STOL TECHNOLOGY BIBLIOGRAPHY UPDATE

J. H. DE LEEUW - Project Manager

L. D. REID - Technical Coordinator

December, 1971. CTC Research Report 23

UTIAS Report No. 176
STOL TECHNOLOGY BIBLIOGRAPHY UPDATE

J. H. DE LEEUW - Project Manager
L. D. REID - Technical Coordinator

A STUDY PREPARED FOR THE

CANADIAN TRANSPORT COMMISSION

SYSTEMS ANALYSIS BRANCH

December, 1971. CTC Research Report 23
UTIAS Report No. 176
This bibliography is intended to update that contained in "An Assessment of STOL Technology", UTIAS Report No. 162/CTC Research Branch Report RB 7006, published in 1970. The same reviewing procedures and major headings have been used in the present report. In choosing the papers to be included, areas of immediate interest to Canada have been covered and consequently most vehicle oriented topics are concerned with the first generation of STOL transports (i.e. those with turboprop powerplants) although some papers on turbofan STOL transports have been reviewed.

The bibliography is fully annotated by the reviewers as to the quality and relevance of the contents of the papers. The outlines presented reflect the reviewers' impressions of the work and may differ considerably from the authors' abstracts.

This bibliography is organized under five main headings:

- Vehicle Design and Performance
- Operational Aspects
- Navigation, Guidance and Air Traffic Control
- Non-Passenger Public Acceptance
- STOLports
CONTENTS

GENERAL INTRODUCTION

I. VEHICLE DESIGN AND PERFORMANCE
   INTRODUCTION
   GENERAL PERSPECTIVE
   DESIGN STUDIES
   AERO DYNAMICS/HIGH LIFT DEVICES
   PROPULSION SYSTEMS
   HANDLING QUALITIES
   PERFORMANCE
   CREW FACTORS
   APPENDIX I

II. OPERATIONAL ASPECTS
   INTRODUCTION
   OPERATION AND ECONOMICS
   TRANSPORTATION DEMAND
   SYSTEM COST STUDIES
   ACCESS AND EGRESS PROBLEMS
   REGULATIONS AND SAFETY
   APPENDIX II

III. NAVIGATION, GUIDANCE, AND AIR TRAFFIC CONTROL
   INTRODUCTION
   GENERAL PERSPECTIVE
   COMMUNICATIONS
   NAVIGATION
   APPROACH AND LANDING
   AIR TRAFFIC CONTROL
   COCKPIT INSTRUMENTATION INCLUDING CAS
   *APPENDIX III

IV. NON-PASSENGER PUBLIC ACCEPTANCE
   INTRODUCTION
   GENERAL PERSPECTIVE
   NOISE EXPOSURE FORECASTING/NOISE RATING SCALES
   SUBJECTIVE RESPONSE
   COMMUNITY RESPONSE/COMPATIBLE LAND USE
   ECONOMIC AND LEGAL ASPECTS
   OPERATIONAL PROCEDURES
   REGULATION AND CERTIFICATION
   AIRCRAFT AND HARDWARE
   POLLUTION
   *MATHEMATICAL THEORIES OF AIRCRAFT NOISE
   APPENDIX IV

V. STOLPORTS
   INTRODUCTION
   COMPREHENSIVE PLANNING AND GENERAL DISCUSSIONS
   ENVIRONMENT, REAL ESTATE, SITES
   INDIVIDUAL STOLPORT DEVELOPMENTS AND PROPOSALS
   *NORTHERN SITES AND TRANSPORT
   *COMPARATIVE ECONOMICS
   NETWORK PLANNING, STATISTICS, FORECASTING
   FLIGHT SAFETY AND OPERATIONS
   *RUNWAYS, TERMINALS, FACILITIES
   APPENDIX V

*No reports found for this section.
This bibliography is intended to update that contained in "An Assessment of STOL Technology", UTIAS Report No. 162/CTC Research Branch Report RB 7006, published in 1970 (referred to as The 1970 STOL Report). The same reviewing procedures and major headings have been used in the present report. In choosing the papers to be included, areas of immediate interest to Canada have been covered and consequently most vehicle oriented topics are concerned with the first generation of STOL transports (i.e. those with turboprop powerplants) although some papers on turbofan STOL transports have been reviewed.

Most of the reports reviewed herein appeared in the open literature in the period from early 1970 to late 1971, although earlier reports have been included if they were of interest and were not reviewed in The 1970 STOL Report. These include some reports that were listed in the Appendices of the 1970 report.

The bibliography is subdivided into five main sections with a different individual responsible for each.

I. Vehicle Design and Performance
   Dr. L. D. Reid
   (Technical Coordinator)

II. Operational Aspects
    Mr. A. Toplis

III. Navigation, Guidance and Air Traffic Control
    Dr. J. H. deLeeuw
    (Project Manager)

IV. Non-Passenger Public Acceptance
    Dr. G. W. Johnston

V. STOLports
    Mr. P. T. Hodgins

Within each section the reports have been grouped under a few main headings as a further aid. Although this attempt at classifying the reports has certain shortcomings, it is felt that it will provide a useful guide for readers interested in a particular topic. An appendix to each section contains those reports that were considered to be of interest but were not reviewed as a result of the time constraint placed on the project: no rating or comments have been attached.

To provide a simple index as to the relevance of each reviewed paper, a rating of R-1, R-2 or R-3 has been placed at the start of each review. This rating scheme is intended to aid the user in obtaining the desired depth of coverage in the minimum of time. In the opinion of the reviewer those rated R-1 should be read first, those rated R-2 second, and those rated R-3 third, for progressively more detailed coverage of a particular field. Papers under each heading are grouped according to their rating and within each of these groups they are listed in chronological order. In preparing this bibliography the reviewers have been encouraged to comment on the quality and relevance of reports in an attempt to present a balanced picture of the field.

The project began by having a library assistant (a graduate student in aeronautics) search through the yearly aeronautical indexes for 1970 and 1971 under the topics used for The 1970 STOL Report. The abstracts of all papers found under these headings were copied and supplied to the appropriate reviewer who in turn scanned them to determine which reports to read. Additional titles were found in the bibliographies of these papers. The individual reviewers obtained their reports either through personal contacts or through the University of Toronto Institute for Aerospace Studies Library.

The introduction to each section indicates the state of the literature in the particular field as it appeared to the individual reviewer. In general, the papers included deal with the concepts of STOL technology and do not treat in detail the theories and experimental techniques employed in arriving at the results. It is felt, however, that those interested in this detailed information can obtain the required references by searching the bibliographies of the papers included herein. It should be noted that a few VTOL papers have been included when their results have implications in the STOL field.
I. VEHICLE DESIGN AND PERFORMANCE

INTRODUCTION
No major technological changes have been reported in the literature surveyed for this section. The same trends in the topics covered were evident in the 1970 STOL Report. Again certain areas have not received adequate coverage; e.g. STOL aircraft subsystems (APU's, landing gear, stairs, etc.), barrier crash survival (as required at elevated STOLports), internal noise and cabin design, and crew factors.

Several interesting items stand out from the rest. A report on the "Channel Wing" STOL concept reviews the status of this novel STOL design dating back to the 1920's. Although it appears to be quite a promising concept for turboprop vehicles it has not captured the interest of any major airframe manufacturer. Another development of interest is the air cushion landing system employing a cushion of air to replace the conventional landing gear. This allows operations from unprepared sites, water, snow and ice. Although perhaps not required for any interurban STOL service, this system could find application in Canada's North.

Review papers were found in a few areas. A particularly well-written paper on V/STOL aircraft and operations. Many tables and graphs are included but little explanation of how they were derived. The paper is quite pro-VTOL and attempts to prove that the VTOL concept is superior in all respects. However, the required technology has not yet been developed. This paper is of interest because it presents the other side of the VTOL vs. STOL argument.

The reports have been divided into the following eight sections:

<table>
<thead>
<tr>
<th>General Perspective</th>
<th>Design Studies</th>
<th>Aerodynamics/High Lift Devices</th>
<th>Propulsion Systems</th>
<th>Handling Qualities</th>
<th>Performance</th>
<th>Crew Factors</th>
<th>Appendix I</th>
</tr>
</thead>
</table>

Based on the material read in preparing this section it appears that turboprop STOL vehicles still represent the least technical risk of all possible STOL designs. However, the work on turbofan propulsion systems is progressing steadily and will probably receive a considerable boost from the military side of the industry. In addition, airline operators do not appear to be favorably impressed by the idea of purchasing a fleet of propeller-driven aircraft (e.g. the paper by G. P. Sallee under the Propulsion Systems heading). VTOL still appears to be at least a decade away and thus should not prevent the initial introduction of a STOL system. In summary, there does not appear to be any technical reason to prevent the timely introduction of turboprop STOL transports.

GENERAL PERSPECTIVE

DESIGN CONSIDERATIONS OF INTERCITY V/STOL AIRCRAFT
M. J. Brennan
BALPA Technical Symposium, London
V/STOL in Civil Aviation, November 1970

This is a rather general survey of V/STOL aircraft and operations. Many tables and graphs are included but little explanation of how they were derived. The paper is quite pro-VTOL and attempts to prove that the VTOL concept is superior in all respects. However, the required technology has not yet been developed. This paper is of interest because it presents the other side of the VTOL vs. STOL argument.

SRDS PROGRAM - GOALS, ACHIEVEMENTS, TRENDS
1 April 1970 to 31 March 1971.
Systems Research and Development Service

This is a progress report on the work of the FAA's Systems Research and Development Service and is mainly concerned with ATC. Three reports on subprograms relate to STOL; one on hookless arresting systems, which is to include feasibility studies of various safety systems for elevated STOLports is scheduled for completion in June 1972; one on short haul operational evaluation, which relates to aircraft evaluation and a survey of possible sites for a proposed elevated STOLport, and one which relates to a future program of evaluation of V/STOL handling characteristics in deteriorating weather conditions.

Very little is said about these programs, but it is useful to know that the FAA has the problems under investigation.

DESIGN STUDIES

A PARAMETER STUDY OF A STOL TRANSPORT
R. L. Schwing
AIAA Paper No. 70-387, April 1970

This is a rather sketchy outline of the use of a hybrid simulator to evaluate STOL handling qualities. The major conclusion is that simulators are useful for such studies. A table of Desired Motion and Visual Simulation summarizes some design recommendations.
AERODYNAMICS/HIGH LIFT DEVICES

THE CHANNEL WING - AN ANSWER TO THE STOL PROBLEM
E. F. Blick
Shell Aviation News 392, pp. 2-7, 1971

This brief article outlines the progress of a STOL concept dating back to the 1920's. The required high lift at low forward speeds is achieved by creating a high speed flow over a portion of the upper surface of the wing only (as opposed to the immersed flow technique of the Breguet 941). This flow is achieved by mounting the propellers on top of the wing, which at that station appears like the lower half of a shrouded propeller system. The slipstream from the power plant thus induces a high-speed flow over the upper surface of this portion of the wing, creating high lift.

Results of experimental programs over the years are reported. These include research aircraft, some of which are presently in operation. An engineering theory is presented to describe the lift produced. However, little detail is available in this report. One unique feature of this type of aircraft is the fact that there is no power-on stall.

Several reasons are given for the lack of development of the concept - "exaggerated claims, inaccurate conclusions on government research reports, inadequate financing, and lack of an acceptable engineering theory to explain the demonstrated performance". The main attraction of this design is its simplicity - it does not even require flaps. It is claimed that its DOC's may be lower than other powered lift STOL concepts.

The commercial operating characteristics have not been determined, but it appears that there is potential.

ANALYSIS OF EFFECTS OF SPANWISE VARIATIONS OF GUST VELOCITY ON A VANE-CONTROLLED GUST-ALLEVIATION SYSTEM
L. K. Barker, G. W. Sparrow
NASA TN D-6126 April 1971

The theoretical aspects of the design and effectiveness of a gust alleviation system are outlined. The renewed interest in this system (earlier NASA work is reported in NACA TN 2416, 1951; NACA TN 3612, 1956; and NASA TN D-532, 1961) stems from V/STOL applications to improve the passenger comfort in aircraft flying at low altitudes with light wing loadings.

The system under study consists of a single angle of attack sensing vane in front of the wing sensing gusts and driving a control system connected to the flaps. The flaps are actuated in a manner to reduce the influence of the gust on the lift generated by the wings. The approach used is mathematical in nature with assumed models for the atmospheric turbulence, the wing lift distribution and the control system response. The effect of the alleviation system is predicted as a function of the wing and control
system parameters. It appears that quite adequate results can be obtained with a suitably designed system (about 80% alleviation). In particular low frequency gust effects are removed, the very band width of most concern in passenger comfort.

The report is sketchy in places but the implications of the results are quite clear. The approach is quite straightforward but requires an understanding of the concepts of power spectral densities and correlation coefficients.

STABILITY AND CONTROL CHARACTERISTICS OF STOL AND V/STOL AIRPLANES
J. R. Chambers
NASA SP-258, Performance and Dynamics of Aerospace Vehicles pp. 1-70 1971

The section of this paper that covers pure STOL vehicles is based upon a report in The 1970 STOL Report "The Development of a BLC High Lift System for High Speed Airplanes", L. B. Gratzer and T. J. O'Donnell, AIAA Paper 64-589, August 1964. The present paper also discusses the characteristics of other V/STOL concepts and indicates several testing techniques presently employed.

PROPELLION SYSTEMS

V/STOL PROPULSION
N. D. Sanders et al
NASA SP-259, Aircraft Propulsion pp. 135-168, November 1970

The first section of this report is concerned with STOL propulsion concepts. In particular the characteristics of the externally blown-flap, the augmentor wing, and the multifan concept are discussed. The multifan system consists of multiple low pressure-ratio fans spread along the wing trailing edge. These fans are driven from several main air pumps (or gas generators). The fans are mounted on a hinged flap to achieve a downward deflected jet for high lift.

The conclusions concerning these concepts are of interest.

Externally Blown-Flap: "The desired lift coefficients and control of engine-out rolling moments can be achieved with an airplane thrust to gross weight ratio of 0.6. Further development of the trend to lower fan pressure ratio engines is required to meet the noise limits".

Augmentor Wing: "The augmentor wing is an efficient high lift system. It is possible to get the required duct sizes into the aircraft wing. A two-spool engine of special design can generate the required wing duct flows and pressures with a low jet core exhaust noise. Considerable work is still required to optimize the matching between the engine, airframe and noise."

Multifan Airplane: "The multiple fan airplane appears to have a number of significant advantages, but there are also problems that require further study such as cruise drag, aeroelastic stability, and system weight."

This report is clear and concise. Although a minimum of detail is presented, the main characteristics of the systems described are brought out.

V/STOLs for the Airlines; Filling the Propulsion Gaps
G. Rosen
Space/Aeronautics, pp. 32-37 May 1970

When the range of available propulsion characteristics is studied it is found that two gaps exist at precisely the disk loadings required by many V/STOL designs. Designs are currently under development to fill these gaps - the Rotor-Prop to fit between the helicopter rotor and conventional propellers and the Prop-Fan to fit between shrouded propellers and turbofans. Figures are presented to illustrate how the various propulsors match current and proposed vehicle requirements. The source of power in all cases will be the gas turbine. It is estimated that it should be possible to reduce the specific weight of these power plants by 50 percent and the fuel consumption by 25 percent based on new materials. The pros and cons of the following propulsors are reviewed; turbojet, turboprop, rotor-prop and prop-fan. Noise and takeoff thrust rule out present turbojet and turbofan engines. The author feels that turboprops are quite feasible despite the added mechanical complexity. The shrouded propeller in particular has the potential for reducing noise as well as looking somewhat like a turbofan engine to the general public. Prop-fans are an extension of shrouded propeller.

In-house studies indicate that the turbo-prop STOL was definitely superior to the turbofan STOL with auxiliary
lift fans (required for short field performance). Prop-fan STOL's ran a close second to the turbo-prop.

With its general treatment of the topic, this paper provides a useful picture of the propulsor aspect of STOL and is a good introduction to the subject.

AN INITIAL LOOK AT MANAGEMENT AND DESIGN CONSIDERATIONS FOR COMMERCIAL STOL PROPULSION SYSTEMS
G. P. Sallee
SAE Paper No. 700810, 1970

This brief but interesting paper presents the (American Airlines) management side of the picture in the selection of suitable STOL propulsion systems. Several important points of a general nature are made about acceptable STOL aircraft -

(i) It must look aesthetically like current aircraft so as not to frighten the public or conservative bankers.

(ii) A program will not be started until a noise level of 95 PNDB at 500 ft. can be achieved.

(iii) There must be no pollution.

In the view of the author only 3 STOL configurations are capable of meeting the requirements; cross-shafted turbo-prop, externally blown-flap with high by-pass turbofans, and the internally blown augmentor flap with moderate bypass turbofans.

The most interesting point made in this paper concerns the use of propellers. The author feels that based on his company's experience with the propeller system of the Lockheed Electra, such systems are too difficult to maintain and are not sufficiently reliable for STOL operations. The more complex system employed with the cross-shafted STOL design would not be practical.

It is proposed that the engine manufacturers accept more system responsibilities and work together with the airframe manufacturer and the airline to produce an acceptable system.

HANDLING QUALITIES

V/STOL HANDLING, I. CRITERIA AND DISCUSSION
AGARD-R-577-70, December 1970

This report is an updating of "Recommendation for V/STOL Handling Qualities", AGARD-R-408, October 1962. In addition this report includes:

1. Evaluation of the various handling-qualities items in terms of criteria, rather than requirements or specifications.

2. A discussion section to explain the purpose of each criterion.

3. Data and reference material to support the criteria.

This is a well-written document and the discussion sections are especially helpful in indicating the nature of the requirements. It is stated that this should help in the application of the criteria.

Five main areas are covered:

- Characteristics of the Control Systems
- Longitudinal Stability and Control
- Lateral Directional Stability and Control
- Hovering and Vertical Flight Path Characteristics
- Transition Characteristics

In addition, an appendix is included outlining a range of manoeuvres that can be applied in V/STOL aircraft handling-qualities evaluations. The purpose of this is to encourage the use of a consistent set of procedures to ease the difficulty that presently exists in obtaining handling qualities data.

Several interesting points are made concerning the application of the criteria. It must be expected that at some time a system failure will occur. When this happens some degradation in handling qualities should be allowed, depending on the likelihood of the failure. At the present time little experience under IFR conditions has been achieved and hence care must be taken when applying the criteria to this flight case. Finally, most of the data
used to formulate the criteria are based on limited flight experience obtained largely from test-bed type aircraft. "As a result, some inconsistencies would be expected when applications were made to operational V/STOL designs."

R-1

LOW SPEED HANDLING CHARACTERISTICS OF THE STOL AIRCRAFT
M. D. Marks, D.O. Carpenter
AIAA Paper No. 70-1332, October 1970

This paper gives a very thorough description of the flight characteristics of the Breguet 941 in the landing and take-off configurations. The areas covered include the following:

Powered Lift System - With the lift depending upon the level of thrust, flight path correction is best obtained through thrust modulation.

Control - The system is based on the normal controls (with spoilers instead of ailerons) augmented by propeller pitch controls.

Operational Characteristics - Takeoff and landing procedures. Sufficient detail is provided to allow the reader to grasp the fundamental concepts behind the successful operation of such a vehicle. The report even mentions an undesirable characteristic of the vehicle, its tendency to "wallow" from side to side under approach conditions. The "Typical" performance curves in the report are quite useful in assessing STOL performance.

R-3

SIMULATOR STUDY OF FLIGHT CHARACTERISTICS OF A JET FLAP STOL TRANSPORT AIRPLANE DURING APPROACH AND LANDING
W. F. Grantham, R. W. Sommer, P. L. Deal
NASA TN D-6225, February 1971

This program involved the use of a fixed-base simulator to study the handling qualities of a particular externally blown flap STOL vehicle. The equations of motion were obtained from previous wind tunnel tests of a vehicle model. The landing phase of flight was simulated with the help of a closed-circuit TV presentation obtained from a scale model of an airport. The main flaw in the report is the lack of comment on the fixed-base nature of the simulation; motion cues could be important under the flight conditions investigated. The basic vehicle was found to be rated as unacceptable by the pilots. This was corrected by the alteration of

the equations of motion (in the case of an actual flight vehicle this implies that considerable stability augmentation is required). In addition it was found that an autospeed control was mandatory for satisfactory instrument approaches.

Many handling qualities parameters were measured and compared with previous work. Generally speaking, the present program confirms the suitability of the previous recommendations. In addition, a direct-lift control system was evaluated. This was based on symmetrical spoiler deflection in one case and on thrust modulation in another. In general it was found to be beneficial for tracking the glide slope during the approach.

This report points out that rather complex electronic controls will be required to create acceptable flight characteristics for the externally blown flap, turbo-fan STOL vehicle.

R-3

A FLIGHT SIMULATOR STUDY OF STOL TRANSPORT LATERAL CONTROL CHARACTERISTICS
D. E. Drake, et al
FAA-RD-70-61, September 1970

A series of simulator runs were carried out by 5 pilots to assess the influence of various vehicle parameters on the lateral handling qualities of a STOL transport. The vehicle simulated was the Breguet 941, altered as required to investigate a range of lateral characteristics. The simulator had three degrees of freedom (pitch, roll, and heave). The simulated task was an approach to a STOLport, including a holding pattern. Visual cues were provided by a closed-circuit colour TV system. Various levels of turbulence were included. Pilot ratings of the various configurations were obtained and utilized in assessing acceptable values.

The following aspects were investigated: control sensitivity, control power, control linearity, control lag and surface rate limitation, control harmony, lateral-directional control coupling, roll subsidence, directional stability and damping, aircraft size and weight, stick-wheel preference.

The results reported apply specifically to this class of vehicle, although some generalizations are possible. One interesting result was that if adequate control is available, then lateral control linearity is desirable but is generally of less concern than control sensitivity and power. The results of this report will be useful in the
R-3

THE EFFECT OF LATERAL CONTROL NON-LINEARITIES ON THE HANDLING QUALITIES OF LIGHT STOL AIRCRAFT. A FLIGHT SIMULATOR STUDY
D. R. Madill, O.M.S. Colavincenzo, W. E. B. Roderick
ICAS Paper No. 70-55, September 1970

A program is described, covering the influence of the control system on STOL vehicle handling qualities. It was felt that the most meaningful results could be obtained by employing a flight vehicle. The aircraft used was the National Aeronautical Establishment's variable stability Bell 47G-3B1 helicopter. This is a four-degrees-of-freedom simulator, capable of flight. The simulator has independent control of pitch, roll, yaw, and heave; but since there is no independent means of generating longitudinal or lateral forces, the characteristics in these two translational degrees-of-freedom are essentially those of the helicopter, modified somewhat by the rotational simulation.

A range of control systems was simulated and these were generally nonlinear in control wheel force per degree and roll acceleration per degree. A typical approach pattern was flown under varying conditions and evaluated by the 4 test pilots using a pilot rating scale. The experimental design was quite complex and allowed a wide range of conditions to be tested.

The results of the work are presented in a series of graphs and tables too detailed to present here. It was possible to define boundaries for desirable control characteristics. An interesting analytical approach was used to analyze the tendency towards pilot induced oscillations.

Although this paper will be of most interest to vehicle designers, it does give insight into the complex nature of STOL vehicle handling qualities.

R-3

SUMMARY OF A FLIGHT-TEST EVALUATION OF THE CL-84 TILT-WING V/STOL AIRCRAFT
H. L. Kelley, J.P. Reeder, R. A. Champine
NASA TM X-1914, March 1970

This report details the evaluation of the Canadian CL-84 by a team of NASA test pilots in 1966. Quite detailed descriptions are provided of the control system and response, the control techniques required and the pilots' opinions concerning the vehicle's handling qualities. Of particular interest is the description of the highly complex control system employed. This includes mixing of several methods of control and a stability augmentation system for all three axes. One gets the impression that the tilt-wing concept is an overly complex solution for STOL operations and even perhaps for VTOL.

The following gives some of the major results of the program:

"In general, based on the limited evaluation performed, most of the flying qualities in the hover, transition, and cruise modes of flight were considered good. However, at one conversion angle at least, in transition flight, low normal-velocity damping was experienced at moderate rates of descent which could make glide-path control difficult during instrument flight without augmentation."

R-3

INVESTIGATION OF LATERAL-DIRECTIONAL DYNAMIC STABILITY OF A TILT-WING V/STOL TRANSPORT
J. R. Chambers, S. B. Grafton
NASA TN D-5637, February 1970

This report is of interest because it deals with a propeller driven STOL and because it indicates the type of results that can be achieved through the use of wind tunnel studies. This program utilized a 1/9-scale powered model of a tilt wing V/STOL with four interconnected propellers. Both static and forced oscillation tests were carried out, allowing the measurement of all necessary stability derivatives. Some of the results of the study are summarized below.

"Large effects of power on the values of static and dynamic stability derivatives are to be expected for this type of airplane."

