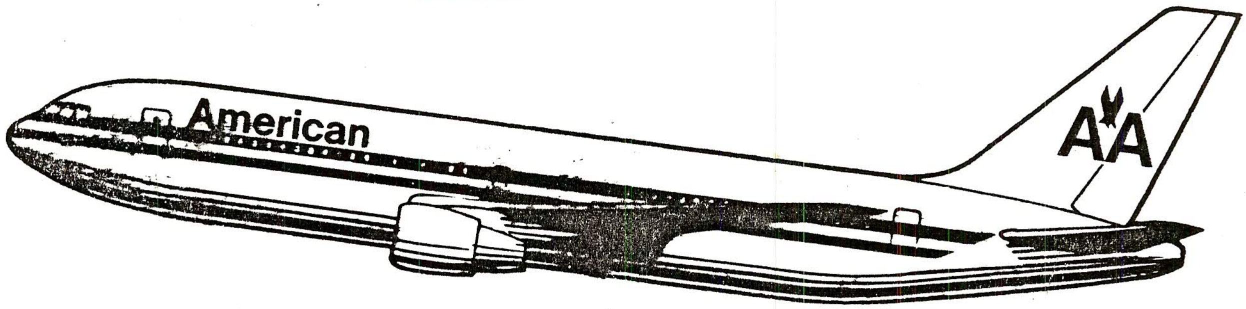
Introducing the

767



INTRODUCING THE BOEING 767

DESIGN BACKGROUND

From inception through project definition, construction, flight testing and entry into service, the development of a major new airplane typically spans at least a decade. In the 1970-71 period, the Boeing Commercial Aircraft Company began looking ahead to the eighties and nineties to determine the marketing requirements for this time frame and to see how they might respond to these requirements.

Over the next several years, as the process of defining the project reacted to evolving circumstances, design concepts changed accordingly. An initial four engine (two wing-mounted, two tail-mounted), Mach 0.98, 200 passenger transport yielded to a short haul, 150 passenger, four-engine, high wing, T-tail, Mach 0.8, STOL type. Then shoulder mounted engines on a low wing were favored as an answer to noise reduction requirements. A return to the traditional underwing podded engine configuration came next, followed by tri-jet versions with varying fuselage lengths and cross sectional dimensions, all being influenced by changing payload and range demands.

As Boeing's studies continued, two major designs began emerging. One was a derivative aircraft using the 727/737 fuselage cross-section, sized to accommodate 120 to 180 seats, but featuring a new wing and new engines. Its designation: The 7N7

The other was a new generation, medium-to-long-range twin or tri-jet of the wide-body class, with a 180 to 200 passenger capacity that would "fill the gap" between the 727 and DC-10 aircraft. Its designation: The 7X7.

Defining gave way to refining as the developmental process continued into 1978. Early that year Boeing announced that the 7N7 design would be offered as the 757, and further announced that the 7X7 would be offered in a two engine configuration as the 767, and with three engines as the 777. The 767 was planned to go forward in two versions, a -100 shortie and a -200 stretch, with the -200 finally emerging as the main project.

When American Airlines announced the decision to order the 767-200 in November of 1978, that action came as the culmination of two years of exhaustive study of all competing concepts and designs. Officially the aircraft delivered will have the designation B767-223 – the "23" being Boeing's identification for all aircraft it builds to AA's specifications. A review of its particulars are described in Figure 1.

Our primary concerns in selecting an airplane for the 'eighties and 'nineties obviously involved operating economics, and number one in this category had to be fuel efficiency. The selection of the CF6-80A as the 767 power plant was one step in this direction. From an airframe standpoint, Boeing's emphasis on lowering aerodynamic drag and reducing structural weight were two other major steps.

Basic to the reduction in drag was the employment of a new wing design, with its significant features relating to airfoil shape and wing planform. The airfoil shape, described by its developer, Dr. Richard T. Whitcomb, as "super-critical", features a flatter upper surface and a thinner, curved trailing edge (Figure 2).

On the super-critical wing, the shock wave initially forms further forward than on a conventional wing, but is lower in strength. The weaker the shock, the lower the drag.

