ICAS PAPER
No. 72 – 41

THE DEVELOPMENT OF A PROTOTYPE
STOL SYSTEM DEMONSTRATION

by

Donald L. Button, Manager
Canadian Air Transportation Administration STOL Project
Ministry of Transport
Ottawa, Ontario, Canada

The Eighth Congress of the International Council of the Aeronautical Sciences

INTERNATIONAAL CONGRESCENTRUM RAI-AMSTERDAM, THE NETHERLANDS
AUGUST 28 TO SEPTEMBER 2, 1972

Price: 3. Dfl.

THE DEVELOPMENT OF A PROTOTYPE STOL SYSTEM DEMONSTRATION

D. L. BUTTON
Manager, CATA STOL Project
Canadian Air Transportation Administration
Ministry of Transport
Ottawa, Canada.

ABSTRACT

The Canadian Ministry of Transport has embarked on a program to implement a downtown to downtown IFR STOL demonstration service. The system will operate between specially constructed STOLports built in Ottawa and Montreal. The demonstration is designed to test passenger and non-passenger public acceptance of STOL operations and to develop standards, criteria and regulations for STOL. Area navigation and scanning beam microwave landing systems are an integral part of the system, as well as steep approaches and departures, including newly developed zoning standards. Specially modified de Havilland DHC-6 Twin Otter aircraft will be used.

INTRODUCTION

For a number of years there has been much discussion in many parts of the world regarding the application of STOL as a solution to the short-haul air transportation problem. Considerable research and testing has been carried out on various facets of STOL, however, for a number of reasons, no true downtown to downtown IFR STOL system was ever developed.

Canada appeared to be in a rather unique position regarding STOL. We had a vehicle, the de Havilland of Canada DHC-6 Twin Otter, which was being used in many parts of the world in the STOL role. On the drawing boards we had the DHC-7 which was designed as a commercial C/STOL aircraft and the Canadair CL-246 which was a partial variable incidence wing derivative of the V/STOL CL-84 test vehicle.

Canada also had the organizational infrastructure which was capable of initiating and implementing a full STOL system trial.

It was obvious that if the full potential of the proposed DHC-7 and CL-246 type aircraft was to be realized in their STOL role the additional components of the STOL system had to be developed.

Therefore, as a result of proposals and recommendations by the Science Council of Canada and the Canadian aviation industry, the Minister of Transport, in May 1971, instituted a program to implement a STOL demonstration system.

While a number of Canadian Government Departments are participating, the main thrust is being provided by the Ministry of Transport.

Several parts of the Ministry are involved; The Transportation Development Agency is responsible for design of operating policies and evaluation of the demonstration; an Air Canada subsidiary will be the air carrier on the system; the Canadian Air Transportation Administration is responsible for the development, implementation and operation of the technical system; a component of the Ministry itself is responsible for the administration of the project.

This paper will discuss mainly the activities of the Canadian Air Transportation Administration.

The specific tasks allocated to the Air Administration were:

(a) Determining operational requirements;
(b) Selecting and evaluating potential system components;
(c) Developing operating criteria, procedures and regulations compatible with the systems developed, and consistent with existing levels of safety;
(d) Providing the necessary STOLports, navigation and communication facilities, and airfield maintenance equipment;
(e) Finally, operating the STOLports and facilities.

After a study of various possibilities the route chosen was Ottawa, Ontario, to Montreal, Quebec, a distance of 90 miles. Some of the factors considered were, stage length, competition with existing travel modes, ability to carry out trials in a high density terminal area, availability of STOLport sites, and forecast passenger demand of a reasonable level.

Sites were selected in each city using standard airport site selection procedures with the major considerations being:

- Proximity to city centre;
- Minimum noise exposure to residential areas;
- Ability to have the facility construction completed by a mid-1973 operation start date.

