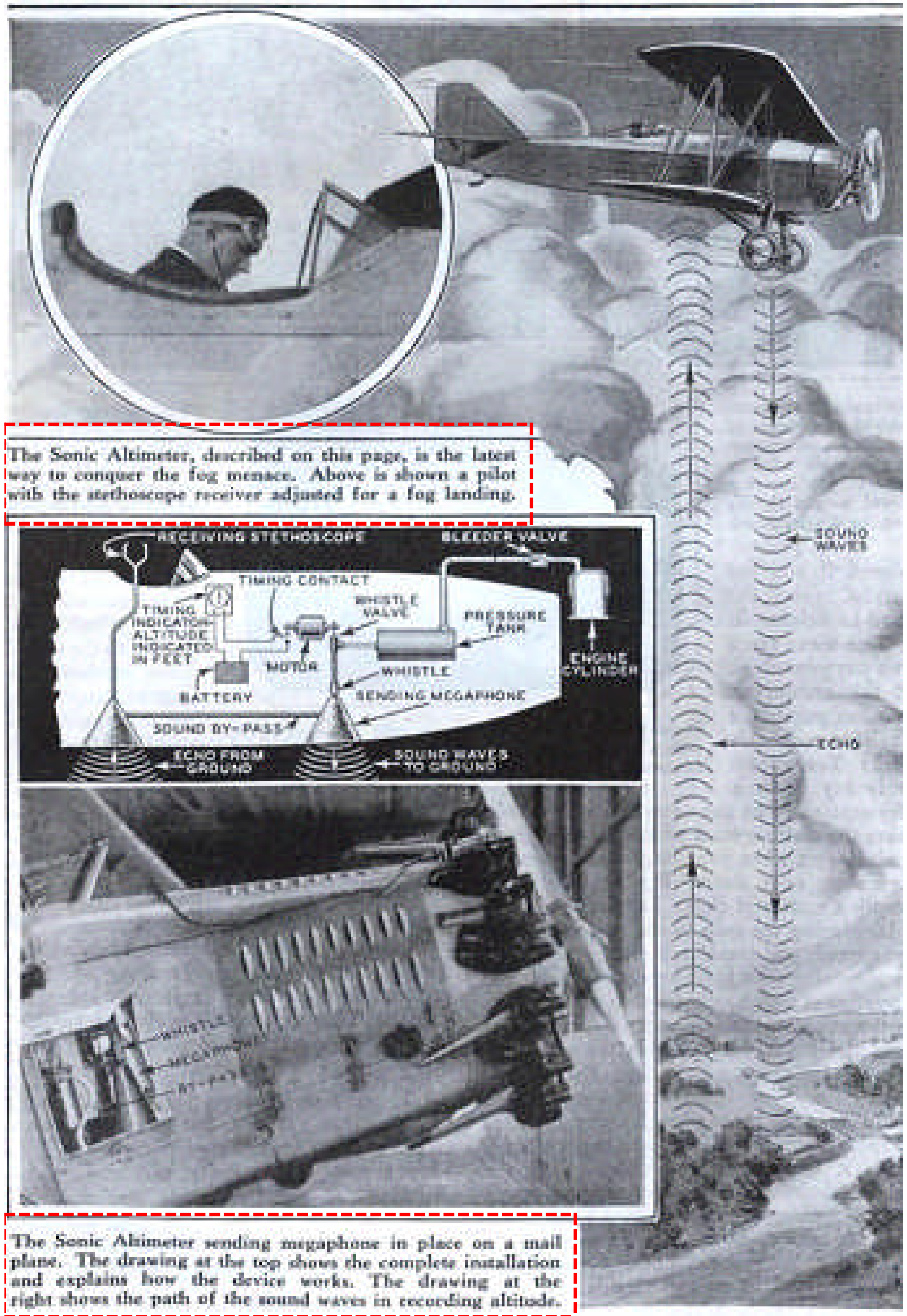
<u>Bottom</u>: caption: "Doppler radar provides exact ground speed and angle-of-drift information which is continuously fed into a computer previously primed with basic position and distance data. The computer digests this information and the results of the computer's cerebration appear as meter readings. Everything a pilot needs to know for pin-point accuracy is contained on one easily read instrument panel."

Doppler radar is based on an 1842 discovery by Austrian physicist *Christian Johann Doppler*. Doppler found that the pitch of a given sound is relative to the movement of its source with respect to an observer. Imagine an observer standing by a railroad track listening to the whistle of an approaching train. If the speed of the train is constant, the pitch of the whistle will seem higher to the observer than it does to a passenger on the train. As the train passes by, the observer detects (hears) a sudden drop in frequency. That's because the sound waves are "stretched" when the locomotive moves away from the observer. In a similar manner, when the train was coming towards the observer, they were compressed (thus, raised in frequency). This same phenomenon occurs with radio waves.



If a radar set is placed in an airplane and its beamed at the ground ahead of the plane, the faster the plane flys, the higher will be the frequency of the signal reflected from the ground. If a signal is beamed at the the ground behind the plane, an increase in the plane's speed makes the returning signal drop to a lower frequency. Unlike conventional radar systems, Doppler radar doesn't measure the time a transmitted signal takes to bounce back. Instead, it measures the frequency shift between the transmitted signal and the reflected signal. In actual practice, at least two radar beams are used. A simple Doppler system has a dual antenna sending out two beams, one forward and to the left, the other forward and to the right. A servo motor turns the antenna assembly automatic-ally.

<u>Left T&B</u>: caption: "Determining Drift. In zero position (diagram at top), twin radar beams straddle plane's nose, one aimed to the left and one to the right. When wind causes plane to move in direction different from heading (direction in which nose is pointed), Doppler frequency shift of right beam is greater than that of left beam and antenna swings until frequency shifts are equal again (diagram underneath top diagram)."



<u>Top: caption</u>: "The Sonic Altimeter, described on this page, is the latest way to conquer the fog menace. Above is shown a pilot with the stethoscope receiver adjusted for a fog landing." <u>Bottom: caption</u>: "The Sonic Altimeter sending megaphone in place on a mail plane. The drawing at the top shows the complete installation and explains how the device works. The drawing at the right shows the path of the sound waves in recording altitude." (*Popular Mechanics*, August 1931)

The introduction of Doppler radar navigators is generally credited to *General Precision Laboratory, Inc*. This company test-flew the first Doppler gear in 1948. By 1954, it was in quantity production for the USAF*.* A variation of the first Doppler system was put into production for the RAF by *Marconi's Wireless Telegraph Co., Ltd*., in England. In Canada, a corporate affiliate of the British firm; *Canadian Marconi Co*., began supplying the *Royal Canadian Air Force* (RCAF) with its own version of the Doppler system. The U.S. Navy retained *Ryan Aeronautical Co*. to continue development of its own system. *Laboratory for Electronics, Inc.,* came out with several systems, one particularly suitable for helicopters. Doppler radar navigators were popular with the military since they required no ground installation. The military kept Doppler radar devices under wraps (for security reasons), but in 1957 various manufacturers began to offer commercial versions geared to the needs of civil aviation. The first commercial purchase of Doppler equipment was made in 1958 by PAA (from Canadian Marconi Co.). Six systems were ordered and installed in PAA's initial six-plane fleet of Boeing 707s.

"…While a tremendous advance in the art when introduced about 10 years ago, Doppler is not trouble-free. A glassy ocean does not properly reflect radar waves, causing one or both sensors to kick-off. The pilot must then rely on LORAN – a low frequency device, which at times suffers from weaknesses of such devices. This is why 120-mile spacing is required on busy international routes…"

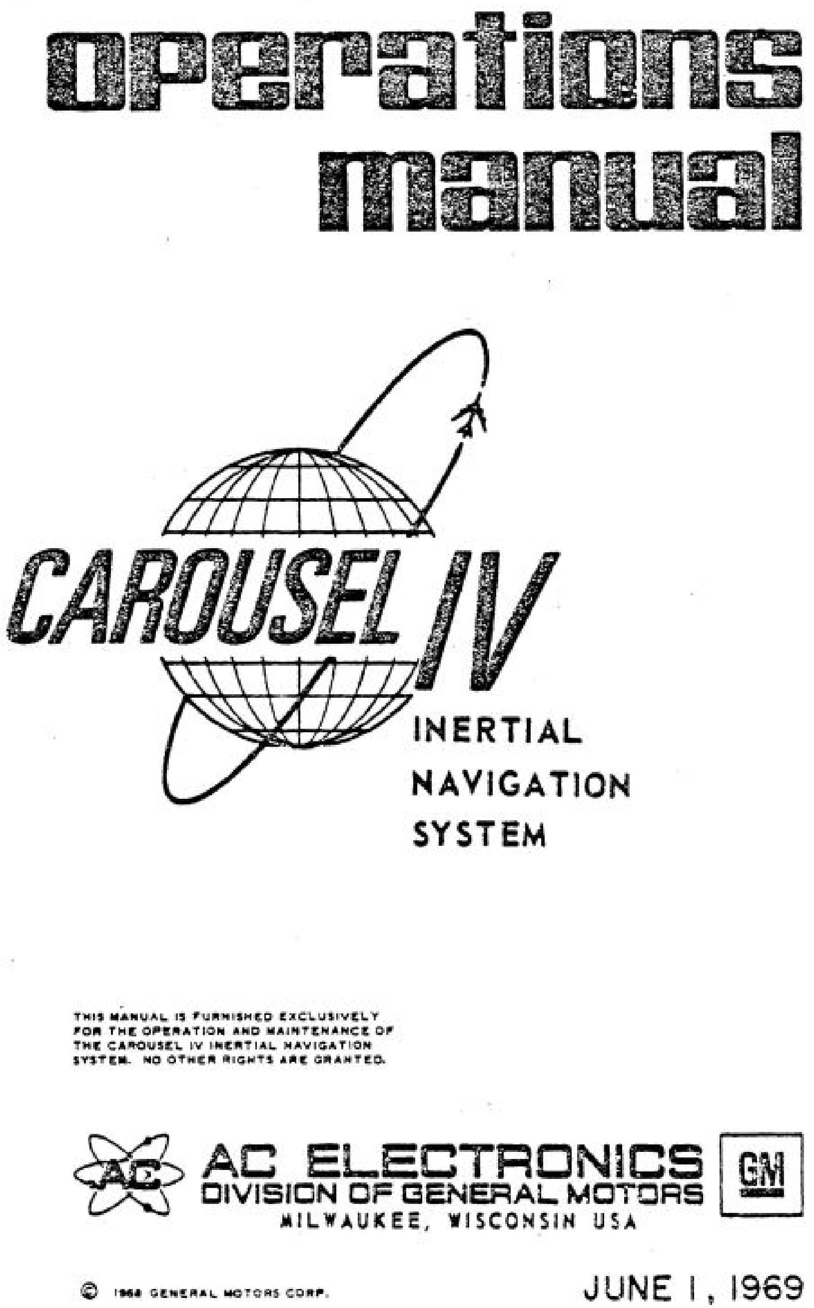
Popular Mechanics, **October 1971**

RE: airliners which were equipped with Doppler radar had several advantages over airliners using other types of navigation systems. Doppler-equipped airliners could sniff-out favorable jet streams and latch onto them for free rides. They could also avoid speed-killing headwinds the same way. Combined with the ability to fly undeviatingly along the shortest possible route, this wind-sniffing talent allowed for much quicker flights and substantial fuel economy. It was estimated that a Doppler navigation system could cut fuel consumption by at least 15%. Another dividend was offered by Doppler radar; it allowed pilots to report their exact position, flight path and speed to air traffic controllers. This meant a greater reduction in the likelihood of mid-air collisions (a real threat, at the time). "Deluxe" versions of the Doppler navigational computer could be hooked to an autopilot, virtually allowing the airplane to self-navigate itself to any point on the globe. Even so, it was an imperfect technology. Something old would return (in a high-tech form) to make Avigation the navigation system of choice.

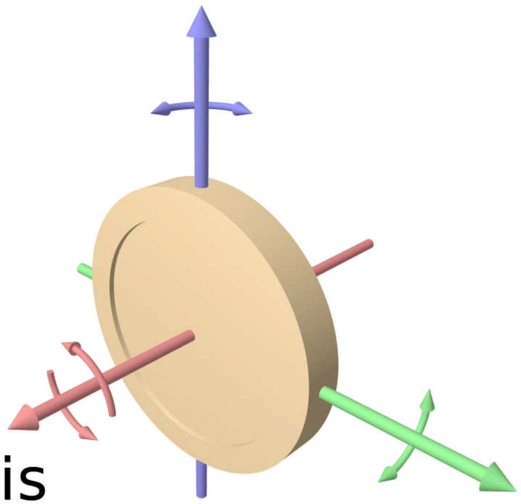
Dead Reckoning Deja Vu

"…The idea of inertial navigation is not new but it took the space program to make it practical and economical enough for commercial use. Three accelerometers small enough to be held in the palm of a hand precisely measure changes in velocity of the aircraft. They are mounted on a platform stabilized by three small gyros spinning at 24,000 rpm. The platform remains rotationally fixed in space, no matter what changes the aircraft happens to make about its three axes. Accelerometer signals are fed to a digital computer which keeps track of time and each change, however minute, in speed and direction…"

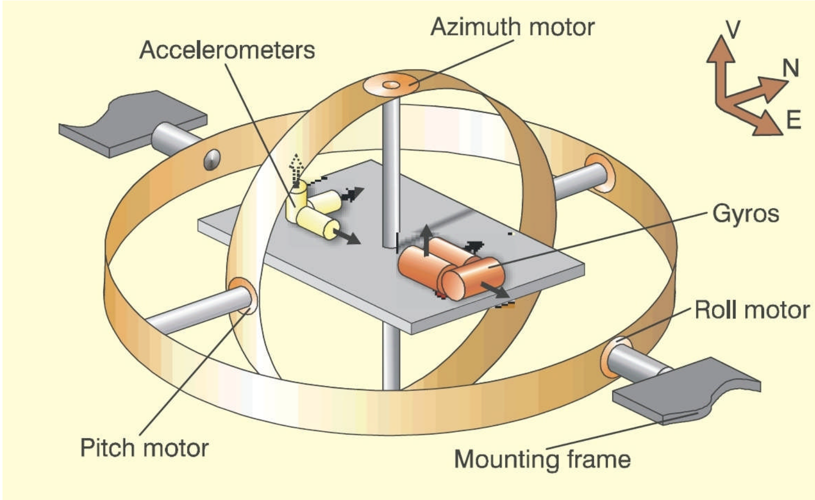
Popular Mechanics, **October 1971**



"…Carousel IV takes its name from a technique developed by AC Electronics in which the stable platform is rotated or 'carouselled,' thus reducing the propagation of system errors by minimizing the effects of gyro drift, accelerometer errors and errors due to misalignment of the platform…"
FLIGHT International, **Sept. 4th 1969**



An accelerometer is an instrument that measures acceleration along a single axis. Integrate the output once and you have velocity. Integrate again and you have position or, rather, change of position along the accelerometer's axis. If the direction of travel is known, current position can be deduced. Thus, *Inertial Navigation* is simply a form of "Dead Reckoning."



For example, take three accelerometers with their sensing axes *orthogonal* (perpendicular at point of intersection). Arrange them so that their axes are aligned north, south, east, west and vertical. To maintain this orientation when the aircraft maneuvers, the accelerometers are suspended in a set of three gimbals that are gyro-stabilized (to maintain direction). Similarly, the gyros are single-axis devices of a type known as *integrating gyros* (they give an output proportional to the angle through which they have been rotated about their input axis). The gyros are used as the sensing elements in null seeking servos (with the output of each gyro connected to a servomotor driving the appropriate gimbals thus keeping the gimbal in a constant orientation in inertial space). Integrating gyros also have what is called a "torquer" (a means of processing the input axis at a rate proportional to input current). This forms a convenient means of canceling out any drift errors in the gyro. The gimbals (not identified in the figure above) have a bearing at each end. Each has a motor (built around one of the bearings) and at the other end a "synchro." No matter how the aircraft maneuvers, the innermost gimbal maintains its orientation in inertial space. The synchro on the innermost gimbal thus measures *azimuth* (heading), the synchro on the middle gimbal measures *pitch* and the outermost gimbal measures *roll*. The innermost gimbal can be thought of as a stable platform on which are mounted the gyros and accelerometers. The whole arrangement is generally referred to as a "gimballed platform."

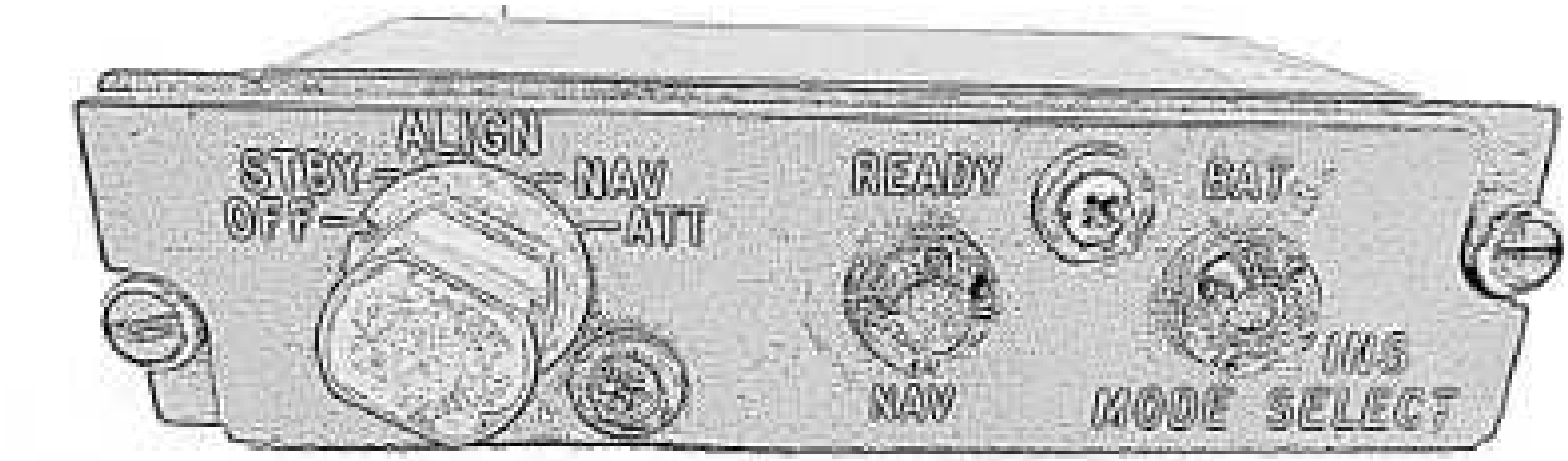
"…During preflight checks a crew must 'tell' the INS where it is by inserting into its computer the exact position of the airplane. This must be accomplished while the plane is parked and at least 15 minutes prior to departure for the system to properly align itself. Then the latitude and longitude of the destination are inserted, along with coordinates of up to nine 'waypoints.' A flight from Dallas to Honolulu is not programmed from city to city, or airport to airport, but from its <u>gate</u> at Dallas to its <u>gate</u> at Honolulu. It is that precise. The INS is 'told,' in effect, 'Guide us from Gate 12 at DAL to Gate 29 at HNL.' An experienced crew can complete the setup for any flight in five minutes…"

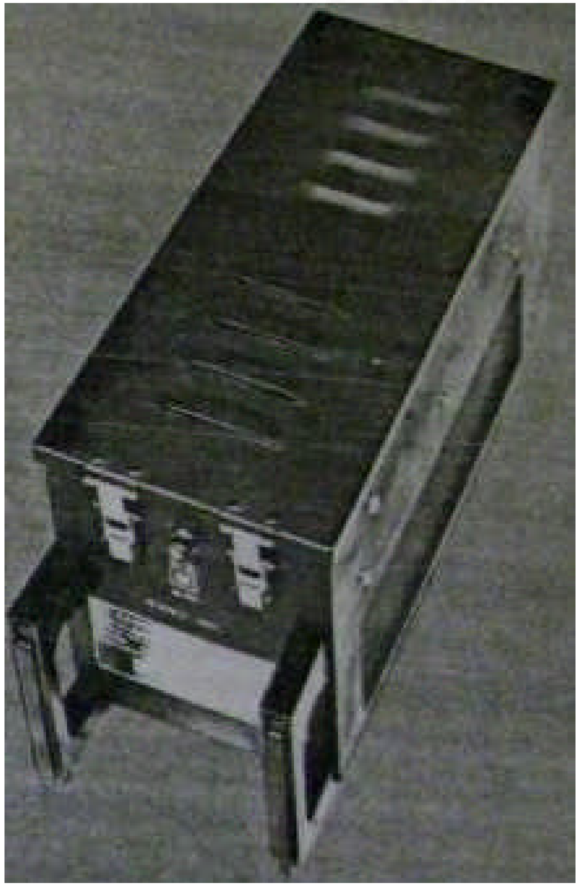
Popular Mechanics, **October 1971**

"…A second key component of Carousel IV is the control and display unit, which can tell the pilot continually his precise latitude and longitude and the distance and direction to his destination via readout panels. The pilot uses pushbuttons on the unit's keyboard to feed information into the system and request information from it…"

FLIGHT International, **September 4th 1969**

<u>LEFT T&B</u>: caption: "The Carousel IV was a popular INS-based navigation automation system for aircraft developed by AC Electronics. Before the advent of sophisticated flight management systems, the Carousel IV allowed pilots to automate navigation of an aircraft along a series of waypoints that they entered via a control console in the cockpit or via an optical paper card reader, namely the <u>A</u>utomatic <u>D</u>ata <u>E</u>ntry <u>U</u>nit (ADEU)."





"…The third unit is a mode selector mounted in the panel above the pilot and co-pilot. It is used to turn the system on and off and establishes the basic operating condition, such as aligning the inertial reference unit during warm-up or navigating in flight. The fourth unit is a battery pack to provide back-up power."

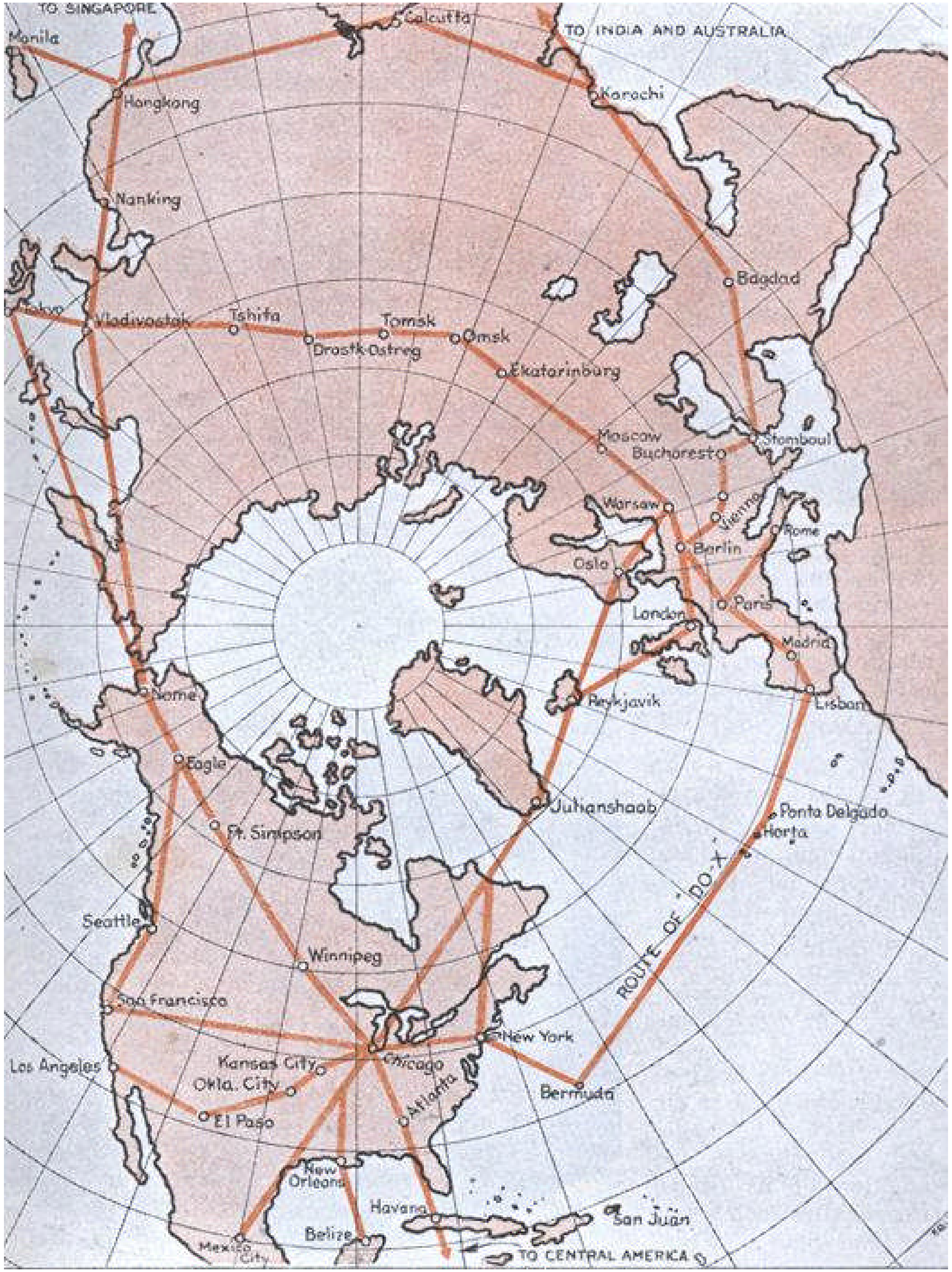
FLIGHT International, **September 4th 1969**

<u>Above</u>: mode selector

<u>Left</u>: battery pack

“…The INS is self-contained and does not require any outside magnetic, radio or radar inputs. It provides course data in degrees from <u>true</u> North and is totally unaffected by the continuously changing variation that complicates all magnetic systems of navigation. It always navigates along a great circle route (a string connecting any two locations on a globe approximates a ‘great circle’ – the shortest distance between these locations)…”

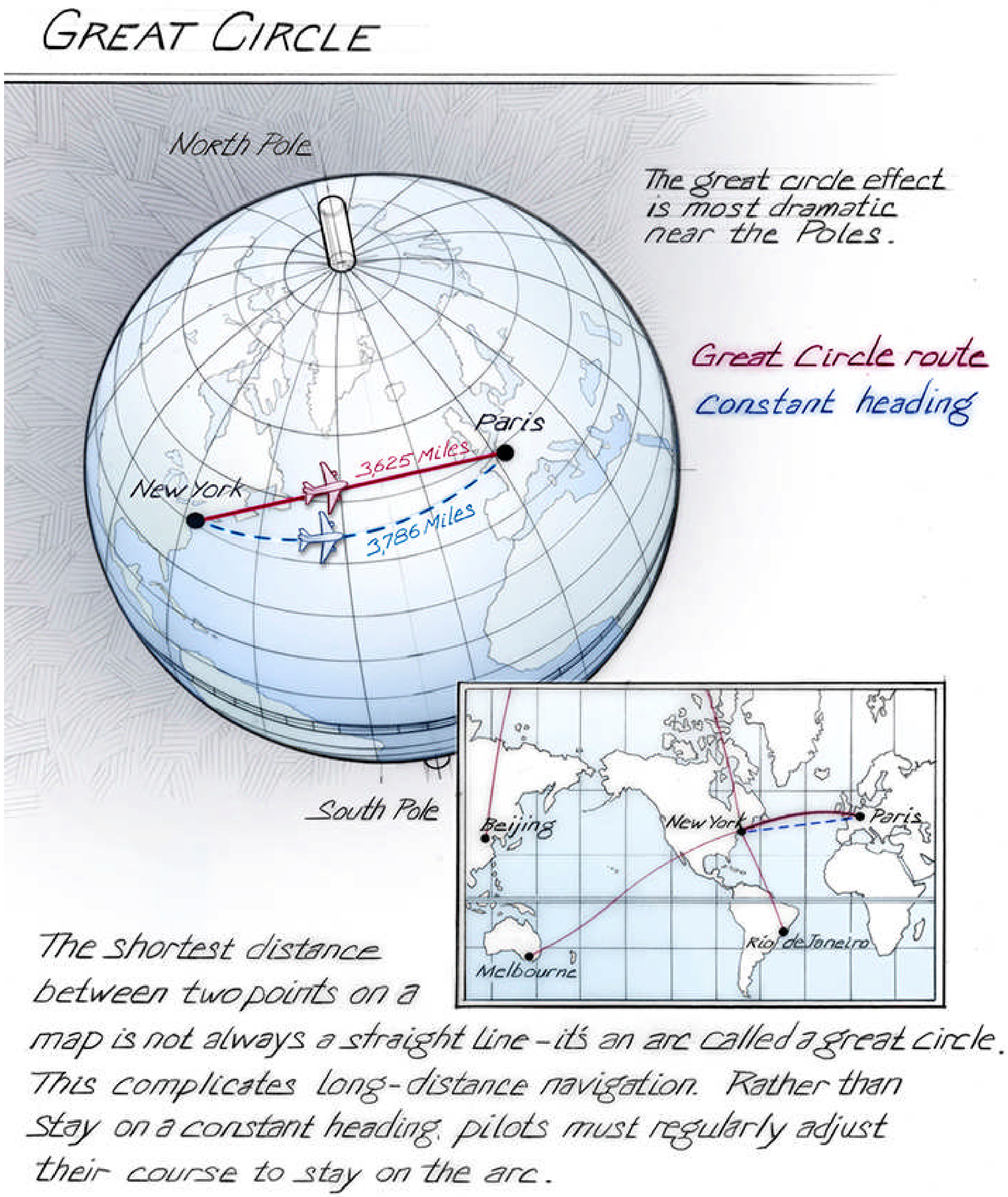
***Popular Mechanics,* October 1971**



"…the great circle courses, which are the shortest distances between two points, appear as straight lines. Thus Berlin, Chicago and Mexico City are virtually on a line, and the great triangle of Chicago, Warsaw, Tokyo and back to Chicago represents the nearest approach to an all land route around the world. Chicago, it will be seen, is the logical focal point for air lines from North America to Europe and Asia. This map shows the routes suggested and in addition points out many of the existing airways which would serve as connecting links…"

***Modern Mechanics,* January 1931**

<u>Left</u>: caption: "Projected Great Circle Course Routes"



"…This is not to say that present Dallas-Honolulu flights are operating along great circle routes. Such a flight would cross northern Mexico, several area reserved for military use and conflict with the four primary airways currently employed for California-Hawaii traffic. At this writing, relatively few airliners are equipped with INS and they must often fit into the flow of Doppler-equipped aircraft. The FAA is currently establishing a new domestic network of routes between major terminals to allow INS users to cut corners and fly straight through on a regular basis. As INS comes into more general use traffic control methods will be further modified, allowing INS trips to fully exploit the system's unique possibilities…"

***Popular Mechanics*, Oct. 1971**

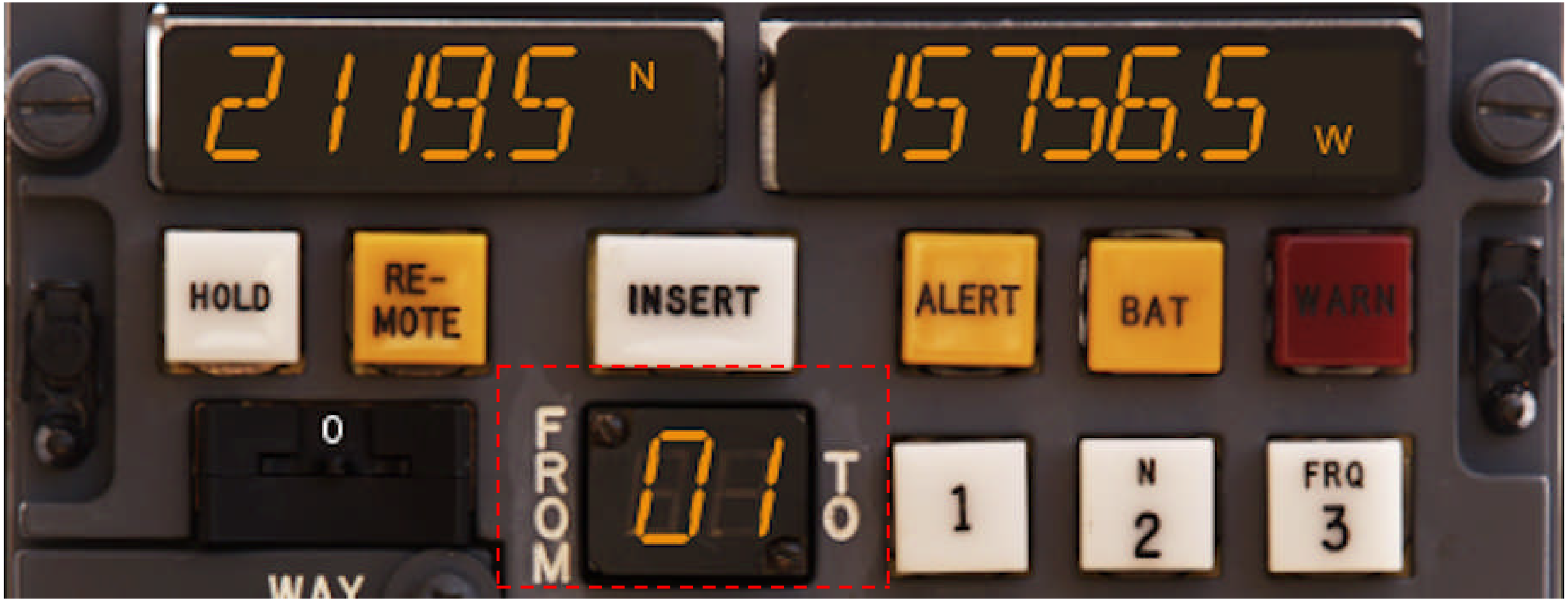
"…Ideally, all INS-directed flights would fly great circle routes from takeoff to landing. Today, a Dallas-Honolulu schedule must usually make 15 to 20 heading changes to comply with a routing that takes it across Los Angeles, 200 miles north of the shortest way to Hawaii. In cruise, a 747 burns about 400 pounds of fuel a minute; anything that can reduce a flight by 5 minutes, or 10 or more, adds up to significant savings in operating costs. INS will eventually make such savings possible to all airlines…"

Popular Mechanics, **October 1971**

Above: caption: "Distance from Dallas to Honolulu is 3,795 miles or 3,298 nautical miles"

“…Operation of the INS requires little special training. While Doppler/LORAN crews spend up to two weeks in a classroom and fly 50 to 100 hours under the supervision of a navigator in the process of being ‘rated,’ INS theory and practice can be explained in two days of school and two hours in the cockpit simulator. One over-water hop should fully qualify a pilot to operate on his own with the Carousel IV…”

Popular Mechanics, **October 1971**



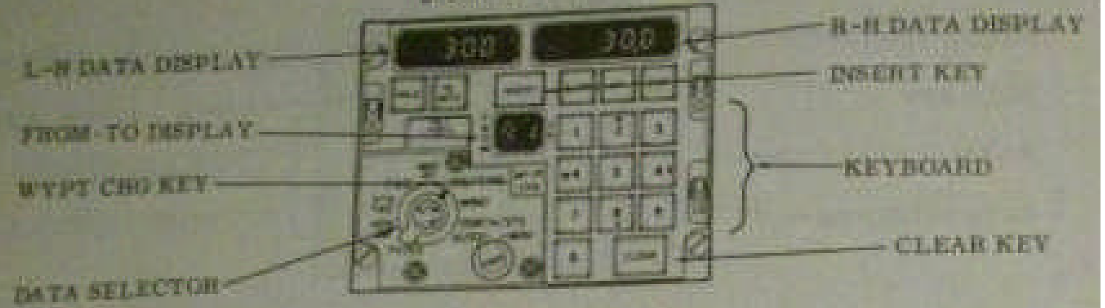
"…After takeoff a flight is normally vectored by radar to its assigned route, at which time the autopilot is selected to INS mode. The Carousel IV then guides the aircraft from waypoint to waypoint to destination without further crew attention. Instantly available on the cockpit display panel are ground speed, wind direction and velocity, present position, heading and drift data and the distance and time to the next waypoint (or the destination, point of departure or any other waypoint, for that matter). Should a diversion to another route or destination be required, it is a simple matter to insert new coordinates…"

***Popular Mechanics*, October 1971**

Above: C-IV from-to coordinate display

Delco Electronics

OPERATIONS MANUAL



Step	Control	Operation	Display or Indicator	Indication
1	Data selector	Rotate to DIS/TIME	L-H data display R-H data display FROM-TO display	Distance to next waypoint Time to next waypoint Present course
2	WYPT CHG key	Press	WYPT CHG key INSERT key	Lights Lights
3	Keyboard	Press two keys in sequence for waypoint numbers to be loaded in FROM-TO display	FROM-TO display L-H data display R-H data display	Loaded numbers Distance between waypoints loaded in FROM-TO display Time between waypoints loaded in FROM-TO display based on present ground speed

NOTE: To restore normal displays on the C/DU, press the CLEAR key.

AC ELECTRONICS Division of General Motors Corp
CAROUSEL IV INERTIAL NAVIGATION SYSTEM

OPERATIONS MANUAL

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Jun 1/69

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"…The INS takes its own pulse continuously and reports its state of health. Should it receive insufficient electrical power or overheat, it will shut down and turn on a warning signal. Less critical malfunctions are reported in number codes: one of 68 numbers pinpoints the problem, and one of five other numbers directs the action to be taken…"

***Popular Mechanics*, October 1971**

"…Federal regulations require that two complete and independently operating systems be aboard flights using INS and these are as standard on the 747 as windshield wipers on a car. Most airlines carry a third operating INS, using it as a 'hot spare' rather than storing replacement units at each 747 station. Should a set fail, a trip can legally depart with the remaining two. During the FAA certification tests of the Carousel IV aboard three Boeing 707s in 1969, the system proved so accurate and dependable that operators are not required to back it up with radio or celestial means of checking position…"

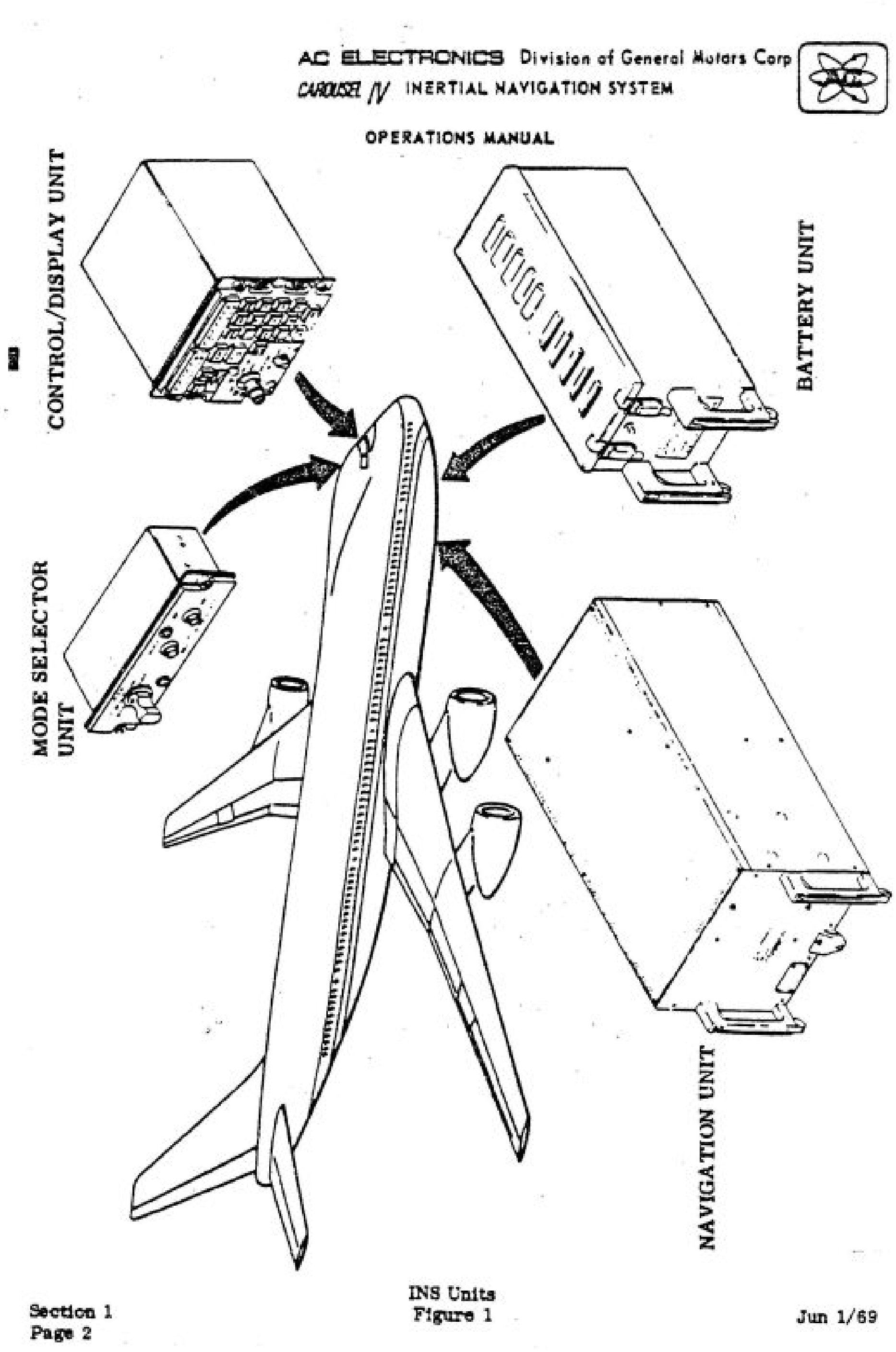
***Popular Mechanics,* October 1971**

"…Finnair was the first airline to use Carousel IV as its primary navigation reference. In late 1969 it operated an INS trip nonstop from Helsinki to New York with stops at Copenhagen and Amsterdam using DC-8 equipment. During the 3,200-mile over-water leg, the flight encountered cross-winds of 120 knots, yet the INS maintained a near-perfect track. Upon arrival at New York after nine hours of flight, the three INS sets showed errors of 0.002 to 0.005 percent, well within Finnish and American specifications…"

***Popular Mechanics*, October 1971**

<u>Above</u>: Finnair DC-8 (ca. 1969)

A Space-Age Marvel



"…So the day is finally at hand when the airplane will be able to fly to anywhere in the world in a truly straight line, with all the benefits that will entail for the airlines and their customers. Since and entire INS system – navigation unit, mode selector, control and display unit and battery – weighs but 74 pounds, this space-age marvel is entirely suitable for small private aircraft. Delco Electronics has them for sale at about $100,000 each! (installation extra)."

***Popular Mechanics,* October 1971**

No Horizon So Far

"…We fly, but we have not 'conquered' the air. Nature presides in all her dignity, permitting us the study and the use of such of her forces as we may understand. It is when we presume to intimacy, having been granted only tolerance, that the harsh stick falls across our impudent knuckles and we rub the pain, staring upward, startled by our ignorance...One day the stars will be as familiar to each man as the landmarks, the curves, and the hills on the road that leads to his door, and one day this will be an airborne life. But by then men will have forgotten how to fly; they will be passengers on machines whose conductors are carefully promoted to a familiarity with labeled buttons, and in whose minds knowledge of the sky and the wind and the way of weather will be extraneous as passing fiction…I learned what every dreaming child needs to know - that no horizon is so far that you cannot get above it or beyond it…"

Beryl Markham, **Aviator**

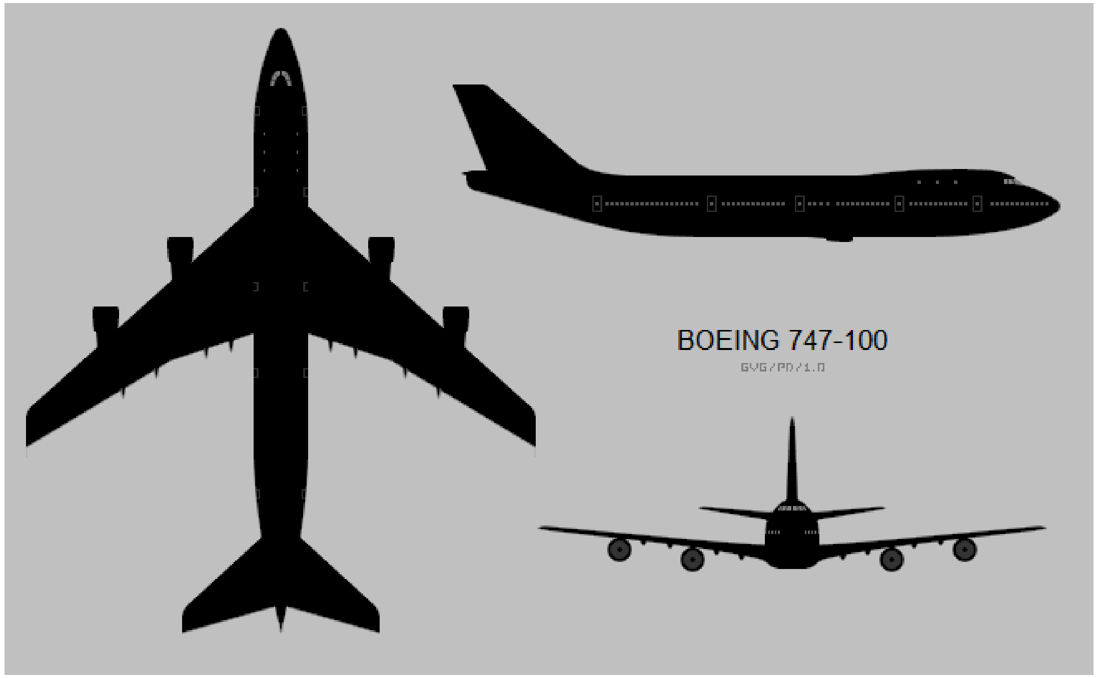
RE: excerpt from her 1942 memoir entitled: ***West With the Night***

Part 10

Through the Years

Improving the Baseline

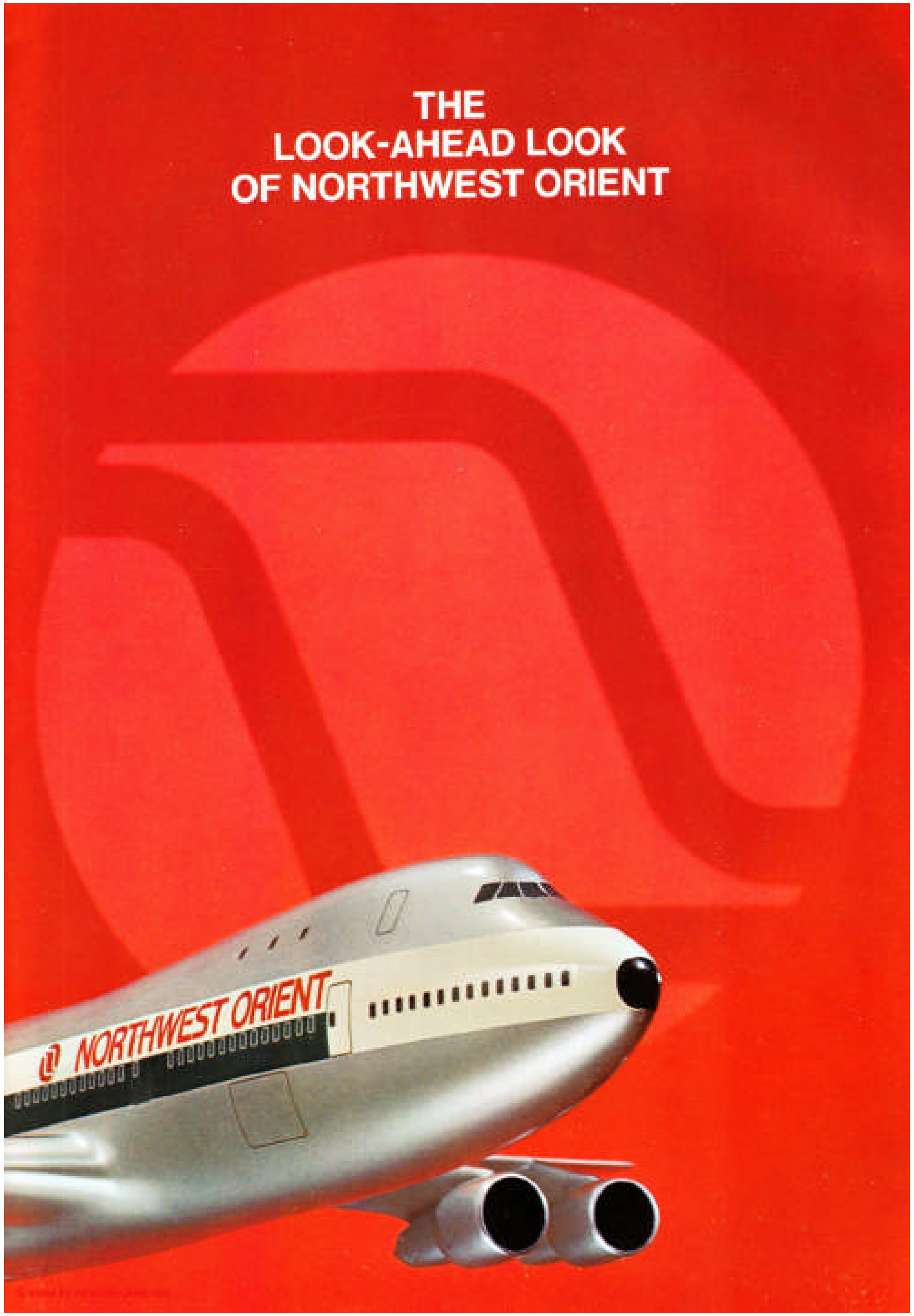
The 747-100 provides a baseline for the 747 series of aircraft. The basic configuration was that pioneered by the Boeing 707; a low-wing aircraft of all metal construction and all swept flight surfaces, with four turbofan engines mounted on pylons under the wings and tricycle landing gear. Of course, the 747 was an entirely new aircraft and on a substantially larger scale than the 707. The wings had a sweepback of 37.5 degrees (at quarter chord) with a dihedral of 7-degrees and an incidence of 2-degrees. There was a triple slotted flap inboard on each wing, followed by a high-speed aileron, then a triple slotted flap outboard and a low-speed aileron near the tip. There were four flight spoilers ahead of the outboard flap and two ground spoilers/lift dumpers ahead of the inboard flap. There was a three-segment “flip-over” Krueger flap on the leading edge of each wing (between the fuselage and the inboard engine) plus a drooping leading-edge flap (in ten segments) along the leading edge of the rest of the wing. The tail unit was of conventional configuration, with rudder and ailerons. The incidence of the tailplane could be adjusted for flight trim. All flight controls were hydraulically powered. There was a single nose gear assembly (with two wheels) retracting forward and four main gear assemblies (each with four wheels in a 2x2 bogie arrangement). Two of the main gear assemblies were mounted under the fuselage along the line of the trailing edge of the wings and retracted forward while the other two were mounted forward (in the wings, between the fuselage and inboard engine) and retracted inward toward the fuselage. The main gear was intended to support the 747’s massive weight and ensure that the aircraft didn’t damage airport tarmac.



- Wingspan: 195-feet 8-inches
- Wing Area: 5,500 square-feet
- Length: 231-feet 10-inches
- Height: 63-feet 5-inches
- Empty Weight: 358K pounds
- MTO Weight: 735K pounds
- Cruise Speed: 555 MPH / 480 KT
- Cruise Altitude: 35K-feet
- Max. Range: 6,100 MI / 5,300 NMI

The 747-100 was powered by *Pratt & Whitney JT9D* high-bypass turbofans, proving troublesome from the outset. The -100 had undergone "weight creep" during development, and the immature JT9D engines used in prototype development and early production could only generate 39K foot-pounds of thrust, leaving the aircraft underpowered. Worse yet, these engines were very unreliable (big, high-bypass turbofan engines were a relatively new technology at the time) and were also afflicted by unforeseen problems (i.e. difficulties with engine starting in crosswinds due to the oversized fan). The worst problems were worked out, with the -100 going into service with the JT9D-3A variant, providing 45,800 foot-pounds of thrust. An APU was fitted to provide engine starting and ground power. There was a fuel tank in the wing center section, plus three fuel tanks in each wing, giving a total fuel supply of 47,210 U.S. gallons (there was a refueling point on each wing).

