TESTING THE NEW BOEING TWINJETS

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Abstract

By 1978, the forces of the marketplace indicated a need for a new intermediate range airliner to replace the Boeing 727 which had been in service since 1964. Although the 727 had been an economical airplane, higher fuel prices and the availability of new engine and airframe technology made a new model attractive to the airlines. United Airlines became the first airline to order the twin-aisle 206 passenger 767 in August, 1978.

Meanwhile, studies were underway to develop a derivative of the 727. Derated high bypass engines finally resulted in a model satisfactory to Eastern Air Lines and British Airways called the 757. A later decision resulted in use of the 767 flight deck and a two-man crew. The passenger seating was set at 170 in mixed class, close to the 206 of the 767.

The flight test programs overlapped substantially in 1982 to create an unprecedented work level in Flight Test that year. To manage the workload, Flight Test management had to take strong action. They developed a new flight test computer system, prepared to hire hundreds of engineers and set up an extensive training program. Remote test sites were selected. Close coordination with the FAA certifying authorities was set up to enable them to examine the mass of data sent to them.

The airplane programs proceeded on schedule with the 757 about six months behind the 767. Flight testing began in September, 1981 for the 767 and March, 1982 for the 757 and both were certificated by the FAA after ten months of testing. Both aircraft exceeded their performance guarantees on all counts and showed a fuel burn improvement of about ten percent over the original specification. Program costs, recurring and non-recurring, were on target and the programs were both considered very successful.

The airplanes were put into service with few training or operational problems. Technical dispatch reliability to date has been 98 percent. Problems with the digital avionics appeared but are now greatly diminished with engineering changes and increased experience. The airlines like the airplanes and it now appears those decisions of six years ago are clearly vindicated.

Introduction

By 1978, a market had developed for a medium range airplane to replace the DC9, 737, 727 and Trident types that first went into service in the 1960s. Airline profits had been good and the optimistic mood of the times launched the MD80, the A310, the 757 and the 767. Complex decision processes in Boeing's marketing plans resulted in the 757 and the 767 being close together in both timing and passenger seats. Boeing Flight Test, after drifting through the doldrums that followed the certification of the 747 in 1969, knew there was a difficult task ahead.

Figure 1

Figure 2

Company schedules called for a ten month flight test program for each airplane; the 767 to begin in September 1981 and the 757 in March 1982. Thus the programs overlapped a great deal, especially when one considers that nearly half the flight test manpower budget is spent prior to first flight. Both airplanes involved new technical concepts in aerodynamics, structure and flight deck design that would require development testing and new certification criteria. The unprecedented workload required strong action on the part of Flight Test management.

Data Management

Boeing has not produced small airplanes in number since 1936 and our approach to data has always been to record it on board the test airplanes instead of telemetering it to the ground. Commercial aircraft in particular, permit heavy, bulky instrumentation equipment to be carried, as well as engineers to operate, monitor and, if necessary, repair it. We telemeter data only for flutter testing, which is done with a minimum crew on board.

In recent years we have been asked to acquire more data, increase the sample rate, increase the accuracy and decrease the flow time from aircraft landing to final data delivery.

To meet these demands, we have had to continually improve our data handling methods. In April 1977, Flight Test initiated a general redevelopment of its entire data system. The redeveloped system is shown in Figure 3. The system is on-line and has been used for testing since February 1981.

