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The Jetliner Flight Trials & Other Things

Chronology

The development flight trials started with the engine ground runs in May of 1949 and lasted until February 1951. However flying did continue until November 1956, at which point the airplane was scrapped and destroyed. The post development flying was devoted to the support of the CF-100 program principally as a high speed observation program for aircrew escape trials, canopy ejection, rocket firing, and as a possible airborne platform for the development of the Hughes radar and fire control system for the CF-100. Hughes aircraft who were under contract to the Canadian Government for the CF-100 fire control system realized the potential of the Jetliner with its high speed and altitude performance would be a major asset in this program. This investigation resulted in the direct involvement of Howard Hughes himself who quickly realized the potential of the airplane for his TWA (Trans World Airlines). He spent considerable time flying the aircraft and did every thing possible to convince the Canadian Government to make a deal. After 6 months of trials and negotiations the deal fell through much to the disappointment of Avro. We had another go with the USAF for a crew trainer, but it also fell through. We did manage to get a letter of intent to buy 6 or so Jetliners from National Airlines who wanted the aircraft primarily for the Miami to New York traffic to challenge Eastern Airlines who held the record for the shortest time between the two airports with their Lockheed Constellations. Unfortunately the Canadian Government would not allow us to dilute our resources which were committed to making up for lost time on the CF-100 problems.

The trials:

Engine Ground runs

These began in May of 1949, and it soon became apparent that the nacelle structure surrounding the jet pipes were overheating, as I had predicted several years earlier when I performed the analysis, and at that time had proposed a possible solution. Unfortunately no action had been taken by the design people with the result that we did not have a ready made fix. I proposed a rather simple solution, but had a number of detractors. The upshot of it all was that I was instructed to contact AVRO and Rolls Royce in England about my proposal. I was also instructed to phone them as well, which was quite an expense, and erratic in those days. I had proposed that it was necessary to increase the flow of the ambient air between the outside of the jet pipe and the inner surface of the surrounding nacelle. I had a scheme to add a simple flared ring that projected out past the tail pipe exit at the rear end of the nacelle so that it would act like an atomizer on a perfume bottle. The high velocity of the hot jet efflux would create a low pressure at the ring and this would "suck the cooler air from the engine compartment thus achieve the desired result. This device (augmentor) was approved by my colleagues in England and we installed the augmenter and ran some more engine tests with gratifying results. Additional insulation had been added to the pipes during this interval without much success. Most of the delay was spent waiting around for a decision. The actual fix itself only required a few days. This episode did cost us the honour of being first in the world to fly a jet transport, which went to DeHavilland with their Comet which occurred about two weeks ahead of us. We also lost precious time during the taxi trials.

Taxi Trials

The Taxi tests were conducted during July of 1949. Two major obstacles occurred that caused our already tight schedule to slip further. The first obstacle was that the Department of Transport had decided to up-grade the runways and forced us to operate from an extremely short macadamized runway in very poor condition. The second obstacle was the unusually high temperatures which were consistently in the upper 90s and lower 100 degrees Fahrenheit. The high temperatures meant that the thrust derived from the Derwent engines would be well below their rated values, thus significantly reducing the Jetliner acceleration which in turn meant that we had to reduce the maximum speeds attainable. We were confined to the lower speeds which did not allow the test pilot, Jim Orrell to get a good feel of the flying controls. We also discovered that the macadam surface became very soft that it actually flowed as the aircraft wheels passed over and left grooves in the runway surface. This resulted in the wheels locking as the brakes were applied due to the resultant low coefficient of friction of the viscous macadam and the tires. The rubber on the tires was quickly scuffed down to the tread resulting in tire blow-outs. We used up an excessive quantity of tires, wheels and brakes. It combination of these most difficult trials and excessive heat was extremely hard on both flight and ground crews. We wanted to reach take-off speed to achieve a short hop in order to give the pilot a brief "feel" and then bring the aircraft to a safe stop. We waited until late afternoon when the temperature had dropped a bit. Jimmy Orrel tried to pull this off, but the aircraft acceleration was still insufficient to safely get airborne, so he had to quickly apply his wheel brakes resulting in blow-outs of all four tires. So we had to give up and carry on without the benefit of the "short hop".