A full-time project team of nine people was set up to plan and direct the activities. The team included four specialists from Canadian industry, covering the fields of architecture, avionics, ground electronics and aeronautical engineering.

The activities were divided into five general areas:

- STOLport criteria development, planning and design.
- Test and selection of ground electronic systems.
- Test, selection and development of aircraft avionics package.
- Aircraft flight trials and operating procedures development.
- Demonstration aircraft modification and procurement.

STOLPORT CRITERIA DEVELOPMENT PLANNING AND DESIGN

The planning criteria for the runway and taxiway were established for both a typical STOLport and for the specific sites. (Figure 1)

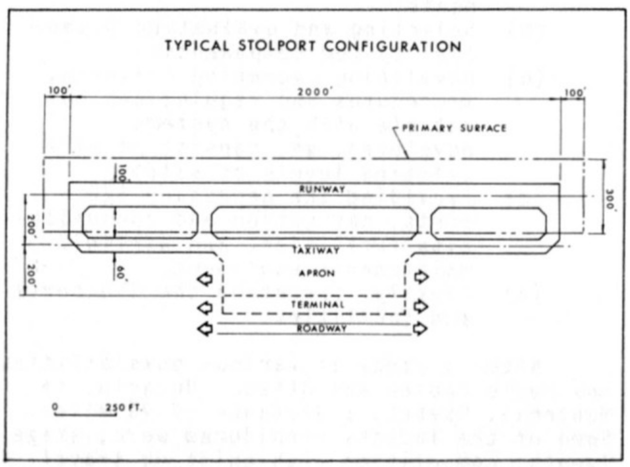

Figure 1

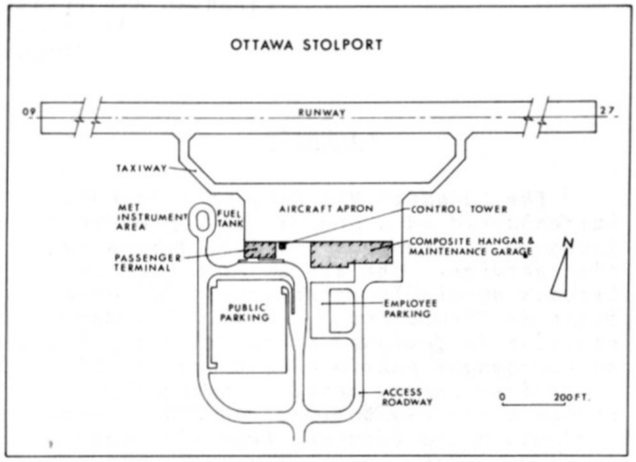

Figure 2

The typical configuration was modified to meet the requirements of the site and the expected initial peak hour demands on the airport. This resulted in the design for the Ottawa STOLport as shown in Figure 2.

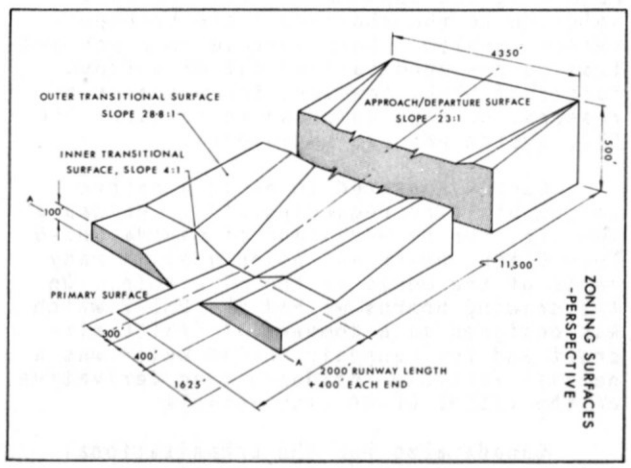

Figure 3

Obstacle clearance slopes and instrument approach criteria are under development for IFR STOL operations. A preliminary zoning surface is shown in Figure 3 for Twin Otter operations. This is presently being refined as a result of further study.