"In hovering flight, the control-fixed motion of the airplane without artificial stabilization will be dominated by an unstable oscillation involving roll angle and sideward translation."

"As the transition to forward flight progresses, the oscillation becomes less unstable and becomes the classical Dutch roll oscillation in conventional flight."
This article outlines the status of a program to evaluate the use of air cushion technology to replace the conventional wheeled undercarriage in use today. The system is "based on the ground effect principle employing a layer of air to provide the aircraft's contact with the ground. It is made up of a rubber trunk connected to the underside of the fuselage and pressurized by the auxiliary power system. Air escaping through hundreds of perforations in the trunk creates the layer of air on which the aircraft rides during takeoff and landing".

The cushion of air exerts a ground pressure of less than 3 psi and as a result it allows an aircraft to operate on water, snow, soft soil or ice. Sufficient clearance is provided to allow rough terrain operations. The weight of such a system should be less than that of conventional undercarriages. Because there is no direct contact between the vehicle and the ground it is possible to land in an extreme yawed attitude in the presence of a crosswind. This is of interest to single runway operations as might be encountered with a STOLport.

The system is quite resistant to damage and has provisions for braking and parking. To date tests performed with a system installed on an LA-4 light aircraft have been quite successful. At the present time a Buffalo STOL transport is being fitted with an air cushion system for further tests. It appears that this approach could reduce costs and add to the flexibility of a Canadian STOL operation.

All the landing approaches were made under visual conditions, some with the visual landing aid, some with the 50 ft. barrier and some with both. Approach angles of 40°, 80°, and 100° were employed. Parameters measured were glide path error, approach speed error, height of landing flare initiation, height over the barrier, C_L at peak 'g', touchdown distance from the barrier, rate of descent at touchdown, and airspeed at touchdown.

The main conclusions were:

1. The visual landing aid was quite successful in improving the approach and landing.
2. Steep approaches could be safely and consistently made.
3. There were significant differences in the consistency and accuracy of approaches by different pilots.

A series of flight tests were performed using aircraft that would not be classed as truly STOL in the normal sense of the word. The aircraft used (a Varsity and an Andover, twin engined transports) had speeds of the order of 90 knots on the approach. Approach glide slopes were varied from 40° to 100° with the use of a simple visual glide slope system. An interesting experimental technique was the use of jets of water to simulate a 50 ft. barrier in front of the touchdown area.

Since these vehicles did not have the thrust/lift interaction usually associated with STOL vehicles and were not operating at the large values of C_L produced by extreme high lift devices, the results of this work must be applied with caution. However, this report was the only one found containing extensive information concerning the expected scatter in approach and landing parameters.

The basic point made is that not enough information is presently available on the structure of atmospheric turbulence near the ground. Even when automatic landing systems are employed problems exist in determining under what conditions the automatic system is capable of carrying out a safe landing. Some
means of specifying and reporting the level of turbulence in the area of the runway is required.

THE PHYSICS OF SHORT TAKEOFF AND LANDING (STOL)
D. O. Carpenter, P. Gottlieb
AIAA Paper No. 70-1238, October 1970

Simple formulations are presented to indicate the major factors involved in establishing takeoff and landing distances. A thrust parameter is developed that is useful for describing STOL vehicles of a given class with respect to takeoff distance. In addition it is shown that climb gradient is closely related to takeoff distance.

The material contained in this report is not especially startling but does indicate some relevant aspects of performance.

FLIGHT TEST OF THE ARAVA ISRAEL STOL AIRPLANE
A. Hacohen

This report briefly describes the testing of a STOL aircraft designed to carry 20 passengers or 4400 pounds of cargo. It is of particular interest because it is powered by two turbo-prop power plants (PT6-A27) and appears to be aimed at the same market as the deHavilland Twin Otter. The vehicle features a tail supported by twin booms, allowing the fuselage structure to be of simple construction with a rear loading door.

A combination of ailerons and spoilers provide lateral control. Large span double slotted flaps coupled with light wing loading provides the high lift required for STOL performance. Several problems were encountered and overcome in the course of the program. Longitudinal stability was improved by adding a V-tab to the elevator. The lateral-directional stability was corrected by reducing the aerodynamic balance of the rudders. These alterations had to be made before the aircraft could achieve the desired STOL performance.

This paper illustrates that even a rather unsophisticated STOL design involves a great deal of cut and try engineering.

ADVANCES IN V/STOL COCKPIT INFORMATION
D. Dougherty-Strother
AGARD CP-55, Problems of the Cockpit Environment, pp. 26-1, 26-4, March 1970

This is a very brief description of some new display concepts that appear to be mainly aimed at military helicopter applications. The new sensors are television cameras capable of low light level operation for night work and radar designed for navigation using small ground features. The displays involve helmet mounted "eyeglass displays" using ultra small TV tubes and optics. This provides the ultimate in heads-up display, with optical splitters allowing the pilot to view his instrument panel and the outside world directly.

PERFORMANCE PREDICTION AND EVALUATION OF PROPULSION-AUGMENTED HIGH LIFT SYSTEMS FOR STOL AIRCRAFT
R. L. Gielow
AIAA Paper No. 71-990, October 1971

A technique has been developed for predicting the aerodynamic forces of powered-lift systems. Theoretically-generated powered section data are distributed spanwise along a lifting line to produce three-dimensional characteristics which exhibit good correlation with experimental results. Employing this technique, baseline-configured aircraft are sized to perform a military STOL mission for field lengths of 1500 to 2500 feet. The lift system concepts include the internally and externally blown jet flaps, BLC, and pure thrust deflection. Direct lift engines are also considered. The sizing process recognizes differences in lift system weight and aerodynamic performance. A comparison of the optimally-sized aircraft produces some interesting conclusions concerning the trade-off between sophisticated systems and their associated weight penalties.

Three primary conclusions have been reached based upon the results of this study. They are:

1. The aerodynamic advantages promised by internally-ducted jet flap and BLC systems could not be realized in this study because of the weight penalties assigned to these
systems. Future design efforts to reduce these weight penalties should be given high priority.

2. With its minimum OWE (Operating Weight Empty) penalty and good aerodynamic performance capability, the externally-blown flap airplane compares favorably with the conventional flap airplane. The externally-blown flap requires no nozzle for thrust vectoring as does the conventional flap. Another advantage of the externally-blown flap is its increased wing loading for improved ride qualities. These factors combine to make the externally-blown flap the most desirable of the four pure STOL systems investigated.

3. The minimum OWE of each airplane with direct lift engines is consistently and significantly less than that of each corresponding pure STOL system, especially at the shorter field lengths. Also, the wing loadings are appreciably increased which results in improved ride qualities. The direct lift engine systems consume significantly less fuel and also possess the potential of growth to VTOL.

FACTORS IN STOL FLIGHT CONTROL CONFIGURATION
W. P. A. Harris
AIAA Paper No. 71-993, October 1971

The STOL flight control problem is discussed in relationship to its unique operational requirements. A survey is made of the historic growth of control system techniques, and their implementation, in order to put into perspective the STOL position. The danger of regarding STOL control as a simple extension of CTOL technique is discussed, and in contrast, the concept of task orientation and configuration is developed as pertinent to the STOL problem. Reference is made to current control system technology and analytical tools, and thoughts are presented on future trends. The need for a composite approach to control implementation is emphasized.

Operational and performance requirements dictate STOL configurations whose low-speed basic flying qualities are poor compared to the properties of CTOL airplanes. The operational requirements at the same time generate a need for precise flight path control.

The utilization of advanced control techniques allows development and application of control laws necessary to solve the STOL problem. This is accomplished by reducing the pilot workload through the improvement of basic handling qualities, and secondly by the provision of optimum airplane response to pilot commands for various flight conditions and tasks.

The application of DLC to provide adequate flightpath response was illustrated. Modern control design techniques can be used effectively for incorporating DLC into STOL control systems.

The effective implementation of the control laws does not preclude the utilization of mechanical signal paths that may still be required (at this time) in both civil and military configurations for vulnerability and reliability reasons. However, careful system configuration effort is required such that the mechanical systems do not degrade the performance of the feedback systems.

The application of the control-oriented approach appears to be entirely pertinent to the STOL configuration process because feedback control techniques are mandatory for the STOL system, and because of the strong interrelationship that exists between the propulsion, high-lift, and flight control areas.

Because feedback techniques allow a flexible approach to the selection of airplane handling qualities and piloting technique, it is possible to generate qualities that are similar to existing CTOL approach and landing characteristics.

THE AIR CUSHION AIRCRAFT - ITS BENEFITS TO THE ARCTIC
L. H. Hildebrandt, K. H. Digges
Fifth Canadian Symposium on Air Cushion Technology (CASI)
Paper No. 71/4, August 1971

The Air Cushion Aircraft (ACA) combines the speed and range of the aircraft with the mobility of the Air Cushion Vehicle (ACV). This combination creates a new form of transportation which frees the aircraft from its dependence on prepared runways. It offers the potential of air transportation to thousands of smaller communities where costly runways are not feasible. It is particularly attractive for application to the Arctic. The Air Cushion Landing System consists of all components required to duplicate the functions of the conventional landing gear.
The elongated doughnuts on the bottom of the fuselage are called trunks. These trunks form the flexible ducting required to provide a continuous curtain of air around the periphery of the fuselage. Air is fed into the trunk from an on-board compressor. The air is ducted by the trunk to the fuselage periphery and exhausted to form a jet curtain. This jet curtain causes a pressure to develop under the aircraft fuselage when the ground is approached. This slight overpressure is sufficient to support the aircraft. The Air Cushion Landing System is similar to the Air Cushion Vehicle support system in principle. However, the ACA has a number of requirements which are not imposed on ACV's. Some of these requirements are as follows:

(a) Retraction - The trunk must retract to provide an acceptably low drag during flight.

(b) Vertical Energy Absorption - The cushion must absorb vertical sink rates in the order of 10 fps without exceeding the g limit of the airframe.

(c) Braking - The braking system must provide deceleration rates of 10 ft/sec².

(d) Steering - The steering system must provide for steering and close quarter manoeuvring.

STOL HIGH-LIFT STUDY VOLUME I
C. A. Widdison

The state of the art of STOL aerodynamic technology for selected lift propulsion concepts has been surveyed to identify the available test data and prediction methods in the literature. The report consists of two volumes.

In Volume I important areas of technology and information necessary for the evaluation of STOL aircraft aerodynamics are listed; the aerodynamic test data and prediction methodology relevant to the deflected slipstream and externally blown flap concepts are assessed, with emphasis on the latter; an empirical method for the prediction of the longitudinal aerodynamic characteristics of externally blown flap configurations is presented; and high-lift technology for five lift propulsion concepts is assessed in application to a medium-sized STOL transport.

Volume II consists of a bibliography that resulted from a literature search for aerodynamic information related to seven lift propulsion concepts suitable for STOL aircraft. The bibliography contains references to approximately 900 reports classified by concept and by technological area.

EFFECT OF ENGINE POSITION AND HIGH-LIFT DEVICES ON AERODYNAMIC CHARACTERISTICS OF AN EXTERNAL-FLOW JET-FLAP STOL MODEL
C. C. Smith Jr.
NASA TN D-6222, March 1971

An investigation has been conducted to provide some basic information on the aerodynamic design parameters of an external-flow jet-flap configuration. Included in the investigation were static force tests to determine the effects of engine vertical and longitudinal position, jet-exhaust deflectors, flap size and type, leading-edge slat chord and deflection, and gap and overlap of the slats and flaps. The force tests were made in the Langley full-scale tunnel with a model having an unswept untapered wing and powered by four simulated high-bypass-ratio turbofan engines.

The results of the investigation showed that higher lift and better turning of the jet were obtained with the engines up close to the wing rather than well below the wing. Exhaust deflectors improved the lift and turning of the jet for a given installed engine thrust especially for the engine positions well below the wing. Large-chord flaps were found to produce more lift for a given installed engine thrust than small-chord flaps. Leading-edge slat deflections and chords slightly larger than those used for more normal lift operation were found to be necessary for high-lift jet flap operation. Double-slotted-flap and leading-edge slat gaps and overlaps generally used for normal lift operation were also found to be effective for high-lift jet-flap operation.

LOW-WING-LOADING STOL TRANSPORT RIDE SMOOTHING FEASIBILITY STUDY
The Boeing Company No. D3-8514-2, February 1971

This document presents results of an analytical study conducted by the Wichita Division of The Boeing Company for the Langley Research Center, National Aeronautics and Space Administration, under Contract NASl-10410. The primary objective of the study was to determine the feasibility of providing satisfactory ride qualities using modern
controls technology on a high performance, low-wing-loading STOL aircraft. The aircraft configuration was designed to be competitive with present high speed jet aircraft economics and block times and to meet proposed noise requirements.

Gust alleviation is not a new concept as indicated by the references shown in the bibliography. During the late 1930's and 1940's, NACA personnel conducted analyses, wind tunnel tests and flight tests of gust alleviation systems and flight demonstrated acceleration reductions of up to 60 percent.

Advances in electronic and hydraulic actuation hardware indicate the mechanization of a satisfactory ride smoothing system is now a realizable goal with current technology. This study was conducted to synthesize such a system for a high performance, low-wing-loading STOL aircraft.

Conclusions of this limited study indicate that a low-wing-loading STOL aircraft with ride smoothing stability augmentation provides satisfactory ride qualities and competitive high speed performance.

Further studies should be conducted to analyze potential problem areas in depth and to obtain additional confidence in the concept.

ASSESSMENT OF LIFT AUGMENTATION DEVICES
AGARD LS-43-71, April 1970

This publication contains edited versions of the lecture notes and complementary discussions from the AGARD - VKI Lecture Series on "Assessment of Lift Augmentation Devices", at the von Karman Institute for Fluid Dynamics during the week 20-24 April 1970.

The lecture series was designed to provide an up-to-date account of special aerodynamic problems and applications of lift-augmentation devices; including appraisals of the present state of knowledge, novel aerodynamic advances, experimental and theoretical treatments, applications for transport and combat aircraft, important areas for research and development. It was primarily intended for aeronautical engineers with a need to acquire a more adequate background on lift-augmentation devices. But short discussions were held after most of the lectures, together with a final Discussion Seminar, to take advantage of participants with specialized knowledge as appropriate.

The Course was well supported as regards both the number of attendees (about 100) and their technical quality. The organization was carried out under the auspices and with the support of AGARD, in collaboration with the von Karman Institute who had the responsibility for the general administration and local organization.

DEVELOPMENT OF A V/STOL MULTI-CREW RESEARCH SIMULATOR
D. T. Watkinson
AIAA Paper No. 70-356, March 1970

The full task research simulator plays an important role in the problem solving process of control-display research by providing the essential means of measuring the effects of change of one element upon the total problem while operating under realistic conditions. Such a simulator was recently developed by the Air Force Flight Dynamics Laboratory for initial application toward solution of the V/STOL IFR control-display problem. Consisting of a C-135B cockpit, three degree-of-freedom motion system, television visual display, digital computer and an experimenter's control console, the simulator is thought to be unique in its capability to investigate the control-display problems. Initial checkout and sample studies, conducted primarily to provide a baseline of simulator performance, have demonstrated this capability. However, there remains a definite need to quantify the effects of the visual and motion cues upon the V/STOL flight task.

WIND TUNNEL INVESTIGATIONS OF THE STOL AIRPLANE, WITH ATTENTION TO THE RELATIONS BETWEEN THE AERODYNAMIC CHARACTERISTICS AND THE WAKE STRUCTURE
N. Inumatu et al

Wind tunnel measurements have been carried out extensively on the flow field behind a powered model of the twin-propeller deflected slipstream STOL airplane.

By the use of new equipment in the measurement, spacial distributions for the flow velocity, down wash angle and side wash angle were obtained. Consequently the extraordinary deformation of the slipstream boundaries, and also the complicated movements of wake vortex systems have been recognized in the flow field. Furthermore by changing the direction of the
propeller rotation, marked influences of the rotating flow on the flow field have been exhibited.

These observed experimental facts seem to have some connection with the nonlinear aerodynamic characteristics of such a type of STOL airplane. The aerodynamic forces and moments of the model have also been obtained by the use of a sting type balance. Then, the probable relations among the relevant facts are discussed.
II. OPERATIONAL ASPECTS

INTRODUCTION

The bibliography in this section is subdivided under the following headings:

- Operation and Economics
- Transportation Demand
- System Cost Studies
- Access and Egress Problems
- Regulations and Safety

Many of the reports reviewed fall into several categories. The choice of category was the reviewer's, and readers interested in a particular aspect are advised to look under more than one heading.

The present study was restricted to operational aspects relevant to turboprop STOL aircraft. Some literature relating to jet STOL has therefore been omitted.

In the year that has elapsed since the 1970 STOL Report the major development concerning operational aspects has been the widespread acceptance of the demonstration STOL service as a desirable method of breaking the cycle of inaction. In papers by airlines and manufacturers in both North America and Europe and in reports by governments, STOL demonstration services are recommended. However, at the time of writing, Canada is the only country whose government has committed itself to such a service. Canada's lead is described in the paper on the progress of the Canadian STOL program by C. C. Halton of the Ministry of Transport.

OPERATION AND ECONOMICS

CANADA'S STOL PROGRAM - A PROGRESS REPORT
C. C. Halton
Ministry of Transport, Ottawa
AIAA Paper 71-982, October 1971

The paper is a general one and covers the following areas:

1. The role of Government in transportation in Canada.
2. The potential for STOL in the Canadian (Quebec-Windsor) corridor.
4. A progress report on the program to date.

The role of Government has always been a major one because of the importance and high cost of transportation for Canada's thinly distributed population.

In the Quebec-Windsor corridor the high proportion of air travel to travel by other modes, 31% of total passenger traffic is by air, is seen as a unique opportunity for STOL to supplement and complement conventional air service. A penetration of 1/3 of the air passenger market on Toronto-Montreal-Ottawa-Toronto routes is forecast. A first generation, STOL turboprop aircraft carrying about 48 passengers would be the vehicle.

The criteria used to select the Ottawa-Montreal route are described as a trip length suitable for the demonstration vehicle (the Twin Otter), an adequate level of potential traffic, availability of suitable STOLport sites, substantial competition from other modes, ability to command attention in the international market place and a suitable level of conflicting air activity to provide for testing of ATC facilities and procedures. The Ottawa-Montreal route best meets these criteria.

The demonstration program would be operated under normal civil air transport rules, i.e. FAR 25, and flight tests were in progress to establish flight procedures under these conditions and to investigate navigational and other equipment requirements. Progress with the associated STOLports is also described.

International interest in the program is mentioned and the memorandum of understanding between the Canadian Minister of Transport and the U.S. Secretary of Transportation is seen as being of advantage to both countries. The paper looks forward to a fully developed STOL system which should be operable on some of the routes which Canadian airlines now fly to American cities.

AN ECONOMIC ANALYSIS OF FUTURE SHORT-HAUL TRANSPORTATION
G. C. Kenyon, T. L. Galloway, H. M. Drake
NASA Ames, TMX-2228, March 1971

"A simplified economic analysis has been made of one transportation mission: intercity short-haul business passenger travel. The analysis includes both air and ground transportation modes for 1968 based on current mode characteristics, and for 1975 and 1982 based on projected characteristics for two assumed levels of R & D. The effects of changes in
the transportation mode and interface characteristics are investigated.

"The simplified approach allowed a qualitative assessment of the relative merits of transportation modes. Specifically, the results for 1968 indicated that the auto, bus, and subsonic jet were competitive while the train was not. The helicopter could be competitive at ranges between 50 and 150 miles for time values above $5/hour. The light aircraft was particularly attractive for multiple travellers.

Results for 1975 and 1982 indicated that: (1) the auto will remain the major mode for short distances; (2) the bus will remain competitive at low time values; (3) the high speed train will not be competitive unless heavily subsidized; and (4) the STOL transport will be a major transportation mode until it is replaced by the VTOL. An intensive level of R & D effort will be required to produce a competitive VTOL transport by 1982. The light aircraft mode, particularly with STOL performance and multiple travellers, appears very promising."

(Authors)

There are two points worth elaborating in this report. The first is in the method of presentation of the competitive areas for each mode, which the authors have used in other papers. The vertical axis is a value of time scale and the horizontal axis is a distance scale. The area in which each mode is competitive can be mapped onto the chart and the reader can make his own choice concerning the contentious value of time parameter.

The second point is to indicate one important factor concerning the good showing of the light aircraft with STOL characteristics. Access, delay and egress times are taken to be less than that of the automobile in 1975, and approximately half that of rail or STOL commercial transportation.

The priorities for civil aviation are seen to be the combatting of noise and congestion, the development of the high-density short-haul system and the development of the low-density short-haul system. The stress, in the reports, is on demonstration programs, as Government-industry joint enterprises where necessary.

The institutional constraints on the development of a STOL system are seen to be such that only a demonstration, appropriately Government-sponsored, of some magnitude would be capable of adequately introducing such a new system. Experiments in fare, schedule and deregulation effects should be conducted in the low-density short-haul market to guide R and D and future Government regulation. In this market also NASA should study the type of aircraft required, and, in conjunction with the market experiments, define the characteristics needed to serve this market best.

While it is not possible to adequately summarize all the other valuable data in these reports some indication can be given. The approach taken in the Supporting Studies Report is to forecast the growth of air traffic in the U.S.A., to segment this traffic into long-haul, short-haul, air cargo and general aviation, to consider the elements of the systems which contribute to these segments, e.g. environmental and financial, to consider policy and
in institutional factors and to note the benefits to the users, regions and the nation. Each section of the Supporting Studies is relatively complete on its own and each is worth reading.

**R-1**

**OPERATIONAL CONSTRAINTS FOR STOL AIRCRAFT**


The paper discusses the influences on the speed, size, propulsion system, field performance and maneuverability of a STOL aircraft of various operational constraints. These constraints are the short-haul market characteristics, the operating environment, community acceptance and economics.

The Short-Haul Market Characteristics

The point is made that the concept of city-centre to city-centre has been oversimplified and that what should be substituted is the concept of connecting points which will "produce enough traffic to make it worthwhile". The hub and spoke nature of the market is indicated by a map showing U.S. routes of 250 miles or less with 50,000 O and D passengers per year. Suburban airports may be convenient as an origin but not as a destination making both suburban and downtown airports desirable. The designation of a city as at least two points results in a proliferation of routes. This, in general, leads to a need for small aircraft if adequate frequency is to be maintained. The effect of frequency of service on penetration of the market is illustrated.

The Operating Environment

The landing field length required is plotted as a function of approach speed and glide slope. Lines of constant sink speed are overlaid and it is shown that, if a reaction time of 3/4 sec., a glideslope of 7.5 degrees, and an average deceleration of 0.4 g are assumed, a sink speed of 800 - 1000 fpm results in a field length of 1500 to 1800 ft.

The authors, basing their conclusions on analysis of the joint American Airlines/McDonnell Douglas STOL evaluation, consider that IFR STOL strips can be placed at most major airports without violating FAA separation criteria. The only exceptions are Washington National, La Guardia and San Diego and VFR STOL operations can be conducted even at these. The slow speed maneuvering capabilities of STOL aircraft produce turn radii from one-fourth to one half of those of CTOL for reasonable bank angles and turn rates.

The size of ground facilities required is discussed. The authors consider that the relatively large passenger handling and service facilities for a high density elevated STOLport or VTOLport would make the costs of both types of port virtually the same.

Community Acceptance

The overriding constraint is considered to be noise and the operating characteristics of STOL aircraft lend themselves to noise abatement through low propeller tip speed. Reference is made to successful, no-complaint, operations with the MD188 during the American and Eastern Airlines evaluations and the use of flyover noise measurements in the siting of a possible STOLport in St. Louis.

Economics

The STOL system is shown to be more expensive to the traveller but is justified on the basis of value-of-time, reduction in congestion and deferred spending in major airport expansions.

Cruise speed is investigated for the short-haul market and, because the ground time is a higher proportion of the total time, high speed is not as important as in long-haul economics. An interesting result, from the final chart in the paper, is that if there is a period of, say, three hours over which the peak demand exists and the stage length is 200 miles, then there is no difference in the number of departures made by a 300 mph and a 500 mph aircraft during the peak period. Both can achieve at least 3 departures.

**R-1**

**AIRLINE ECONOMIC REQUIREMENTS FOR 1975 STOL AND VTOL SYSTEMS**

R. K. Ransone


This is a brief paper, barely four pages long, but it puts succinctly the need for a demonstration STOL service in the Northeast Corridor. Such a demonstration would break the 'chicken-and-egg' cycle and provide information on the many unknowns. The author briefly discusses the landing facility, the aircraft, the air traffic, the market and the type of service required. He poses the demonstration service as the system necessary to attain Metroflight in 1980.
ADVANCED TECHNOLOGY FOR STOL TRANSPORTS
J. J. Cornish III
Lockheed-Georgia Co., SAE Paper 710751, September 1971

From an analysis of a typical large airport and its growth problems, it is concluded that STOL aircraft systems are needed now - with or without high-speed ground transportation. It is also shown that the needed first generation STOL aircraft can be in operation in 1975. These contemporary STOL aircraft will, however, be only a step in the evolution to improved aircraft of the future. The needs for technological improvements are discussed, and some new prospects in STOL technology are described.