Initial Flights

The maiden flight took place on Wednesday August 10,1949 with Jimmy Orrell, Don Rogers and Bill Baker. The flight was lasted about an hour and described by Orrell as a "piece of cake" and that the Jetliner was a perfect lady.

The second flight took place with the same crew on August 16 and turned out to more than we had bargained for. On this flight Jimmy Orrell carried a number of engineering and handling tests including stalls. When he selected undercarriage down, the main gear failed to respond. Only the nose gear came down. Although there were several emergency procedures, including manual to lower the gear, none worked and after numerous attempts the predicament became worse as all the hydraulic fluid was pumped overboard (inherent in one of the emergency procedures) and the final situation was that the nose gear was locked down, and could not be retracted and the landing flaps were inoperative due to the lack of hydraulic fluid and pressure. The decision was made to land the Jetliner on an unused, and very short runway in this unorthodox configuration. Fortunately with this arrangement the landing was almost normal, like a "tail sitter", and minimal damage occurred. In addition to further pilot familiarization tests, the flight had been planned as a demonstration for the employees and was intended to last about an hour. The flight time ended up at two and a quarter hours. We had the Jetliner flying again within five weeks completely repaired and with the undercarriage flaw fully understood and rectified. In retrospect this misfortune, the way it turned out may have been a blessing in disguise.
The third flight took place on September 20 to check out the modifications to the landing gear locking system. All went well.
The fourth flight took place later that day with me onboard. The purpose of this flight was to obtain an assessment of the effectiveness of the double surface rudders in order to assure ourselves that the effectiveness of the directly pilot operated smaller rudder was indeed as we had predicted and would meet the one engine out failure scenario at take-off speed. This we were able to verify. The forward rudder was designed to be electrically driven controlled by an electronic servo device to follow the manual rudder as it was moving. Unfortunately the designers contracted to supply the equipment could not guarantee that the system would behave as specified; there was a possibility it might enter into an oscillatory mode which lead to serious consequences. The servo system had been abandoned, and it was replaced by an electric power actuator which was controlled by a pilot operated switch. In essence what we had was form of "trim tab". Another concern, and we were able to resolve it on this particular flight was the potential loss of rudder effectiveness in those situations where a "dog-leg" developed. To explain further in the event that the power driven rudder was say 10 degrees to the right and suddenly the pilot applied full manual rudder 15 degrees to the left would the aerodynamic lift and moment coefficients become non-

linear? Fortunately this did not occur and the control system behaved as we had predicted. It was shortly after these flight trials that it occurred to me that we could completely fulfill all the Jetliner directional flight requirements by solely using the manual rudder with increasing its travel from 15 to 30 degrees and permanently locking the power rudder at the zero angle. I was firmly convinced that this would be satisfactory as I had performed all the original analyses several years previously when I, as group leader of aerodynamics, was reporting to Chamberlin. Unfortunately when my proposition was referred to Engineering, Jim Chamberlin was opposed to the modifying the rudder travel limits on the grounds that the vertical and rudder effectiveness at the greater angles (above 15 degrees) would be far less than I anticipated. I believe that Chamberlin took this stance since he may have felt that his design authority was being challenged (or his "ego" or personalities); anyhow the rift between us rapidly became greater. I had the flight test results along with my original design analyze to absolutely prove that he was wrong! Having failed with this statement, he then threw up a second obstacle wherein he warned of the strong probability that with the forward (powered) rudder locked in place, the tail section could flutter with disastrous consequences. He managed to frighten the Chief Engineer into adding a second seal on the forward rudder (a lot of poppy-cock) and conduct a series of ground resonance tests, which were unnecessary. Needless to say everything checked out satisfactorily. The irony of this futile exercise is that it required a 48 hour non-stop effort as the Jetliner was scheduled to be flown for an airline executive who was very interested in the application of the aircraft for his company. This was a particularly hectic time for the aircraft program and we could ill afford this type of nonsense where the company was being held at ransom due do the temperament of one individual. Incidentally we knew that all was well prior to the resonance tests as a member of Chamberlin's staff, tipped us off about the validity of the flutter analysis lacking sound technical substance.

