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V/STOL AIRCRAFT AERODYNAMIC PREDICTION METHODS INVESTIGATION. VOLUME IV. LITERATURE SURVEY

Peter T. Wooler, et al

Northrop Corporation

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V/STOL AIRCRAFT AERODYNAMIC PREDICTION METHODS INVESTIGATION

Volume IV. Literature Survey

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H.R. Wasson
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Northrop Corporation
Aircraft Division

TECHNICAL REPORT AFFDL-TR-72-26, Volume IV
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13. ABSTRACT

Analytical engineering methods are developed for use in predicting the static and dynamic stability and control derivatives and force and moment coefficients of lift-jet, lift-fan, and vectored thrust V/STOL aircraft in the hover and transition flight regimes. The methods take into account the strong power effects, large variations in angle of attack and sideslip, and changes in aircraft geometry that are associated with high disk loaded V/STOL aircraft operating in the aforementioned flight regimes. The aircraft configurations studied have a conventional wing, fuselage and empennage. The prediction methods are suitable for use by design personnel during the preliminary design and evaluation of V/STOL aircraft of the type previously mentioned.

This report consists of four volumes. The results of a literature survey are presented in this volume. The theoretical development of the prediction methods may be found in Volume I. The methods are applied to a number of V/STOL configurations in Volume II. Details of the computer programs associated with the prediction methods are given in Volume III.

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Rotary Derivatives						
V/STOL Aerodynamics						
Nonlinear Aerodynamics						
Wing Stall						
Separated Flows						
V/STOL Transitional Flight						
Engine Wake Effects						
Jet Exhaust Fields						
Jet Interference Effects						
Jet in Cross Flow						
Jet Path						
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Jet Interaction						
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V/STOL AIRCRAFT AERODYNAMIC PREDICTION METHODS INVESTIGATION

Volume IV

Literature Survey

P.T. Wooler
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FOREWORD

This report summarizes the work accomplished by the Aircraft Division of Northrop Corporation, Hawthorne, California, for the Air Force Flight Dynamics Laboratory, AFSC, Wright Patterson Air Force Base, Ohio, under USAF Contract No. F33615-69-C-1602 (Project 698 BT). This document constitutes the Final Report under the contract.

This work was accomplished during the period 1 May 1969 to 31 January 1972, and this report was released by the authors in January 1972. The Air Force Project Engineers were Mr. Robert Nicholson and Mr. Henry W. Woolard of the Control Criteria Branch, Flight Control Division, AFFDL. Their assistance in monitoring the work and providing data is greatly appreciated.

This technical report has been reviewed and is approved.

C. B. Westbrook
Chief, Control Criteria Branch
Flight Control Division
Air Force Flight Dynamics Laboratory

ABSTRACT

Analytical engineering methods are developed for use in predicting the static and dynamic stability and control derivatives and force and moment coefficients of lift-jet, lift-fan, and vectored thrust V/STOL aircraft in the hover and transition flight regimes. The methods take into account the strong power effects, large variations in angle of attack and sideslip, and changes in aircraft geometry that are associated with high disk loaded V/STOL aircraft operating in the aforementioned flight regimes. The aircraft configurations studied have a conventional wing, fuselage and empennage. The prediction methods are suitable for use by design personnel during the preliminary design and evaluation of V/STOL aircraft of the type previously mentioned.

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SECTION I

INTRODUCTION

This volume is the fourth and final volume treating V/STOL aerodynamic prediction methods. The results of an extensive literature survey are presented in this volume. The objective of the literature survey was to investigate the available data relevant to the three V/STOL aircraft concepts being studied under this program and to identify areas for which further wind tunnel test data were required. This information would then be used to define a wind tunnel test program which would generate the required data. The data obtained from this test program, together with data already available, would be used to validate and/or modify the prediction methods developed during the investigation.

The majority of the reports were collected following literature searches carried out by the Defense Documentation Center and the NASA Scientific and Technical Information Facility. Those searches of the literature were made in May and June of 1969. Although reports pertaining to wind tunnel test data were of prime interest, searches were also made to identify relevant flight test data and theoretical aerodynamic prediction methods. Additional reports were made available by Air Force Flight Dynamics Laboratory and NASA Langley Research Center personnel. Some reports were also available from previous literature reviews by Northrop personnel.

With the application of the literature survey to the aerodynamic prediction methods in mind, the survey was broken down into two general areas:

1. Literature relevant to aircraft components.
2. Literature relevant to aircraft concepts.

The literature dealing with aircraft components is discussed in Section II of this volume. The literature survey has been organized to parallel the methods development presented in Volume I. Thus, subsections on the literature treating wing, body, engine inlet and jet exhaust may be found in Section II.

The V/STOL concepts studied in this investigation have been the lift-fan, lift-jet and vectored thrust concepts. Consequently, Section III includes a discussion of the literature pertaining to each of these concepts.

A summary table, indicating the primary areas of investigation or analysis, of the more applicable of the references is given in an Appendix.

The literature survey was completed in October 1969 and was first published in the Interim Report, Northrop Report NOR 70-121, in June 1970. Since that time, further publications, relating to this investigation, have appeared in the literature. No attempt has been made to incorporate these additional reports into the summary tables. However, they have been included in the list of references as References 278 through 315.

SECTION II

LITERATURE ON AIRCRAFT COMPONENTS

1. WING EFFECTS

The references dealing with the aerodynamic characteristics of the wing can be separated into those treating the power effects and those dealing with nonlinear wing aerodynamics. The references dealing with the power effects are discussed in Sections II. 3 and II. 4.

a. Nonlinear Aerodynamics

Reference 55. - A nonlinear theory of small aspect ratio rectangular wings is presented. In this theory, the wing is divided, along the span, into a number of equal panels. The vorticity for each panel is concentrated on a line at the quarter chord of the panel. The vorticity is assumed to be constant along the wing span. The tip vortices are assumed to be rectilinear and directed along the local flow velocity vector at the trailing edge of the wing. The intensities of the vortices are determined from the boundary conditions (no leakage condition) on the three-quarter chord lines of each panel. Calculations of the aerodynamic characteristics of the proposed method agree quite well with test data for a wing having an aspect ratio of unity. For a wing with an aspect ratio of five, the stall behavior of the wing is not correctly calculated by this approach.

Reference 72. - Semispan-wing models were tested at angles of attack from 0° to 180° at low subsonic speeds. Eight plan forms were considered, both swept and unswept with aspect ratios ranging from 2 to 6. Except for a delta-wing model of aspect ratio 2, all models had a taper ratio of 0.5 and an NACA 64A010 airfoil section. The delta-wing model had an NACA 0005 (modified) airfoil section. With two exceptions, the models were tested both with and without a full-span trailing-edge flap deflected 25°. The Reynolds numbers based on the mean aerodynamic chord were between 1.5 and 2.2 million. Lift, drag, and pitching-moment coefficients are presented as functions of angle of attack.

Reference 113. - Presented in this report is a comprehensive review of the existing technical literature and a design summary of stall characteristics applicable to light straight wing aircraft. These characteristics are obtained with the aid of a digital computer program which utilizes methods employing lifting line theory and the available experimental test data for wing section characteristics. The computer results are presented in the form of stall charts suitable for preliminary design purposes.

Reference 201. - Information from the literature and from recent investigations is used to summarize briefly the effects of airfoil section parameters and flow variables on the aerodynamic characteristics of two-dimensional symmetrical airfoils at high angles of attack. The results presented indicate that airfoil thickness ratio, Reynolds number, Mach number, and surface roughness can all have an important effect on the maximum lift coefficient. The effect of surface roughness seems to be particularly important. Not only can surface roughness cause large decreases in maximum lift coefficient, but also the magnitudes of the effects of Reynolds number, Mach number, and airfoil thickness ratio are much reduced by surface roughness. Beyond the stall, changes in section thickness ratio appear to have little effect on the aerodynamic characteristics of airfoil sections. An investigation of one section through an angle of attack range of from 0° to 360° shows that the drag coefficient reaches a value of 2 at an angle of attack of 90°.

Reference 202. - The results of an investigation of the two-dimensional aerodynamic characteristics of 15 NACA airfoils at four Reynolds numbers from 2.0×10^6 to 0.7×10^6 are reported in this reference. These data, together with those from previous NACA papers for the same airfoils at three Reynolds numbers from 3.0×10^6 to 9.0×10^6, are presented and analyzed in the present paper. The airfoils investigated consisted of 10 systematically varied NACA 6-series airfoils and 5 airfoils of the NACA 4- and 5-digit series. The NACA 6-series airfoils had thickness ratios varying from 9 to 18 percent of the chord, design lift coefficients varying from 0 to 0.6, and positions of minimum pressure on the basic thickness form at zero lift varying from 30 to 60 percent of the chord. The NACA 4- and 5-digit-series sections investigated consisted of the NACA 0012, and the NACA 44- and 230-series sections of 12 percent and 15 percent thickness. The tests were made for both smooth and rough surface conditions and also included the determination of the effectiveness of the different airfoils at various Reynolds numbers when equipped with split flaps.

The results of the investigation indicate that the drag coefficient at the design lift coefficient and the maximum lift coefficient are the important aerodynamic characteristics which are most affected by variations in the Reynolds number between 9.0×10^6 and 0.7×10^6. For each of the 15 airfoils in both the smooth and rough surface conditions, the drag coefficient at design lift increased as the Reynolds number was lowered from 9.0×10^6 to 0.7×10^6. For the smooth NACA 6-series airfoils the magnitude of this increase became larger with increasing airfoil thickness and with rearward movement of the position of minimum pressure on the basic thickness form at zero lift. In the rough surface condition and at the lower Reynolds numbers in the smooth surface condition, the saving in minimum drag to be derived from the use of NACA 6-series as compared with NACA 5-digit series airfoil sections disappears. Decreasing the Reynolds number from 9.0×10^6 to 0.7×10^6 caused reductions in the maximum lift of all the airfoils in both the smooth and rough surface conditions. The magnitude and character of this reduction varied rather inconsistently with airfoil design and surface condition, however, so that the comparative merits of a group of airfoils changed markedly and in a rather unpredictable manner with Reynolds number and surface condition.

Reference 236. - Two analytical methods are presented for determining the spanwise lift distribution. One method is a lifting surface theory and the other a lifting line method. Calculations using the two methods are compared and show that the lifting line method, which takes much less computational time, agrees extremely well with the lifting surface theory.

Reference 237. - A method is presented which allows the use of nonlinear section lift data in the calculation of the spanwise lift distribution of unswept wings with flaps or ailerons. The method is based on lifting-line theory and is an extension to the method of Reference 239. A few comparisons of calculated lift and stall characteristics with experimentally obtained data are shown.

Reference 239. - A method is presented for calculating wing characteristics by lifting-line theory using nonlinear section lift data. Detailed examples are given for symmetrical lift distributions. Calculated wing characteristics are compared with test data and agree very well for the range of angle of attack considered ($0° \leq \alpha \leq 20°$).

Reference 240. - The experimental and calculated aerodynamic characteristics of 22 tapered wings are compared. The wings have aspect ratios from 6 to 12 and taper ratios from 1.6 : 1 to 5 : 1. Some of the data are relevant to the nonlinear angle of attack range.