The airport studied is Atlanta and it is shown that 66% of the scheduled flight arrivals are from distances of less than 500 miles. It is concluded that the addition of two STOL runways to serve short haul would permit a considerable capacity increase without additional land acquisition.

The aircraft suggested as the first generation STOL is the Lockheed LG-100-107D, a development of the C-130 Hercules. This was a candidate aircraft in the submissions made by manufacturers to American Airlines and a brief description of the modifications required to the basic C-130 design is given. The remainder of the paper is concerned with design rather than operational matters.

EXPECTED TECHNICAL AND ECONOMIC CHARACTERISTICS OF 1975 STOL SYSTEMS
M. D. Marks, R. F. Schaefer Jr. and J. P. Caldwell
McDonnell Douglas Corp. SAE Paper 700311, April 1970

This, like the paper by Ransone reviewed elsewhere in this section, is a plan for an evolutionary approach to the introduction of STOL systems. The paper briefly outlines the passenger market, the aircraft, the ground terminal facilities and air traffic control. From these outlines a schedule of the development of the STOL system is produced. The associated economic characteristics of the system are postulated - 15-30 million STOL passengers by the time of the introduction of the second generation STOL aircraft in 1979, CTOL fares higher than STOL but reduced trip time, and perhaps reduced trip costs, and minimal indirect cost increments for use of STOL facilities.

STOL AIRCRAFT IN FUTURE TRANSPORTATION SYSTEMS
E. E. Marshall
British Aircraft Corp.
RAeS Journal, October 1971

This paper is mainly relevant in that the way ahead is seen to consist of an evolutionary process via turboprop STOL.

The paper goes through the usual arguments for STOL, small land use and quietness. The author shows that the addition of STOL runways at the U.K. Heathrow and Gatwick Airports and the building of a STOLport at London's Poplar Docks could enable a doubling of the number of annual aircraft movements. This is seen to permit the system to cope with traffic demands beyond 1990.

After describing various BAC jet STOL aircraft the author describes the way ahead. This is seen to consist of immediate experimental services without passengers from STOL strips at Heathrow and Gatwick using the Twin Otter or the Skyvan.

The next step, "within two or three years, fare paying passenger QSTOL operations should be started with these small aircraft and slightly larger ones such as the proposed DHC-7 operations would be from STOL runways at existing airports and from new STOLports in urban areas."

The final stage, of course, comes with the operation of jet STOL and progressive developments are seen, seating up to 200 passengers in the 1980's.

V/STOLS FOR THE AIRLINES
S. M. Levin

This is an introductory article on V/STOL using Eastern Airlines RFP for a V/STOL aircraft as a starting point. It illustrates the vehicles proposed to Eastern and, in general terms, covers the aspects of V/STOL field length versus cost and $C_L$ max, noise, navigation, STOL ports and even deals with some of the politics involved.

THE POTENTIAL AND DEVELOPMENT OF A V/STOL INTER-CITY AIRLINER
D. H. Jagger, E. D. G. Kemp
Hawker Siddeley Aviation, Aircraft Engineering, Vol. XLII No. 1, pp. 6-13, January 1970

The article is mainly concerned with a
review of the arguments for fan lift VTOL aircraft. The main advantage of VTOL is seen to be in reducing the noise footprint, over that achievable by STOL. The article reviews the H.S.A. concept of the short haul market in the 70's in Europe, Japan and U.S.A. and predicts a swing towards VTOL. The operating environment is discussed, leading to the need for VTOL on noise, and hence terminal availability, grounds. The development of fan lift aircraft is discussed in some detail and lavishly illustrated. As regards economics the authors consider that the fan-lift VTOL is likely to be some 66% more expensive in first cost than STOL but that a time saving of 25% on journeys of 400 miles would give overall DOC's of only 10% greater than CTOL.

TRANSPORTATION DEMAND

INTERCITY PASSENGER TRANSPORT STUDY
Research Branch, Canadian Transport Commission, September 1970

This major report is a study of passenger transportation in the urban corridor which stretches from Quebec City to Windsor. Future transportation strategies are evaluated for the more heavily travelled links of this corridor, Montreal-Toronto-Ottawa. The report recommends an improved rail service for the 1970-1990 time period. STOL and TACV's are considered worthy of further research and consideration. The study is divided into five sections:

1. A technological evaluation of new modes of transportation, STOL, TACV and rail transport of various speeds.
2. Characteristics of existing modes of transport.
4. Formulation and calibration of demand models.

The technological evaluation considers the likely modes which will be available in the time period and rejects, for various reasons, VTOL, gravity vacuum tube and monorail transportation. The developments of existing modes are discussed and changes assumed in the study are noted. Automobile, bus, rail, TACV, CTOL and STOL are covered. Operating costs per passenger mile are plotted versus passengers per day for rail, against passenger miles per year for TACV and against stage length for CTOL and STOL.

STOL is given credit for being able to fly a more efficient route. The block time allowances are reduced from 21 to 8 minutes and the FAA 20 mile air traffic allowance is omitted. In spite of this, the aircraft operating cost plots, rather surprisingly, show a CTOL DC-8-61 as having lower direct and total (direct + indirect) operating costs on a 180 mile stage than the STOL DHC-7.

The section on present transport mode characteristics covers time, cost, distance, O and D distributions, access and terminal waiting times, and some user characteristics. The section on population and income distribution sets out the existing and projected trends for use in the prediction of future traffic demand.

The section on the demand model is one of the most interesting in the report. The travel demand predicted is for total annual trips by common carrier and takes the following form:

\[ V_{AB} = K_T P_A P_B L_{AB}^{1.30} e^{-.17/T_A} e^{0.23(D-T)} (C-P)^{-0.41} W^{0.205} \]

where \( V_{AB} \) = total annual trips generated by city A to city B by common carrier;

\( K_T \) = a constant;

\( P_A, P_B \) = populations of city A and city B (units of thousand);

\( L_{AB} \) = index of linguistic pairing between cities A and B (defined over the range zero to one);

\( T_A \) = fraction of families with annual incomes greater than $12,000;

\( D \) = highway driving time (centre to centre) (hours);

\( T \) = average total trip time by common carrier, weighted according to the modal split (hours);

\( C \) = average total trip cost by common carrier, weighted according to the modal split (dollars);

\( P \) = perceived cost of automobile (3t/veh-mile and 2.15 pers/veh);
The two noteworthy points are the index of linguistic pairing and the inclusion of competition from automobile as a predictive measure. For a service between cities having different majority languages the index of linguistic pairing is a useful insight. The demand for automobile travel is not predicted, and the common carrier demand depends on the differences between the average time and cost by common carrier and that by automobile. Of the two differences, the time difference has the greatest effect. The modal split model by contrast is more conventional.

\[ W_i = \frac{w_i}{W} \]

where \( W = \sum w_i = \text{common carrier level of service (System Impedance)} \)

\[ MS_i = \frac{w_i}{W} \]

\[ W_i = K_i(T_i) -3.05 -4.85 -3.9/F_i e \]

\( MS_i = \text{fraction of traffic to mode } i \) (Modal Split);

\( W_i = \text{level of service of mode } i \);

\( T_i = \text{total user trip time (including access, egress, terminal waiting, and block time, units - tens of hours)} \);

\( C_i = \text{total user cost (includes access, egress and fare, units - tens of dollars)} \);

\( F_i = \text{perceived daily departure frequency} \);

\( K_i = \text{Modal constant or acceptability factor (Bus = 1.65, Rail = 10.0, Air = 31.8)} \).

The report also provides data on the reliability of the models in tabular and graphical form.

The evaluation of the various development strategies covers present technology (the do nothing case) STOL, high speed rail 1 (existing track and turbobrain vehicles), high speed rail 3 (3 hours between Montreal and Toronto) and TACV. A network consisting of three links is considered, Montreal-Toronto-Ottawa.

The STOL strategy assumes that downtown STOLports are in operation in Montreal and Toronto by 1974, at a cost of $30 million. The DHC-7 is assumed to operate, between these two cities only, from 1974 to 1980 and an Augmentor-Wing aircraft between 1980 and 1990. Present technology vehicles are assumed to operate on the other two links. On the other hand, the high speed rail 1 (HSR 1) strategy is assumed to have no capital costs of new track to contend with and is applied to all three links, starting in 1971. HSR2 and HSR3 are applied to the Montreal-Toronto route only, and start in 1976 with fixed facilities costs of $200 and $500 million. The TACV is applied to all three links, starting in 1980 after an expenditure of $520 million on track and other fixed investment.

In the 1974 to 1980 period, when the DHC-7 is assumed to be in operation, the modal split acceptability factor, \( K_i \), for STOL is assumed to be half that of CTOL, and only STOL among the new modes is assumed to encounter competition. After 1980, the CTOL operators are assumed to inaugurate a shuttle service and reduce terminal waiting time by 30 minutes. The market available to STOL is reduced by about 25% by the assumption that only business travellers use the STOL service and a premium of $3 is charged for STOL travel on the Toronto-Montreal route. The conventional air mode loses money on this service between 1970 and 1990, on the assumption of DC-9 type aircraft running at 70% load factor. It seems evident that the frequency of service is inadequate to make the mode attractive and the costs at this short range are prohibitive. The smaller DHC-7 STOL aircraft, operating from the Ottawa CTOL airport to the Montreal STOLport, could have been assumed at no additional capital cost, would have provided a more attractive frequency and might well have contributed to a more favourable picture for the air mode. The results of the economic evaluation show that the HSR1, because of its three year lead, no requirement for capital investment and application to all three links, provides the highest system profit followed by the present technology and STOL, in that order.

The report is well illustrated with charts and diagrams.
This report deals with a proposed STOL network in the State of Florida.

The approach used is to select some 13 markets within Florida, project growth and estimate the STOL market share. The current commuter market share is assumed for STOL I, a turbo-prop STOL similar to the Twin Otter, and a 'significantly higher' share for STOL II, a STOL aircraft similar to the DHC-7. This latter share is determined from trip length, travel cost and demand for intercity and interline service. An overall airline market share of about 9% for STOL I and 32% for STOL II is foreseen, on the basis of estimated 1971 traffic.

The recommendations mainly deal with STOL port site selection and definition of STOL areas at existing airports.

The model approximates the mix of aircraft, routes, schedules, and terminal facilities that satisfy air carrier passenger demand at a minimum social (time) and economic cost. Eastern Airlines data was used to calibrate the model, which is written in extended FORTRAN IV for a CDC 6600 computer. Demand is forecast by a modified gravity model. The market split, between air carriers, is performed on the basis of frequency, or % of total carrier service. The cargo demand is based on departures, population, employment (total and government) and growth rate. The authors recommend further research on this segment of the model. The routing and network assignment segments obtain some degree of optimization through a linear programming approach. The time table building segment follows a method proposed by R. Simpson of M.I.T. The airport access model assumes circular access areas.

The documentation is extensive, about 4000 pages in all. The program tape is available.

This article relates more to mode-splitting than to demand prediction and covers in broad outline the results of a survey of 300 business travellers in the Midwestern U.S.A.
The travellers, in hub city A, were asked to complete questionnaires which quantified their attitudes towards car and airline travel to cities B and C; B was 274 miles from A and C was 112 miles from A. Two types of questions were asked:

1. Rate the acceptability of a given characteristic of the mode on a scale of 1 to 7.
2. Assign a relative order of importance to the above characteristics.

The characteristics given were total travel time, convenience (which was not defined for the traveller), safety, weather reliability, comfort, cost and noise. The results are shown in tables.

As regards time and convenience, the airline trip of 274 miles was seen as shorter and more convenient than the car trip but the 112 mile trip was seen as shorter and more convenient by car. Safety, weather reliability and comfort were rated higher by air than by car at both distances. Airline travel was considered more acceptable than car travel, on a cost criterion, for a trip to B. The situation was reversed on the shorter trip to C.

The relative order of importance in which the travellers rated the characteristics was as given above. Noise was ranked so low that it would appear that it is not a factor in a passenger's mode choice.

The report concludes that business travellers will constitute an active V/STOL market "only if the V/STOL's offer significant time savings, convenience approaching that of an automobile, safety records similar to those of conventional airlines and at least competitive levels of weather reliability and comfort".

THE CASE FOR THE CONVERTIBLE ROTOR
R. Hafner
Tenth Cierva Memorial Lecture, October 1969

The paper is a thorough study of the characteristics and case for the convertible rotor VTOL aircraft. It is compared, in a generalized environment with large and small cities with 25 origin and destination points per city and distances between cities of up to 800 nautical miles, with CTOL, Rail, Jet STOL, helicopters and fan lift VTOL. The main relevance of the report is in the technique of mode splitting. This is a variant of the value of time method and uses a vectorial approach which permits the consideration of three modes simultaneously.
an important political document and contains a large amount of useful and sometimes factual data. The report recommends a series of policy actions necessary to resolve future short-haul intercity passenger transportation problems in the Northeast Corridor of the U.S.A. Emphasis is placed on the development of ground transportation which could be used to obtain relief of the most pressing problems during the 'interim' 1970's time period, and on the actions required at the present time to ensure adequate lead time for 'long term' solutions in the 1980's.

The report is in three Volumes:

Vol. 1 Summary Report, which contains recommendations and supplementary conclusions, and discusses in summary form the background to the Corridor's transportation problems and the general study approach.

Vol. 2 Main Report, which contains discussion of the Corridors' population growth patterns, transportation problems, national transportation goals, and provides analyses of various alternative transportation modes both for the interim and the long term periods.

Vol. 3 Appendix, which contains four appendices: the delays, airborne, terminal and access for air travellers; the methodology used in the analysis of the highway system; the environmental impacts of transportation in the corridor and an environmental bibliography.

The report recommends for the 'interim' 1970's, period:

1. Improvement of high speed rail service.

2. Development of a real time highway information service to assist intercity drivers in making route decisions.

The actions recommended for the present to ensure adequate transportation in the 1980's are:

1. Planning of a right of way for high speed ground transportation.

2. R and D on tracked air cushion vehicles (TACV's).

3. More R and D for STOL and VTOL in the areas of airport and air traffic control system capacity, safety, noise, air pollution and ride quality.

4. Establishment of 1976 as a decision date for a corridor transportation investment program, based on the results of the R and D and the improved high speed rail service.

Recommendations are also made to extend the automated highway information system and to prepare for the associated legislation.

In general, the report tends to look optimistically at the future potential of high speed rail and gloss over the present failings of the rail transportation while, at the same time, exaggerating the problems with air transportation.

The present decline in rail passenger demand is expected to be reversed and a remarkable growth in rail patronage is assumed. While the text at one point notes that the "current annual figure of intercity rail passengers" is 9 million, a later table disarming labelled "3% annual growth" shows a 1970 demand of 12.8 million and a 1975 demand of 14.8 million, for a demonstration rail service. The net present values of the rail systems are, not surprisingly, healthily positive.

As regards land requirements for transportation the only areas singled out for mention as having problems are air and highway facilities and yet any rail improvements beyond the demonstrator (71 mph average speed) service will require land acquisition. STOL and VTOL in particular are seen by the report as having severe difficulty in the acquisition of land for their small terminal areas, but the acquisition of land costing $261 million for the TACV is merely covered by a recommendation that the DOT should "begin at once to explore possible routes".

No mention is made of the dirt, rattles, and longitudinal and lateral vibration of rail travel but the expected ride quality of the interim STOL of the 1970's, a low wing loading turboprop aircraft receives severe, if entirely subjective, criticism. It is made the major argument for casting doubt on whether a STOL system would divert passengers from CTOL. If CTOL passengers are so intolerant of change in ride quality, however imaginary, what reason is there to expect them to support rail rather than STOL?

The report, making use of the MITRE model reviewed elsewhere, compares VTOL and STOL, to the detriment of STOL. This is achieved by allocating high
high levels of required rate of return on the land and structure of the V/STOL ports. The smaller areas assumed for Vports more than compensate for the higher operating costs of VTOL aircraft. The question of the associated parking and service areas, which other authors consider could cause the total areas required for both Vports and STOLports to be quite similar, is sidestepped by assuming such parking areas to be 'self supporting'.

Neither VTOL nor STOL are considered the ultimate solution by the report because "to keep up with demand, additional expenditures would be continually needed for STOL or VTOL systems since terminal capacities are limited".

This is perhaps the point which has been missed in the whole study. If demand for STOL does increase to the extent that the terminal facilities are limiting, the options for meeting this demand are much more flexible than those of other systems. The aircraft size increase which will take place automatically will absorb much of the additional demand, but the ability to site new STOLports based on O and D surveys is the advantage that air systems have over rail. (It is interesting to note that at one moment the report considers that it is doubtful whether there will be a demand for STOL and at the next worries whether it can adequately be served).

On the matter of terminal access problems a curious double standard exists. Terminal access problems are only air and rail problems. No discussion or study is made of what will happen if rail travel is successfully promoted, and the multi-million passengers forecast attempt to reach the one terminal in each city.

There is a large investment in track and land in the rail lines of the Northeast Corridor which is rapidly becoming a complete write-off. There is no doubt that rail has a part to play in the total transportation scene in the Northeast Corridor. There is no doubt also, that relief funds for the railway disaster areas are badly needed to bring their technology, cleanliness, level of service and organizational structures into the 20th century. It is unfortunate that a technical approach has been used to justify what is essentially a political decision.

**Short Haul Inter-Urban Air Systems 1975-1985**

Mitre Corp. MTR-1653, January 1971

This report investigates the economics of a variety of air transportation systems against a background of automobile, bus and high speed ground modes in the Northeast Corridor of the United States. These were used as part of the input to the NASA/DOT CARD report.

The major conclusion concerns air vehicle size. A VTOL or STOL aircraft between 40 and 80 passengers is found to be superior to one of 120 or more passengers. This conclusion stems from the use of frequency as one of the factors governing passenger demand. A service with a frequency of between 2 and 5 flights per day between any STOLport pair is found to be so unattractive that patronage would decline to zero. The 120 passenger aircraft is unable to provide adequate frequency, in cases with a large number of terminals, to stay above this minimum and still have an adequate load factor. "The smaller size aircraft has a much broader initial applicability and is the preferable starting point".

No strong conclusions are drawn as to the preferability of either VTOL or STOL. Economically, the two vehicles come out on a par since the operator is assumed to bear the major part of the costs of the V/STOLports in indirect operating costs. The higher DOC's of VTOL are offset by smaller indirect costs resulting from smaller terminals. The report considers the VTOL to have a greater likelihood of community acceptance, on account of the smaller terminals and lower noise levels.

The simulation is run for two time periods, 1975 and 1985.

For 1975 the air vehicles considered are as follows:

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>McDonnell MDC-210G</td>
<td>122 passengers</td>
</tr>
<tr>
<td>Douglas DHC-7</td>
<td>48 passengers</td>
</tr>
<tr>
<td>DeHavilland S-65</td>
<td>86 passengers</td>
</tr>
<tr>
<td>Sikorsky DC9-3C</td>
<td>100 passengers</td>
</tr>
</tbody>
</table>

For 1985 some 'rubber' aircraft are used, in three passenger sizes:

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>STOL, 1500 ft. field length</td>
<td>120 passengers</td>
</tr>
<tr>
<td>STOL, 2500 ft. field length</td>
<td>120 passengers</td>
</tr>
<tr>
<td>VTOL, (Tilt Wing)</td>
<td>120 passengers</td>
</tr>
</tbody>
</table>

II,10
Curves are shown of daily passenger demand for 1975 and 1985 versus vehicle capacity. The 1975 curve drawn through the three 1975 V/STOL aircraft capacities indicates a peak at the 865 capacity of 86, largely arising from the use of an expensive Manhattan STOLport which causes a high fare and depressed demand for the DHC-7 and MDC210. Three different sets of terminals are considered for 1985 - a 10 terminal set, a 24 CBD terminal set and a 24 suburban terminal set. The optimum vehicle capacity with the 10 terminal set is about 120, with 24 CBD terminals is about 70 and with 24 suburban terminals is about 40, reflecting the lower demand and need for adequate frequency as the number of terminals increases.

The report also describes the model in greater detail than that of the associated report M71-24. The model is basically divided into two parts, the demand model and the supply model. In the demand model the Northeast Corridor is split into 29 super-districts and the demand for transportation is a function of the socio-economic conditions within each area and the characteristics of the modes serving them. Distinction is made between business and non-business travellers, the form of the model remaining the same but different coefficients being used for each type of traveller.

The demand model is described in the report as follows:

\[ D_{ij} = e^{\beta_1 F_1 F_2} \left( \sum_{k=1}^{n} W_{ijk} \right)^{\beta_3} \]

where:

- \( D_{ij} \) = Total daily demand between Super-District i and Super-District j.
- \( F_1 \) = Field length
- \( F_2 \) = Curves are shown of daily passenger demand for 1975 and 1985 versus vehicle capacity. The 1975 curve drawn through the three 1975 V/STOL aircraft capacities indicates a peak at the 865 capacity of 86, largely arising from the use of an expensive Manhattan STOLport which causes a high fare and depressed demand for the DHC-7 and MDC210. Three different sets of terminals are considered for 1985 - a 10 terminal set, a 24 CBD terminal set and a 24 suburban terminal set. The optimum vehicle capacity with the 10 terminal set is about 120, with 24 CBD terminals is about 70 and with 24 suburban terminals is about 40, reflecting the lower demand and need for adequate frequency as the number of terminals increases.

The term \( W_{ijk} \) describes the service offered on a single mode K between i and j. This is a function of travel time, travel costs and frequency of service. The equation has the form:

\[ W_{ijk} = e^{a_0 t_{ijK} a_1 c_{ijK} a_2 f_{ijK} a_3} \]

where:

- \( t_{ijK} \) = Total door to door time (access + line haul + egress) for mode K between i and j.
- \( c_{ijK} \) = Total door to door cost (access + line haul + egress) for mode K.
- \( f_{ijK} \) = \( 1 - e^{-L f_{ijK}} \) = transformation of frequency for use in the demand mode.
- \( L \) = Parameter set so that at some prescribed level additional frequency has little or no effect on demand.
- \( a_0, a_1, a_2, a_3 \) = Constants arrived at through regression analysis, where \( a_i \) is different for each mode.

Total demand is then split among the modes based on the relative service of
each mode.

Thus:

\[ D_{ijK} = \sum_{M=1}^{n} W_{ijM} \]

where

\[ D_{ijK} = \text{Demand for mode } K \text{ between } i \text{ and } j. \]

\[ n = \text{The number of modes in competition.} \]

The values of the constants used are provided but no indication is given of the order of the associated standard deviations.

The supply model, or OSM for Operator Supply Model, can define a mode as being reactive, i.e., responding to changing demand by changing service, or non-reactive. The OSM consists of a routing, a scheduling and a costing subprogram which simulate the decisions which an operator would make. The examples reported in the text are for reactive air modes and non-reactive ground modes. While some useful detail information is given on the methods of treatment of costs of facilities the description of the routing and scheduling processes is more general. In two appendices tables are provided of access times and costs to all modes and of the impedances for the ground modes.

VTOL PROFITABILITY IN THE NORTHEAST CORRIDOR


The paper is a report on the application of the Sikorsky S-65-200 to the Northeast Corridor in 1975. It represents a convenient summary of the VTOL case in the Northeast Corridor Investigation. Tables are given of the forecast demand, flight operations per hour, sites and costs of Vports, DOC's on each route, IOC's and revenues and profitability. No detail is given of the traffic forecasting and modal split methods except to note that a value-of-time method is employed for the split. The DOC's are given in greater detail. Considerable improvements over present day power train reliability are assumed in the maintenance costs, but the remainder of the DOC's in accordance with standard airline accounting procedures. The IOC's are based on Eastern Airlines 1966 experience and amount to $11.06 per passenger and are considered to be high. It is not clear whether terminal depreciation and associated taxation are included in the IOC's. A fare of $9 plus 64 per mile and an additional $2 surcharge are assumed. The resultant system using 40, S-65-200's returns a profit of over $15 million annually, but barely breaks even without the surcharge.

ACCESS AND EGRESS PROBLEMS

V/STOLPORT ACCESSIBILITY CONSIDERATIONS


Of 23 counties in the New York area, Manhattan generates 40% of all short haul traffic, 70% of which is business traffic.

Some access times and data are provided for other cities.

REGULATIONS AND SAFETY

SAFETY MARGINS FOR TAKE-OFF AND LANDING FOR THE BREGUET 941

J. Bastidon

Lessons with Emphasis on Flight Mechanics from Operating Experience, AGARD AD721692 October 1970 (In French)

The paper covers speed margins and distance margins.

Speed Margins

These should be based on \( V_{\text{min}} \) or the equivalent normal force coefficient \( C_{z_{\text{max}}} \) with power appropriate to each configuration.