Stability Testing

Early in the flight test program we investigated the longitudinal flight stability limits to determine the static and maneuver (stick force per "g") margins. Don Whittley, who was in charge of the aerodynamic flight tests, had during his previous stint as an aerodynamist reporting to Jim Chamberlin voiced his concerns about the destabilizing effect of the air flow over the wing being entrapped downstream by the jet engines' efflux would increase the downwash over the horizontal stabilizer and thus reduce the stability margin for what we termed the "engine on" case. With idle power from the engine this additional destabilizing effect should not occur as there would little effective jet efflux. Don based his analysis on data from the German sources and from the Gloster Meteor flight measurements. Although the wind tunnel tests conducted during the design phase gave us excellent stability data, it was not possible to simulate the effect of jet engine inlet and outlet (exhaust) flows. Preliminary flight test data indicated that there was an adverse effect, but we had to wait until we had installed the necessary instrumentation and water ballast tanks which we used to alter the center of gravity of the Jetliner during flight. We were able with this water ballast system to place the center of gravity beyond both forward and aft limits allowing us to investigate the more sensitive zones. The final result did establish that this phenomena did indeed exist and that we were faced with a loss in the stability for the aft center of gravity situation. The generally agreed, except for one dissenter, yes Chamberlin, remedy for this was quite simple, requiring the addition of a twenty four inch section to the forward, ahead of the wing, Jetliner fuselage. This would also allow us to squeeze an additional row of seats, accommodating four extra passengers. This modification was planned for the second Jetliner along with a revised tailplane and slotted landing flaps. Jim Chamberlin's objection was that the forward center-of-gravity would be limited. In a memo he issued was that in the event there were only four passengers on board, and these passengers all occupied the first row of seats, leaving the rest empty and the fuel remaining was zero, then we would have a serious stability problem. Need I say more! Stability limits are generally pegged at those center-of-gravity positions wherein the aircraft will, when the hands are off the controls and any disturbance encountered such as an air gust enter a divergent motion eventually leading to a stall, dive or spiral. Stated in another way the unstable aircraft demands that the pilot constantly control the aircraft which can be tiring, but in no way catastrophic if he is on "the ball". The Spitfire was not a particularly stable aircraft which enhanced its maneuverability leading to one of its attributes as a successful fighter aircraft. It would only be a matter of time that we would have adopted a "fuel management" system (common day practice now) where-in the fuel remaining in the aircraft tanks would be pumped or transferred in maintain the center of gravity in an optimum position, not only for the sake of stability, but to minimize the aircraft drag by reducing the amount of elevator deflection required for trim or in new designs smaller control surfaces. This stability problem was blown out of proportions by those that did not understand the basics. Jim Chamberlin came up with a scheme, that could solve this another way by using weights and springs integrated into the elevator control system. He was very secretive about it, had the equipment made and flight tested it the Jetliner. The results were never divulged, so we can only assume that it did not work. We did our own separate analysis of the device and concluded that it did not have any merit. In the interest of company harmony we kept our assessment to ourselves.