The Ottawa STOLport dimensions are designed for DHC-6 Twin Otter operations with provisions for taxiway and ramp increases to DHC-7 size aircraft. The runway is 2000 feet by 100 feet. Taxiways are 30 feet wide. Runway centre-line to building line has been set at 400 feet.

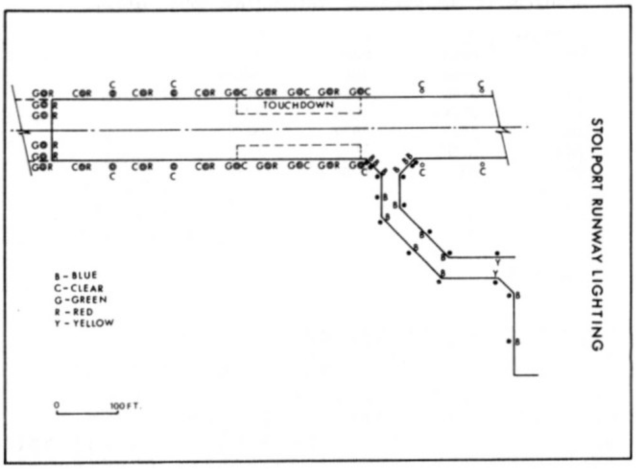

Figure 4

Special STOL runway lighting has been developed to indicate the target touchdown area in green lights and floodlights, and the last 500 feet of runway with alternate red and white lights. The layout is shown in Figure 4. The modified lighting system was developed because the STOLport will be located in a downtown area where high ambient light conditions may already exist. In addition, the steep approach necessitates high rates of descent with minimal time available to the pilot on an instrument approach to identify the runway to position the aircraft for landing.

The terminal building for the demonstration service has been designed to accommodate 150,000 passengers per year. The building houses passenger public areas, airline operations offices and airport manager's offices. The total area comprises 5000 square feet.

A free-standing control tower has been placed next to the terminal.

In addition, a combination hangar and airfield maintenance and emergency services building is also being provided at each site. The maintenance building also houses snow-removal equipment.

TEST AND SELECTION OF GROUND ELECTRONIC SYSTEMS

The present VHF instrument landing system in a downtown location with its profusion of buildings, power lines, vehicular traffic, etc., is not capable of performing to the desired levels of accuracy. Nor can it be adapted for steep approaches.

A large number of possible alternative landing systems were surveyed and it was decided that a microwave system best met the STOLport requirements. Two types of Microwave Landing Systems, TALAR and CO-SCAN were evaluated. Flight test data on a third, MODILS, were obtained from the FAA. After considerable study, CO-SCAN, a scanning beam microwave landing system designed by AIL in the United States was selected for use in the demonstration.

Some of the advantages of a scanning beam MLS over conventional ILS are;

- High level of accuracy;
- Relative ease of siting;
- Selectable glide slope to satisfy the individual requirements of different aircraft types;
- Eventual development of curved approaches to satisfy congested airspace and environmental demands:
- Ability to ground monitor the system well enough to reduce and possibly eliminate regular flight checking.

The siting of the MLS as we plan to use it is such that the localizer and glide slope are co-located, requiring approaches offset 3° to the runway centre-line. The MLS will be located on the right side of the runway, 125 feet from the approach end.

In future phases, when Category II and III approaches are required, it will be necessary to split the localizer and glide slope as in present VHF systems.

An MLS installation is planned at each end of the runway and the MLS will be used on each approach as a matter of policy for noise abatement and obstacle clearance purposes.

A Distance Measuring Equipment (DME) is being installed 200 feet opposite the centre of the STOL runway at each STOLport.