Reference 241. - The aerodynamic characteristics of the NACA 0012 airfoil section were obtained at angles of attack from 0^{o} to 180^{o}. The tests were conducted in a low turbulence pressure tunnel at Mach numbers no greater than .15.

Reference 258. - Semi-empirical methods are given for determining wing lift and pitching moment in the nonlinear angle of attack range.

2. BODY EFFECTS

The references dealing with body aerodynamics can be separated into those treating power effects and those dealing with nonlinear body aerodynamics.

a. Power Effects

Reference 75. - Data from tests of a wing-body configuration with a fan mounted in the fuselage are presented. Power-on and power-off pitching moment, normal force and axial force were obtained and comparisons made to determine scale effects and wall effects. Some pressure information on the fuselage was obtained.

Reference 76. - A configuration of a jet in a fuselage at two locations, with and without a wing attached, was tested. Pitch plane forces and moments were obtained. No inlet effects were determined.

Reference 77. - Test results for a fan-in-fuselage with power on and power off are presented. Pitch plane forces and moments are given. Comparisons with theory, which treats the configuration as a thin cylindrical ducted fan, are made. Poor correlation is obtained at high forward speeds.

Reference 163. - The results of static bench tests for jet and inlet with wing and fuselage are presented. Only thrust and temperature data are given. These tests were conducted primarily to examine ground effects.

b. Nonlinear Aerodynamics

Reference 90. - Test results for non-aerodynamic shapes, such as parallelepipeds and cylinders, are presented. This investigation has little applicability to the present study.

Reference 224. - This reference presents vorticity measurements for an ellipsoid of revolution at low angle of attack.

Reference 225. - Drag measurements for a circular cylinder started impulsively from rest are presented. This reference also presents the drag due to arbitrarily positioned vortices near a circular cylinder.

References 234 and 242 document methods for tracking vortices in the presence of a cylindrical body (Ref 242), and a body with an elliptical cross section (Ref 234). The analytical treatment of the bodies is restricted to simple shapes. The vortex tracking method of this study is essentially an attempt to extend the same concept to general body shapes.

References 243, 258 and 259 are simplified methods of producing body nonlinear aerodynamics. They utilize slender body theory results and the viscous crossflow concept for nonlinear forces and moments. These methods are limited to bodies of revolution, primarily.

3. INLET EFFECTS

Experimental data are available for three types of lift-fan configurations: fan-in-fuselage; fan-in-wing; and fan-in-semi-span wing.

References 71, 75, 166, 169 and 189 present data for fan-in-fuselage models. The reports cover one configuration which was tested with various inlets and in two model scales. The single fan is located at the intersection of the wing quarter-chord and the fuselage centerline. All tests yielded force data and fuselage pressure data. References 75, 166, 169 and 189 contain data on installed fan performance. Wing component lift is presented in References 75, 169 and189.

References 78, 81, 151-153, 186 and 261 present results of tests involving fan-in-wing configurations. References 78 and 81 present data for a swept wing model with two to four fans located at the trailing and/or leading wing roots. The XV-5A configuration is discussed in References 151-153. Test results for a shoulder-wing, twin-fan configuration are found in Refs. 186

and 261. All tests present data on overall model forces and on installed fan performance. References 81, 151-153, 186 and 261 also give wing pressure data.

References 166 and 267 discuss tests of single fan, semi-span models. The wing of Reference 267 contains a comparatively crude fan. Basic force data are presented, as well as a limited amount of pressure data. Additional tests of complete configurations are discussed in other sections of this report.

Documented analytical methods for fan-in-wing configurations are of two types: those employing two-dimensional conformal transformation techniques; and, those involving complicated three-dimensional potential flow computer programs.

References 1, 4, 10 and 56 document potential flow analyses. All involve the use of complex variable analysis and conformal transformations. Reference 56 gives a detailed discussion of the applicability of the Kutta condition at the trailing edge of the airfoil and demonstrates that the form of the two-dimensional solution can be made to fit three-dimensional data. The two-dimensional analysis of Reference 1 is extended to finite wings in Reference 4, by means of lifting line theory. Quantitative results are poor. It may be that this results from difficulties in representing the jet in two-dimensional potential theory, or it may be the result of the two-dimensional inlet flow which yields incorrect section lift.

References 91, 127 and 250 describe the use of computer techniques to simulate three-dimensional flow about arbitrary lift-fan configurations by means of source panels and vortex lattices. Results are in good agreement with data.

References 230 and 268 present inlet analyses based upon simple momentum theory. Reasonably accurate results are obtained.

References 7 and 57 apply two-dimensional and three-dimensional flow analysis to inlet distortion studies. These are of limited value to the present investigation.

4. JET EXIT EFFECTS

For the purposes of this investigation, interest is centered on the interference effects due to a jet efflux which is directed at large angles both to a crossflow and to a supporting system, which may consist of a wing, body or flat plate.

The relationship between the crossflow and jet exit velocity defines two major areas of interest The condition of a very small crossflow, when compared with the jet exit velocity, is termed the hover phase. The condition of comparable magnitudes of crossflow and jet exit velocities is called the transition phase.

a. Hover Phase

References 78 and 216 indicate that for an aircraft hovering out of ground effect, the jet-induced lift loss is a function of overall planform area and the rate of mixing of the exhaust gases and the surrounding air. An expression for the relationship between the decay of the jet and the induced loads is is presented in References 78 and 216. Reference 216 shows that the lift loss is a linear function of the square root of the planform to jet area ratio, as well as being a function of the jet decay characteristics.

A considerable amount of experimental data is available for the case of a single jet , or a cluster of jets, emerging from the central area of a wing or body in ground effect. For a single jet, the jet efflux entrains the free air between the lower surface of the wing-body and the ground, and the resulting induced velocities tend to increase with decreasing ground clearance. Surface pressures well below ambient are thereby generated on the lower surface, producing significant reductions in the net upward thrust.

References 174, 216, 220, 221, 232 and 264 concern themselves with evaluating the loss of effective jet thrust caused by the induced pressure forces on supporting structures in ground proximity. Several simple planforms (circular, rectangular and triangular plates) as well as models of VTOL airframes are studied. Single and multiple circular and rectangular jets are considered

Reference 220 presents a method for correlating test data for single, centrally located jets. The use of this method for correlating data from full-scale tests, using hot jets. is justified in Reference 23[illegible].

Reference 264. - The problem of scaling is investigated further for a two-jet configuration.

Further investigations relevant to the hover phase are documented in References 59, 165, 210, 217, 223 and 266. Details of those tests and others are given in summary form in Table I. Survey papers are presented in References 78, 256, 262 and 263.

b. Transition Phase

A summary of the available data is shown in Table II. The test data may be classified in two categories:

1. Data for a single jet exhausting from a flat plate simulating an infinite plane boundary.
2. Data for multiple jets in a wing body configuration.

References 252, 228, 245, 246 and 274 present jet centerline data for single jets exhausting normally from a flat plate.

References 271, 272 and 275 present data on the jet centerline for single jets exhausting at various angles to the crossflow.

References 184, 211, 246 and 274 give data for the plate pressure coefficients and References 246, 274 and 275 define certain features of the flow using visualization techniques.

The literature search identified a lack of data on plate pressure coefficients for single jets exhausting at angles other than 90 to the crossflow. No data of any kind for multiple jets exhausting from a flat plate was located.

Multiple-jet data for jets exhausting from wings, bodies, or other configurations are presented in References 5, 30, 34, 76, 193, 214, 217, 228 and 270. A summary of the test data obtained is included as part of Table II.

The analytical investigations have been directed toward obtaining the jet deflection and deformation. There have been basically three approaches to the problem of obtaining the jet centerline. They are:

1. An inviscid model in which the jet boundary is replaced by a vertex sheet which at time $t = 0$ is fixed and is then allowed to deform

freely. Time is then related to distance along the jet through the jet velocity (References 231 and 276).

2. A model which assumes that the deflection of the jet is due to a cross flow drag force (References 206, 226, 255, 265 and 272).
3. A model which assumes that the jet is deflected due to both a cross flow drag force and viscous entrainment of cross flow fluid (References 227, 228, 271 and 274).

References 56, 94, 95, 120, 127, 226, 228, 250, 251 and 255 investigate the computation of the aerodynamic characteristics of an aircraft component which contains a jet exhausting at an angle into the freestream.

References 12, 23, 38, 123, 203, 256 and 263 are review papers covering the problem area and contain test data and analytical results.

Conference proceedings relating to the subject may be found in References 78, 262 and 149.

TABLE I. SUMMARY TABLE FOR HOVER PHASE

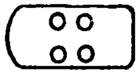
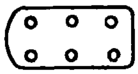
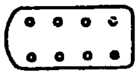
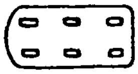
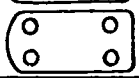
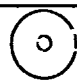
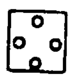
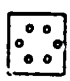
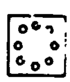
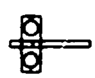
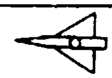
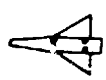
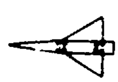
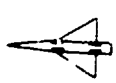
REFERENCE	YEAR	MODEL	TEST DATA	ANALYSIS	NO. OF JETS	JET ARRANGEMENT	COLD JET	HOT JET	GROUND EFFECT	AREA, PLATE / AREA, JET	FORCE DATA	PRESSURE DATA
59	1969	14% XV-4B	X		4		X		X		X	
			X		6		X		X		X	
			X		8		X		X		X	
			X		6		X		X		X	
			X		4		X		X		X	
78	1966	VARIOUS				SURVEY PAPER						
165	1963	PLATE	X		1		X		X	64	X	
			X		1		X		X	64	X	
			X		2		X		X	64	X	
			X		ANNULAR		X		X		X	
210	1960	PLATE	X		1		X		X	10	X	
			X		4		X		X	40	X	
			X		6		X		X	27	X	
			X		8		X		X	20.5	X	
		WING-BODY	X		2		X		X	10,20	X	
216	1966	WING-BODY	X		1		X		X	34.5-49.5	X	X
			X		4		X		X	34.5-49.5	X	X
			X		6		X		X	34.5-49.5	X	
			X		4		X		X	34.5-49.5	X	X

TABLE I. (Continued)

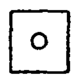
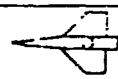
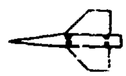
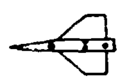
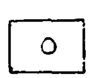
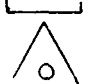
REFERENCE	YEAR	MODEL	TEST DATA	ANALYSIS	NO. OF JETS	JET ARRANGEMENT	COLD JET	HOT JET	GROUND EFFECT	AREA, PLATE / AREA, JET	FORCE DATA	PRESSURE DATA
216 cont		PLATE	X		1		X		X	10-69.5	X	X
			X		1		X		X	38-95	X	X
			X		1		X		X	34.5-49	X	X
217	1966	WING-BODY	X		1		X		X		X	
			X		4		X		X		X	
			X		1		X		X		X	
			X		4		X		X		X	
			X		2		X		X		X	
			X		4		X		X		X	
220	1962	PLATE	X	X	1		X		X	10-100	X	
			X	X	1		X		X	10-100	X	
			X	X	1		X		X	10-100	X	
221	1958	PLATE	X		1		X		X	5.1 128	X	X
			X		1		X		X	20.4 81.5	X	X
			X		1		X		X	46-127	X	X
		WING-BODY-TAIL	X		1		X		X		X	
		PLATE WITH CHANNELS	X		1		X		X	127	X	X