The water ballast system served two purposes; 1) a rapid and precise way of locating the centre-of-gravity at will an 2) a quick manner of jettisoning the water in order to rapid reduce the aircraft weight for landing. There was no provision for fuel jettisoning on the first aircraft as it was not required in the specifications that had been agreed upon with Trans Canada Airlines, since at that time the gross take-off weight of the Jetliner differed very little from the allowable landing weight. (this would have become a requirement as the aircraft was further developed to carry greater payloads and/or increase in range. The following story has been told a number of times and concerns the ballast system. On this particular flight the water ballast tanks were full and sufficient jet fuel had been taken on board to achieve maximum allowable take-off weight of 63,000 pounds. During the tests which were being conducted at high altitude necessitating the use of oxygen masks, the battery compartment began emitting some smoke and the pilot issued the command "dump water". The engineering observer in charge of the ballast system must have only heard the first word "dump" which sounded like "jump" and called the pilot on the intercom if he really meant "jump". He was assured that by the pilot that he meant dump water. The story of this incident has been repeated numerous times and embellished out of all proportions. It did point to our own failings in not providing correct terminology such as "jettison ballast" instead of "dump water". The engineering observer was subjected to a lot of harassment over this incident. He did become excited but he certainly did not panic.

Aborted Take-off Trials

The take-off performance of an aircraft must meet several criteria: one of which is to establish the take-off distance to clear an imaginary 50 foot obstacle located at the end of the run-way, with the sudden failure of the most critical engine at the ground speed where the decision must be made by the pilot to either continue his take-off and clear the 50 foot obstacle or if he decides to stay on the ground be able to bring the aircraft by cutting the power of the remaining engines and apply braking, to a safe stop at the end of the runway. The speed can vary with the take-off weight of the aircraft and must be considered for every take-off as a go or no-go point.

We performed the tests to clear the 50 foot obstacle with the simulated engine failure at decision velocity at Malton since we were not concerned with aborting the take-off. In order to conduct the aborted take-off trials we needed all the safety margin we could get, and since the runways at Dorval Quebec were much longer than those at Malton, we decided to do the tests at Dorval which used to be the jumping off point for the Ferry Command ~~ferry~~ service to the U.K. during the war and in most ferrying operations the aircraft were probably over-loaded and required all the take-off ground roll they could get.

We had installed anti-skid devices on all four wheel brakes. They were the latest thing then (they have been become standard (40 years later) on automobiles today, and the purpose was that when the pilot applied wheel brakes through his rudder pedals they would be activated to sense the rotational deceleration and if the deceleration were to exceed a predetermined value that would lead a particular wheel brake to lock-up and result in the tire skidding with not only losing the frictional force (once a tire skids the co-efficient of friction drops rapidly) thus requiring a longer distance to stop the aircraft but also lead to tire blow-out. Only if we had had these devices during taxi trials, we may have been able to upstaged the DeHavilland Comet's first flight. Unfortunately the Department of Transport (D.O.T.) would not allow us to use the anti-skid system since they had yet to been approved by the U.S. Flight Authorities as their application had not been recognized as critical since their propeller driven were equipped with reverse pitch propellers which were used as brakes during landing. Anyhow after much cajoling we reached a compromise with the D.O.T. staff to let use the signal lights on the pilot's panel to warn him that the wheel brake was exceeding the pre-set limit. The automatic feature that would prohibit the braking wheel from locking up was disconnected. The D.O.T. did not want us to succeed since this would have put the responsibility on their shoulders for setting up requirements. D.O.T. had always let the British and United States air authorities do the spade work and were satisfied to ride on their coat tails. Despite the negativeness of the D.O.T. we were able to establish the critical speed, or as it is now called V-decision where the distance required to clear the imaginary 50 foot obstacle at the end of the runway or bring the aircraft to a safe stop within the same distance. In several of the runs the aircraft stopped within a few feet of the end of the runway but the penalty in burst tires and worn brakes was quite costly. As a matter of fact we ran out of spares and had to delay some of the tests until additional equipment arrived from Malton. The tests were also telling on the test pilot, Mike Cooper-Slipper who nevertheless kept his "cool" throughout the ordeal. Mike was never fore-warned as to which engine would be cut by the copilot in order to simulate a realistic random engine failure. It is a far cry from today's jet airliners who not only have anti-skid breaking systems but are equipped with reverse thrusters which have greatly contributed to their safety record. We had to conduct these test at 5 A.M. to take advantage of the still air conditions and to off the runway by 8 A.M. so that we would not impede normal air traffic operations. We were well treated by the local authorities.