For take-off Bastidon considers 'equivalent safety' to conventional aircraft for which, for 4 engined aircraft, \( V_2 = 1.15 V_\text{s} \) and hence is the speed for \( C_{z_{\text{max}}}/1.33 \). For powered lift aircraft the \( V_2 \) speed should be that for \( C_{z_{\text{max}}}/1.33 \). \( V_{\text{mc}} \) need not be considered since power loss is covered by cross-shafting and propeller loss is considered as unlikely as that of loss of a helicopter rotor. For landing three margins are considered, a speed margin to cover tail gusts, an incidences margin for vertical gusts and a 'g' margin. A speed margin of 0.3 \( V_{\text{min}} \) where \( V_{\text{min}} \) corresponds to three engines at maximum power, is recommended, together with a 'g' margin of 0.25 g.

Distance Margins

For take-off Bastidon recommends the same rules as for conventional aircraft.
i.e. the one-engine-inoperative take-off, accelerate-stop and 1.15 x the all engines distance.

For landing the author comments that "if a manufacturer is allowed to take credit for power on lift, there is no reason why he should not be allowed to take credit for power on braking, since the means are the same".

He suggests that the landing performance should be demonstrated with the most adverse propeller pitch control failure.

Some landing distance data from the F.A.A. testing at Atlantic City is provided. The conclusion is drawn that the landing field length should be based on a factor of 0.7 applied to a performance measured with brakes and reverse thrust, the reverse thrust being that available with the most adverse single failure.

Noise Certification.

The author envisages that the noise requirement would define the perimeter around STOLports with the specified maximum noise level at the perimeter.

The thinking is that a STOL aircraft should be defined as an aircraft capable of operating from a STOL runway in compliance with STOL operational and airworthiness requirements.

Control System duality.

The concept of duality of control systems used in fixed wing aircraft is very difficult to apply to some V/STOL configurations, e.g. tilting rotor, lift fan, etc., without presenting an insurmountable design problem. Some form of equivalent safety will need to be found.

All weather operation.

Landing guidance is seen as the lagging item.

Cluster of engines and fire protection of lift engines.

The independence of systems for engines in the current requirements may prove unnecessarily penalizing for clustered engines. In particular, the fire protection system could be made a common item for a cluster of engines, and this would not be permitted under the present regulations.

Endurance test for lift engines.

The present endurance testing is inapplicable to engines used at high power for short durations only.

Handling qualities.

Because of the greater significance of crosswinds, turbulence and wind shear during the approach and landing of STOL aircraft some revision of the handling qualities requirements will be needed.

Performance.

Landing is seen as prime area of interest with concentration on the field length factor and the use of reverse thrust.

As regards take-off the need for obstacle clearance in metropolitan areas is seen to point towards aircraft with more than two engines.
To respond to the need to increase speed, reliability and convenience of surface transportation link of air flight trip this study developed plans for improved transit services in the study area, examined the feasibility of those plans, and recommended means of implementing and funding. The effort was to connect the airport to the rapid transit system. The choice of extending BART (the rapid transit system) to the airport or install a separate connector system was considered. The Oakland Airport Connector System was selected as more advantageous because of lower cost and more frequent service. A comparison of the various Oakland Airport Connector Systems found a small vehicle service to be the most attractive as far as service, flexibility, and cost.

INTER-CITY VTOL STUDIES (UK) BUSINESS TRAFFIC AND POTENTIAL SITES VOLUME 1: BUSINESS TRAFFIC

The surveys and analyses which were made of business travel from establishments in eight urban areas in the United Kingdom are presented. The studies were undertaken to determine the economic feasibility of establishing a vertical takeoff and landing airline operation. The basic trip characteristics of business travelers and the relationships of trip generation and distribution are discussed.

INTER-CITY VTOL STUDIES (UK) BUSINESS TRAFFIC AND POTENTIAL SITES VOLUME 2: POTENTIAL SITES

Feasibility studies and analyses associated with potential sites for VTOL terminals in eight selected urban areas within the United Kingdom are presented. Analyses were made of the proposed land use patterns, population, employment, communications, and traffic to identify a number of possible VTOL sites. It is concluded that a number of potential sites for VTOL terminals are available and that VTOL commercial air transportation is feasible.
INRODUCTION

In comparing the reviewed papers in this section with the material that was considered in The 1970 STOL Report, a strong impression is created that very little of really new significance has appeared in the literature. Although there is no dearth in the number of publications in this period of just over one year following our previous annotation, much of the material is directly based on earlier papers and serves primarily the function of summarizing and spreading the available information to a larger audience. The inference is clearly that the 1960's were particularly fruitful in that the basic problems associated with STOL operation were defined, various tentative solutions for system operation were proposed and hardware development was initiated and carried to the prototype stage. All this came to focus in the very productive STOL test programs run by Eastern Airlines and American Airlines with the McDonnell-Douglas 188 aircraft in 1969. Following this very active phase, the generation of new data in the literature has considerably slowed down, most likely because the major problems in the implementation of STOL services now are associated with the non-technical political problem of gaining public acceptance.

This does not mean that there are no useful papers in this set. A number of useful and concise statements reviewing the current position are available as noted in the annotation and indicated by the relevancy ratings. It is also worthy to note that in response to the findings in the test programs of heavy pilot work load related to the waypoint introduction in RNAV systems, an interesting suggestion is made to alleviate this problem by a system of universal and standardized waypoints rather than look for solutions involving greater automation (see e.g. the paper by T. Oakes and R. W. Howlett "STOL Guidance and Control Operating Techniques").

GENERAL PERSPECTIVE

INTER URBAN AND INTER CITY V/STOL SERVICES
A. S. Crossfield
V/STOL in Civil Aviation
British Airlines Pilots Association, November 24-26, 1970

A general discussion is given of the desired characteristics of a short-haul air transportation system to lead to reduced cost based on Eastern Airlines experience. The separate elements that are treated in such a system are (a) STOLports, (b) Avionics, (c) Air Traffic Control, (d) Vehicle. The discussion centres on the North East Corridor and it is argued that suitable STOLport locations can be found. As to avionics the point is made that RNAV systems provide important advantages. Especially in relation to Air Traffic Control, the point is made that waypoints should be defined by a limited set of inputs which are the same for each station in order to reduce complexity, and thus pilot workload and the possibility of error.

COMMUNICATIONS

NEW TECHNIQUES IN AREA NAVIGATION AND DATA COMMUNICATIONS
B. F. McLeod
AIAA Paper No. 69-1054 presented at AIAA Annual Meeting
20-24 October, 1969

The author restates the case for area navigation as a necessity for the development of significant movement capacity of STOL and VTOL Services. Examples are given in the form of detailed maps of possible route structures associated with a STOLport on Manhattan, interleaved with the CTOL patterns of LaGuardia, J.F. Kennedy and Newark airports. A case is made for the addition of many more DME stations to enable a widely based RNAV system. Tests are summarized made by PanAm in collaboration with Bendix, G. E. and the F.A.A. on the effectiveness of data links. Messages contained position and altitude data as well as a variety of engine parameters of importance for maintenance.
Early tests were made to show satisfactory transmission in advance of an extensive test program to be run in 1970 between the West Coast and Honolulu.
from en route navigation to terminal area flight was found to be too high. After presenting a brief summary of the various types of STOL services, and the new aspects of multiple parallel routings and curved approach paths, the authors introduce a proposal for a RNAV system in the terminal area based on VOR/DME stations, in which the complication of way point setting is greatly simplified by the use of a standardized system to be used at all stations. It is proposed to do this by allowing only 12 radials (clock concept) and a single 8 mile distance from the station. This way all VOR/DME would have the same 12 way points, which can be used for arrival and departure. The use of such standard way points coupled with data link communication with ATC computers can lead to effective STOL operation.

Area Navigation Systems for STOL Operation
J. D. Wheeler
Shell Aviation News, No. 384, pp. 8-15, 1970

This paper is an excellent brief review of the American Airlines operated test program in which a McDonnel Douglas 188 (Breguet 941S) aircraft was used to test a number of navigation and guidance systems for STOL applications. The material has been discussed in a number of earlier and more extensive treatises. This one is useful because of its clear descriptions of the systems and the beautiful illustrations. The accuracies obtained are listed and the conclusion that pilot work load would be too heavy without additional automation is emphasized. It is also indicated that on-board position data will be communicated directly to ATC computers.

Area Navigation in Commuter/Taxi Operations
G. A. Gilbert

This paper describes the use of a 3 dimensional area navigation system based on the particulars of the Butler National system. The advantages of such a system for increased utilization of aircraft in short haul service and the increase in operation rate of the air traffic control system are summarized. It is also noted that fewer communications between aircraft and ground control follow as desirable consequences of greater responsibility for the flight path by the pilot.

A Survey of General Coverage Navaids for V/STOL Aircraft: A VOR/DME Error Model
H. Johansen
NASA CR-1588, May 1970

This report represents a detailed and highly technical review of some of the basic aspects of hybrid low cost inertial navigation systems which are updated by radio navigation aid data. After a general discussion of various navigation aids that can be used in such a hybrid system, a detailed analysis of the existing VOR/DME system and its errors is presented in a useful and exhaustive manner. The use of the system for curved approach paths is also briefly discussed.

A Three Dimensional Navigation and Guidance System for Transport Aircraft
M. G. Pearson

An existing system is described consisting of a number of components especially designed to alleviate acute operational problems existing in the North East Corridor of the U.S. The operational requirements were jointly generated by Eastern Airlines and the Decca Company. The system consisted of an area navigation system based on a moving map display driven by a choice of various input data: hyperbolic navigation and (HARCO), LORAN/C, a Dead Reckoning possibility, and VOR/DME or combined Doppler radar and VOR/DME. The vertical guidance is computed from the groundspeed and barometric altitude. The paper discusses the possible sources of error in the altimetry; it states the auto pilot steering program and the requirements for the filtering and mixing of the position data. A data link system was used in the flight trials, which transmitted position and altitude at 10 second intervals. Flight trial data obtained by the use of a DC9 aircraft as well as the McDonnell Douglas 188 are reported. No assessment of the acceptability is given in this report. The data link appeared to reduce transmission by about 29%
AREA NAVIGATION - A MAJOR CAPABILITY IMPROVEMENT FOR AIR TRAFFIC CONTROL
G. A. Gilbert
Paper presented at 27th Meeting of the Institute of Navigation
Monterey California, U.S. Naval Postgraduate School, June 19-21, 1968

A fairly general, non-technical description is given of the advantages of RNAV on-board systems. A description of one particular system, the Butler National 'Vector Analog Computer' is given and by considering a number of city pairs the case is made for distance savings up to 23 percent by using direct routes rather than current airways. Also, it is indicated that acceptable approaches could be made to 600 airports to low minima, which are now without such service.

IFR DESIGN REQUIREMENTS FOR STOL NAVIGATION EQUIPMENT

This is another summary of the flight test assessment of the McDonnell Douglas 188 in 1969 by American Airlines. A variety of 3 dimensional RNAV systems were evaluated for accuracy, for operation under real IFR conditions, to provide data on the relative suitability of cockpit display instrumentation and for cockpit workload. In addition the need for a STOLport landing approach system was determined. Since the systems under test have been described in several other pages in this annotation they will be omitted here. Suffice it to note that accuracy was acceptable but pilot workload was too heavy, leading to the conclusion that extensive programming of the required data for an entire flight route may be necessary. It is also concluded that a ground landing aid is needed for category II landing, but positioning for the approach by the RNAV system is adequate.

V/STOL GUIDANCE SYSTEMS FOR APPROACH AND LANDING
M. A. Meyer
Society of Automotive Engineers, Paper 700322, National Air Transportation Meeting, New York, April 20-23, 1970

The author discusses the general reasons for requiring curved approach paths and steeper glide path angles for V/STOL operation in the terminal zone. He indicates also the greater freedom for the approach direction in azimuth for pure VTOL vehicles because STOL aircraft must be aligned with the runway at least on the very last stages of the approach. The guidance system must provide angular and distance data and must be capable of operation at low altitudes in hilly terrain, unlike the equipment in current use for CTOL. The categories for such characteristics as designated by the Radio Technical Commission for Aeronautics (RTCA) are summarized. This is followed by a description of a microwave guidance system. It operates with a scanning beam and is capable of 60 degree coverage in azimuth and glide path angles between 2 and 12 degrees. This apparatus developed by the Electronics Division of Epsco Inc. provides 40 scans/second and angular measurements are made by the comparison of the time of maximum received signal with a time reference transmitted by the guidance system. Range is provided by a separate cycle which is time-multiplexed with the cycle that determines angle.
This brief paper reports on the technical and operational feasibility of STOL transportation as demonstrated in the joint program between McDonnell Douglas and Eastern and American Airlines. Although these demonstrations have been described in greater detail elsewhere as noted in this bibliography, this paper finds its value in an extremely compact tabulation of the various systems and the accuracy and repeatability obtained with each. It also reports on the vertical accuracy and lateral dispersion of the approaches that were flown in the tests. The results are shown to prove the feasibility of STOL operation.

The presentation in this paper gives an overall description of the research program at NASA Langley devoted to the problems of flying IFR approaches with V/STOL aircraft. Much attention is devoted to the problems arising from very low speed flight. Although some of the material is relevant to pure STOL operation most of the considerations are applicable primarily to vehicles not normally considered in the STOL category. Some of the material on cockpit displays and pilot assessment of flying qualities will be of interest to those involved with these subjects in STOL aircraft.

Although this paper relates to the specific case of vertical guidance of a VTOL aircraft, the technical details of computing techniques to generate the required digital-analog computations and inputs to the flight control system could be of interest to similar system designs for STOL operation.

The air traffic system under consideration in this paper is that of the U.K. projected into the 1980's. It is assumed that STOL services in domestic intercity service will possibly become of significance in the middle 70's, and that second and third generation STOL aircraft with increased passenger capacity and speeds up to 400 knots will become available around 1980. It also is assumed that by 1985 subsonic jets capable of vertical take-off and landing may be possible. To ensure high utilization, reliable interconnections with other transportation modes must be provided, and short routes on a non-interfering basis with CTOL in the terminal area will be mandatory.

In the terminal area the author proposes integration of V/STOL and CTOL modes by segregation, while en-route the later generations of V/STOL aircraft will have performance comparable to that of CTOL services and no segregation is required, except for feeder services which will occupy the air space below the conventional routes. Several examples are provided of possible route structures for each of the categories of

1. STOL operations at conventional airports
2. STOL operations at urban STOLports
3. VTOL operations at city centers.

At existing airports the use of parallel runways is considered and various separation standards are discussed, e.g. a 5000 ft. separation between adjacent instrument approach paths is standard, and simultaneous approaches may be allowed for less separation by requiring the STOL aircraft to make a side-step manoeuvre or to make an angled approach, with missed approach points so located that the missed approach path is adequately separated from the CTOL approach.

The use of urban STOLports requires
discrete routes in the terminal area for the STOL traffic so as not to interfere with and reduce the airspace capacity for CTOL traffic.

With regard to VTOL operation at city centers a stepped approach is suggested with a final vertical descent of about 1000 ft to minimize noise. Since the capacity of the VTOL port may well critically depend on the wake turbulence produced along this vertical path, considerable research on this aspect is indicated. Proper timing and spacing of aircraft while decelerating along the approach path, is felt to require the development of automatic control and special displays for the ground controller to monitor proper performance and timing of the required manoeuvres.

AIR TRAFFIC IN THE 1980's
S. Wheatcroft

This report contains predictions on aircraft movements in the U.K. for 1985. The content is mainly devoted to conventional aircraft services. In the part of the paper where the short haul domestic market is considered, the author points out that prediction for this kind of traffic for routes less than 350 miles will strongly depend on possible improvement in rail service. It is stated that in order to remain competitive new types of air service like V/STOL will have to be used.

With regard to such, use of V/STOL requires a preparation of the ATC system in the 1980's to make effective use of the low level airspace, now lying underneath the controlled paths of conventional aircraft.

V/STOL CONSIDERATIONS IN AIR TRAFFIC CONTROL
J. T. Stulz

In this short paper the author summarizes the arguments for special ATC arrangements that are to be made for V/STOL aircraft, in order to allow these vehicles to make a meaningful contribution to the overall transportation system. The advantage of RNAV and of departure and arrival schedules arranged as part of a preplanned optimum use of the system's capacity are considered. The author suggests a set of V/STOL approach criteria for IFR operation in which the angle of the approach path is progressively increased as the RVR decreases. This, of course, leads to the need for a microwave multipath approach guidance system, which may also be desirable to increase system capacity by avoiding the problem of blanking of the radiation pattern by an aircraft on approach for following aircraft along the same path. The possibility that continuous surveillance may become unnecessary in the future with the more accurate on-board navigation aids and data link communication with ATC is presented as a real possibility. Finally, a case is made for a more integrated display system on cathode ray tubes in the cockpit to provide a pictorial presentation of horizontal position, as well as a vertical situation display with a presentation closely related to the real world which incorporates information from guidance, altitude, air speed and computer systems.

VTOL INSTRUMENT OPERATION STUDY:
PROBLEM OF PILOTS AND ATC'S FOR VTOL COMMERCIAL FLIGHTS
A. M. Stave

Proposed modes of operation are discussed for an overall ATC/vehicle system for VTOL aircraft in which a 99% operational reliability would be obtained as far as weather conditions are concerned. The features of this suggested system are:

(a) IFR landing system with automatic approach and manual landing for the last 200 ft under the guidance of high intensity lighting.

(b) An accurate RNAV system for high density en route operation.

(c) Separation criteria based on velocity dependent time separation.

(d) Data link for communication and flight direction.

(e) Approach time issued prior to take-off.
Although some aspects of the discussion, e.g. the approach criteria and varying approach slope, are related specifically to the capability of VTOL aircraft, the material nevertheless has a significant bearing on the integration problems of STOL aircraft in the ATC system. A significant point to increase system capacity of obvious applicability in both cases is the envisaged direct linkage of ATC information and instructions to the pilot or on-board flight control system.

TECHNOLOGICAL GAPS IN V/STOL DEVELOPMENT
R. E. Kuhn
Notes for the Course "Modern Developments in Low Speed Aerodynamics with Application to STOL", University of Tennessee Space Institute, September 25 - October 6, 1967

In this report, which concentrates on the identification of aerodynamic problem areas associated with V/STOL aircraft, a short section is devoted to Air Traffic Control and Instrument Flight. The importance of being allowed to make more direct approaches to the runway that are in current use for CTOL operation is indicated and brief mention is made of ATC traffic simulation studies that could be made to study this problem. The usefulness of the comments is limited because of the much greater detail available in the literature devoted specifically to these problem areas.

COCKPIT INSTRUMENTATION INCLUDING CAS

V/STOL FLIGHT DIRECTOR SYSTEMS
C. M. Scott, Jr.

A three-axis flight director developed by Sperry Rand is described. The development is based partially on flight test results with a conventional two-axis flight director used on the McDonnell-Douglas 188 aircraft in the STOL studies by Eastern and American Airlines in 1969. It was found that because the STOL aircraft is operated in the approach on the backside of the power curve, the required control action to remain on the glide path is significantly different from that in CTOL where constant power is used and pitch control yields the desired flight path. In the STOL aircraft the vertical path should be controlled primarily with thrust, as it is in helicopters. This resulted in the development of a three-cue system in the flight director, in which airspeed control and pitch commands, altitude control and power commands are related. Several modes of its operation are described in detail.

SOME THOUGHTS ON V/STOL DISPLAYS AND APPROACH TECHNIQUES
R. W. Millward
In AGARD Problems of the Cockpit Environment, March 1970

This is a short statement of the pilot's requirements in an IFR approach task in a V/STOL aircraft. The author emphasizes landing at minimum conditions of 200 ft and 1/2 mi visibility. Good natural stability or alternatively an autostabilizer is desired to demand minimum attention of the pilot for physical control. The author believes that emphasis should be devoted to presenting the pilot with a high quality situation display, even at the expense of flight directors. He also favours head down displays. The type of approach envisages a "stepped" procedure, with preferably two pilots for division of the work load.

V/STOL VERTICAL SITUATION DISPLAY
R. A. Bondurant III and J. H. Kearns III
Society of Automotive Engineers, Paper 690694, National Aeronautics and Space Engineering and Manufacturing Meeting, Los Angeles, Cal., October 6-10, 1969

A discussion is given of display concepts developed at the USAF Flight Dynamics Laboratory to provide the pilot with vertical navigation information in a most effective manner. The vertical information is obtained from slant range data obtained from a ground based DME or TACAN station and altitude. A series of instrument displays giving line-of-sight-to-station angles and flight path angles is described representing earlier concepts. The need for the presentation of additional information like vertical track error and range for complicated multi-angle approach paths led to the development of a cathode ray tube display. On this instrument, the Flight Profile Indicator, the total vertical flight profile is depicted, together with the aircraft's present position and a clear
indication of the velocity in magnitude and direction in the vertical plane. Although the paper refers to a flight test program to assess the CRT display, no results are quoted on the efficacy of this type of display in comparison with the earlier systems. Also, the particular application in the test program is for VTOL aircraft only. However, the final test results will have meaning for STOL operation as well, although to a more limited extent.

APPENDIX III

No reports found for this section.
IV. NON-PASSENGER PUBLIC ACCEPTANCE

INTRODUCTION

As discussed in The 1970 STOL Report, a rather strong research effort had been noted in the literature, during the period 1966-1969, in the general area of aircraft noise and to a somewhat lesser degree, in the area of aircraft pollution. The same trend appears to be continuing at the present time with a significant fraction of this research being devoted to the special problems associated with V/STOL aircraft systems.

During the past 12 to 18 months the following aspects of the non-passenger public acceptance factors relating to V/STOL systems appear to have taken on an increased importance:

1. A continued absence of even "interim" regulations relating to permissible STOL noise levels.
2. An increasing concern over power plant exhaust pollution in the terminal areas.
3. An increasing realization, by various interested groups, that V/STOL aircraft systems must be seen in total as a summation of a number of important socio-economic trade-off factors.

Each of these topics is discussed, in special contexts, by several of the reviewed reports below, and it would appear that some progress is being slowly achieved towards the evolution of a viable short haul transportation system. It is interesting to notice the changing emphasis that has appeared in the efforts of the various system proponents to expedite this development. In the earliest days emphasis was placed on the convenience of the travelling public afforded by short haul V/STOL transportation systems with favourable terminal locations. Later detailed economic studies extensively exploited the value-of-time concept. Still later V/STOL systems were emphasized as a solution to the airport congestion at the larger international airport sites. Presently studies are being advanced to indicate the possible noise/pollution relief to be expected within the neighbouring community areas, through the introduction of carefully situated and controlled V/STOL aircraft systems.

Reports which were received too late for review are listed in the appendix to this section, together with a copy of the actual reported abstract/summary, if given. The reviews are arranged in the following categories with appropriate cross referencing as required.

- General Perspective
- Noise Exposure Forecasting/Noise Rating Scales
- Subjective Response
- Community Response/Compatible Land Use
- Economic and Legal Aspects
- Operational Procedures
- Regulation and Certification
- Aircraft and Hardware
- Pollution
- Mathematical Theories of Aircraft Noise

GENERAL PERSPECTIVE

SOCIAL AND INDUSTRIAL IMPLICATIONS OF V/STOL TRANSPORTATION SYSTEMS

I. C. Cheeseman, M. Judd, G. M. Lilley
B.A.L.P.A. Symposium, (University of Southampton, Dept. of Aeronautics and Astronomy) November 1970

A general review of the potential of V/STOL aircraft systems in the U.K. in the short-haul civil passenger and freighter roles has been carried out. A quantitative analysis is presented based on a recent comprehensive travel survey carried out for the British Ministry of Technology (also by Southampton University). This survey acquired extensive information relating to the travel plans of individuals and companies including business and pleasure trips, and including also air freight planning. The main requirements identified for the V/STOL system are as follows: inter-city business travel, inter-connections with international air routes, and integration with inter-urban surface transport systems.

Although no attempt is made to define the preferred V/STOL systems which would best fill the required roles, the authors do favour VTOL over STOL solutions, as a class, for the U.K. Factors cited to substantiate this preference are as follows:

1. STOL terminal areas are larger than VTOL port (and therefore more costly and difficult to
miles from the terminal area. Power plant exhaust pollution in the terminal area also appears to be a very important concern although the new generation power plant pollution characteristics and atmospheric diffusing and dispersion effect are still largely unknown at this time.

This is an excellent general review paper placing major problem areas in sharp focus. The only reservation which can be given applies to an implied emphasis on the VTOL system which is not always clearly stated.

R-2

PROCEDURES FOR ESTIMATING THE EFFECTS OF DESIGN AND OPERATIONAL CHARACTERISTICS OF JET AIRCRAFT ON GROUND NOISE

R. Lee et al

NASA CR-1053, June 1968

A very ambitious study has been attempted in this rather lengthy report (175 pgs.) which strives to expose the basic transport airframe and power plant design parameters which directly influence the perceived aircraft noise at ground levels. Quantitative descriptions are attempted to relate the important aircraft and power plant design factors to the perceived noise ground levels. The authors of this note are committed to the basic premise that the aircraft noise problem is essentially a system problem and can no longer (because of its seriousness) be regarded as the province of the "acoustics experts" above. Planners, mission analysts, designers and operators all must be technically involved and responsible for ultimate solution.