Avionics were conventional for the era, with radios, navigational aids, identification transponder and a weather radar in the nose. There was a flight crew of three (with provision for one or two observers). Up to 500 passengers could be accommodated in a ten-across "cattle car" configuration (more reasonable accommodations were 447 seats, nine across, or 385 passengers, including 337 economy passengers and 48 first-class passenger, 16 of them seated in the upper deck). Of course, the aircraft was pressurized and climate-conditioned. There were five doors on each side of the aircraft and fore and aft cargo holds under the floor (with doors on the right side of the aircraft - one door on the forward hold, two on the rear hold). Although there were teething problems early in service (i.e. the JT9D engines), the -100 became known as a safe and reliable aircraft. It was also surprisingly easy to fly, though handling such a huge aircraft on the ground presented challenges (most particularly due to the fact that the cockpit crew were perched high off the ground during taxi).



At the outset (mainly due to the global energy crisis and economic slowdown of the early 1970s), airlines had trouble finding enough passengers to fill up the 747 every flight. So, for a few years, sales of the 747 went soft in favor of smaller wide-body jets such as the DC-10 and/or L-1011. This seemed to vindicate 747 critics who had suggested there was no way airlines could economically operate such a large aircraft. As some compensation for passengers, low-density seating arrangements were the norm for the 747 in its early days. Fortunately for Boeing (but not for passengers), sales eventually picked up and high-density seating arrangements became commonplace. However, it seems Boeing executives gradually came to the conclusion that the main selling point of the 747 was more about range than passenger capacity.

"The aircraft was a Boeing 747-100 - the last flying example of the type. The Boeing 747-186B EP-IAM (msn 21759) was ferried from the Tehran domestic airport at Mehrabad Airport to Imam Khomeini International Airport (IKA). Images of the final flight were captured by Shahram Sharifi, the group manager of he Iranian Spotters – an aviation photography team made up professional aviation photographers. The 15 photographers have to work around the heavy restrictions at the Iran airports to meet their aim of showing the best photographs depicting flight in Iran. This milestone final flight – which lasted just 10 minutes – was recorded with the support of Iran Air CEO Farhad Parvaresh. EP-IAM has been with Iran Air since it was delivered new from Boeing on August 2, 1979…"

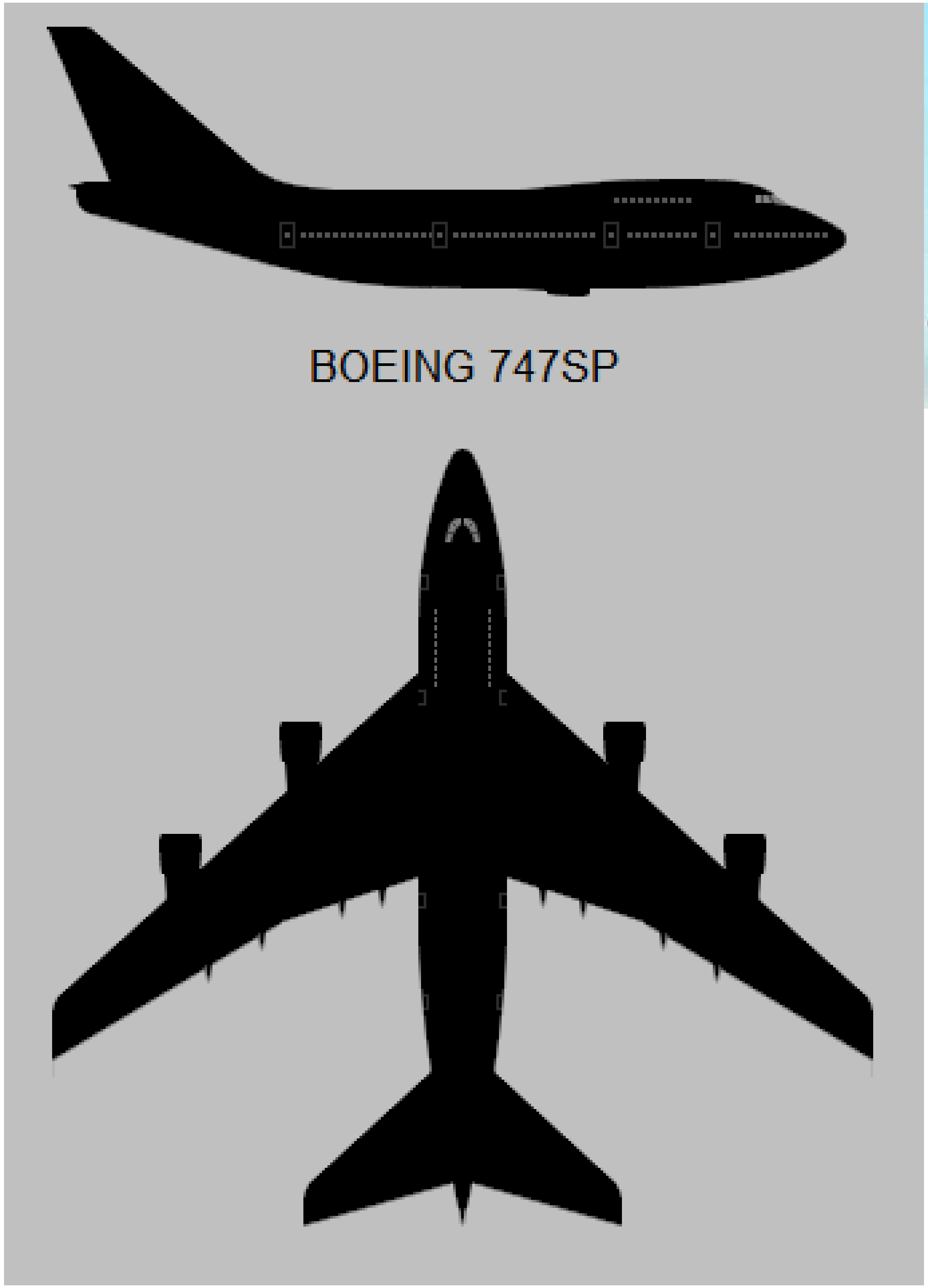
Arabianaerospace, January 22nd 2014

Above L&R: caption: "An Iran Air crew waved goodbye to one of the classic aircraft in its fleet and closed the chapter on a piece of aviation history"


25c
50th. ANNIVERSARY
AIR MAIL SERVICE TO BERMUDA
BOEING 747 AUGUST 1970
BERMUDA

The 747-100 entered service in January 1970. Engine performance and power upgrades led to an improved version of the 747-100; the 747B (later called 747-200, above), which made its first flight on October 11th 1970. Orders rolled in and in 1973, *El Al* – Israel's national airline, received the 200th copy of the 747-200. At the same time, the freighter version of the 747-200 (with increased thrust) became the model 747-200F. Not all 747 variants had distinct designations but they did lead, by steps, to the 747-100B and then the 747-200B, with greater capacity and airframe reinforcements. The 747-200B was introduced in early 1971 and was almost identical externally to the 747-100. The only noticeable difference being ten passenger windows on each side of the upper deck on the -200 versus three on the -100. However, some early -200B units still had the three windows and some -100s were retrofitted with ten windows. Along with the new engines and other tweaks, the -200B also featured a bigger center wing section fuel tank (providing about 9% greater fuel capacity) for a total of 51,430 U.S. gallons.


PAN AM

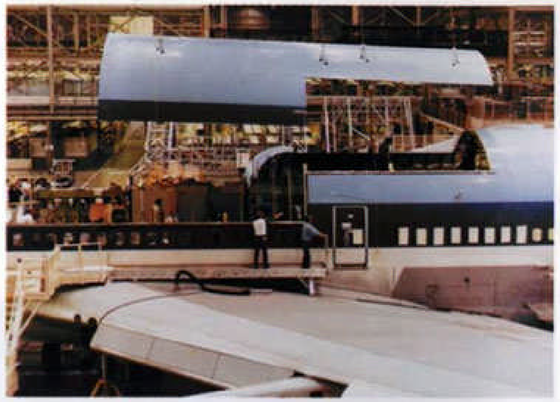


At the request of several airlines, Boeing developed two special versions of the 747: the SR 747 (Short Range) and SP (Special Performance). The SR was a 747-100 equipped with a reinforced landing gear allowing it to land and takeoff again more frequently than the base model 747 (it was mainly used by Japanese companies for short-haul, domestic routes).

Above: model of a "747 Super Airbus" SR demonstrator

Left: plan/side views – 747SP

A. Existing U/D crown removed.

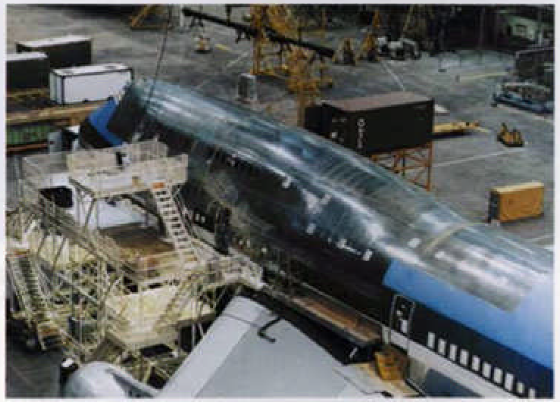


B. Removals aft of U/D.

C. Cab crown removed.

D. Structural preparation.

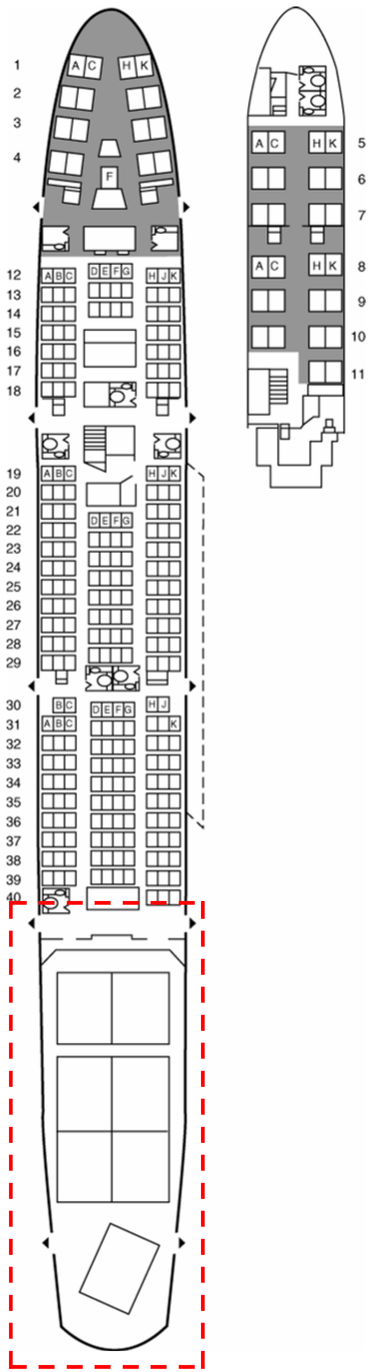
E. New structure positioned.



F. New structure in place.

Able to carry up to 528 passengers (at the expense of range and featuring a reinforced fuselage to handle twice the number of pressurization-depressurization cycles) the 747-100SR went into service with *Japan Air Lines* (JAL) in 1973. With seven built; these units were followed by the 747-100BSR featuring higher takeoff weight (20 were built) and then two 747-100BSR-SUD (Stretched Upper Deck). That provided a total of 29 Series -100 Short-Range 747s (out of a total of 205 Series -100 units built). Almost twice as many Series -200 (393) units were built as Series -100s. No -100 units were ever built as freighters, even though there had been considerable customer interest in 747 freighters at the outset of the 747 project (the early JT9D engines just weren't powerful enough).

Left: caption: "The SUD modification process shown in sequence"



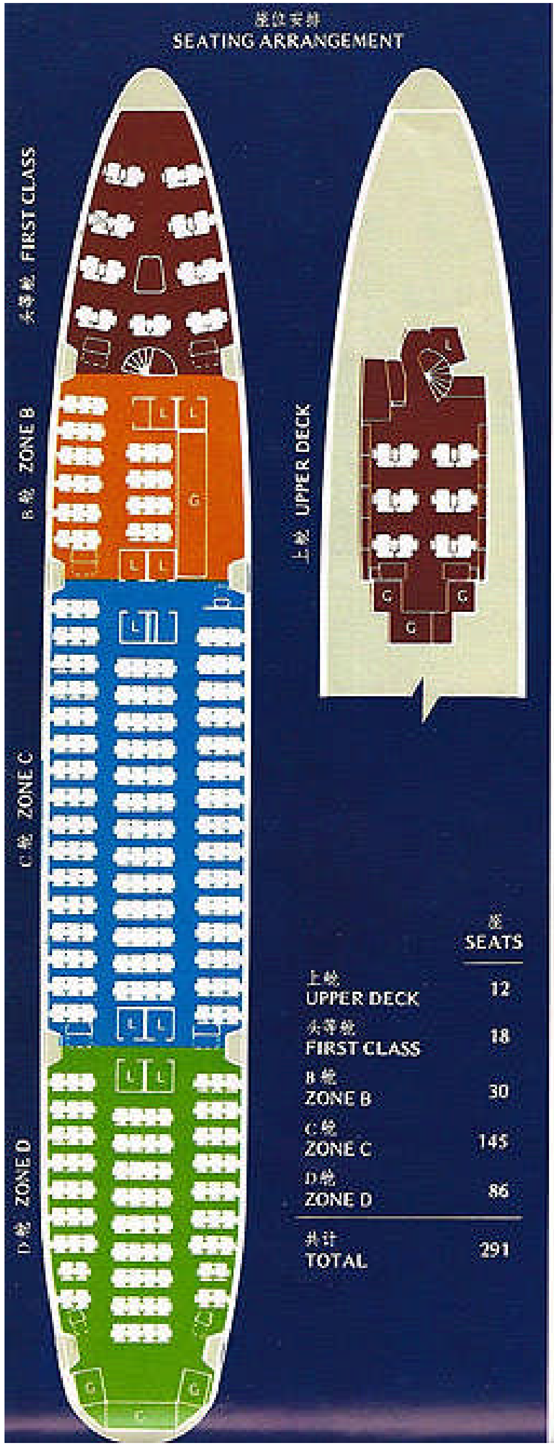
Boeing rebuilt two -100s as de facto prototypes for the 747-200M convertible and there were after-market freighter conversions of -100 units when phased-out of passenger service. It appears that the convertible configurations were popular (since filling up a 747 with passengers might be problematic on some routes, it was attractive to use a single flight to haul both passengers and cargo).

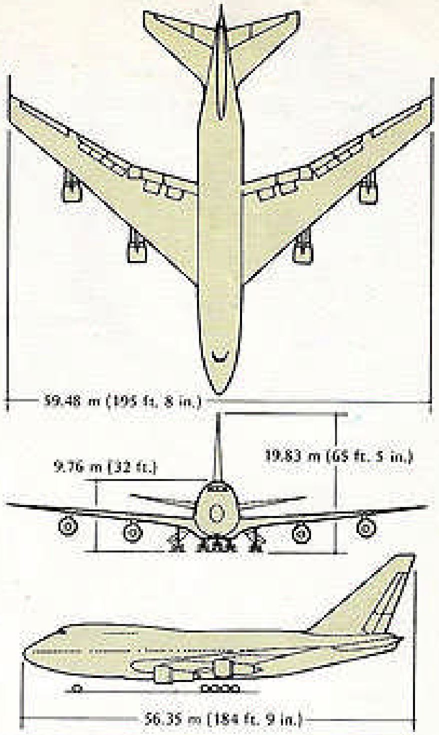
Left: caption: "Boeing 747 Combi Layout." This configuration allowed seven pallets to be loaded on the main deck.

The 747SP version was a shortened version of the 747-100 designed to be able to take-off from short runways (even in hot weather) and have a much longer range. The 747SP was costly to produce thus, its commercial success was considerably less than Boeing had hoped for at its inception.

<u>Top</u>: caption: "PAA returned to China in 1980 with this second China Clipper - a Boeing 747SP"

In 1973, Boeing announced development of a derivative of the 747-100 for low-density/long-range intercontinental routes, designating this variant the "747 Special Performance" (747SP). Boeing reduced the length of the 747-100 to 184-feet 9-inches (which turned out to be much more troublesome than anticipated). Stretching a jetliner by adding fuselage sections is not particularly unusual, but cutting-out sections of a base aircraft to make it shorter is not often done. In the case of the 747SP, it required certain changes to the airframe to get it to work. The shorter fuselage affected lateral stability thus, the 747SP was given a taller tailfin. Tailplane span was also increased and the triple slotted flaps were traded for single slotted (the 747SP was the only 747 variant that didn't have multiple slotted flaps). Passenger capacity was up to 360 seats, though 305 was more practical. There were four doors on each side (instead of five). Fuel capacity was the same as for the 747-100, but range was increased by about 9%.





四台美國普拉特惠特尼公司的JT9D-7型發動機，單台推力超過20,000公斤。
Equipped with four Pratt & Whitney JT9D-7 engines, each with a thrust of over 20,000 kilograms.

<u>Above & Left</u>: Boeing 747SP 713

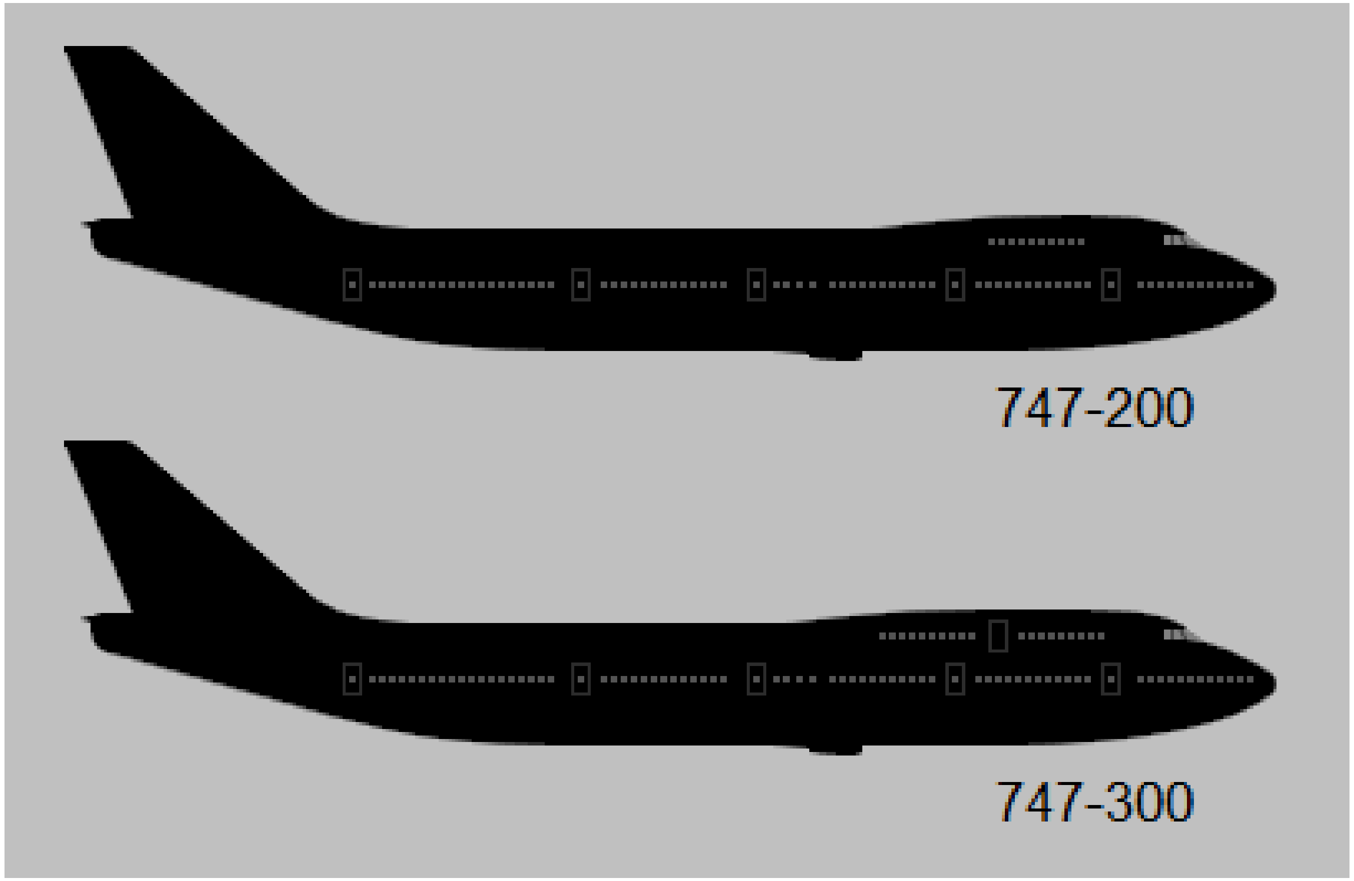
<u>Above</u>: **looking like a cracked egg is the remains of an ex-United 747SP that once served with Pan Am. In the background is one of United's original 747-100s. Both of these planes were flown in from Las Vegas where they were stored. Both airframes had relatively complete interiors when this image was taken in November 1999. Improvements in engine technology and the greater fuel capacity of the 747-200 made the 747SP redundant and so only forty-five 747SP units were sold. However, those that were sold were retained in service for a long time and had good resale value. In retrospect, it appears the 747SP worked well enough in its niche market.**

Trijet

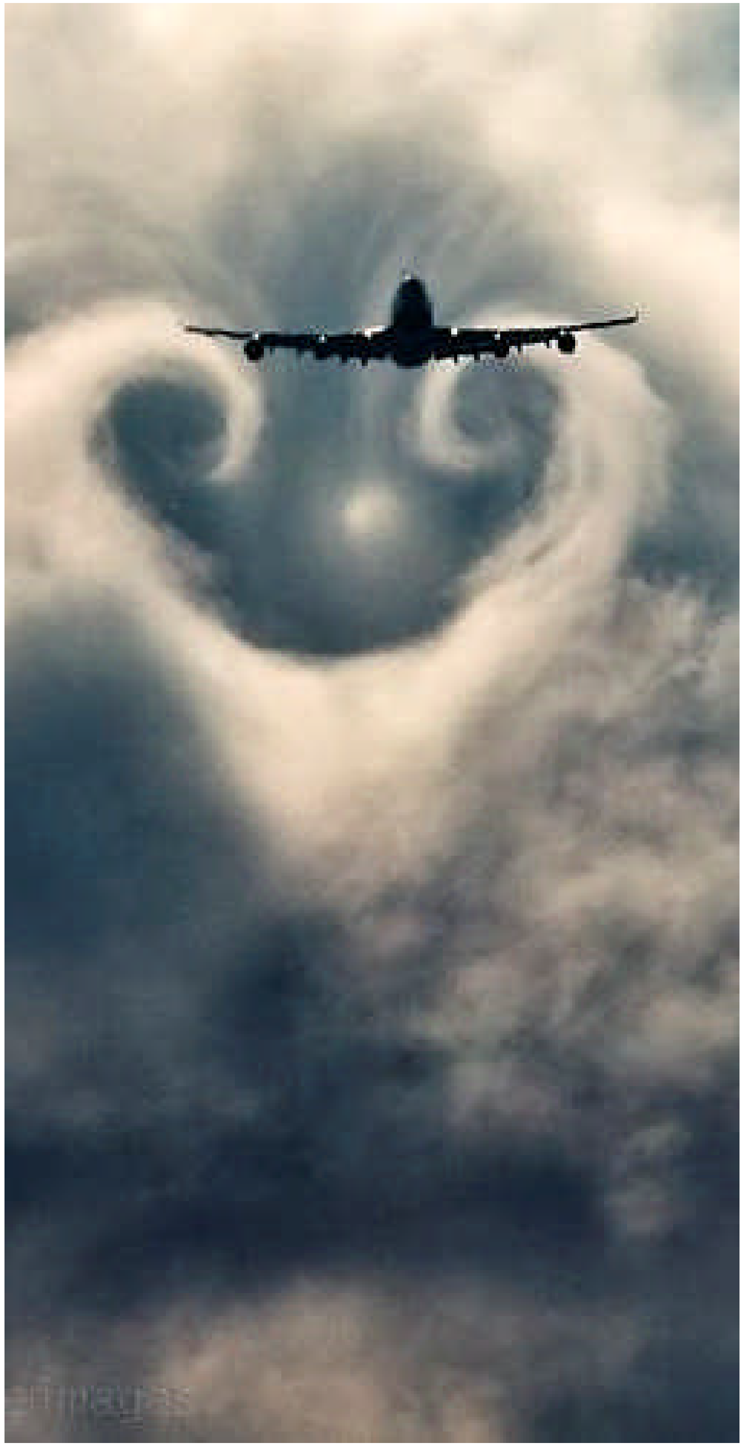
During the 1960s and early ‘70s, Boeing studied the development of a shorter 747 with three-engines to compete with the smaller *Lockheed L-1011 Tristar* and DC-10. The *Boeing 747-300 Trijet* (model above) would have had more payload, range and passenger capacity. The center (No. 2) engine would have been fitted in the tail with an S-duct intake (similar to the L-1011's). However, testing revealed that airflow over the front “hump” (upper deck) decreased the efficiency of the No. 2 engine. Aerodynamic studies also demonstrated that the wing would need to be completely redesigned. As well, maintaining the 747’s handling characteristics would be important to minimize pilot retraining. Boeing decided instead to pursue a shortened four-engine 747 that resulted in the 747SP. In the 1990s, the *Boeing 777* (a long-range twinjet airliner smaller than the 747-400) entered service in the market where the 747-300 Trijet had been targeted.

747SUD

From the mid-1970s onward, the global economy began to pick up (after the Arab Oil Embargo of the early 1970s) and sales of the 747-200 improved. Airlines had less trouble filling seats and, in fact, wanted more capacity for primary long-haul routes. Boeing considered stretching the 747, but decided instead to extend the upper deck by 23-feet 4-inches. The SUD increased passenger topside accommodations (in all-economy configuration) from 32 to 91 passengers; six abreast with a single aisle while replacing the original spiral staircase to the upper deck with a straight staircase also freed up space on the main deck for seven more economy seats (the SUD could also accommodate 26 sleeper seats in a first-class configuration). The SUD featured an emergency exit on both sides of the upper deck (above, L&R). Otherwise, the new "747-300" was similar to the 747-200 and, in fact, it's likely that early units with the SUD were actually sold as 747-200s (several 747-200s already in-service were, indeed, updated with the SUD). Also, improvements in engine power (nearly 30-tons of thrust per engine) allowed for additional payload. The first 747-300 flew on October 5th 1982.

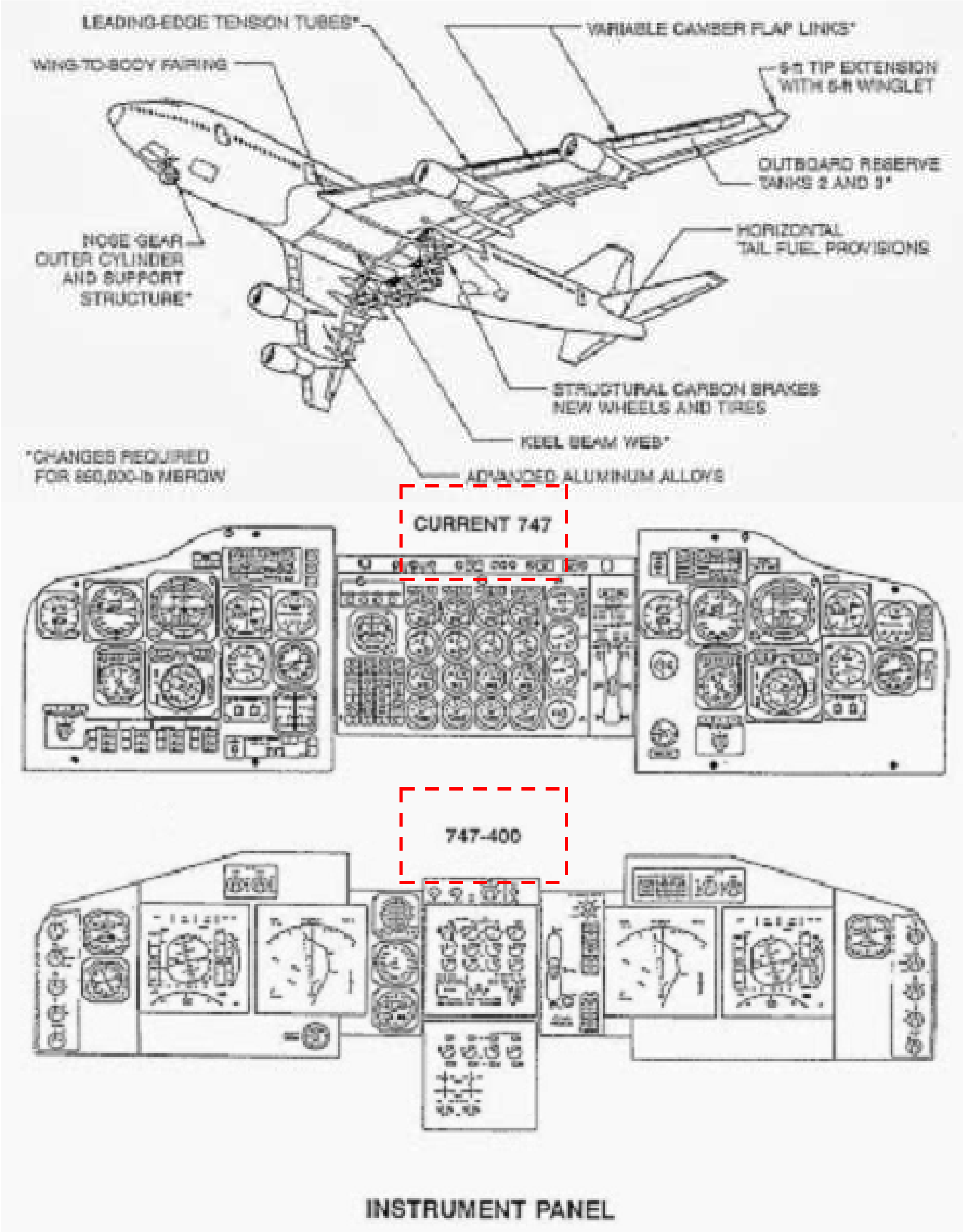

747-200
747-300

Second Generation



With sales of the 747-300 sluggish, it ended up being something of an interim type, with only 81 units built. In the face of slow sales, Boeing decided to use the 737-300 as the basis for a "second generation" 747: the "747-400" featuring:

- **Updated turbofan engines (the new P&W PW4056, or the latest variants of the CF6 and RB211) in the thrust range of 58K foot-pounds plus a new *Pratt & Whitney Canada* (PWC) APU which replaced the older Garrett unit. Qualifying all three types of turbofan engines at the outset turned out to be a major problem;**
- **Use of composite materials and advanced aluminum alloys to save airframe weight;**
- **A 6-foot stretch of each wing, with composite "winglets" 6-feet tall at the ends to reduce "vortex drag" (left) around the wing-tips, resulting in more efficient cruise;**
- **A new digital flight deck "Electronic Flight Instrumentation System" (EFIS) with six CRT displays (derived from work on the 757/767 jetliners to permit two-crew operation).**
- **Fuel tanks in the tailplane, and;**
- **A modular floor layout (per customer request).**



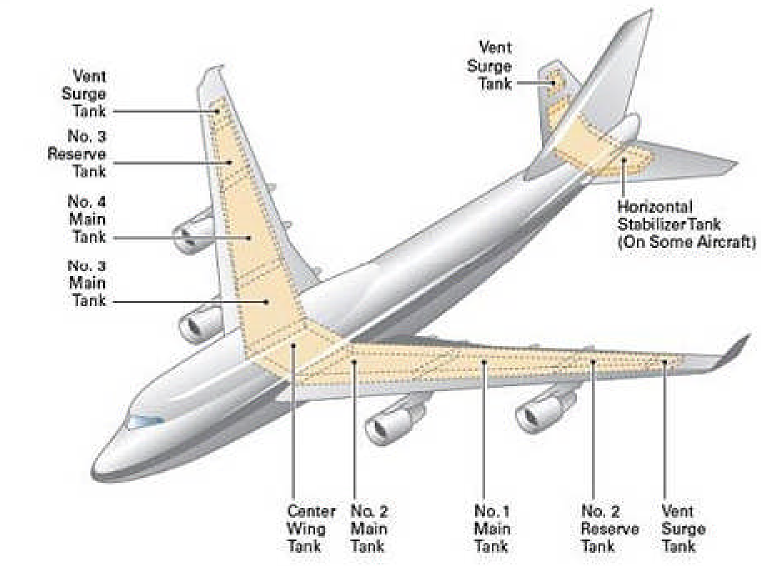
In May 1985, Boeing announced the development of the "ultimate" version of the 747; the 747-400. In addition to more powerful engines, the 747-400 was a substantially revised and improved version of the original 747-100/200. The cockpit was completely redesigned and now included multifunction displays to replace classic instruments, allowing for a two-man flight crew rather than three (the flight engineer was eliminated). Digital technology also replaced the analog avionics. The *Whitcomb* wing tips and the presence of a lighter lithium aluminum wing structure set the -400 apart from its predecessors. The 747-400 could take more passengers farther (1,800 km) as compared to the 747-300 (a fuel tank located in the horizontal stabilizer further increased the -400's range)

<u>Top</u>: caption: "Major improvements 747-400"

<u>Bottom</u>: caption: "The dashboard of the 747 'standard' vs. '-400'"

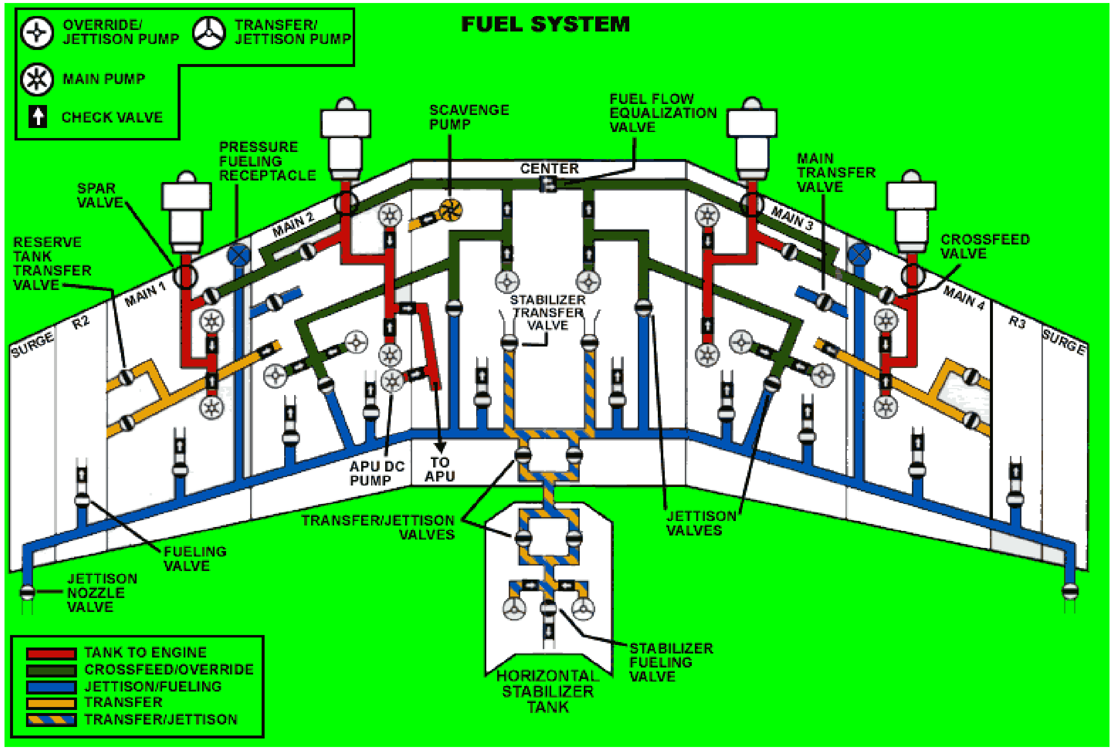

STATIC PORTS COVERED

The 747-400 (a/k/a “Dash 400”) was launched in 1985 with final assembly occurring in September 1987. In a departure from the 747 “Classic,” more then 50% of the Dash 400’s components were produced by sub-contractors. The first Boeing 747-400 was rolled out on January 26th 1988 (above). *Northwest Airlines* (the 747-400 launch customer) took its first delivery on January 26th 1989 and it entered service a month later. After the exuberance of the 1980s, clouds were forming on the horizon. On October 5th 1989, 57K unionized machinists walked off their jobs, halting production on all Boeing jets for 48 days. This established an adversarial relationship between Boeing and their labor force.

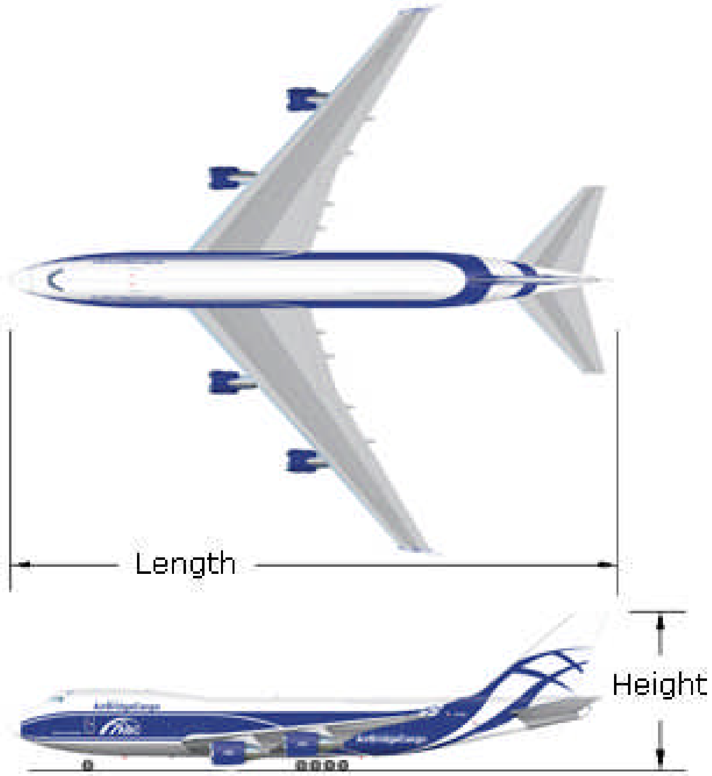


Total Usable Fuel

Airplanes With a Horizontal Stabilizer Fuel Tank	216,389 liters (57,164 U.S. gallons)
Airplanes Without a Horizontal Stabilizer Fuel Tank	203,897 liters (53,864 U.S. gallons)



<u>Above L&R</u>: **caption: "The 747-400 has eight fuel tanks, with a combined capacity of 57,164 gallons of "Jet-A" fuel. This amount weighs in excess of 380K pounds (pilots normally discuss fuel in terms of weight rather than volume). The distribution of fuel among these tanks has a profound effect on how the aircraft performs. In particular, during a long trip, it's important that the fuel in some tanks be burned-off before using the fuel in other tanks. Otherwise, the aircraft can become unbalanced. Fuel management in the 747-400 is largely automated, but there are still certain actions that are required from the crew."**



- **Wingspan:** **211-feet 5-inches**
- **Wing Area:** **5,650 square-feet**
- **Length:** **231-feet 10-inches**
- **Height:** **63-feet 8-inches**
- **Empty Weight:** **399K pounds**
- **MTO Weight:** **800K pounds**
- **Cruise Speed:** **570 MPH / 495 KT**
- **Cruise Altitude:** **35K-feet**
- **Max. Range:** **8,355 MI / 7,260 NMI**

The last orders for a 747-400-series aircraft were taken in the summer of 2006. A total 1,419 first and second generation 747s were built by Boeing, almost half of them were 747-400 units.

Left: caption: “Boeing 747-400”

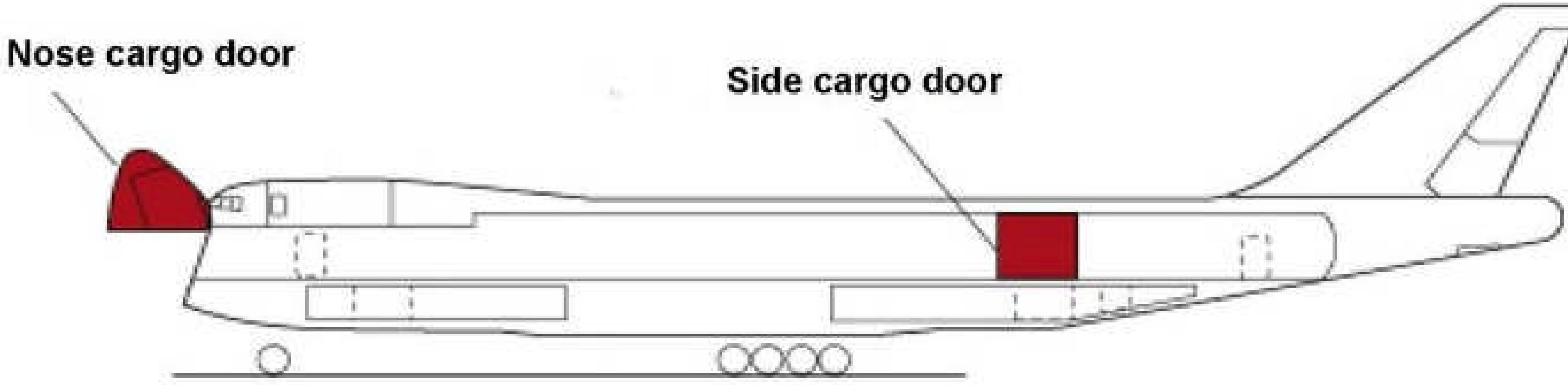
The proven base of the classic 747 combined with the intensive modernization program of the -400 helped restore the 747 series to the forefront of the Boeing product line-up. Production on the original Boeing 747 "Classics" ended in 1991 with a 747-200 delivery. The 747-400 accumulated 694 orders by the time deliveries ended in 2009.

<u>Above</u>: caption: "The first Boeing 747-400"
<u>Top Left</u>: caption: "Lufthansa Airlines received the 747th 747 in September 1989"
<u>Bottom left</u>: caption: "The 1,000th Boeing 747; a 747-400, going to Singapore Airlines in 1993"

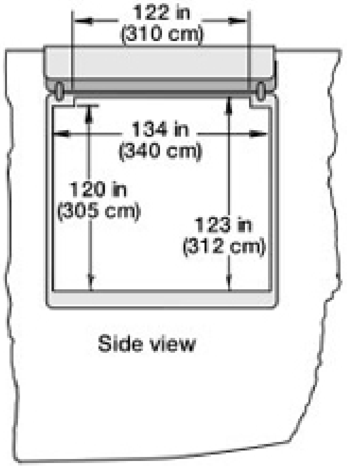
With the 747-400 proving very popular, Boeing produced several variants:

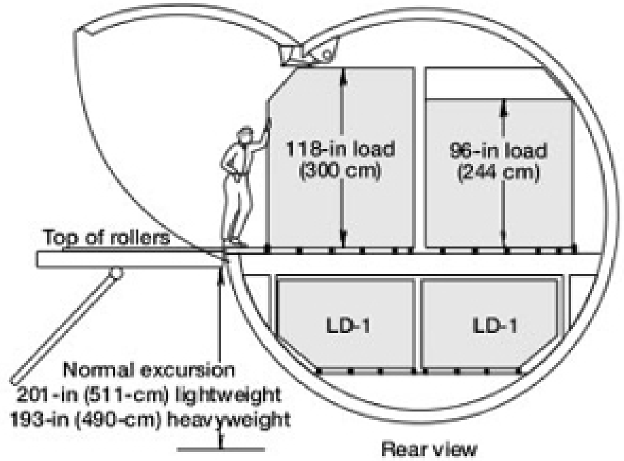
- **A "747-400F" (left) freighter variant (lacking the SUD, but still recognizable by its winglets). It replaced the 747-200F in production in 1991, offering substantially more payload capacity and range; the -400F became something of a standard in the large air freighter category;**
- **A "747-400M" convertible variant (retaining the SUD), and;**
- **A short-range/high-density "747-400D" ("D" for "Domestic" - for the Japanese market) with a maximum of 568 seats**

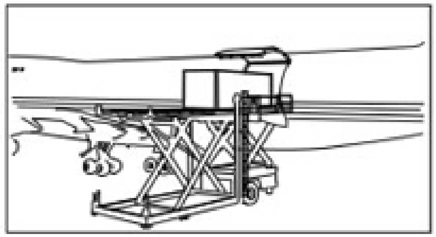
In 2000, Boeing focused on an <u>E</u>xtended <u>R</u>ange -400: "747-400ER" (originally simply called the "Longer Range 747-400") - a slightly updated version of the original -400, initiating production of the type in early 2002. The 747-400ER had a reinforced wing and stronger landing gear (inherited from the -400F) and a modernized flight deck with multifunction flat-panel displays and could carry up to 416 passengers in a more spacious seat layout and with greater overhead bin capacity. Range was extended by about 6%. A "747-400ERF" freighter was also built.



The 747-400ER/ERF was the final 747-400 production variant, but the popularity of the 747 series as an air freighter led Boeing to initiate a "747-400SF" (Special Freighter) conversion program for -400 aircraft in 2003 (as a collaboration with Chinese partner firms). The primary modification was the fitting of a side cargo door. Total payload was 50K pounds) with accommodation of 30 standard cargo pallets. Since 747-400 airliners had the SUD for first-class passengers while 747-400F freighters did not, the -400SF conversions were able to accommodate up to 19 passengers (very useful for transport of large animals that needed handlers and caretakers while in transit).



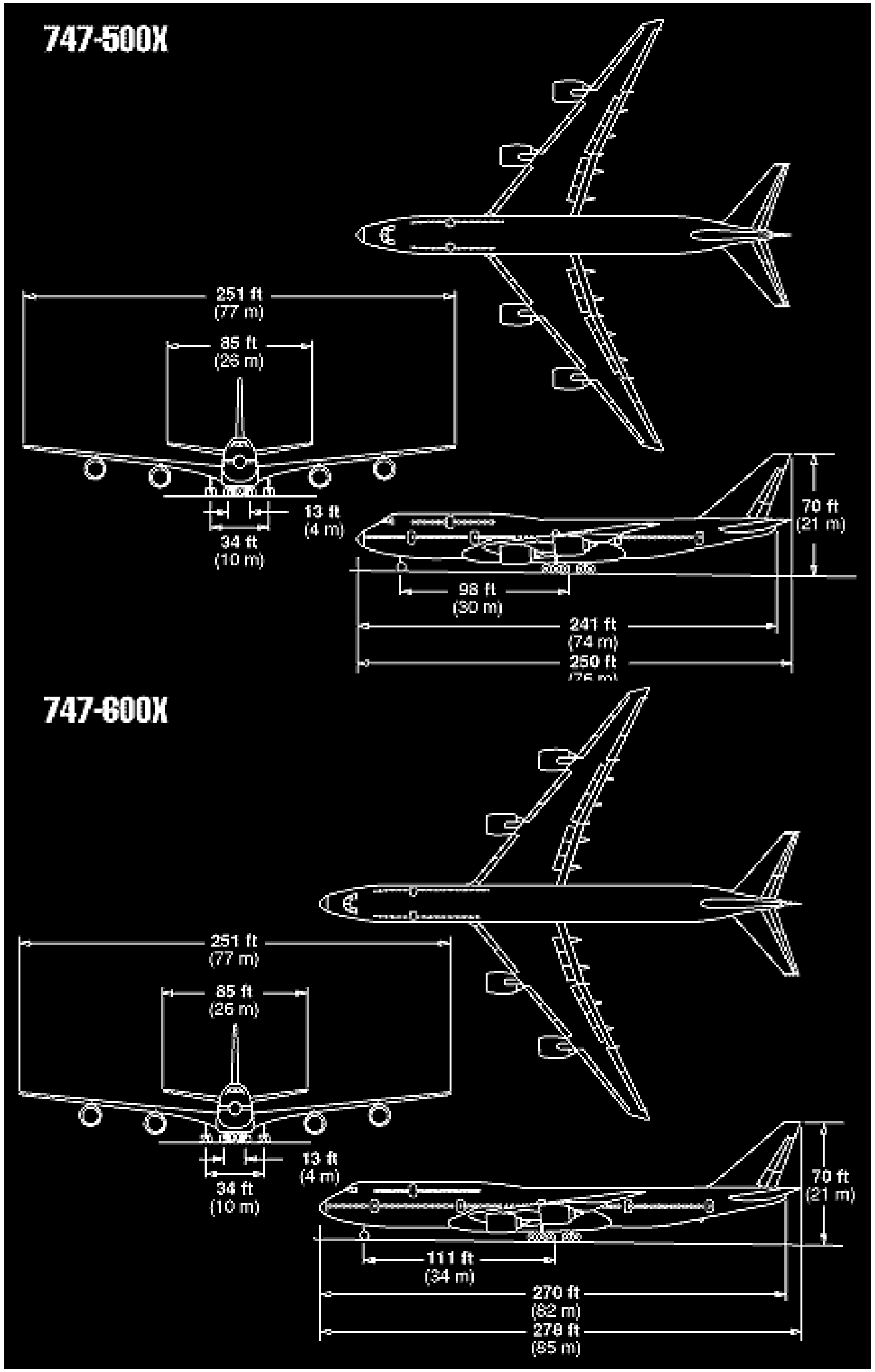




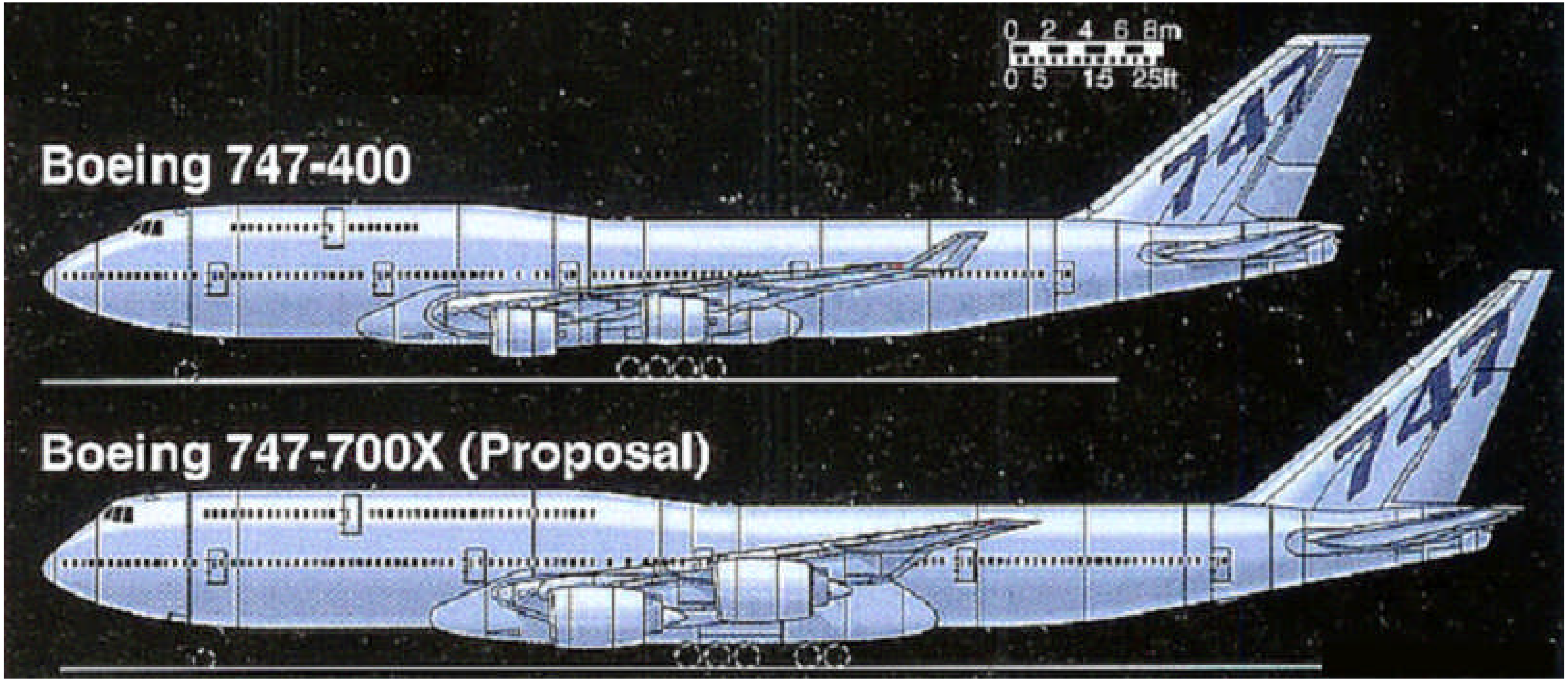
The 747-400F side cargo door offers the same•ease of loading that airlines are accustomed to•with other main deck cargo 747s: the Combi, the•-200F, and the special freighter.
This ensures efficient online and interline transfer capability for higher efficiency and profitability.