TABLE I. (Concluded)

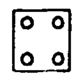
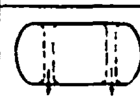
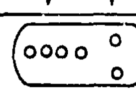
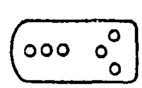
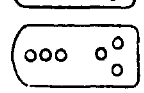
REFERENCE	YEAR	MODEL	TEST DATA	ANALYSIS	NO. OF JETS	JET ARRANGEMENT	COLD JET	HOT JET	GROUND EFFECT	AREA, PLATE / AREA, JET	FORCE DATA	PRESSURE DATA
223	1966	PLATE	X		1			X	X	19.5-44.0	X	X
			X		4			X		19.4-43.6	X	
232	1967	PLATE	X		1		X		X	142		X
			X		1			X	X	142		X
262	1968					SURVEY PAPER						
		PLATES	X		1,4		X	X	X	150, 83		
		WING-BODY	X		1,4		X		X	39		
		X-14	X		2			X	X			
		WING-BODY-TAIL	X		8 10 12	6 BAC MODELS	X		X			
264	1969	BODY FUSELAGE	X		2		X	X	X			X
264	1968	FULL SCALE VTOL FIGHTER A/C	X		6			X	X			X
			X		6			X	X			X
			X		6			X	X			X

TABLE II. SUMMARY TABLE FOR TRANSITION PHASE

REFERENCE	YEAR	PLANFORM	TEST DATA	ANALYSIS	NUMBER OF JETS	GROUND PROXIMITY	FORCE DATA	PRESSURE DATA	FLOW VISUALIZATION	JET CENTERLINE
5	1964	VARIOUS	X		1-5	OUT	X	X		
13	1967	VARIOUS	X	X	1-4	IN, OUT	X	X		
23	1968	VARIOUS	X	X	1-4	IN, OUT	X	X		
30	1962	VARIOUS	X		4	OUT	X			
34	1961	WING-BODY	X		1	IN, OUT	X			
38	1965	VARIOUS	X		1-5	IN, OUT	X			
56	1961	WING	X	X	1	OUT	X			
76	1963	WING WING-BODY	X		1	OUT	X			
78	1966		CONFERENCE PROCEEDINGS							
94	1968	WING		X	1	IN, OUT				
95	1967	WING		X	1	OUT		X		
120	1968	FLAT PLATE		X	1	IN, OUT	X			
123	1966	VARIOUS	X	X	1, MULTIPLE	IN, OUT	X	X		
127	1967	WING		X	1	OUT	X	X		
148	1968	CYLINDER FLAT PLATE	X		1	IN		X	X	
149	1967		CONFERENCE PROCEEDINGS							
168	1961	WING	X		1	IN, OUT	X	X		
184	1964	WING	X		1	OUT		X	X	X
193	1961	VARIOUS	X		1-4	OUT	X			
203	1968	VARIOUS	X	X	1-2	OUT	X	X		
206	1969			X	1	OUT				X
211	1963	FLAT PLATE	X		1	OUT		X		
214	1964	WING-BODY	X		1-4	IN, OUT	X			
217	1966	WING-BODY	X		1-4	X	X			
226	1964	WING FLAT PLATE		X	1-8		X	X		X
227	1966	FLAT PLATE		X	1			X		X
228	1957	WING	X	X	1-2	OUT		X		
231	1969	FLAT PLATE		X	1	OUT				X
245	1963	FLAT PLATE	X	X	1	OUT				X
246	1965	FLAT PLATE	X		1	IN, OUT		X	X	X
250	1965	WING		X	[illegible]	OUT	X			X
251	1967	WING	X	X	1-[illegible]	OUT	X	X		X
252	1958	FLAT PLATE	X		1	OUT				X

TABLE II. (Concluded)

REFERENCE	YEAR	PLANFORM	TEST DATA	ANALYSIS	NUMBER OF JETS	GROUND PROXIMITY	FORCE DATA	PRESSURE DATA	FLOW VISUALIZATION	JET CENTERLINE
255	1961	FLAT PLATE WING	X	X	1-2	OUT	X	X		X
256	1969	SURVEY PAPER								
262	1969	CONFERENCE PROCEEDINGS								
263	1968	SURVEY PAPER								
265	1969	FLAT PLATE		X	1	OUT				X
270	1969	WING	X		2	OUT	X	X		
271	1969	FLAT PLATE	X	X	1	OUT				X
272	1969	FLAT PLATE	X	X	1	OUT				X
274	1969	FLAT PLATE	X	X		OUT		X	X	X
275	1968	FLAT PLATE	X	X	1	OUT			X	X
276	1942			X	1	OUT				X

SECTION III

LITERATURE ON AIRCRAFT CONFIGURATION CONCEPTS

This portion of the literature survey will be a discussion of the existing experimental and theoretical data pertinent to complete configurations of the three V/STOL concepts, lift-fan, lift-jet, and vectored thrust.

Included in this section are three tables which list and describe in detail the applicable experimental reports pertaining to each of the V/STOL concepts. In conjunction with these tables there are included three lists containing abstracts on each of the aforementioned experimental reports. The lists also contain abstracts on reports which are not included in the experimental tables, but nevertheless are pertinent to the investigation, such as theoretical and analytical reports.

The discussion will now be focused on each of the V/STOL concepts.

1. LIFT-FAN CONCEPT

An examination of Table III reveals that a great deal of time and effort has been expended on this V/STOL concept, especially on the XV-5A program. Wind tunnel tests have been conducted on three different lift-fan locations, in the wing, fuselage, and fuselage pods. In addition to the normal six-component force and moment data being obtained, there were tests conducted to obtain the local flow field around the lift-fan location by static pressure recordings.

There are test data covering the hover, transition, and conventional speed regimes for both wind tunnel models and full-scale flight aircraft. Data are available for hover in and out of ground effect. In addition, there are analytical reports which contain methods to predict the static and dynamic stability derivatives and also flight test data to substantiate these predictions.

Abstracts of Lift-Fan Concept Reports

5. Kuhn, R. E., McKinney, M. O., Reeder, J. P., Aerodynamics and Flying Qualities of Jet V/STOL Airplanes, SAE Paper 864A, April 1964 (A64-20157)

TABLE III. SUMMARY OF LIFT-FAN EXPERIMENTAL DATA

Reference Number	Year of Publication	Lift-Fan Location	Wing Aspect Ratio	Wing Airfoil Section	Fuselage Fineness Ratio	Tail Volume-V	Number of Lift Fans/Configuration	Ratio Total Fan Area to Total Wing Area	Wing Taper Ratio	Wing Sweep of 0.25c-Deg	Model Scale	α Range-Deg	q-Dynamic Pressure-PSF	Speed Regime-H, T or C	Reynolds Number in 10^6	β Range-Deg	Ground Effects	Power Effects	Force Data	Moment Data	Pressure Survey	Downwash Survey	Longitudinal Stability	Lateral Stability	Directional Stability	Dynamic Stability	Comments
36	1964	W	3.11	NACA 65-[illegible]	10.80	0.404	2	0.149	0.32	11-25	Full	-4 to +20	0 to 115	H.T	10.75	-12 to +12	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Pitch fan in nose. Similar to XV-5A.
71	1963	F	5.0	NACA 63A-21[illegible]	5.52	0.600	1	0.0867	0.50	0.0	Large	-1 to [illegible]	0 to --	H.T	6	0.0	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	NASA VTOL model. G.E. J85-7 generator (in ground effect).
79	196[illegible]	W	3.41	NACA 65-210	10.20	0.405	2	0.164	754/400	15-28	0.18	-10 to +10	0 to 33.9	H.T	Un-known	Un-known	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	First flight test of the XV-5A model
81	1967	F P*	5.8	NACA 65-412	7.35	0.803	4	0.123	0.30	35	Large	-4 to +24	0 to 66.5	H.T	10.4	-10 to +4	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	V/STOL transport model. Two different configurations
82	1967	W	3.1[illegible]	NACA 65A 211	5.42	0.197	6	0.170	0.47	20	Large	-4 to +22	0 to 53	H.T	14.2	-12 to +8	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Six lift-fans in wing. NASA transport model.
85	196[illegible]	W	3.41	NACA 65-210	10.20	0.405	2	0.164	754/40	15-28	0.18	-20 to +20	0 to 33.9	H.T	Un-known	0.0	No	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Static and dynamic tests of XV-5A model.
147	1968	W	Correlation of Test Results from Reference Numbers 36, 79, 85, 151, 153, 154 and 200																								XV-5A models
151	1964	W	3.42	NACA 0012-64	10.20	0.40[illegible]	2	0.163	752/40	15-28	0.125	-8 to +20	120	C	2.21	-20 to +20	No	No	Yes	No	Yes	No	No	No	No	No	XV-5A model. Pressure data and hinge moment data only.
153	1963	W	3.42	NACA 0012-64	10.20	0.400	2	0.163	752/40	15-28	0.166	-90 to +90	0 to 10	H.T	0.21 to 0.885	-90 to +180	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	XV-5A model. Complete static test
155	1966	W	3.42	NACA 0012-64	10.20	Vary	2	0.163	752/40	15-28	Full	Vary	Vary	C	Vary	Vari-able	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	XV-5A flight tests by contractor (conventional flight)
156	1965	W	3.42	NACA 0012-64	10.20	Vary	2	0.163	752/40	15-28	Full	Vary	Vary	H.T.C	Vary	Un-known	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	XV-5A flight simulation study
166	1962	F	5.0	NACA 63A-210	5.52	0.600	1	0.0867	0.50	0.0	Full	-4 to +18	0 to 22	H.T	6.3	0.0	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Same tests as Reference 71. More hover performance.
169	1961	F	5.0	NACA 63A-210	5.52	0.600	1	0.0867	0.50	0.0	Full	-6 to +16	0 to 33.9	H.T.C	6.3	-16 to +16	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Same test program as Reference 166. More cruise performance.
177	1967	W	3.42	NACA 0012-64	10.20	Vary	2	0.163	752/50	15-28	Full	Vary	Vary	H.T.C	Vary	Un-known	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	XV-5A flight tests by USAF (handling qualities evaluation).
178	1964	W	3.42	NACA 0012-64	10.2	0.400	2	0.163	752/50	15-28	0.125	-1 to +15	237 to 1200	C	Vary	-5 to +5	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	High-speed (0.40 M to 0.9 M) wind tunnel tests on the XV-5A.
179	1964	W	3.42	NACA 0012-64	10.2	0.400	2	0.163	752/50	15-28	0.125	-8 to +20	120	C	2.21	-20 to +20	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Low speed (0.285 M) wind tunnel tests of the XV-5A
180	1966	W	3.42	NACA 0012-64	10.2	Vary	[illegible]	0.163	752/50	15-28	Full	Vary	Vary	H	Vary	Un-known	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	XV-5A flight tests by contractor (fan-powered flight)
[illegible]	1965	W	3.42	NACA 0012-64	10.2	Vary	2	0.163	752/50	15-28	Full	Vary	Vary	H.T.C	Vary	Un-known	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	U.S. Army's preliminary pilot evaluation of the XV-5A.
[illegible]	[illegible]	W	[illegible]	NACA 65-210	8.6[illegible]	0.425	2	0.0997	0.50	16	Full	-4 to +20	0 to 53	H.T	0 to 12.0	-12 to +12	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	More detailed report of Reference 39 emphasizing the fan.
[illegible]	[illegible]	F	5.0	NACA 63A-210	5.52	0.600	1	0.0897	0.50	0.0	Full	-6 to +18	0 to 33.9	H.T	7.9	0.0	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Similar to Reference 71 only out of ground effect.
192	[illegible]	F	5.0	NACA 63A-210	5.52	0.600	1	0.0897	0.50	0.0	Full	-8 to +18	0 to 33.9	H.T	7.9	0.0	No	Yes	Yes	Yes	No	Yes	Yes	No	No	No	Limited analysis of the test results of Reference 189
200	[illegible]	W	3.42	NACA 0012-64	10.2	0.400	2	0.163	752/50	15-28	Full	-4 to +20	0 to 33.9	H.T.C	Un-known	-10 to +10	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Full-scale XV-5A wind tunnel tests and thrust stand tests
207	1964	W	3.42	NACA 0012-64	10.2	0.400	2	0.163	752/50	15-28	Full	Vary	Vary	H.T.C	Un-known	Vari-able	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	U.S. Army's pilots' evaluation of the XV-5A stability and control.
2[illegible]1	1963	W	[illegible]	NACA 65-210	8.69	0.425	2	0.0997	0.50	16	Large	-4 to +20	0 to 33.9	H.T	12.4	0.0	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Predecessor to XV-5A. Two different wing sizes tested.