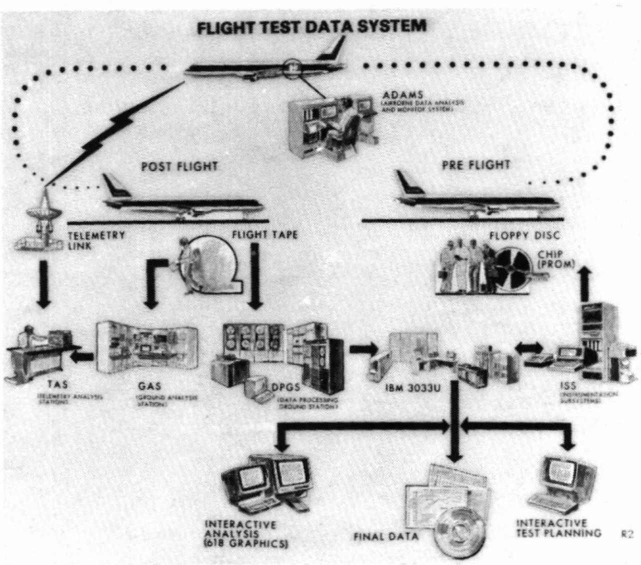

Figure 3

Airborne Data Analysis and Monitor System

The Airborne Data Analysis and Monitor System (ADAMS), which is an airborne computing system, has undergone extensive redesign to improve efficiency and provide capability. New analysis programs have been written and a graphics capability is provided. This system provides considerable final data, thus relieving the ground based computers.

Gross Weight/CG Computer

The development of micro-processors has made it possible for Instrumentation to design an effective Gross Weight/CG computer for use on board the test airplane. This not only allows us to observe Gross Weight/CG in near real time, but by recording directly on the test tape cuts out a step in our final data processing.

Water Ballast System

The Water Ballast System, which allows us to change the center of gravity in flight, has been improved by adding bigger pumps and better instrumentation.

Micro-Wave Airplane Positioning System

A Micro-Wave Airplane Positioning System, called MAPS has been developed as a possible replacement for the Airplane Position and Attitude Camera System. This system, which operates in near real time, allows the test crew to view data on board the airplane during testing, rather than waiting for film to be processed and read.

Data Processing Ground Station

The Data Processing Ground Station (DPGS), which edits and formats the flight tape data for the large scale computer, has approximately six times the capability it had during the Model 747 SP test program.

Data Analysis Systems

The Ground Analysis Station (GAS), which is a ground based version of the Airborne Data Analysis and Monitor System, has been integrated into the same facility with the expanded Telemetry Analysis Station (TAS). This allows us to share the common hardware and software that is used by each of the systems. In addition, a Modal Analysis Station (MAS) has been added, which allows Flight Test to gather and analyze various structural mode data.

Flight Test Computing System

The Flight Test Computing System (FTCS) has been completely redeveloped into an interactive system that allows the Flight Test Engineer to communicate directly with the large scale computer through the use of terminals. The heart of the computing system is an IBM 3033 computer, with all the necessary peripherals, a laser printer capable of up to 20,000 lines of print per minute, six Versatec plotters with a capability of over 40,000 feet of plotted material a day, a mass storage system and up to 130 remote terminals located throughout the Flight Test area.

Instrumentation Subsystems

Instrumentation Subsystems (ISS), which allow the Instrumentation Engineers to communicate with the large scale computer, have been installed at Everett and Renton, as well as Boeing Field. These systems are also capable of operating from remote sites such as Edwards Air Force Base or Glasgow, Montana, using telephone lines.

Improvements have also been made in the Instrumentation Calibration and Equipment Conditioning Laboratories making extensive use of mini-computers.

All of these improvements were completed prior to the first flight of the Model 767 airplane, and are being used for all current testing.

The FAA

The dual 757/767 program put pressure on the FAA just as it did on Boeing. This position had been made even more difficult by an Administration-imposed freeze on hiring and severe cuts in their budget for travel and overtime pay. We spent considerable time with FAA management and worked out a solution.

Designated Engineering Representatives

All commercial manufacturers have used Designated Engineering Representatives (DERs) to assist the FAA in certification of their products. DERs are specially selected company engineers who are deputized by the FAA to accept certain designs or test results for them in the course of their doing this work for Boeing. Most Boeing DERs come from our Technical Staff and Flight Test Engineering areas and not from our Design Groups. Therefore, their work at Boeing is that of checking or testing the work of our Design Engineers. it has been suggested that their dual role results in a conflict of interest between their responsibilities to Boeing and to the FAA. I have never heard of a single instance in the entire industry where improper approval has taken place, and I believe this to be because the DER's company responsibilities are, in fact, nearly identical to their FAA responsibilities.