First flight:	- 747-100 February 9, 1969, N7470. - 747-200B October 11, 1970, N611US. - 747-200F November 30, 1971, N1794B. - 747-200C March 23, 1973, N747WA. - 747SP July 4, 1975, N747SP. - 747-200M November 18, 1974, N8297V. - 747-300/SR October 5, 1982 N6005C. - 747-300M February 14, 1983, N4548M. - 747-400 April 29, 1988, N401PW. - 747-400M June 30, 1989, N6038E. - 747-400D March 18, 1991, N60668. - 747-400F May 4, 1993, N6005C. - 747-400ER July 31, 2002, N6018N. - 747-400ERF September 30, 2002, N5017Q.
First delivery:	- 747-100 December 13, 1969 to Pan Am. - 747-200B January 15, 1971 to KLM. - 747-200F March 10, 1972 to Lufthansa. - 747-200C April 30, 1973 to World Airways. - 747SP March 5, 1976 to Pan Am. - 747-200M March 7, 1975 to Air Canada. - 747-300/SR March 1, 1983 to UTA. - 747-300M March 5 1983 to Swissair. - 747-400 January 26, 1989 to Northwest Airlines. - 747-400M September 1, 1989 to KLM. - 747-400D October 10, 1991 to Japan Air Lines. - 747-400F October 22, 1993 to Cargolux. - 747-400ER October 31, 2002 to Qantas. - 747-400ERF. October 17, 2002 to Air France.
Last delivery:	- 747-100 July 1986 to Japan Air Lines. - 747-200B December 1990 to USAF. - 747-200F November 1991 to Nippon Cargo Airways. - 747-200C September 1988 to Martinair. - 747SP December 12, 1989 to Abu Dhabi Government (UAE). - 747-200M December 12, 1989 to Abu Dhabi Government (UAE). - 747-300/SR October 1988 to Japan Asia. - 747-300M September 1990 to SABENA. - 747-400M April 10, 2002 to KLM. - 747-400D December 1995 to All Nippon Airways.

SuperJumbo

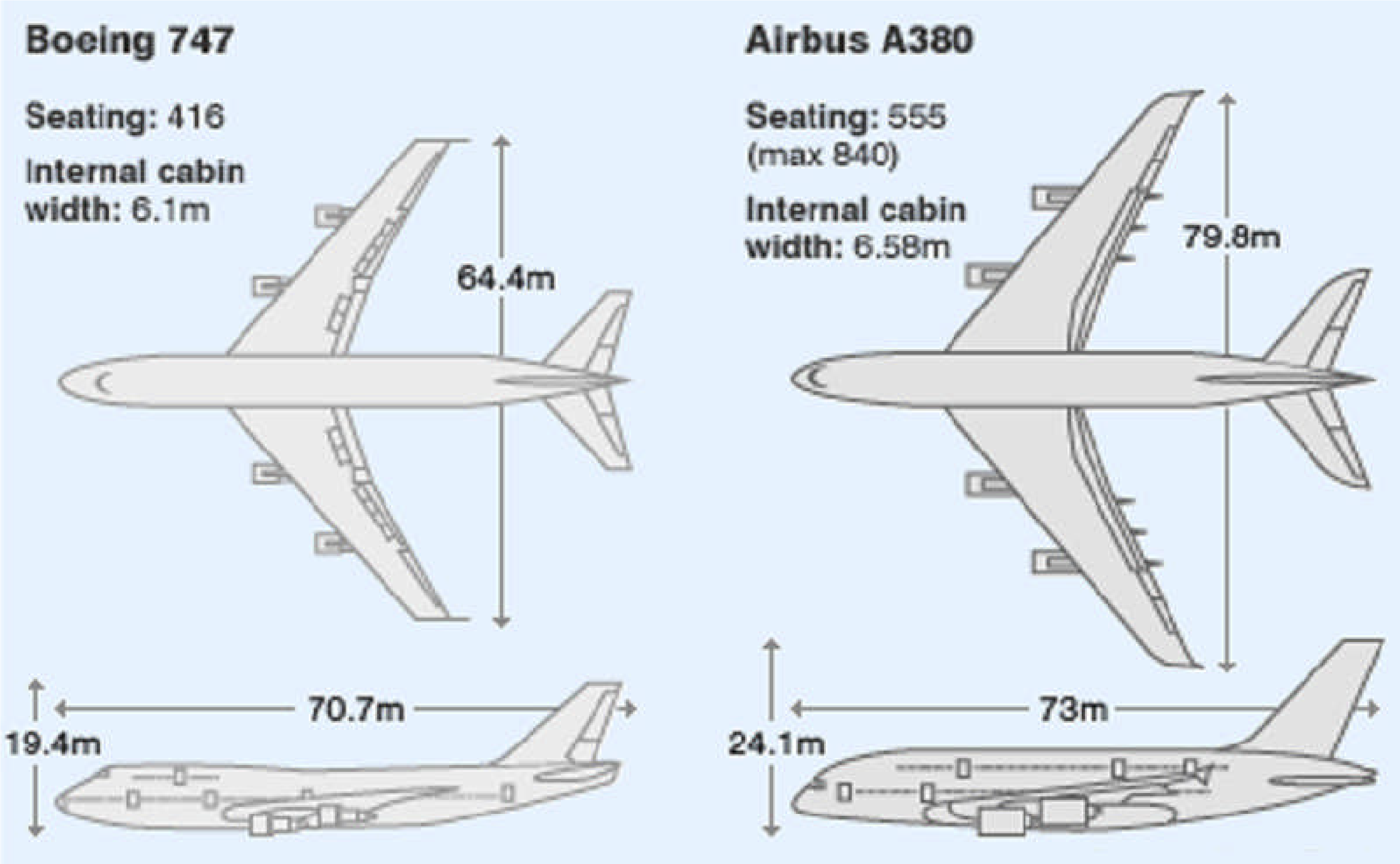


Given the airlines enthusiasm for the 747-400 series, Boeing considered their next move. In response to the Airbus initiative to develop the A3XX series of "Super-Jumbo" aircraft, Boeing investigated a number of options for enhanced 747 models. In 1995-96, the company considered stretched variants. Boeing announced the 747-500X and -600X (left) at the 1996 *Farnborough Airshow*. The proposed models would have combined the 747's fuselage with a new 251-foot span wing (derived from the *Boeing 777*). Other changes included more powerful engines and increasing the number of tires from 2 to 4 on the nose gear and from 16 to 20 on the main gear. The 747-500X concept featured an increased fuselage length (to 250-feet) and the aircraft was to carry 462 passengers over a range up to 8,700 nautical miles. The 747-600X concept featured a greater stretch (to 279-feet) with seating for 548 passengers and a range of up to 7,700 nautical miles.

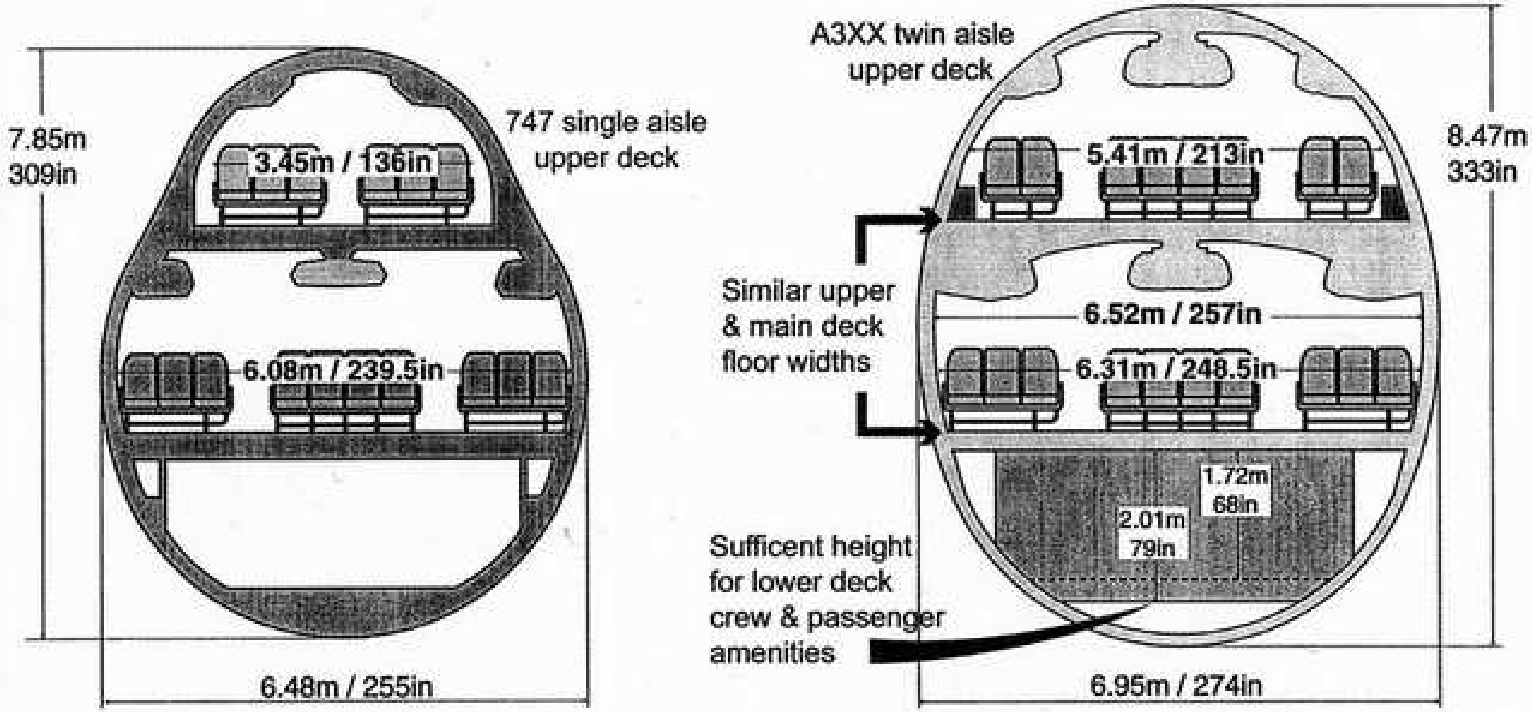


Above: a third study concept; the 747-700X (bottom) would have combined the wing of the 747-600X with a widened fuselage, allowing it to carry 650 passengers over the same range as a -400. The cost of the changes (in particular, the new wing for the -500X and -600X) was estimated to be more than $5 billion.

<u>Above</u>: caption: "Boeing also studied a full double decked version that looked very similar to an Airbus A380." Mainly due to doubts that the SuperJumbo concept was commercially feasible (filling up so many seats seemed problematic, this having been an issue with the original 747) along with the fact that the company was not able to attract enough interest in the aircraft among their airline customers, Boeing abandoned the SuperJumbo project/s shortly after the merger with *McDonnell Douglas* in 1997.

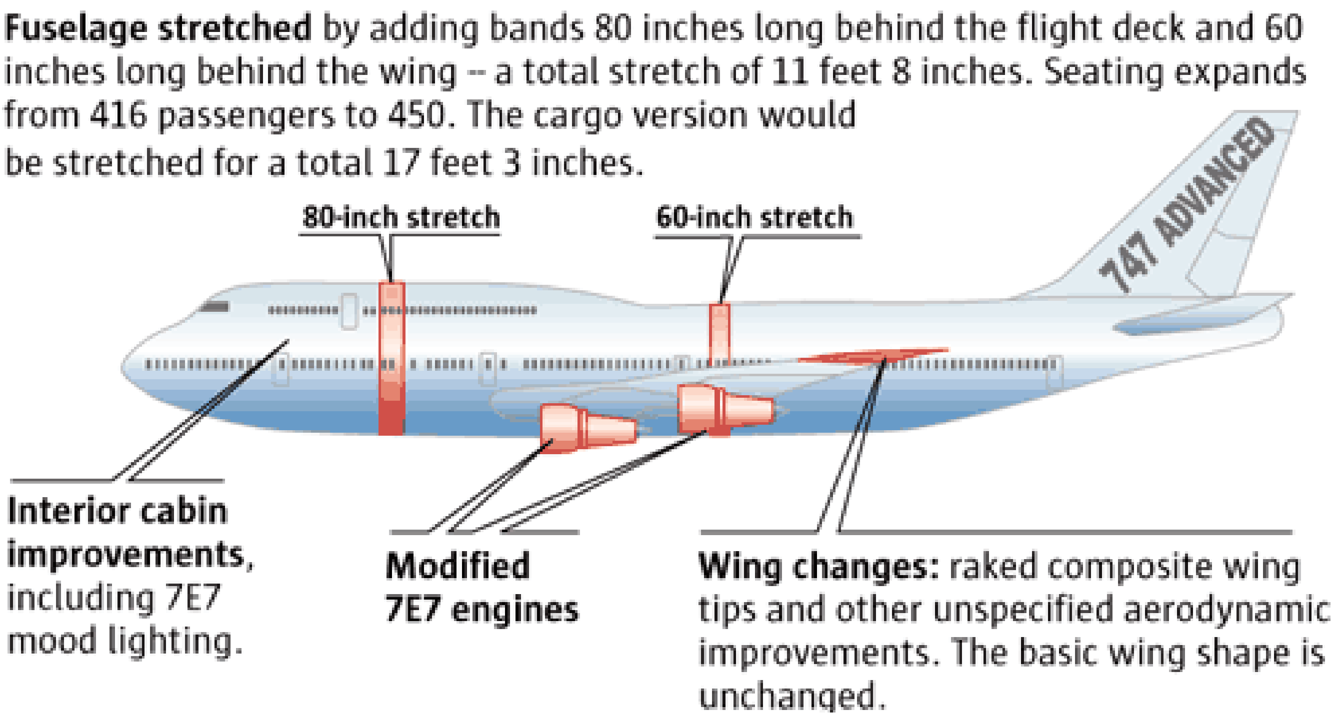


<u>Above</u>: caption: "Comparison of Boeing 747 and Airbus A380." Boeing's abandonment of their SuperJumbo concepts left the *Airbus A3XX*, (which eventually became the *Airbus A380*) alone in the NLA (<u>N</u>ew <u>L</u>arge <u>A</u>irliner) category until 2005, when the 747-8 was launched.



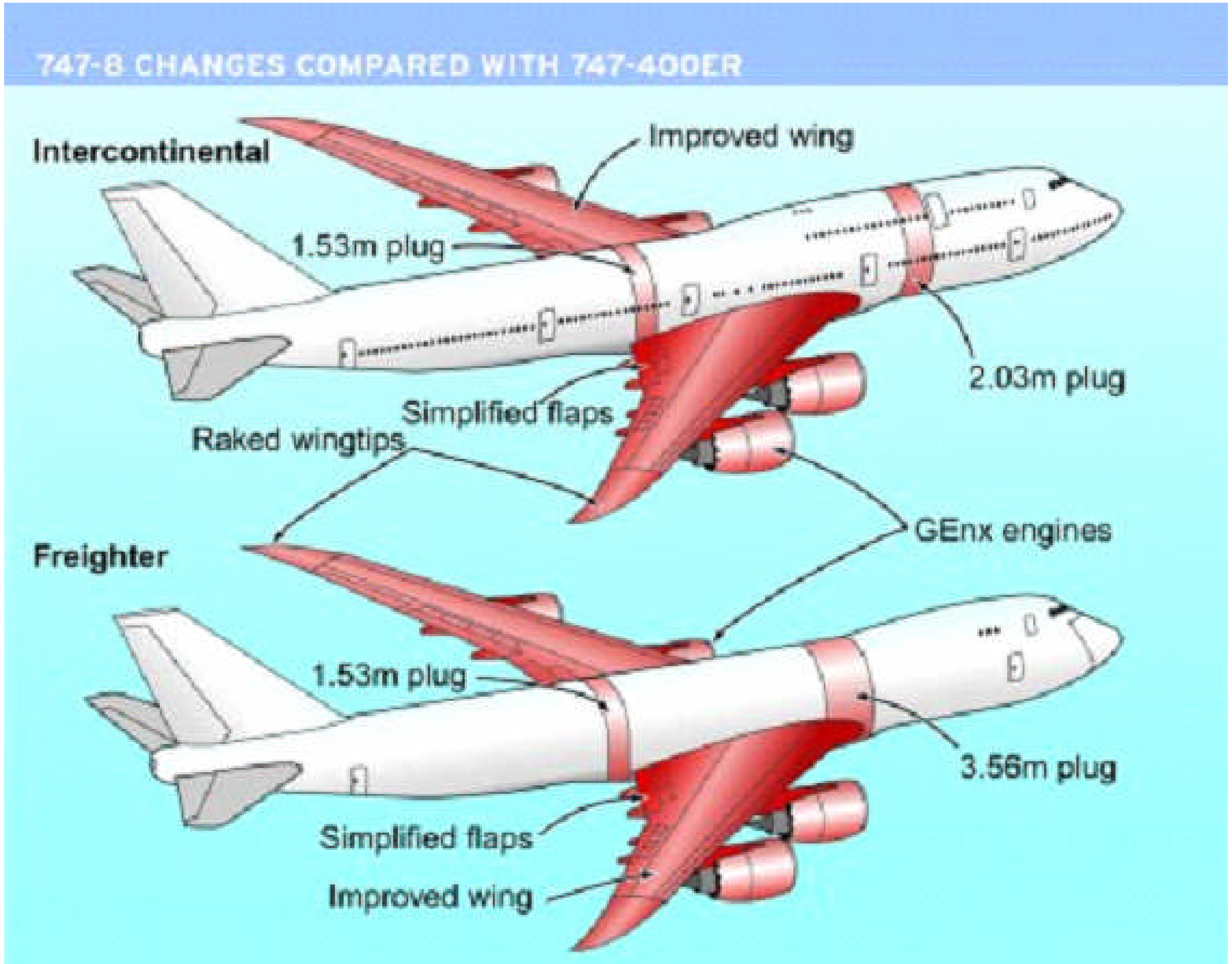
747 & A3XX passenger cabin cross section comparison

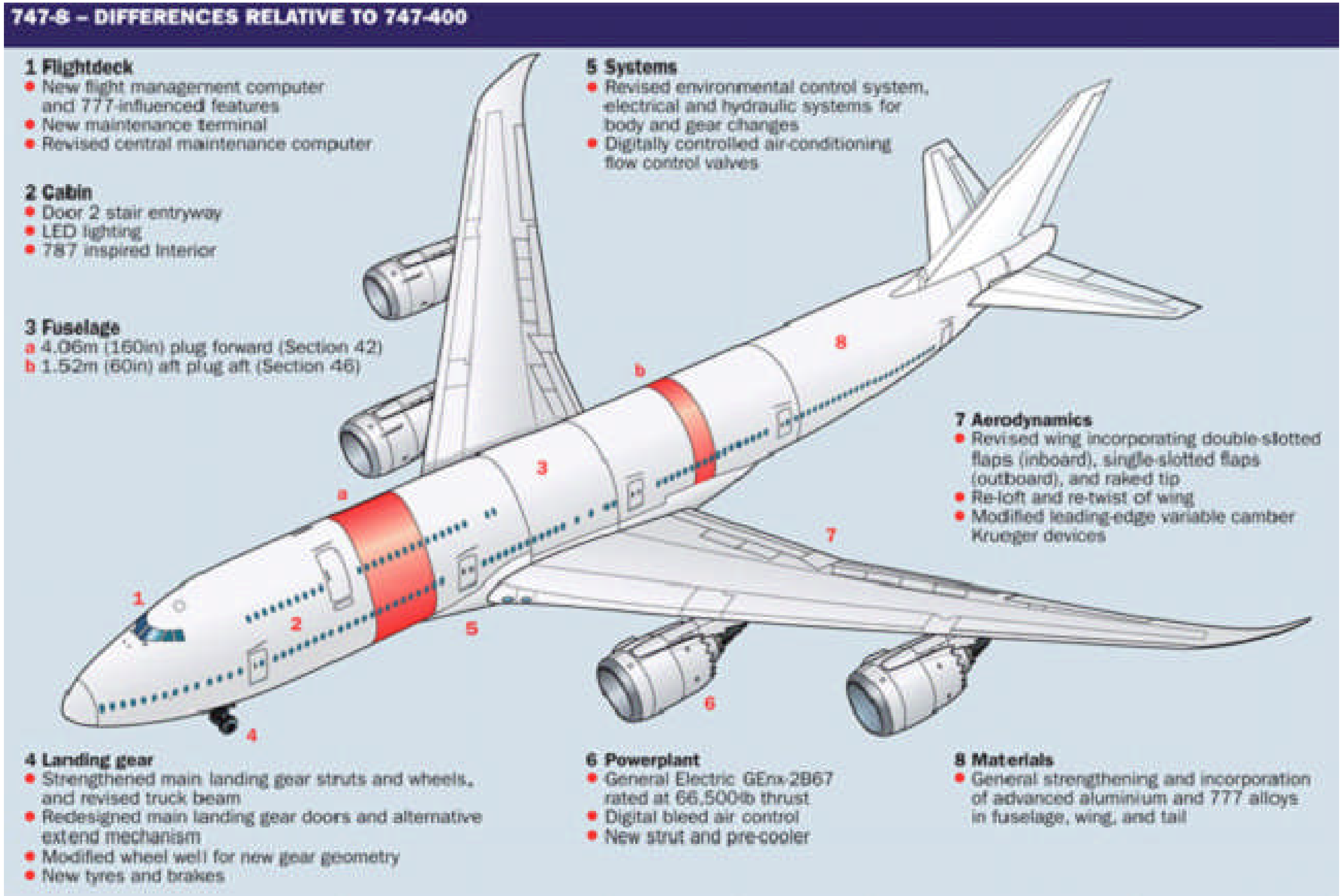
Third Generation



On November 15th 2005, Boeing officially launched the "Third Generation" in the 747 series. Two variants were initially developed, including a "747-8 Passenger" (a/k/a "747-8 Intercontinental" {747-8I} and a "747-8 Freighter" {747-8F}). The 747-8 was stretched (by 11-feet 8-inches, as compared to the -400) making it the first "stretch" 747 (there was talk of making the 747-8I a bit shorter than the 747-8F, but they remain the same length). Dash 8s are only offered with the *General Electric GEnx-2B67* engine, developing 66,500 foot-pounds of thrust (this engine was developed for the *Boeing 787*). It appears Boeing was growing weary of supporting multiple engine types and formed a strategic alliance with GE. The turbofans feature the serrated noise-reducing cowlings first introduced on the 787.

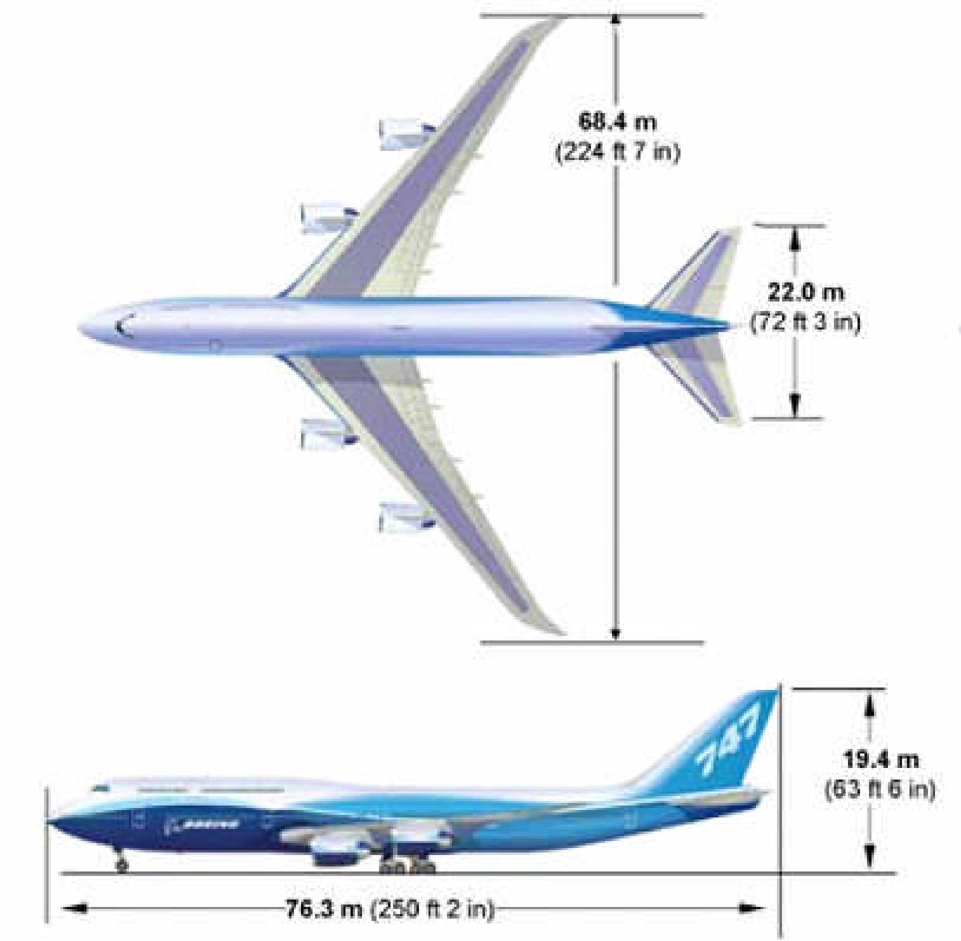
Above: caption: "Boeing's Proposed 747 Advanced"


747-8 CHANGES COMPARED WITH 747-400ER
Intercontinental
Improved wing
1.53m plug
2.03m plug
Simplified flaps
Raked wingtips
GEnx engines
Freighter
1.53m plug
3.56m plug
Simplified flaps
Improved wing


747-8 – DIFFERENCES RELATIVE TO 747-400
1 Flightdeck
• New flight management computer and 777-influenced features
• New maintenance terminal
• Revised central maintenance computer
2 Cabin
• Door 2 stair entryway
• LED lighting
• 787 inspired Interior
3 Fuselage
a 4.06m (160in) plug forward (Section 42)
b 1.52m (60in) aft plug aft (Section 46)
4 Landing gear
• Strengthened main landing gear struts and wheels, and revised truck beam
• Redesigned main landing gear doors and alternative extend mechanism
• Modified wheel well for new gear geometry
• New tyres and brakes
5 Systems
• Revised environmental control system, electrical and hydraulic systems for body and gear changes
• Digitally controlled air-conditioning flow control valves
6 Powerplant
• General Electric GEnx-2B67 rated at 66,500lb thrust
• Digital bleed air control
• New strut and pre-cooler
7 Aerodynamics
• Revised wing incorporating double-slotted flaps (inboard), single-slotted flaps (outboard), and raked tip
• Re-loft and re-twist of wing
• Modified leading-edge variable camber Krueger devices
8 Materials
• General strengthening and incorporation of advanced aluminium and 777 alloys in fuselage, wing, and tail
1
2
3
4
5
6
7
8
a
b


BOEING 747-400
Lufthansa
Maximum Payload Range = 7,260 nm
3 Class Seating Capacity = 416
Cargo Capacity = 5,332 cu ft
MTOW = 875,000 lbs
BOEING 747-8I
Lufthansa
lufthansa.com
Maximum Payload Range = 8,000 nm
3 Class Seating Capacity = 467
Cargo Capacity = 5,705 cu ft
MTOW = 975,000 lbs

747-8I

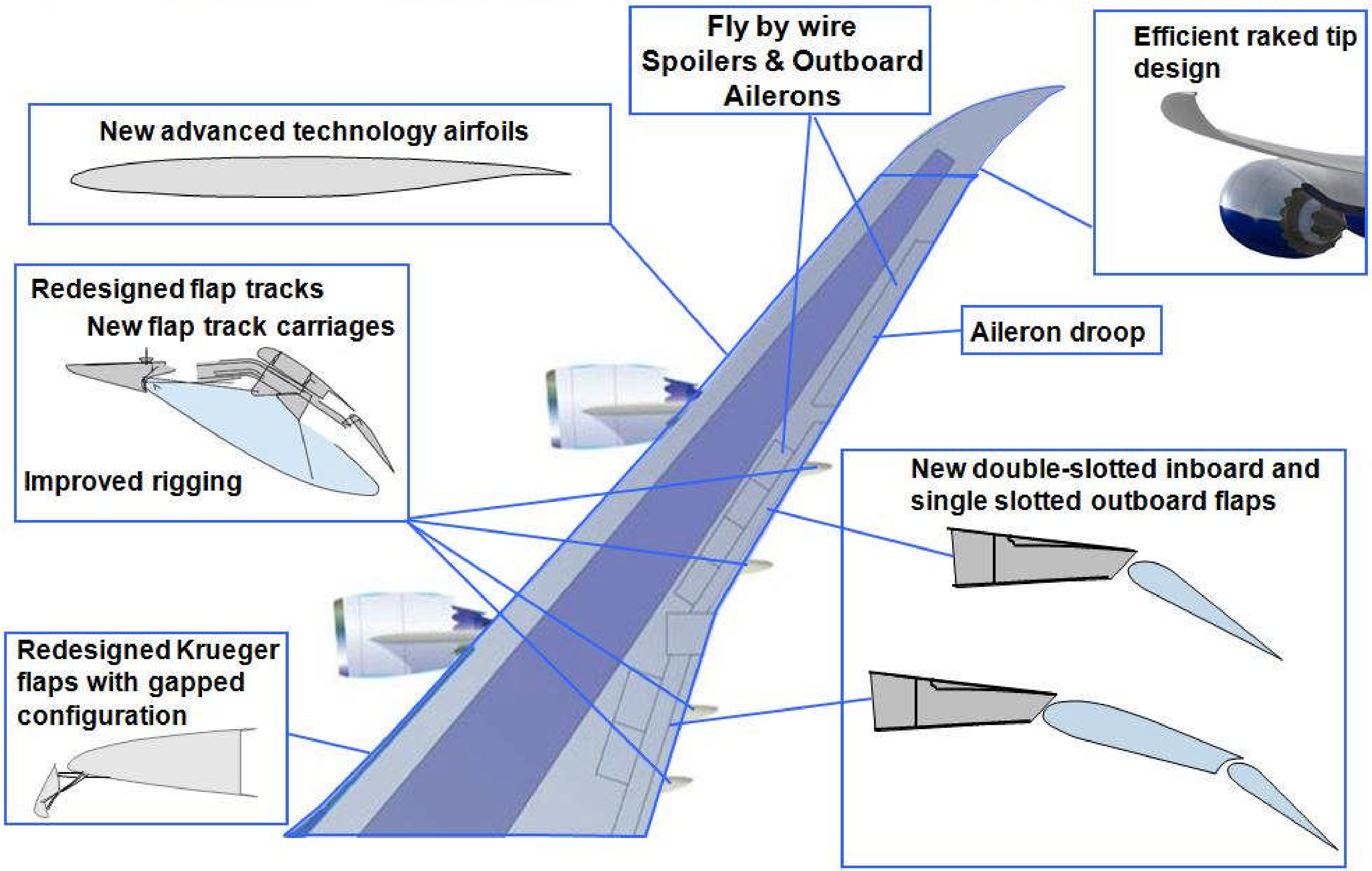


- Wingspan: 224-feet 7-inches
- Wing Area: 6,028 square-feet
- Length: 250-feet 2-inches
- Height: 63-feet 6-inches
- Empty Weight: 651K pounds
- MTO Weight: 987K pounds
- Cruise Speed: 570 MPH / 495 KT
- Cruise Alt.: 43K-feet
- Max. Range: 89,210 MI / 8K NMI

The 747-8 features a modernized cockpit (top) and wing (bottom). The wing retains the same sweep general arrangement but has been re-profiled, featuring a span-stretch plus raked wingtips (instead of winglets). It has double-slotted flaps inboard and single-slotted outboard (instead of the triple slotted flaps of its predecessors).

The wing design: additional performance with lower noise

747-8

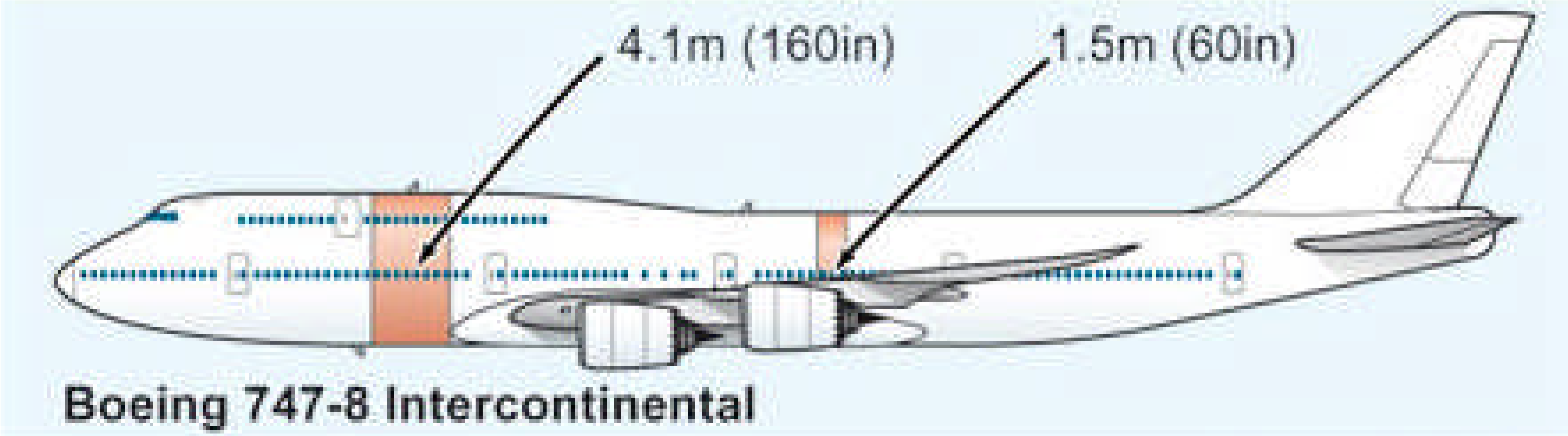


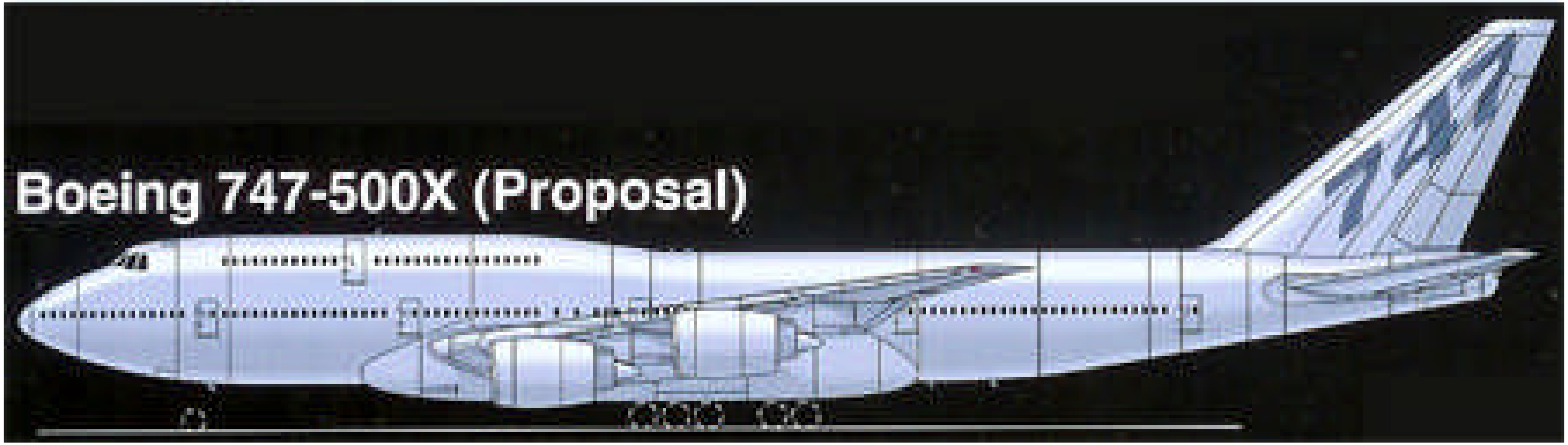
Production of the freighter version began in August 2008. The passenger version attracted fewer orders thus, for the first time in the history of Boeing, the freighter version rather than the passenger version of a commercial aircraft was first to enter service and first to fly. By airline-industry standards, launching an air freighter variant before a passenger airliner variant is backwards, but not surprising in this case given the popularity of the 747-400F. The 747-8F freighter version is derived from the 747-400ERF and can accommodate 154-tons of cargo (16% more payload capacity than the 747-400F) and can hold seven additional standard air cargo containers. To aid loading and unloading, it features both nose and side cargo doors (but does not have the SUD). The first flight took place on February 8th 2010 (well behind schedule) and entered service first with *Cargolux* (above) on October 12th 2011. Pilots flying the 747-8I/F do not require a new type rating (a problem that afflicted earlier attempts to define a next-generation 747).


The right choice for the large freighter market
747-8
16% more cargo capacity
16% lower fuel costs per tonne
16% lower tonne-mile costs
Utilizes today's infrastructure
Nose door equipped
Capable of carrying "real world" densities
QC2 noise guaranteed
747 commonality
747

Initially attracting twenty orders from *Lufthansa,* the first passenger version entered commercial service on June 1st 2012. Other customers included *Korean Air, Arik Air* and *Air China* (and VIPs). With production delays, the lack of orders was actually a blessing-in-disguise. 747-8 production peaked at two aircraft per month and was lowered to 1.75 per month (in July 2013) due to decreasing demand (mainly in its primary freighter market). As of the end of July 2013, there had been 52 delivered and 107 orders. In June 2014, the 1,500th 747 ever built (right) was delivered to Lufthansa.

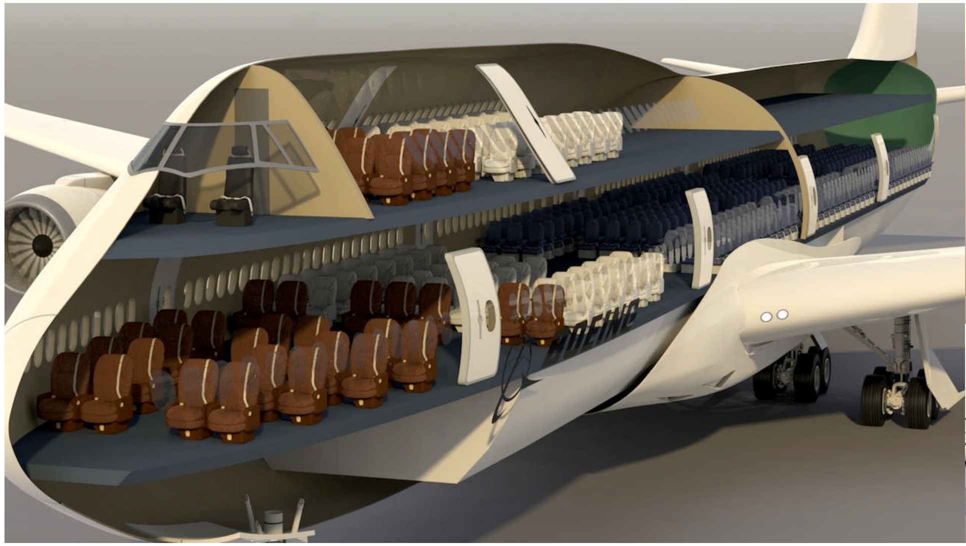
<u>Left</u>: caption: "Boeing 747-8I being assembled at the Boeing plant"

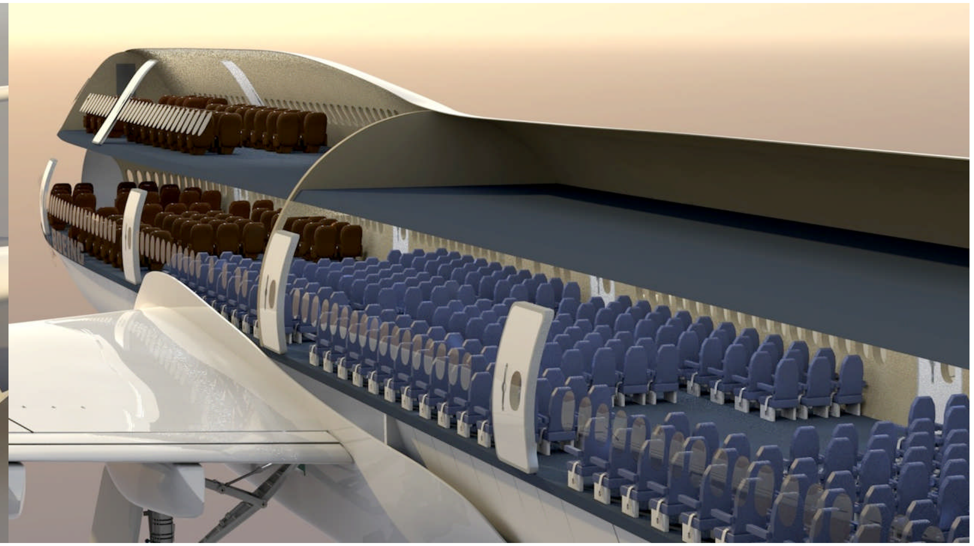


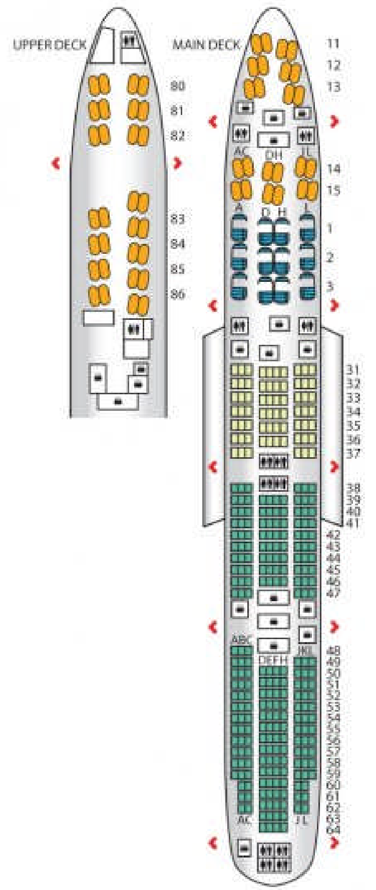


<u>Above</u>: caption: “The 747-8 is most similar in size to the 747-500X. Its fuselage was lengthened from 232 to 251-feet, surpassing the *Airbus A340-600* as the world’s long-est airline.”

<u>Top Left</u>: caption: “The engine fan diameter is almost as wide as a B-29 bomber’s fuselage”
<u>Top Right</u>: caption: “The landing gear tires are filled with nitrogen to prevent explosive tire blowouts”
<u>Left</u>: caption: “The upper deck of the 747-8I has the same square footage as a Boeing 737”





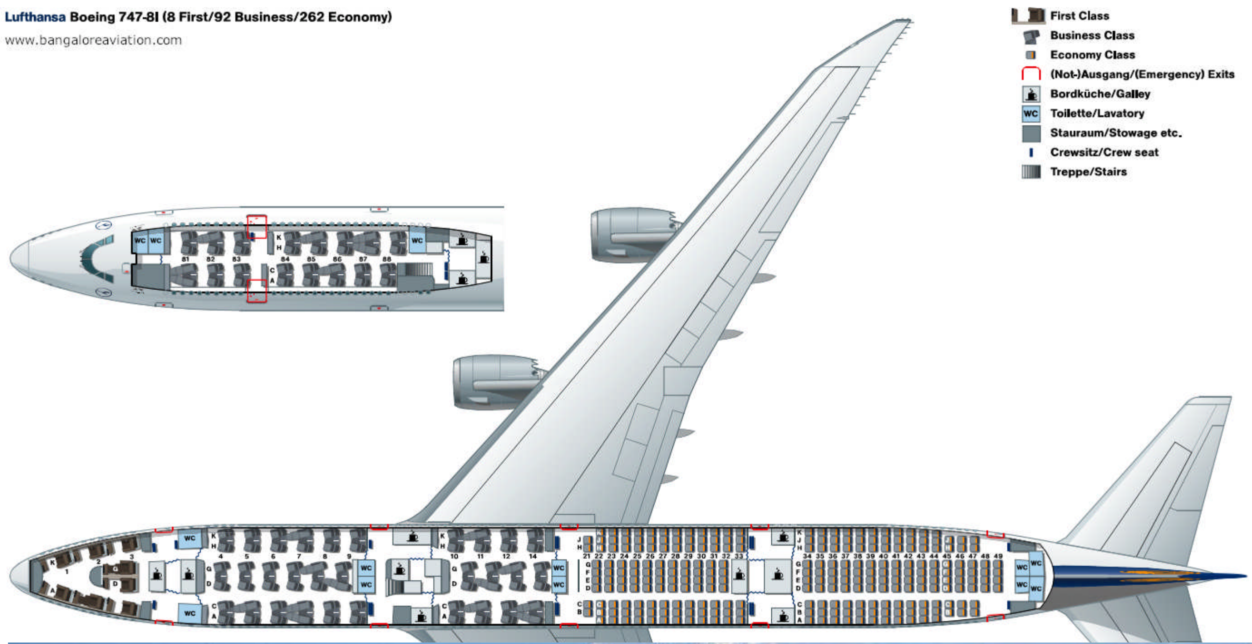


Maximum passenger capacity for the 747-8I is 605 seats, or 467 in a three-class arrangement; the upper deck is stretched to allow more passenger capacity topside. The interior was modernized, along the lines of that developed for the *Boeing 787*, with the same color-controlled LED lighting scheme as well as bigger windows (though they have sliding blinds, not the electronic dimming used on the 787). Since its introduction, the 747-8 has been improved. For example, at introduction the aircraft was slightly under its fuel efficiency specs but, due to refinements to the *GEnx-2B67* engines along with other tweaks (i.e. weight reduction and smarter software for the flight management system), it's presently slightly above the spec, with further improvements forthcoming.