* Fuselage pods

A summary of information on airplane aerodynamics, ground effect, propulsion system aerodynamics, stability and control, and flying qualities of jet V/STOL airplanes (both direct jet lift and lift-fan configurations) is presented.

22. McKinney, M. O., Newsom, W. A., Fan V/STOL Aircraft, New York Academy of Sciences, Annals, Vol. 154, Nov. 1968 (A69-15565)

A summary of information on airplane aerodynamics, ground effects, propulsion system aerodynamics, stability and control of fan V/STOL aircraft (primarily ducted fan and lift-fan configurations) is presented.

36. Hall, L. P., Hickey, D. H., Kirk, J. V., Aerodynamic Characteristics of a Full-Scale Fan-in-Wing Model Including Results in Ground Effect with Nose-Fan Pitch Control, NASA TN D-2368, (N64-28323)

Model had a mid-mounted wing of A. R. = 3.1. Results cover the fan-powered flight speed range from 0 to 100 knots. Longitudinal and lateral-directional characteristics with and without fan exhaust vectoring, downwash at the horizontal tail, and the effects on performance of exhaust gas reingestion are included. Installed fan performance was measured for the fan-powered flight speed range. Control power available by means of throttling lift-fan exhaust and by modulating pitch-fan thrust is presented.

41. Anon, Aerodynamics of Power Plant Installation, AGARDograph-103, 1965 (N66-22286)

A compilation of technical papers presented at the 1965 AGARD meeting on The Aerodynamics of Power Plant Installation, Part 2. Contents include discussions on air inlets and nozzles, airframe propulsion system interference, VTOL propulsion including jet lift intakes and exhausts, also lift-fan inlets and airframe VTOL propulsion interference effects.

60. Goldsmith, R., Hickey, D., Characteristics of Aircraft with Lifting-Fan Propulsion Systems for V/STOL, IAS Paper No. 63-27, Jan. 1963 (A63-11581)

Results from wind tunnel tests of several large-scale lifting-fan

models (Refs. 36, 39, 71) are analyzed with respect to the induced lift, pitching moment, and flying qualities. Rudimentary methods for estimating induced lift and the thrust-drag relationship are also presented.

71. deSavigny, R. A., Hickey, D. H., Aerodynamic Characteristics in Ground Effect of a Large-Scale Model with a High Disk-Loading Lifting Fan Mounted in the Fuselage, NASA TN D-1557, Jan. 1963 (N63-11617)
Large-scale VTOL fan-in-fuselage airplane model tested had a shoulder-mounted unswept wing of aspect ratio 5. Characteristics of the model with and without the horizontal tail were obtained with the wing at 1.83 and 2.93 fan diameters from the simulated ground plane installed above the wind tunnel floor. Test airspeeds ranged from 20 to 80 knots. Longitudinal forces and moments, some installed fan performance, static-pressure distributions on the fuselage, and downwash at the horizontal tail are presented.

78. Anon, Conference on V/STOL and STOL Aircraft, NASA SP-116, April 1966 (N66-24606)
A compilation of papers presented at the 1966 NASA Conference on V/STOL Aircraft. Contents include discussions covering the results of NASA research on problems associated with V/STOL aircraft, such as, aerodynamics and propulsion of helicopters and propeller V/STOL, also lift-fan and lift-jet V/STOL aircraft.

79. Chambers, J. R., Kirby, R. H., Flight Investigation of Dynamic Stability and Control Characteristics of a 0.18-Scale Model of a Fan-in-Wing VTOL Airplane, NASA TN D-3412 (N66-32941)
A free-flight investigation of a 0.18-scale model of the XV-5A was made to study the stability and control characteristics during hovering flight, both in and out of ground effect and fan-powered low-speed forward flight. Data were obtained mainly from pilot observations and from studies of motion picture records of the flights.

81. Hall, L. P., Hickey, D. H., Kirk, J. V., Aerodynamic Characteristics of a Large-Scale V/STOL Transport Model with Lift and Lift-Cruise Fans, NASA TN D-4092, Aug. 1967 (N67-33454)

A wind tunnel test of two configurations of a V/STOL transport model powered by tip-turbine-driven fans. First configuration was combination of two lift fans and two rotating cruise fans. Second configuration consisted of four tandem mounted lift fans. Both configurations used a high-mounted wing with an aspect ratio of 5.8, swept back 35° at the quarter-chord line, and a taper ratio of 0.30. Aerodynamic characteristics, including force and moment data, were obtained for the hover and low forward speeds. Some fan exit pressures and wing surface pressure distributions were also measured during the tests.

82. Hall, L. P., Hodder, B. K., Kirk, J. V., Large-Scale Wind Tunnel Investigation of a V/STOL Transport Model with Wing-Mounted Lift Fans and Fuselage Mounted Lift-Cruise Engines for Propulsion, NASA TN D-4233, Nov. 1967 (N67-40198)
The low-speed aerodynamic characteristics of a large-scale fan-in-wing V/STOL transport model were investigated. The model had six fans mounted in the wing and two lift-cruise engines mounted forward of the wing in the fuselage. The high mounted wing had an aspect ratio of 3.43, taper ratio of 0.47, and a 0.25 $\bar{c}$ sweepback of 20°. Combination of 2, 4, and 6 fans were investigated as well as the chordwise position of the fans in the wing to determine the interference effects of the flow field. The effects of operating two lift-cruise engines in conjunction with the six lift fans were also studied.

85. Chambers, J. R., Grafton, S. B., Static and Dynamic Longitudinal Stability Derivatives of a Powered 0.18-Scale Model of a Fan-in-Wing VTOL Aircraft, NASA TN D-4322, Feb. 1968 (N68-15894)
An investigation was conducted to determine the static and dynamic longitudinal stability derivatives of a powered 0.18-scale model of the XV-5A for trimmed level flight at an angle of attack of 0°. The investigation covered a range of values of thrust and oscillatory frequencies for the model with the horizontal tail both on and off.

106. **Anon, Estimated Dynamic Stability Characteristics, G. E. Report No. 151, Sept. 1964 (AD 639 235)**
This report presents the dynamic stability characteristics of the XV-5A lift-fan research aircraft based on theoretical and empirical estimates of dynamic stability derivatives and static aerodynamic characteristics derived from scale model wind tunnel tests. Except for a presentation of the lift fan natural damping contributions to flight in the lift-fan mode, the report is restricted to analysis of conventional flight characteristics.

147. Parks, W. C., Swingle, R. L., Swope, W. A., XV-5A Aerodynamic Propulsion Data Correlation and Characteristics Development Based on Wind Tunnel Characteristics, Ryan Report No. 29467-1, July 1968 (AD 676 862)
This report contains the results of a wind tunnel and thrust stand data correlation and characteristics generation program using data from tests of the XV-5A lift fan research aircraft. The program efforts were limited to the lift-fan mode of operation and were restricted to correlation of longitudinal test data and to development of longitudinal stability characteristics for calculated flight conditions. Data from five wind tunnel programs (majority of data correlation utilized results from the Ryan 1/6-scale and NASA full-scale model tests) provided the primary basis for the work. Longitudinal stability derivatives for the XV-5A were developed and numerical values were calculated for the fan mode of operation.

151. Anon, Wind Tunnel Test Report Conventional Model. Volume II. Low-Speed Pressure and Hinge Moments, G. E. Report No. 141-Vol. II, Jan. 1964 (AD 653568)
This report presents the results from wind tunnel tests of a 1/8-scale conventional model of the XV-5A (M = 0.285). Hinge moment coefficients and pressure data in plotted and tabular form with pertinent detail explanatory information are presented.

152. Anon, One-Fifth-Scale Inlet Model Wind Tunnel Test Report, Volume II, G. E. Report No. 154-Vol. II, March 1965 (AD 617 395)
This report contains the tabulated pressure data from the low speed tests (M = 0 to M = 0.2) of the XV-5A 1/5-scale inlet model.

153. Anon, Wind Tunnel Test Report, Lift Fan Powered Scale Model, G. E. Report No. 137, Nov. 1963 (AD 647 386)
This report presents the results of wind tunnel tests of a 1/6-scale powered model of the XV-5A. Data were obtained to define the static characteristics in and out of ground effect; aerodynamic characteristics in forward flight for the transition, conversion, and low speed conventional flight modes; and flight characteristis at low translational speeds near hovering in vertical, lateral, and rearward directions. In addition, wing surface static pressures and wing fan inlet closure door hinge moments were measured.

154. Anon, Estimated Static Stability and Control Characteristics, G. E. Report No. 146, March 1964 (AD 639 236)
This report contains the estimated static stability and control characteristics of the XV-5A. The estimates are based on theoretical and empirical considerations, including the results of 420 hours of wind tunnel tests of 1/8- and 1/6 scale models, and also data from tests of a full-scale model similar to the XV-5A.

155. Anon, Phase I Flight Tests Results, Volume II, G. E. Report No. 166, Volume II, March 1965 (AD639 232)
This report presents the conventional flight test results (wing-supported lift) of the XV-5A aircraft test program which was conducted by the contractor. Contents include flight test plots on thermodynamics, airplane stall performance, climb performance, static longitudinal stability, static and dynamic lateral-directional stability, and also control effectiveness.