The DME will be used for several purposes:

- No outer or middle marker equipment is planned and DME fixes will be available in conjunction with the MLS throughout the entire approach to give a continuous indication to the pilot of his distance from touchdown.
- The DME will be used for continuous gain scheduling of the flight director computer during MLS approaches. This will ensure progressive and smooth command steering throughout the approach.
- The area navigation equipment is capable of using DME-DME inputs for computation. The DME on the field in conjunction with another DME in the area will give more accurate track guidance in the STOLport vicinity and R-NAV can then be used for approaches and departures.

The DME will be a standard airway type equipment. A VOR was not installed on the STOLport as it was felt it could encounter siting problems in an urban environment.

TEST, SELECTION AND DEVELOPMENT OF AVIONICS SYSTEM

Considerable emphasis was placed on developing a well integrated avionics package for the STOL aircraft. It was expected that the aircraft might on occasion be required to land at a CTOL airport. Therefore, the aircraft was equipped with the avionics package equivalent to that of a contemporary airline aircraft in addition to the specialized STOL operation equipment.

The aircraft has the standard package of VHF communications, VOR/ILS, DME, transponder, weather radar, ADF, radio altimeter, marker receivers, etc., and, in addition, has a specially modified dual flight director system, dual CO-SCAN MLS receivers and a single Area Navigation System.

TIME TO TOUCHDOWN 1500' – Ground

6° – 7.5° Glide Slope Compared to 2.5° Glide Slope120 Kts
True Airspeed 77 Kts
7.5° Glide Slope – Rate of Descent 1020 FPM – 17fps
6° Glide Slope – Rate of Descent 815 FPM – 13.6fps

.TIME TO TOUCHDOWN

ALTITUDE	7.5°	6°	2.5°	RATE of DESCENT
1500'	88.2	110.4	169.5	531 FPM
1000'	58.8	73.6	113.0	8.85 FPS
500'	29.4	36.8	56.5	@120 KTS
400'	23.5	29.4	45.2	
300'	17.6	22.1	33.9	
200'	11.8	14.7	22.6	

HORIZONTAL DISTANCE TO TOUCHDOWN 1500 - Ground

ALTITUDE	7.5°	6°	2.5°
1500'	11394	14272	34356
1000'	7596	9515	22904
500'	3798	4757	11452
400'	3038	3806	9162
300'	2279	2854	6871
200'	1519	1903	4581
50'	380	476	1145

Figure 5

Flight Director System

An approach speed of 75 knots and a $7\frac{1}{2}^{o}$ glide slope angle gives a rate of descent of approximately 1000 feet per minute. Our experience confirms NASA technical note TND5594 entitled "Airworthiness Considerations for STOL Aircraft" which states that the maximum acceptable sink rate below 200 feet above ground level is 1000 feet per minute. It is considered that any rate of descent in excess of this amount deprives the pilot of the required time for decision making in the landing phase of the flight. Comparative times to touchdown for specified speeds and approach angles are shown in Figure 5.

If a $7\frac{1}{2}^{o}$ approach is examined several factors become obvious:

(a) The glide slope would be intercepted approximately 1.4 miles from touchdown (assuming glide slope intercept at 1000 feet above ground level).

(b) Time from glide slope intercept to touchdown would be approximately 59 seconds.

(c) Time from decision height at 200 feet to touchdown would be approximately 12 seconds.

(d) During approach the speed margin between 1.3 V_s and the VMC of 66 knots could be as little as 4 knots in the DHC-6.

(e) Speed control can be difficult since the aircraft is essentially in the gliding configuration with low power and high drag. Wind shear becomes a very noticeable factor.

These and the additional requirement to program standard VOR routings, ILS, MLS and R-NAV through the flight director indicated the need for a top quality system. After considerable study a specially modified Collins FD 108-109 system was selected. The system is programmed to accept VOR, ILS, MLS and R-NAV modes as required. It has single cue command steering, pilot selectable speed reference (fast-slow indicator), expanded localizer and glide slope deviation pointer, as well as minimum descent altitude and go-around warning and annunication lights.