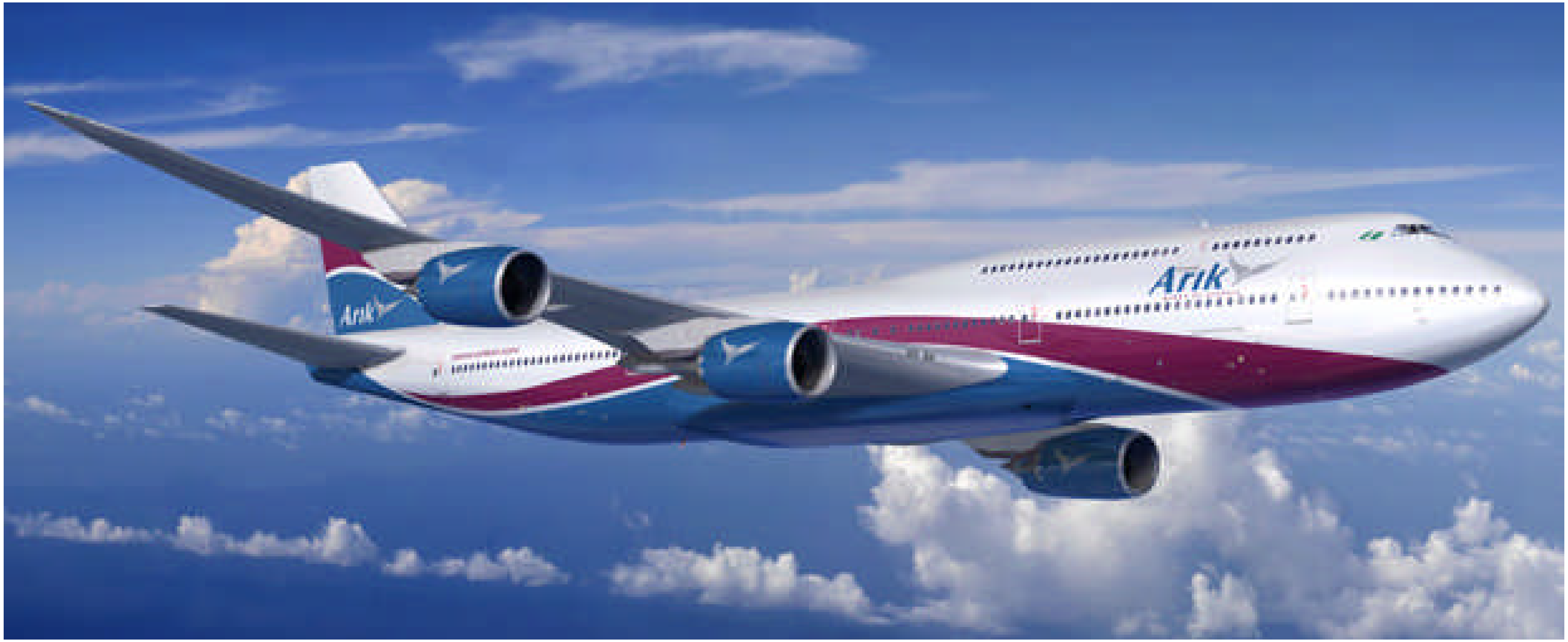
<u>Left</u>: caption: "Air China B747-8 seat map plan"

"…Not only is the 747-8I a very different aircraft than the 747-400, but the 70th 747-8 is much more efficient than the first one, and they plan to keep making it more efficient. The aircraft has been doing very well while in service with eight different operators. The 747-8 has flown over 385,000 flight hours and have served 150 different airports. The 747-8 has a dispatch reliability rate of 98.9%, which is exactly where Boeing was hoping it would be. Boeing has improved the operating costs of the 747-8 3.5% since the introduction of the first aircraft. The number might seem small, but it adds up to big money. A 3.5% improvement is a savings of about $1.94 million dollars per year per aircraft. The 747-8 is 16% more fuel efficient than the 747-400 - that's $8.8 million per aircraft per year savings. They have done this by implementing the Performance Improvement Package (PIP) engine upgrade, aerodynamic improvements, activating the additional tail fuel tank, and reducing the weight by 7,200 pounds…One example of future operations was wanting the 747-8I to be able to takeoff, fully loaded, any time of the year (even in a hot environment) and fly 8,200 miles…this could make the aircraft fly routes like Hong Kong to New York and Los Angeles to Dubai…"

***AirlineReporter*, June 2014**

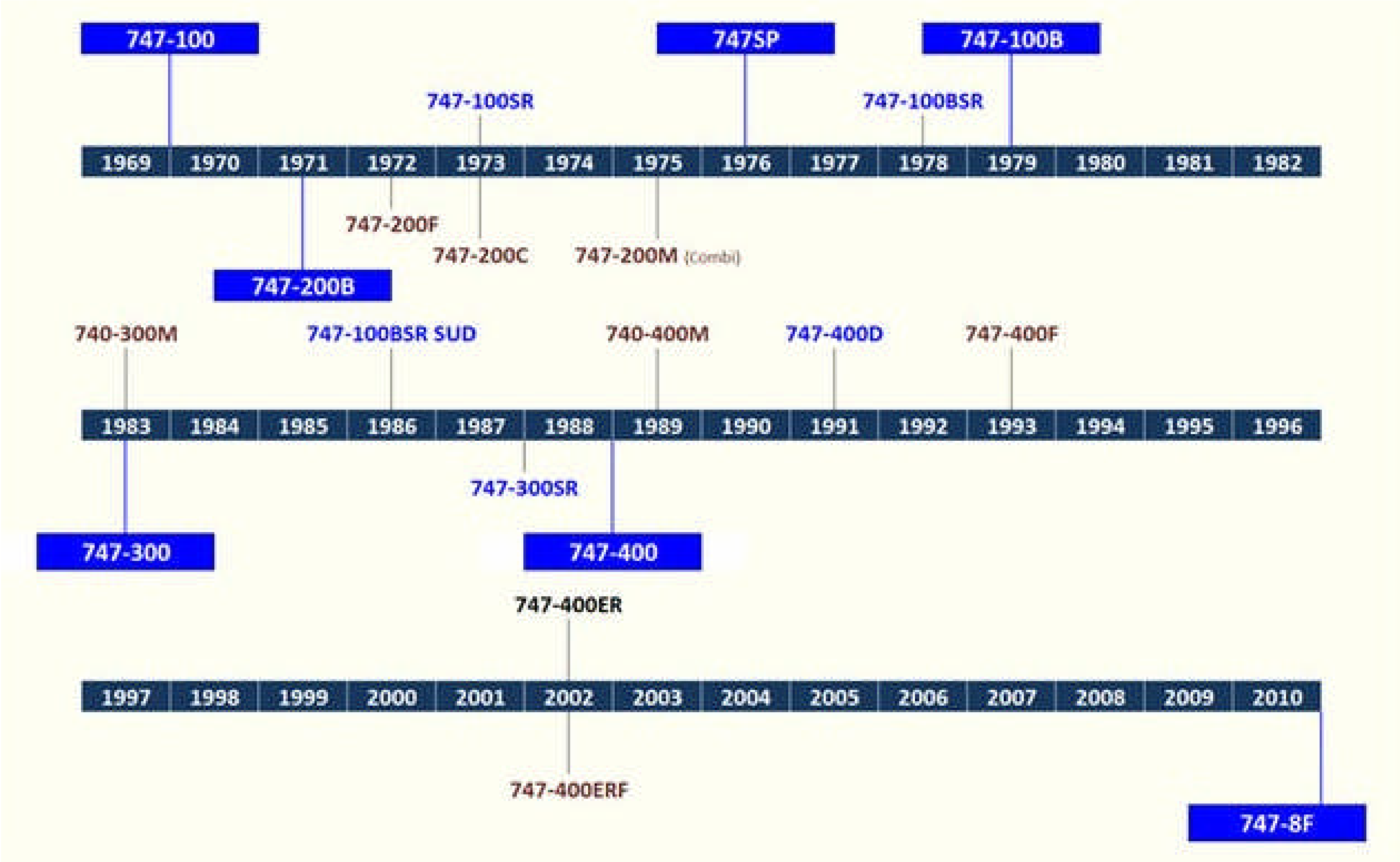

Lufthansa Boeing 747-8I (8 First/92 Business/262 Economy)
www.bangaloreaviation.com
First Class
Business Class
Economy Class
(Not-)Ausgang/(Emergency) Exits
Bordküche/Galley
Toilette/Lavatory
Stauraum/Stowage etc.
Crewsitz/Crew seat
Treppe/Stairs


737
747
BOEING



"….Many have questioned the continuing viability of the 747. Without many orders on the books, can the 747 line survive the long-term? Boeing needs to get additional customers to ensure the survivability of the aircraft…Boeing is able to announce at least one additional customer for the plane. At the very least, hopefully the 747-8 will be the basis for the next-generation Air Force One, allowing the signature airframe to represent the U.S. to the world. Boeing is confident that the 747 will be built for quite a bit longer, and they are optimistic that they have campaigns that will result in additional sales of the aircraft…as Boeing is able to improve the numbers of the 747-8, it might open up the door to potential customers."

***AirlineReporter*, June 2014**



Above: caption: “747 Delivery Timeline”


CATHAY PACIFIC CARGO
CATHAY PACIFIC CARGO
CATHAY PACIFIC
BRITISH AIRWAYS
cargo
cargo
ATA

Accidents Involving 747s
(Mechanical/Electrical/Structural)

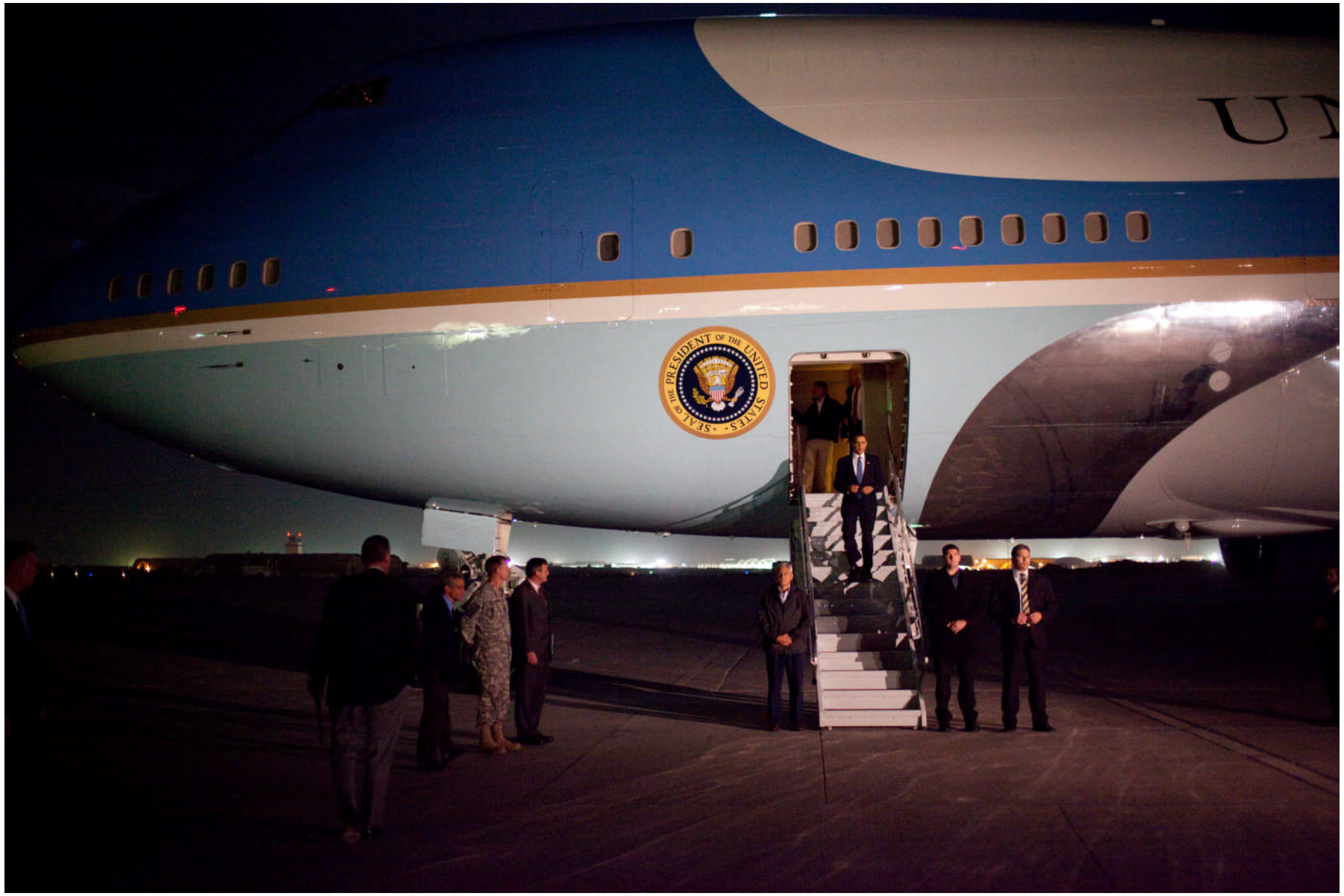
- **November 20th 1974; Lufthansa 747-100; Nairobi, Kenya:** The aircraft was not properly configured for takeoff and stalled shortly after becoming airborne, crashing about 3,600-feet beyond the end of the runway. The crash killed 55 of the 140 passengers and 4 of the 17 crew.
- **November 3rd 1977; El Al 747; over Belgrade:** One passenger died after a decompression event.
- **January 1st 1978; Air India 747-200; Bombay, India:** The plane crashed in the sea shortly after takeoff, killing all 190 passengers and 23 crew. *Flight International* magazine states that this accident was due to a failure of an attitude detector.
- **November 19th 1980; Korean Air Lines 747-200; Seoul, South Korea:** The aircraft undershot its landing and impacted just short of the runway causing severe damage to the landing gear. The aircraft caught fire after it slid to a stop. Six of the 14 crew members and eight of the 198 passengers were killed. Also killed was one person on the ground.
- **August 12th 1985; Japan Air Lines 747SR; Mt. Ogura, Japan:** The aircraft had a sudden decompression that damaged hydraulic systems and the vertical fin. That damage also disabled the flight controls for the rudder and elevator. All 15 crew members and 505 of the 509 passengers were killed.
- **November 28th 1987; South African Airlines 747- 200 Combi; over Indian Ocean:** The aircraft crashed during a flight between Taiwan and South Africa apparently due to a fire in the main deck cargo area. All 141 passengers and 19 crew were killed.
- **February 24th 1989; United Air Lines 747-100; Flight 811; near Hawaii**: The aircraft was on a scheduled international flight from Honolulu, HI to Auckland, New Zealand. About 16 minutes after takeoff, when the aircraft was climbing through about 22K-feet, the forward cargo door on the right side of the aircraft blew out and the resulting explosive decompression led to the loss of parts of the fuselage and the cabin interior, including a number of seats and passengers. Some of the ejected debris damaged the two right side engines and the crew had to shut them down. The crew was able to return to Honolulu and land about 14 minutes after the decompression. All 18 crew members survived, but nine of the 337 passengers were killed. (continued...)

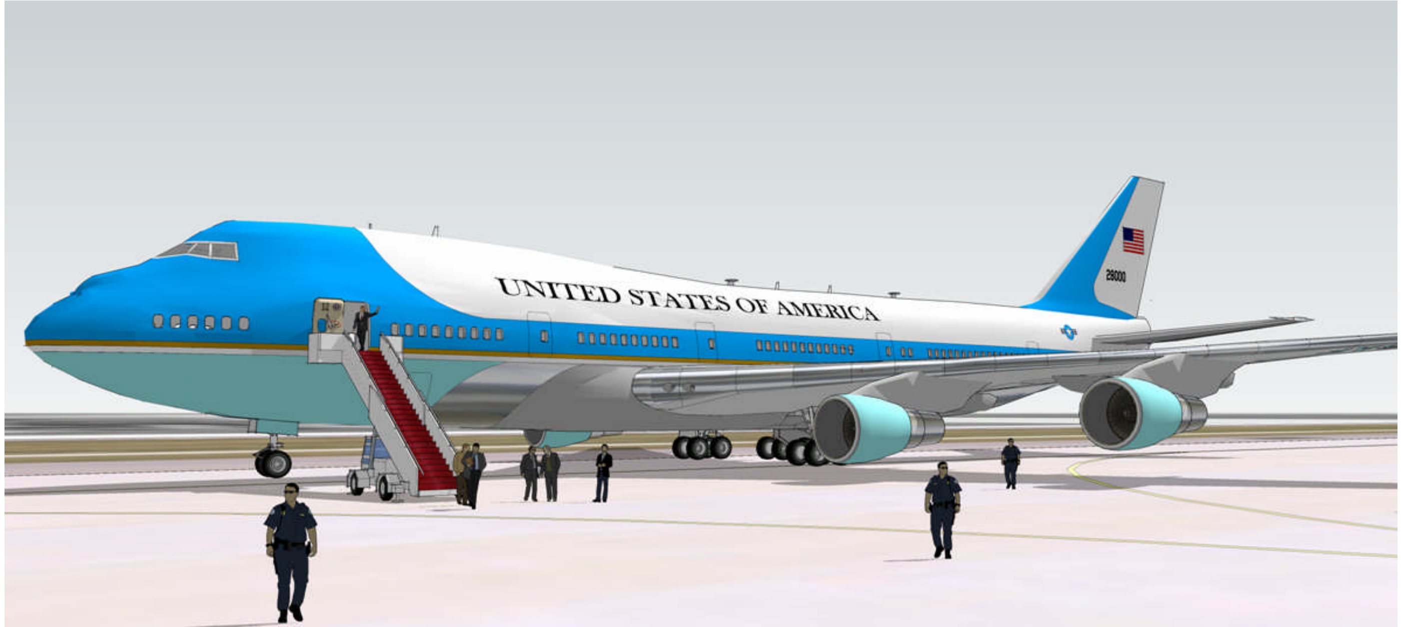
- **October 4th 1992; El AL 747-200; Amsterdam, Netherlands:** Shortly after departing Amsterdam on a flight to Tel Aviv, the number three engine and pylon separated from the wing and collided with the number engine. This collision also caused the number four engine and pylon to separate. Part of the leading edge of the right wing was damaged and several other aircraft systems were affected. During an emergency air turn-back to Amsterdam's Schiphol Airport, the crew experienced problems controlling the aircraft. The crew lost control of the aircraft shortly before landing, and the aircraft crashed into an apartment building. All three crew members and one other aircraft occupant were killed, as were 43 people on the ground.
- **July 1996; TWA 747-100; Atlantic Ocean near Long Island, NY:** The aircraft was on a flight from JFK airport in New York to Paris and had a catastrophic in flight breakup shortly after departure. The NTSB determined an electrical short-circuit caused fumes in the center fuel tank to ignite with explosive effect. All 18 crew and 212 passengers perished.
- **July 27th 2011; Asiana Airlines Boeing 747-400 cargo jet, Jeju Island, South Korea;** The plane, which was flying for South Korea's Asiana Airlines, came down off Jeju island in the very south of the country It had left Inchon en route to Pudong in China. A South Korean coast guard boat found debris from the jet in waters about 66 miles west of Jeju city. After taking off at 0305 (1800 GMT) the plane disappeared from radar at 0409 while trying to reach Jeju airport. Both the pilot and co-pilot were killed in the crash. The cause of the crash appeared to be mechanical problems.
- **April 31st 2013; 747-400; N949CA; Bagram Air Base, Afghanistan:** The aircraft had just departed on a cargo flight to Dubain, UAE when the aircraft entered a stall and crashed near the end of the runway. At one point, the aircraft had rolled to the right in excess of 45 degrees. Although the crew was able to put the wings more or less level, the aircraft impacted the ground at a high vertical speed, causing an explosion and fire. All seven crew members were killed. Speculation about the cause of the crash includes loose cargo (five 13.5-ton armored vehicles) and/or incorrect flap trim settings for a steep climb-out after takeoff (to avoid surface-to-air missiles)

On December 21st 1988, while flying high over Lockerbie, Scotland, a terrorist bomb went off in the luggage compartment of *Pan Am Flight 103* over Lockerbie, Scotland. The 747-100; *Clipper Maid of the Seas*, was flying from London Heathrow to New York JFK. All 259 people on-board were killed in addition to eleven people on the ground, making it the worst air disaster in U.K. history and the most deadly terrorist attack against the U.S. (up to that time).

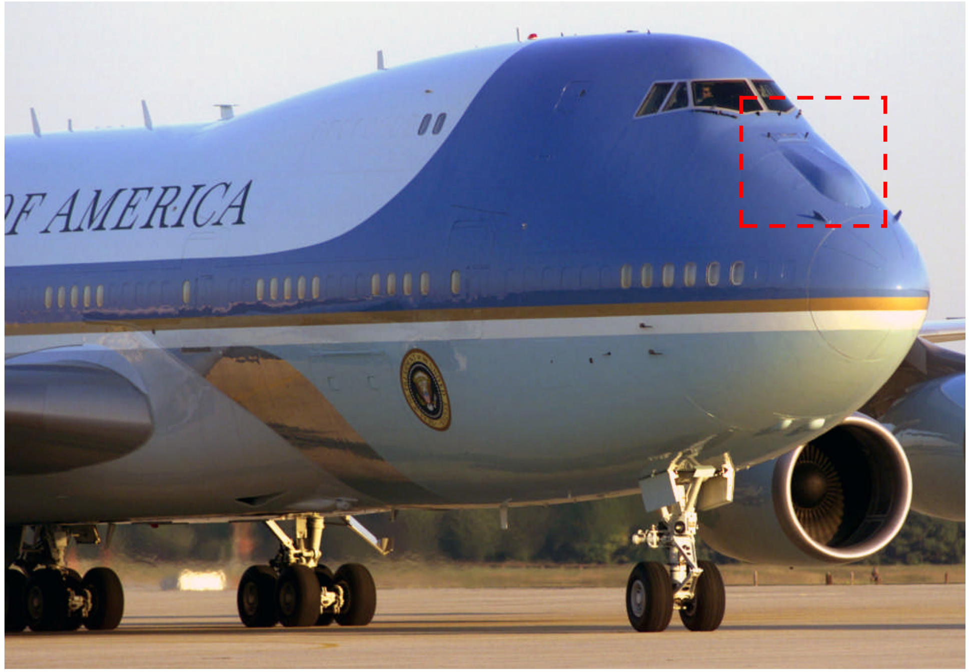
Flying White House

The 747 series has seen military use, the best-known example being two "VC-25" (747-200B-based) aircraft used by the USAF to fly the *President of the United States* (POTUS) and his entourage around the world. They are typically referred to as "Air Force One," but strictly speaking, that's the call sign for any aircraft carrying the POTUS. The program to obtain the two 747s was begun in 1985 (during the Reagan Administration) with the first aircraft making the initial flight on May 16th 1987, followed by the second plane on October 23rd 1987 (the aircraft were delivered in the 1990s). They are powered by *GE CF6* engines. A subtle external difference with the 747-200B is the door arrangement. The VC-25s appear to retain the normal 747-200B door scheme (the POTUS will use the forward left exit to make a "Presidential" exit down red-carpeted stairs), but some of the exits were plugged. However, they also have an "Airstair" (highlighted) mounted low (fore and aft) on the left side of the aircraft (for use at airstrips where normal airport flight handling facilities are not available).


UN
SEAL OF THE PRESIDENT OF THE UNITED STATES


UNITED STATES OF AMERICA


UNITED STATES



Externally, the VC-25s look, in general, like a stock 747-200B. The most noticeable difference is a bump on the nose (highlighted, at left) for an in-flight refueling receptacle. They also have a long-range fuel tank configuration and an augmented engine oil supply to allow the aircraft to stay in the air for up to six days. As well, the top of the fuselage features an extensive “farm” of antennae (for secure global communications) from hump to tail.


UNITED STATES OF AMERICA

Internally, the VC-25s have been fitted with a custom VIP interior (though not particularly plush, more like a working high-end office than the Sultan of Brunei's lavish 747). The bottom cargo holds include freezers for storing meals (a VC-25 on a mission carries enough provisions to keep all on board fed for the duration of a mission, which may number several days of continuous flight). The upper deck behind the cockpit includes a crew rest area and a communications center. The main deck provides passenger facilities including, from front-to-back:

• Living quarters for the POTUS in the nose, with twin beds and bathroom including shower. The windows have roll-down blinds so the POTUS and their spouse can get some sleep during local daylight hours;

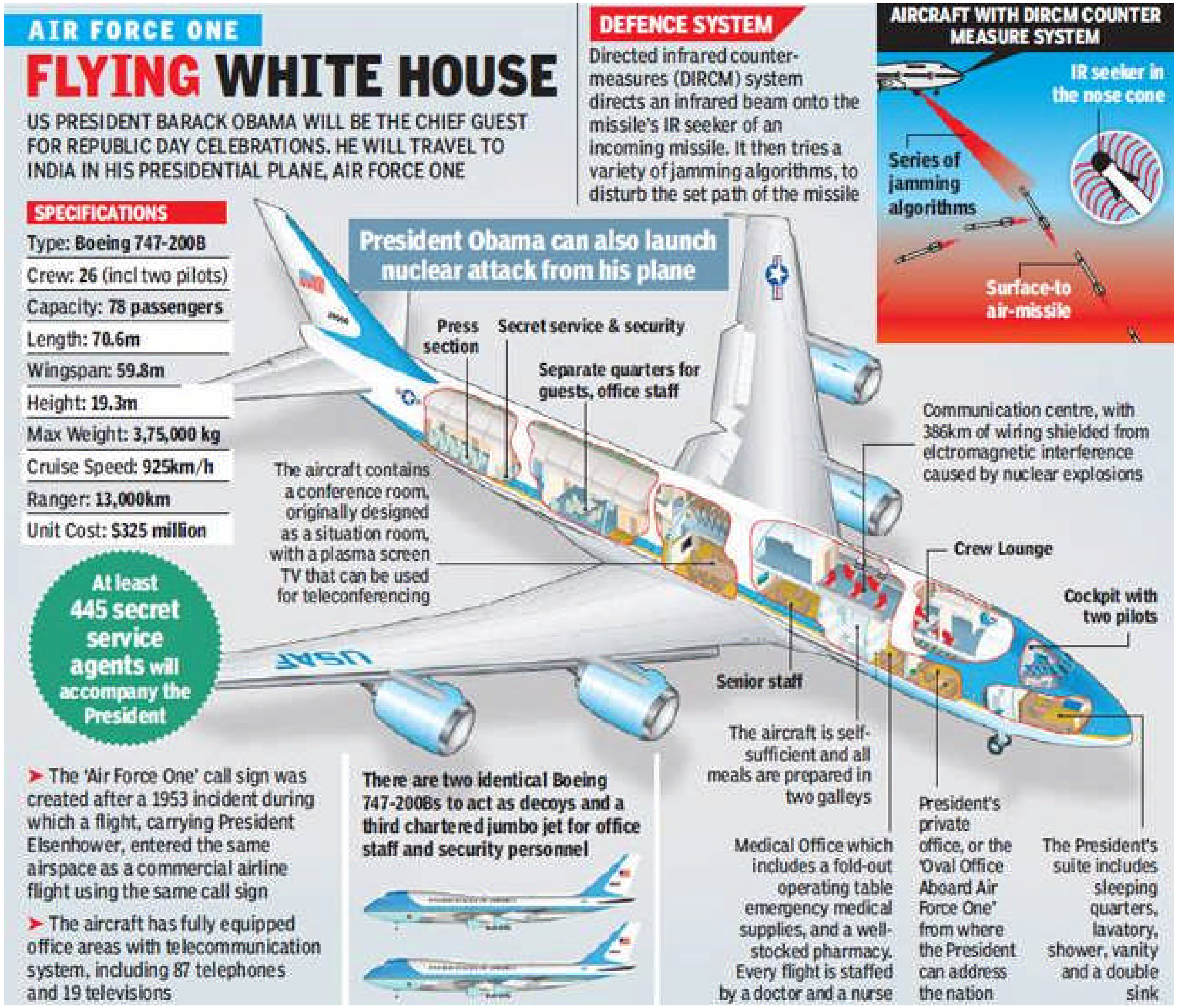
• A flying "Oval Office";

• A medical section (with emergency surgery) followed by the main galley, and;

• Senior staff section including: conference and dining room; general staff section; VIP guest section; security section and seats for press and support staff at the very rear. The security/press section is arranged along the lines of a first-class passenger cabin, with six-abreast seating.

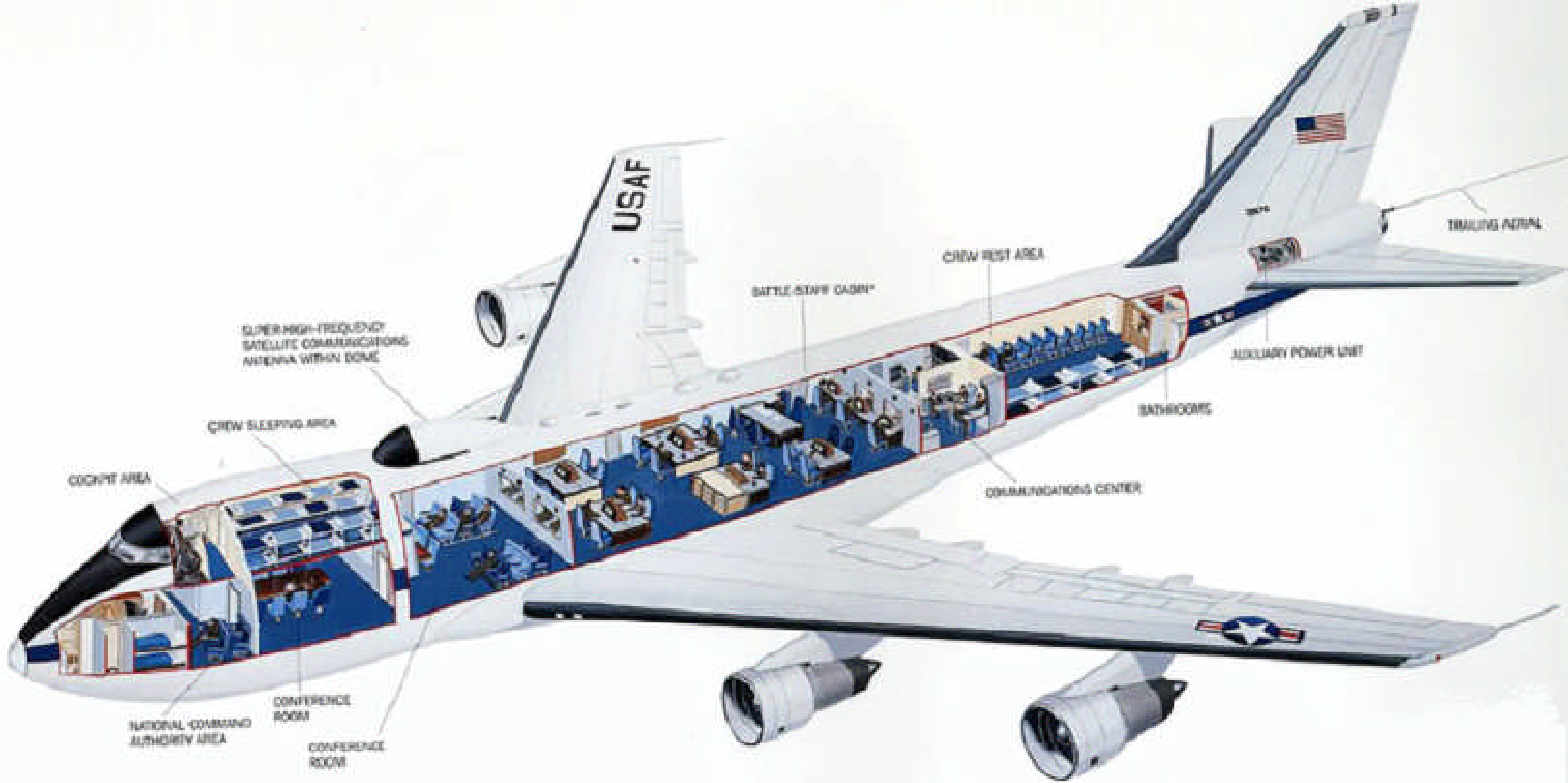
There is a rough hierarchy of status in the main deck, from front to rear (passengers may go back from their section but not forward, except by invitation).

There are, of course, toilets and a small secondary galley in the rear of the fuselage. The VC-25 aircraft also feature a defensive counter-measures system (an AN/AAR-54 missile warning system on the tail and twin *AN/AAQ-24 Nemesis* <u>D</u>irected <u>I</u>nfrared <u>C</u>ounter <u>M</u>easures {DIRCM} turrets to “dazzle” heat-seeking missiles). The avionics systems are “hardened” against the electromagnetic pulse (EMP) of a nuclear blast. Given their custom avionics, the VC-25As have twice as much wiring as an ordinary 747-200B. Security associated with flights of a VC-25 is, not surprisingly, tight and thorough. The presidential 747s have not seen hard use (their flight schedules being far less burdensome than those of a 747 in full-time commercial service). Each VC-25 logs about 360 flight hours per year. In 2015, the USAF announced that the 747-8 would be acquired as a replacement platform (Boeing will execute the VIP customizations).

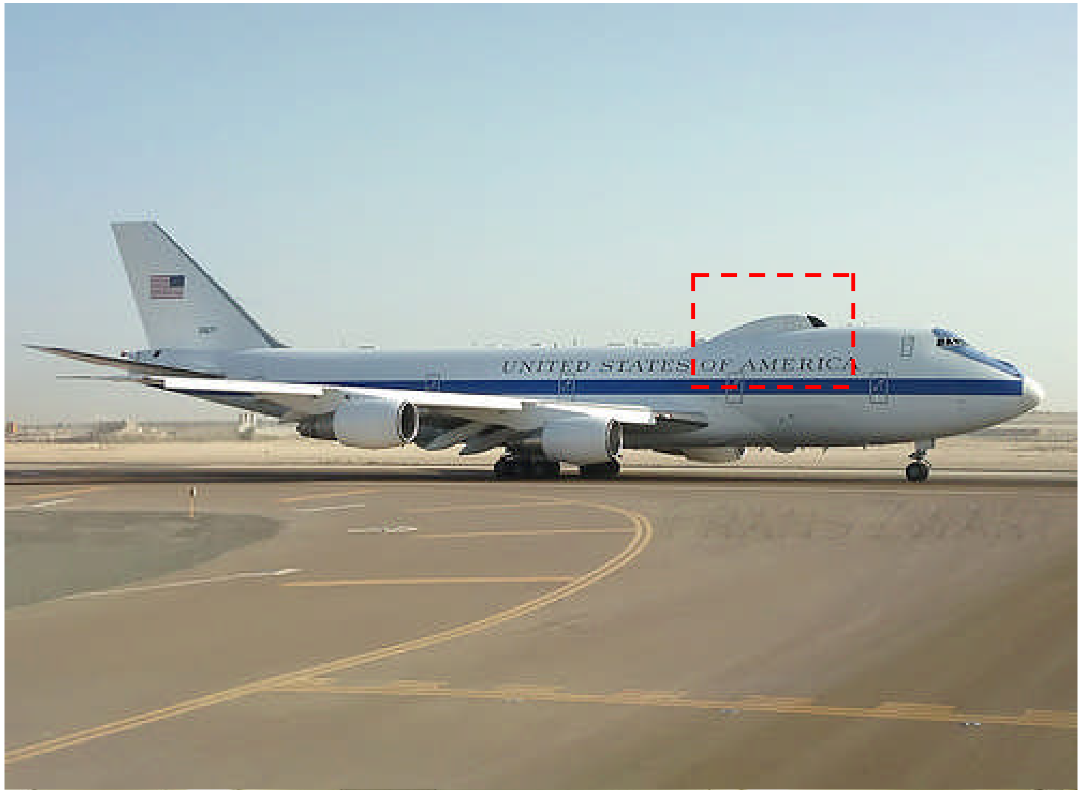

AIR FORCE ONE
FLYING WHITE HOUSE
US PRESIDENT BARACK OBAMA WILL BE THE CHIEF GUEST FOR REPUBLIC DAY CELEBRATIONS. HE WILL TRAVEL TO INDIA IN HIS PRESIDENTIAL PLANE, AIR FORCE ONE
DEFENCE SYSTEM
Directed infrared counter-measures (DIRCM) system directs an infrared beam onto the missile's IR seeker of an incoming missile. It then tries a variety of jamming algorithms, to disturb the set path of the missile
AIRCRAFT WITH DIRCM COUNTER MEASURE SYSTEM
IR seeker in the nose cone
Series of jamming algorithms
Surface-to air-missile
SPECIFICATIONS
Type: Boeing 747-200B
Crew: 26 (incl two pilots)
Capacity: 78 passengers
Length: 70.6m
Wingspan: 59.8m
Height: 19.3m
Max Weight: 3,75,000 kg
Cruise Speed: 925km/h
Ranger: 13,000km
Unit Cost: $325 million
President Obama can also launch nuclear attack from his plane
Press section
Secret service & security
Separate quarters for guests, office staff
Communication centre, with 386km of wiring shielded from elctromagnetic interference caused by nuclear explosions
The aircraft contains a conference room, originally designed as a situation room, with a plasma screen TV that can be used for teleconferencing
Crew Lounge
Cockpit with two pilots
At least 445 secret service agents will accompany the President
USAF
Senior staff
The aircraft is self-sufficient and all meals are prepared in two galleys
➤ The 'Air Force One' call sign was created after a 1953 incident during which a flight, carrying President Eisenhower, entered the same airspace as a commercial airline flight using the same call sign
➤ The aircraft has fully equipped office areas with telecommunication system, including 87 telephones and 19 televisions
There are two identical Boeing 747-200Bs to act as decoys and a third chartered jumbo jet for office staff and security personnel
Medical Office which includes a fold-out operating table emergency medical supplies, and a well-stocked pharmacy. Every flight is staffed by a doctor and a nurse
President's private office, or the 'Oval Office Aboard Air Force One' from where the President can address the nation
The President's suite includes sleeping quarters, lavatory, shower, vanity and a double sink


UNITED STATES OF AMERICA
28000

Command & Control



Four customized 747-200B aircraft are also used by the USAF as the "E-4 Advanced Airborne Command Post" (above). They were ordered in the early 1970s to replace EC-135J flying command posts, with one interim-spec "E-4A" delivered in 1973, two more E-4A machines delivered in 1975 and a full-spec "E-4B" delivered in 1979. The three E-4A machines were all updated to E-4B spec by 1985. The E-4B aircraft are intended to be used as flying command posts for the POTUS and other senior officials in case of all-out war. Like the VC-25 machines, they have an in-flight refueling socket in the nose; a custom interior with quarters, conference rooms and control centers; comprehensive communications avionics and EMP hardening.

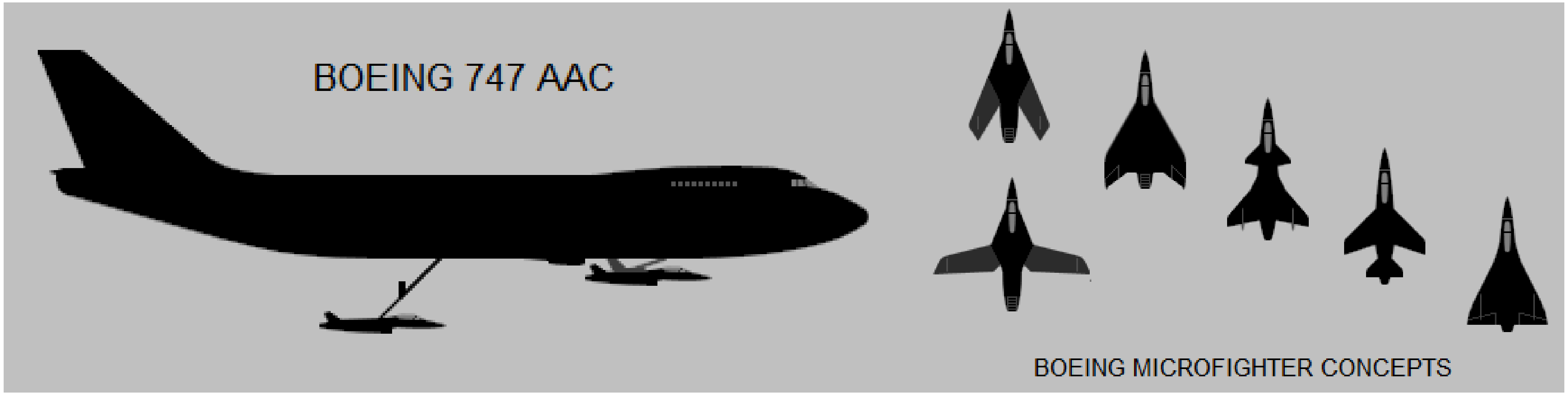


The E-4B has a distinctive feature in the form of a fairing for a Satellite Communications (SATCOM) antenna behind the upper deck (top). It has a farm of other antennas, including a long wire antenna that can be reeled out from the tail for low frequency communications with submarines. The fairing was not fitted to the E-4A aircraft, which had less sophisticated systems in general, and they were not EMP hardened (their electronics were taken from the EC-135J aircraft they replaced). The VC-25 aircraft can also perform the flying command post role, leaving the E-4B aircraft underutilized. As a result, the E-4B aircraft have ended up being flying command posts for disaster relief operations. A program to update the E-4B aircraft was initiated in 2005.

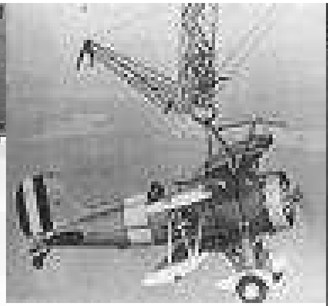
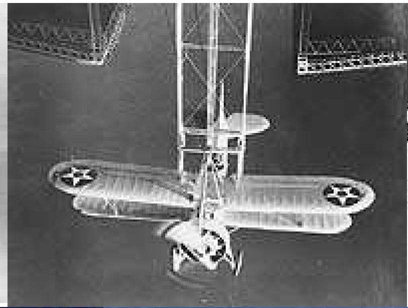
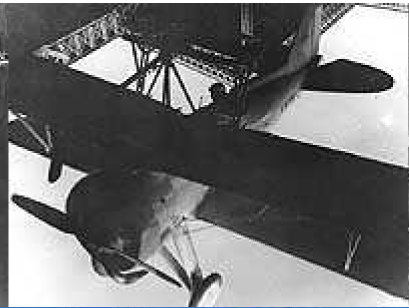
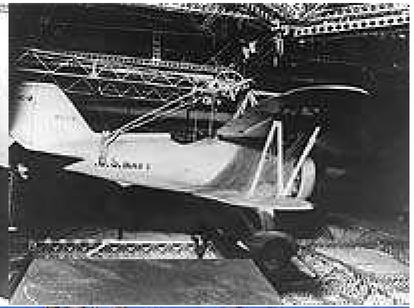
Ready Reserve

<u>Above</u>: caption: "Pan Am 747 operated troop CRAF (<u>C</u>ivil <u>R</u>eserve <u>A</u>ir <u>F</u>leet) flights to Saudi Arabia during Operation Desert Storm in 1991." The only other operational 747 aircraft associated with the U.S. military were several 747s of various descriptions (modified from 1985 onward) with a side cargo door and cargo handling apparatus by Boeing for "combi" operations as part of the *Civil Reserve Air Fleet* (an arrangement in which civil aviation companies operated the aircraft, but the USAF had them on call in an emergency). These aircraft were given the designation "C-19A."

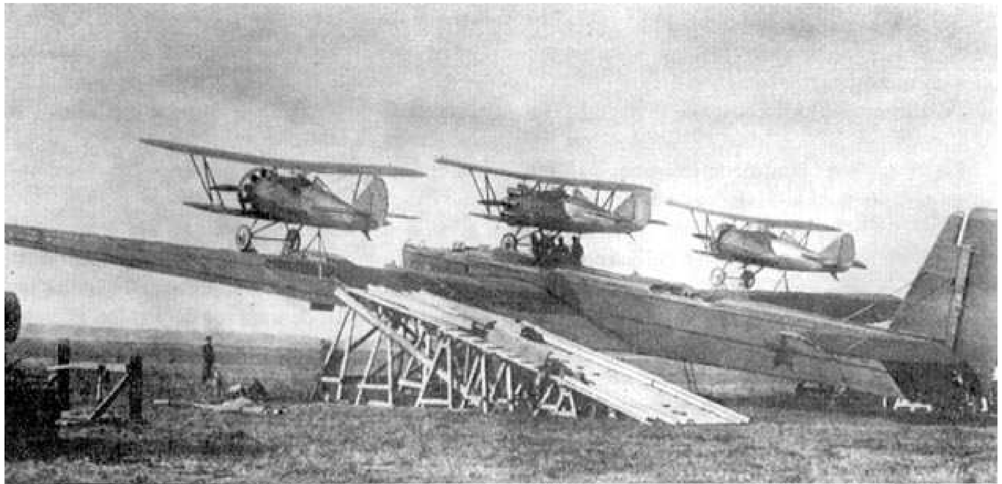
What Might Have Been

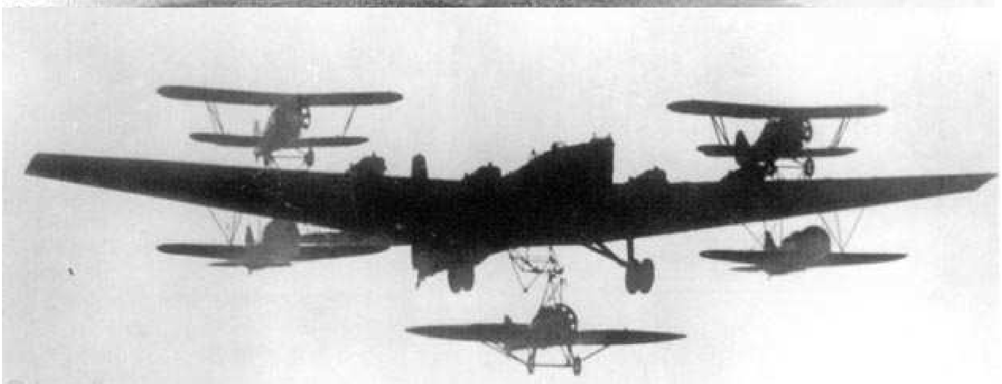


One fascinating USAF/Boeing study in the early 1970s concerned a military use for the 747-200 platform as an "Airborne Aircraft Carrier" (747-AAC) which would act as a mother ship for ten Boeing-designed "microfighters" (right). The little jet fighters would be released and recovered via bays fore and aft of the 747's wing (left). A boom refueling probe was to be used to snag a fighter for recovery and a trapeze system would then extend from the bay to haul it in (the two refueling booms also could be used to top-off the fighters without recovering them). The -AAC would carry enough materiel to support three sorties per microfighter. Once the belly hatch was closed, the flight deck bay would be re-pressurized, allowing service crews to prep the aircraft for another sortie. Munitions would be hauled on rail-mounted trolleys. Turnaround time between sorties was estimated at about ten minutes. In reality, it was a revisit to an old idea.

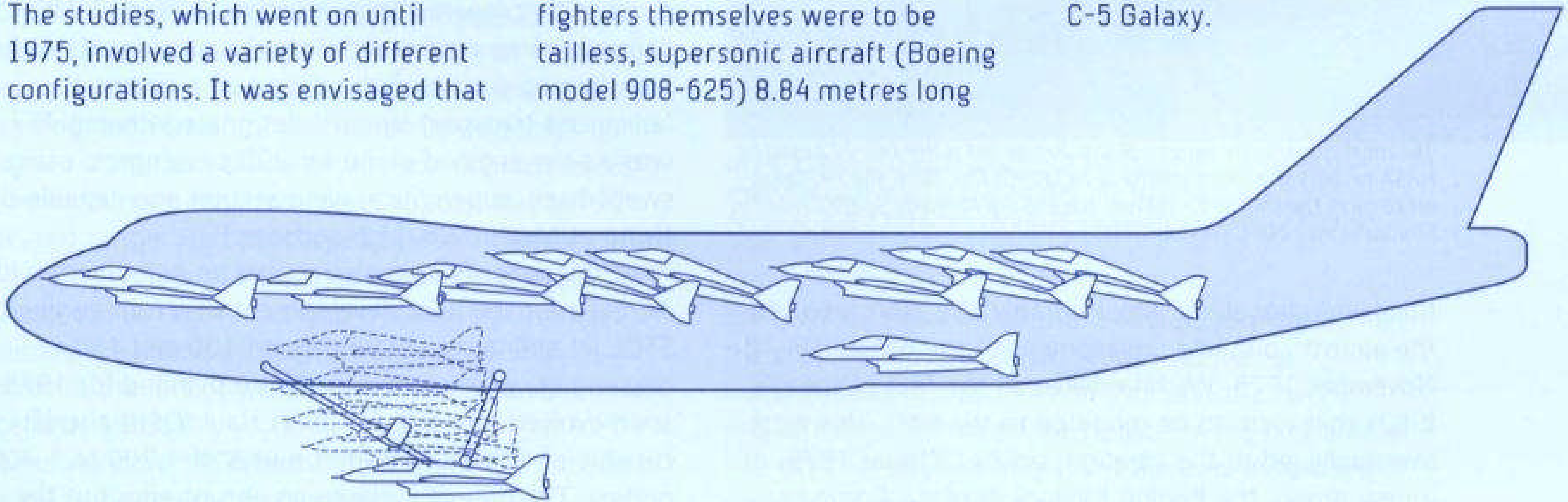
Above & Left: the use of LTA (Lighter-Than-Air(dirigible to launch and recover HTA (Heavier-Than-Air) fighter air-craft (ca. 1930s)

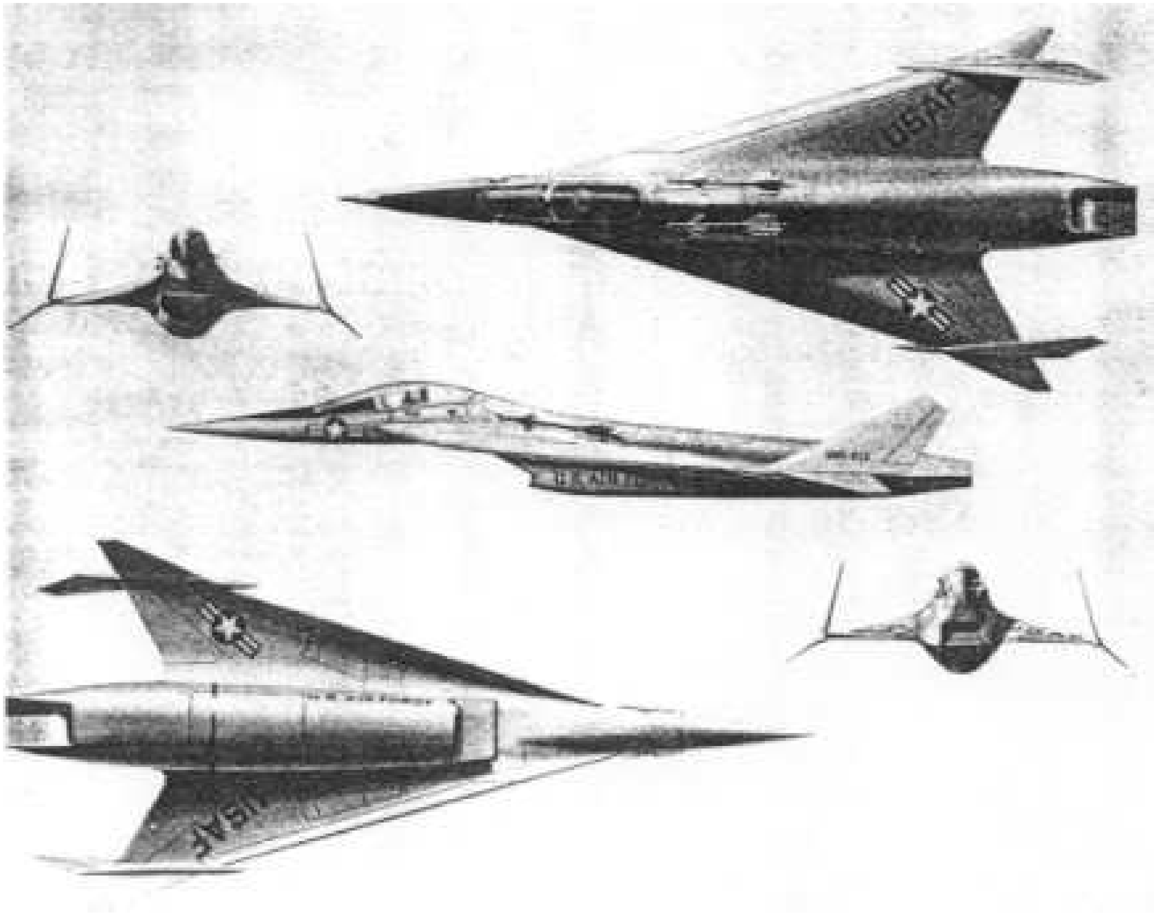


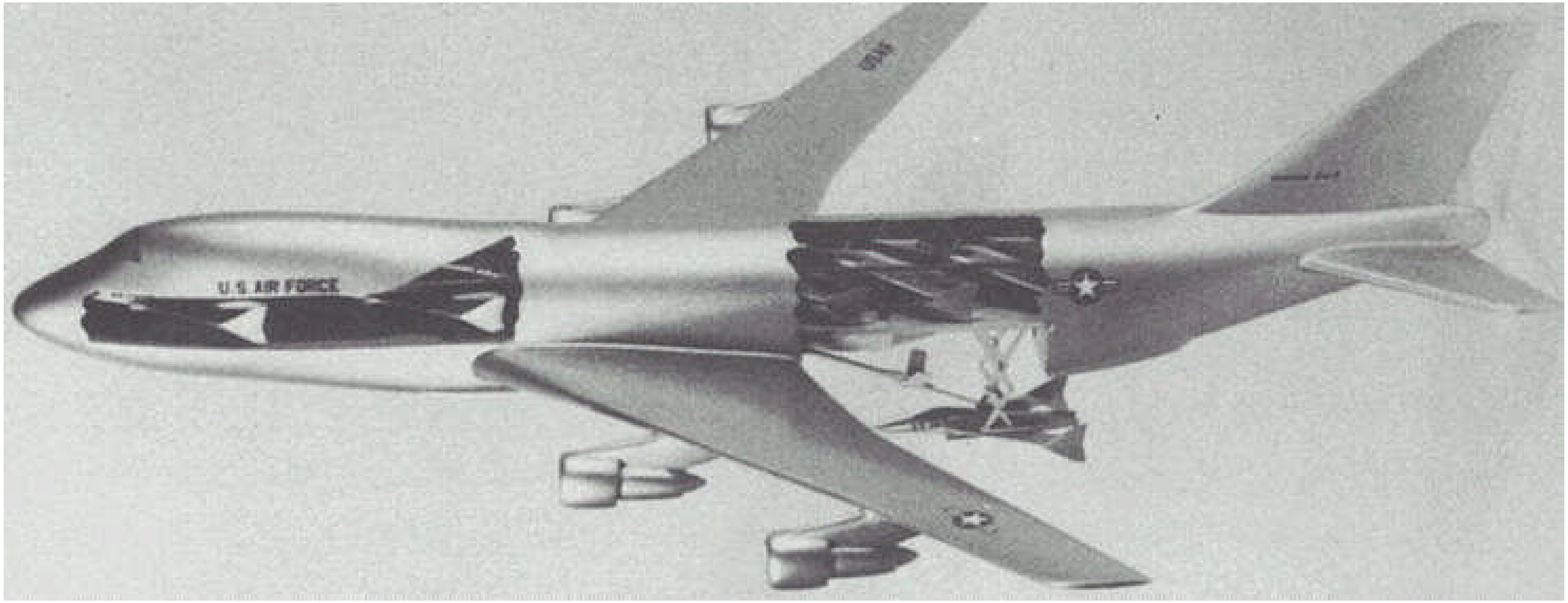


The Boeing 747 as an aircraft carrier

In the early 1970s, the arrival of heavy transports revived the dream of aerial aircraft carriers. In 1973, Boeing announced that its engineers were investigating the possibility of using a 747 to carry a dozen or so 'advanced micro fighters'. The studies, which went on until 1975, involved a variety of different configurations. It was envisaged that not only would the tiny aircraft be launched from the mother plane, but that they would also return to it, be refuelled and rearmed and launched once again. These tasks were expected to last no more than about ten minutes per plane. The micro fighters themselves were to be tailless, supersonic aircraft (Boeing model 908-625) 8.84 metres long with a wing span of 5.33 metres and weighing 3,760kg fully loaded and would be armed with a rotating 25mm cannon and air-to-air or air-to-ground missiles. Lockheed was simultaneously working on a comparable adaptation of its C-5 Galaxy.