156. Anon, Final Systems Analysis and Flight Simulation Report, Volume II, G. E. Report No. 157, Volume II, March 1965 (AD 639 230)
This report presents the results and details of the XV-5A simulation and analysis for the hover, transition, and conversion modes of operation.

166. Przedpelski, Z. J., Results of Wind Tunnel Tests of a Full-Scale, Fuselage Mounted, Tip Turbine Driven Lift Fan. Volume III, G. E. Report No. TR 61 15 V3, March 1962 (AD 275 711)
This report presents the results of wind tunnel tests of a full-scale

VTOL airplane model with a fan-in-fuselage power plant. The model had a shoulder-mounted unswept wing with an aspect ratio of 5.0 and taper ratio of 0.50. Contents include powered and unpowered performance in and out of ground effect, static longitudinal stability, and STOL performance. Reference No. 71 presents NASA data for same tests.

159. Anon, Results of Wind Tunnel Tests of a Full-Scale Fuselage Mounted, Tip Turbine Driven Lift Fan, Volume II, G. E. Report TR 61 15 V2, April 1961 (AD 263 450)
This report presents the results of wind tunnel tests for the same test program as Reference no. 166. The contents include more conventional flight data than Reference 166, no ground effect, and emphasis on the J85-7 generator performance.

177. LaPlant, P. C., Flight Evaluation of the XV-5A V/STOL Aircraft, AFFTC-TR-66-30, March 1967 (AD 810 922)
This report presents the results of a USAF flight evaluation of the XV-5A aircraft. The primary emphasis is placed on the handling qualities. Stability and control characteristics are presented for the hover (in and out of ground effect), level flight performance, transition regime, and STOL operation.

178. Anon, Wind Tunnel Test Report Conventional Model, Volume III. High Speed (Mach = 0.4 to 0.9), G. E. Report No. 141, Volume III, Jan. 1964 (AD 653 569)
This report presents the results of the high speed (M = 0.4 to M = 0.9) wind tunnel tests of the 1/8-scale conventional model of the XV-5A. Six-component data plus wing and fuselage static pressure data are contained in the report. Control surface hinge moment coefficients are also presented.

179. Anon, Wind Tunnel Test Report Conventional Model. Volume I. Low Speed Force and Moment Data, G. E. Report No. 141, Volume I, Jan. 1964 (AD 653 566).
This report presents the results of the low speed (M = 0.285) wind tunnel tests of the 1/8-scale conventional model of the XV-5A. Static longitudinal, lateral, and directional stability characteristics are presented along with the control effectiveness parameters.

180. Anon, Phase I Flight Test Results, Volume I, G. E. Report No. 166, Volume I, March 1966 (AD 639 231)
This report presents the results of flight tests on the XV-5A conducted by the contractor. The major portion of the tests is centered on the fan-powered speed regime (hover to transition); performance, stability and control (in and out of ground effect), and tail downwash are included in the report's experimental plotted data.

182. Anon, Preliminary Pilot Qualitative Evaluation of the XV-5A Research Aircraft, AATA-AFB-Letter Report, Oct. 1965 (AD 623 514)
This report presents the results of the U. S. Army's Aviation preliminary pilot evaluation of the XV-5A. Contents include pilot's comments on the performance and handling qualities during hovering (in and out of ground effect), transition, and conversion speed regimes. Some experimental data are presented.

186. Anon, Results of Wind Tunnel of a Full-Scale Wing-Mounted Tip-Turbine-Driven Lift Fan, ATRECOM TR 63-21, Sept. 1963 (AD 426 785)
This report presents the results of wind tunnel tests of a full-scale fan-in-wing model. The tests are the same as the tests of Reference 39. However, the results are more concerned with the fan characteristics than the external aerodynamic characteristics reported in Reference 39. Tabulated plus plotted data are presented.

189. Aoyagi, K., Hickey, D. H., deSavigny, R. A., Aerodynamic Characteristics of a Large-Scale Model with a High Disk-Loading Lifting Fan Mounted in the Fuselage, NASA TN D-775, Oct. 1961 AD 265 252)
This report presents the results of wind tunnel tests of a large-scale fan-in-fuselage model. The longitudinal characteristics, static pressure survey and horizontal tail downwash are presented for the hovering and transition speed regimes, all out of ground effect. The model is the same as the one used in Reference 71; these tests were conducted prior to Reference 71.

192. Maki, R. L., Hickey, D. H., Aerodynamics of a Fan-in-Fuselage Model, NASA TN D-789, May 1961 (AD 256 074)
This report presents a limited analysis of the longitudinal test results of Reference 189. The primary emphasis is centered on the large pitching-moment variation with increase in flight speed. Very little qualitative and/or quantitative data are presented.

200. Anon, Full-Scale Wind Tunnel Test Report, G. E. Report No. 153, June 1966 (AD 654 043)
This report presents the results of full-scale XV-5A aircraft wind tunnel tests performed at NASA Ames. The contents include power on and power off plotted data for the static longitudinal characteristics, the static lateral and directional characteristics, control effectiveness, and static engine thrust stand parameters.

207. Ferrell, K. R., Finnestad, R. L., et al, Engineering Flight Research Evaluation of the XV-5A, Part I - Stability and Control, Final Report, USAATA Report, 1966 (AD 800 937L)
This report presents the results of the U. S. Army Aviation's engineering flight research evaluation of the XV-5A. The flying qualities and the stability and control characteristics of the XV-5A are evaluated in detail, qualitatively and quantitatively. Complete plotted data in terms of time history and control displacements are presented for the fan-mode and jet-mode speed regimes. Pilots' opinions are given for each aerodynamic stability and control criteria.

261. Hickey, D. H., Hall, L. P., Aerodynamic Characteristics of a Large-Scale Model with Two High Disk-Loading Fans Mounted in the Wing, NASA TN D-1650, Feb. 1963
Model has a shoulder-mounted wing of A. R. = 3.5. Results cover the fan-powered flight speed range from 0 to 100 knots. Longitudinal forces and moments, pressure distributions, and lateral forces and moments when the fans were throttled to give control are presented. Installed fan performance over the pertinent speed range is presented for three inlets and with and without fan exhaust vectoring.

2. LIFT-JET CONCEPT

An examination of Table IV reveals that the major testing conducted on this V/STOL concept was centered on the XV-4A and XV-4B. It is emphasized at this point that the results of this literature survey are based on the reports available and known to exist at this time. The DDC and NASA literature search services were employed in this study. There are probably contractors' test reports, both in the United States and foreign countries, which are proprietary and therefore unavailable. Consequently, only the available, existing reports are discussed in this literature survey.

The normal six-component force and moment data have been measured for the hover (in and out of ground effect), transition, and conventional speed regimes. There has been no static pressure survey around the lift-jet or surrounding areas in order to identify the local flow field in a complete configuration model.

There is a limited amount of analysis on the dynamic stability derivatives, and a small amount of flight test data (all of these data are presented for the XV-4A, which employs an augmented jet ejector and not a lift jet).

Abstracts of Lift-Jet Concept Reports

5. Kuhn, R. E., McKinney, M. O., Reeder, J. P.; Aerodynamics and Flying Qualities of Jet V/STOL Airplanes, SAE Paper 864A, April 1964 (A64-20157)
A summary of information on airplane aerodynamics, ground effects, propulsion system aerodynamics, stability and control, and flying qualities of jet V/STOL airplanes (both direct jet lift and lift-fan configurations) is presented.

30. Otis, J. H., Jr., Induced Interference Effects on a Four-Jet VTOL Configuration with Various Wing Planforms in the Transition Speed Range, NASA TN D-1400, 1962 (N62-15319)
Wind tunnel results of a limited investigation with a simplified model at zero angle of attack to study the jet interference effects in transition from hovering to forward flight out of ground effect. A series of wings (5) were tested with a fuselage employing four convergent nozzles to provide some preliminary data on the effects of planform. Lift losses and nose-up pitching moments were encountered at low forward speeds.

TABLE IV. SUMMARY OF LIFT-JET EXPERIMENTAL DATA

Reference Number	Year of Publication	Lift-Jet Location	Wing Aspect Ratio	Wing Airfoil Section	Wing Taper Ratio	Wing Sweep of 0.25c-Deg	Fuselage Fineness Ratio	Tail Volume - V̄	Number of Lift-Jets/Configuration	Ratio Total Lift-Jet Area to Total Wing Area	Model Scale	α Range-Deg	β Range-Deg	q-Dynamic Pressure-PSF	Speed Regime-H, T, or C	Reynolds Number in 10^6	Ground Effects	Power Effects	Force Data	Moment Data	Pressure Survey	Downwash Survey	Longitudinal Stability	Lateral Stability	Directional Stability	Dynamic Stability	Comments
				Configuration Geometry								Test Conditions					Test Data										
30	1962	F	Vary	Un-known	Vary	Vary	11.1	No Tail	4	.049 to .0733	Small	0	0	0 to 108	H, T, C	0 to 0.20	No	Yes	Yes	Yes	No	No	Yes	No	No	No	Five different wings. Same fuselage and jet areas.
59	1969	F	6.28	Slab	0.360	5.0	5.7	N/A	4 to 8	*.0101 to .0202	0.14	0	0	Static	H	Static	Yes	Yes	Yes	Yes	No	No	No	No	No	No	Static tests of 16 nozzle configurations on an XV-4A model with 9 different wing planforms.
59	1969	F	2.31	Slab	0.0	52.0	5.7	N/A	4	*.0202	0.14	0	0	Static	H	Static	Yes	Yes	Yes	Yes	No	No	No	No	No	No	Static tests of 18 nozzle configurations on an XV-4A model with 8 different wing planforms.
50	1966	F	6.00	NACA 64A012	0.39	4.2	6.7	0.856	40	0.218	Full	-12 to +28	0 to -10	0 to 33.9	H, T, C	0 to 4.7	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	XV-4A full-scale model tests (40 small nozzles).
87	1968	F	6.40	NACA 63A006	0.18	11.0	12.0	1.40	5	.0436	Small	-6 to +20	0 to -20	0 to 11.0	H, T	0 to 0.4	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	NASA VTOL fighter model. Five lift-jet engines in line.
88	1969	F	5.90	NACA 64A012	0.39	4.2	5.6	0.923	6	.045	0.16	-8 to +28	+6 to -28	2 to 11.0	H, T, C	0 to 0.44	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	XV-4B model tests by NASA, Langley.
150	1965	F	6.00	NACA 64A012	0.39	4.2	6.7	0.856	40	0.218	Full	-12 to +28	+4 to -10	0 to 33.9	H, T, C	0 to 4.7	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	XV-4A full-scale test report by contractor.
181	1966	F	6.00	NACA 64A012	0.39	4.2	6.7	0.856	40	0.216	Full	Vary	Vary	Vary	H, T, C	Vary	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Summary report on XV-4A complete program.
208	1966	F	6.00	NACA 64A012	0.39	4.2	6.7	0.856	6	.0322	0.16	-20 to +20	+20 to -20	0 to 73.6	H, T, C	Un-known	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	XV-4A model with six simulated jet engine nozzles.
209	1967	F	5.00	NACA 64A012	0.39	4.2	6.4	0.92	6	.045	0.16	-7 to +46	+5 to -208	0 to 11.0	H, T, C	0 to 0.43	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	XV-4B model tests by Lockheed at NASA, Langley.
257	1968	F	5.90	NACA 64A012	0.39	4.2	6.4	0.92	6	.045	0.16	-6 to +98	+4 to -98	0 to 11.0	H, T	0 to 0.44	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	XV-4B model low-speed tests at NASA, Langley.
257	1968	F	5.90	NACA 64A012	0.39	4.2	6.4	0.92	6	.045	0.16	-7 to +13	+10 to -7	60 to 100	C	1.0 to 1.87	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	XV-4B model high-speed tests at NASA, Langley.