Additionally, on a conventional airfoil, as the speed of the airplane increases toward cruise Mach, shock strength increases, reaching a point where airflow separates and becomes turbulent – which of course is the classic "drag rise" (Figure 3). But on the super-critical wing, because of its flatter surface, little or no flow separation occurs as the shock wave moves aft with increasing speeds. Therefore, the rapid drag rise associated with flow separation occurs at a much higher Mach number for the super-critical airfoil (Figure 3), and the term "super-critical" refers to this raising of the "critical" Mach number. For the sake of accuracy, we should note that while the 767 airfoil embodies all the principles of the super-critical concept, it also features certain Boeing refinements, and so they refer to it as the "advanced airfoil".

In addition to producing less drag, this new airfoil design provides more lift. It has a better flow distribution, which increases lift over a larger portion of the airfoil. It also has a curvature toward the trailing edge which produces lift in a manner similar to a flap, and does so almost to the tip of the trailing edge. This total combination works to distribute a significant portion of lift over the entire cord.

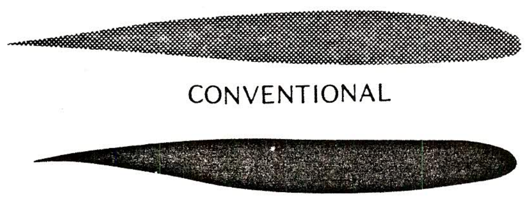


Figure 2.

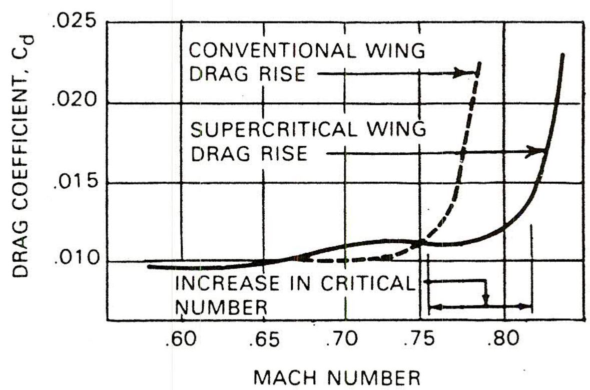


Figure 3. Drag Rise Comparison

The supercritical wing also has an improved buffet boundary; higher lift coefficients are achieved before airflow breaks down causing perceptible buffet. This means that the operational "G" and speed envelope is opened up in terms of both Mach number and buffet-limited cruise altitude, thereby providing an additional safety margin.

As to the planform of the 767 wing, it represents a reversal of the traditional design concept. Previously, the quest for faster more efficient transport aircraft tended toward increasing the wing's sweepback and decreasing its thickness, thus structural constraints dictated its span. The supercritical airfoil, with its reduced drag, permits a more advantageous configuration of thickness and span.

Less airplane weight. Improved lift. Reduced drag. All these things relate also to power requirements, which in turn associate very closely to another important contemporary aircraft consideration: NOISE. In this regard the 767 is one of the quietest large transports in the air. The engine/nacelle combination, together with the airplane's improved aerodynamic characteristics, enable the 767 to conform easily to the stringent FAA community noise requirements for the 'eighties and beyond. During the flight test program, ramp noise measured below specification levels, and flight deck noise levels were the subject of much favorable pilot reaction.

Without going into all the details of the project development, let's just note that the 767 has been designed to meet all the important criteria involving operating economics, systems reliability and noise considerations. During the flight test period, indications across the board pointed to a meeting or exceeding of all design parameters.

FLIGHT TEST PROGRAM

On September 26, 1981, at 11:45AM the first B-767 took off on its inaugural flight at Everett, Washington. What followed was a 1500-hour flight test program involving five airplanes and two engine types. This program operated with maximum efficiency by making extensive use of ADAMS-2 (Boeing's Airborne Data Analysis and Monitor System) to "gather, measure and calculate flight data", and to monitor, analyze, compare and check the validity of that data. ADAMS-2 allowed members of the flight test team from varied engineering disciplines to interact in real time with test data as it was gathered. They were able to evaluate test results instantly and get immediate repeats if needed. Considerable time and effort were saved, and paperwork was greatly reduced. As the program progressed, test data began to show very consistently that in all aerodynamic performance categories the 767 was equalling or exceeding the predictions of wind tunnel testing. "Better than nominal...," and "excellent throughout flight envelope...," were among the most frequently entered comments.