Des Murphy and the Broken Rudder Pedal

We were very fortunate that during our pre-certification trials to have a very capable test pilot on D.O.T.'s staff conduct flight tests. It was rare to find amongst the negativism of the D.O.T. department an individual who was not only extremely capable but objective in his role. Thanks to him we made some real progress.
On a particular series of test flights we were deterring the Jetliner's rate of climb with one engine out, landing gear extended and with the wing flaps in the take-off configuration and flying at a speed 20 percent above the stall. In spite of the fact that we had established the engine failure take-off from start of ground roll to take-off and climb out, the U.S.A. Civil Aircraft rules (C.A.R. 04) specified that the total distance should be demonstrated by performing each segment, that is ground roll with one engine out, additional ground roll to the decision speed and then stop. The climb-out was to be performed in at a safe altitude and the resulting performance added to the results established during ground tests. In other words the real life case was not required to be demonstrated, probably due to the hazards involved with windmilling propeller contributing a great deal of drag and the lower net trust from the remaining operating engines as well as the need for the pilot to counteract the aircraft swing caused by the high off-set drag from the windmilling engine. Under a critical condition such as engine failure on take-off the pilot and the propeller pitch system response, there is insufficient time available for feathering the propeller.
We did carry out an engine failure take-off with Des Murphy at the controls. All went smoothly, Des applying a slight rudder correction to compensate for the asymmetrical thrust, and proceeded with the climb to altitude of several thousand feet. We then proceeded to perform the low speed, one engine out, flaps and landing gear down tests. The unthinkable happened the rudder pedal arm snapped, quick response by Des by increasing the power of the dead engine easily got us out of this hazardous situation. I have often wondered what would have happened if the rudder pedal failure had occurred during the earlier take-off tests. I'll never know. We were embarrassed and even more so when after we had landed one of the ground crew came to us with a piece of the rim off the main wheel. Some one had found it off the side of the runway that we had been using during the take-off tests. A quick inspection revealed a large bulge on the side of the tire at the spot where the piece had broken off. The gentle landing had not put any undue strain on the damaged tire as it held firm and did not burst. What a day.

High Speed Flight

On the 22 of November,1949 we decided to fly the Jetliner to its limiting speed. We found it fairly quickly. At 30,000 feet we gradually accelerated and as we reach a true speed of 500 miles per hour, the Jetliner suddenly pitched nose down, and Don Rogers quickly pulled back the throttles and the aircraft recovered. I knew instantly what had happened, as I had been aware of the criticality of the juncture between the horizontal stabilizer and the vertical fin where the peak negative pressures of the two surfaces coincided and at a modest Mach number would break down with the result that the center of pressure of the tailplane would suddenly move aft, along with some loss of lift, thus increasing the nose down moment. Compare CF-100 / JETLINER — CF100 TAIL/FIN

Position Error Measurements

We used three techniques to determine the position error of the Jetliner Air Speed System.

a) Using a trailing streamlined body "bomb" which was housed under the fuselage and when in flight lowered by means of a cable and winch system so that the "bomb" was several hundred feet below and behind the aircraft. We would then record all the static pressure instruments, pilot and co-pilot's, those mounted on the photographic observer panel and piped to various test orifices on the fuselage and of course the "bomb" itself. Recordings were made for the complete speed range of the Jetliner and also for the landing and take-off configurations, that is for landing gear down and various flap deflection angles.

We conducted the tests at both high and low altitudes to cover any effects of Mach Number (air compressibility).