Despite the widely accepted view that accurate acoustic predictions for any new (arbitrary) compressor, fan and propulsive jet design configurations are presently much more of an art (based chiefly on the extrapolation of data for closely related configurations) than a science, which the authors apparently ignore, some interesting interim conclusions based solely on the airplane design and performance factors including operational factors are developed. These conclusions, being independent of the noise source characteristics, can be well substantiated. For example, it is shown that independent of the engine noise source characteristics an increased aircraft power loading and \( C_{\text{max}} \) can in general both provide a substantial noise improvement at ground level.

The reviewer cannot accept the apparent basic premise of this study; nevertheless the authors do develop several interesting interim conclusions which appear
to be adequately substantiated. Unfortunately these are well submerged in a large volume of data and general descriptive material which are much too approximate for the attempted refined trade-off studies. The analysis methods adopted herein allow no scope whatsoever for the innovative acoustic design changes which are currently being explored by several power plant manufacturers.

NOISE IMPLICATIONS FOR VTOL DEVELOPMENT
W. Z. Stepniewski, F. H. Schmitz
Air Transportation Meeting, SAE 700 286, April 1970

This paper is largely a review article, summarizing other earlier acoustic work relating to the community noise problem associated with design and operation of both conventional and advanced helicopter VTOL aircraft configurations. The advanced helicopter configurations the authors have in mind appear to be of the compound or unloaded rotor types, with cruise potential to approximately 300-400 mph.

A modified community noise index is proposed, termed the total community annoyance measure (TCAM). This index is defined in terms of an integral involving the product of the local EPNdB value and a new weighting function termed the Annoyance Awareness Function. (This product function is integrated over the entire area for which it is desired to establish a TCAM value.) No discussion of the required Community Awareness weighting function is included by the authors, and this remains a rather vague concept throughout. (It would appear in fact that this function is very closely related to the desired or existing local community noise levels prior to the occurrence of any interfering VTOL noise. In fact this type of assumption has now been made in certain recent community noise studies.)

On the whole this article offers no new or original concepts or ideas concerning the difficult VTOL community noise problem. It does however offer a quick and readable review of the main facets of the problem together with an adequate listing of a number of the more significant and relevant references.

see also:

AIRCRAFT NOISE - MITIGATING THE NUISANCE
E. J. Richards
Astronautics and Aeronautics, January 1967 on page IV.5 of this bibliography.

NOISE EXPOSURE FORECASTING/NOISE RATING SCALES

FREQUENCY SPECTRUM AND TIME DURATION DESCRIPTIONS OF AIRCRAFT FLY-OVER NOISE SIGNALS
D.E. Bishop
FAA Report DS-67-6 May 1967

The analysis of tape recorded noise obtained during an aircraft fly-over (or other transient noise disturbance), to provide a meaningful subjective annoyance figure (EPNdB) is complicated by a variety of factors. Much of this complication arises from our present incomplete understanding of the correct relationship of the physically measurable characteristics of a complex noise signature to the resulting subjective annoyance. This report discusses in a clear manner many of the present difficulties and uncertainties in some detail. Accordingly, this note will prove of great value to those faced with the actual measurement of complex noise spectra for subjective purposes. It will also be of assistance for those carrying out research work in the area of subjective acoustic response.

Some 32 fly-over aircraft noise signals have been processed, using alternative reduction techniques to obtain a measure of the corrected perceived noise or annoyance. Some of the alternative reduction methods utilized include the following.

1. Perceived Noise - calculated on basis of octave bands (maximum levels)
2. Perceived Noise - calculated on the basis of 1/3 octave bands (maximum levels)
3. Perceived Noise - calculated on the basis of 1/3 octave bands, at the time the N level registered a maximum value

In addition, the alternative methods of applying the correction to PNdB to account for the presence of pure tones and for time duration are discussed in some length. The difficulties introduced by the Doppler shifting of discrete tone components in particular are reviewed in detail. It is shown
that this feature may often establish the limiting accuracy for practical measurements. It is also shown that if the amplitudes of the pure tone components are only slightly above (3-5dB) the adjacent portion of the broad-band noise signal, frequency analysis in bands narrower than one-third octave band will be necessary.

This report is not recommended by the reviewer for those readers having only general interest in the community noise problems associated with V/STOL aircraft systems because of its specialized nature. The report, however, is well-written incorporating many actual aircraft noise signatures and their reduced forms, and unquestionably of considerable value to those faced with the reduction of complex transient noise signals for subjective comparisons.

REVIEW OF RESEARCH AND METHODS FOR MEASURING THE LOUDNESS AND NOISINESS OF COMPLEX SOUNDS
K. D. Kryter
NASA CR 422, April 1966

The author (who himself has contributed much important research in the subjective acoustics field, including, most recently, a text entitled "The Effects of Noise on Man") gives an historical account of research leading up to the development of the concept of perceived noisiness or "unwantedness" of a sound.

The review begins by summarizing the development of methods for predicting the perceived loudness including the dependence of loudness on frequency (pure tones) and frequency spectra (broadband - both Stevens' method and Zwicker's method), the dependence of loudness on intensity level, and the dependence of perceived loudness on duration of the noise signal. The author then goes on to show how the subjective quality of sound termed "Noisiness" was introduced, and how this subjective attribute of sounds is in general rather different from the loudness of the same sound. Very sizeable differences exist between the subjective reaction measured on the basis of noisiness as opposed to loudness when the evaluated sound signature has a marked time varying intensity, contains one or more embedded pure tones, or has a predominance of higher frequency broad band energy. In these cases the judged annoyance is much greater than the judged loudness. This report concludes by carrying out some comparisons, based on the results of recent subjective noise evaluation tests, of the ability of the various loudness and perceived noise prediction methods to match carefully measured subjective reactions. It is indeed rather surprising (and confusing) to note that these comparisons show that the dB(A) weighting (loudness measurement) actually predicts the observed annoyance of many important real life sounds just as accurately as the PNdB evaluation applied to the same sound. This result is especially true when the evaluated sound signature has no dominant discrete components, and comprises mainly lower frequency, broad band noise, for example, motor vehicle traffic noise.

see also:

GROWTH OF NOISINESS FOR TONES AND BANDS OF NOISE AT DIFFERENT FREQUENCIES
J. E. Parnell, D. C. Nagel, H. J. Parry
on page IV.4 of this bibliography.

THE EFFECTS OF NOISE ON MAN
K. D. Kryter
Academic Press, 1970
on page IV.5 of this bibliography.

SUBJECTIVE RESPONSE

GROWTH OF NOISINESS FOR TONES AND BANDS OF NOISE AT DIFFERENT FREQUENCIES
J. E. Parnell, D. C. Nagel, H. J. Parry

This study is devoted to basic subjective research in the area of perceived annoyance. Measurements carried out include the following basic investigations.

(1) The growth of annoyance for both a 1KHz tone and an octave band of noise centered at 1KHz (the experimental technique included both the continuous adjustment method and the method of magnitude estimation).

(2) Equal noisiness contours were obtained for a variety of listening conditions including pure tones (other than 1KHz) in a free field and one-third octave bands of noise in both free and diffuse field conditions.

(3) Comparison tests were performed to evaluate the effects of stimulus duration on the derived equal noise contours.
It is clearly demonstrated that (as found earlier by Kryter and others, for loudness measurements) the growth of annoyance depends strongly on the method of testing employed. Consistent with the loudness quality of sound, the annoyance growth is found to be much slower when the magnitude estimation tests are employed. The results from the adjustment test method indicate that an 11dB sound pressure level change is required to double or halve the perceived annoyance; magnitude estimation testing produces results showing that a sound pressure level change approximately twice as large is required, 22dB. This discrepancy cannot as yet be satisfactorily resolved. However, the authors go on to demonstrate that the specific value used for the growth of noisiness with sound pressure level does not significantly affect the relative PNL values calculated for different noise spectra.

The effects of the listening conditions, free field or diffuse field and the effects of stimulus duration in the range tested were found to introduce no important new features in the resulting equal noisiness contours.

This report is written primarily for those interested in carrying out research in the subjective acoustics field. However, it does briefly outline many of the important difficulties currently unresolved which complicate and restrict the interpretation of much of the widely quoted and apparently straightforward basic annoyance data associated with signatures.

R-3

THE EFFECTS OF NOISE ON MAN
K. D. Kryter
Academic Press, 1970

This new text attempts a rather detailed review and analysis of the relevant literature and research in the field of subjective acoustics, covering the period 1950-1970. The text is divided into three major parts as follows:

Part 1 - Auditory System Response to Noise
Part 2 - Subjective Response to Noise
Part 3 - Non-Auditory System Responses to Noise

Part 1 covers the topics, masking and speech communication, audio-metry, aural detection, aural damage risk, and procedures for estimating damage risk. Part 2 covers the topics, loudness, perceived annoyance, evaluation of environmental noise, and procedures for the evaluation of environmental noises. Part 3 covers the topics, general physiological response to noise, and the effects of noise on mental and motor performances.

The reviewer feels that the author has stressed an historical review rather than a critical review of the wealth of material included. On occasion it will be difficult for the average reader to immediately recognize and separate the important research findings - those leading to a substantial improvement in our understanding of subjective acoustic response. A succinct review of the established features of the present state of knowledge, at several points throughout the text, would have been appreciated by the reviewer. On the other hand, the author carefully includes much (if not all) available research on a given topic with extensive cross comparisons of experimental data given in most cases. An excellent reference and bibliographical section is included.

The reviewer feels that the subject material covered by the author certainly fills an important gap within the available acoustic texts. The book is expected to be of greatest value to new research scientists in the subjective acoustics field.

COMMUNITY RESPONSE/COMPATIBLE LAND USE

R-1

AIRCRAFT NOISE - MITIGATING THE NUISANCE
E. J. Richards
Astronautics and Aeronautics pp. 34-45
January 1967.

The author, in a stimulating article discusses community noise disturbances due to aircraft overflight in regions remote from the immediate airport site. He develops arguments leading to the introduction of new social annoyance index termed the "Community Nuisance Index". This is based on the concept that the noise nuisance experienced by any one individual is proportional to the total noise energy received in a specified period (24 hour period). The Community Nuisance Index then is defined as the product of acoustic energy reaching the community area and the population density in that area. Richards discusses several basic factors
affecting the former of these quantities, including the number of aircraft movements daily, the static thrust per aircraft (with forward speed correction factors), path correction factors including spread of movements, the height of operation etc. and the acoustic conversion factors (containing the subjectively weighted acoustic energy radiated during climbout).

In reviewing these factors individually, in some detail, the author reaches several rather significant conclusions concerning noise, as follows:

1. The thrust per passenger for all recent jet aircraft is very roughly constant, with the exception of the SST configurations which require approximately three times as much thrust per passenger.

2. The thrust rule also applies equally well for propeller driven aircraft if about 2 pounds thrust/hp is assumed.

3. The Jumbo jet concept by itself can do very little to help community noise levels, in fact, since thrust per passenger is held constant conditions will likely deteriorate as these jets will allow a given airport to handle more passengers. Any improvement for these configurations must be achieved with improved power plant acoustic technology.

4. The acoustic conversion factor for propellers combined with a proper subjective weighting indicates a very substantial noise reduction relative to jets and fan jet propulsion units is achievable. Reductions of up to 25 PNdB for equivalent thrust values are indicated for moderately loaded propeller/ducted fan configurations.

The author concludes his study with a more detailed examination of specific noise radiation effects peculiar to the SST configurations.

This article is clearly written and the arguments advanced are well developed. It outlines in a succinct manner the most important noise radiation features which are at play in the current airport-community noise problems. Item 4 in the above listing would appear to have much potential in relation to the specific V/STOL community noise problems, however the author does not pursue this aspect of the study in depth.

EFFECTS OF NOISE ON COMMERCIAL V/STOL AIRCRAFT DESIGN AND OPERATION
H. Steinfeld, E. Hinterkeuser,

An ambitious and somewhat involved study has been carried out to assess the potential community annoyance attributable to the operation of six specific V/STOL configurations, each typical of, and optimized within, differing basic aircraft design concepts. Basic to the study reported was the development of actual tape recorded aircraft signatures constructed to simulate the noise generated by each individual account. These tapes were then played back and evaluated by a jury of listeners using the method of paired comparisons as developed earlier by Kryter ("Scaling Human Reactions to the Sound from Aircraft", Journal of the Acoustic Society of America, Vol. 31, No. 11, Nov. 1959). The standard reference noise, against which all subjective comparisons were made was that noise appropriate to current jet aircraft producing 112 PNdB, outdoors (the current noise criteria used by the Port of New York Authority for existing jet aircraft). The specific configurations studied for annoyance were representative of the following design concepts: Fan Lift; Jet Lift; Tilt Wing; Turbofan STOL; Stowed Rotor; Tandem Rotor. These study aircraft configurations evolved in response to an earlier NASA short-haul transport study (Feasibility of V/STOL Concepts for Short Haul Transport Aircraft, CR 743, June 1967, NASA). In general these design study aircraft were optimized for economic criteria with no major concessions to noise radiation.

Results of these studies indicate that all configurations must develop a substantially lower comparative peak PNdB value for equal community annoyance especially during take off/landing. (Separate tape simulations were developed for take off, landing and cruise in each case.) Thus all aircraft would require about a 10 dB peak PNdB reduction relative to today's aircraft to produce equal community annoyance. This noise increment appears to cover two main aspects of the V/STOL operations:

1. Vehicles will operate in closer
proximity to sensitive neighborhoods.

2. Duration of high noise level periods will be increased above today's values.

This is only a part of the story, however, since these vehicles will start out (generally) with higher noise levels than today's aircraft. Thus the total noise reduction required for equal noise community annoyance for these vehicles is in the range 20 to 30 PNdB (take off and landing) with the Tilt Wing STOL and Turbo Fan STOL being slightly preferred/quieter.

The basic item brought out in this work is the additional 10 PNdB (approximately) quieting that V/STOL aircraft must provide to achieve equal community annoyance. This factor arises due to the reduced community distance separation and greater percentage time in the high noise level mode which are both implicit factors to the Short Haul V/STOL aircraft concept. A basic premise of this work lies in the assumption that the equivalent 112 PNdB (outdoor) annoyance will be adequate. Data elsewhere would suggest that this level is too high for future community tolerance. The rather complex methodology developed for this study rests on the stated assumption that an adequate noise criterion index capable of subjectively rating arbitrary noise spectra for annoyance, is presently lacking. The concurrent subjective annoyance research carried out by D. W. Robinson (NFL Aero 38) U.K. would appear to provide the required subjective criteria, permitting therefore a much more direct approach (analytical) to this evaluation problem in the future.

see also:
GROWTH OF NOISEINESS FOR TONE AND BANDS OF NOISE AT DIFFERENT FREQUENCIES
J. E. Parnell, D. C. Nagel, H. J. Parry
on page IV.4 of this bibliography.

THE EFFECTS OF NOISE ON MAN
K. D. Kryter
on page IV.5 of this bibliography.

ECONOMIC AND LEGAL ASPECTS

see:
SOCIAL AND INDUSTRIAL IMPLICATIONS OF V/STOL TRANSPORTATION SYSTEMS
I. C. Cheeseman, N. Judd, G. M. Lilley
on page IV.1 of this bibliography.

EFFECTS OF NOISE ON COMMERCIAL V/STOL AIRCRAFT DESIGN AND OPERATION
H. Steinfeld, E. Hinterkeuser
on page IV.6 of this bibliography.

OPERATIONAL PROCEDURES

REDUCTION OF VTOL OPERATIONAL NOISE THROUGH FLIGHT TRAJECTORY MANAGEMENT
F. H. Schmitz, W. Z. Stepnowski

This study discusses the probable noise reductions which can be realized in the vicinity of a Vertiport site through the use of controlled flight path approaches and departures. Two hypothetical VTOL types are studied; a prop-rotor configuration (low disc loading type) and a lift-fan configuration (high disc loading type). Performance data and noise radiation characteristics are derived analytically for both design configurations for a common vehicle size of 46000 lbs. all-up weight. Details of the analysis methods used are not given; however, the reader is referred to a NACA CR by the same authors, to be available shortly. (The noise characteristics for the lift-fan aircraft configuration are apparently based on published data applicable to the General Electric fan-in-wing high by-pass ratio tip-driven lift fan unit.)

For both vehicle types, a number of flight plans in the terminal area to and from an altitude of 3000 ft. have been developed. In each case, reference trajectories have been calculated which minimize one of three quantities of interest as follows:

1. Time to climb to altitude (3000 ft.)
2. Fuel to climb to altitude (3000 ft.)
(3) Noise measured at selected ground stations (in the plane containing the aircraft track)

Again the methods of optimization are not included in the present study, and the reader is again referred to the same NASA CR by the same authors to be printed shortly. In addition, for each vehicle additional partially compromised flight paths have also been studied in detail.

The study results show very similar patterns for both vehicle types. The maximum performance flight paths require the a/c to accelerate (decelerate) horizontally near the ground to (from) an optimum climbing (descending) speed which is then maintained to (from) 3000 ft. altitude. (The maximum performance flight paths therefore resemble STOL aircraft operations to a considerable degree.) On the other hand, however, the minimum noise flight paths involve vertical ascent (descent) directly over the terminal area to 3000 ft. altitude with a conversion at this altitude to (from) the steady horizontal flying condition. It is concluded that steepening the flight path to reduce ground level noise conditions would be an effective manoeuvre for both vehicles studied. The cost in performance is estimated to be (approximately) a 50% increase in the time required for take-off and landing and for fuel consumed, for the prop-rotor configuration and a 100% increase in these quantities for the lift-fan configuration.

The study also attempts to evaluate the total community annoyance due to daily aircraft operations at the local community Vertiport. An index, termed total community annoyance measure, TCAM, is proposed. This index is a weighted summation of all points in the community experiencing aircraft annoyance, of the annoyance at a given community location multiplied by the population density at that location and by a relative annoyance factor - the "annoyance awareness" factor. Methods for determining this later factor in a given community are not clear and are not discussed although the general intent is fairly clear. The reviewer feels that the TCAM concept proposed is a valid and desirable one, however, the method of calculation indicated is unlikely to see wide usage due to the vague and unavailable "annoyance awareness" factor implicitly required. The validity of the "two dimensional" TCAM calculations included near the end of this report is also questioned by the reviewer.

STUDY OF THE EFFECT OF DEPARTURE PROCEDURES ON THE NOISE PRODUCED BY JET TRANSPORT AIRCRAFT
W. J. Galloway, A. C. Pietrasanta
Bolt Beranek & Newman for FAA,
FAA ADS 41, March 1965.

Noise data have been recorded in the noise sensitive areas adjacent to Kennedy airport of the signatures developed by regular commercial jet aircraft operating to various departure procedures. These procedures include a datum case, based on performance/safety considerations only and a variety (seven) of alternative noise abatement departures. These latter include a variety of power cut-back schemes, varying both the magnitude and duration of the power reduction. Both turbojet and turbofan aircraft were included in the test series. Aircraft adherence to specified flight procedures was assessed during each run by detailed radar measurements.

Results show conclusively that very substantial noise (annoyance) reductions can be achieved at ground level for the better procedures established. Attenuations in PNdB as high as 8 - 10 were established. It was noted that even small increases of a transient nature in power levels, during cut-back operation, resulted in relatively large increases in perceived noise at the ground stations so that careful attention to the required power setting is essential if maximum benefit is to be derived.

see also:
PROCEEDURES FOR ESTIMATING THE EFFECTS OF DESIGN AND OPERATIONAL CHARACTERISTICS OF JET AIRCRAFT ON GROUND NOISE
R. Lee et al.
on page IV.2 of this bibliography.

REGULATION AND CERTIFICATION

STOL AIRCRAFT NOISE CERTIFICATION
F. B. Metzger, W. M. Foley
SAE Paper 700325, April 1970

A general review of the community noise problems to be encountered with the introduction of new urban STOLports is given. The overall noise characteristics of STOL transports (150 passenger size) are summarized on a single curve (band) plotted as
a function of powerplant disc loading. The authors feel that currently there is inadequate information available in several important areas to develop adequate and completely rational STOL noise certification rules. On the other hand they also point out that the absence of rules, even tentative ones, is a great deterrent to the airframe manufacturers in their attempts to develop successful aircraft configurations.

The main areas where additional data and work are required are reviewed in some detail as follows:

1. An improved Subjective Annoyance Rating system is urgently required. (Deficiencies inherent in the PNdB rating scheme in the correction for background noise level influence in the duration correction and in the tone corrections are especially noted.)

2. Adequate community noise level (ambient) data appropriate to likely (or typical) siting areas is not yet available.

3. The permissible community tolerance levels are not yet defined.

The report goes on to list and review several types of noise certification regulations which could be considered as follows: Three Point Method (extension of existing rule for Subsonic Transport CTOL), Operating Rule Method, Maximum Noise Limit Method, Noise Exposure Forecast Method and Aircraft-Community Compatibility Method. (Some or all of these proposals had been submitted earlier at an FAA conference held in January 1969 - see FAA Report No. 69-1). The authors feel that the difficulties outlined above combined with basic difficulties inherent in all certification schemes already proposed (above) prevent even an interim (rational) STOL Noise Certification procedure from being developed.

The authors then discuss their own ideas for a rational set of STOL noise rules briefly. They introduce an interesting concept that has not been previously noted, that is the permissible level of STOL aircraft be specified in terms of the passenger capacity of the vehicle. The specification noise level would increase at a rate of about 4.5 or 5 dB per doubling or passenger number. This would appear to be a rather attractive type of incentive regulation (from the manufacturer's point of view) however from the community's point of view it would also mean continuing annoyance increase paralleling the STOLport growth (unless levels were continually adjusted to match the expected terminal growth).

**AIRCRAFT AND HARDWARE**

ENVIRONMENTAL FACTORS IN THE DESIGN OF DIRECT LIFT V/STOL TRANSPORT AIRCRAFT
T. K. Szlenkier

A general discussion and review of the continuing project studies carried out by Hawker Siddley Aircraft (Hatfield, U.K.) for new V/STOL and STOL aircraft configurations is given. The aircraft design philosophy discussed, is based on the use of a large number of small lift fan engines mounted in two streamlined wing mounted sponsons located at about the mid-span position symmetrically on either side of a conventional fuselage. The author presents some cost, performance, and layout information concerning a 100 passenger V/STOL aircraft configuration based on this design concept.

Noise and power plant exhaust emission pollution of the proposed aircraft design concept are also discussed. The noise criterion tentatively adopted is 90 PNdB level, in the adjacent community areas with a noise clearance (control) area extending out 3000 ft. from take off/landing zone. (This noise specification is apparently much less stringent than the present Canadian STOL requirement of 95 PNdB @ 500 ft. - by about 10 PNdB.) To achieve this requirement the author proposes tightly controlled field operations involving very steep approaches/departures, and monitored horizontal accelerations when the aircraft is fully converted to horizontal flight. Atmospheric pollution from the engine exhausts is discussed and is expected to be a problem if the factors cited by the author are applicable simultaneously. These factors include the frequency and scale of short haul service provided, the concentration of these service activities within the restricted airport area, and the thrust level of the aircraft in service.

The author concludes his paper with a briefer discussion of related military V/STOL requirements (noise, pollution, operational) for aircraft having the same general design features.
A short non-technical article discussing the potential of an advanced Sikorsky compound helicopter now in the early planning stages in the short haul passenger/freight role. An 86 passenger helicopter with cruising speeds to 200 plus knots has been extensively studied by Sikorsky in the North Eastern Corridor area, on city centre to city centre routings. Shatz feels that the key to the North Eastern V/STOL aircraft system lies in the Manhattan terminal selection, which he feels will necessarily be restricted to a smaller heliport. The author feels that both VTOL and STOL systems will ultimately emerge and that the VTOL system will capture the travel market into major downtown hub areas. The STOL systems will operate from peripherally located STOLports.

The report covers several important advantages claimed for the compound helicopter configuration in comparison with CTOL and STOL systems. These include travel time, community noise levels, terminal siting and power plant pollution. The somewhat higher operating costs are offset to a degree by reduced indirect operating costs including site and terminal costs. It is also argued that in total an adequate 11% annual return on investment can be achieved with the VTOL compound helicopter system (in the short haul North East Corridor route system). The expected noise levels of the advanced Sikorsky aircraft are also shown (as PNdB values at 500 ft.). These are claimed to be in excess of 10 PNdB quieter than a comparably sized turboprop STOL transport. The reviewer finds this latter claim to be rather optimistic.