In all other categories as well – structures, propulsion, fuel, electrical and hydraulic systems, flight controls, stopping systems, anti-icing, air conditioning, the complete flight management system with all its sophistication — the summary descriptions of the flight test program were noting such things as "equals or exceeds nominal predictions" or "no major problems encountered".

Fuel consumption has proved to be lower than expected. Range and payload have exceeded expectations, and so the airplane's economics are looking to be about 7% better than originally predicted.

COCKPIT DESIGN

The 767 cockpit sets new standards for comfort and visibility. Its lamb's wool seat covers are warmer in winter, cooler in summer and conducive to better circulation and support. Its windshields, designed for greater visibility and lower drag, reduce cockpit noise as well. Innovative colors and an uncluttered appearance present a cleaner interior display. And the comfort provided by a unique air distribution system, plus improved stowage space, add two more highly desired features.

But the most significant design objectives were those that produced the features which reduce flight crew workload. The effort to simplify the overall cockpit layout concentrated on the simplification of controls and displays, lights and switches, and an attendant reduction in the number of work procedures. The "quiet dark" philosophy was employed throughout, meaning the elimination of those lights that tell you something's operating normally, and giving more attention to those that signal a problem. Extending that philosophy, emphasis has also been placed on displaying only that information pilots can do something about, eliminating that which cannot be acted upon in flight. Such information is gathered and retained, but it's stored primarily for the use of ground personnel who require it.

Now we've been purposely emphasizing the positive side of the 767's electronic equipment because automation – and that's what we're dealing with – is the wave of the future. We either adapt to this wave or, as one researcher put it, "flounder in a sea of turmoil".

But automation is not without its negative side. A focal point of any automated system is the man-machine interface. Existing on the man side of this interface is perception, a matter often influenced more by attitude than intellect. On one end of the spectrum is the perception that submission to technology equates to surrendering individualism – another facet of the classic struggle for personal identity in our modern society. The ultimate effect of this can be a reluctance to accept the reliability and capability of the equipment involved. Doubt and suspicion can generate over-monitoring and distracting fixations, a self-induced increase in workload that defeats the intent of the system.

On the other end of the spectrum is the perception that automation is the great panacea. This view trends toward a dependency that becomes a crutch. It can produce a degradation of individual proficiency. It can ultimately generate a dangerous type of complacency.

As automated systems do more of the actual flying, pilots may tend to be hesitant about questioning what they are monitoring (i.e., "This can't be wrong, the computer is doing the flying"). They may be less likely to take necessary actions, or may mentally redefine potentially dangerous situations as being non-threatening. And they may relax their overall vigilence, even though they remain consciously aware of their professional responsibilities.

The balance lies somehwere in between these two perceptions at that point where understanding and training and experience give them the perspective of intellect.

In any sophisticated technological system, a proficient, experienced, well trained, human has proved to be the critical component, capable of serving as an organizing, computing, decision-making, controlling, actuating and information-recording unit. Based on our descriptions of the automated 767 systems, these functions might be applied to many of the machine components as well. As regards the man-machine combination, the well-designed automated system is one that integrates these functions to increase the operational efficiency of both man **and** machine.

But as the role of the pilot evolves more toward that of a systems monitor, one basic question arises: Does automation change flight crew responsibility? The answer is an emphatic **NO**! Everything the sophisticated 767 systems do equates to technique. They change capability, not responsibility. They greatly enhance the ability of the "pilot-in-command" as a resource manager, and they add new dimensions to the established principles of Flight Deck Resource Management. Let's look at them again:

- Utilization of all available data to conduct an operation; consultation with all sources, printed or oral.
- Continuous monitoring and cross-checking of essential instruments and systems.
- Clear communication between crewmembers on all system information, and on all plans and intentions.
- Assessment of problems with care.
  - Avoidance of preoccupation with minor ones.
  - Establishment of a logical order of priorities.
- Assurance of sound leadership by the "pilot-in-command".
  - Appropriate delegation of tasks and assignment of responsibilities, with attention to decisions on when to take control, or when to delegate and command.
  - Avoidance of over-delegating to the point of overloading.

767 TRAINING

We've presented the 767 as a sophisticated technological system. In accepting that the critical component in any such system will be a proficient, experienced, well-trained crewmember, we recognize that the training program for this aircraft is, likewise, a critical part of the system. Accordingly, this program incorporates a new sophistication plus appropriate elements of automation that perform as well as the aircraft.