One on of the flights that I was on board, we were flying at about 16,000 feet and I had removed my oxygen mask, as the pressurization system had not been as yet ~~had been~~ completely installed, in order to operate the winch for the trailing bomb and return to the observer's station to operate the recording camera. The camera chose this particular instant to act up. In my frustration I removed the film cassette and hurled it down the fuselage which was unusual for me to lose my "cool" in this manner. Upon later reflection I concluded that I must have been suffering anoxia due to the lack of oxygen. Later on we purchased a more reliable camera equipped with a large spool of film which relieved the observer from the task of chaining film cassettes in the middle of the tests.

b) Photographic Method

As a cross check to the trailing "bomb" a series of fly-by were conducted at the airport which were photographed by several cameras, and by triangulation it was possible to determine the exact height of the Jetliner above the ground. These readings were then compared to the indicated altitude recorded on board the airplane and the difference was then converted to a velocity value for each of the indicated air-speeds. The tests covered a range of speeds from 1.2 times the stall up to maximum of about 450 miles per hour in the "clean configuration" and a narrower range of speeds for the flap and landing gear extended representing take-off, approach and landing speeds. The results were in complete correlation with the trailing "bomb" tests.

c) Calibrated pacer aircraft

We were able to take advantage of an offer from the United States Air Force to use their specially calibrated pacer jet fighter to fly along-side the Jetliner and check the speeds over the operating range. Again these readings verified the results of the other two methods.

Fortunately the tests with the U.S.A.F. pacer aircraft ended a long standing controversy that had started several years earlier during the design phase. Again it was Jim Chamberlin on the one side and myself on the other. The issue in my opinion was to have far reaching consequences. In a nutshell when we were calculating the performance of the Jetliner and using these data to determine range, cruise speed and economics of airline operation, Jim who was the boss, insisted that in determining the drag of the Jetliner and thus the engine thrust required that we use the "compressible q" (the dynamic pressure which was the product of half the atmospheric density multiplied by the square of the true velocity multiplied again by the compressibility factor relating to the true velocity). What this meant was that for a given velocity of say 400 miles per hour at 30,000 feet the "q" (dynamic pressure) would be 250.5 pounds per square foot. Introducing the compressibility factor of [1 plus (Mach squared divided by 4) where Mach Number for 400 miles per hour at 30,000 feet is 0.59], then the compressible "q" becomes 272.3 pounds per square foot. This would then require additional thrust from the engines along with an increase of fuel consumption. As I stated earlier in this report our drag estimates were right on, but unfortunately we were penalizing the Jetliner with this unsubstantiated and incorrect method of performance determination. During our negotiations with Trans Canada Airlines in 1950 when we were soliciting their continued support for the Jetliner, one of the negatives that they used for abandoning the project was that they wanted an airplane with an optimum cruising speed well above 400 miles per hour instead we were only claiming something less. (we at that time had not determined that we indeed had an optimum cruising speed of 425 to 450 miles per hour).

Through-out the entire flight testing program for both the Jetliner and the CF-100, we were always on the defensive from engineering concerning accuracy of our results, especially in those cases where the results did not agree with their (engineering's predictions). We could never completely satisfy them.

Compressible "q"

During the design stage, Jim Chamberlin had insisted that the effect of Mach Number on the stagnation pressure "q' = 0.5 (X) air density X true velocity squared be used to establish the speed/power relationship. This decision (we could not sway him) meant that the speed of the Jetliner would always be lower than the true speed thus mislead the operators in believing that the block time for the various routes would be longer than actual and that the fuel consumption would also be greater. He was absolutely wrong in his interpretation of predicting the true speed. The table below shows the differences for flight speeds at 30,000 feet altitude;

True Speed M.P.H.	Mach No.	Compressibility Factor	Original Computed Speed M.P.H.
300	0.44	1.024	293
350	0.51	1.032	339
400	0.59	1.043	383.5
450	0.66	1.053	427
500	0.735	1.065	469.5

We were then able to update our performance figures which had a significant impact on reduced flight time for the longer stage routes as well as a reduction in operating costs.

Other Events

WW II TYPE ELEVATORS

Icing Trials

Fuel Consumption Flights
- Triangle Non-Stop
  - Rumble over Ottawa
- Intercity Flights
  - LaGuardia Shimmy
  - Winnipeg Deep freeze
  - Los Angeles
  - New York City
  - Miami National Airlines
  - Washington

Howard Hughes Interlude

CF-100 Testing Support
- Canopy Jettison
- Pilot Bail-out

Rocket Firing

TO BE COMPLETED!