CO-SCAN Microwave Landing System Receivers

It was necessary to modify the MLS receivers to meet civil requirements and certification, and also to re-design the control heads to meet space limitations in the Twin Otter. As mentioned before, the MLS is programmed through the flight director and gain scheduling on approach is carried out using the DME installed at the STOLport.

The MLS has no back course and, in addition, can only be received when the aircrafts' heading is within 60^{o} of the on-course heading inbound. These problems can be overcome by using the R-NAV system to track the aircraft to the MLS approach gate and by programming the missed approach in the R-NAV.

Area Navigation (R-NAV) System

The primary navigation system for the STOL aircraft is R-NAV. Special R-NAV routes, Standard Instrument Departures (SID) and Standard Terminal Arrival Routes (STAR) have been developed for the demonstration. The objectives of the route development were to:

- Obtain as direct a route as possible to minimize block times;
- Minimize controller workload;
- Reduce or eliminate radar vectors;
- Minimize cockpit workload by automating navigation;
- Separate STOL traffic from CTOL traffic.

The Litton LTN-101 R-NAV equipment which is being used is capable of being programmed by a card reader to store up to 40 3D waypoints. The entire flight profile is therefore capable of being programmed by the pilot before take-off. This includes SID's, enroute airways, STAR's, R-NAV approaches and missed approach.

On a typical flight the aircraft would be cleared by one of a series of canned flight plans. The pilot would insert the appropriate card in the card reader to program his SID and enroute profile in the R-NAV computer. After take-off, the pilot would fly the command signals on his flight director to maintain the profile. On approaching the terminal area of the landing airport the aircraft would be given the landing runway and the associated STAR.

The pilot would then insert the proper card into the card reader for this procedure and then fly the profile. ATC would only be required to monitor the flight to ensure separation.

The R-NAV profile will take the aircraft to the approach gate (Figure 6) for the MLS where the pilot will select MLS on his flight director and carry out the approach. R-NAV information would revert to a separate indicator on the pilot's panel where raw data in the form of R-NAV glide path and azimuth would be displayed to provide redundancy for the MLS and for missed approach guidance if required.

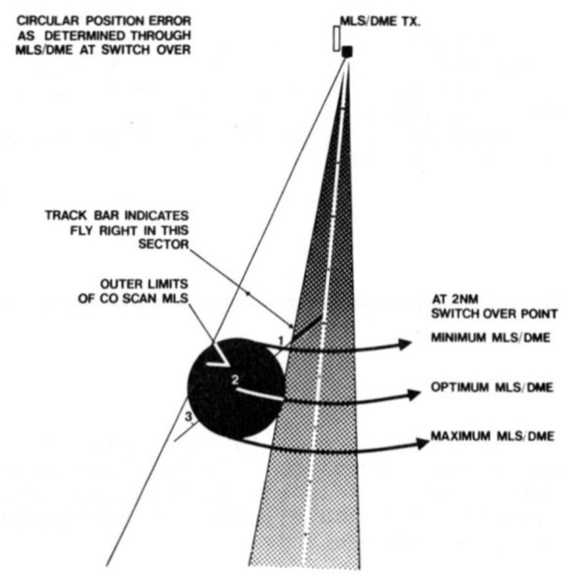

Figure 6

AIRCRAFT FLIGHT TRIALS AND OPERATING PROCEDURES DEVELOPMENT

Flight trials of procedures and equipment have been carried out on a Ministry owned DHC-6 Twin Otter Series 100. The aircraft was completely re-equipped with a new avionics package to test the system that is to be installed on the demonstration aircraft.

Trials were carried out at our test site where a specially marked and lighted STOL runway was placed on an existing runway. The trial site was equipped with MLS, DME, meteorological equipment and VHF communications.

The MLS was tested and trials were carried out to determine the most suitable approach angle for the DHC-6. The optimum angle appears to be between 6^{o} and 7.5^{o}. Final resolution of this will take place after further tests are completed on a DHC-6-300S production aircraft.