LIFTING FAN NOISE STUDIES
G. Krishnappa, G. G. Levy,

As part of an on-going V/STOL research program at the N.R.C. Montreal Road Laboratory site, the authors report on noise measurements carried out in an anechoic chamber with a 12 inch model fan. The model is a single stage unit without inlet guide vanes, mounted in a high aspect ratio wing and driven by a remotely mounted air turbine. Due to the wing surface constraints, the fan has a relatively short intake section ahead of the fan rotor with a closely coupled outlet stator stage downstream.

Measurements reported include overall sound pressure level directivity data, first and second harmonic directivity data and broad band noise data for three fan operating speeds (static condition). Comparisons are attempted with the analytical studies and results due to Lowson ("Theoretical Studies of Compressor Noise" - NASA CR-1287 March 1969) for the discrete noise components. For the broad noise measurements comparisons with predictions carried out by Sharland ("Sources of Noise in Axial Flow Fans", Journal Sound & Vibration Vol. 1 No. 3 1964) are presented. The former comparisons are somewhat complicated in the present case since no additional dynamic data is apparently available concerning the unsteady fan blade forces occurring. Broad band comparisons appear to confirm the sixth power dependence for sound intensity on mean velocity as suggested by Sharland (and others).

The work reported here is of a preliminary nature only, and as suggested by the authors, additional information, especially concerning the unsteady aerodynamics will be required before fan noise pressure signatures can be properly identified, as to relevant source mechanisms, etc.

see also:

SOCIAL AND INDUSTRIAL IMPLICATIONS OF V/STOL TRANSPORTATION SYSTEMS
I. C. Cheeseman, N. Judd, G. M. Lilley

on page IV.1 of this bibliography.

PROCEDURES FOR ESTIMATING THE EFFECTS OF DESIGN AND OPERATIONAL CHARACTERISTICS OF JET AIRCRAFT ON GROUND NOISE
R. Lee et al.
NASA CR-1053, June 1968.

on page IV.2 of this bibliography.
POLLUTION

see:

ENVIRONMENTAL FACTORS IN THE DESIGN OF DIRECT LIFT V/STOL TRANSPORT AIRCRAFT
T. K. Szlenkier
AIAA Symposium on VTOL Designs, No. 38388
November 1970.
on page IV.9 of this bibliography.

SOCIAL AND INDUSTRIAL IMPLICATIONS OF V/STOL TRANSPORTATION SYSTEMS
I. C. Cheeseman, N. Judd, G. M. Lilley
on page IV.1 of this bibliography.

MATHEMATICAL THEORIES OF AIRCRAFT NOISE
No reports found for this section.

APPENDIX IV

STUDY OF NON-RADIAL STATORS FOR NOISE REDUCTION
G. V. R. Rao
NASA CR-1882, September 1971

The effect of non-radial orientation of stator vanes on fan noise is investigated. A suitable representation of the fluctuating pressures arising from vane-blade interaction is employed to formulate a simple method of evaluating sound pressure levels in the radiation noise field. Co-relation of calculated results with available experimental data on LF336 fan and a small-scale experimental fan indicate the profitable use of leaning vanes for noise reduction.

ANALYTIC STUDIES OF SOUND PRESSURE INSIDE THE DUCT OF DUCTED PROPELLERS
J. A. Drischler
NASA TN D-6345, September 1971

The sound-pressure field of a rotating ducted propeller in forward flight is analyzed by replacing the duct by an infinite coaxial circular cylinder and assuming that the blade-loading distribution associated with the thrust and the torque can be represented by a distribution of acoustic pressure doublets acting at the propeller disk. Trend studies are made to ascertain the effect on the pressure distribution inside the duct of variations in propeller loading, tip clearance, free-stream Mach number, tip Mach number, and hub-tip ratio. The effect on the pressure distribution of concentrating the loading at various radial positions on the propeller blade is also investigated.

REPORT ON A STUDY OF NOISE GENERATION BY A ROTATING BLADE ROW IN AN INFINITE ANNULUS
J. A. Lordi
(AFOSR TR 71-1485), May 1971

Discrete-tone noise generation by high-speed fans and compressors has been studied by applying existing theories for the flow through a rotating blade row in an infinitely long annulus. McCune's analysis for the linearized, three-dimensional, compressible flow through a non-lifting blade row and its recent extension to lifting blades have both been used to find the acoustic disturbances produced by such flows. These analyses contain the cutoff condition for the duct acoustic modes, including the effect of through flow, and relate the amplitudes of the propagating modes to the blade thickness and loading. In the present work these relationships have been evaluated for some specific thickness and loading distributions to find the pressure and velocity fields away from the blade row. Methods have been developed to calculate the sound intensity flux upstream and downstream of the blade row and results are presented which demonstrate the influence of blade geometry and operating conditions on noise generation.

STUDY AND DEVELOPMENT OF TURBOFAN NACELLE MODIFICATIONS TO MINIMIZE FAN-COMPRESSOR NOISE RADIATION, VOLUME III
The Boeing Company
NASA CR-1713, January 1971

The program objective was the reduction by 15 PNdB of Boeing 707-320B/C airplane noise during landing approach. It was determined that this goal could be achieved by attenuating the fan noise of the P & W JT3D engines by acoustically treating the engine nacelle. The nacelle fan exhaust duct design was required to contribute the full 15-PNdB attenuation, while the inlet need only attenuate 10 PNdB, since forward noise radiation was 5 PNdB lower. Various configurations of the inlet and fan duct, with acoustic treatment, were studied. The inlet design selected has two concentric
rings supported from the cowl by struts at eight radial locations. Polyimide fiberglass acoustic sandwich material is used integrally with the structure of the concentric rings, inner cowl wall, and centerbody. A full length fan exhaust duct with annular nozzle essentially coplanar with the primary nozzle was selected. Acoustic treatment was applied to approximately one-third of the duct length in which inner and outer duct walls as well as four radial flow channel splitters are of polyimide fiberglass acoustic/structural sandwich materials. Ground test results, compared with baseline ground test data on the 707 airplane production nacelle, showed approximately 2 percent increase in thrust due to the new duct design. This gain is offset by increased recovery loss of the new inlet. A take-off thrust noise reduction of 5 to 6 EPNdB was predicted from the test results.

INVESTIGATION OF DC-8 NACELLE MODIFICATIONS TO REDUCE FAN-COMPRESSOR NOISE IN AIRPORT COMMUNITIES, PART IV
E. L. Zwieback et al
NASA CR-1708, December 1970

Acoustically-treated engine nacelles for Douglas DC-8-50/61 airplanes were flight tested using a DC-8-55 airplane. The flight noise and performance measurements were supplemented by measurements made on an engine test stand. Significant noise reductions were obtained with the nacelle modifications. Beneath the landing approach path, at a height of 370 ft. and with a landing weight of 240,000 lb, the effective perceived noise level would be reduced by 10.5 EPNdB. Beneath the initial-climb flight path, a 325,000 lb airplane climbing with rated-takeoff thrust would produce 3.5 EPNdB less noise at a point 3.5 n. mi. from start of takeoff roll and 3 EPNdB less maximum noise along a 1500-ft sideline. Installed net thrust at rated-takeoff power was reduced 2.1 percent with the nacelle modifications. Cruise performance was improved with an average 3 percent increase in specific range. No adverse engine operational characteristics were encountered.

ACOUSTIC AND AERODYNAMIC PERFORMANCE OF A 6-FOOT-DIAMETER FAN FOR TURBOFAN ENGINES
A. W. Goldstein, J. G. Lucas, J. R. Salombin
NASA TN D-6080, November 1970

This fan, designed for low-noise output, produced significantly less
INTRODUCTION

During the period since The 1970 STOL Report, nothing in the nature of a great breakthrough has been noted in the literature relating to STOLports themselves. It is true that a number of new papers of varying degrees of relevance have been obtained in the meantime. As a general observation, though, perhaps the most notable STOL trends and developments are not reflected in the literature of this section. There is the current Canadian effort to develop an intercity demonstration STOL service between Ottawa and Montreal, but in this case an authoritative written description has yet to emerge, the project being perhaps too urgent at the present time for the protagonists to publish accounts, and the details of the STOLports involved not yet being entirely firm. Indeed, important criteria are still being hammered out in a series of studies, which include test flying operations still in progress as this review is being written. Progress reports of sorts have not infrequently appeared in the daily newspapers, but have not been judged to contain the sort of information which could usefully be treated in the present context.

It must be pointed out, however, that such comments, and the selection of reports reviewed hereunder, are based on a relatively narrow specialization on STOL matters in the present instance. A broad approach was taken in The 1970 STOL Report in order to provide insights and information on a wide range of topics which might some day impinge on STOLports and on related operations or problems, but that basic information having been sampled once, it has not been considered necessary to survey again all such related or subsidiary fields as bird hazards, real estate transactions, pavement technology, and terrain problems. In essence, only if some specific relation to STOLports has been stated or implied in the papers considered, have the papers been reviewed here. It is the writer's understanding that this treatment of the assignment is in line with the wishes of those who have commissioned the work; a certain hazard exists, unfortunately, that important developments may have taken place which have not been noted in the search for literature specifically on STOLports.

As was the case in The 1970 STOL Report, it has seemed almost inescapable in the present instance to take issue with some authors over some of their printed statements. It may perhaps be justly complained that certain special interest groups tend to propagate literature clearly intended to support their own positions, which may be an acceptable activity if done properly, but not if in so doing they tend to overstate their cases - in other words not if they flirt with crossing the limits of literal or implicit truth. The conscientious reviewer can scarcely make himself a party to the intentions of such groups; he must do more than simply summarize a paper, he must if necessary "debunk" it in order to bring the reader's impressions as close as possible to the objective truth the reviewer, albeit with his own shortcomings, sincerely understands it to be. He must furthermore take a firm stand as much in relation to those rabidly supporting STOL as to those rabidly attacking it. To do so is no great joy, and it must be hoped that the quality of the literature will in future so improve as to make this disagreeable and possibly unpopular (certainly so with the authors involved) duty unnecessary.

There seems to be a continuing tendency in the literature to ignore many of the important support facilities at airports, without which safe and reliable allweather operations would be impossible. In the present review it has been noticed that authors supporting both STOL and its competitor, VTOL, have overlooked such adjuncts as hangars, maintenance garages, fuel depots, firehalls, and air traffic control towers in considering STOLport layouts, or in developing cost estimates. An important airport facilities study by the Canadian Air Transportation Administration of the Ministry of Transport is currently underway, however, and may produce a very comprehensive document by 1972. This document will probably be in the form of a land use planning manual, such as in fact now exists in preliminary draft form; it will treat airports in general, but on many points its coverage should apply closely to STOLports. In the process of considering land use it will, of course, have to discuss all facilities to be placed upon the land, such as buildings, roads and aprons.

It may perhaps be appropriate to mention that the Construction Engineering and Architectural Branch of the Canadian Air Transportation Administration is currently in the process of a major revision of its statements of internal objectives, policies, design and construction standards, and recommended practices (guidelines), and that part of this effort consists of incorporating the "Pavement Design and Construction Manual" into a larger overall context, where it will pertain to the Branch and not specifically to the Engineering Design Division as previously
noted (page V.47 of The 1970 STOL Report). Extensive work is in fact being carried out in the entire "policies and standards" area by the whole Branch, and should give rise within a further year's time to a range of newly framed documents. Work in this area may be continuous over many years, though, and so it should not be supposed that the final work will be available one year from the present time; quite simply, the picture should at that point be much better formed than it is at this moment.

The situation may be roughly the same in the other branches of the Administration, and the policies, standards etc. of those units may be expected to be of as much interest in many cases as are the Construction Engineering and Architectural Branch's (with which this reviewer happens to be more familiar in general).

COMPREHENSIVE PLANNING AND GENERAL DISCUSSIONS

STOL TRANSPORTATION SYSTEM PLANNING

R-1
2nd EDITION

The first edition of this report, issued under the title "A Guide to STOL Transportation System Planning", was reviewed as part of The 1970 STOL Report, which the present contribution is intended to update. Although a certain promotional aspect remains, the new edition is more attractive than the old because it provides numerous illustrations of actual and projected STOLports from all over the globe. This is not to say that all such STOLports necessarily would meet the regulatory requirements connected with Class 1 commercial services, but within a certain context (often comparable to bush flying in Canada's North), the pictorial additions are undoubtedly interesting. The figure numbers referred to in the report's text apply only to the diagrams, the photos not being numbered in any way.

The frontispiece of the new edition shows a reworked version of the same but the entire "police" scheme (for Houston, Texas) as graced the frontispiece of the older edition. Apparent changes have been made, as far as the immediate STOLport is concerned, in the runway paint markings, the size and positioning of the structure by which access to the flight deck is achieved from below (hence already mentioned), and the arrangement of parked aircraft (their tails no longer appear to overhang the edge of the building). Solutions to the lateral edge restraint barrier problem still seem to be lacking, the aerodynamics of the deck edges still look questionable, and the noses of parked aircraft still seem excessively close to the runway, and in fact are now backed up by a sizeable fixed obstruction in the form of the superstructure already mentioned. It is interesting to note that no fixed facilities are clearly and specifically indicated for the important functions of air traffic control, airport maintenance and operation (e.g. snow clearance, which may or may not be of concern in Texas, but which can be a vital consideration elsewhere), aircraft fuelling, and hangarage for the purpose even of minor aircraft maintenance, which may be an essential condition prior to take-off under various conditions.

The proposal appears to imply high capital expense, and would require high frequency operations to justify and hopefully amortise the investment. Unfortunately, the configuration does not appear economically viable in its present form, supposing that it may be technically feasible, which is not yet established, e.g. in respect of certifiably safe and practical edge restraint barriers.

The report includes diagrams of different possible types of STOLport. At the time of writing, requirements governing Canadian STOLports from the operational safety viewpoint are still being evolved, and in fact a test flying program is currently underway. Thus it may be considered somewhat surprising if the configurations ultimately to be chosen should turn out to be identical with the layouts illustrated.

Costs in particular might well be accepted with reservations, if at all. For example, it may be true that one could grade and drain a Canadian site, build a runway, and perhaps even furnish some lighting for a construction cost of $250,000, as alleged, but would this investment be enough to support commercial operations? A number of important items have already been mentioned in this review which, along with terminal facilities, vehicle and equipment needed for all-weather airport operation, radio aids to navigation, and access facilities, might push the total non-real estate cost much higher. Possibly of even greater import, the cost of land, including easements on lands affected nearby, could run into the millions of dollars in various urban areas.
Criticism of the meagre separation between the runway and the locations of parked aircraft, as entered into within the second paragraph of this review, must at the present stage be qualified somewhat in relation to official requirements, such as those of the U.S. Federal Aviation Administration's Advisory Circular 150/5300-8, "Planning and Design Criteria for Metropolitan STOLports". It is stated within the report under review that each layout as advanced conforms to the FAA's requirements and, if so, these layouts can hardly be faulted for U.S applications, as long as such requirements remain in force; or at least, this would be the case unless one felt prepared to criticize the FAA requirements themselves. For Canadian applications, however, what with our more difficult winter conditions coupled with the general availability of more land, placing parts of parked aircraft within 200 feet of the runway centerline as suggested in Figures 2 and 3 of the deHavilland report might not be justifiable. In this connection one must keep in mind the possibility of accidents such as that which occurred at Gatwick Airport, London, in which a landing aircraft ran out of control and destroyed both itself and a number of other aircraft parked at the terminal, killing its own crew and its load of horses (fortunately, the other aircraft happened to be unoccupied at that moment). Nonetheless, Canadian regulations in this area are, as noted, still in the process of formation, and a decision to follow the American lead may be one of a number of possibilities.

The report's Chapter 5, STOLport Capacity, is an area of some particular concern, inasmuch as this and a previous review have noted that there is a tendency on the part of deHavilland to overstake the capacities of given STOLport facilities. The capacity question actually has two main aspects, that of demand and that of capacity.

The report includes interesting generalized information on the distribution of air passenger transport demand by time of year, of the week, and of day, and finds that at the critical hour, between 5 and 6 p.m. on Fridays in July, demand will theoretically reach 274% of the yearly average hourly demand level. Since, however, such conditions will supposedly apply for only 4 hours during the design year, the report recommends choosing a more economical level such as 200% of average. The difficulty then arises that such a level would be exceeded i.e. the facility would be overloaded 87 hours during the design year alone, and no doubt progressively much more in the years thereafter. At the design year's peak hours, moreover, a facility planned on this basis would be some 37% overloaded: 274 x 100% = 137%. Depending upon the floorspace criteria etc. used in the design, the terminal building might or might not prove intolerable under these conditions, but it seems fair to question at all events whether the carpark, for instance, would be able to accommodate 37% more cars than the design limit adopted.

With continuing growth of demand, the situation would as noted only become worse in later years. On the other hand, though, it might also be possible under some circumstances to develop new STOLports within an urban region as the old become saturated, so that demands at any one site might never have to exceed design-year levels. Such a process of system development, though, would require a good deal of very astute planning and other actions.

Concerning runway capacity, the report alleges that 36 operations per hour is about equivalent to 2-minute separations between flights (either landings or takeoffs). The degree of approximation allowed here is fairly significant; the ratio actually works out to one operation per 1-2/3 minutes, or to one flight per 100 seconds. Considering that the report's Figure 8 indicates a total of 80 sec. for an aircraft to touch down on a runway lacking a parallel taxiway, turn at the runway end, and taxi back to the ramp, the implicit suggestion is that there would be, on average, only 20 seconds' space of time between one aircraft clearing the runway and the next one touching down. Because deviations from the average of such performances will always occur, the report seems to accept conditions of even lower safety margins between successive operations. It is doubtful that the aviation safety and air traffic control authorities would concur in this matter, and it in fact is worth noting that any other airport would undoubtedly be furnished with parallel taxiways long before reaching the level of 36 commercial operations per hour.

When it comes to calculating numbers of gate positions and occupancy time, the quantities stated by the report seem even further divorced from reality. The report makes no provision for standby or other supernumerary aircraft
stands such as operators require in practice, and does not seem to include fuelling, cabin cleaning, etc. in its calculation of turnaround times for the active gates. It is interesting to note that Air Canada is requiring four aircraft stands at either STOLport in the forthcoming Ottawa-Montreal demonstration STOL service project, with scheduled flight frequencies of only one per 20 minutes. In other words, unless Air Canada changes its mind, the four positions together are theoretically going to handle only about one turnaround per stand per 2-2/3 hours or, considering the two active gate positions in front of the terminal only, at best one turnaround per gate per 1-1/3 hours (or per 80 minutes). Perhaps with increased familiarity with STOL the operators will feel able to improve on this performance, but at all events the point has to be made that gate provision should not be worked out on the basis of an assumption of clockwork regularity. Sometimes things go wrong!

Despite these generally dissenting remarks, the report does furnish much information of potential use and value, if treated with discretion.

VSTOL AIRPORT DESIGN AND LOCATION
R. D. Nutt

The first sentence of this report indicates that, in addition to the topics mentioned in the title, complementary ground access transport is also to be covered. The same sentence also defines VSTOL as "STOL and VTOL", whereas elsewhere it has developed that V/STOL (the variant spelling is not considered an important point) is thought of in terms basically of VTOL, with the capability of deriving benefit on takeoff from rolling forward for added lift. Thus under Mr. Nutt's definition, an aircraft such as the DHC-7 would be VSTOL (or V/STOL) while under the alternative definition it would not. Other reviews have already pointed out the need for standardized terminology; perhaps by way of a positive contribution one might suggest that Mr. Nutt's definition be adopted, together with a different term, VSTOL (Vertical Take Off, Vertical Land) to denote aircraft having both VTOL and STOL capabilities?

The paper under review covers both STOLports and VTOLports as alternatives, rather than considering combined V/STOLports. A decision to employ either one system or the other exclusively is implicit. For either system, the paper assumes aircraft of 100 seats. The STOL parts of the paper lean on (somewhat modified) American findings, whereas the VTOL parts are based on work done for Hawker Siddeley Aviation Ltd. in the U.K.

Reference to "the vast transport potential...in the region of the Californian Corridor" as the reason for American interest in V/STOL makes one wonder whether there has been some sort of slip in the processes of the report's composition and printing, whether the author is actually unaware of the U.S. Northeastern Corridor, or whether he is onto something that we don't know? It is to be hoped that an author writing on the subject chosen would be aware of the immense activity generated by the Northeast's transport problems.

At all events, on the topic of STOLports, Mr. Nutt commences by reviewing the FAA interim criteria of January 1969 (since replaced by more or less permanent criteria contained in an Advisory Circular), using these to develop a partially complete, ground-level STOLport system including an apron and terminal building of his own conception. The apron is shown in the report's Figure 1 with seven aircraft positions; the terminal building is indicated as being 900 feet long, 250 feet deep, and eight storeys in height - a huge structure as deep as, and some 200 feet longer than the original core of the terminal at Montreal International Airport (Dorval) and, depending on how the storeys are counted, at least as high. The Montreal facility supported four times as many aircraft positions. However, much of the STOL structure would be occupied by garage space.

According to this author, the operational capacity of one runway with "separate taxing" (full-length parallel taxi plus three connecting taxiways) is about the same as deHavilland Canada claims for a single runway having no taxiways, in their "STOL Transportation System Planning", also reviewed in the present study. Obviously both views cannot be right, and considering the facts but without performing yet a third analysis, it would appear that Mr. Nutt is the closer to correct.
It may in fact serve as an interesting counterpoise to several statements by deHavilland Canada to quote the following paragraph in toto from the paper now under review:

"To calculate the minimum requirement of the apron for the layout shown in Fig. 1, assumptions were made as regards the size of aircraft, the capacity of a single runway and the turn-round time. A 100-seater STOL aircraft could be about 110 ft. long by 105 ft. wide. It is suggested that, under precision instrument conditions, a single runway with separate taxiing could have a maximum (but not sustained) capacity of 40 take-off and landing operations in a peak hour. The author considers that a turn-round time of 15 minutes from landing to take-off should be the aim. Assuming that the aircraft is jet propelled, and that the apron parking layout and terminal building are suitably designed, the total taxiing time could account for up to two minutes.

On the assumption that no routine maintenance would be carried out on the apron, it is considered that the parking bay standby factor should be at least 30%. Based upon these assumptions, seven parking stands would be required. To arrive at the size of terminal building, it has been assumed that each aircraft would have 100% load factor. Although optimistic, such an assumption would make provision for some degree of future increase in aircraft capacity. A terminal building to handle 4,000 passengers per hour would need to be of eight-storey construction, with 210,000 sq. ft. floor area per storey; this would allow for car parking, bus station and apron service areas. The overall airport land requirement would be 55 acres."

A point, though, which might well be questioned here is the assumption that no routine maintenance would be carried out on the apron; in practice, it almost certainly will be, and certainly it can't be carried out in the air! Mr. Nutt shows no specific alternative facilities for aircraft maintenance or, for that matter, for such essential functions as airport maintenance and operation (snow removal equipment, lawnmowers, etc. would presumably not be housed in the "apron service area" within the terminal building), firefighting and crash rescue service, air traffic control or meteorological observation. It must be assumed that such features would be needed at an airport of this size, and hence that, among other things, the overall airport land requirement may have been understated in the paper.

The assumption of 100% load factors, on the other hand, is not reasonable, and when applied to 100-seat aircraft, tends to lead to calculated passenger and access traffic volumes which would more properly correspond to the case of 167-seaters at 60% load factor; that is to say, on this point Mr. Nutt has probably overstated the terminal building's land area requirement, and will almost certainly have considerably exaggerated the floor space required, if he really intends to deal with the 100-seater case. His vague reference to "future increase in aircraft capacity" does not answer here, and if he wishes to discuss larger aircraft than 100-seaters, then he should state his actual assumptions.

Single-orientation, two-runway schemes with parallel and tandem (in-line) runways, attributed to the FAA are depicted in Figures 2 and 3. The paper's comments are not altogether accurate. It states that both designs allow for only 95% wind coverage, which is a site-dependent matter not subject to such general statements. The text also indicates that the Figure 2 layout shows only two aircraft positions, whereas 14 are illustrated; in the latter case, though, there is some evidence that one or two further illustrations may have been dropped out of the report, with only partial adjustments to the text. (In fact, there are several points on which the paper appears to have become confused.)

Certainly, the paper is right in criticizing the parallel runway arrangement for STOLports, if 5,000-foot lateral separations should be required just as for CTOL. In fact, not only would the required land area be greatly increased as the paper notes, but also the very feasibility of finding a site over 5,000' x 2,000' in size would be virtually zero, unless one went out to rural surroundings. Even there, demand might scarcely justify such a size of STOLport, and also one could in all probability develop a full CTOLport.

More or less by the same token, the tandem layout which the paper seems to prefer would be on the order of 4,000' long, which would be hard to arrange in an urban area and which, at all events, is within the overall length range of some CTOL runways. It would be surprising, in addition, if at least the Canadian authorities would permit two aircraft, one landing and one taking off simultaneously, to use opposite ends of a single runway pavement, marked off though it might be to look like
two separate runways placed end to end. Thus the two-runway layouts illustrated in the paper are not regarded by the reviewer with a great deal of optimism or enthusiasm.