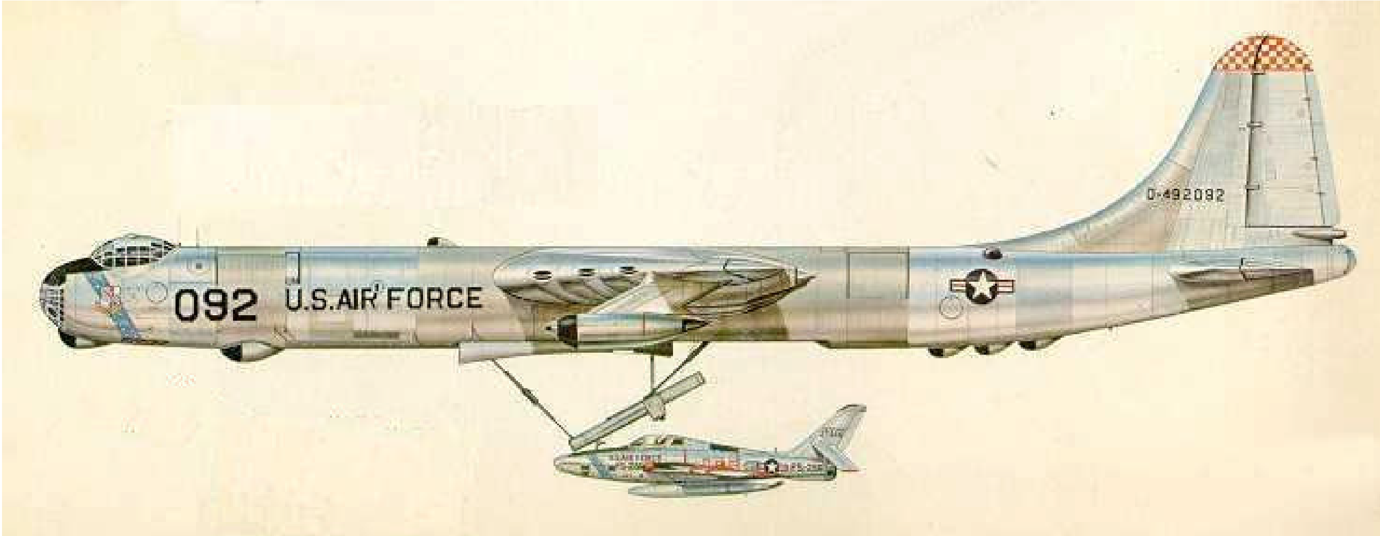

USAF

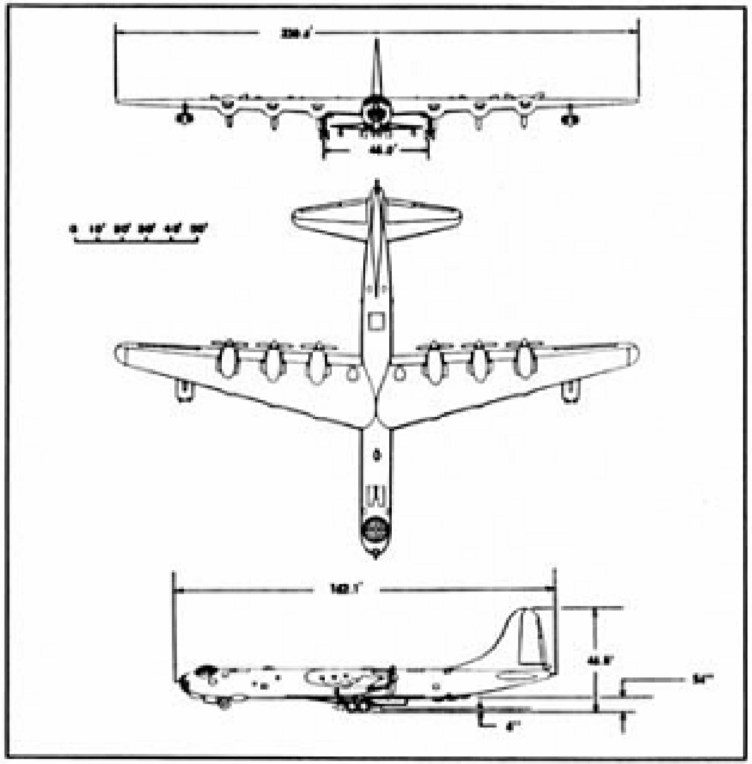


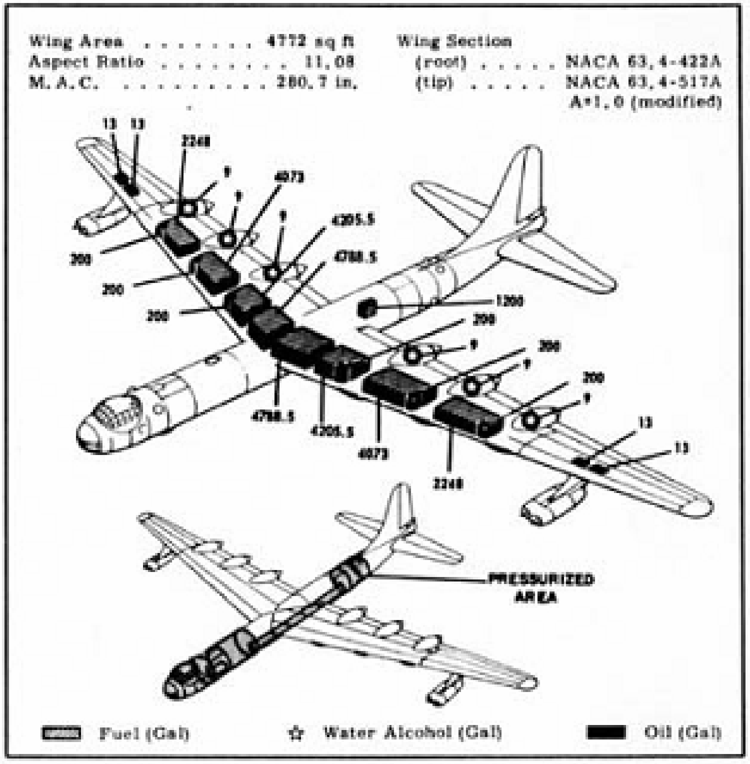
The 747-AAC was envisioned as having two decks, with an upper hangar deck where aircraft were stowed and a lower flight deck where they could be handled for sorties. There were two launch/recovery bays, one fore and one aft of the wing, allowing the carrier aircraft to launch and recover microfighters simultaneously. The 747 carrier aircraft would have a crew of 42 (including the 747 aircrew, microfighter aircrew/s and service crew/s). Along with use as a microfighter carrier, the 747-AAC could be used as a tanker for other aircraft and was to be convertible (to a degree) to the cargolift mission. A complementary "Airborne Warning & Control System" (AWACS) 747 was considered, featuring a radar radome and communications links. The AWACS 747 would also carry two microfighters configured for reconnaissance missions (the re-connaissance film would be processed on board).

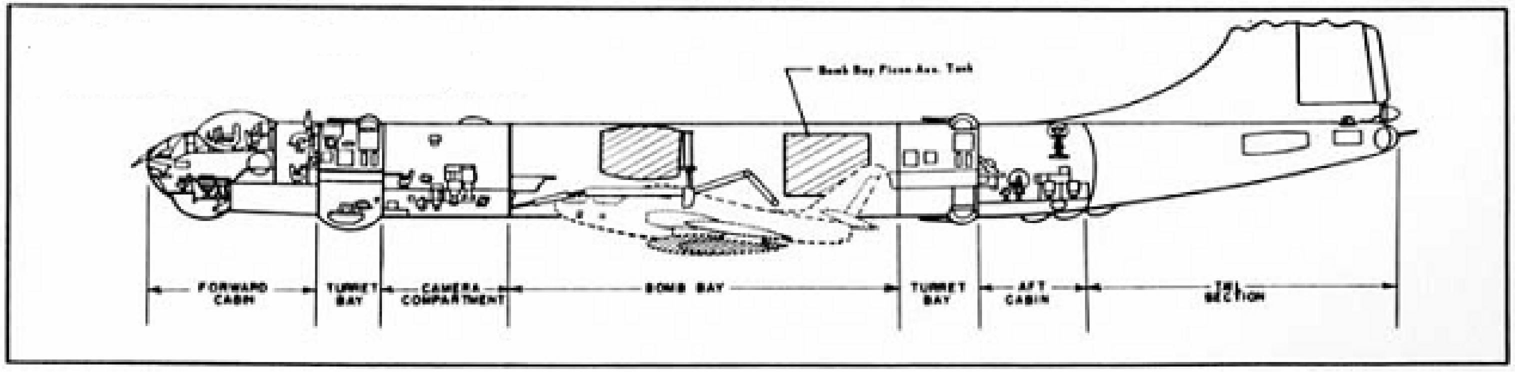
The 747-AAC was never realized. The rationale behind the concept was as a system to deliver an air combat element to a remote war zone on short notice to project force in regions where land or sea basing was not possible and/or practicable. The USAF study made the claim that the 747-ACC was cheaper than setting up a land base in a forward area (at least for a short-term mission). The need for such a system was not seen as serious enough to justify the cost of development (the limited capability of the microfighters also contributed to the concept's demise).

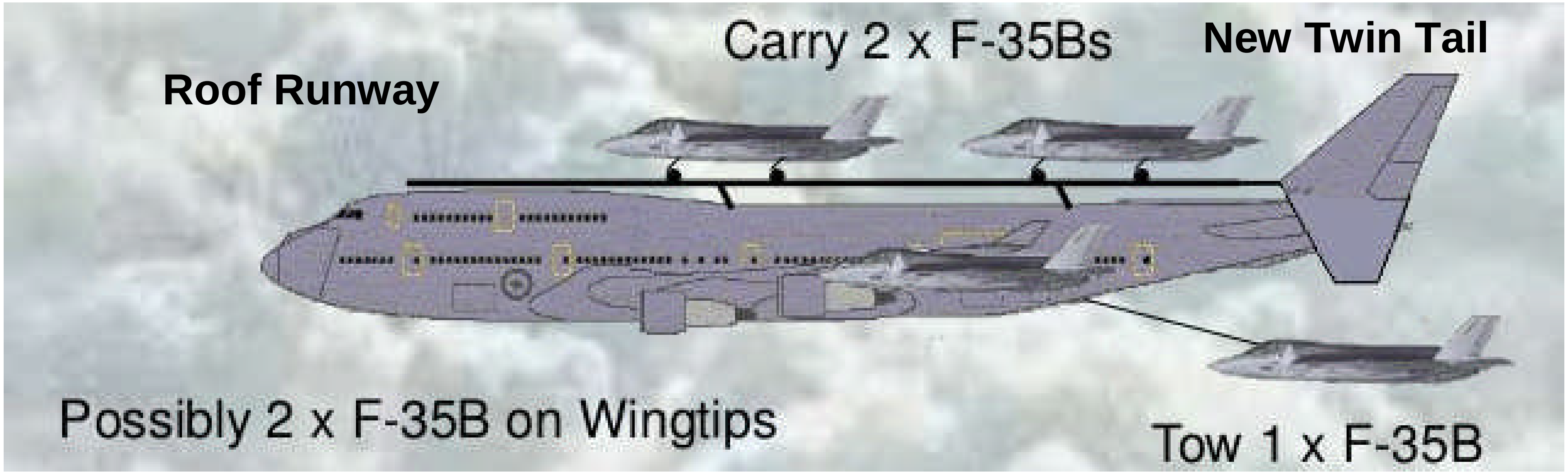
Left: "F-84 Thunderjets are carried aloft by giant B-36 bombers in the FICON concept" (June 1948)


092
U.S.AIR FORCE
0-492092

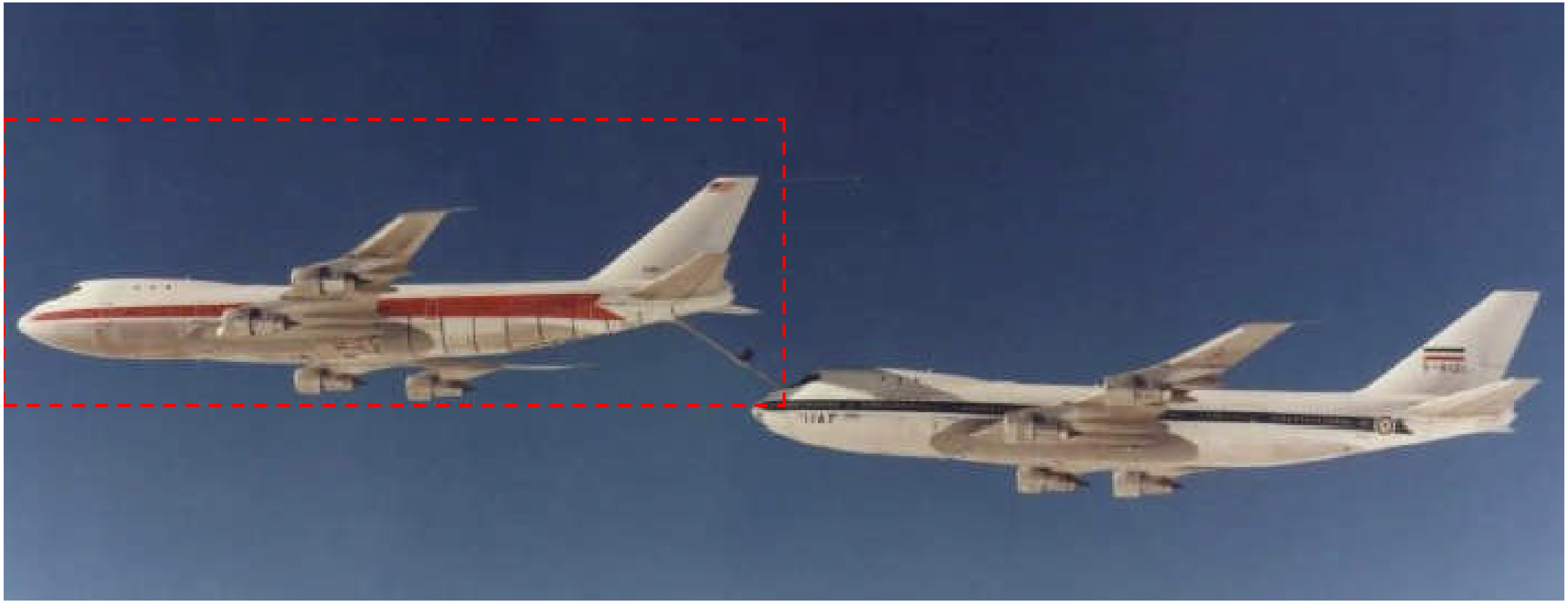




Wing Area . . . . 4772 sq ft
Aspect Ratio 11.08
M. A. C. . . . . 280.7 in.
Wing Section
(root) . . . . . NACA 63, 4-422A
(tip) . . . . . NACA 63, 4-517A
A=1.0 (modified)
PRESSURIZED AREA
Fuel (Gal)
Water Alcohol (Gal)
Oil (Gal)

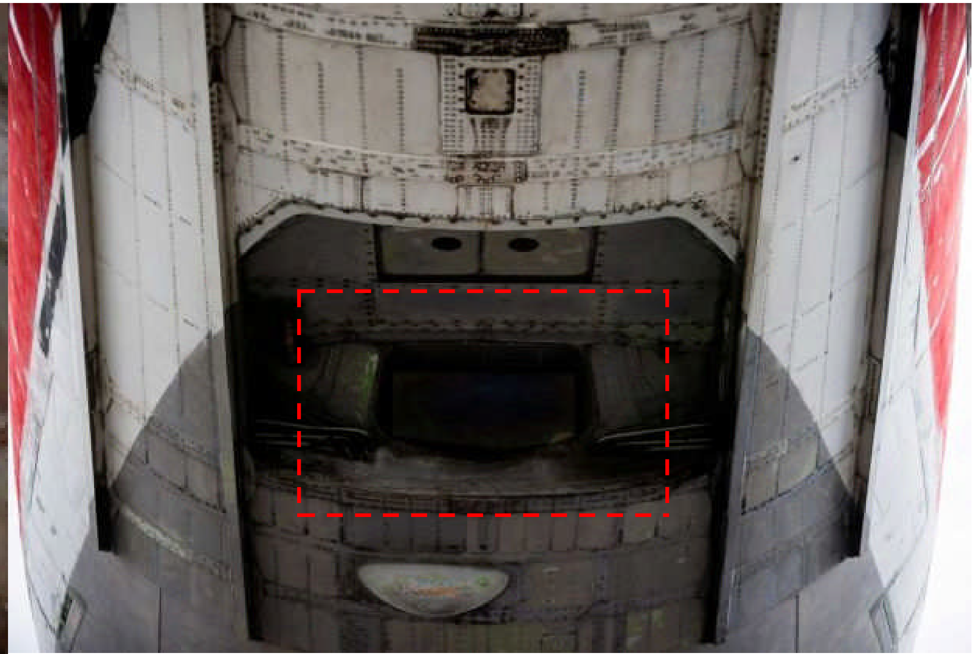

FORWARD CABIN
TURRET BAY
CAMERA COMPARTMENT
BOMB BAY
TURRET BAY
AFT CABIN
TAIL SECTION



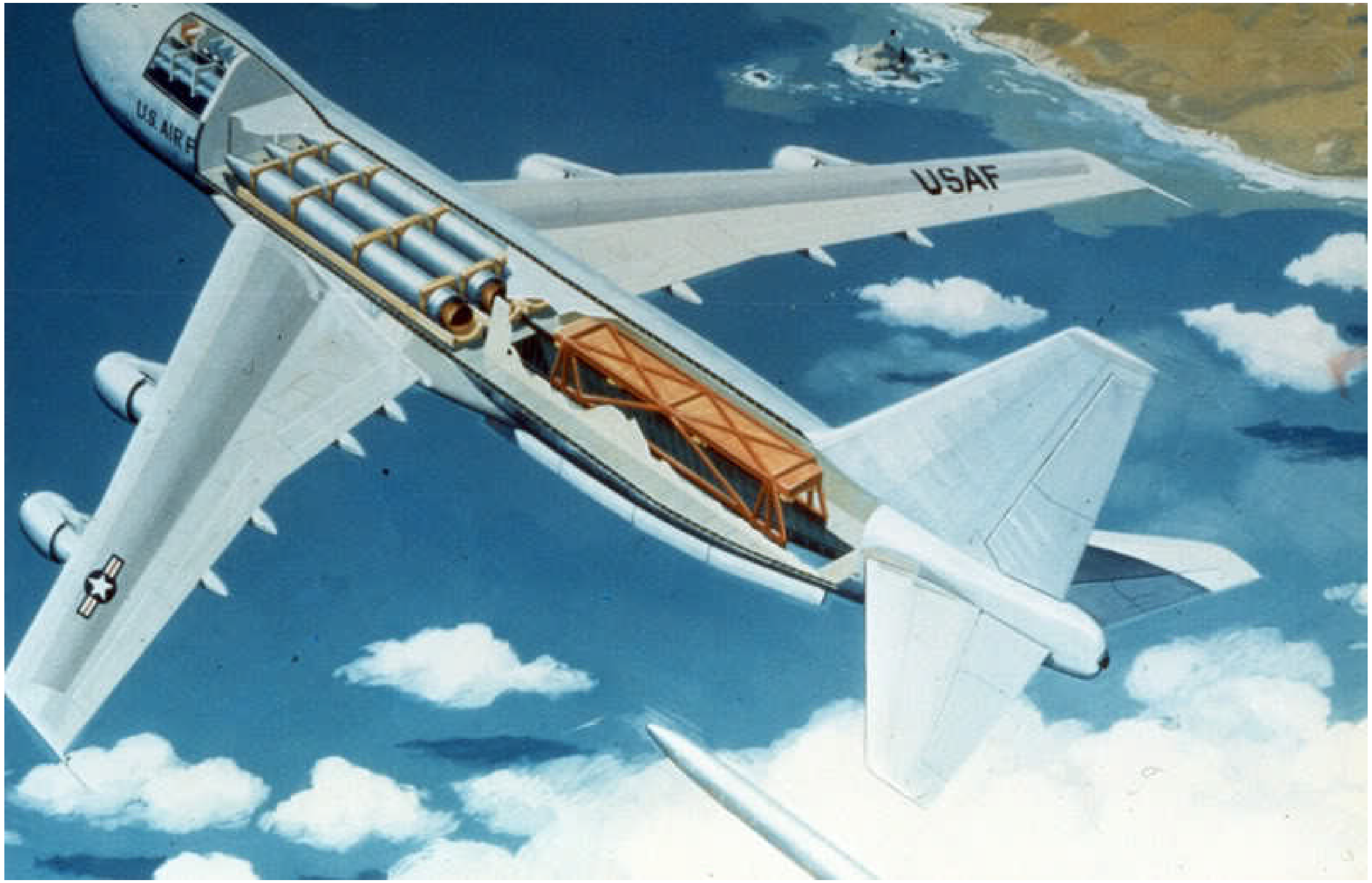
Above: caption: "Depicted here is a proposal to add a flat runway surface to the top of a cargo/tanker version of the 747 (KC-25 if converted from existing 747s or KC-33 if new build) as pioneered by Australian Aerospace genius Dr. Carlo Kopp so fuel and range-challenged F-35B/K STOVL fighter-bombers can launch & recover. The only technical challenges would be to guide them in to a safe landing and how to lock the F-35B/K's wheels afterwards. Moreover, additional F-35B/Ks or other aircraft could be transported to conserve their fuel by towing using the rear refueling boom or to connect in-flight to the 747's wing tips which was proven successful in the 1950s with a B-29. Appears on radar to be only a 'harmless' 747."



Boeing lobbied the USAF for a number of other military roles for the 747 including a cargolifter, several missile launcher platforms, a maritime patrol configuration and a "KC-747" tanker (above, left). Although a 747 was mocked up with a tanker boom for flight tests, the USAF didn't bite (an AWAC variant was considered to go along with it, but was never realized).

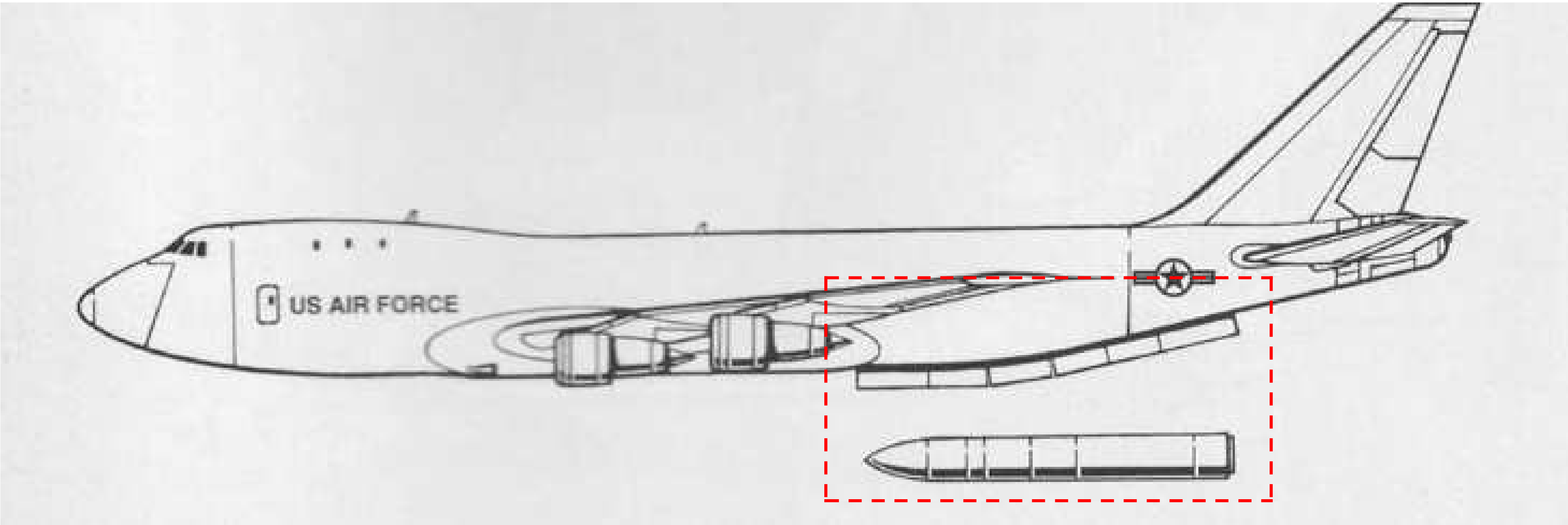


<u>Above & Left</u>: caption: "Window from the tail section of the first Boeing 747 prototype, installed to help develop aerial refueling systems"

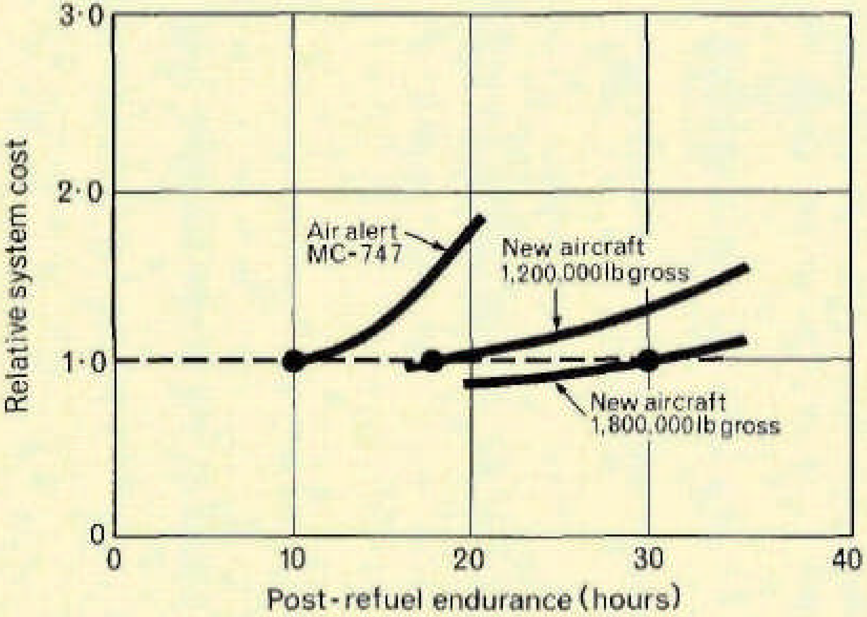


"…Boeing's concept of the system uses a derivative of the commercial 747, having a four-missile payload of 400,000 lbs…The missile-carrying aircraft would operate on airborne alert from two bases, one on the east coast and one on the west…the carriers might operate from any base with sea-level runways at least 9,000 ft. long and 9 in. thick…the 747 tanker is assumed for the role because it could operate from a 6,000 ft. runway to deliver 300,000 lbs. of fuel at a radius of 1,000 n.m…"

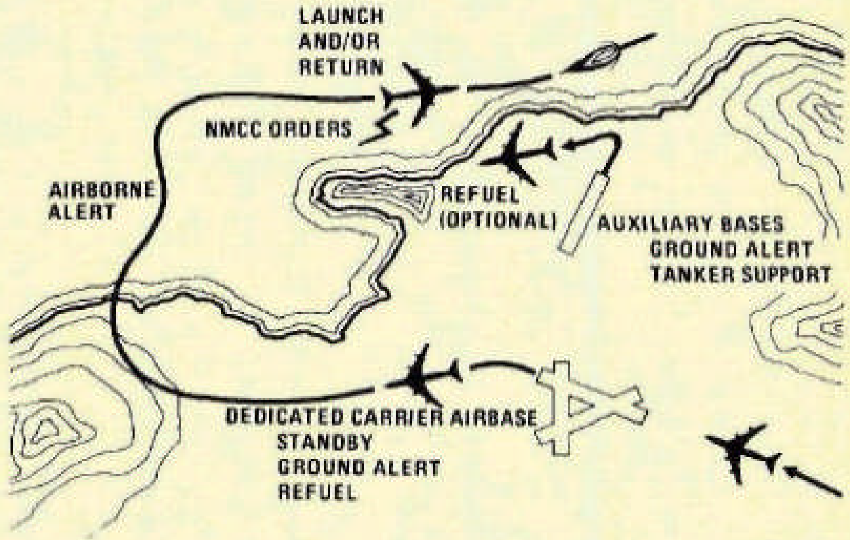
***FLIGHT International*, March 7th 1974**



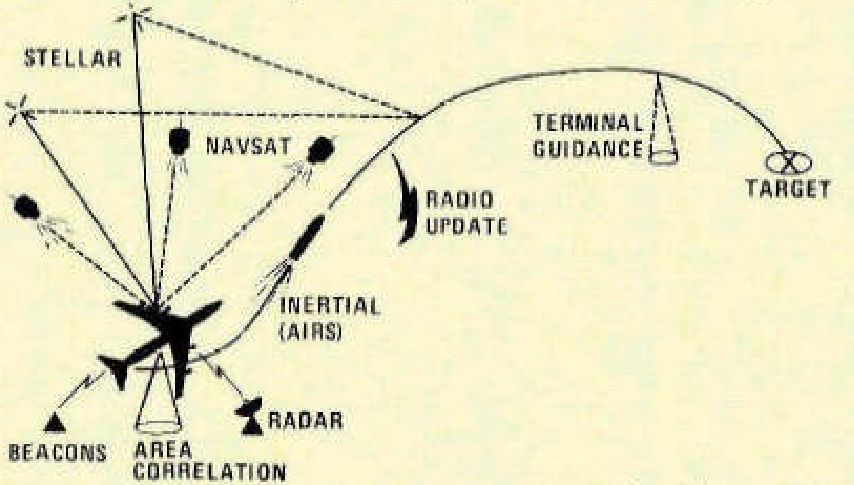
<u>Above</u>: caption: "One of several missile-carrying MC747 study concepts involved dropping a ballistic missile through enormous bomb bay doors cut into the base of Section 47." The missile would have been released at 0.72 Mach and 30K-feet and was supposed to tilt base down as it fell below the 747 and ignite when clear of the aircraft. The ICBM was then expected to pass through the 747's flight path about 5K-feet ahead of the aircraft. Thirty seconds after launch, the missile would have been 20K-feet in front and 7K-feet above the 747. Boeing believed this launch method would increase the missile's range by up to 15 percent, compared to an equivalent ground-launched missile. The range could be stretched by up to 25 percent by launching in a climb.



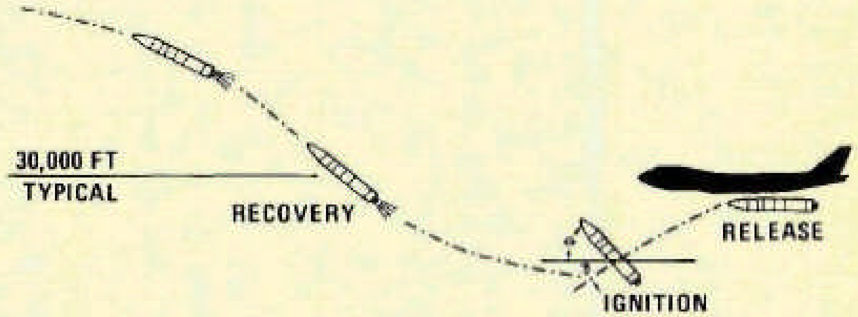
Relative system costs of three Boeing air-mobile ICBM concepts



Boeing's operational concept of an air-mobile ICBM force



Boeing's MC-747 has various navigation and missile-guidance options



The airborne launch profile of a Boeing MC-747

<u>Above</u>: caption: "Air-Mobile ICBM Systems. B.T. Plymale of the Boeing Space and Ballistic Missiles Group examined several air-launched ICBM systems in a paper given at the recent American Institute of Aeronautics meeting in Washington" (*FLIGHT International*, March 7th 1974)

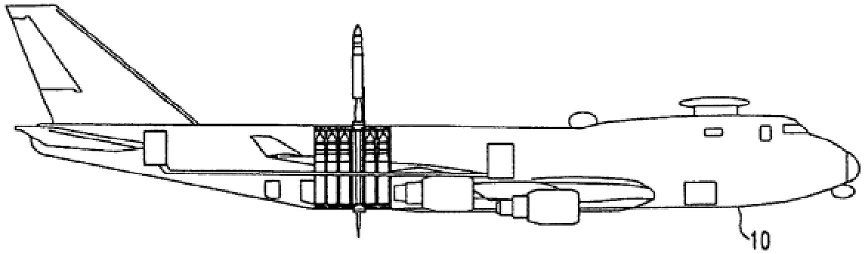


FIG.5a

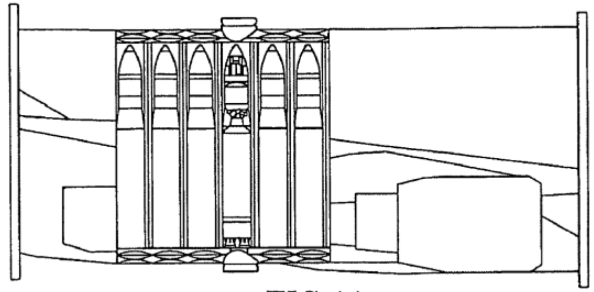


FIG.11a

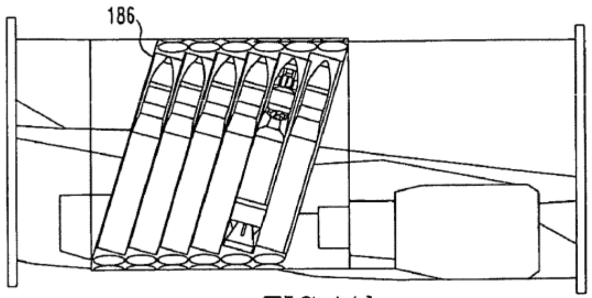


FIG.11b

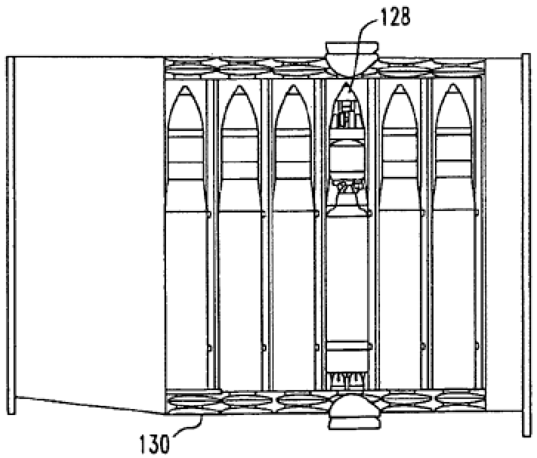


FIG.5b

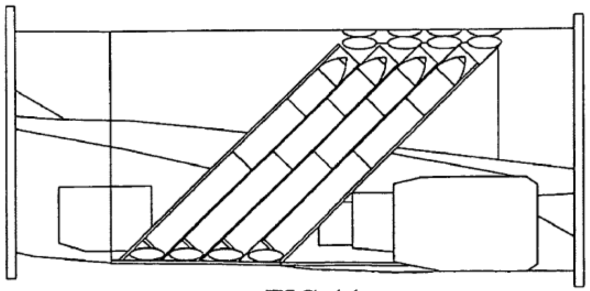
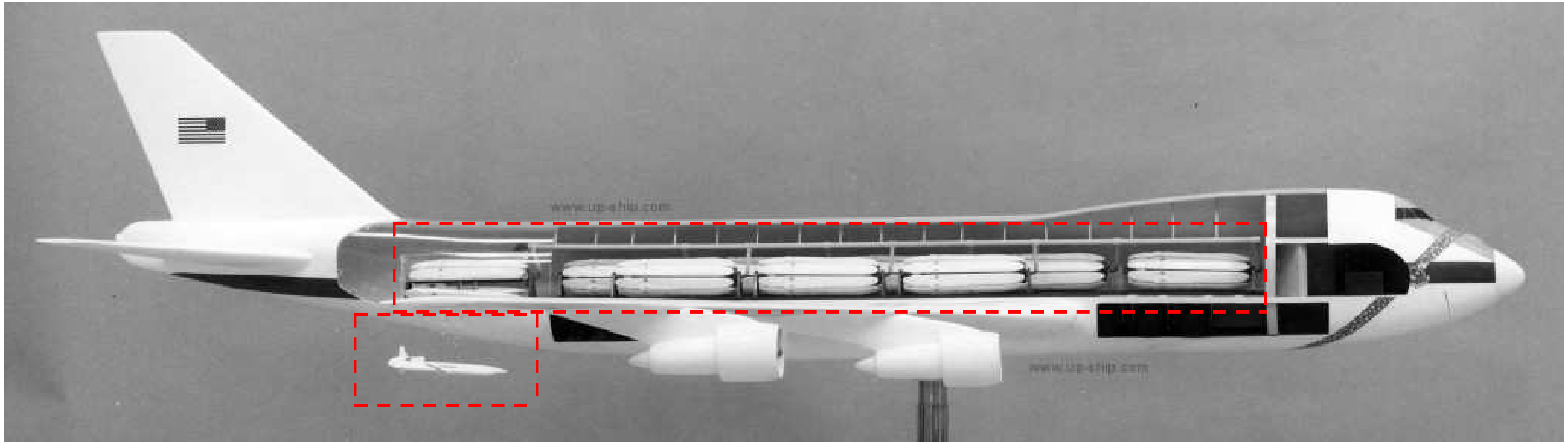


FIG.11c

<u>Above</u>: caption: "Air-based Vertical Launch Ballistic Missile Defense" (patent drawings). Another concept described a 747 carrying 32 or more missiles, each missile capable of launching a 2K-pound JDAM weapon a range of 500+ miles.



President Carter's cancellation of the B-1 bomber in the late 1970s left the U.S. without a new manned strategic nuclear delivery system (without the B-1, all the U.S. had was the B-52 which was starting to show its age). Thus, Boeing put forward the idea of using 747 cargo conversions serving as cruise missile delivery vehicles (above). Rotary launch racks would be carried internally in the spacious cargo bay (nine racks each holding eight ALCM's gave a respectable loading of 72 cruise missiles, each armed with a single nuclear warhead) and there was a single launch port on the starboard (right) side of the aft fuselage. The rack next to the port would eject a single missile sideways through the port, rotate the next missile into place and then launch it. When all eight missile had been launched, the rack would slide to the left and another rack would slide aft into the position vacated. When that rack was empty, the first rack would slide forward, giving room for the second rack to slide sideways and a third rack to slide aft into position. In this way, nine racks could be carried and moved into position. It was somewhat cumbersome and a slower process than unloading the equivalent rotary racks that the B-1 would have carried internally (the B-1 could only carry three such racks). Boeing filed for a patent on the concept in 1978 and received it in 1980. Eventually, the B-1 filled the void and the concept was never realized.

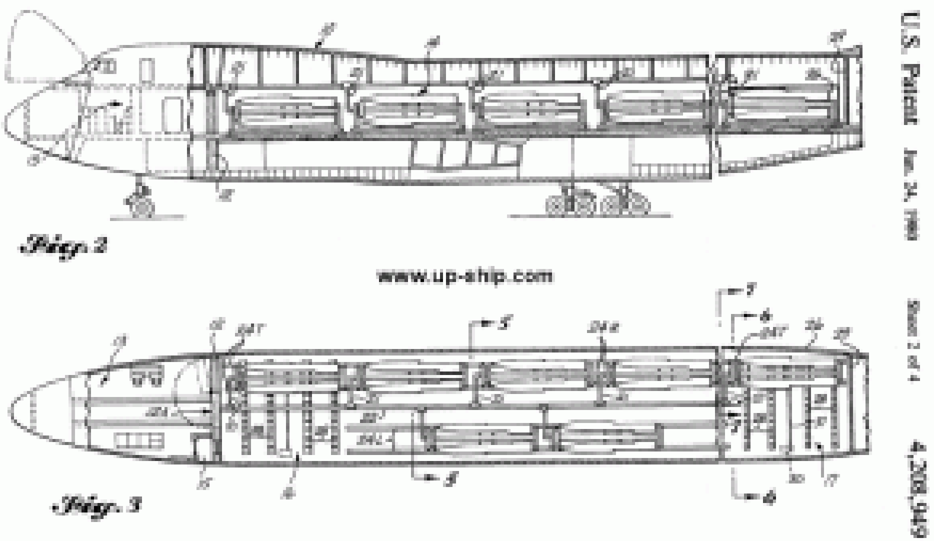
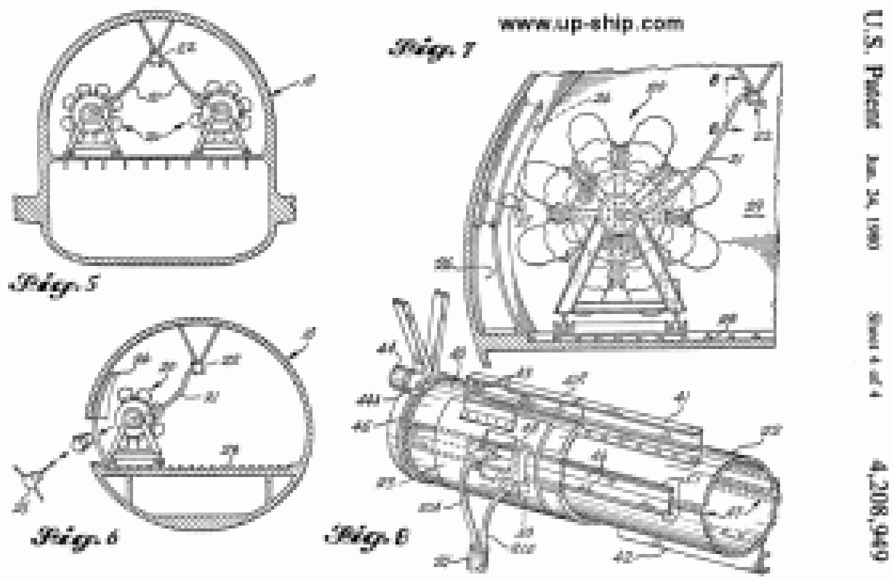
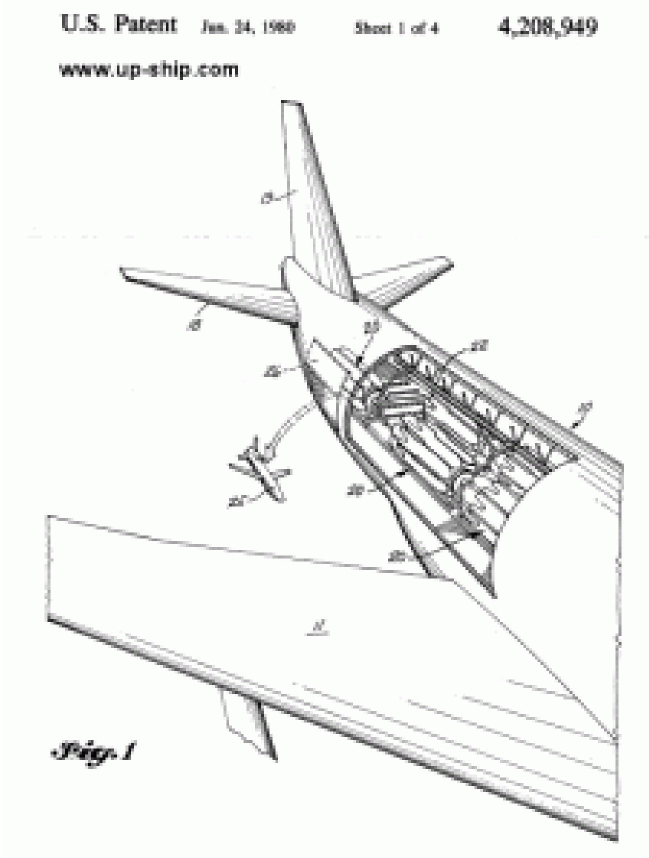
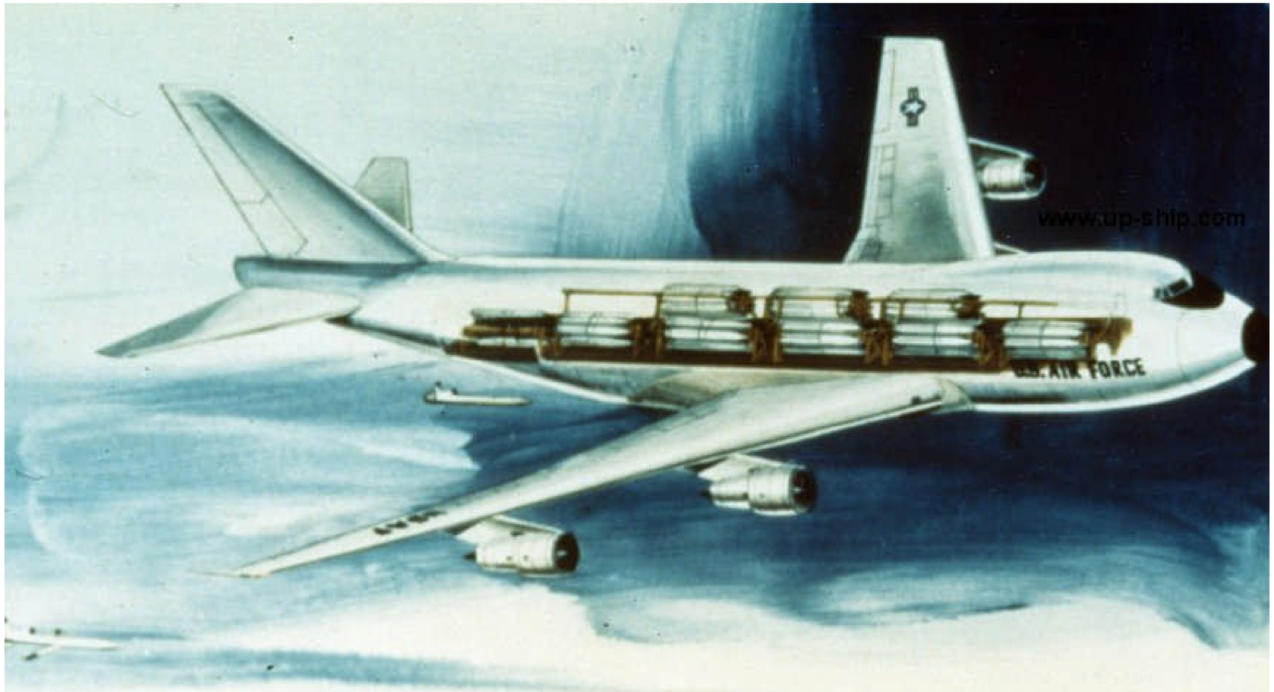


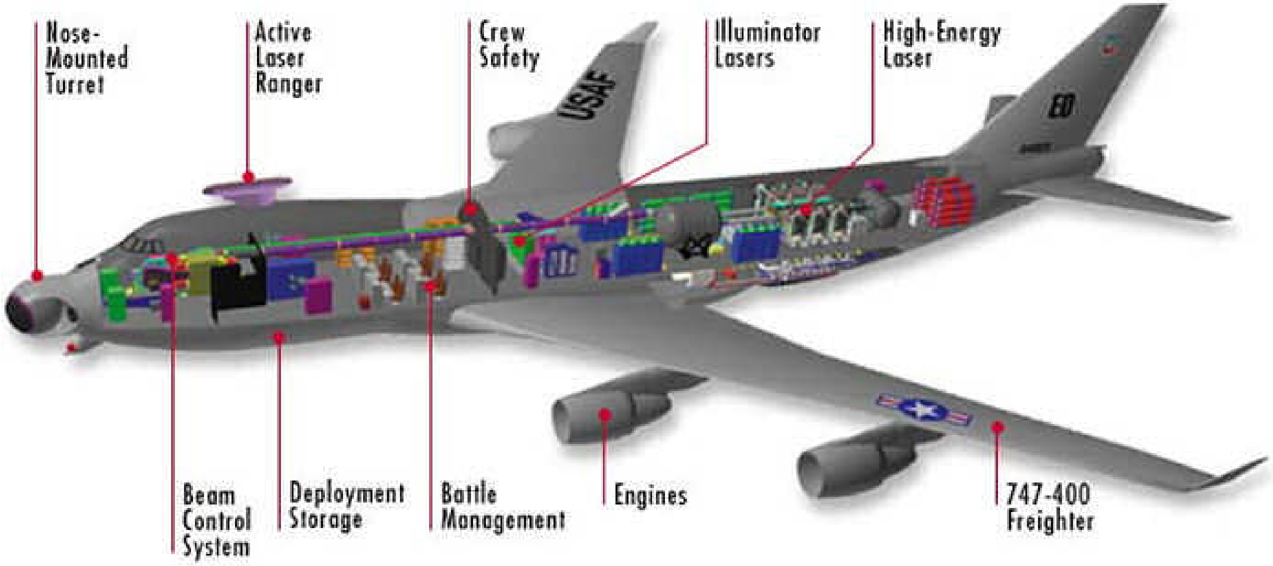
Fig. 2
www.up-ship.com
Fig. 3
U.S. Patent Jun. 24, 1980 Sheet 2 of 4 4,208,949


www.up-ship.com
Fig. 7
Fig. 5
Fig. 6
Fig. 8
U.S. Patent Jun. 24, 1980 Sheet 4 of 4 4,208,949


U.S. Patent Jun. 24, 1980 Sheet 1 of 4 4,208,949
www.up-ship.com
Fig. 1


www.up-ship.com
U.S. AIR FORCE

Though the military 747 concepts never bore fruit, the USAF did convert one 747 to a platform to test a high-power "Chemical Oxygen-Iodine Laser (COIL)" weapon, fired from a nose turret (left) to intercept missiles from long range. Known as the "YAL-1A Airborne Laser" (ABL), the YAL-1A (above) was modified from a 747-400F air freighter platform. Boeing executed the modifications at the company facility in Wichita and the initial flight took place in 2002. Getting the COIL to work was problematic and, though the USAF wanted to acquire a fleet of seven operational aircraft, the effort was scaled back to a purely experimental effort in 2009. The YAL-1A was mothballed in early 2012.