The past success of the DER method lead us to believe that an expanded use of DERs in the engineering details would permit the certification process to occur on time. We believed the FAA should free themselves from these roles to permit them to oversee the process as a whole and assure themselves that our methods result in accurate data to enable them to evaluate the aircraft against the Regulations. The FAA accepted our plan which was a big help in completing the program on time.

Manpower also posed a problem. Within one year we had to double our engineering manpower to 900 while training the new hires completely. Even the experienced engineers had to learn the new computer system. Furthermore, to stay within our budget, we had to move about 300 people off the program in a very short time at the end of the test period. Fortunately, other Company divisions needed engineers at that time so the process was completed without layoffs.

The Flight Decks

The BAC 1-11, DC9 and 737 had long since shown that modern airliners could be flown safely with a two-person crew, but the pilot unions of the world had been opposed to operating any new airliner with less than a three-person crew. A U.S. Presidential Commission in 1981 found the two-person crew to be safe and the various pilot associations generally accepted this finding. The 767 had been designed for either a two or three person crew but had been ordered with a side facing flight engineers position. Our customers now asked Boeing to change to a two-person flight deck while maintaining delivery dates starting in August of 1982. The first thirty 767s were actually built with flight engineers positions but only the six flight test aircraft were flown in that configuration. The others were all sent through a modification line and converted to a new two-person flight deck. Fortunately, the design was already available.

The 757, mainly upon the insistence of British Airways, had been designed from the beginning with a two-person flight deck. Although workload in the 737 had been completely satisfactory, further steps were taken to reduce crew actions in the 757 and 767. Both airplanes had been designed with digital avonics including a fail-operational autopilot system, a thrust management system, laser inertial reference units and a flight management system with a moving map display. The 757 engine indicating and crew alerting system (EICAS) was now added to the 767. In fact, the flight deck design was kept close to identical in the two aircraft so that a common FAA type rating might be obtained.

Figure 4

The idea of a common type rating began when the decision was made early in the 757 program to replace the 727 flight deck of the 757 with the fully designed 767 flight deck. Although the cabin width of the 757 was much narrower, the flight deck could be faired in retaining the 767 structure forward of the pilot's shoulders. Although the airplanes were considerably different in size, weight, payload and range, every effort was made to make the handling qualities and systems as alike as possible. Any differences in the flight deck had to be approved by a senior vice president and very few were.

Flight Test Development

In the very early period of the 767 program we found that the leading edge flaps deflected excessively at flap placard speeds. A new supporting structure had to be designed and the flutter tests were completed with a conservative flap placard. Fortunately, both airplanes met their guarantees on both low and high speed performance and, with the exception described below, met all handling characteristics required by the FAA without design changes.

In the early design period, a lot of controversy existed about the position of the horizontal stabilizer. A T-tail prevented pitchup at high speed in accelerated flight but exhibited difficult stall characteristics. A low position of the stabilizer displayed the reverse. After much discussion about drag, a low-mounted stabilizer was selected and plans were made to correct any pitchup encountered in flight test. As soon as flutter clearance was obtained, high speed turns at high altitude were conducted revealing that pitchup did occur at a level beyond certification limits. This is illustrated in Figure 5.