On page 3 of his paper, Mr. Nutt implies that a McDonnell study is wide of the mark in using 2,000 passengers per hour per runway in estimating the peak-hour capacity of a STOLport serving 100-seat aircraft. In fact, the figure is not really bad; inasmuch as Mr. Nutt concedes that a rate of 40 movements per hour cannot be sustained, one might presume that a realistic rate could be about 35 and that if the seat load factor were to average out to 60% during peak hours, then the product 35 x 100 x .60 would come to 2,100, which is within reasonable range (5% error) of the McDonnell study's conjecture.

Mr. Nutt next takes up the question of runway width, stating that the lower speeds of STOL should result in more severe cross-wind effects than with CTOL, which requires 150-ft. runways as opposed to STOL's 100 ft. It would appear that he ignores two important factors, viz., that STOL aircraft are designed specifically to cope adequately at low speeds with high crosswind factors, and that the lower forward speeds of STOL allow more time for compensation of alignment within a given distance covered. To dramatise the latter point, a CTOL aircraft might have a landing speed (in m.p.h.) of 150 on a 150'-wide runway, whereas the equivalent STOL ratio of perhaps 70 : 100 may be viewed as more favourable, from the point of view of correcting misalignments while staying within the runway's limits.

The author then proposes his own version of a STOLport. The chief feature of this is the provision of two runways in V formation, intended to raise wind coverage from 95%, which is stated to pertain to the single-runway case, to 99%. (Some gross assumptions seem to have been made on this point.) Closing the V's top is a connecting taxiway along which have been arranged an apron and terminal building. The layout appears fairly attractive operationally, but would be best suited to essentially rural surroundings, CTOLport-style. According to the author's calculations the land area required would be 72 acres, up 17 from what he determined for a single-runway layout; the main problem, though, would in most instances likely be the difficulty of finding a single site associated directly with two acceptable flight corridors over the city. One must design facilities to fit the relevant circumstances, and even if one could manage two runways at an urban STOLport, the layout might not necessarily come out with runways laid out in V shape; they might equally come out as an X, as an L, or as a figure even more widely spread than an L.

The total effect of Mr. Nutt's analysis and proposal in respect of STOL could well be one of discouragement, because of practical difficulties which would be encountered in attempting to carry out his scheme.

He next examines the VTOL situation. Here it becomes clear that his firm has been directly involved in VTOL studies for Hawker Siddeley Aviation Ltd., who have been developing jet-lift VTOL technology for some time. The implicit consultant-client relationship is a point to keep in mind when weighing the objectivity of the paper.

The Author's view is, however, valuable in that it goes beyond the usual American view of VTOL in terms of helicopters only. The chief effect of this difference is that he envisions the ready taxiing of aircraft between multiple parking stands and single, instrumented takeoff/landing pads. In one proposal, though, he suggests separate takeoff and landing pads so as to double the capacity of the VTOLport; presumably only the landing pad would need precision approach aids. He estimates the capacity of a VTOLport as 35 movements per hour for one pad, or 70 for two and, in addition, he shows a "simplest system" having only two parking stands with a capacity of 8, as limited by the turnaround times of the aircraft rather than by the operations at the pad.

Looking at the drawings attached to the paper, acreage calculations appear to have been biased, inasmuch as the indicated aircraft parking positions on all STOL aprons have been shown with clear spaces between adjacent circles, whereas on all VTOL aprons, the circles are shown actually overlapped. The VTOL parking arrangement has thus been made, apparently quite arbitrarily to appear significantly denser than that of the competing STOL system.

The paper next considers passenger (not freight) terminal buildings, noting that VTOL, STOL, and even CTOL requirements are more or less
the same, all other things being equal. International inspections, however, hopefully would generally take place at CTOLports - at least in Britain, one would think, although even here it has been shown that helicopter flight between London and Paris is a practical possibility. Generally, the treatment of terminals is somewhat superficial, but a cross-section of an elevated VTOLport is illustrated. In the latter connection, the author states that "...there is no reason (except the time involved) why the aircraft should not descend by lift to, say, the level below the roof for handling operations to be carried out." This remark seems to overlook the questions of cost, operational flexibility, headroom, and the possible dangers of, say, fuelling indoors. Essentially the same proposal has been treated more thoroughly elsewhere.

The next topic is noise wherein, on the basis of certain assumptions, STOL is shown to affect an order of magnitude more territory than VTOL with noise over 90 PNdB, and CTOL a further order of magnitude more than STOL. The VTOL vehicle is assumed to be a 100-seat fanlift aircraft which, the author believes, would affect only 160 acres with 90 PNdB noise during approach, landing, climbout and takeoff. This makes one wonder a bit; if the installed power were in the general order of 100,000 pounds of thrust or more, wouldn't it make a pretty dreadful bellow? Also, what would be the approach slope, and over how long a track would the lift engines operate? Details are not provided, but would seem to merit review.

Based on the outlined findings, STOLports are generally relegated by the paper to the periphery of the city, whereas VTOLports would be accepted within the city. This supposition again needs verification.

On the topic of "Ground Connections", the paper assumes that STOL services would be concentrated at a single STOLport for each city, and that this facility would be at the city's periphery. The access picture is then painted in fairly bleak terms. (However, the author refrains from directly claiming superiority for VTOLports in this respect.) In general, the paper contributes little on ground access.

An "interim period" featuring the use of compound (winged) helicopters for inter and intra-city transport is foreseen. Compound helicopters would be freed from some of the restrictions applying to pure helicopters, and "There seems to be no reason why cost should be a deterrent to a section of business travellers." (The latter is true, just as it is true that a certain section of business travellers ride Rolls Royce limousines; but such standards are in the minority.) The system of heliports would later provide sites for other VTOL use.

The paper's conclusions tend to exclude STOL from the air transport scene of the future, because according to the author it will be necessary to place STOLports outside the city in competition with CTOL, while VTOL operates within the urban area. It is in fact claimed that, "...the VTOL concept presents the greatest breakthrough in transportation since the invention of the motor-car, because it will allow the traveller to go from origin to destination with the least inconvenience."

Overall, while the paper makes some show of giving STOL a fair treatment, specifically by assuming 100% load factors which attribute more capacity to a given number of aircraft stands than would be attainable in practice, it appears on closer scrutiny to do STOL at least equal disservices by, for example, spacing those aircraft stands out relatively widely, and also by assuming two runways instead of one, thus doubling the number of approach/departure areas affected by noise. The positive aspect of this total treatment is obvious, and also is specifically pointed out by the author; the negative aspects, on the other hand, are glossed over.

As noted earlier in this review, the paper does make an interesting counterpoise to certain other reports supporting STOL. Probably the real truth lies between the extremes represented. It is to be hoped that impartial agencies will seek this truth out.
airport progress, land use planning on both sides of the airport boundaries needs to be periodically updated. The environment, a public resource, needs to be safeguarded; decisions should be openly arrived at, and should if possible remain reversible so as to maintain the greatest number of options for the future. Airports should be surrounded by buffer zones of compatible land use.

The above truisms, widely recognized already, serve to introduce and presumably to support the ideas of the author's consulting firm regarding modular airport development and expansion, a principle which is itself perhaps not entirely unknown; something approaching it is in fact being practised at the new Montreal International Airport site at Ste. Scholastique, Quebec. The relation of most of the truisms to the proposal itself is a little puzzling, however; the truisms seem to relate to existing sites, whereas the freedom to develop large airports free of constraints such as the paper proposed implies new sites in the open countryside.

The paper thus says little about how to live within existing, possibly cramped airports into which a good deal of capital investment has been poured over the years. Its concepts are likely to be applicable under relatively utopian conditions, if at all. It would appear that even a fair degree of topographic regularity and freedom from complications in the forms of, say, airspace obstructions or pre-existing noise sensitive areas may be essential to the full implementation of the theories expressed. Crosswind runway requirements would not fit into the proposal as it is now expressed, although the paper states that "a hybrid variation can be developed".

The concept involves not merely the modular treatment of the terminal complex, which is often sited between a fixed pair of parallel, interconnected runways (with their parallel taxiways et al) in current practice, but in fact the modular treatment of virtually the entire system together including runway, taxiways, terminal facilities and access system. Thus, "...the modular, multi-linear approach envisions a series of long, narrow rectangles laid side by side to form a large square." Each rectangle contains one complete system module, and the square is surrounded first by airport related development, and then by a further compatible land use buffer. The buffer is shown just as deep along the sides of the runway alignments as at the ends, raising a question of whether the author really understands much about the nature of airport noise etc.; he deserves the benefit of the doubt, however, and perhaps the illustrations are only diagrammatic.

Where a "small hub" is involved - comparable to a "mainline feeder" airport in Canada - initial development involves one module. A second module taking the airport to its ultimate development is a mirror image of the first, laid out in such a way that the old and new terminal areas are located contiguously between the parallel runways. Thus the access facilities may at least potentially be shared by the two modules and passenger transfer complications are at least potentially capable of being minimized. In medium and large hub situations, however, the third and subsequent modules are placed back to back with the first two, so that quite widely separated terminal areas develop. Extreme operational splits would seem to be an inevitable and serious problem. In this respect, it would not seem to pay to be doctrinaire about maintaining the purity of the scheme; one should rather provide a single, large terminal area between the innermost runways, and add runway and taxiway modules on the outside of the complex. This could then be done independently of the development of new terminal and apron modules on the inside, as in fact is the plan for Ste. Scholastique.

One of the peculiarities of the scheme depicted in the paper under review is that there apparently is no provision for crosslinking taxiways between modules. Thus it would be essential to land each aircraft only on that runway which might pertain to the aircraft's particular set of ground facilities; an aircraft could not be landed on, say, the west runway if it had to be attended to in any way on the airport's east side. Under such circumstances, the airport would lack much of the flexibility of today's facilities.

It would of course be possible to add linking taxiways to the basic scheme, probably at the price of bridging over one or more access routes and possibly of interfering with terminal area land use, and the more the terminal and servicing facilities might be split up, the more this modification would seem to be needed. In the event that operational flexibility might not seem a sufficiently convincing argument,
consider the effects on airport operational capacity: without links on the ground, it might be a normal occurrence for aircraft to be forced to loiter before using one particular runway, while one or more other runways might at the same time have capacity to spare. The unusable runway time would then be wasted, and the effect would be to reduce the airport's overall practical capacity.

Airspace modules are considered in the paper to be available as part of the total modular package. This assumption seems particularly utopian. Through the adoption of enough such assumptions, "large hub airports are presumed to be capable of handling about 50,000,000 enplanements annually, i.e. 100,000,000 enplanements and deplanements annually. "The concept provides a 'fail-safe' system of airport modules of eight complete airports-in-one for the large hub".

A point on which the paper is sometimes unclear is that it criticizes one form of modular expansion without explicitly indicating which form is in question. Thus one does not know whether it is in further criticism of the disparaged type, or alternatively an admission of shortcomings in the proposed type, when the paper says, "The disadvantages of decentralized modular expansion include the requirements for a more sophisticated exterior graphics system (presumably traffic sign system)* and a beefed-up security system. The use of some type of people-mover system between terminals (where transfer factor is significant) would be needed also... Lack of centralized baggage facilities requires interline baggage transfer between unit terminals. This in turn causes confusion for unsophisticated (first time) passengers because airlines are located in different buildings. Multiple staffing of different buildings imposes an additional overhead burden on airport management and concessionaires." It would seem, however, that the paper is here criticizing its own proposal, because of the land use buffer associations of the claim which follows: "The main advantage of modular expansion is that it allows airports to grow horizontally and vertically while still maintaining a land use buffer around the airport."

At all events the proposal put forth in the paper is aimed at CTOLports, evidently in the open countryside, and is probably not directly applicable to the bulk of urban STOLports as they are now expected to take form, i.e. with but a single runway. Nevertheless, the paper's total-system approach to its subject is worthy of note.

PUBLIC-USE HELIPORTS-STOLPORTS - V-PORTS - A CURE FOR CONGESTION

This paper is essentially a propaganda piece rather than a vehicle for the dissemination of useful technical information. It chiefly recommends the use of helicopters for intercity as well as airport access travel, and proposes the provision of public use heliports in downtown areas of American cities. The availability of such heliports in London and Paris is underscored, as is the Presidential use of helicopters from the White House lawn in Washington. The American public, it is held, should have access to such facilities. Further justification is brought in through reference to the growing numbers of helicopters in use, and to the positive results achieved in demonstration applications within the U.S. Northeast Corridor. Although the aviation safety regulating authorities have limited the number of flights at some American airports, it is noted helicopters have been exempted because, amongst other things, they have minimum impact on fixed-wing operations. The advantages of being able to fly over ground congestion but under the air congestion, in theory from essentially the point of origin to the point of destination without changes of vehicle, are emphasized. Studies are recommended in conjunction with the (U.S.) Airport and Airways Development Act of 1970.

Concluding recommendations include the following: "In addition to planning public use facilities, certainly any new office building, hotel, motel, shopping center or hospital built today should provide a level or rooftop heliport." The proposal seems to ignore the implicit noise, safety, regulatory and economic problems of
having perhaps hundreds of heliports
competing for airspace and patronage
within a given city.

Other recommendations include the
provision of discrete control tower
radio frequencies for helicopter
traffic, and suggestions as to the
possible future siting of "...Facil-
ities to serve helicopters -- and
other types of V/STOL aircraft." At
least, then, STOL comes into the
report in its penultimate paragraph,
to justify use of the word "STOL-
ports" in the title. The application
to STOL in practical terms is never-
theless rather minimal.

FEDERAL DESIGN CRITERIA FOR
VTOL PORTS AND STOL PORTS
George L. Buley (FAA Washington)
Presented at Joint Symposium on
Environmental Effects on VTOL
Designs, Arlington, Texas, Preprint
No. SW-70-43 American Helicopter
Society, November 1970.

This quite short paper has been
composed to introduce the American
reader to U.S. Federal programs and
regulating authorities, as much as
to the regulations covering VTOLport
and STOLport design. Seven subjects
are covered within 2-1/2 pages of
text, only two or three paragraphs
being devoted to each item. One
such subject, receiving three para-
graphs plus an illustration by way
of coverage, is "STOL Port Criteria".

On this topic, the paper states
that a new advisory circular is at
the printer's, that in part the
document will be intended to en-
courage the development of STOLports,
that the dimensional criteria for
STOLports will be as illustrated,
and that answers have not yet been
found to the problems of emergency
arrester systems and adequate visual
aids for elevated STOLports, such as
may find application in several major
metropolitan areas.

To the non-U.S. reader having no
special interest in U.S. airport
development aid programs, national
airport development plans and the
like, the paper says very little,
particularly about STOL. What it
does say can better be obtained from
the advisory circular in question
itself.

ENVIRONMENT, REAL ESTATE,
SITES

THE AQUAPORT DEFINED
Airport World, Vol. 4, No. 11,
pp. 47-48, November 1971

Immediate reference should be made
here to the comprehensive studies on
offshore airports reviewed in 1970
(pages V.17 and V.21 of The 1970 STOL
Report). The short article reviewed
hereunder constitutes a further
chapter in the attempt to develop
and promote a viable offshore airport
scheme.

To some extent, one has to wonder
what the future holds by way of quiet,
non-polluting aircraft, if one is to
appreciate the main future justifi-
cation for considering offshore air-
ports. If aircraft should markedly
improve in the respects mentioned,
offshore airports will lose much of
their appeal and, if already built,
could become virtual white elephants.

That floating offshore airports will
in general tend to be very expensive
(despite their savings in land cost)
is once again confirmed by a brief
item in the weekly bulletin Airports
& Ground Services, English Edition,
No. 344, 4th November 1971 (published
by the International Civil Airport
Association, Orly Airport, Paris),
that cites the cost of a proposed
floating jetport for New York as
U.S. $9,000,000,000. Although the
much reduced size of a STOLport, and
hopefully also its location in more
sheltered waters, potentially could
dramatically reduce this figure, none-
thless costs do bear close scrutiny
in the consideration of all these
proposals, and an ample service life
of the facility must be assured in
order that such costs may be amor-
tised. Technical obsolescence of off-
shore STOLports, brought about by
improved compatibility of the aircraft
with the environment, would be a threat
to the attainment of the required amor-
tisation lifespan.

The Airport World article, based on
the views of a Toronto architectural
firm having the structural engineering
support of a firm of U.S. consultants
begins with the following ringing
prophecy:

"Within a decade the world's most
modern jetports will float in bodies
of water like the Great Lakes, the
Mediterranean Sea and the oceans.
They will be built of multiple con-
crete cells that are hollow. Run-
ways will be movable to fit changing
winds."
The scheme's chief promoter, who calls his concept of floating airports "aquaports" (which might cause confusion with seaplane bases, marinas or even shipping ports, all these having equal relation to the coined term's roots), is said to emphasize that aquaports "...offer the only genuine answers to the environmental problems of noise and air pollution associated with major air terminals," i.e. with major airports, no doubt. His ideas are said to have received an enthusiastic welcome from over 20 nations at the Paris Air Show.

A proposed Toronto/Buffalo/Niagara Falls (Ontario and New York) major CTOL aquaport in Lake Ontario, 10 miles off Toronto's waterfront, having two 12,000-foot runways of 525 ft. width with control tower and maintenance loading complex situated in the central space, would be capable of changing its runway orientation in 20 minutes, the article claims. During the swingover, however, the runways would presumably be out of service. How shipping, fishing and pleasure boating might be affected is not clear; nor is it explained what would happen if ice were to be encountered.

The concept misses few advanced ideas, and includes access via underwater tube train at 150 m.p.h. and also via air cushion vehicle over the lake's surface. Access from distant points, however, might be costly at best. The detail of how the facility would be anchored in place in something like 500 feet of water, particularly in such a way as to assure alignment with various off-airport navigational aids, is not discussed in the article. It is recalled from an oral expose of the idea attended by the reviewer earlier in the year though, that the proponents would use a set of powerful propulsion engines and water propellers for positioning the runways, for station keeping, and for maintenance of alignment. Thus the proposal envisions a large investment in mechanical equipment and a substantial continuing outlay for energy and for equipment operation and maintenance as partial substitutes for the solidity of a land base (a further substitute is the provision of structural buoyancy).

The above discussion, touching only a few of the highlights of the proposal as discussed in the article under review, unfortunately confines only a CTOLport version of the basic floating airport idea. In fact, an offshore Toronto STOLport has also been recommended elsewhere by the same group, and it is this latter scheme which has been depicted in the illustration accompanying the article. The sketched layout shows a pair of short parallel runways flanking a circular terminal area which features six radiating and one circumferential taxiway, the whole assembly resembling a huge wheel sandwiched between parallel and slightly offset planks.

This Toronto STOLport would lie much closer inshore than the CTOLport also proposed; it is in fact sketched not far off the harbour's outer breakwater and, incidentally, what appears to be a STOL DHC-7 is illustrated in the foreground. Despite the clear indications of STOL in the sketch, the discussion nevertheless fails to mention STOL directly, and in fact the caption discusses the illustrated STOLport as if the latter were the major jetport. This might cause some confusion to the reader looking in the sketch for 12,000-ft. runways!

Since STOL aircraft are supposed to be adaptable to strong crosswinds, the need for swivelling runways would not seem to be a strong factor favouring any floating proposal over a more normal STOLport on fill somewhere along, or near, the Toronto Harbour breakwater. Nor might the noise and pollution question justify a floating STOLport in the Toronto instance, as compared to its competitor on fill.

One should finally ask whether investing heavily in a single floating STOLport might preclude investment in a decentralized set of local fill and/or land STOLports covering all sectors of the urban complex? If so, access would on average most probably suffer, and the passenger would thereby be encouraged to travel by other means in many cases.

The STOL transport system might in this way be limited in its potential by any policy of centralizing investment in but one, expensive STOLport facility, supposing that the latter's technical problems could be resolved.

Perhaps it is for these reasons that the article does not push for a floating STOLport, but suggests such a development only if a waterfront location is not feasible.
A Master of City Planning Thesis, presented to the Faculty of Graduate Studies and Research, University of Manitoba, Winnipeg, October, 1969

The comprehensive nature of this thesis, within its sphere of interest, is perhaps best illustrated simply by quoting the headings listed in its Table of Contents:

INTRODUCTION

1. Airport and Urban Growth
2. Airport and Community
3. The Scope of the Study

CHAPTER I - HISTORICAL PERSPECTIVE OF AVIATION AND EFFECTS ON CITIES

A. Growth of Aviation Since World War II
   1. Development of Aircraft Design
   2. Growth of Air Passenger Traffic
   3. Air Freight and Its Development
B. Airports and Postwar Urbanization
C. Special Problems of Airports
   1. Problem of Physical Size of Airports
   2. Problem of Airport Access
   3. Problem of Integration in the Community
D. Analysis of the Problem

CHAPTER II - AIRCRAFT NOISE AND LAND USE IMPLICATIONS

A. Physical and Biological Characteristics
   1. Noise - Definition, Measurements and Propagation
   2. Effects of Noise on Human Life
B. Community Reaction to Aircraft Noise
   1. Effects of Noise on Community Life
   2. Nature of the Community Reaction
   3. Acceptable Noise Level
C. Identification of Noise Zones and Their Use
D. Compatible Land Uses for Noise Affected Areas

CHAPTER III - AIRCRAFT SAFETY AND URBAN GROWTH AROUND AIRPORTS

A. Significance of Aircraft Accidents
   1. Losses Through Aircraft Accidents
   2. Causes of Aircraft Accidents
B. Conditions of Aircraft Safety Around Airports
   1. Danger of Physical Obstructions
2. Hazard of Aircraft-Bird Collisions
3. Conditions of Poor Visibility
4. Other Factors
   a. Hazard of General Aviation Planes
   b. Practice of Noise Abatement Procedures
   c. Interference of Flight Information
C. Compatible Land Uses

CHAPTER IV - POTENTIALS OF INDUSTRIAL DEVELOPMENT IN THE VICINITY OF AIRPORTS - WITH SPECIAL EMPHASIS ON AIR-FREIGHT INDUSTRIES

A. Airports and Industrial Locations
   1. General Significance of the Phenomenon
   2. Heavy or Light Industry
B. Air-Freight
   1. Definition and Its Characteristics
   2. Advantages and Disadvantages Over Surface Transportation
C. Use of Air-Freight Service
   1. Nature of Air Freight Commodities
   2. Business Situations of Air-Freight Use
   3. Major Air-Freight Commodities
   4. Air-Freight Oriented Industries
D. Compatible Land Uses

CHAPTER V - LOCATION OF AIR PASSENGERS' FACILITIES IN THE VICINITY OF AIRPORTS

A. Characteristics of Modern Air Travel
   1. Generation of Air Travel
   2. The Survey of Air Travellers
   3. Social Characteristics of Air Travellers
B. Passenger Facilities Adjacent to Airports

CHAPTER VI - GROUND TRANSPORTATION TO AND FROM AIRPORT

A. Elements of Design
   1. Travel Time
   2. Users of Airport Access
B. Recommendations

CHAPTER VII - CONCLUSIONS

A. Definition of Airport Vicinity
B. Desirable Land Uses
C. Implementation

BIBLIOGRAPHY

APPENDICES
One of the thesis' attractions consists of a few memorable quotations on the subject of airports, such as the following:

"We are very slow to learn. Our new airports are still planned with old attitudes and talents; the same interests that failed in the past are recalled for still more advice; and the results are the same static conception of airports as being merely bases for airplanes... What airports are really meant to be and how they should best serve continue to elude us... the opportunities have existed, but foresight has not, to take the Air Age for what it really is -- a gigantic evolution in the habits of man -- and to plan for it being just as practical as it is imaginative... Airports today are a result of location of our cities... The Air Harbour will be where Nature and enormity of things to come determine. Then around it -- possibly under it -- a city will grow."  

In defence of airport planners, it is not possible to agree that, as Mr. Basi subsequently puts it, "In North America, the general approach of a Development Plan while dealing with airports, is simply to provide for the future air traffic volume, with some concern which is rather occasional, shown to the effects of the aircraft noise." Such a remark seems on the surface to be a little unkind to those who have struggled to take a well-rounded approach to airport planning, and in particular to those whom the author has consulted in the process of developing his thesis; in effect, his words seem critical of their work. It later on becomes evident, however, that the thesis in fact criticizes the approach taken by city planners, who at least have the excuse of not having first-hand familiarity with airports as very special areas within the overall urban environment.

The thesis is correct when it alleges that a good deal of inferior planning, or even non-planning, has taken place in the past, and this applies even within the airport's boundaries. Here we come upon the matter of human frailties, and in particular upon the usual human assumption that we can do no wrong, but should plunge forward with whatever first seems a good idea (such as the slaughter of various animal species which have since become extinct) without a care for the consequences. It would seem that we have at last learned our lessons, however, and hopefully we are now beyond the mistakes alluded to.

One result in fact seems to be that so much concern is currently shown about all manner of possible consequences of different airport schemes, that it is sometimes difficult to resolve all the real and potential problems so as to arrive at an agreed plan of action.