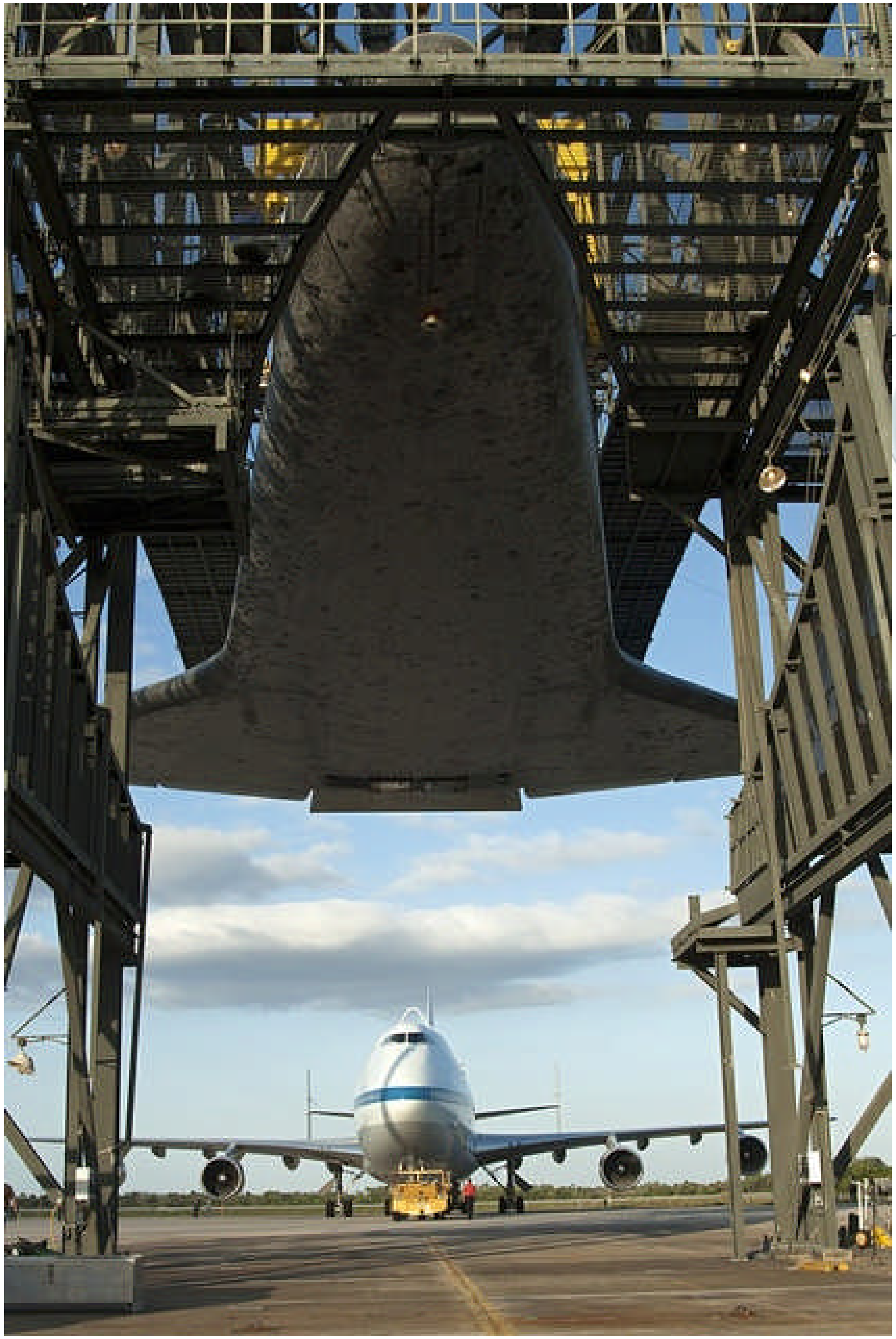

Nose-Mounted Turret
Active Laser Ranger
Crew Safety
Illuminator Lasers
High-Energy Laser
Beam Control System
Deployment Storage
Battle Management
Engines
747-400 Freighter

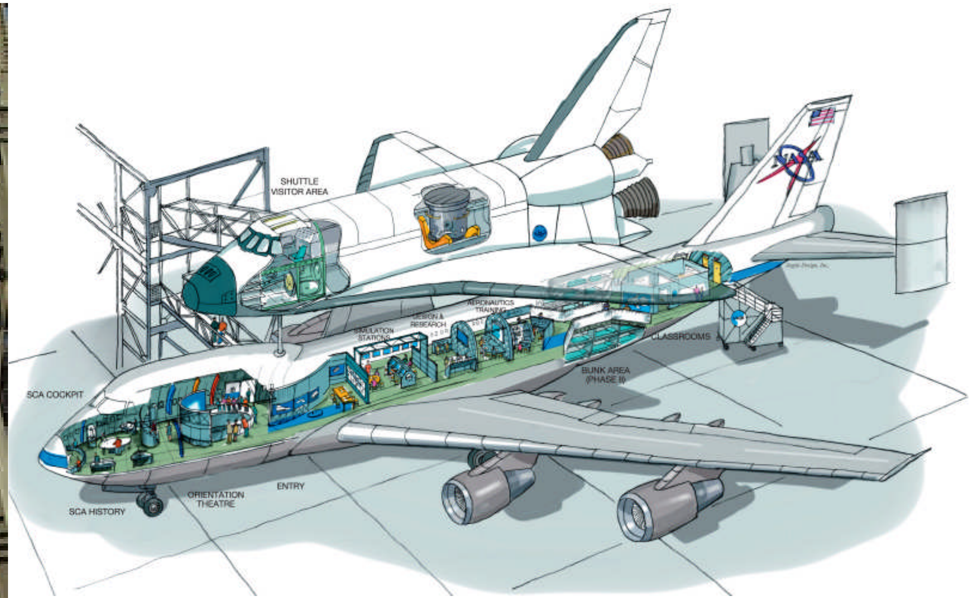
Iran acquired a set of 747s for military use before the fall of the Shah in 1979. Details of these aircraft are sketchy. It appears that sixteen used aircraft were obtained and, in general, operated as combi transports. However, two or three of them were fitted with in-flight refueling booms by Boeing, making them the only 747 in-flight refueling tankers in service. Some sources claim they were also fitted with refueling pods. The flight status of these aircraft is uncertain. The Iranians have been resourceful when it comes to keeping old military hardware operational (there's an international aftermarket for old 747 parts).

Above: caption: "An Iranian Air Force F4 Phantom refuels from an IAF 747 tanker"

Special Configurations

Over the years, there have been many special civil configurations of the 747 platform, some of them quite exotic. Among the more familiar were two "Shuttle Carrier Aircraft" (SCA) used by the *National Aeronautics & Space Administration* (NASA) to transport the space shuttle orbiter from *Edwards Air Force Base* in California (the shuttle's alternate landing site) to *Kennedy Space Center* in Florida, the launch and primary landing site.





The SCAs were both used 747-100s, acquired in the mid-1970s. They were fitted out with struts on the top of the fuselage for mounting the shuttle (the orbiter was mounted by a special crane). Large endplate fins were mounted on the tips of the tailplane to compensate for the aerodynamic interference of the shuttle. The bulky payload cut badly into the 747's range, making the transcontinental trip time-consuming since it required multiple fuel stops. The SCAs were also used early in the program for drop tests of the orbiter and on occasion, to haul other large payloads around. They were retired at the end of the shuttle program in 2012, to be used as spares hulks.


HE 402-024

The space shuttle *Enterprise* (NASA Orbiter Vehicle Designation "OV-101") was the first space shuttle orbiter. It was built for NASA as part of the *Space Shuttle Program* to perform test flights in the atmosphere. It was constructed without engines or a functional heat shield and was therefore not capable of space flight. Enterprise was stored at the Smithsonian's hangar at *Washington Dulles International Airport* before it was restored and moved to the newly built Smithsonian National Air and Space Museum's *Steven F. Udvar-Hazy Center* at Dulles (above L&R) where it was the centerpiece of the space collection.

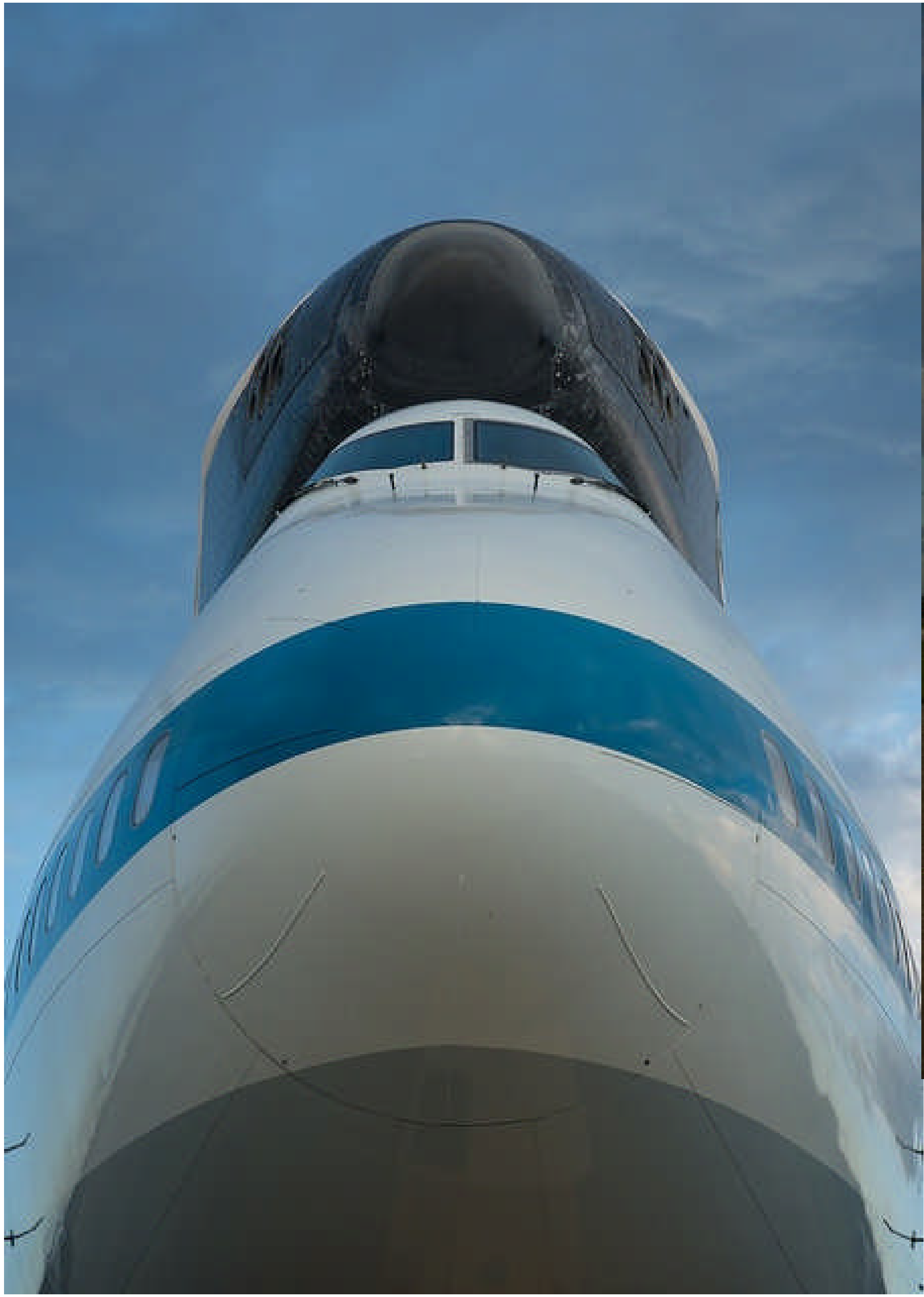

Discovery


Enterprise
www.gothereguide.com ©

On April 12th 2011, NASA announced that the space shuttle *Discovery* - the most traveled orbiter in the fleet, would be added to the Smithsonian collection once the Shuttle fleet was retired. On April 17th 2012, Discovery was transported by SCA to Dulles from *Kennedy Space Center* (where it made several passes over the nation's capital (left).

Above: the Over Land Transporter (OLC) is mated to the space shuttle *Endeavour* not long after Endeavour was de-mated from Nasa's SCA on September 22nd 2012 at *Los Angeles International Airport* (LAX). Endeavour (built as a replacement for *Challenger*) completed 25 missions, spent 299 days in orbit and orbited Earth 4,671 times while traveling 122,883,151 miles. Beginning October 30th 2012, the shuttle went on permanent display in the California Science Center's *Samuel Oschin Space Shuttle Endeavour Display Pavilion.*

Left: Endeavour and the SCA over Hollywood on its way to LAX

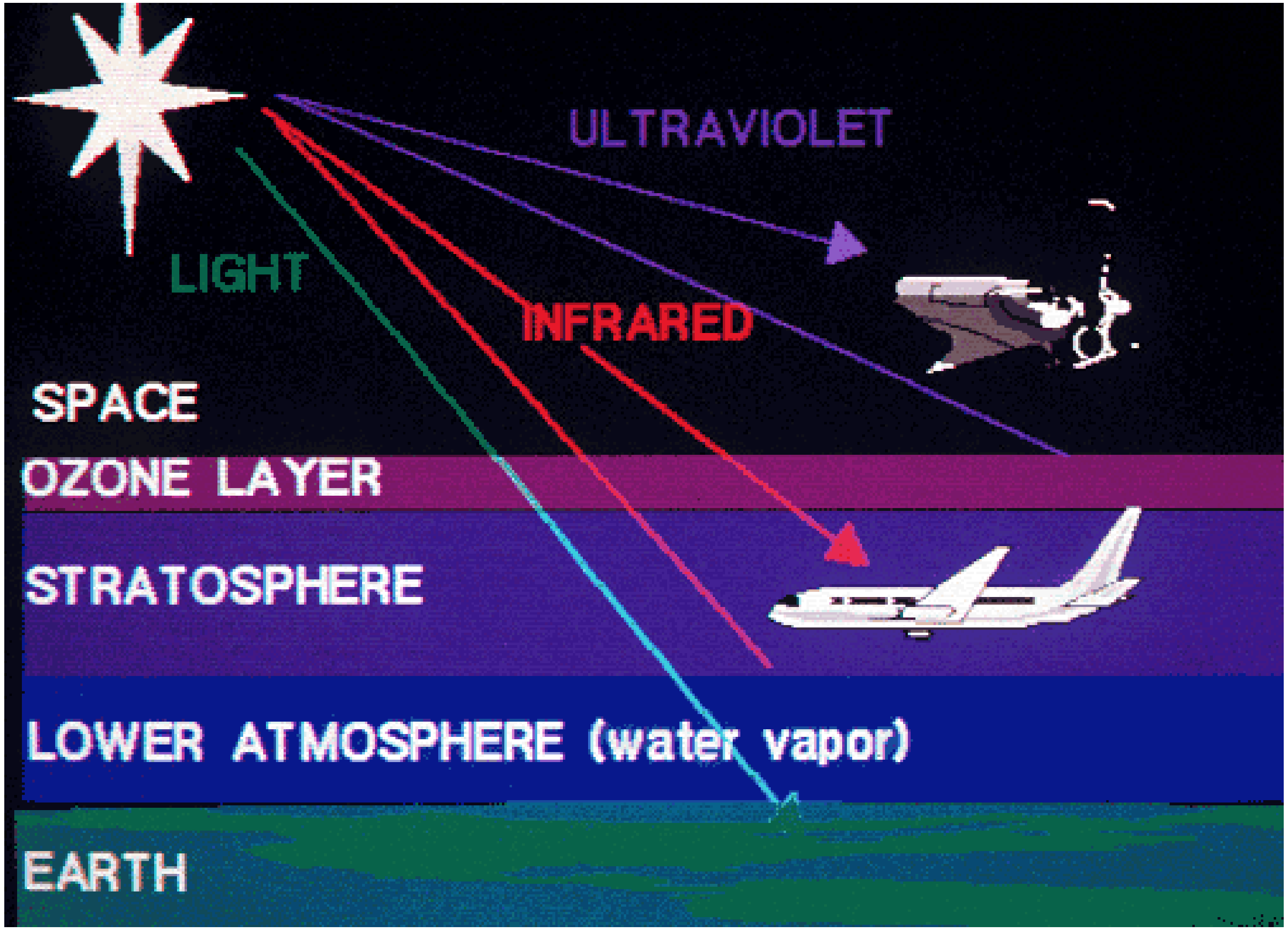


<u>Above & Left</u>: NASA's SCA carrying Endeavour arrives at LAX

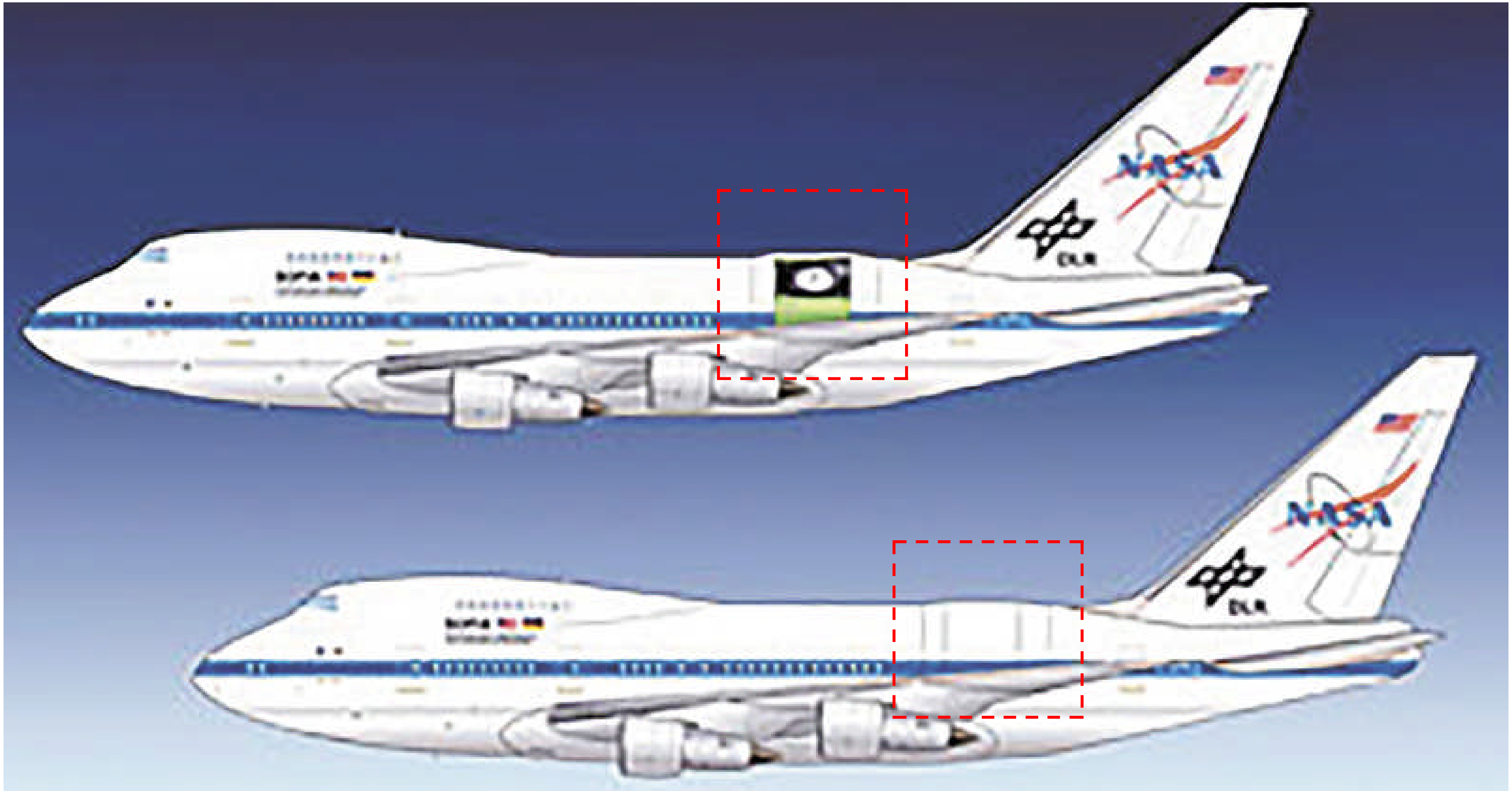

PAVILION
Space Shuttle Endeavour

The spare assemblies provided by the two grounded SCAs are primarily used to support the "Stratospheric Observatory For Infrared Astronomy" (SOFIA) - a 98-inch infrared telescope mounted in a *Boeing 747SP*. Infrared light tends to be blocked by water vapor thus, it's difficult to perform telescopic observations in the infrared from the ground. Infrared observations can be obtained from orbit, or (for shorter durations) by high-flying balloons or aircraft. From 1974 to 1995, NASA flew the "Kuiper Airborne Observatory" (KAO) - a converted *Lockheed C-141A Starlifter* four-jet transport aircraft carrying a 36-inch reflecting infrared telescope.

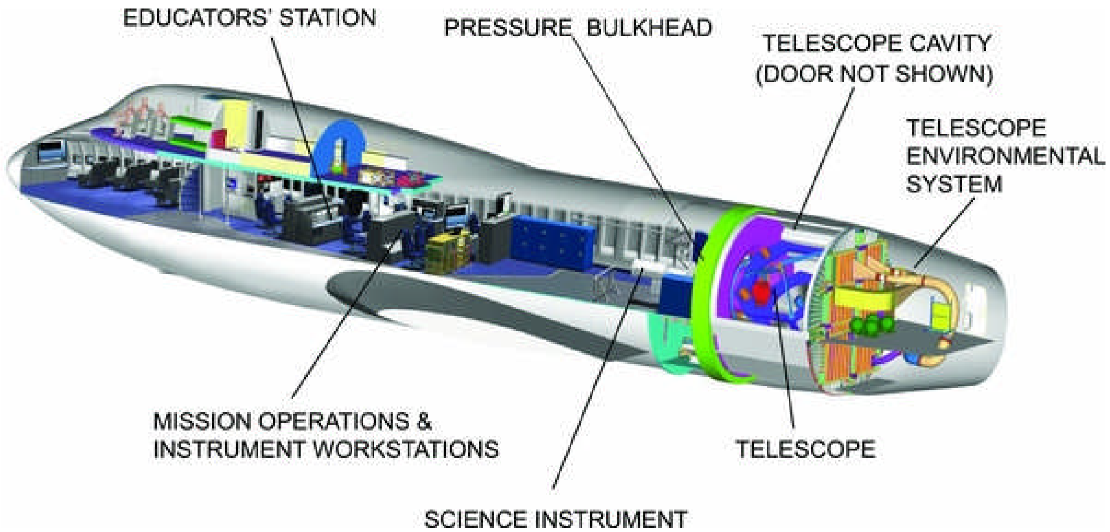
Above: caption: "The KAO Flying Observatory was a modified C-141 cargo aircraft operated by NASA Ames Research Center to carry a 36-inch infrared telescope"

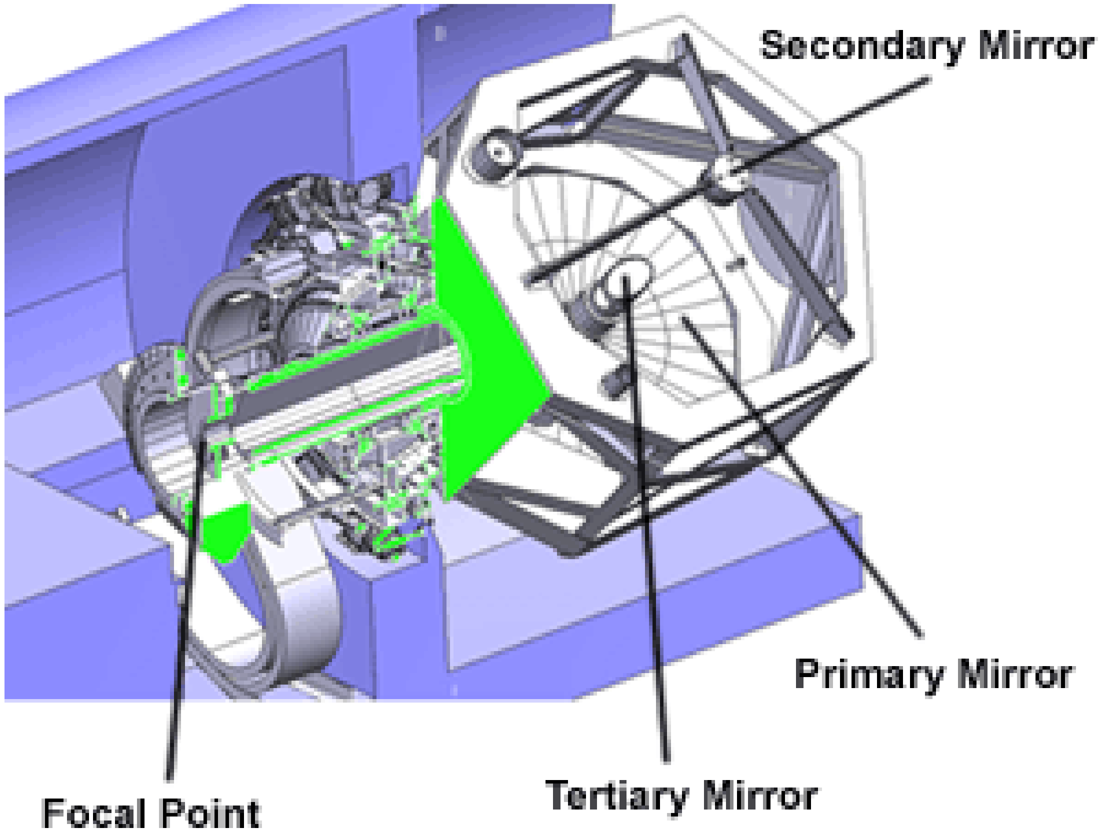

ULTRAVIOLET
LIGHT
INFRARED
SPACE
OZONE LAYER
STRATOSPHERE
LOWER ATMOSPHERE (water vapor)
EARTH

The KAO's replacement SOFIA started out in a collaboration established in 1997 between NASA and the *German Aerospace Center* (DLR) with a contract awarded that year to the "<u>U</u>niversities <u>S</u>pace <u>R</u>esearch <u>A</u>ssociation" (USRA) for construction and operation of SOFIA. The American members of the team were responsible for the aircraft while the Germans were responsible for the infrared telescope.



Used 747-200 and 747SP airframes were considered for SOFIA, but the 747SP was much cheaper and entirely sufficient for the task-at-hand. The 747SP obtained by USRA had entered service in 1978 (originally with PAA, then sold to UAL in 1986). It had 40K flight hours when obtained by USRA, but it proved to be in excellent condition with no major structural repair necessary (although engine, APU and landing gear were overhauled). *Raytheon Systems* performed the updates to turn the aircraft into a flying observatory, installing control systems for the telescope, a "flying classroom" and the telescope mounting section.


EDUCATORS' STATION
PRESSURE BULKHEAD
TELESCOPE CAVITY
(DOOR NOT SHOWN)
TELESCOPE
ENVIRONMENTAL
SYSTEM
MISSION OPERATIONS &
INSTRUMENT WORKSTATIONS
TELESCOPE
SCIENCE INSTRUMENT

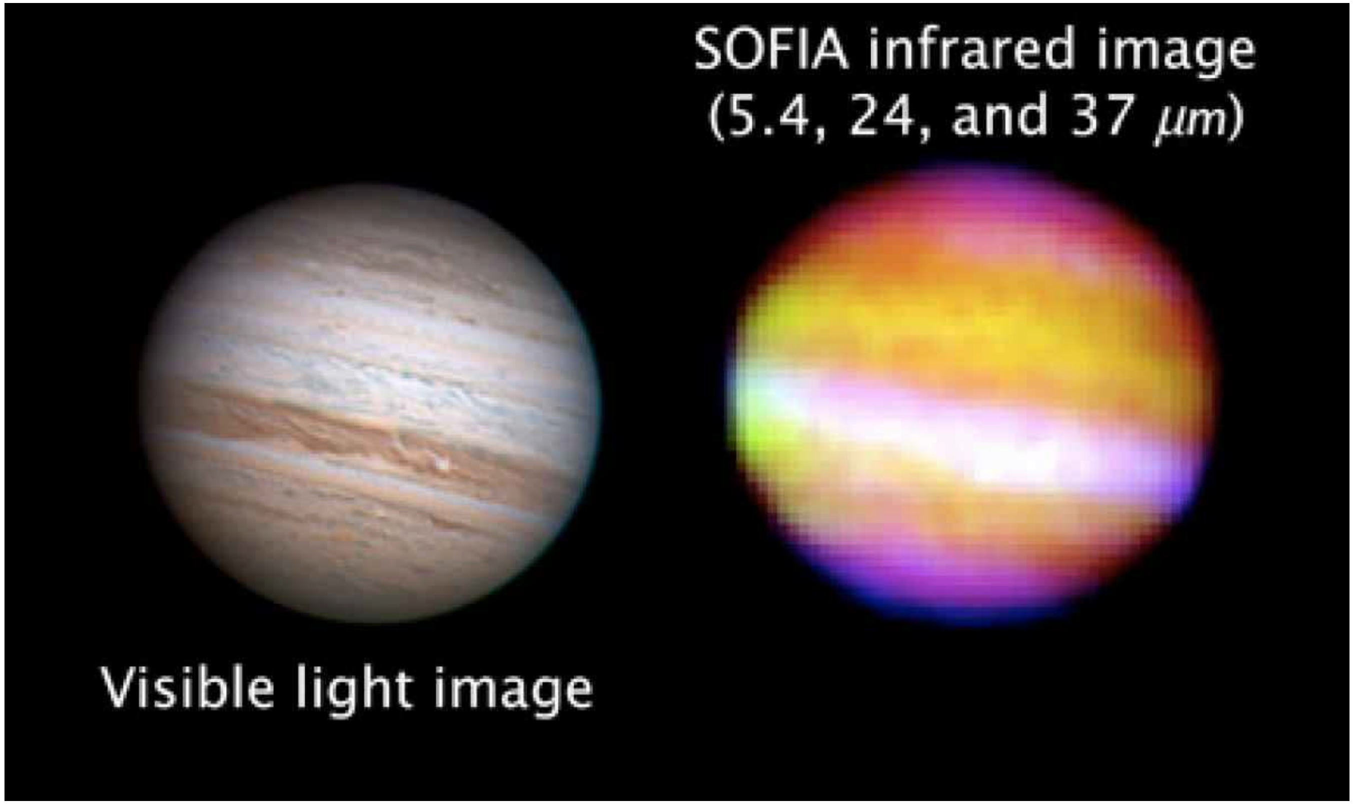

Secondary Mirror
Primary Mirror
Tertiary Mirror
Focal Point

The infrared telescope is mounted in the rear fuselage and features a stabilized mount with a precision pointing system. A configuration was also considered with the telescope forward of the wing, but that would have demanded a pressurized tunnel between the forward and rear fuselage through the telescope bay, adding considerably to cost. The telescope peers through a door on the left side of the fuselage with dimensions of 18 x 13.5-feet that extends for a quarter of the aircraft's circumference.

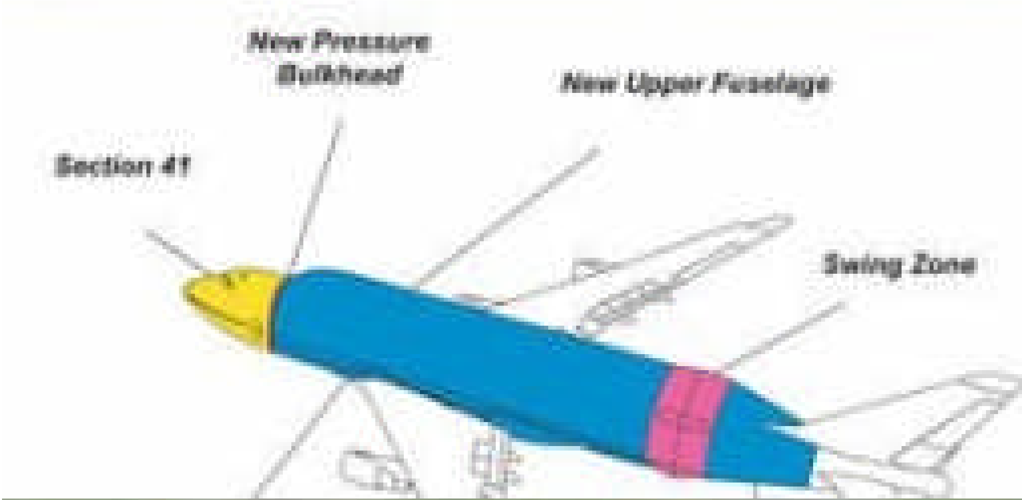

SOFIA
NASA
DLR

Despite the presence of a gaping hole in the fuselage, no modifications of the aircraft's flight surfaces (like the SCA's tailplane endplates) were necessary (though ballast had to be loaded into the aircraft's nose to maintain trim given the great weight of the telescope assembly; about 40K pounds). Even with the ballast, the overall aircraft load is easily within the payload capacity of the 747SP. After several years of delays and complications, SOFIA's initial test flights began in 2009, with first observations performed in mid-2010. The observatory is expected to fly three times a week for 44 weeks out of the year and it is anticipated to last 20 years. SOFIA was taken out of service for part of 2014 for comprehensive maintenance, but was back in operation by 2015.

<u>Above</u>: caption: "Sofia Infrared Observatory"

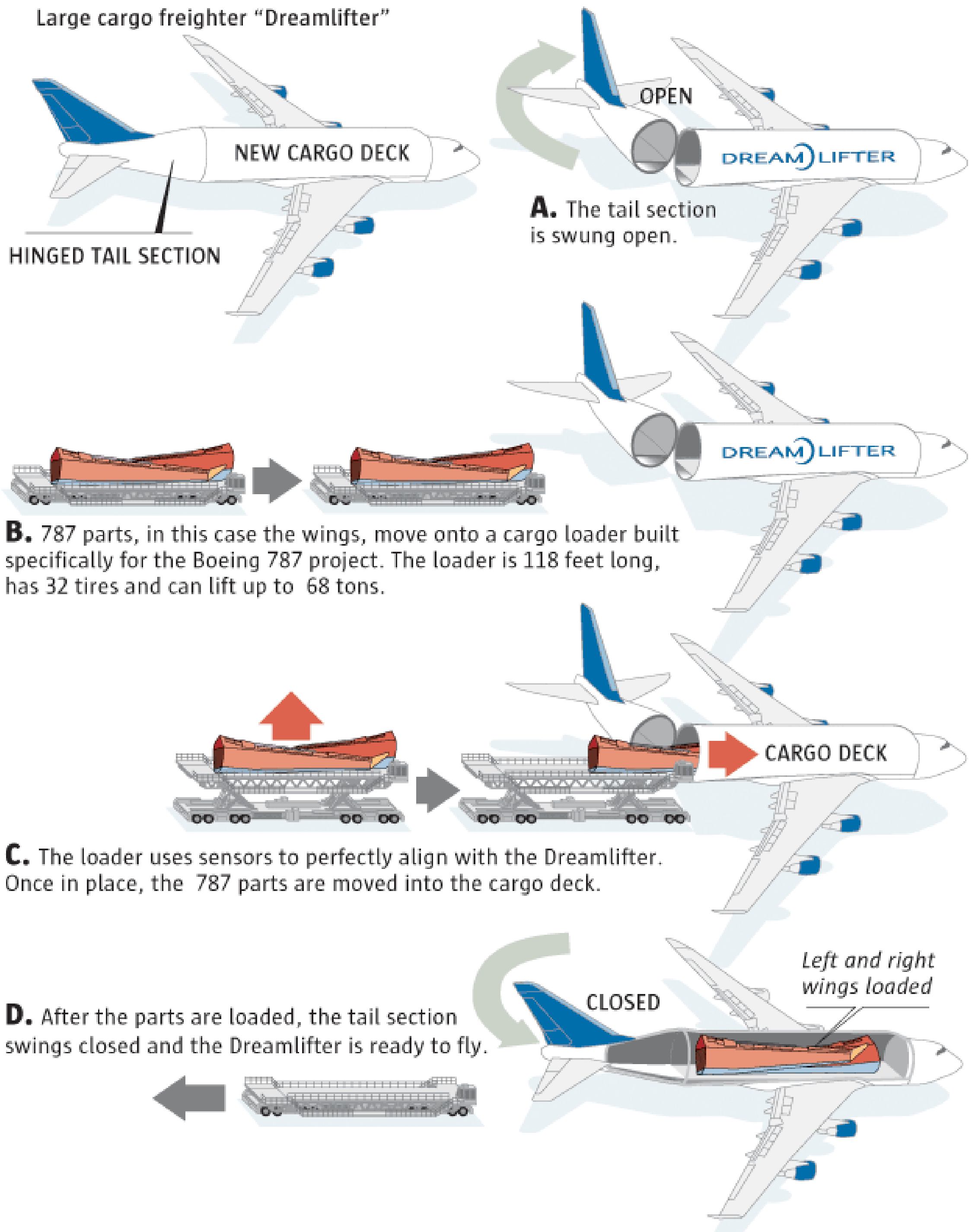

SOFIA infrared image
(5.4, 24, and 37 μm)
Visible light image

Boeing created a set of "Large Cargo Freighter" (LCF) aircraft (based on used 747-400 airframes) for support of the company's 787 program. The LCF (a/k/a "Dreamlifter") features an enlarged "guppy" fuselage with a tail assembly that breaks at the APB (Aft Pressure Bulkhead) and swings to the left. Cargo volume is three times that of a standard 747-400 air freighter and, in fact, it has more cargo volume than any other aircraft ever flown. The LCF can carry bulky payloads (with a maximum radius of 12-feet 4-inches). The assemblies carried are relatively lightweight and so no need was seen to modify a freighter 747, which has greater load capacity. The tailfin was increased in height by 5-feet and forward ballast was added to compensate for aerodynamic and Center-of-Gravity (CG) changes caused by the enlarged fuselage.



The 747-400 LCF will have a "swing tail" that opens and closes to swallow major Boeing 787 Dreamliner sections whole, and a vertical fin that extends five feet higher than a typical 747-400. Its first scheduled test flight: mid-2006.

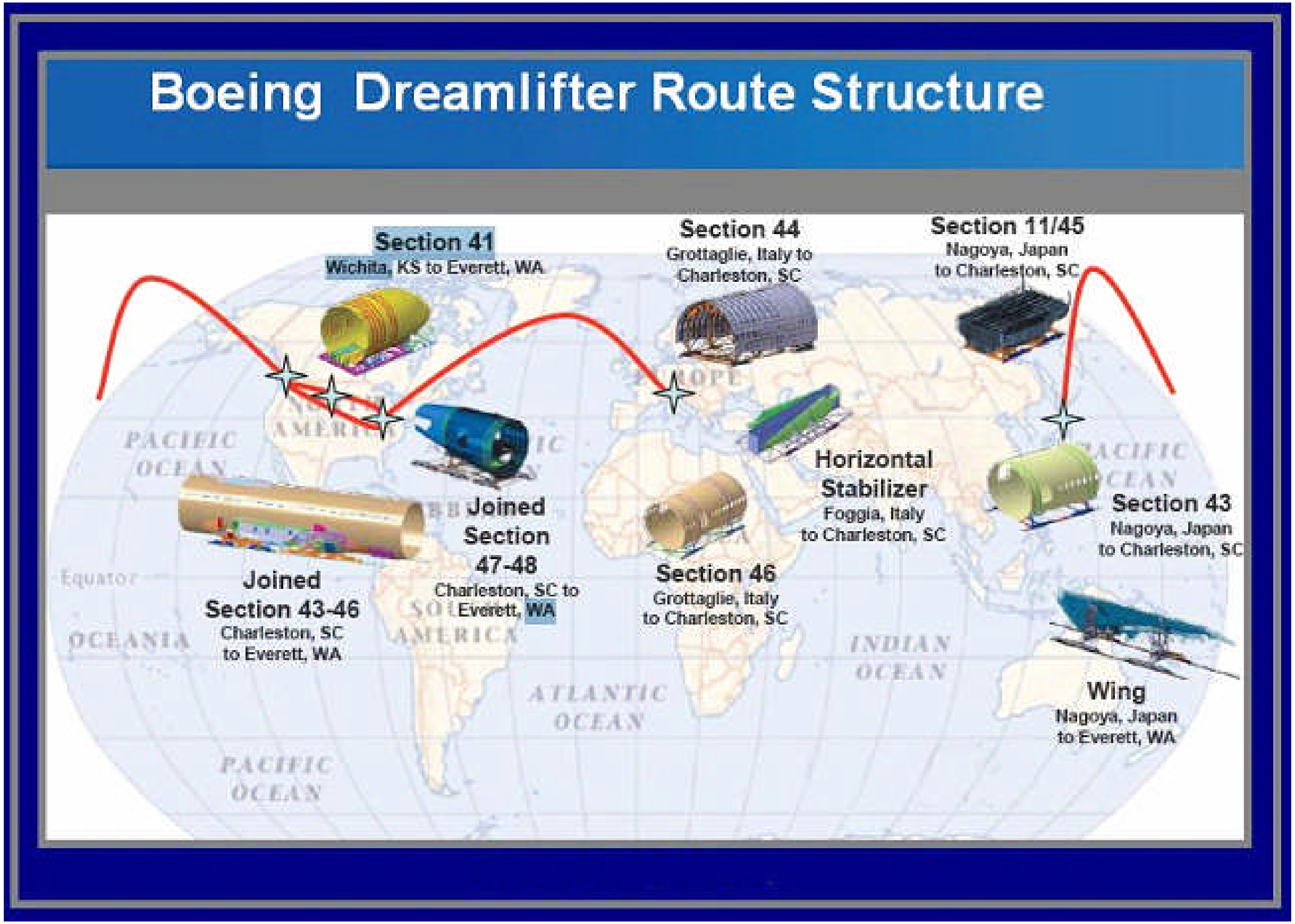
The cargo bay (left) is heated but not pressurized. The tail (above) is supported by a stand when the aircraft is being loaded and unloaded (the stand carried with the aircraft). The aircraft deck is selectively reinforced and integrates roller systems to help load and unload cargo.



<u>Left</u>: caption: "Delivering the Dreamliner's Major Sections. Boeing has modified old 747 jets into new large cargo freighters. The freighters, dubbed 'Dreamlifters,' have a redesigned cargo deck, upper fuselage and hinged tail section to transport the 787 fuselage sections, wings and horizontal stabilizers from Japan, Europe and South Carolina. The design work was done with help from engineers at the Boeing design center in Moscow. The aircraft modifications were done in Taiwan."


TLD


TLD
DREAMLIFTER


Boeing Dreamlifter Route Structure
Section 41
Wichita, KS to Everett, WA
Section 44
Grottaglie, Italy to Charleston, SC
Section 11/45
Nagoya, Japan to Charleston, SC
Horizontal Stabilizer
Foggia, Italy to Charleston, SC
Section 43
Nagoya, Japan to Charleston, SC
Joined Section 47-48
Charleston, SC to Everett, WA
Joined Section 43-46
Charleston, SC to Everett, WA
Section 46
Grottaglie, Italy to Charleston, SC
Wing
Nagoya, Japan to Everett, WA
PACIFIC OCEAN
ATLANTIC OCEAN
INDIAN OCEAN
OCEANIA
Equator


787 DREAMLINER™

Three Dreamlifters were built (*Evergreen Aviation Technologies Corp*. of Taipei, Taiwan - a Boeing partner, performed the modifications) and the first trials began in early 2007. Other than the changes to the airframe, the aircraft did not receive any serious modifications (i.e. latest engines and/or avionics) and the modified fuselage was built out of standard aircraft aluminum, not composite materials.


DREAMLIFTER
DREAMLIFTER


EVERGREEN
DREAMLIFTER


787
DREAMLIFTER

Evergreen Aviation **converted two 747s into a "Supertanker" configuration for fighting forest fighters. Modifications included:**

- **The cargo hold was fitted with ten fluid tanks with a total capacity of 20,500 U.S. gallons of water or fire retardant. The tanks were mounted on pallets that could be easily removed to allow the Supertanker to haul cargo outside of the fire season;**
- **Eight air tanks were bolted to the rear cargo deck (pressurized up to 165 PSI to drive the fluid from the tanks;**
- **Four circular ports (12-inches in diameter) were fitted to the belly of the aircraft behind the wing, and;**
- **A data acquisition system was wired into the airframe linking together 141 strain gauges, 5 accelerometers, air data probes and *Global Positioning System* (GPS) coordinates**

Left: caption: "B747-100 Evergreen Supertanker"

Right: caption: "The pressurized retardant tanks on the 747 Supertanker. The retardant is forced out by compressed air, much like on the MAFF C-130 air tankers."

The Evergreen Supertanker was designed as a system that could be operated at any airport capable of handling a 747. Ground support equipment, aside from that normally required for a large commercial aircraft, consists of a fork-lift and a large bladder tank that is filled from a fire hydrant. The Super-tanker is rapidly reloaded from the bladder tank using a hose-and-reel system fitted into the aircraft.

<u>Top</u>: caption: "U.S. Evergreen 747 Supertanker arrives to assist firefighting efforts in Northern Israel"

<u>Bottom</u>: caption: The four nozzles that dispense retardant"

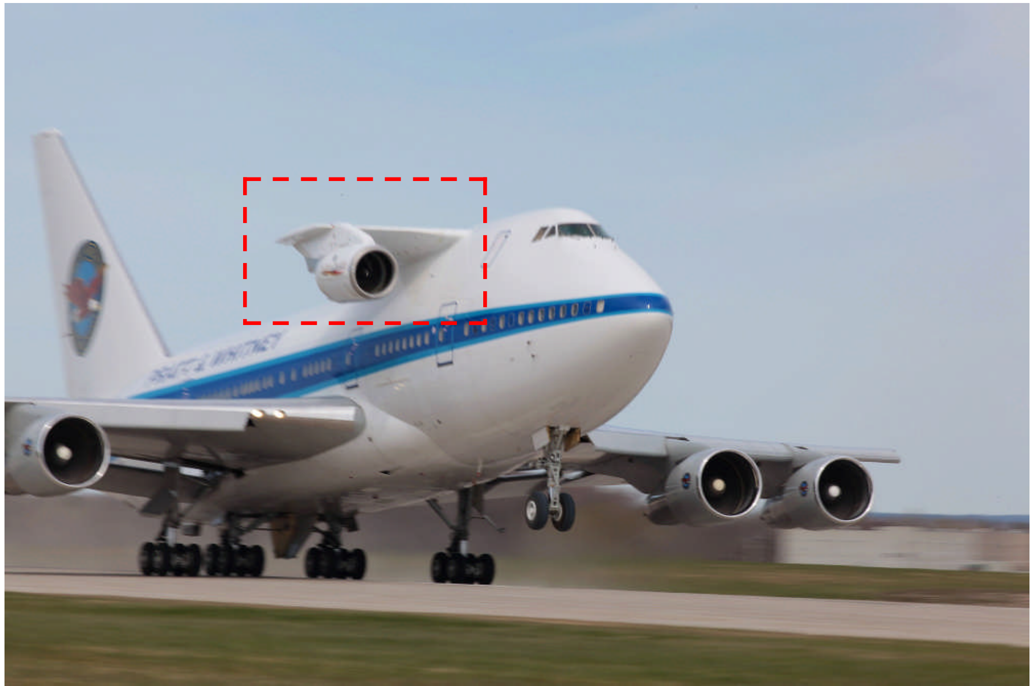
Initial flight of the first Supertanker (a converted 747-200) was in 2004, followed by a 747-100 conversion. Initial operational use was in 2009. After the treacherous 2012 fire season and the loss of several air tankers, the *U.S. Forest Service* has been providing funding for updating of the U.S. air tanker fleet, the plan being to acquire a number of 747 or DC-10 supertankers as part of the inventory.

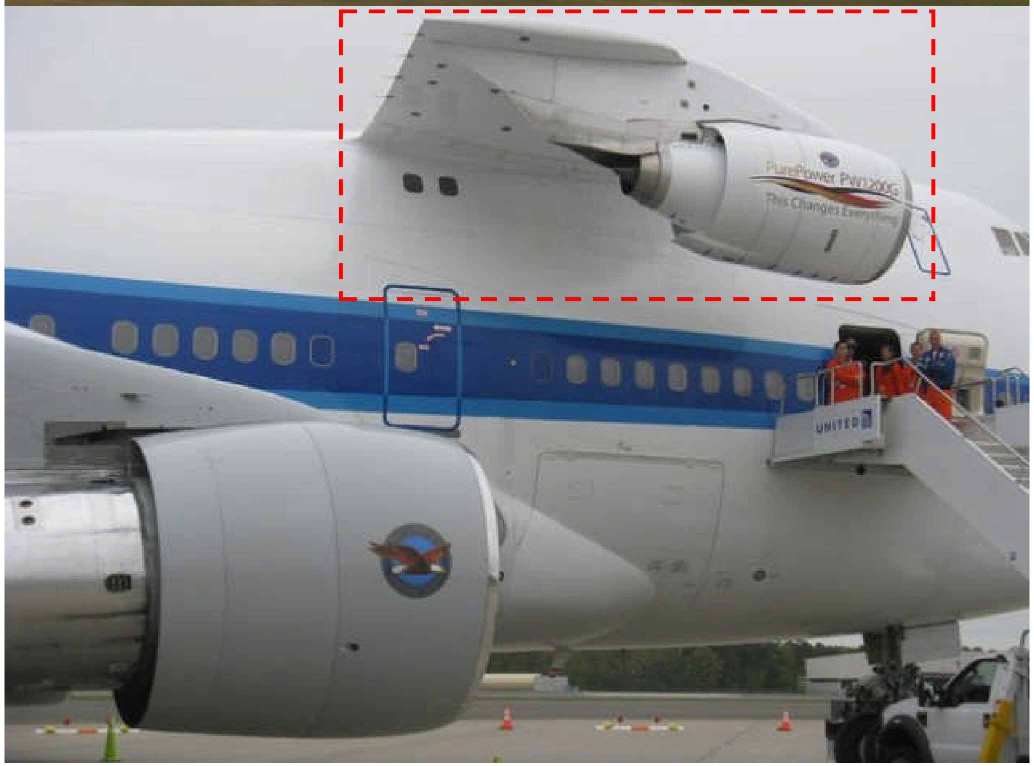
<u>Above</u>: caption: "Evergreen 747 Supertanker"


910

"…Pratt & Whitney's flying test bed is a Boeing 747SP. P&W Canada is in the process of testing their PW1200G engine, that is slated to for the Mitsubishi Regional Jet (MRJ)…P&W uses a Boeing 747SP that was originally delivered to Korean Airlines on January 30, 1980. It flew with the airline until it was placed into storage in 1998. Then in 2008, P&W purchased the 747SP to use for engine testing…"

***AirlineReporter*, May 2012**




UNITED

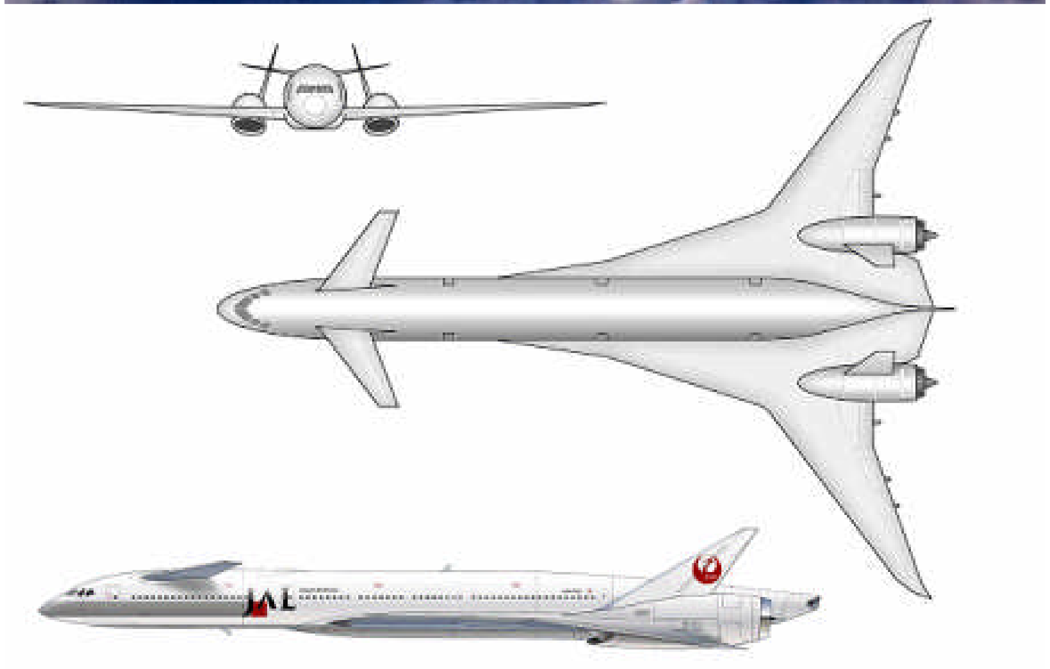
The Yellowstone Project

"Yellowstone" is a Boeing commercial airplanes project designed to replace the company's entire civil aircraft portfolio with advanced technology aircraft. New technologies to be introduced include composite aerostructures, more electrical systems (reduction of hydraulic systems) and more fuel-efficient turbofan engines (such as the *Pratt & Whitney PW1000G Geared Turbofan*, *General Electric GEnx,* the *CFM International LEAP56* and the *Rolls-Royce Trent 1000*). The term *Yellowstone* refers to the technologies while "Y1" through "Y3" refer to the actual aircraft. Yellowstone is divided into three projects:

- **<u>Boeing Y1</u>: to replace the Boeing 737 product line. Y1 covers the 100- to 200-passenger market, and is expected to be the second *Yellowstone Project* aircraft to be developed. If launched, it will compete with the *Bombardier C-Series* and the planned *Airbus NSR* family.**
- **<u>Boeing Y2</u>: to replace the Boeing 767 product line. It may also replace the 777-200. Y2 initially referred to the highly efficient, more conventional, baseline aircraft for the *Sonic Cruiser* (a/k/a "Project Glacier") It has now been built as the 787 and covers the 220- to 320-passenger market. It will compete with the *Airbus A330, A340* and later *A350* families.**
- **<u>Boeing Y3</u>: to replace the 777-300 and 747 product lines. Y3 covers the 300 to 400+ passenger market and is expected to be the third Yellowstone Project aircraft to be developed. It will compete with the *Airbus A380* family as well as the largest model of the A350 family; the *A350-1000*.**

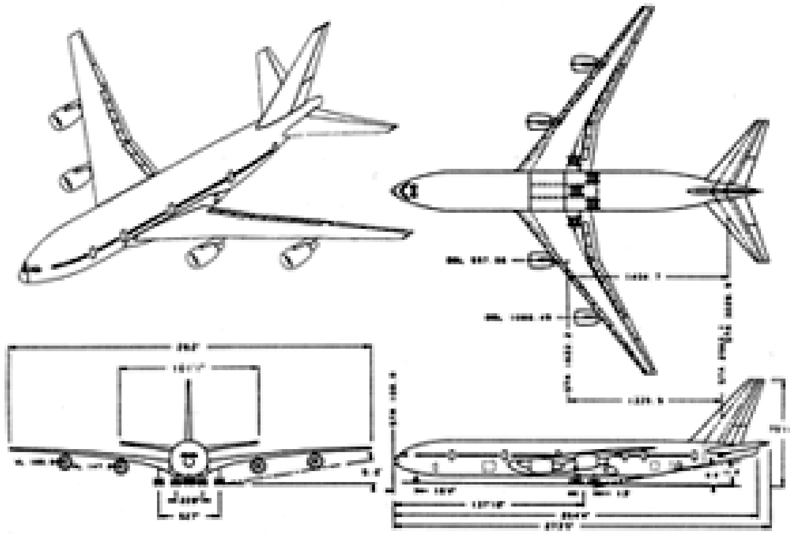
Boeing abandoned both the upgraded 747 and any potential replacements (at least temporarily) when it announced plans to focus on a completely different market for its next major project. Instead of building a very large jetliner (to carry 500+ passengers), Boeing believed a more lucrative market existed in carrying about 250 passengers over very long ranges at higher speeds than is possible with conventional airliner designs. This philosophy was reflected in the "Sonic Cruiser" concept which was unveiled in early 2001 (above). This aircraft would have been a competitor in the 767 and A310 class of airliners. Instead, Boeing developed an upgraded 747-400 version: the 747-8I. However, this new model is designed for 450 passengers in a typical three-class configuration rather than 500+.