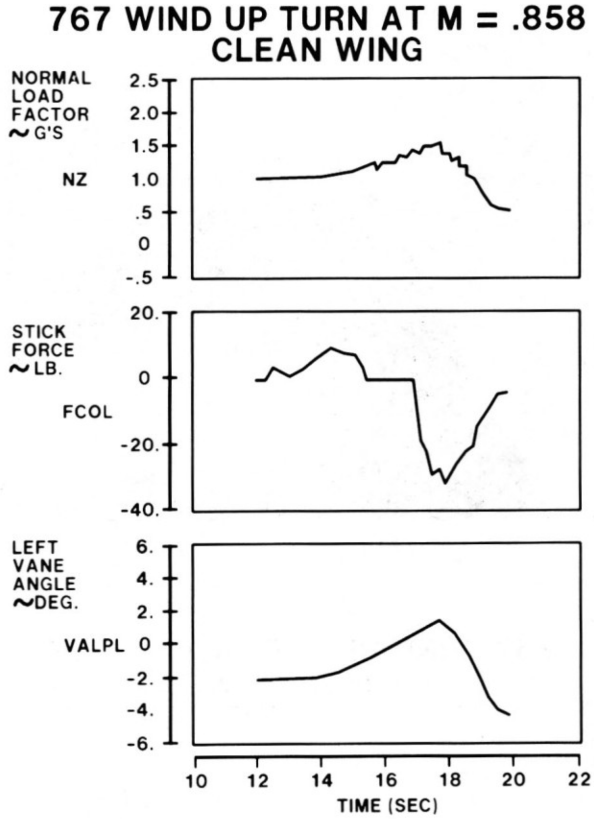

Figure 5

Whenever aerodynamic problems occur, Boeing traditionally turns first to the vortex generator. The upper wing surface was covered with a double row of vortex generators from the nacelle to near the tip. They did reduce the pitchup but the drag would not have been acceptable so sections were removed until we found the minimum number that would still do the trick. A series of tests revealed that the array shown in Figure 6 (only seven small generators on each wing), reduced the pitchup to a safe level as shown in Figure 7. This particular result was one of the most important on the whole program since the solution was simple and gave no measurable increase in drag. The same problem and a near-identical fix occurred on the 757 program as well.

Figure 6

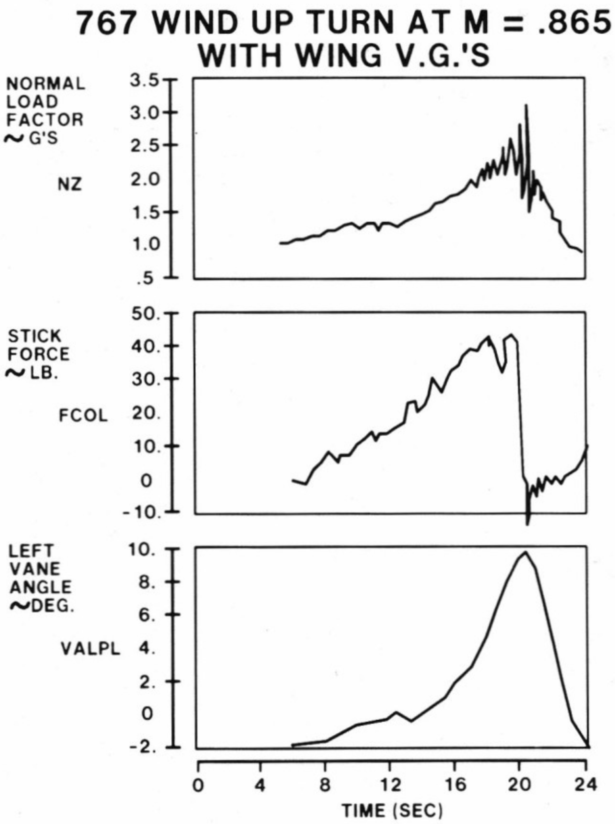

Figure 7

With the exception of the digital avionics, the test program was quite trouble free and consisted mostly of producing data for FAA certification against a very difficult time table. The avionics, however, were new to everyone and required a good deal of development before we could demonstrate a workable system to both the FAA and our customers.

The Results

Both airplanes were really technical successes. They exceeded our nautical air miles per pound of fuel estimates by about four percent. They were ten percent better than the airplane we had promised to our early customers. Noise levels, both inside and out, takeoff and landing performance, empty weight and cruise speeds all equalled or bettered guarantees. The stall characteristics are truly benign as shown in a flaps-up stall in Figure 8 and a flaps five degrees stall in Figure 9.