*Ratio of total lift-jet area to total planform area.

41. Anon, Aerodynamics of Power Plant Installation, AGARDograph-103, 1965 (N66-22286)

A compilation of technical papers presented at the 1965 AGARD meeting on The Aerodynamics of Power Plant Installation, Part 2. Contents include discussions on air inlets and nozzles, airframe-propulsion system interference, VTOL propulsion including jet lift intakes and exhausts, also lift-fan inlets and airframe VTOL propulsion interference effects.

59. Shumpert, P. K., Tibbetts, J. G., Model Tests on Jet Induced Lift Effects on a VTOL Aircraft in Hover, NASA CR-1297, March 1969 (N69-21477)

Jet-induced interference effects were investigated for a jet aircraft in hovering flight using a scale model with numerous nozzle configurations (18) and model components. Interference loads and jet decay data were obtained in and out of ground effect to determine the effects of various parameters on interference loads and to assess a technique for correlating lift loss with jet decay characteristics.

78. Anon, Conference on V/STOL and STOL Aircraft, NASA SP-116, April 1966 (N66-24606)

A compilation of papers presented at the 1966 NASA Conference on V/STOL Aircraft. Contents include discussions covering the results of NASA research on problems associated with V/STOL aircraft, such as, aerodynamics and propulsion of helicopters and propeller V/STOL. also lift-fan and lift-jet V/STOL aircraft.

80. Hickey, D. H. and Kirk, J. V., Full-Scale Wind Tunnel Investigation of a VTOL Aircraft with a Jet-Ejector System for Lift Augmentation, NASA TN D-3725, Nov. 1966 (67-32321)

Wind tunnel results of a full-scale XV-4A airplane to determine its aerodynamic characteristics, including its ejector system, ejector performance, longitudinal characteristics, lateral-directional stability and control, and control power about all three axes were determined at various airspeeds and control settings through the transition flight regime.

87. Gentry, G. L. and Margason, R. J., Aerodynamic Characteristics of a Five Jet VTOL Configuration in the Transition Speed Range, NASA TN D-4812, Oct. 1968 (68-36021)
A wind tunnel investigation of a powered small-scale model of a VTOL fighter configuration having three lift-jet engines in the forward fuselage and two deflected lift-cruise engines in the aft fuselage was conducted to determine the aerodynamic characteristics in the transition speed range and also ground effect during hover. The model was tested with three wing configurations and up to three horizontal tail heights.

88. Winston, M. M., Wind Tunnel Data from a 0.16-Scale V/STOL Model with Direct-Lift and Lift-Cruise Jets, NASA TM X-1758, March 1969 (N69-20016)
Wind tunnel results of a 0.16-scale XV-4B model to determine its aerodynamic characteristics. Six cold air ejectors were used to simulate four direct-lift and two lift-cruise jet engines. Longitudinal and lateral-directional aerodynamic characteristics were investigated for various model configurations, forward speeds, and power conditions in the transition and cruise flight ranges. In addition to control-effectiveness studies, the effects of power variations for different lift-nozzle settings and the effects of height above the ground were investigated. The data are presented without analysis.

123. Williams, J., Wood, M., Aerodynamic Interference Effects with Jet-Lift V/STOL Aircraft under Static and Forward-Speed Conditions, RAE-TR-664-3, Dec. 1966 (AD 813 258)
The nature and magnitude of aerodynamic interference effects which can arise with jet and fan-lift schemes for V/STOL aircraft are considered. Particular attention is paid to adverse flows which can be induced around the airframe by the jet or fan efflux during V/STOL operation near the ground and during transition to and from purely wing-borne flight. The discussion concentrates on the understanding and analysis of major aerodynamic features rather than on optimization of specific aircraft layouts.

150. Anon, Full-Scale Tests of the XV-4A Hummingbird in the Ames 40 x 80 Foot Wind Tunnel, G. E. Report No. ER-7634, Jan. 1965 (AD 654 783)
The results of the XV-4A Hummingbird tests in the Ames 40 x 80 foot wind tunnel (Reference 80) are presented and analyzed. The 41 runs made included pitch, yaw, and control effectiveness tests in hover, transition, and conventional flight.

181. Nicholson, R., Lowry, R. B., XV-4A VTOL Research Aircraft Program, USA-AVLABS TR-66-45, May 1966 (AD 635 106)
This report contains a description of the XV-4A aircraft and highlights the aircraft design characteristics, aircraft systems, flight test program, VTOL improvement program, and wind tunnel tests.

208. Martin, W. O., Low-Speed Wind Tunnel Test Results of a 0.18-Scale Model of the XV-4A, Lockheed-Georgia Report ER 8677, 1966
This report presents the results from a wind tunnel test of a proposed modification to the XV-4A airplane. The 0.18-scale model was tested in the LTV low-speed wind tunnel. Six-component force and moment data were recorded for the hover through transition flight regimes. Six nozzles in the bottom of the model fuselage were employed to simulate the exhaust of six jet engines. No analysis is presented.

209. Whipkey, R. R., XV-4B Wind Tunnel Tests of a 0.16-Scale Model in the NASA Langley 7 x 10 Foot Wind Tunnel, Lockheed-Georgia Report ER 9092, 1967
This report presents the contractor's results from a wind tunnel test of a 0.16-scale XV-4B model. Six-component data are presented for the hover, transition, and conversion speed regimes. Horizontal stabilizer and elevator effectiveness, rudder and aileron effectiveness, with and without power, in and out of ground effect, are also presented. Very little analysis is presented.

257. Swain, W. N., Wind Tunnel Test of a 0.16-Scale XV-4B Model in the NASA Langley 17-Foot Low Speed Wind Tunnel and the 7 x 10 Foot High Speed Wind Tunnel, Lockheed-Georgia Report No. ER 9061, Sept. 1968
This report presents the contractor's results from two wind tunnel

tests of a 0.16-scale XB-4B model at NASA Langley. The first phase was conducted in a low speed tunnel to determine the power effects on the aerodynamic characteristics in the conventional, STOL, and hover modes of flight. Six-component force and moment data were obtained in both pitch and sideslip. Ground effects were determined for several model attitudes. The second phase was conducted in the high speed tunnel to determine the aerodynamic characteristics in the conventional flight regime (unpowered). Six-component force and moment data were acquired in both pitch and sideslip.

3. VECTORED THRUST CONCEPT

An examination of Table V reveals that only a small amount of experimental testing has been conducted on the complete configurations of this V/STOL concept. Of the tests conducted, six-component force and moment data were obtained for the hover (in and out of ground effect), transition, and conventional speed regimes. Noticeably missing are static pressure surveys and tail downwash surveys.

Abstracts of Vectored Thrust Concept Reports

23. Wood, M. N., Jet V/STOL Aircraft Aerodynamics, New York Academy of Sciences, Annals, Vol. 154, Nov. 1968 (A69-15566)
This paper presents a discussion of results of the V/STOL Aerodynamic Research Program carried out in the low-speed tunnel's division of the Royal Aircraft Establishment. Some experimental aerodynamic data are presented for the P-1127 model and some stability data are presented for the Short S. C. -1 model.

34. Spreeman, K. P., Investigation of Interference of a Deflected Jet with Free Stream and Ground on Aerodynamic Characteristics of a Semispan Delta-Wing VTOL Model, NASA TN D-9.5 (N62-71489)
This report presents the results from a NASA wind tunnel test of a semispan delta wing VTOL model with a deflected jet under the wing. Sets of vanes attached to the wing behind the jet deflected the jet stream to different turning angles. Static tests were run in and out of ground effect. Longitudinal aerodynamic characteristics were obtained for various angles of attack and deflection angles.

TABLE V. SUMMARY OF VECTORED THRUST EXPERIMENTAL DATA

		CONFIGURATION GEOMETRY												TEST CONDITIONS				TEST DATA										
REFERENCE NUMBER	YEAR OF PUBLICATION	VECTORED-THRUST LOCATION	WING ASPECT RATIO	WING AIRFOIL SECTION	WING TAPER RATIO	WING SWEEP OF 0.25$\bar{c}$ - DEG	FUSELAGE FINENESS RATIO	TAIL VOLUME - $\bar{V}$	NUMBER OF THRUST NOZZLES/CONFIGURATION	RATIO TOTAL THRUST AREA TO WING AREA	MODEL SCALE	α RANGE - DEG	β RANGE - DEG	q - DYNAMIC PRESSURE - PSF	SPEED REGIME - H, T, OR C	REYNOLDS NUMBER ×10⁻⁶	GROUND EFFECTS	POWER EFFECTS	FORCE DATA	MOMENT DATA	PRESSURE SURVEY	DOWNWASH SURVEY	LONGITUDINAL STABILITY	LATERAL STABILITY	DIRECTIONAL STABILITY	DYNAMIC STABILITY	COMMENTS
34	1961	W	3.00	Slab	0.143	37.	9.0	None	2	0.025	Small	-40 to +63	0	0 to 33.9	H, T, C	0 to 0.30	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No	NASA semispan Delta wing VTOL model with deflected jet under wing.
34	1961	W	1.55	Slab	0.443	37.	9.0	0.24	2	0.0305	Small	-40 to +63	0	0 to 33.9	H, T, C	0 to 0.50	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No	NASA semispan Delta wing VTOL model with deflected jet under wing.
117	1968	F	2.80	NPL 10/5 5	0.40	34.	6.9	0.525	4	0.0502	Full	Vary	Vary	0 to 165	H, T, C	Un-known	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	P-1127 (XV-6A) flight tests by USAF Flight Test Center.
143	1968	F	2.61	NACA 0010	0.059	44.	4.6	None	1	None	0.20	0 to +10	-90 to +90	47.5	C	3 to 4.3	No	No	Yes	Yes	No	No	No	Yes	Yes	No	Short SC-1 roll stability tests at low speeds.
197	1957	F	3.00	Un-known	0.50	13.	5.9	N/A	3	0.028	Small	0	0	0	H	0	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No	Static tests of two NASA VTOL models.
213	1964	Nac	5.48	Un-known	0.613	0.0	6.62	0.868	8	0.0292	0.13	-10 to +20	-10 to +10	0 to 94.5	H, T, C	Un-known	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Freeflight and force tests of combined vector thrust and lift jet.
235	1965	F	4.52	NACA 65A012	0.69	Vary	8.2	Vari-able	4	0.044	Small	-10 to +25	-70 to +10	0.21 to 10.0	H, T	.18 to .47	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	NASA tests of variable-sweep Delta wing model.
269	1967	F	6.15	NACA 23014	0.48	-4.6	5.4	0.55	2	Un-known	Full	-12 to +16	0 & 90	0 to 1.22	H, T	Un-known	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	X-14 NASA, AMES unpublished wind tunnel preliminary tests.