Two major schools of thought on the relation of airports to communities can be distinguished. That generally assumed by this thesis emphasizes the growth of new, airport-centered urban development, whereas the opposite school primarily looks upon the airport as a transportation facility intended to serve people who already live in a given area. Thus the airport may be looked upon primarily as a leader, or alternatively primarily as a follower, of urban growth and development.

While the following may constitute a digression from the thesis' actual coverage, it may be worth noting here that the views of the two schools of thought can produce quite opposite proposals on the location of a given new airport. Being concerned about local and regional development within their own boundaries, for example, the Canadian provinces tend to desire the establishment of new major airports in relatively remote, underdeveloped areas as means for achieving their own aims, while with its responsibilities for viable air transportation, the Federal Government has more of a mandate to place new airports near the existing markets to be served, where the public's total transport costs may be minimized and where economics of the operation can better be assured.

Moderate, well-rounded views take cognizance of both aspects of the problem. The standpoint adopted by Mr. Basi sees the development of a new town, following the establishment of a successful new airport, as inevitable; fortunately he does not try to exploit

this phenomenon by extrapolating metropolitan experience into remote hinterlands. He instead appreciates the importance of the link between the airport and the community served, and simply examines the possibilities of maintaining a compatible relation between the two, by monitoring and controlling the spread of the community into the vicinity of the new airport. The following quotation from the thesis' introductory pages sums up several of the author's main views on the current situation:

"First, an airport is a living and growing organism. Second, airport operation is inherently noisy and spreads its negative effects on the surrounding area. The result of incomplete recognition of these two factors by urban planners is that the airports in the metropolitan areas of today have been excessively ill-planned. Incompatible urban growth around the airports and the ensuing nuisance have been, in most cases, important factors causing their removal or isolation from the urban environment. But, the banishment from the urban built-up area does not provide a tangible solution to the problem. The strong forces of modern urbanization and the airport magnetic-pull, constantly keep on narrowing down the deliberately created physical distance. Thus, a community and its airport tend to become inseparable. An airport, therefore, attracts urban growth irrespective of its location, and tends to create a city of its own, or else, it is functionally ineffective."

A major theme of the thesis in fact echoes what has been said at other times and in other places, as the following quotation will illustrate:

"It is important to recognize that an airport is a causal factor, which can be used to direct, to focus, to guide and to create a business and employment center, to buttress an area's tax base, and to stimulate area development and commerce. Although an airport is an extensive land use, it generates an intensive land use around it. Thus, it is frequently argued that an airport should be moved out into the countryside, hoping to keep the land use around it intensive. Unfortunately, airport isolation simply does not work. An outlying airport either will become an air city and cause perimeter growth of population and commerce, or it will not be used. Thus, land use controls to protect the airport from its neighbours -- and the neighbours from the airport are mandatory."  

After a good deal of analysis on different topics, as indicated in the Table of Contents, the conclusions of the thesis are stated. The questions of height zoning restrictions, local bird hazards, and impingement of CTOL jet noise on the community lead to a finding that the "airport vicinity" should be delimited by "...a circle of 3 miles radius from the geometric centre of the landing area, plus strips of 1-1/2 mile wide, extending 5 miles at either end of the runway being used by the (CTOL) jets." Various land uses, similar to those listed more comprehensively by the Ministry of Transport, are reviewed for their compatibility within the airport vicinity, and the airport-related use of land having good airport accessibility is also discussed. It is recommended finally that the physical boundaries of the airport vicinity be marked, that studies of existing land uses and population distribution be carried out in the enclosed area, that "Policies for correcting the past mistakes and guiding the future growth be formulated...", and that desirable growth be fostered, through the application of zoning powers.

All in all the thesis is a very worthwhile contribution, although several years too late to lead official thinking in most of the area covered. It refers specifically to CTOL jetports, but is far from irrelevant to the comprehensive study of factors affecting STOL.

STOL is, however, expected to involve decentralized systems of relatively small airports, because of the fact that excellence of access is essential to the attractiveness of STOL in competition with other transport, notably CTOL. STOLports may thus never exert the polarizing influence of an O'Hare or a Los Angeles International Airport. Further, STOL may never be an important means of shipping cargo, since convenience of access is not very vital to cargo and since long-distance flights will likely remain CTOL. Therefore, while the thesis is relevant to the present study, it would have been much more so if it had by chance been written specifically about STOL rather than CTOL.

---

INDIVIDUAL STOLPORT DEVELOPMENTS AND PROPOSALS

ROOF HELIPORT KEYED TO 21ST CENTURY
Aviation Week and Space Technology, pp. 50-51, October 18, 1971

A proposal for the eventual development of an operational rooftop heliport atop the new United States Steel Corp. headquarters building in Pittsburgh, Pennsylvania is outlined in this fairly brief article. The building has been specifically designed and built to permit such a development, with aircraft weights up to 60,000 lb. being provided for. City-center to city-center air transport is seen as the mode of the future, and as the 64-storey, 841-foot high building has been designed to serve principally during the 21st century, provision for such a facility constitutes good long-range planning. The company is, however, in no rush to obtain flight equipment at the present time, although a Bell 212 helicopter has been leased for study purposes.

The heliport is stated to be capable of accommodating a V/STOL airplane, the term V/STOL in this case implying "...the capability of taking off in 100 ft. or less and probably landing vertically." It would seem that V/STOL stands in need of a standardized definition, as STOL did a short time ago; in this instance the aircraft, which may or may not be an airplane properly speaking, would essentially be a VTOL machine which could possibly increase its payload by rolling forward during takeoff. Any impression that the heliport could accept STOL operations, as they are defined today, would therefore be false.

Aerodynamic model testing of the building was performed at the University of Western Ontario. "These tests determined, among other things, that airflow over and around the building did not constitute a threat to aircraft landing or takeoff. An airflow baffle, which had been planned to deflect winds from the heliport, was dropped from the plans as unnecessary.

"It would have, in fact, lowered the altitude of turbulent air over the heliport from the present 25-35 ft. to about 15 ft. Most of the pilots queried said they preferred the higher altitude for turbulent air." During landings, one may suppose that a helicopter pilot (such as were asked for their opinions), having ample capability to hover and to make as slow approaches as he might see fit, would be able to acclimatize and to feel his way in turbulence, and would in consequence prefer to encounter such new conditions higher rather than lower. The same evidently would not apply to the STOL case, and so there must be a considerable difference, in this area, between heliport and STOLport requirements.

U.S. Steel is contributing significant studies on such subjects as vertical and horizontal winds atop buildings vis-a-vis at ground level, and on guidance systems. Interest under the STOLPORTS heading may, however, center on features specifically related to the port facilities whether in existence or proposed. Company officials claim that their heliport is one of the safest there is. Principal features described in somewhat more detail in the article include:

- fuel spillage drain system, with interceptor/separator tanks to remove combustibles from precipitation water and/or firefighting agents before admission of the latter to the city sewer system;
- automatic, oscillating foam nozzles ringing the landing area;
- surface floodlighting system and other lighting features designed to aid landings along any of eight alignments, and also to indicate not only the edges of the landing area, but its center as well;
- partially sunken control tower and waiting area, to allow viewing without undue intrusion into airspace;
- a special colour scheme designed to provide high visibility and to enhance depth perception, but at the same time to avoid eyestrain.

AIR TRANSPORTATION CENTRE
Airport World, p. 35, March 1971

The brief text of this announcement of what is, among other things, a STOLport proposal for San Francisco can be quoted in full here, as follows:

"A multi-purpose six-storey building is being planned by Comstol Air Transit Inc. on the San Francisco Waterfront, which features a STOL runway and helicopter landing on its roof.

"Designed as a fully integrated transportation hub, the Comstol concept will include many non-aviation activities, but most of them relate to a need for services desired by air travellers who..."
will arrive or depart at the terminal.

"Supported on concrete piling to be planned at the site of Pier 42 on the San Francisco Waterfront, the center will embody many advanced techniques which blend form and function into a uniform whole.

"Facilities and services to be included at the center include passenger, baggage and cargo services, a marina for pleasure boats and hydrofoil ferry docks, business offices plus eating, sleeping and shopping facilities.

"Pier No. 42 offers San Francisco the optimum in V/STOL flight advantages and safety as its location provides for generally clear weather during local city fog conditions and departures and approaches are clear of obstacles and populated areas.

"Noise levels will be below city standards on a calm, no-wind day and with prevailing winds blowing towards the bay it is expected that the sound of V/STOL craft will hardly be noticed over normal city noises."

The accompanying perspective sketch shows that the STOL runway would be oriented at right angles to the local shoreline. The structure as a whole is L-shaped, with an apparently reasonable separation of fixed obstructions and parked aircraft from the runway proper, although it is impossible to be certain on this point. Ground access provisions are hidden by the perspective chosen. The usual stumbling block of edge restraint barrier requirements may, according to the reviewer's impressions of the current state of the art, be expected to trip this elevated STOLport project up as things now stand. There may also be unsolved aerodynamic problems in the scheme.

Certainly for those who face the prospect of having to resort to elevated STOLports, research and development in the areas of edge barriers and elevated deck aerodynamics would seem to be high priority matters.

**NORTHERN SITES AND TRANSPORT**

No reports found for this section.

**COMPARATIVE ECONOMICS**

No reports found for this section.

---

**NETWORK PLANNING, STATISTICS, FORECASTING**

V/STOLPORT ACCESSIBILITY CONSIDERATIONS

John R. Wiley (Port of New York Authority)


Possibly unknowingly, this paper at times seems to echo ideas brought forth elsewhere, as in Barton E. Cramer's 1966 M.I.T. study, "Optimum Allocation of Transportation Terminals in Urban Areas" (reviewed in The 1970 STOL Report), applying them to the particular problems of New York City and vicinity.

Mr. Wiley begins by stating the familiar reasons why VTOL or STOL intercity (short haul) transport is desirable, particularly in areas such as the U.S. Northeast Corridor with New York at its heart. Although VTOL has inherent advantages over STOL in terms of land area required among other things, STOL is emphasized because its technology is better developed.

Land area requirements, though, have implications not only of purchase cost, but also of social and environmental impacts. Why not, then, locate STOLports within areas already given over to airport use, since new land areas would not be affected? This policy would allow STOL to make use of new airspace which CTOL at least supposedly is incapable of utilizing (an idea which, it must be said, could be debated), and would thus take some of the pressure off the CTOL system. The answer is that, for some cities such as New York, access to conventional airports is already unacceptable while, in any event, STOL would not be able to compete with faster CTOL if forced to use the same ground facilities.

Because of the access problem, the paper next looks at the placement of STOLports within that area which generates more short distance air trips than any other, i.e. within the central business district (CBD). There might be possibilities here within some cities, but not in New York.

Ultimately it appears that the most practical solution for New York may be an urban-linked STOLport located in Secaucus, New Jersey, just a few minutes from mid-Manhattan by bus or rail transit. In addition, a secondary apparatus of decentralized STOLports could be developed as required, preferably near traffic generating
concentrations. Efforts should be made to locate such facilities near points of convergence of existing highway and rail links.

Thus although some cities may be able to develop urban-located STOLports, New York's best choice is basically an urban-linked site. This is seen as the key to the establishment of a viable STOL transport network throughout the entire region.

In evaluation of this paper, it is not felt that a great deal has been said, either in absolute terms (the text is quite short and occasionally repetitive) or in terms of new ideas contributed. On the other hand, the subject area is very important to STOL, impinging as it does on the system's very viability. It is at any rate interesting to note that the Port of New York Authority's thinking is apparently similar to that of other interested parties, indicating a harmony of attitude which bodes well for the future of STOL.

AIRPORT SYSTEM GROWTH
Homer B. Anderson
Airport Operators Council International and Puerto Rican Ports Authority
Airport World, pp. 12-14, October 1971

This paper amounts really to a "pep talk", addressed to all those who hold pieces of the "mammoth jigsaw puzzle" which comprises, in the U.S.A., "the nation's largest non-system", to encourage them to cooperate in striving for a true systems approach to airport network development and coordination. It spends most of its space outlining the present chaotic situation, in which numerous independent authorities and vested interest play parts, and in which competition generally displaces cooperation. Conservationist movements add a further note which discourages airport progress.

There is little discussion of a relatively technical nature. A suggestion is made that parallel runway spacing could be halved, easing the problem of airport expansion in the face of land scarcities. A photo caption states, "An example of utilizing 'future' technology to solve passenger problems is the airside/landside passenger transit system now in operation at Tampa International Airport which shuttles passengers and visitors between main and satellite terminals..." Certainly one need not read this paper if looking for contributions to the actual technology of airport system growth.

STOL is mentioned once; "future V/STOL trends" are to be discussed at a forthcoming annual conference of the organization which Mr. Anderson heads.

AIRPORT AND AIR TRAFFIC REQUIREMENTS FOR SHORT HAUL AIR TRANSPORTATION
A. O. Basnight (FAA)

It appears to be the principal aim of this paper to study the problem of harmonizing CTOL and V/STOL operations at major airports. The author appears to be preoccupied with the question of small V/STOL feeder services for ongoing longer distance flights via large, conventional jet aircraft. Thus the paper does not deal much if at all with the future situation of direct intercity VTOL or STOL connections or of larger VTOL or STOL aircraft. It in other words deals with the present DHC-6-generation problems, and does not consider those of the future, presumably DHC-7 and subsequent generations. It outlines only briefly some aspects of STOLports per se.

Jetport feeder operations are seen as important, but at the same time as a problem for the jetport, which often is already saturated with CTOL movements and the concomitant passenger loads. Use of major runways and other facilities by VTOL or STOL aircraft is a waste of resources, if runway time is denied to the users of larger CTOL craft. The smaller aircraft may in consequence be assessed landing fees equal to those of the larger ones displaced, straining the economics of operating the former at the site.

On the other hand, the special capabilities of V/STOL open up new possible approaches to the problem. In order to follow up the possibilities, the author looks at the overall system of getting aircraft from point to point.

Concerning navigational aids, it is noted that whereas the major jet airports are fully instrumented with ILS, the feeder airports are not and, in the case of (urban) STOLports, probably cannot be so instrumented because of obstacles surrounding the short, narrow runways. Nonetheless, identical navaids should be provided at both ends of the flight, and VOR/DME, as is now generally available in the
merely on the basis of an unconsidered purpose.

As to ATC considerations, the problem of delaying CTOL jets owing to the 65 kt. optimum approach speeds of STOL and the 45 kt. equivalent of VTOL is noted; although many STOL and some VTOL can maintain 140 kt. on final approach, they nonetheless still occupy the same airspace blocks as 250 to 400 seat jets might. Separation constraints also are briefly reviewed, as are potential conflicts with VFR aviation.

By way of meeting the challenge, FAA ideas on urban STOLports are first introduced in relation to geometric criteria. Next the discussion switches to major jet airports, where U.S. experience has shown that separate STOL runways are a requirement. The latter point having been made once again, the discussion then begins, in this reviewer's opinion, to fall apart a bit.

In the first place the statement is made, "For separate STOL ports at major terminals (i.e. at major airports - the author continually uses pilot's terminology in this respect, but does not in fact refer to either passenger or freight terminal buildings), interconnecting surface or subsurface transportation, such as a people mover, with through baggage handling, should be included." This statement is reasonable within a certain context, but one should not assume without examination that there should be separate STOLports at major airports. Separate airspace and approach paths, yes, separate runways, yes, but need ground facilities be separate? Unless the normal terminal area has in one or more respects already reached ultimate saturation, that is where the passenger ought to be processed; there, transfers between flights can be accomplished as easily as if the transfer were between two CTOL aircraft, and "operational splits" can be avoided. After all, once on the ground, what difference does it make how the aircraft may behave in flight? What distinguishes the automobile, suitcase, or the man himself, between STOL and CTOL users? If, on the other hand, the existing terminal has become unsuitable for STOL use, what difference would make it suitable for CTOL use? In addition, why should the same maintenance facilities not be available to STOL as to CTOL aircraft? For example, do both not ice up about equally under adverse conditions? Thus it is held that the quoted paragraph only becomes properly applicable once a reasoned decision has been taken, and not merely on the basis of an unconsidered assumption that STOL should be separated from CTOL, on the ground as much as in the air.

In the second place, in his subsequent paragraph the author directs attention to a Figure 4, "Future Jetport with V/STOL Feeder", a drawing which apparently is extremely poorly executed, illustrating what is considered to be an even worse concept of total airport layout. A particularly confusing feature of the drawing technique is that inconsistent scales are used so that, for example, what is evidently supposed to represent a Boeing 2707 SST comes out looking a mile or more long.

The main framework of the layout consists of four parallel major jet runways running one way, with another four running perpendicularly, each runway being spaced at a mile's distance from its immediate neighbour. The first and second groups of these major runways are superimposed on one another in such a way as to form a square checkerboard pattern. A result is that each runway intersects four others. The layout as illustrated appears entirely devoid of taxiways, while requiring underground surface access to eight widely separated terminal areas and, in the center square of the checkerboard, to an air traffic control tower.

It unfortunately would take several pages to discuss all the shortcomings of this pipedream, but in any event, what may perhaps be the most important point to note here is that four V/STOL runways, in two parallel pairs, are then spaced outside this central CTOL agglomeration, one V/STOL runway being placed outside of and parallel to each side of the big checkerboard. Since these V/STOL runways are also given "...adequate separation for full simultaneous operation", and considering the inconsistencies of the drawing's scale which make anything possible, they may perhaps lie a further mile outside of their nearest CTOL neighbours, making possible five miles of total separation between parallel pairs of V/STOL runways. If these facilities were to be operated unidirectionally (landings on one, takeoffs on the other of a pair), there evidently would be some pretty tall taxiing to do - and that along major CTOL runways, with four active CTOL runways intersecting!

In general, though, a few constructive ideas for the possible location of future V/STOL facilities, e.g. atop a hotel parking garage or above freeways (illustrated, complete with monorail train lines), are offered in this area of the paper.
Getting back to areas in which the author must feel more at home, he notes that a new instrument landing system is essential, that several candidate systems are being evaluated, and that "The selection will probably be a microwave system with selectable glide slopes with readout on existing instrumentation. For elevated STOL ports this ILS is a requirement even for VFR operations to provide adequate accuracy for landing."

The ATC picture is not as encouraging. Current area navigation facilities are not terribly accurate and do not provide full flexibility for STOL. Where available tools such as surveillance radar exist, their use is hampered by shortages of staff or display equipment. Delays from CTOL/STOL intermix may be intolerable.

Conclusions are that STOLports should be encouraged, that some area navigation system like Decca or Loran C is needed, that a new ILS will hopefully be chosen in time to meet new operational demands, and that new ATC standards must be developed, with additional manpower. A two-step approach to these aims is suggested, first using existing tools and second using new ones.

The report, in sum, disregards the subject of possible intercity STOL services and, with regard to airport feeder services, has its chief impact in terms of air traffic rather than ground facility requirements. In the main, problems are outlined by the paper, but concrete solutions are few, and the useful information provided is rather minimal.

The point is made that acceleration from zero to flying speed, or the reverse deceleration upon landing, can be markedly increased even for a large transport aircraft by flying it lightly loaded. It also is established that there is no official or practical objection to making use of such improved performance potential, when the flight plan permits it with adequate fuel reserves. The somewhat doubtful claim then is made that similar acceleration would be acceptable under full load conditions, and implicitly that the achievement of a similar speed would keep the aircraft flying, if the latter could be given augmented thrust, presumably, through the application of external forces.

There is something of a non sequitur here, as the forces applied in the acceleration of an aircraft other than by its engine thrust could conceivably strain the structure severely, and also as the achievement of a given speed might well allow the aircraft to become airborne when lightly loaded, but could easily prove inadequate to provide the needed lift to get the same plane off the ground when heavily loaded. As to the matter of strain, to double the unaugmented acceleration of an aircraft on takeoff one would have to apply a towing force equal to the takeoff thrust of all engines so that, for example, the DC8-55 mentioned in the paper would have to withstand the application of concentrated, longitudinal external forces in the order of 40 tons. Thus it may be suggested that, although the g loading in this instance might be harmless to the passengers and crew, it might be quite harmful to if not to say destructive of, the aircraft unless the latter were specifically designed from the outset to withstand such loads, or heavily "beefed up".

The paper notes that the use of assisted takeoff and landing equipment could allow the reduction of wing area among STOL aircraft, by allowing higher takeoff and landing speeds. Such a change would bring about advantages in terms of gust response and controllability, particularly during the critical approach toward a landing on an elevated facility. In effect, what the paper proposes is the use of launch and arrest equipment so as to endow essentially CTOL aircraft with STOL performance. Even at assisted takeoff speeds it is claimed, the pilot can still select assisted arrestment on the runway.

A specific arrangement for assisted takeoffs and landings is outlined. It is stated that g accelerations would be both suitable and acceptable for
downtown STOLport operations. By way of a trial, use of a suitably modified straight deck aircraft carrier moored in a downtown site is proposed, the aircraft payload being cargo for the first year. What is a straight deck carrier? Well, it is one that lacks the modern angled deck allowing pilots to survive, with luck, if their aircraft should fall into the sea more or less in front of the ship (as has been known to happen more than once); where the ship is moored, the angled feature is not useful. It should be noted, however, that navy pilots generally need more than just an angled deck to save themselves; they also need ejection seats, which even work underwater.

The philosophy adopted by the U.S. Federal Aviation Administration and generally accepted by others is that the aircraft must be capable of true STOL operations, so as to be able to manage itself under all normal circumstances. Thus, although FAA envisions using arrestment as a backup safety device for abnormal circumstances, arrestment would not form a primary stopping system without which an accident would certainly ensue. The lack of a second independent means of stopping in the latter situation would be unacceptable to civilian authorities.

Thus the proposals put forth by the paper would seem to have very little chance of success.

V/STOL FLIGHT EVALUATION OF VISUAL AIDS IN RELATION TO MINIMUM LANDING AREA OPERATIONS
J. A. Johnston
(U.S. Army Aviation)

The lack of agreement on the meaning of the term "V/STOL" rears its head again in this instance. Essentially VTOL aircraft, which happen to benefit in terms of lifting capacity if they can roll forward just prior to liftoff, are involved. The test aircraft in question was the Hawker Siddeley Kestrel, the predecessor of today's operational VTOL Harrier jet fighter. "Minimum landing area" therefore means a square pad such as a rather small helicopter could use. The "visual aids" in their turn consist of parked Land Rovers, yellow barrels and the like. Except possibly for temporary landing strips on ice, such ad-hoc, battlefield-style expedients would not seem to have application to civil STOL operations in the context of the present study.

RUNWAYS, TERMINALS, FACILITIES

No reports found for this section.

APPENDIX V

FLAIR - "THE WAY-OUT" FLOATING AIRPORT
P. Wahl
Popular Science Vol. 197, No. 2, p. 54, August 1970

TRANSMITTAL OF INFORMATION ON STOL PORTS
Department of Transportation, Federal Aviation Administration Report N70-41076-087, April 1970

Purpose: This notice transmits copies of the papers presented at the STOL Port Planning and Design Conference on 20 April 1970.

Background: The STOL Port Planning and Design Conference on 20 April 1970, was attended by 200 persons representing 85 different organizations, both domestic and international. To provide the latest agency thinking on various aspects of planning and design, papers were prepared as follow:

a. STOL Port Conference Objectives by Chester G. Bowers, Director, Airports Service.
d. STOL Runway Length Determination by George Buley, Airports Service.
e. Terminal NAVAIDS and IFR Operations by Gerald Gibson, Flight Standards Service.
f. Obstruction Clearance Surfaces by Gerald Crosby, Airports Service.
g. STOL Port Marking and Lighting by Robert Gates, NAPEC, and Thomas Williams, Airports Service.
h. STOL Port Safety by Howard Eakins, Airports Service, and Carl Schulten, Systems Research and Development Service.
i. Operational Research Related to STOL Ports by Clay Staples, Aircraft Development Service.

j. Planning the STOL Air Transportation System by Thomas McNamara, Airports Service.

k. Funding of STOL Ports by Lamar E. Guthrie, Airports Service.

Although the above papers do not represent final or official agency positions, they are transmitted to keep field personnel abreast of current developments.
This bibliography is intended to update that contained in "An Assessment of STOL Technology", UTIAS Report No.162/CTC Research Branch Report RB 7006, published in 1970. The same reviewing procedures and major headings have been used in the present report. In choosing the papers to be included, areas of immediate interest to Canada have been covered and consequently most vehicle oriented topics are concerned with the first generation of STOL transports (i.e. those with turboprop powerplants) although some papers on turbofan STOL transports have been reviewed.

The bibliography is fully annotated by the reviewers as to the quality and relevance of the contents of the papers. The outlines presented reflect the reviewers' impressions of the work and may differ considerably from the authors' abstracts.

This bibliography is organized under five main headings:

Vehicle Design and Performance
Operational Aspects
Navigation, Guidance and Air Traffic Control
Non-Passenger Public Acceptance
STOLports

Available copies of this report are limited. Return this card to UTIAS, if you require a copy.