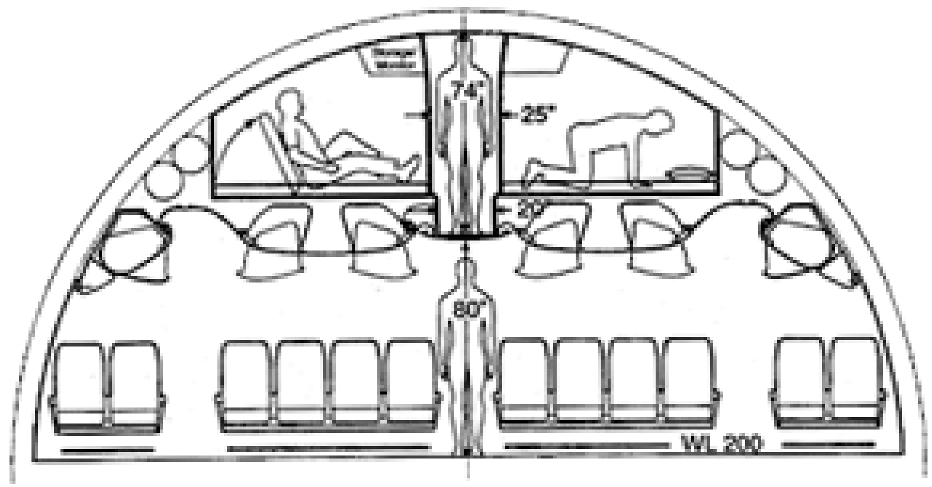
<u>Above</u>: caption: "Boeing Sonic Cruiser concept"



The *Sonic Cruiser* created somewhat of a sensation when first announced in 2001, but airlines and Boeing became progressively less enthusiastic over the ensuing months. The aircraft would require rather substantial improvements in technology to achieve its stated goals of cruising at about Mach 0.95 (compared to Mach 0.8 for most commercial airliners) over a range between 6K and 10K nautical miles. This kind of technological advancement could well drive-up the cost so much that most airlines showed no willingness to commit to the idea. Even the perceived advantage of a faster commercial aircraft caused concern because of all the scheduling difficulties it would raise. The terrible financial situation of the airlines after 9/11 only worsened prospects for launching the design. Due to this lackluster response and its inability to make a strong business case for the plane, Boeing officially shelved the Sonic Cruiser concept in December 2002.

<u>Left T&B</u>: caption: Boeing’s Sonic Cruiser concept”

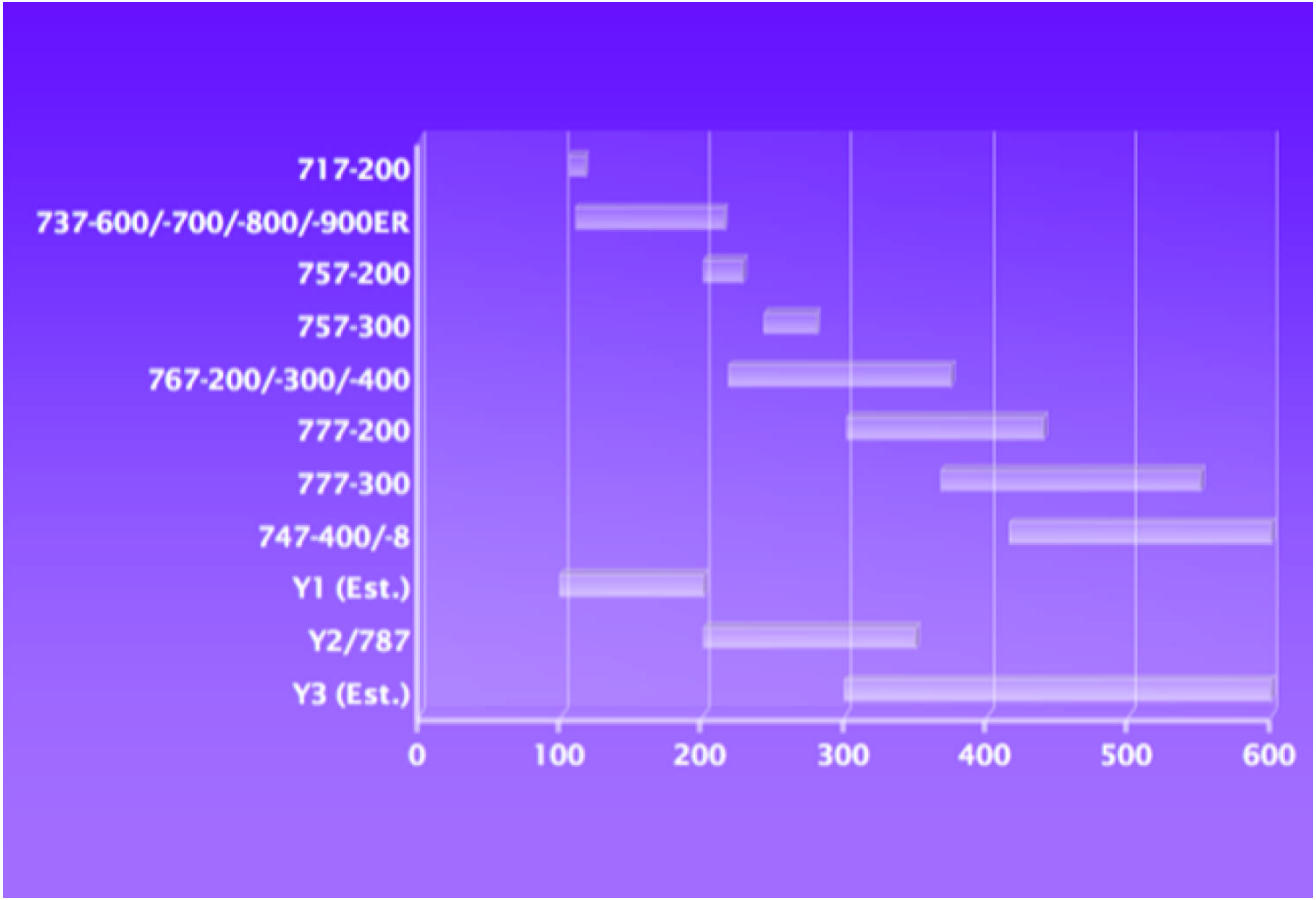




While Boeing pushed developing an upgraded 747 model, most airlines indicated that they would prefer an entirely new design instead. Boeing's internal designation for this design study was the "763-246C." If it had gone into production, it would likely have been re-christened the 787 (to conform to the standard Boeing naming convention). However, the "787" designation has been assigned to the *Dreamliner*. Once the 7-7 designations are exhausted, it's unclear what naming convention Boeing might adopt for its future commercial aircraft (possibly 8-8).

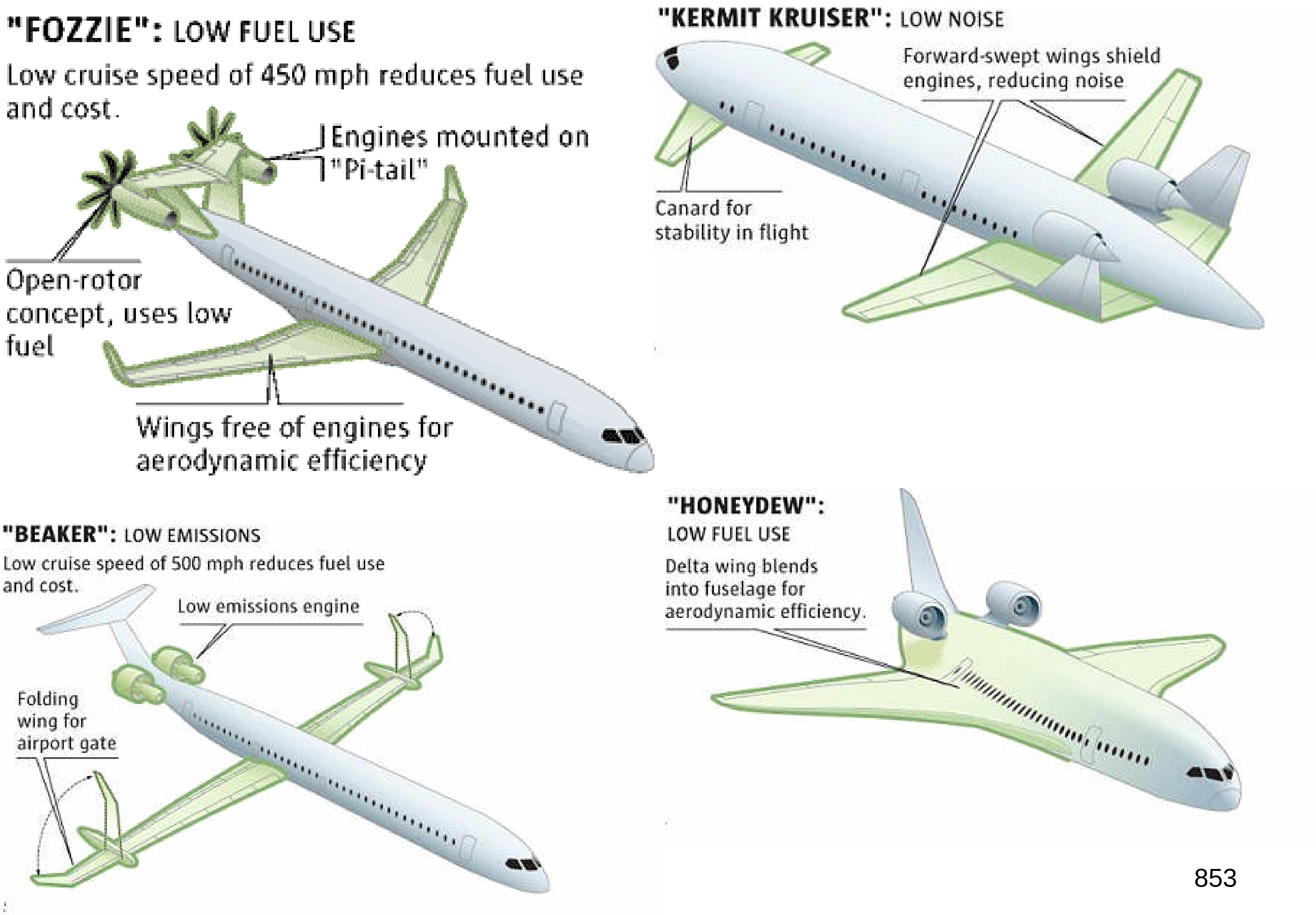
<u>Left</u>: caption: "Boeing 763-246C"

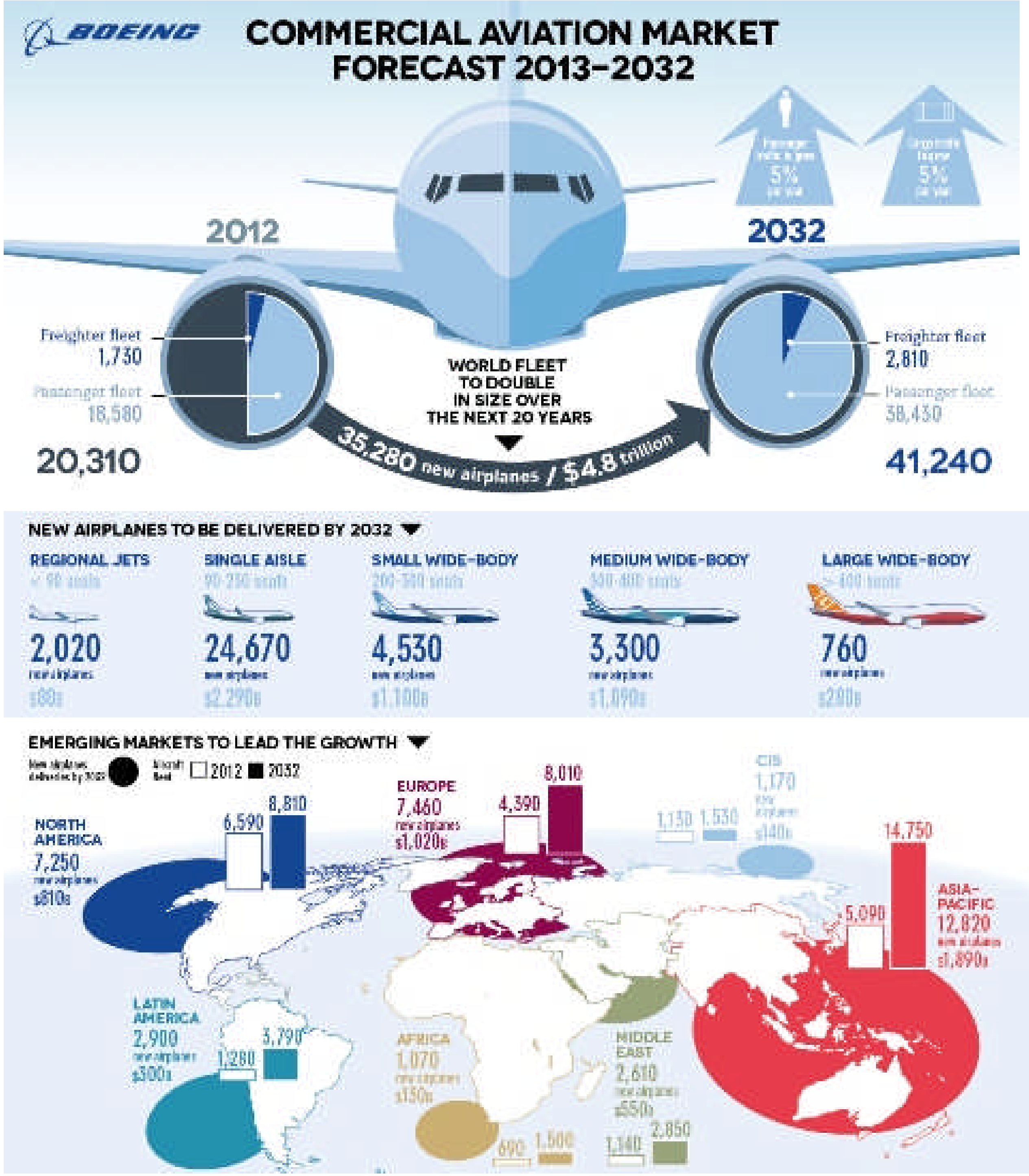
<u>Right</u>: caption: "Boeing 763-246C internal cross-section"



Above: caption: “Passenger capacity of existing and future Boeing civil aircraft”

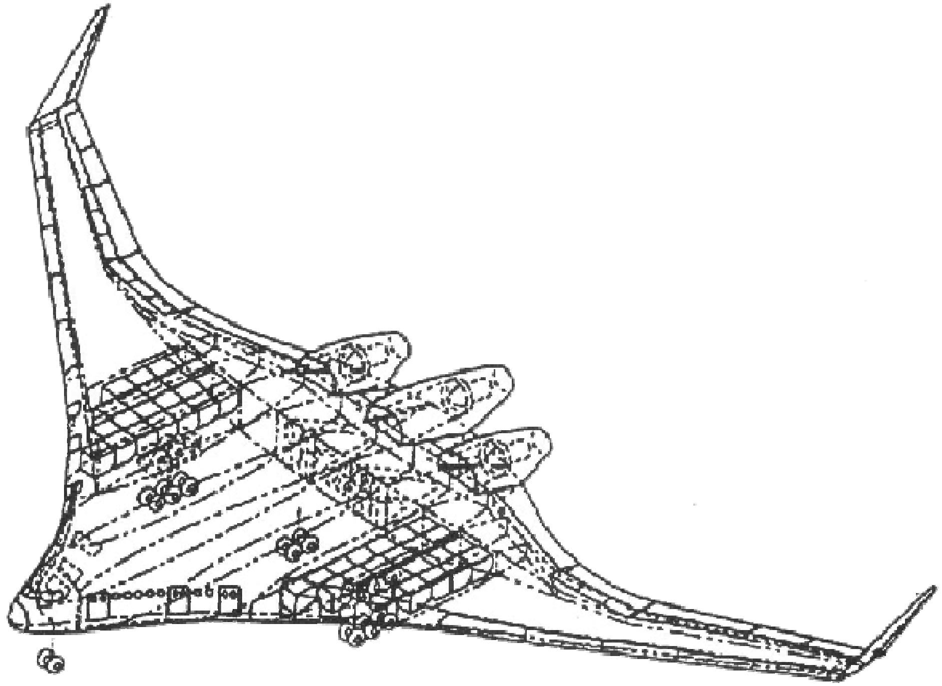
Some of the Boeing "green" planes





BOEING
COMMERCIAL AVIATION MARKET FORECAST 2013–2032
5%
5%
2012
2032
Freighter fleet 1,730
Passenger fleet 18,580
20,310
Freighter fleet 2,810
Passenger fleet 38,430
41,240
WORLD FLEET TO DOUBLE IN SIZE OVER THE NEXT 20 YEARS
35,280 new airplanes / $4.8 trillion
NEW AIRPLANES TO BE DELIVERED BY 2032
REGIONAL JETS
2,020
new airplanes
$80B
SINGLE AISLE
24,670
new airplanes
$2,290B
SMALL WIDE-BODY
4,530
new airplanes
$1,100B
MEDIUM WIDE-BODY
3,300
new airplanes
$1,090B
LARGE WIDE-BODY
760
new airplanes
$280B
EMERGING MARKETS TO LEAD THE GROWTH
2012
2032
NORTH AMERICA
7,250
new airplanes
$810B
6,590
8,810
EUROPE
7,460
new airplanes
$1,020B
4,390
8,010
CIS
1,170
new airplanes
$140B
1,130
1,530
ASIA-PACIFIC
12,820
new airplanes
$1,890B
5,090
14,750
LATIN AMERICA
2,900
new airplanes
$300B
1,280
3,790
AFRICA
1,070
new airplanes
$150B
690
1,500
MIDDLE EAST
2,610
new airplanes
$550B
1,140
2,850

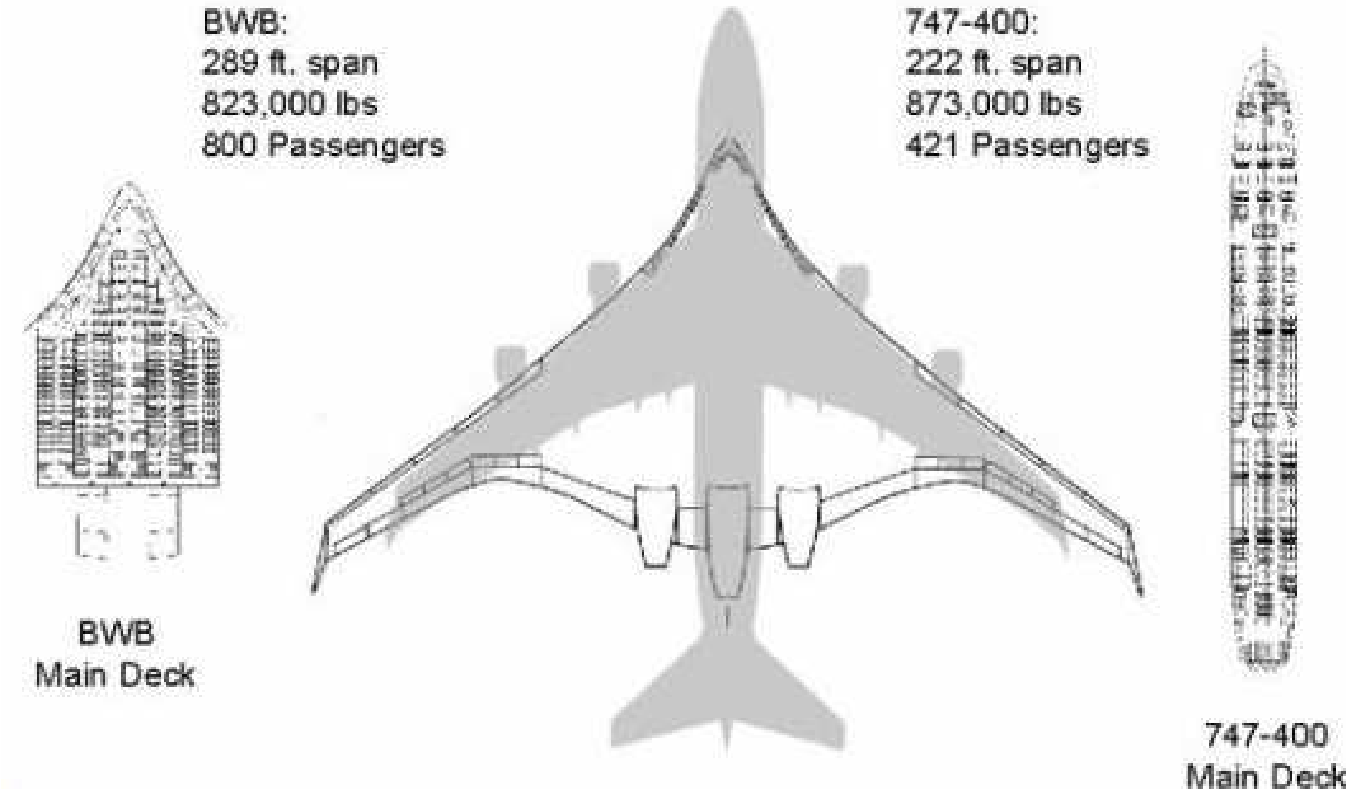
BWB

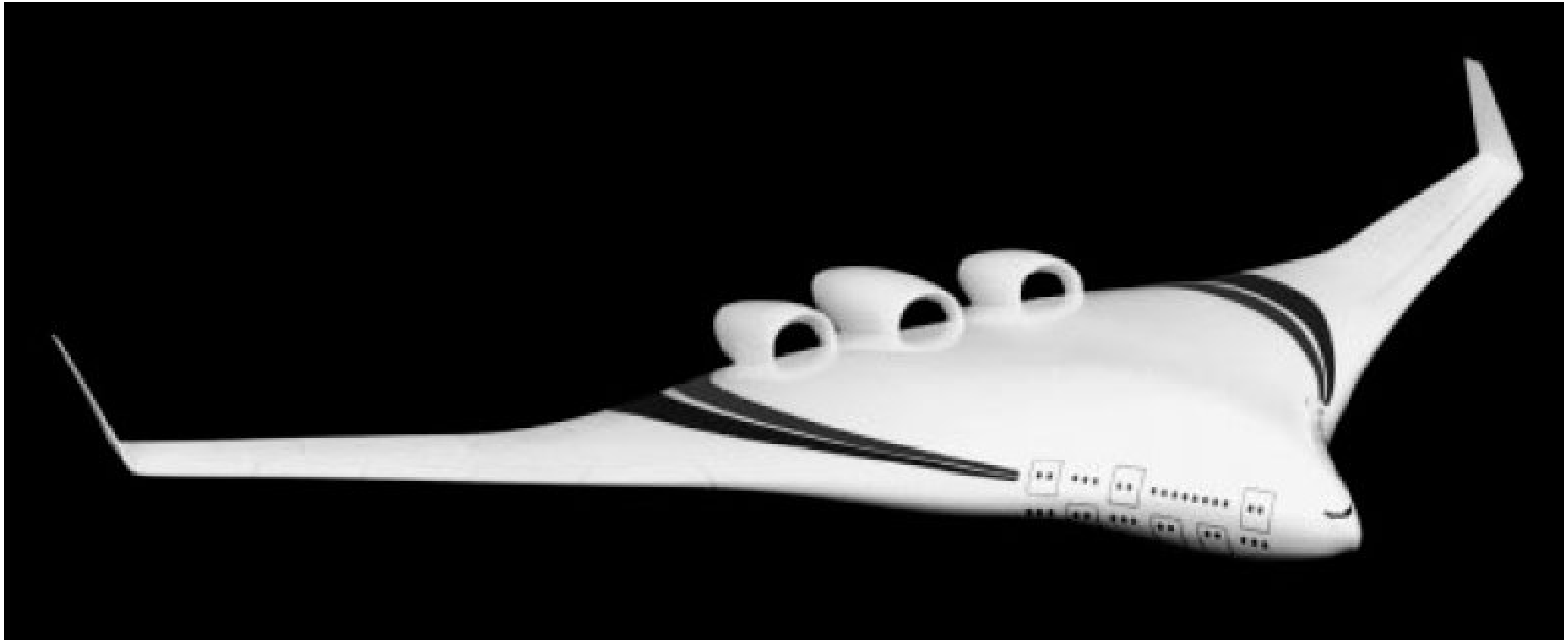


A completely different path that Boeing may choose to pursue in the near future is the "<u>B</u>lended-<u>W</u>ing-<u>B</u>ody" (BWB). The BWB is related to the flying wing, but is a somewhat more sophisticated concept that resulted from a study to determine the optimum low-drag shape to contain a given volume of passenger space. The resulting fuselage resembles a flattened sphere that tapers down and blends into the outboard wings. The thick center-section could hold from 500 to 800 passengers. Additional studies have focused on smaller variants in the 250- to 300-passenger range and another study indicated that a cruise speed of Mach 0.9 over a range of 7,500 to 8,900 nautical miles might be an optimum design goal.

<u>Above L&R</u>: caption: "Blended Wing Body concept"

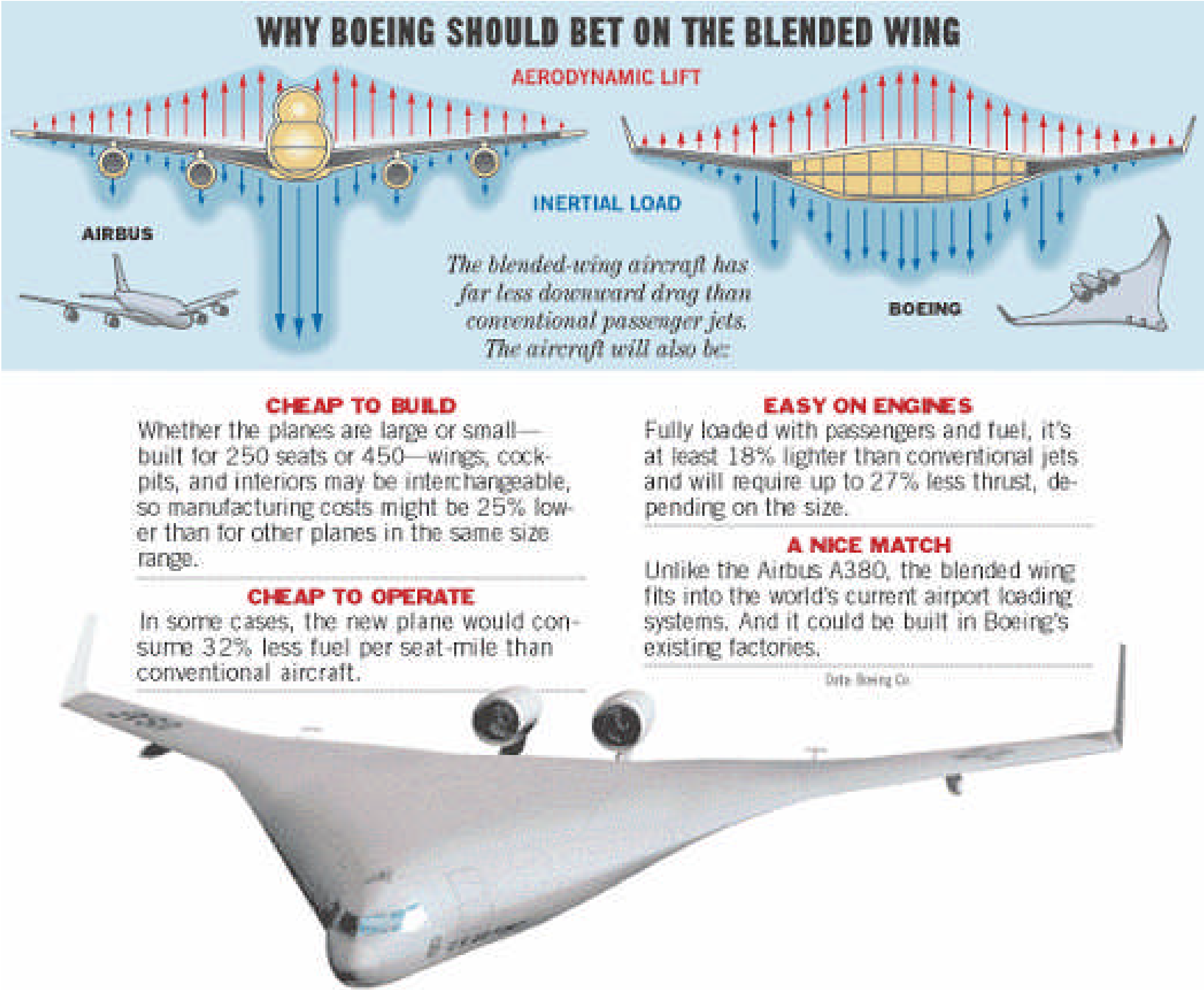
Size Comparison of 747 vs. BWB

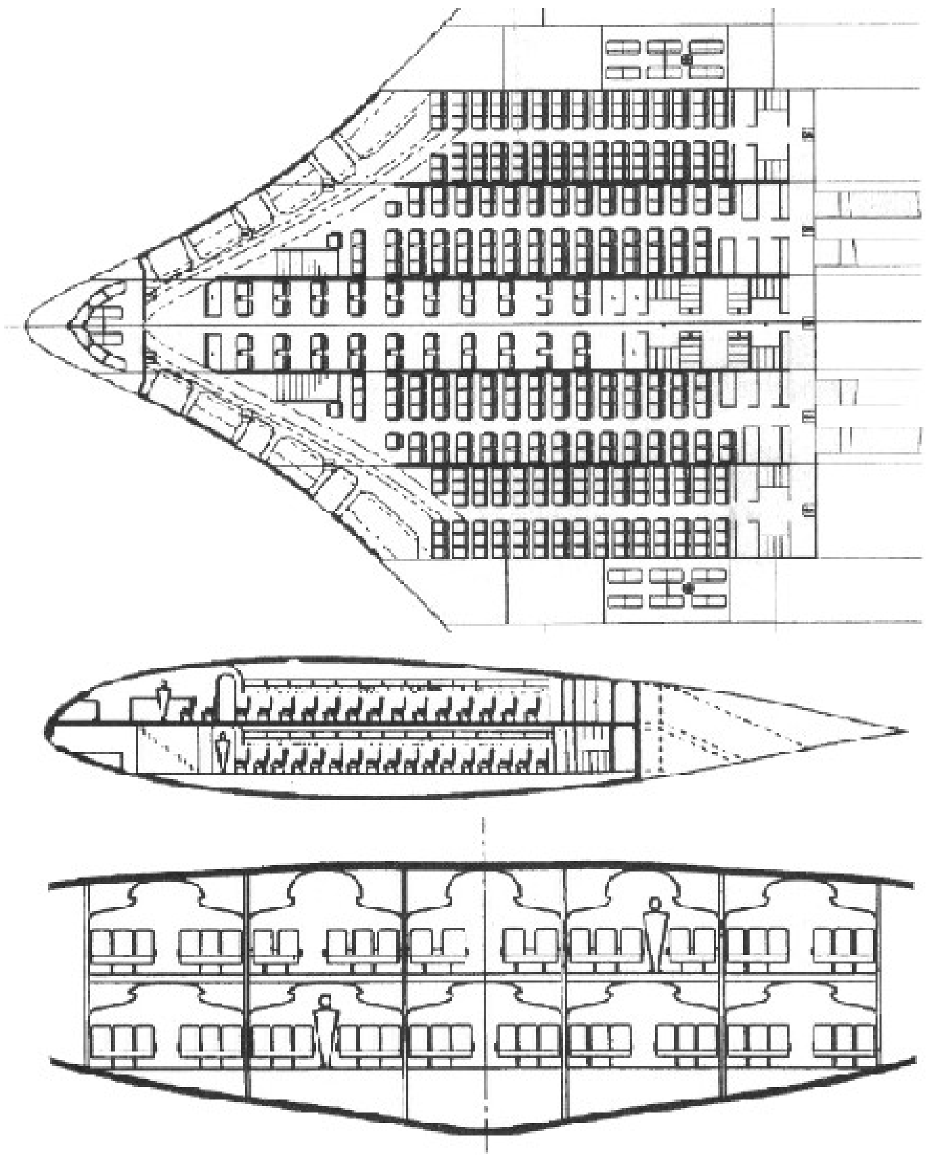




A ***Blended-Wing-Body*** **is a fixed-wing aircraft having no clear dividing line between the wings and the main body of the craft. The form is composed of distinct wing and body structures, though the wings are smoothly blended into the body (unlike a flying wing which has no distinct fuselage. Many BWB craft have a flattened and airfoil shaped body, which produces most of the lift, the wings contributing the balance. The potential advantages of the BWB approach are efficient high-lift wings and a wide airfoil-shaped body. This enables the entire craft to contribute to lift generation with the result of potentially increased fuel efficiency and range. A blended wing body can have lift-to-drag ratio 50% greater than a conventional aircraft.**

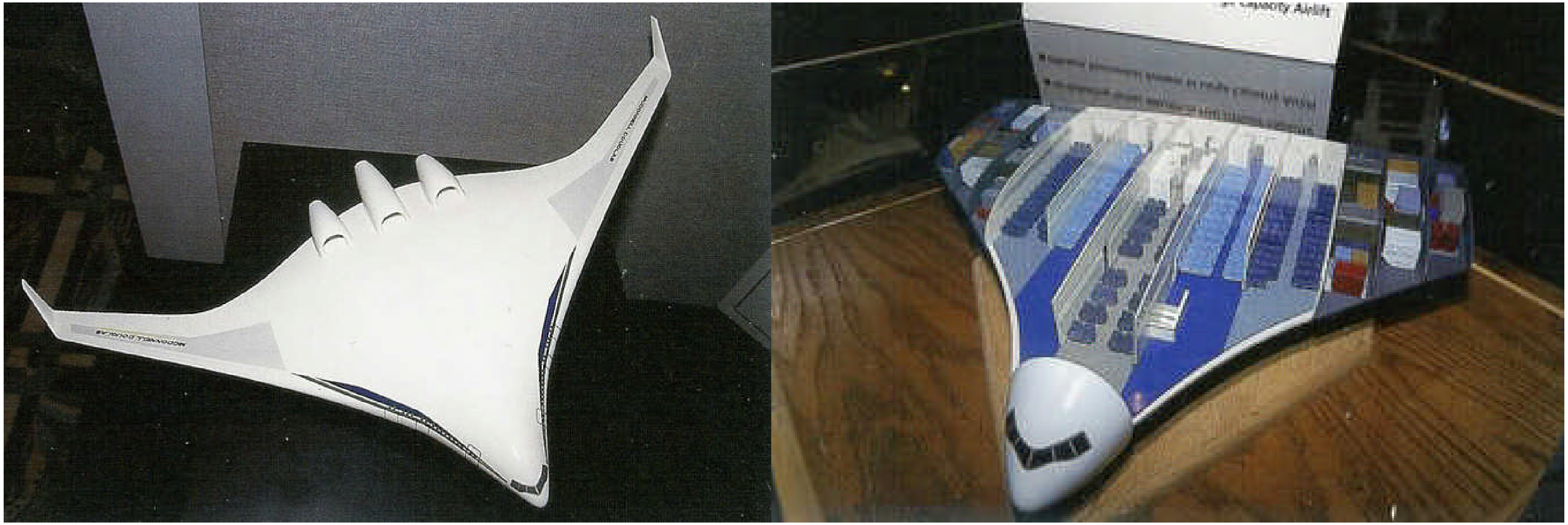
<u>Above</u>: caption: "Computer-generated model of the Boeing X-48"


WHY BOEING SHOULD BET ON THE BLENDED WING
AERODYNAMIC LIFT
INERTIAL LOAD
AIRBUS
BOEING
The blended-wing aircraft has far less downward drag than conventional passenger jets. The aircraft will also be:
CHEAP TO BUILD
Whether the planes are large or small—built for 250 seats or 450—wings, cockpits, and interiors may be interchangeable, so manufacturing costs might be 25% lower than for other planes in the same size range.
CHEAP TO OPERATE
In some cases, the new plane would consume 32% less fuel per seat-mile than conventional aircraft.
EASY ON ENGINES
Fully loaded with passengers and fuel, it's at least 18% lighter than conventional jets and will require up to 27% less thrust, depending on the size.
A NICE MATCH
Unlike the Airbus A380, the blended wing fits into the world's current airport loading systems. And it could be built in Boeing's existing factories.
Data: Boeing Co.

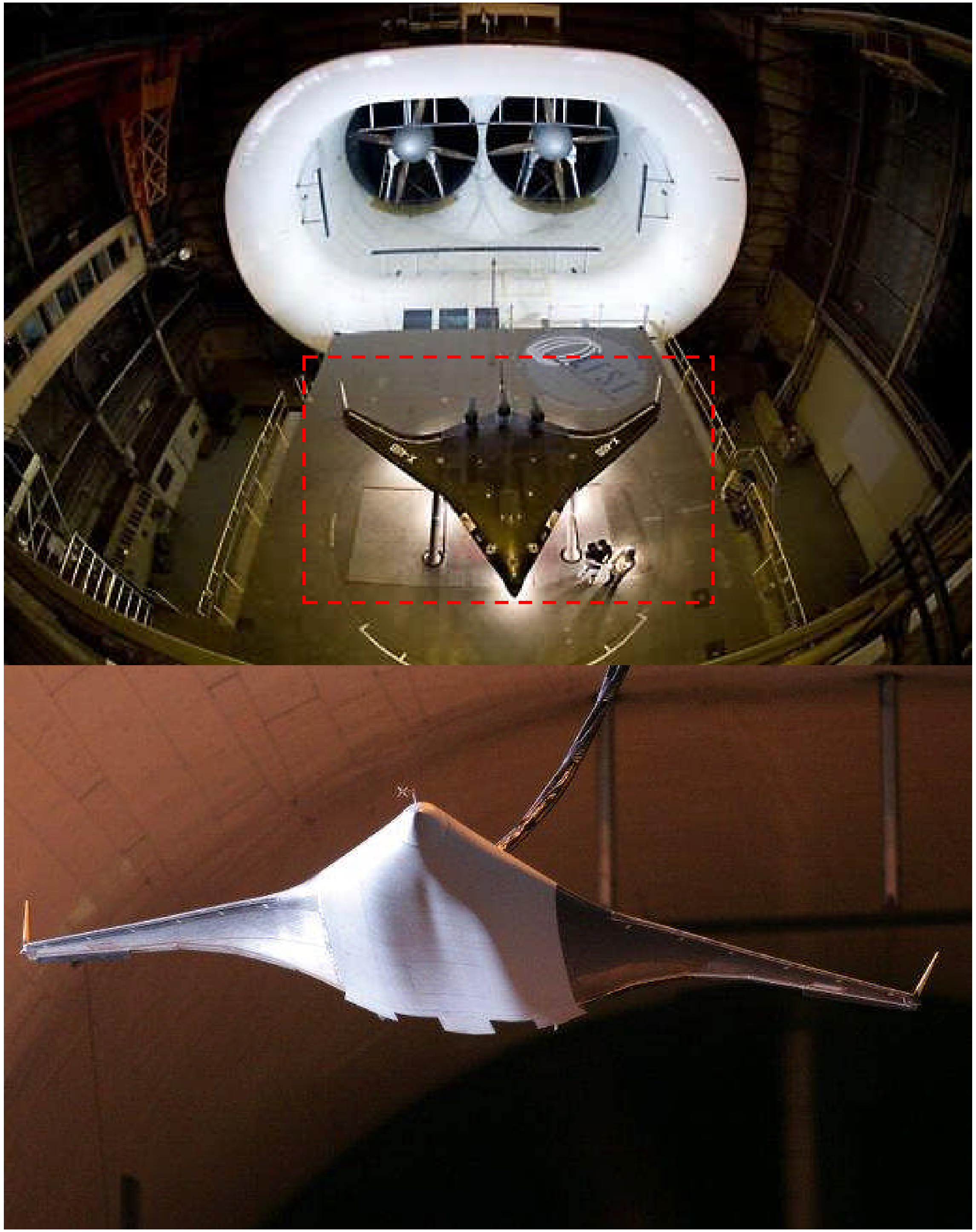


The BWB was first created by the commercial aircraft division of *McDonnell Douglas* (MDD). Though Boeing expressed little interest in continuing most of MDD's projects, the company wisely decided to carry on low-level development of the revolutionary BWB. However, Boeing has not yet provided any indication that the design will go into full-scale development or production. While such an aircraft could potentially reduce operating costs significantly, concerns have been raised about compatibility with existing airport infrastructure and the difficulty of evacuating so many people from the deep interior cabin in an emergency. In addition, many airlines are worried that passengers may be unwilling to fly an aircraft that is so different looking from what they are used to. Perhaps because of these concerns, the most likely application for a BWB design in the near future is a military transport or refueling tanker rather than a commercial airliner. NASA received funding to test a subscale version of the BWB called the X-48 to evaluate the feasibility of the idea.

<u>Left</u>: caption: "BWB internal layout"

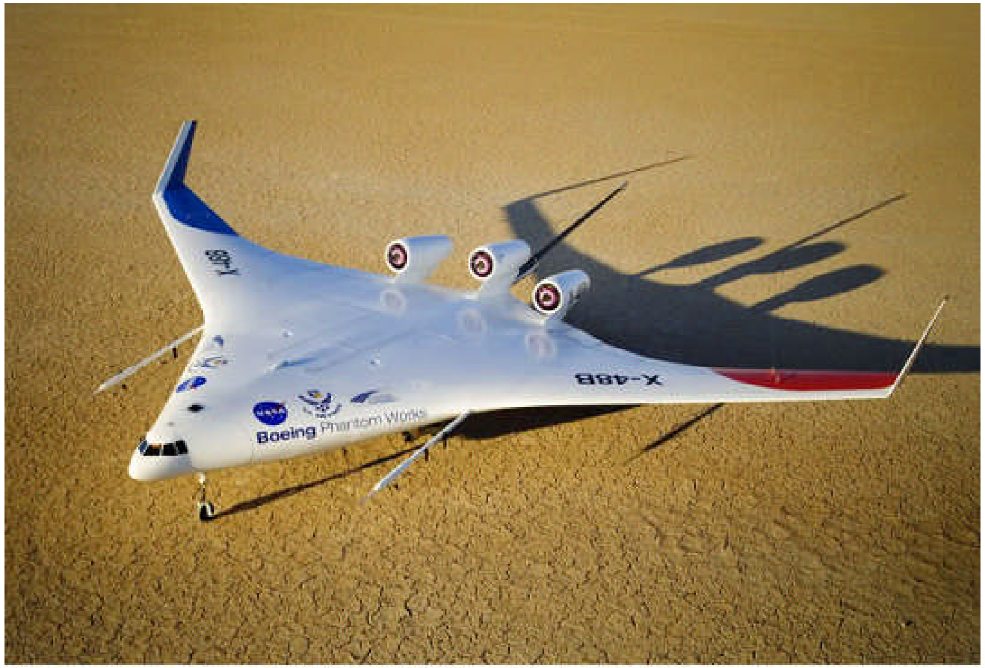


<u>Left</u>: caption: "The last-ever new project made public before McDonnell Douglas was bought by Boeing was the Blended Wing Body (BWB-1-1). Powered by three engines in typical Douglas style, the flying wing was designed to carry up to 800 passengers across 7,000 nautical miles. Wingspan with winglets was estimated to be about 289 feet."
<u>Right</u>: caption: "The BWB-1-1 used the basic wing structure to provide compartments for passengers and freight.
A second deck is located below."



A computer stabilized 17-foot 6% scale model called BWB-17 (sponsored by NASA and built by *Stanford University)* flew in 1997 and showed good handling qualities.

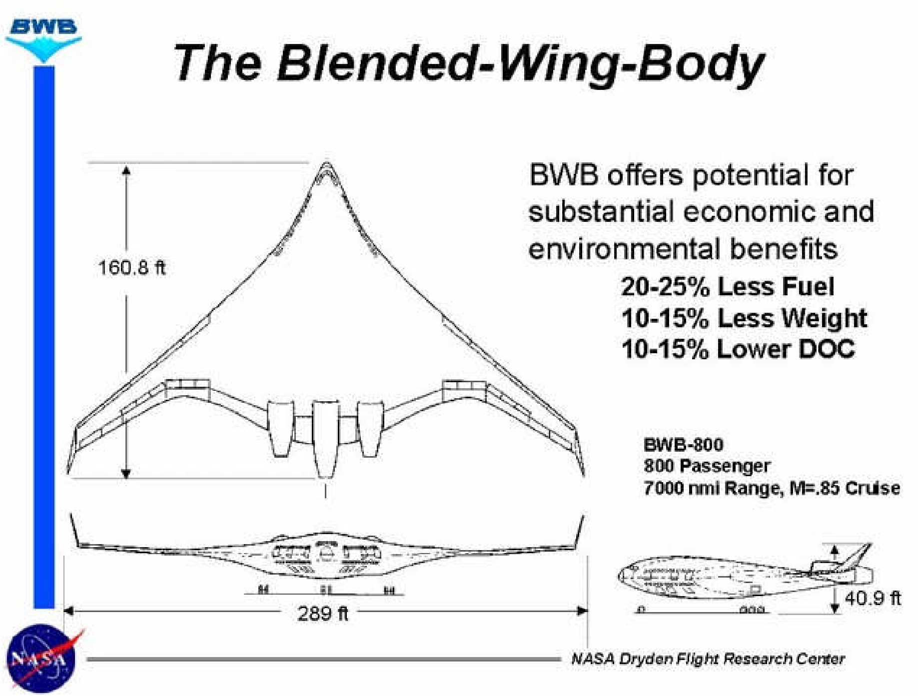
<u>Left</u>: wind tunnel testing of BWB-17 scale model

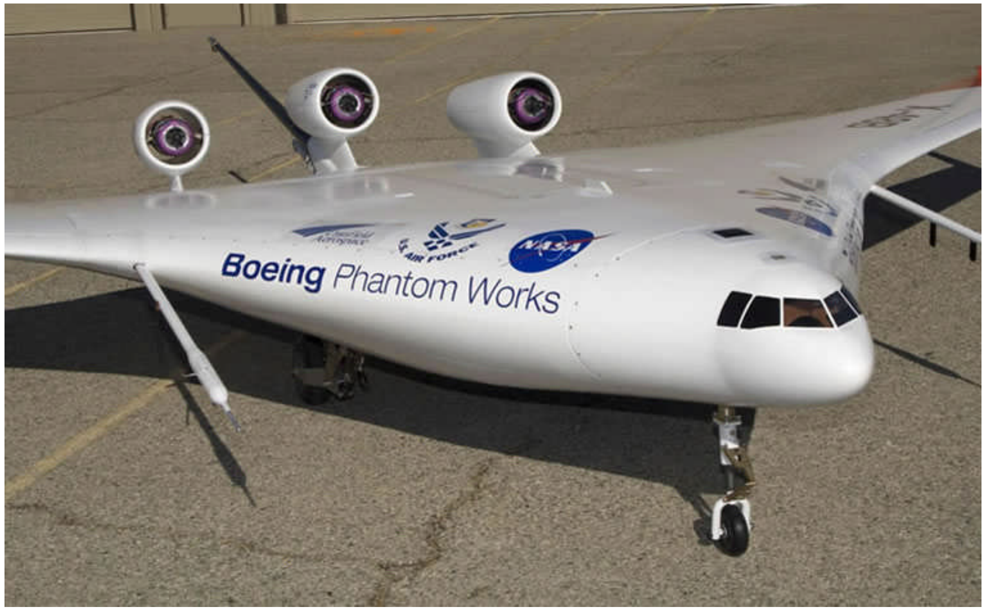


NASA Dryden Flight Research Center Photo Collection

Date: October 24, 2006

Boeing's X-48B Blended Wing Body technology demonstrator shows off its unique lines at sunset on Rogers Dry Lake adjacent to NASA DFRC.