41. Anon, Aerodynamics of Power Plant Installation, Agardograph-103, 1965 (N66-22286)
A compilation of technical papers presented at the 1965 Agard meeting on The Aerodynamics of Power Plant Installation, Part 2. Contents include a paper on the X-14A VTOL Flight Test and some data on the P-1127.

91. Winters, C. P., The Approximate Longitudinal Stability Derivatives of a Vectored Thrust VTOL, AFIT Report No. GAM/AE/68-11, March 1968 (AD 833 396)
This report presents the results of an analytical study to determine the stability derivatives and the stability of the vectored thrust airplane, P-1127. The performance, derivatives and stability were determined for both an accelerating and non-accelerating transition from hover to conventional flight. The results of the accelerating transition were compared to values available from Hawker Siddeley.

117. McKinzie, G. A., Bradfield, E. N., Jr., Ludwig, J. H., Casey, W. R., P-1127 (XV-6A) V/STOL Handling Qualities Evaluation, AFFTC-TR-68-19, Aug. 1968 (AD 839 849)
This report presents the results of a flight test program conducted by the USAFFTC to evaluate the V/STOL flying and handling qualities of the P-1127 (XV-6A) aircraft. The static longitudinal and lateral-directional stability characteristics along with the control effectiveness are presented for the hover (in and out of ground effect) and transition flight regimes. In addition, the dynamic longitudinal and lateral-directional stability characteristics are presented. Also, the rigid mount AFFTC VTOL thrust stand facility was utilized to evaluate the engine, nozzles, and flight control system in a simulated hover environment.

143. Trebble, W. J. G., Low-Speed Wind Tunnel Investigation of the Roll Stability of a 1/5-Scale Model of the Short SC-1 at Large Sideslip, ARC-CP-994, May 1967 (AD 837 313)
This report presents the results of a low-speed wind tunnel test on a 1/5-scale model of the Short S.C.-1. The test was conducted primarily to determine the roll characteristics of the model at

large sideslip angles. Lateral and directional forces and moments are presented for various air speeds and sideslip angles.

197. Newsom, W. A., Jr., Effect of Ground Proximity on Aerodynamic Characteristics of Two Horizontal-Attitude Jet Vertical-Take-Off-and-Landing Airplane Models, NASA TN D-419, Sept. 1957 (AD 144 809)
This report presents the results of a static simulated power test of two jet VTOL models. One model was a tilt-wing and the other was a deflected jet in the fuselage. Tuft studies and some force data are presented. Cascade vanes were employed to obtain the thrust vectoring.

213. Smith, C. C., Parlett, L. P., Flight Tests of a 0.13-Scale Model of a Vectored-Thrust Jet VTOL Transport Airplane, NASA TN D-2285, 1964
This report presents the results of an experimental investigation to determine the dynamic and control characteristics of a 0.13-scale model of a vectored thrust jet VTOL transport airplane. The model has a straight wing mounted on top of the fuselage and is powered by two vectored-thrust turbofan engines mounted in nacelles under the wing (four rotating thrust nozzles per nacelle) and six turbojet lift engines mounted in wing tip pods with three engines in each pod. Free-flight tests were conducted in hover (in and out of ground effect) and transition with motion picture recordings. Static longitudinal and later-directional characteristics are presented from wind tunnel force tests.

235. Vogler, R., Kuhn, R. E., Longitudinal and Lateral Stability Characteristics of Two Four-Jet VTOL Models in the Transition Speed Range, NASA TM X-1092, May 1965
This report presents the results of a NASA investigation of the longitudinal and lateral stability characteristics of two four-jet vectored thrust type VTOL models in the transition speed range. The basic model investigated had a low aspect ratio delta wing with variable-sweep auxiliary wings, twin inlets, and four adjustable exit nozzles. The modified model was obtained by removing the delta wing area rearward of the jet exits of the basic model and adding a

conventional horizontal tail. Six component data were obtained for both models from hover to conventional flight speed range.

269. Anon, Unpublished NASA Wind Tunnel Data on Preliminary Tests of the X-14 at NASA, Ames, 1967
These unpublished data present the results of preliminary tests of the XV-14A in the NASA 40 x 80 foot wind tunnel. Force and moment data have been obtained for power on and off conditions and $\psi = 0°$ and 90°.

APPENDIX

SUMMARY OF V/STOL REFERENCES

KEY TO V/STOL SUMMARY TABLE (See Table VI)

COLUMN HEADING	ABBREVIATION	DEFINITION
V/STOL Concept	LF	Lifting Fan
	LJ	Lifting Jet
	VT	Vectored Thrust
	TD	Tilting Duct
	TW	Tilting Wing
	TP	Tilting Propeller
Nature of Report Material	A	Analytical or Theoretical
	E	Experimental
Flight Regime or Airflow	H	Hover
	T	Transition
	C	Cruise
	LOW	Low Speed Near Hover
Test Article (Component)	W	Wing
	B	Body
	T	Tail
	J	Jet
	DP	Ducted Propeller
	FP	Flat Plate
	D-FAN	Ducted Fan
	I	Inlet
	W, B, T	Total Configuration
Types of Test	WT	Wind Tunnel Test
	FT	Flight Test or Free-Flight
	BT	Bench Test
	SIMUL	Simulator
	HT	Hydrodynamic Test

TABLE VI. SUMMARY TABLE OF V/STOL REFERENCES

							Areas of Investigation or Analysis							Stability & Control			
REFERENCE NUMBER	YEAR OF PUBLICATION	V/STOL CONCEPT	NATURE OF REPT. MATRL.	FLIGHT REGIME OR AIRFLOW	TEST ARTICLE (COMPONENT)	TYPES OF TEST	INLET EFFECTS	JETS (EXIT)	GROUND EFFECT	WING ALONE	BODY ALONE	INTERFERENCE EFFECTS	GENERAL V/STOL	LONGITUDINAL	LATERAL – DIRECTIONAL	DYNAMIC	ROTARY
1	1962	LF	A, E	H, Low	Wing	WT	X	X		X		X		X			
2	1963	LJ	A, E	Low	Jet	WT		X	X								
4	1964	LF	A, E	Low	Wing	WT	X	X		X			X				
5	1964	LF, LJ, VT	A, E	H, L, T	All	WT, FT	X	X	X			X	X	X	X	X	X
7	1964	LF	A, E	H	W	WT	X			X		X	X				
9	1966	LJ	A, E	H	Jet	WT		X	X			X	X				
10	1966	LF	A, E	H	W	WT	X			X			X	X			
13	1967	LJ	A, E	H, L, T	W, B, T	WT, FT		X	X			X		X	X		
14	1967	LF	A, E	H	W	WT	X			X			X				
18	1968	Report Not Available Yet															
22	1968	LF, VT	A, E	H, T, C,	W, B, T	WT, FT		X	X	X		X	X	X	X		
23	1968	VT, LJ	A, E	H, T, C	W, B, T	WT FT		X	X	X		X	X	X	X		
27	1962	LF	A, E	H	W	WT	X		X	X		X					
29	1962	LJ	A	H	Jet	None		X	X								
30	1962	LJ	E	H, T, C	W, B	WT		X				X		X			
31	1961	LJ, LF	A	H, T, C		None							X				
34	1961	VT	E	H, Low	W, B	WT		X	X			X		X			
35	1963	LF	E	H	W	WT	X						X				
36	1963	LF	E	H, Low	W, B, T	WT	X		X			X		X	X		
38	1965	LF, LJ	A, E	H, Low	W, B	WT	X	X	X			X	X	X			
41	1965	LF, LJ, VT,	A, E	H, T, C	W, B, T	WT	X	X	X			X	X	X			
45	1967	LF	A, E	H	Inlet	WT	X	X	X								
46	1967	LJ	A, E	H	Jet	BT		X	X								
48	1961	LJ	E	H	W, B	WT		X	X			X	X				
50	1966	VT	E	H, T	Jet	BT		X	X				X				
52	1967	LJ	E	H, T	W, B, T	WT		X	X			X	X				
56	1961	LF	A, E	H, T	W	WT	X	X		X		X					
57	1969	LF	A, E	H	W, B	WT	X										

TABLE VI. (Continued)

REFERENCE NUMBER	YEAR OF PUBLICATION	V/STOL CONCEPT	NATURE OF REPT. MATRL.	FLIGHT REGIME OR AIRFLOW	TEST ARTICLE (COMPONENT)	TYPES OF TEST	Areas of Investigation or Analysis: INLET EFFECTS	JETS (EXIT)	GROUND EFFECT	WING ALONE	BODY ALONE	INTERFERENCE EFFECTS	Stability & Control: GENERAL V/STOL	LONGITU-DINAL	LATERAL-DIRECTIONAL	DYNAMIC	ROTARY
58	1968	FW, TP	A, E	T, C	W, T	WT						X	X	X	X		
59	1969	LJ	E	H	W, B, T	WT	X	X	X			X					
60	1963	LF	A, E	H, T	W, B, T	WT	X	X				X	X	X			
63	1964	Report Not Available Yet															
64	1966	LF, LJ, VT	A, E	H, T	W, B	WT		X	X			X	X	X			
66	1967	Report Not Available Yet															
69	1961	LF	E	H, T	B	WT	X	X	X		X		X	X	X		
71	1963	LF	E	H, T	W, B, T	WT			X			X	X	X			
73	1960	LF, LJ, VT	E	H, T, C	W, B, T	WT			X			X	X	X	X		
75	1965	LF	E	H, T	B, W	WT	X	X	X		X	X	X	X			
76	1964	LJ	E	H, T	B, W	WT		X			X	X	X	X			
77	1965	LF	A, E	H, T	B	WT	X	X			X	X	X				
78	1966	LF, LJ, VT	A, E	H, T, C	W, B, T	WT, FT	X	X	X			X	X	X	X		
79	1966	LF	E	H, T, C	W, B, T	WT, FT		X	X			X	X	X	X	X	X
80	1966	LJ	E	H, T, C,	W, B, T	WT, FT		X				X	X	X	X		
81	1967	LF	E	H, T, C	W, B, T	WT						X	X	X	X		
82	1967	LF	E	H, T, C	W, B, T	WT						X	X	X	X		
83	1967	LF, LJ, VT	E	H	W, B, T	WT		X	X			X	X				
84	1967	LJ, VT	E	H, T	B	WT	X										
85	1968	LF	E	H, T, C	W, B, T	WT							X	X		X	
86	1967	LJ, VT	A, E	H, T, C	W, B, T	WT	X	X	X			X	X	X			
87	1968	LJ	E	T	W, B, T	WT	X	X	X			X	X	X	X		
88	1969	LJ	E	H, T, C	W, B, T	WT			X			X	X	X	X		
90	1968		E	H	B	WT					X		X	X			
91	1968	VT	A	H, T, C	W, B, T	None	X	X				X	X	X		X	
92	1968	LJ, VT	A, E	H, T, C	W, B, T	Simul							X	X	X	X	X
94	1968	LF	A	T	W	None	X	X		X			X				
95	1967	LJ	A	H	J	None	X	X		X			X				
101	1967	LF	A	H, T		None	X	X		X		X	X	X			