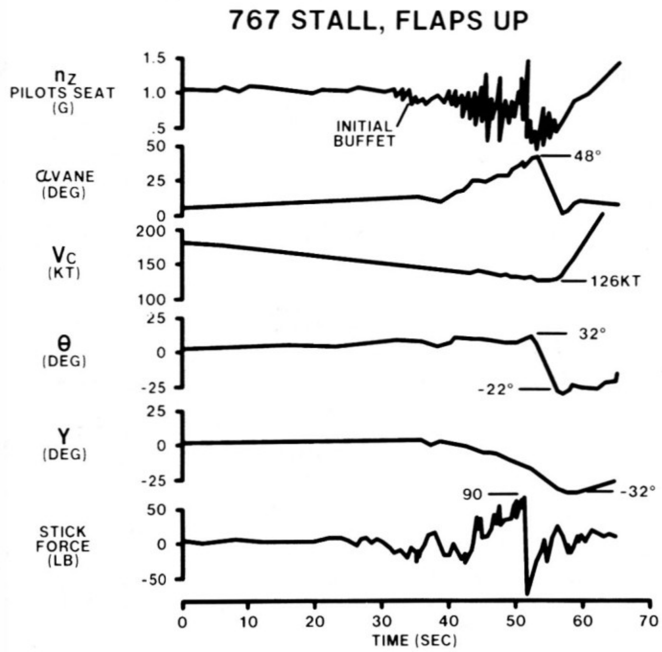

Figure 8

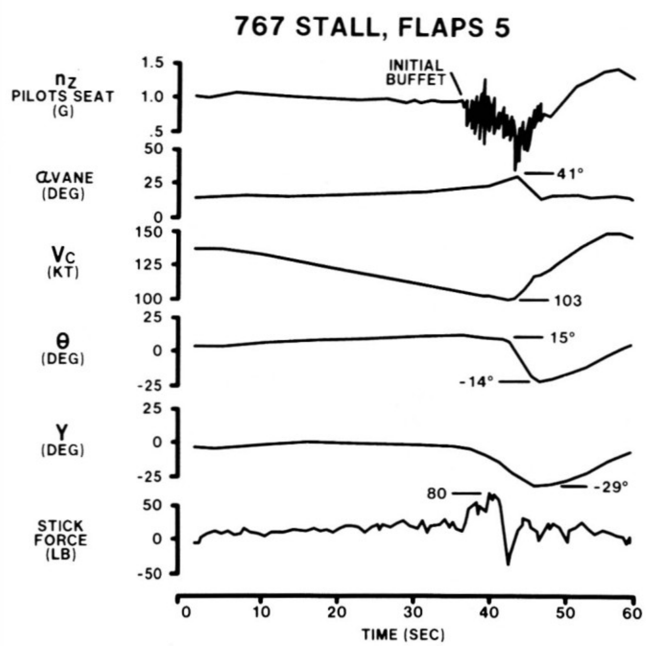

Figure 9

After both airplanes had been certificated we proposed to the FAA that a common type rating be approved. We suggested and the FAA agreed to the following program:

a. Two FAA pilots and two Boeing pilots trained in the 757 but never exposed to, or in any way trained in the 767, would be given standard flight checks in the 767 simulator and aircraft.

b. Similarily, two FAA pilots and two Boeing pilots trained only in the 767 would be given flight checks in the 757 simulator and aircraft.

Both groups passed their checks almost flawlessly; not a surprise to those of us who knew how much effort had gone into keeping the two flight decks and the procedures nearly identical. The FAA then announced that anyone who was rated in one aircraft could be considered rated in the other if given a four hour course in differences. Thereafter a simulator check in one would serve as a check for both.

In Service

As everyone knows, the 757, 767 and A310 have not been ordered in the numbers originally expected. There are many reasons for this but the quality of the new aircraft is not one of them. We have had very good acceptance of the aircraft by airline maintenance, pilots, and passengers. The two-man flight deck and the new flight management system has been accepted happily by nearly all our customers.

Pilot training is demanding for a pilot unused to the new environment, but the modern simulators with their excellent training qualities have enabled us to maintain training periods of slightly shorter duration with only one-half hour in the actual aircraft per pilot.

The maintenance people have also had a great deal to learn but current dispatch reliability is now at 98 percent average - - close to our planned mature rate of 98.5 percent. Many airlines have already exceeded 98.5 percent. Avionic testers are coming into use for the new avionics equipment and experienced technicians now consider the digital units easier to maintain than the analog.

We are proud of our new twinjets and believe they have a lot to offer the airlines. We hope the economic fortunes of our customers improve so they may continue to put these new technical marvels in service.