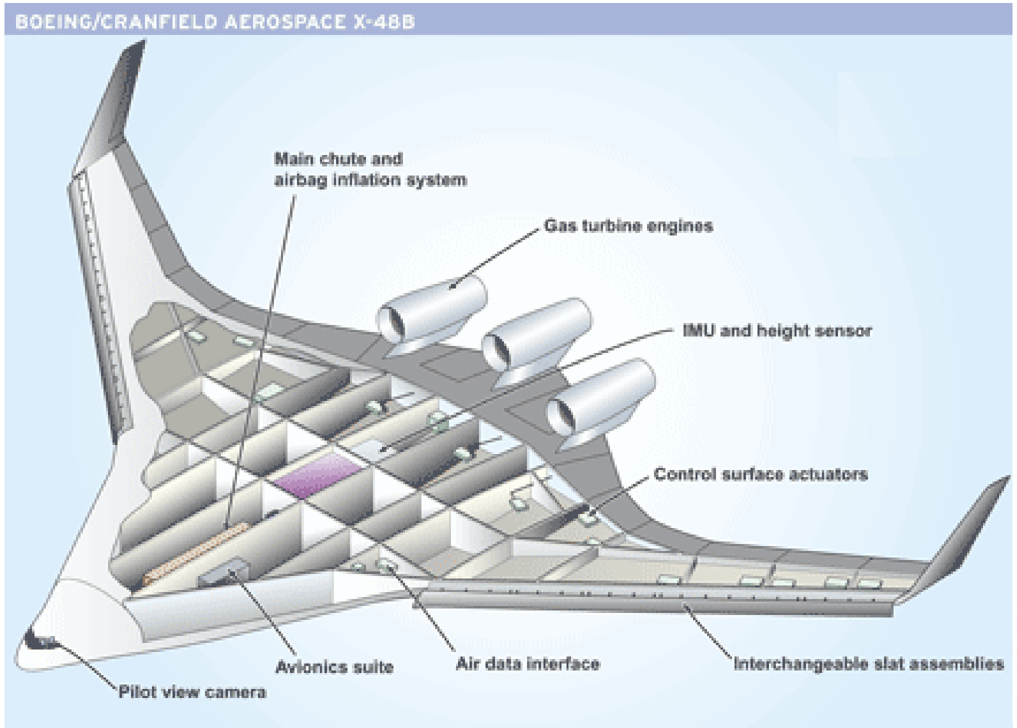


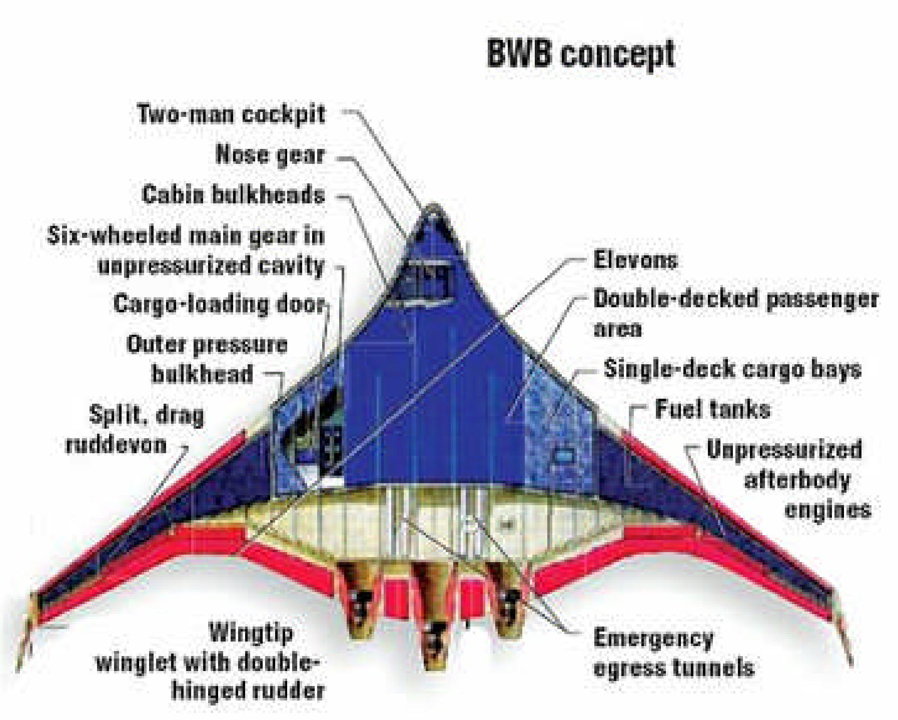


Since 2000, NASA has been developing a remotely controlled model with a 21-foot wingspan. This research is focused on establishing the base data concerning the lift, stall and spin characteristics inherent in a BWB design. Both NASA and Boeing are exploring BWB designs with the X-48 Unmanned Aerial Vehicle (UAV). Studies suggest that BWB aircraft (configured for passenger flight) could carry from 450 to 800 passengers and achieve fuel savings of over 20%.


Boeing Phantom Works


X-48B
X-48B
X-48B
Boeing Phantom Works


BOEING/CRANFIELD AEROSPACE X-48B
Main chute and
airbag inflation system
Gas turbine engines
IMU and height sensor
Control surface actuators
Interchangeable slat assemblies
Air data interface
Avionics suite
Pilot view camera

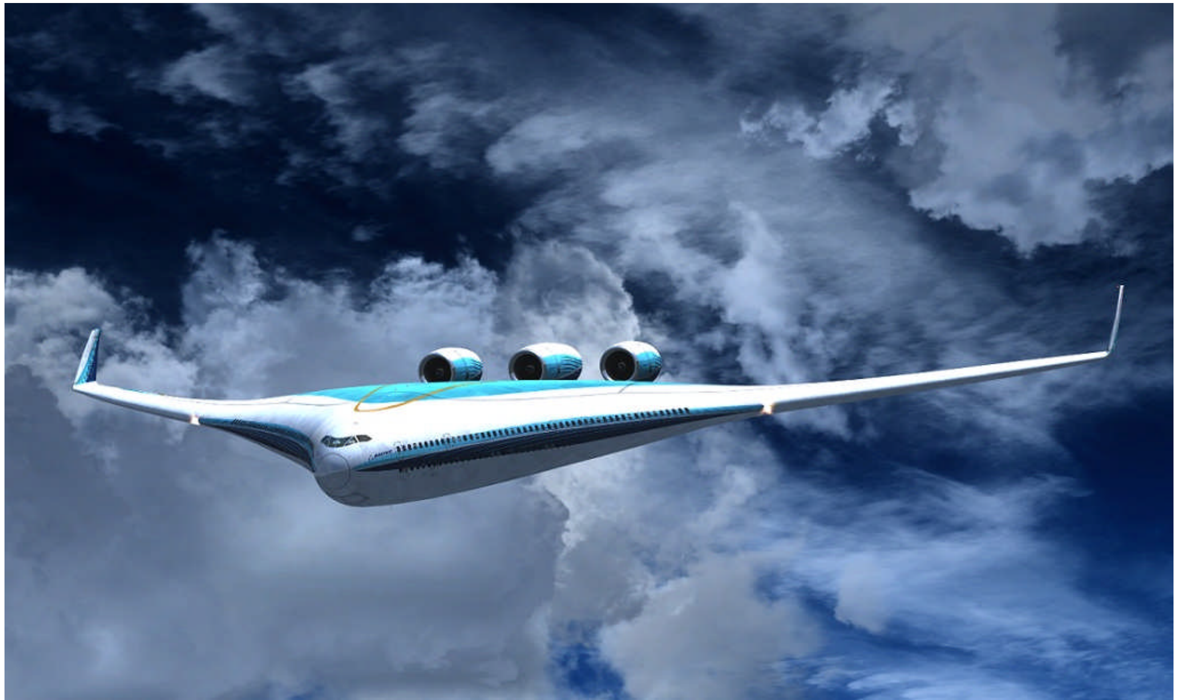

BWB concept
Two-man cockpit
Nose gear
Cabin bulkheads
Six-wheeled main gear in
unpressurized cavity
Cargo-loading door
Outer pressure
bulkhead
Split, drag
ruddevon
Wingtip
winglet with double-
hinged rudder
Elevons
Double-decked passenger
area
Single-deck cargo bays
Fuel tanks
Unpressurized
afterbody
engines
Emergency
egress tunnels

<u>Above</u>: a concept photo of a BWB commercial aircraft appeared in the October 2003 issue of *Popular Science* magazine. Artists *Neill Blomkamp* and *Simon van de Lagemaat* (of *Embassy Visual Effects*) created the photo for the magazine using computer graphics software to depict the future of aviation and air travel. It's likely the photo was inspired by models of BWB-450 (a pre-X-48 concept designed in the late 1990s) or the X-48A concept designed around 2001. The image was subsequently used in emails (since 2006) claiming that Boeing has developed a "1,000 passenger Jet Liner" (the "Boeing 797") with a "Radical Blended Wing Design" in direct competition to the *Airbus A380*. At the time, Boeing denied the claim.

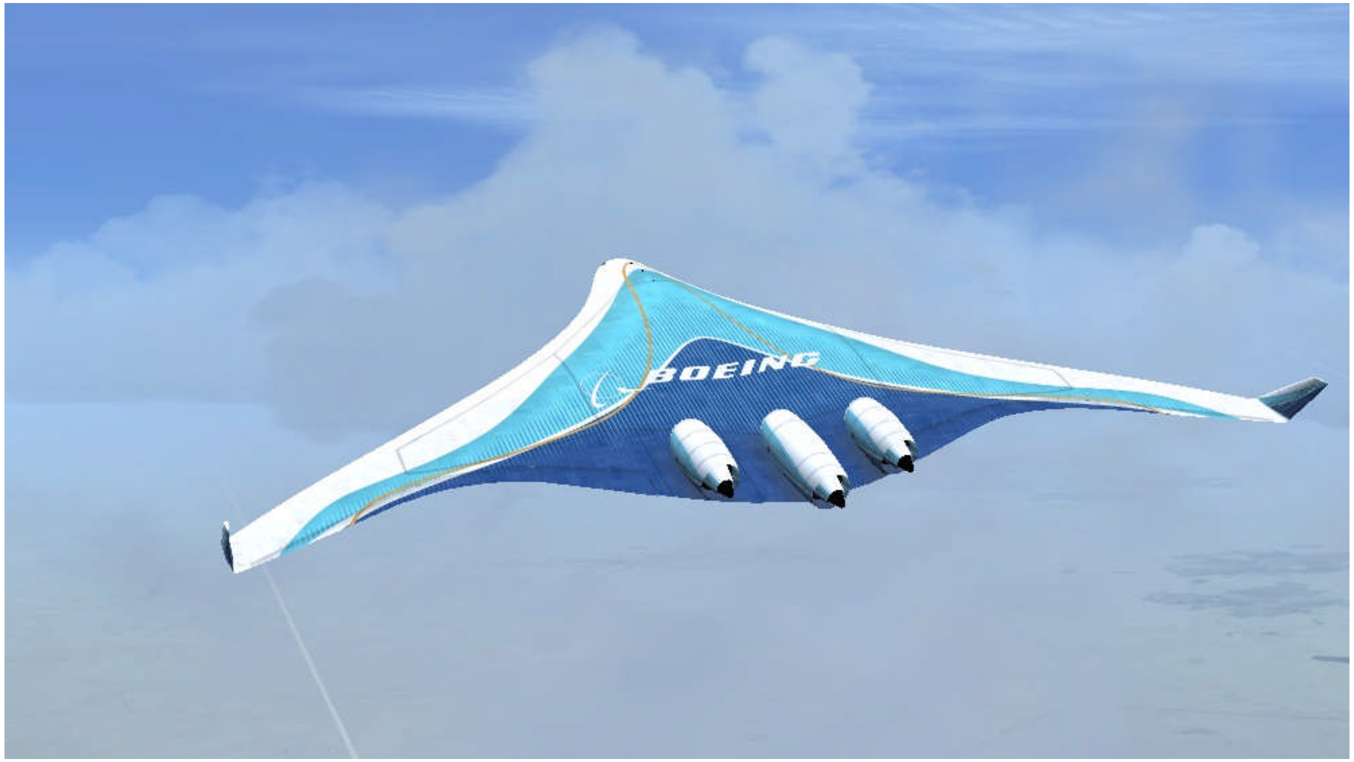

BOEING

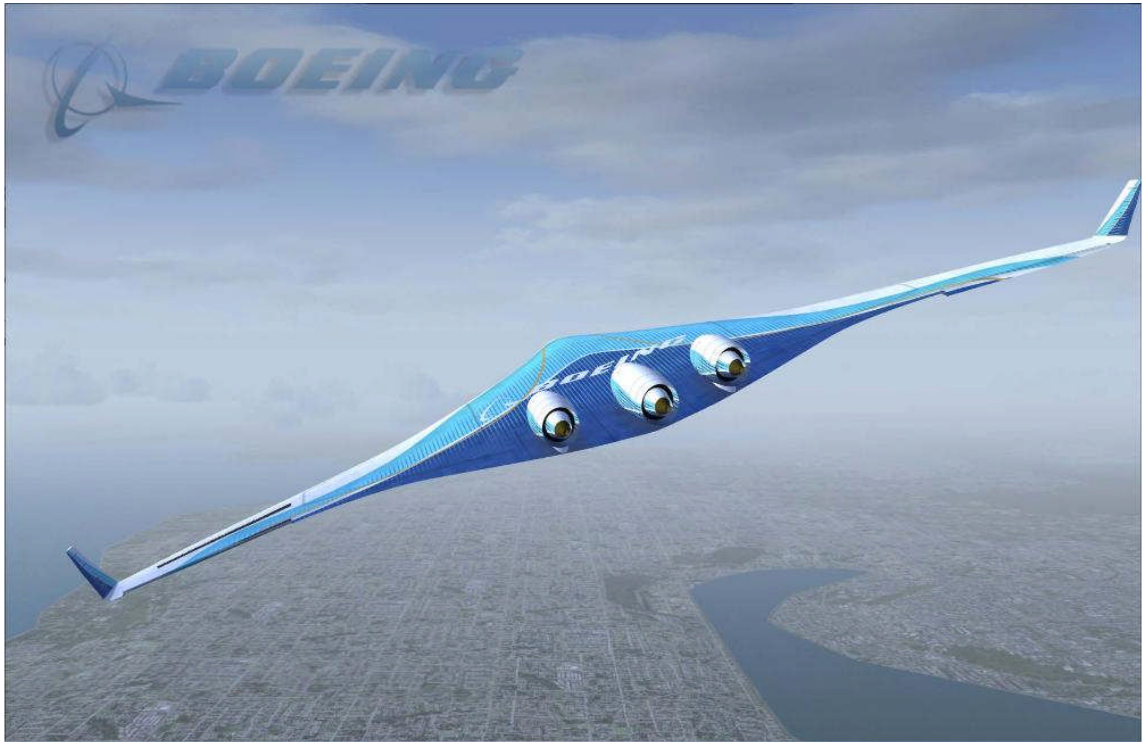

BOEING


BOEING
BOEING

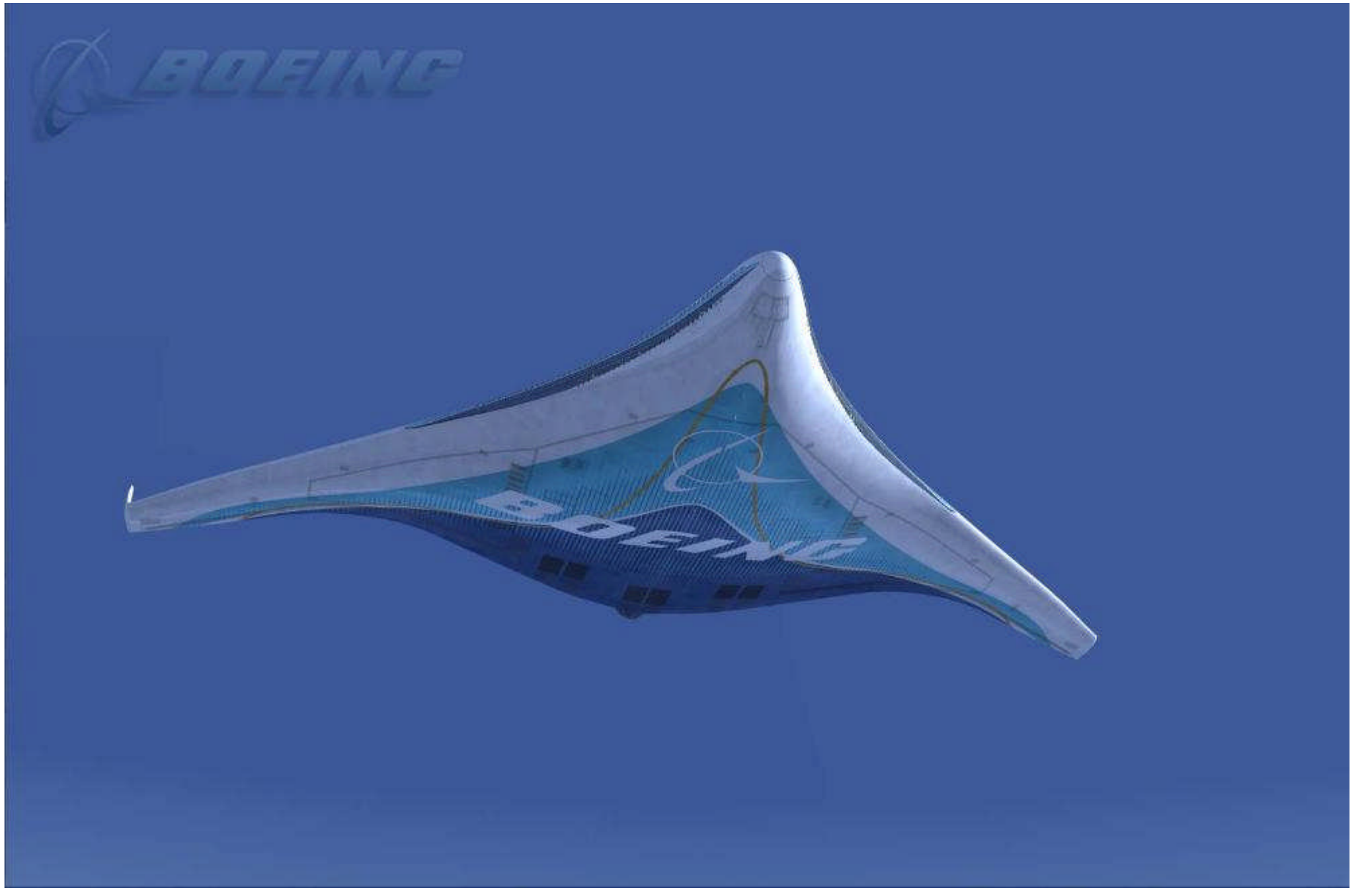


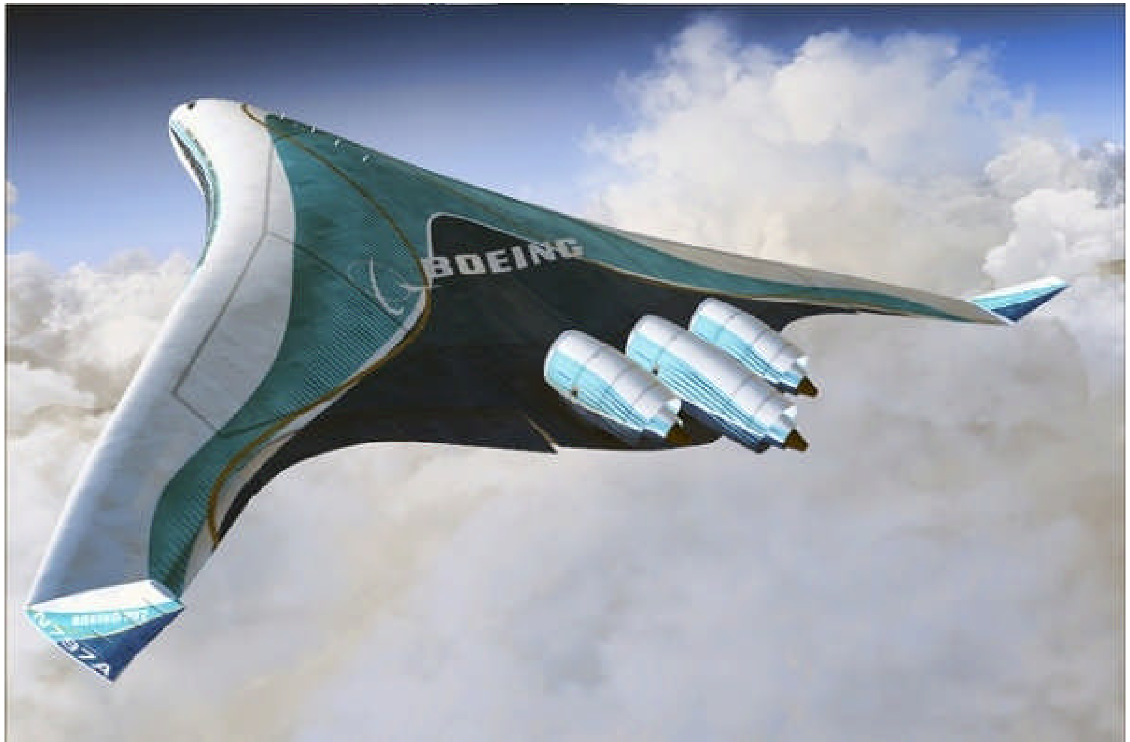

BOEING 797
N797A


BOEING

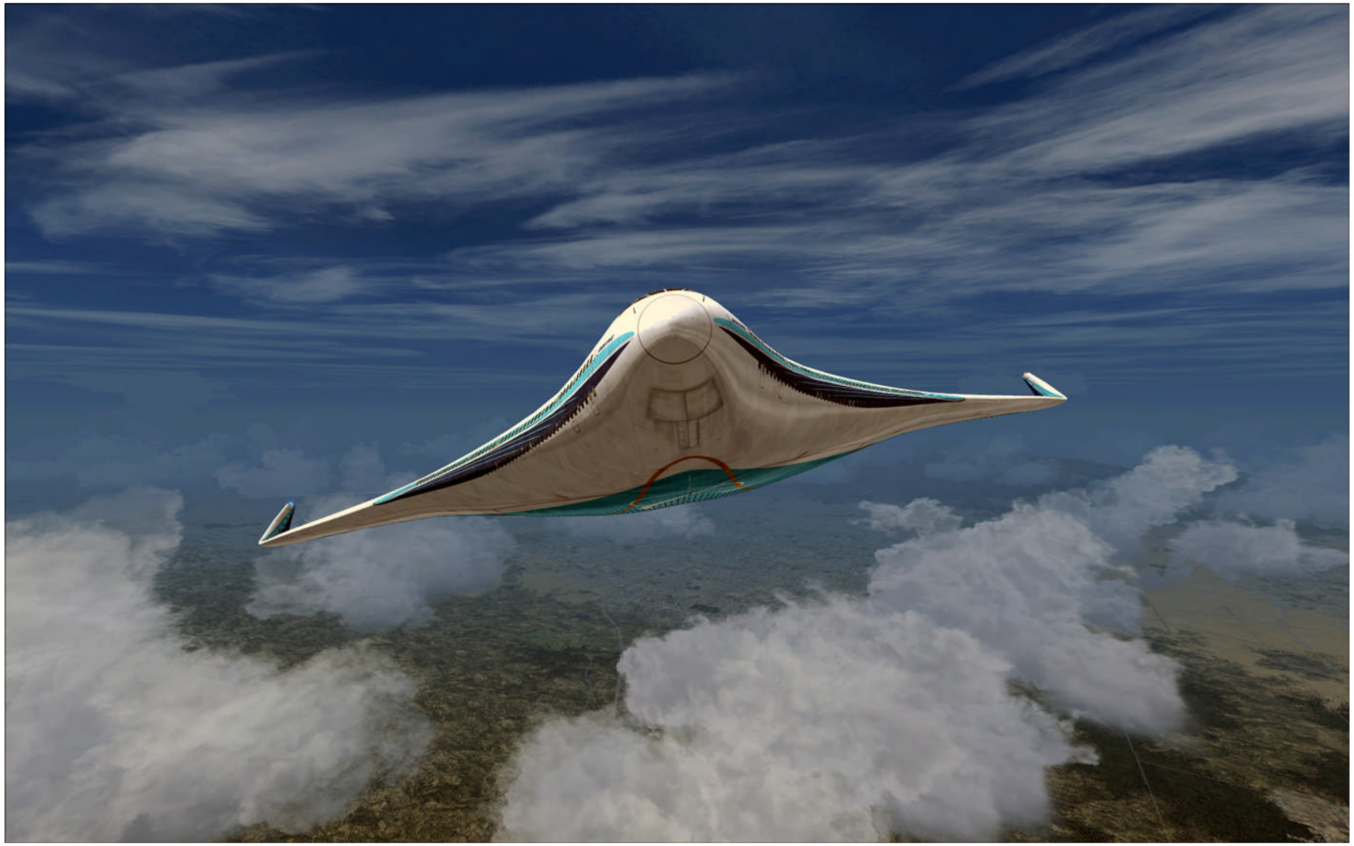

BOEING

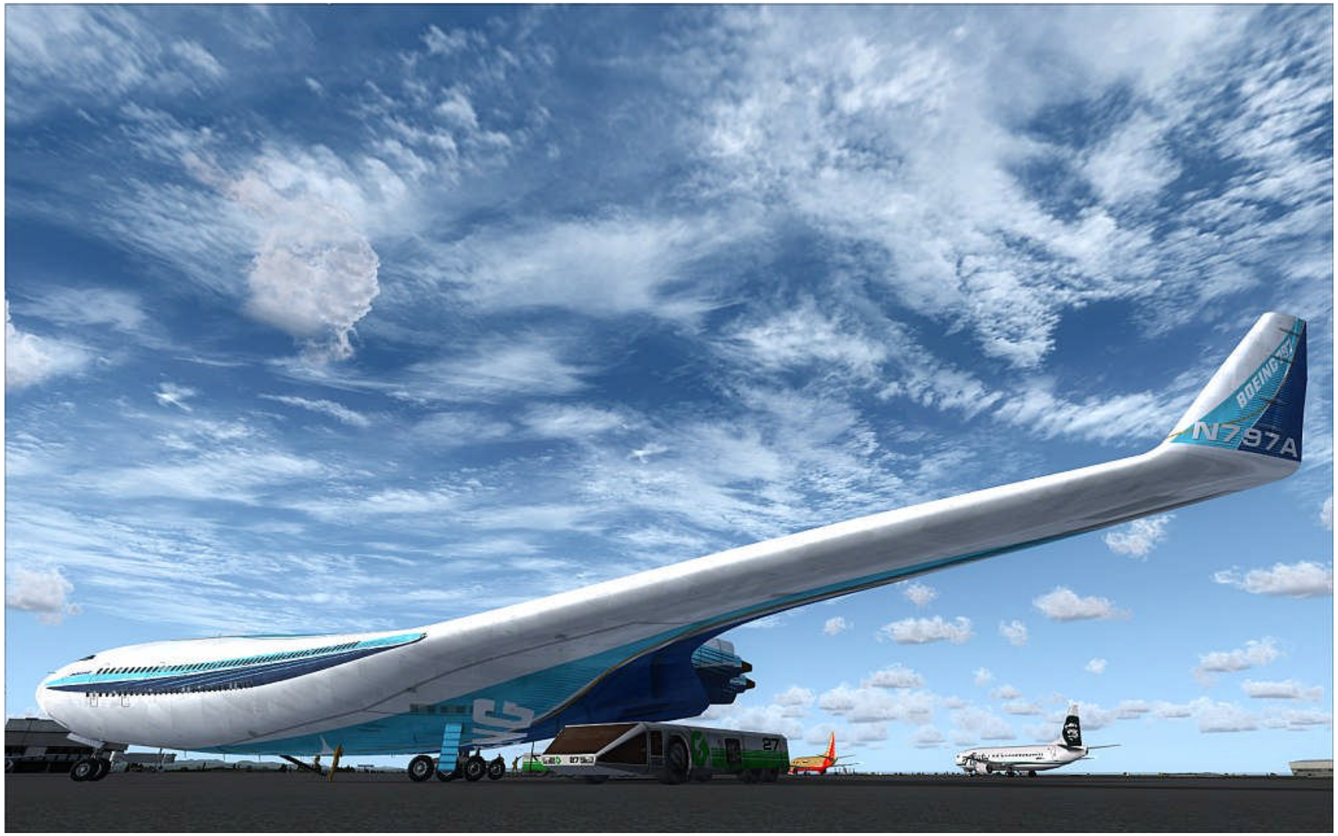

BOEING


BOEING


BOEING


BOEING

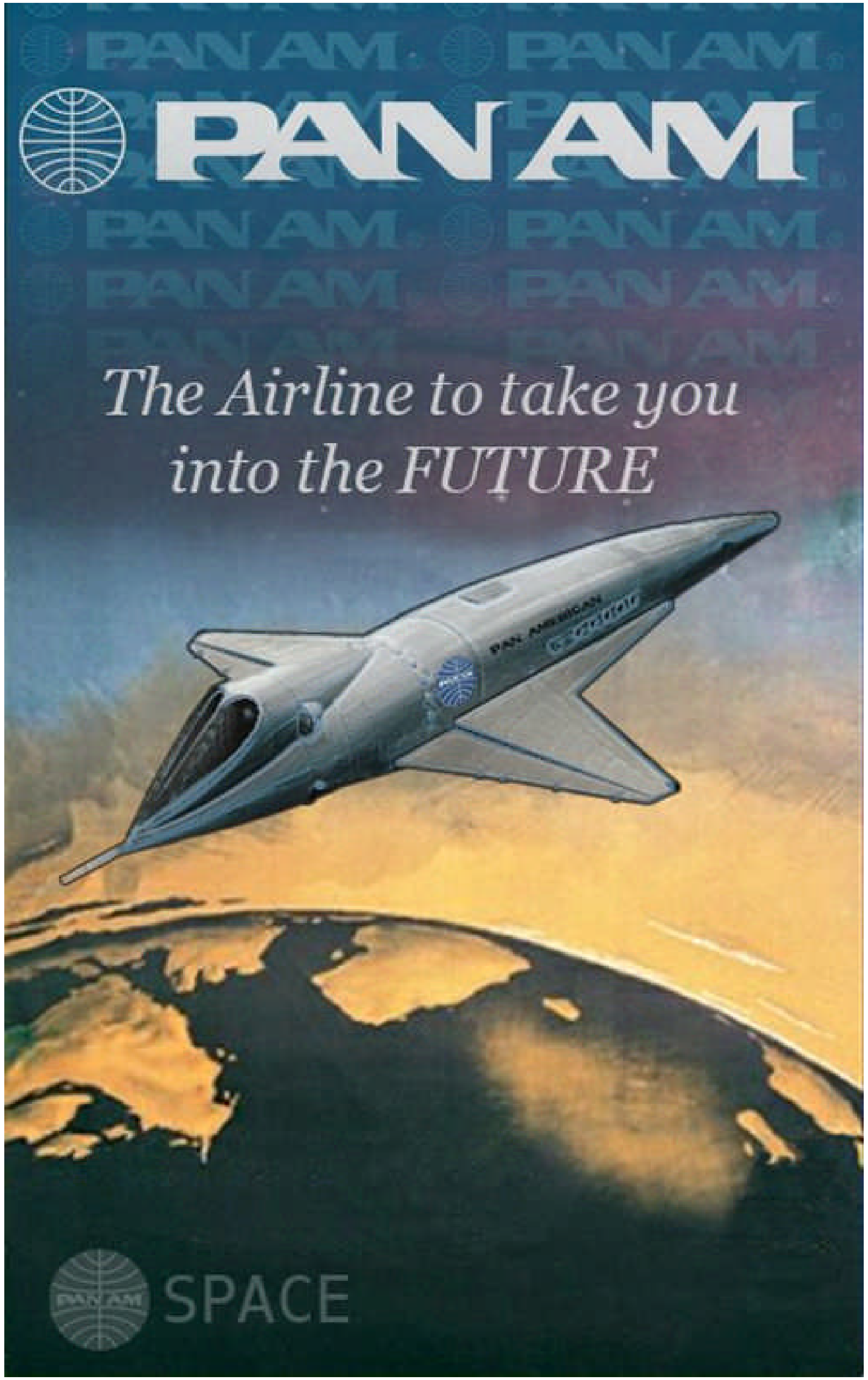



N797A
BOEING

Space Clipper

"Pan American Spaceways, commonly known as Pan Am, is the principal and largest international air and Low Earth Orbit carrier in the United States. Founded in 1927 as a scheduled air mail and passenger service operating between Key West, Florida and Havana, Cuba, the airline became a major company credited with many innovations that shaped the international airline industry, including the widespread use of jet aircraft then jumbo jets then Supersonic Transport, then computerized reservation systems and now Earth-Moon spaceflight services. It was also a founding member of the International Air Transport Association (IATA), the global airline industry association. Identified by its blue globe logo, the use of the word 'Clipper' in aircraft names and call signs, and the white pilot uniform caps, the airline is a cultural icon of the 20th century. In an era dominated by flag carriers that were wholly or majority government-owned, it is also the unofficial flag carrier of the United States. Pan Am's flagship terminal is the Worldport located at John F. Kennedy Airport in New York and its space operations are located at Space Station V in Low Earth Orbit…"

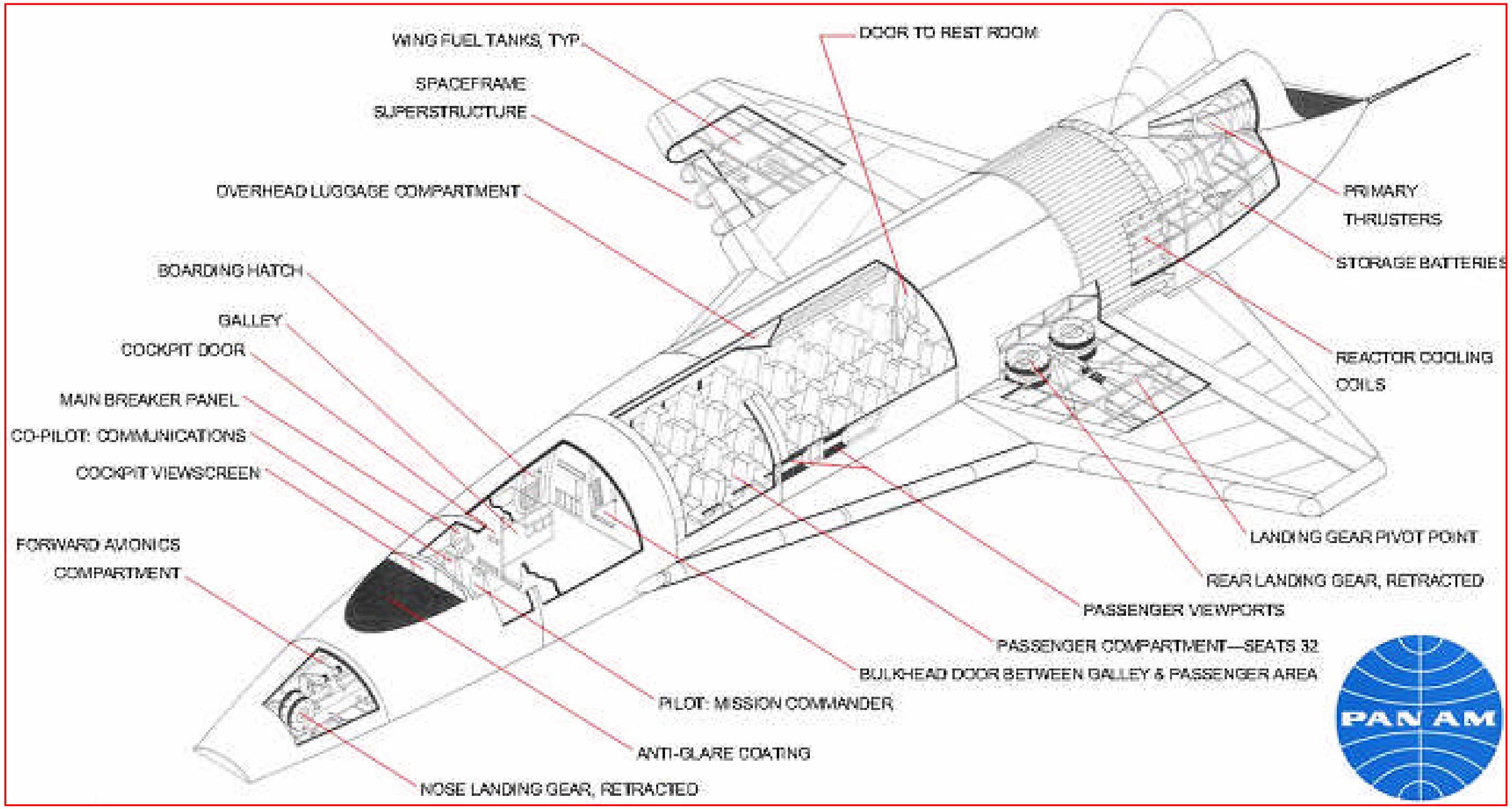
Althistory.wikia

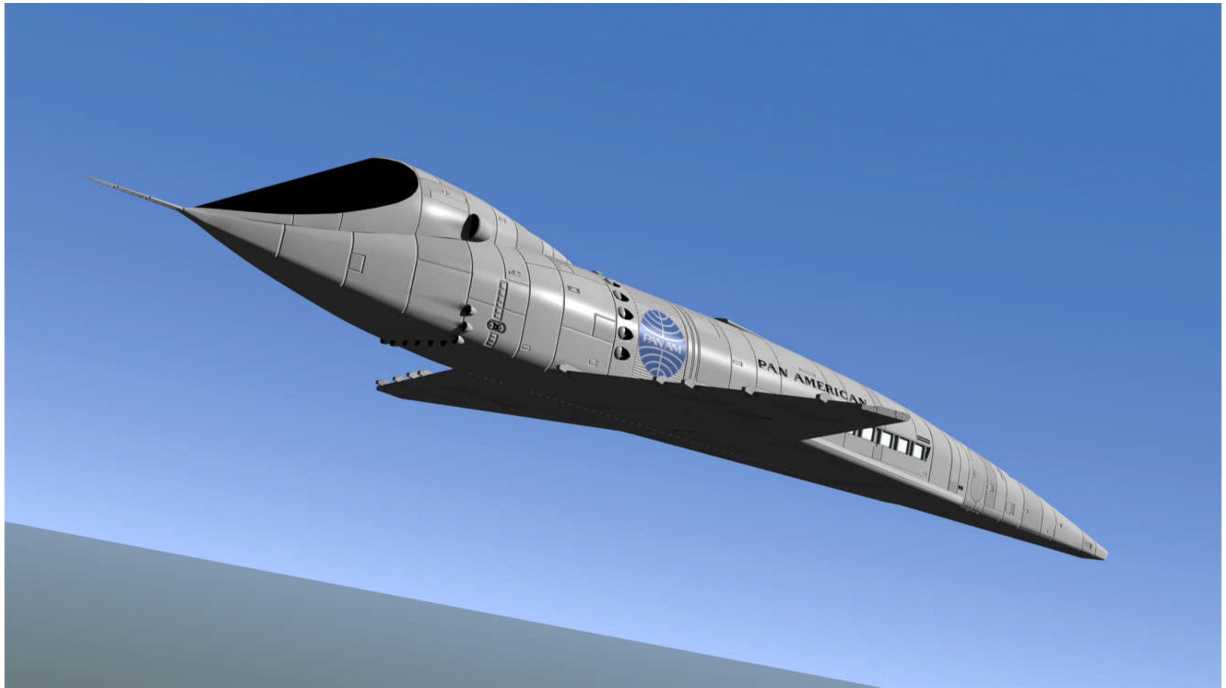


"…In the early 1980s Pan Am became the first commercial spaceline when they began purchasing and reselling seats on the Space Shuttle. Initially these tickets cost millions of dollars and many were taken primarily by the employees of in-space Research, Manufacturing and Satellite companies. By the mid 1980s however, the introduction of a custom passenger module allowed the cost per seat to reach the hundreds of thousands of dollars range. Regular traffic services to Geosychronous Orbit, Lunar Polar Orbit and the Lunar Surface have also been provided by Pan Am since the early 1980s for the low millions of dollars range. Initially, space operations were based at the 100-person Space Station-IV (a/k/a 'Space Base') but with the station's retirement in the 1990s, it has since moved to Space Station V (predicted to last well into the 2020s). The Earth-LEO or LEO-Moon/GEO Shuttles painted with Pan Am logos were dubbed 'Space Clippers…'

Althistory.wikia

Above: caption: "Orion III Spaceplane. Span: 85 Feet. Length: 165 Feet. The Orion III is a passenger spaceplane. It is a two-stage space shuttle launched on a reusable winged booster. It is equipped with Aerospike Rocket Engines and jet engines for atmospheric flight. Pan American World Airways operates the Orion III. Just as it operates the Aries IB."


WING FUEL TANKS, TYP.
SPACEFRAME
SUPERSTRUCTURE
OVERHEAD LUGGAGE COMPARTMENT
BOARDING HATCH
GALLEY
COCKPIT DOOR
MAIN BREAKER PANEL
CO-PILOT: COMMUNICATIONS
COCKPIT VIEWSCREEN
FORWARD AVIONICS
COMPARTMENT
DOOR TO REST ROOM
PRIMARY
THRUSTERS
STORAGE BATTERIES
REACTOR COOLING
COILS
LANDING GEAR PIVOT POINT
REAR LANDING GEAR, RETRACTED
PASSENGER VIEWPORTS
PASSENGER COMPARTMENT—SEATS 32
BULKHEAD DOOR BETWEEN GALLEY & PASSENGER AREA
PILOT: MISSION COMMANDER
ANTI-GLARE COATING
NOSE LANDING GEAR, RETRACTED
PAN AM


PAN AMERICAN


PAN AMERICAN

On the Lighter Side…

"Fliers nostalgic for the golden era of air travel might want to book a trip to Anthony Toth's garage. Mr. Toth has built a precise replica of a first-class cabin from a Pan Am World Airways 747 in the garage of his two-bedroom condo in Redondo Beach, Calif. The setup includes almost everything fliers in the late 1970s and 1980s would have found onboard: pairs of red-and-blue reclining seats, original overhead luggage bins and a curved, red-carpeted staircase…There's one modern update: Mr. Toth installed a flat-panel TV instead of the old projection version that would have been used in the 1980s so he could watch movies and TV using his Pan Am headphones. Airline buffs will notice that the walls actually are from a DC-10 aircraft, not a 747…"

***The Wall Street Journal*, October 26th 2009**

Above L&R: caption: "Anthony Toth in his replica 747 cabin"

"…In his 20s, Toth began gathering pieces for what has become his life's mission. He was working for United outside Chicago, and the airline had bought some of Pan Am's routes and airplanes. The old Pan Am stuff - glassware, ice buckets, serving carts, salt and pepper shakers, dining utensils and cocktail napkins - was no longer needed, so for a month Toth made nightly trips to a warehouse…Wherever he moved, his collection came, too. By the time he arrived in San Francisco several years later, Toth had created a mock airplane interior running through his kitchen, living room and dining room…Toth next moved to Redondo Beach, where he bought a condo in part because it included a 2½-car garage, and in 2007 he hired a contractor. First they worked to install real side panels and overhead compartments from a retired DC-10 airplane. Then he recovered some seats and installed a short piece of a real 747 spiral staircase…"

***San Jose Mercury News*, Feb. 22nd 2013**

"There was no other aircraft I could walk on board that intrigued me more than the Pan Am cabin. Everything symbolized something. That meant something to me as a youngster."

Anthony Toth

Above: caption: "A coffee maker with a Pan Am logo sits in the replica cabin Anthony Toth built in his Redondo Beach, Calif., home"

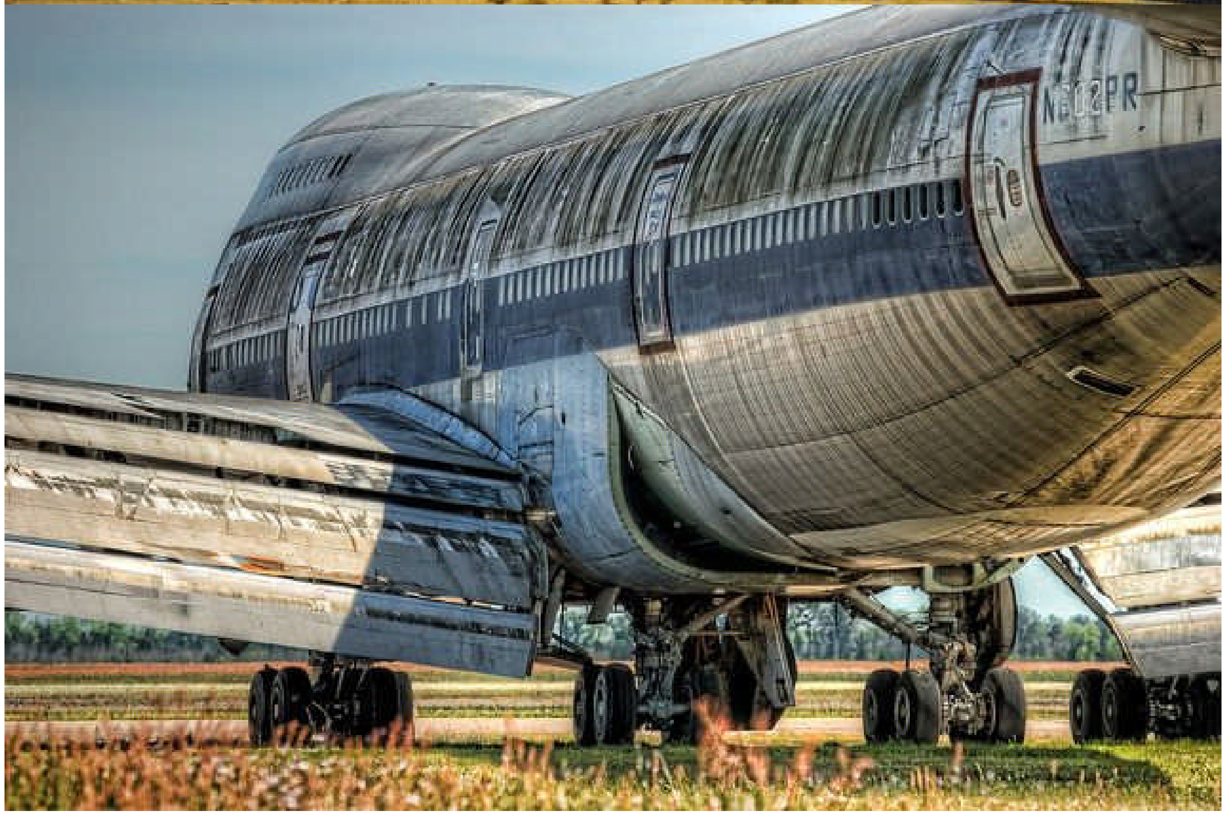
Left: caption: "Toth replicated the interior first and clipper class cabin, and upper lounge (left) of a Pan Am 747"

PAN AM

<u>Above & Left</u>: where do 747s go to die after their useful service life is over? For most, it's the deserts of the southwestern United States, but not for N747PA; the third 747 ever built, and named after longtime PAA Chairman *Juan Trippe*. It's now located in Mokpo, South Korea, where it's been turned into a 150-table restaurant.


생갈비·냉면
점보747
영업중
내부수리중
냉면


-"JUMBO747" Restaurant's History-
세계최초의 747 - 세계최대의 비행기레스토랑에 오신걸 환영합니다

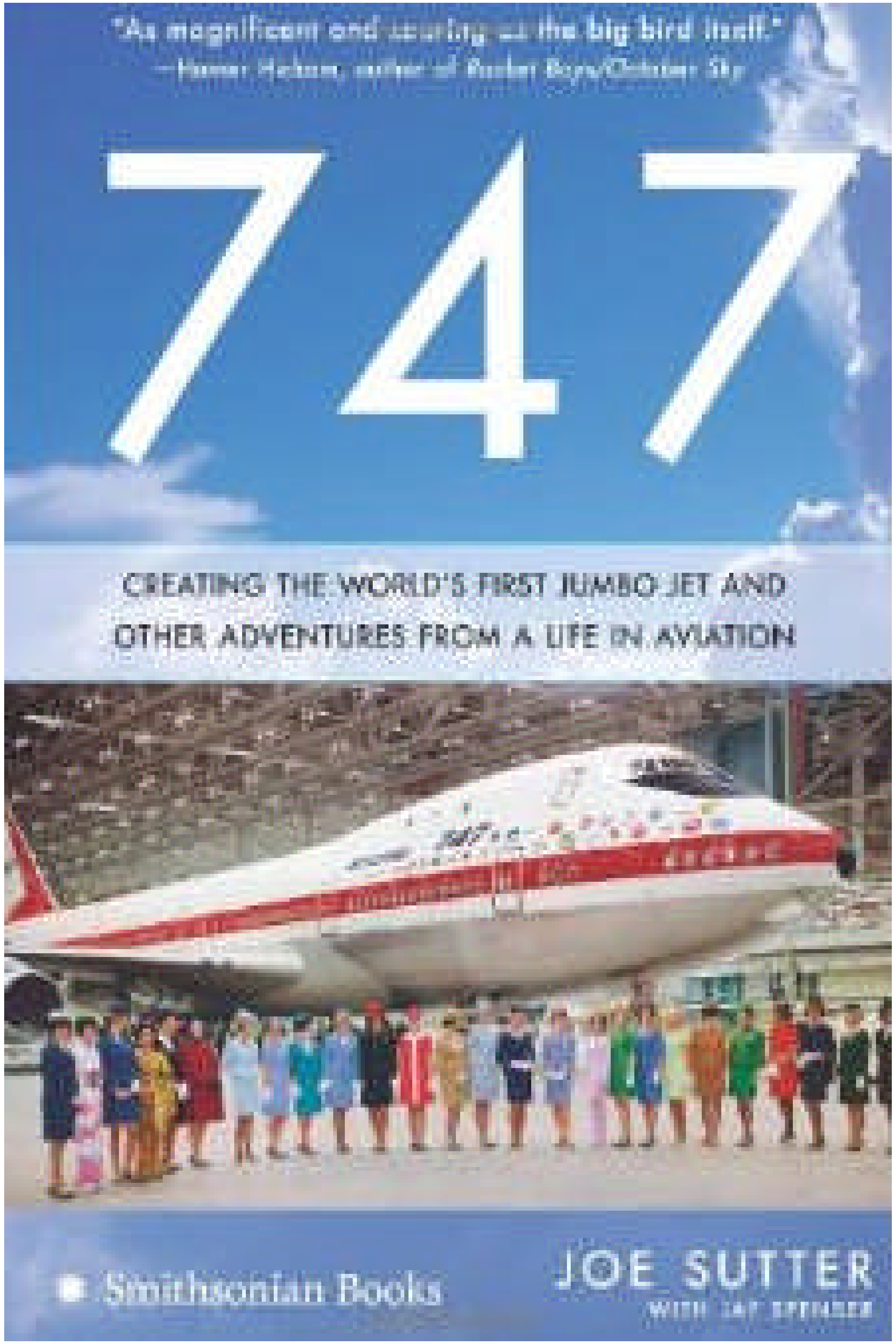


<u>Left</u>: caption: “Two ANA Boeing 747s in special Pokemon liveries.” *All Nippon Airways* (ANA) celebrated its 25th anniversary of service to the U.S. in 2011. Washington D.C. and Chicago were the first U.S. mainland destinations back in 1986. In 2011, ANA became the launch customer for the new *Boeing 787 Dreamliner* and in 2010 it retired the last of its Boeing 747-400s. ANA is now the largest and most profitable airline in Japan.


ANA
Pokémon
Jet
ピカチュウジャンボ
新ANAポケモンジェット
「ピカチュウジャンボ」
ANA

<u>Above & Left</u>: during “Operation Solomon” in 1991, 34 Israeli aircraft flew for 36 hours straight transporting a total of 14,325 Ethiopian Jews. *Operation Solomon* set the record for the largest single flight passenger load, as an El-Al 747 Cargo plane brought 1,122 passengers to Israel on a single flight (five babies were born en route from Ethiopia to Israel). This beat Quantas’ 747 evacuation record of 674 passengers in a single flight.

Father Knew Best



"I think we did something pretty damn good"

Joe Sutter, **747 Project Chief Engineer**

RE: in 2006, Sutter authored a memoir entitled: *747: Creating the World's First Jumbo Jet and Other Adventures From a Life in Aviation* (cover, at left). About once a week, Sutter will get a call from a random pilot who just wants to meet and thank the "Father of the 747" - their favorite plane to fly.