TABLE VI. (Continued)

REFERENCE NUMBER	YEAR OF PUBLICATION	V/STOL CONCEPT	NATURE OF REPT. MATRL.	FLIGHT REGIME OR AIRFLOW	TEST ARTICLE (COMPONENT)	TYPES OF TEST	Areas of Investigation or Analysis: INLET EFFECTS	JETS (EXIT)	GROUND EFFECT	WING ALONE	BODY ALONE	INTERFERENCE EFFECTS	GENERAL V/STOL	Stability & Control: LONGITUDINAL	LATERAL-DIRECTIONAL	DYNAMIC	ROTARY
106	1964	LF	A, E	T, C	W, B, T	WT			X			X	X	X	X	X	X
107	1965	TW	A	H, T	W, B, T	None						X	X	X	X	X	X
108	1964	LF, LJ, VT	A			None							X				
109	1964	TD	A, E	H, T, C	DP	WT						X	X	X	X		
111	1963	TW	A		W	None							X				
117	1968	VT	E	H, T, C	W, B, T	FT			X			X	X	X	X	X	X
120	1968	LJ	A, E	H, T	W, B	WT		X	X			X	X	X			
122	1967	LJ	A	H, T	W, B	None							X				
123	1966	LF, LJ, VT	A, E	H, T, C	W, B, T	WT	X	X	X			X	X	X	X		
126	1968	VT	A, E	T	W, B, T	Simul							X	X	X	X	X
127	1967	LF	A, E	H, T, C	W	WT	X	X		X		X	X	X	X		
128	1966	TW, TD	A	H, T	W, B, T	Simul							X	X	X	X	X
131	1966	TJ	E	H, T	D-FAN	WT	X	X					X				
132	1965	TJ	E	H, T	D-FAN	WT	X	X					X				
133	1964	VT	A	T		None							X				
134	1964	TJ	E	H, T	D-FAN	WT	X	X					X				
143	1967	VT	E	T	W, B, T	WT				X		X	X	X	X		
144	1968	TD	A, E	H, T	W, B, T	WT							X	X	X	X	X
145	1967	LJ	E	H	Jet	WT		X	X				X				
146	1967	LJ	E	H	Jet	HT		X	X				X				
147	1968	LF	A, E	H, T	W, B, T	WT, FT		X	X			X	X	X		X	
148	1968	LJ	A	H	Jet	WT		X	X			X	X				
149	1967	LF, LJ, VT	A, E	H, T, C	W, B, T	WT	X	X	X	X		X	X	X			
150	1965	LJ	E	H, T, C	W, B, T	WT, FT	X	X				X	X	X	X		
151	1964	LF	E	Low	W, B, T	WT		X				X	X	X			
152	1965	LF	E	H, T, C	Inlet	WT	X					X	X				
153	1963	LF	E	H, T, C	W, B, T	WT	X		X			X	X	X	X		
154	1964	LF	A, E	H, T, C	W, B, T	WT			X			X	X	X	X		
155	1966	LF	E	H, T, C	W, B, T	FT			X			X	X	X	X	X	X

TABLE VI. (Continued)

Reference Number	Year of Publication	V/STOL Concept	Nature of Rept. Matrl.	Flight Regime or Airflow	Test Article (Component)	Types of Test	Inlet Effects	Jets (Exit)	Ground Effect	Wing Alone	Body Alone	Interference Effects	General V/STOL	Longitudinal	Lateral-Directional	Dynamic	Rotary
							Areas of Investigation or Analysis							Stability & Control			
156	1965	LF	A, E	H, T, C	W, B, T	Simul			X			X	X	X	X	X	X
159	1965	LF	A, E	T	W, B, T	Simul						X	X	X	X	X	X
160	1963	LJ	E	H	WB	BT	X	X	X			X	X				
162	1964	LF	E	H, T	W, B, T	WT-FT	X		X			X	X	X	X	X	
163	1964	LJ	E	H	W, B	BT	X	X	X		X	X	X				
164	1964	LF, LJ	E			WT	X	X	X			X	X				
165	1963	LJ	E	H, T	W	WT		X	X	X		X	X	X			
166	1962	LF	A, E	H, T	W, B, T	WT	X	X	X			X	X	X			
168	1961	LF	A, E	H, T	W	WT	X	X	X	X		X	X	X			
169	1961	LF	E	H, T, C	W, B, T	WT	X	X				X	X	X			
177	1967	LF	E	H, T, C	W, B, T	FT			X				X	X	X	X	X
178	1964	LF	E	C	W, B, T	WT						X	X	X	X		
179	1964	LF	E	Low	W, B, T	WT						X	X	X	X		
180	1966	LF	E	H, T, C	W, B, T	FT			X				X	X	X		
181	1966	LJ	E	H, T, C	W, B, T	FT, WT			X			X	X	X	X		
182	1965	LF	E	H, T, C	W, B, T	FT			X				X	X	X		
184	1964	LJ	E	H	W	WT		X	X	X		X	X				
186	1963	LF	E	H, T, C	W, B, T	WT	X	X	X			X	X	X			
189	1961	LF	E	H, T	W, B, T	WT		X				X	X	X			
193	1961	LF, VT	E	T	W, B	WT		X				X	X	X			
200	1966	LF	E	H, T, C	W, B, T	WT						X	X	X	X		
203	1968	LJ, VT	A, E	H	W, B	WT		X	X	X		X	X	X			
204	1969	Any	A	H	W	None				X			X				
206	1969	LJ	A	H	Jet	None		X				X	X				
207	1966	LF	E	H, T, C	W, B, T	FT			X				X	X	X	X	X
208	1966	LJ	E	H, T	W, B, T	WT		X	X			X	X	X	X		

TABLE VI. (Continued)

REFERENCE NUMBER	YEAR OF PUBLICATION	V/STOL CONCEPT	NATURE OF REPT. MATRL.	FLIGHT REGIME OR AIRFLOW	TEST ARTICLE (COMPONENT)	TYPES OF TEST	Areas of Investigation or Analysis: INLET EFFECTS	JETS (EXIT)	GROUND EFFECT	WING ALONE	BODY ALONE	INTERFERENCE EFFECTS	GENERAL V/STOL	Stability & Control: LONGITUDINAL	LATERAL-DIRECTIONAL	DYNAMIC	ROTARY
209	1967	LJ	E	H, T, C	W, B, T	WT		X	X			X	X	X	X		
210	1960	LJ	E	H	W, B	BT		X	X			X	X				
211	1963	LJ	E	T	FP	WT		X	X			X	X				
213	1964	VT	A, E	H, T	W, B, T	FT		X	X			X	X	X	X	X	X
214	1964	LJ	E	H, T	W, B	WT		X	X			X	X	X			
216	1966	LJ	E	H	W, B	WT		X	X			X	X	X			
217	1966	LJ	E	T	W, B	WT		X	X			X	X	X			
219	1967	LJ	E	H, T	W, B, T	WT	X	X	X			X	X	X			
220	1962	LJ	E	H	W	BT		X	X	X		X	X	X			
221	1958	LJ	E	H	W, B, T	BT		X	X	X		X	X				
223	1966	LJ	E	H	FP	BT		X	X			X	X				
224	1966	ALL	A, E	H, T	B, FP	HT					X	X	X				
225	1964	ALL	A, E	T, C	B	WT					X		X				
226	1964	LJ	A, E	H, T	W	WT		X	X	X		X	X				
227	1966	LJ	A, E	H, T	W	WT		X	X	X		X	X				
228	1967	LJ	A, E,	H, T	W	WT		X	X	X		X	X				
229	1968	LJ	A, E	H, T	W, B	WT		X	X	X		X	X				
230	1969	LF, LJ	A, E	T	W, B, T	WT	X					X	X	X			
231	1969	LJ	A, E	H	Jet	WT		X				X	X	X			
232	1967	LJ	A, E	H	FP	BT		X	X			X	X	X			
233	1967	Any	A, E	H	W	WT				X		X	X	X			
234	1965	Any	A, E	H	B	WT					X	X	X	X			
235	1965	LJ, VT	E	T	W, B, T	WT		X				X	X	X	X		
236	1947	Any	A, E	T, C	W	WT				X			X	X			
237	1952	Any	A, E	T, C	W	WT				X			X	X			
238	1948	Any	A	T, C	W	None				X			X	X			
239	1947	Any	A	T, C	W	None				X			X	X			

TABLE VI. (Concluded)

REFERENCE NUMBER	YEAR OF PUBLICATION	V/STOL CONCEPT	NATURE OF REPT. MATRL.	FLIGHT REGIME OR AIRFLOW	TEST ARTICLE (COMPONENT)	TYPES OF TEST	Areas of Investigation or Analysis: INLET EFFECTS	JETS (EXIT)	GROUND EFFECT	WING ALONE	BODY ALONE	INTERFERENCE EFFECTS	GENERAL V/STOL	Stability & Control: LONGITUDINAL	LATERAL - DIRECTIONAL	DYNAMIC	ROTARY
240	1958	Any	A, E	T, C	W	WT				X			X	X			
241	1955	Any	A, E	H, T, C	W	WT				X			X	X			
242	1959	Any	A, E	H, T	B	WT					X	X	X	X			
243	1957	Any	A, E	H, T, C	W, B, T	WT						X					
244	1935	Any	A			None							X				
245	1963	LJ	A, E	H	FP	WT		X	X			X	X	X			
250	1965	LF	A	H	W	None	X	X	X	X		X	X	X			
251	1967	LJ	A, E	H	W	WT		X	X	X		X	X	X			
252	[illegible]	LJ	A, E	H	W	WT		X	X	X		X	X	X			
253	1959	LF	A, E	H	W	WT			X	X		X	X	X			
254	1957	LF	A, E	H	W	WT						X	X	X			
255	1961	LJ	A, E	H	W	WT		X	X	X		X	X	X			
256	1969	LJ	A, E	H	W, B	WT		X	X	X		X	X	X			
257	1968	LJ	E	H, T, C	W, B, T	WT		X	X			X	X	X	X		
258	1968	Any	A, E	Any	Any	WT			X	X	X	X	X	X	X		
259	1969	Any	A, E	Any	B	WT			X	X	X	X	X	X	X		
263	1968	Any	A, E	H, T	All	WT, FT			X			X	X				
264	1969	LJ	E	H, T	B	WT	X		X		X	X	X				
265	1969	Any	A	H, T	FP	WT		X					X				
266	1968	LJ	E	H	W, B, T	WT	X		X				X				
267	1959	LF	E	H	W	WT				X			X	X			
268	1960	LF	A	H, T, C	Any	None	X	X				X	X	X			
269	1967	VT	E	H, T	W, B, T	WT		X	X			X	X	X	X		
270	1969	LJ	E	H, T	W	WT		X		X		X	X	X			
271	1968	LJ, VT	A, E	H, T	FP	WT		X					X				
272	1969	LJ, VT	A, E	H, T	FP	WT		X					X				
274	1969	LJ, VT	A, E	H, T	FP	WT		X					X				
275	1968	LJ, VT	A, E	H, T	FP	WT		X					X				

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