Runway marking and lighting trials were carried out to confirm or modify proposed layouts.

Airworthiness trials were also conducted to determine touchdown dispersion and stopping distances using different approach angles. As would be expected, touchdown dispersion decreased as the approach angle increased. Stopping distances did not vary appreciably.

DEMONSTRATION AIRCRAFT MODIFICATION AND PROCUREMENT

The aircraft selected for use in the demonstration project is the DHC-6-300S. The "S" designation indicates that the aircraft is a specially modified version of the Twin Otter which gives it better performance as a STOL aircraft.

Some of the special STOL modifications are anti-skid, high capacity brakes, wing spoilers and propeller discing. A number of additional changes were made to bring the aircraft closer to "FAR 25 Transport category". A few of these changes are; a modified electrical system, double shot engine fire extinguishers, baggage compartment fire warning, modified emergency lighting, emergency brakes and bird-proof windshield. The aircraft will be required to meet FAR 25 performance standards.

One of the objectives of the demonstration program is to obtain as much operational data as possible on STOL system operations so that future STOL regulations and standards can be prepared. To meet this requirement a specially developed Airborne Data Acquisition System (ADAS) is being installed on each aircraft. The ADAS will continuously record over 40 parameters to obtain quantitative data on aircraft performance, aircraft ride, R-NAV performance, MLS performance and pilot workload. The tapes will be removed from the ADAS on the aircraft at the end of each day's flying and will be processed by a dedicated ground computer for analysis by specialists in various aeronautical disciplines.

For example, standard deviation on MLS approaches (localizer and glide slope) can be determined. From this information, approaches where excessive deviations have occurred can be examined to determine the effect of relationship of other parameters. Quantitative data is then available for determining approach limits or zoning criteria.

SUMMARY

The areas covered to this date have revealed many problems. So far none appear to be insurmountable nor do they generate trade-offs that would render the demonstration to be unacceptable.

True, the vehicle in the form of the DHC-6 will not provide a viable economic return in view of the capital costs involved.

It is equally true that the site for the Ottawa STOLport was chosen because of its availability, rather than its proximity to the city centre.

It will, however, be necessary in some cases to convince the residents surrounding the STOLports that the STOL service is a benefit to the community and that STOL operations will cause minimum effect from the point of view of noise and air pollution. Our experience has been that the residents are, in the main, willing to accept the noise generated by the turbo-prop STOL aircraft which we propose, but are apprehensive about the introduction of future pure jet STOL aircraft which they feel may be noisier. It will probably be necessary, therefore, to legislate for noise control of aircraft using STOLports to ensure that noise limits are not exceeded.

Another problem which we have encountered may be more costly to solve. As with all airports, the STOLport must be protected from encroachment of its obstacle clearance slopes by various obstructions. Under normal circumstances, in Canada, we would have enacted official zoning legislation which would prevent the erection of structures which would violate the clearance planes, by providing compensation for the land owner for use of the air rights. This could also be done at a STOLport, but since the STOLport may be in an urban, even downtown, environment, the cost could be extremely high when one considers the value of urban real estate. The high cost of

continued...

continued...

SUMMARY

urban real estate has encouraged the development of more and more high rise buildings to make optimum use of the land. If one of these buildings was constructed off the end of a STOL runway, it could close the STOLport. To compensate the land owner for not constructing the building could obviously cost a great deal. Therefore, to enact official zoning legislation at an urban STOLport, could cost many times more than the cost of the STOLport itself.

However, if STOL is to become an acceptable component of the total transportation system, a start must be made somewhere. It is to this task that the STOL demonstration has been addressed.

If we can demonstrate that a STOL System is feasible from an operational and passenger acceptance point of view, that the basic elements of the system are within the state of the art, then we will have certainly achieved our objectives.