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LIFT/CRUISE FAN V/STOL TECHNOLOGY AIRCRAFT DESIGN DEFINITION STUDY

VOLUME III

DEVELOPMENT PROGRAM AND BUDGETARY ESTIMATES

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INTRODUCTION

Turbotip and mechanical research flight vehicles to demonstrate the lift/cruise fan concept for the NASA and Navy are defined in Report MDC A4551, Volume I. This report is for official Government use only and presents the aircraft development program, budgetary estimates in CY 1976 dollars, and cost reduction program variants. Detailed cost matrices are also provided for the mechanical transmission system, turbotip transmission system, and the thrust vector hoods and yaw doors.

MDC A4551
VOLUME III

TABLE OF CONTENTS

LIST OF PAGES

Title
ii through iv
1 through 12
A-1 through A-13

LIST OF FIGURES

1. RESEARCH TECHNOLOGY AIRCRAFT DEVELOPMENT TEST PROGRAM

1.1 GENERAL DESCRIPTION

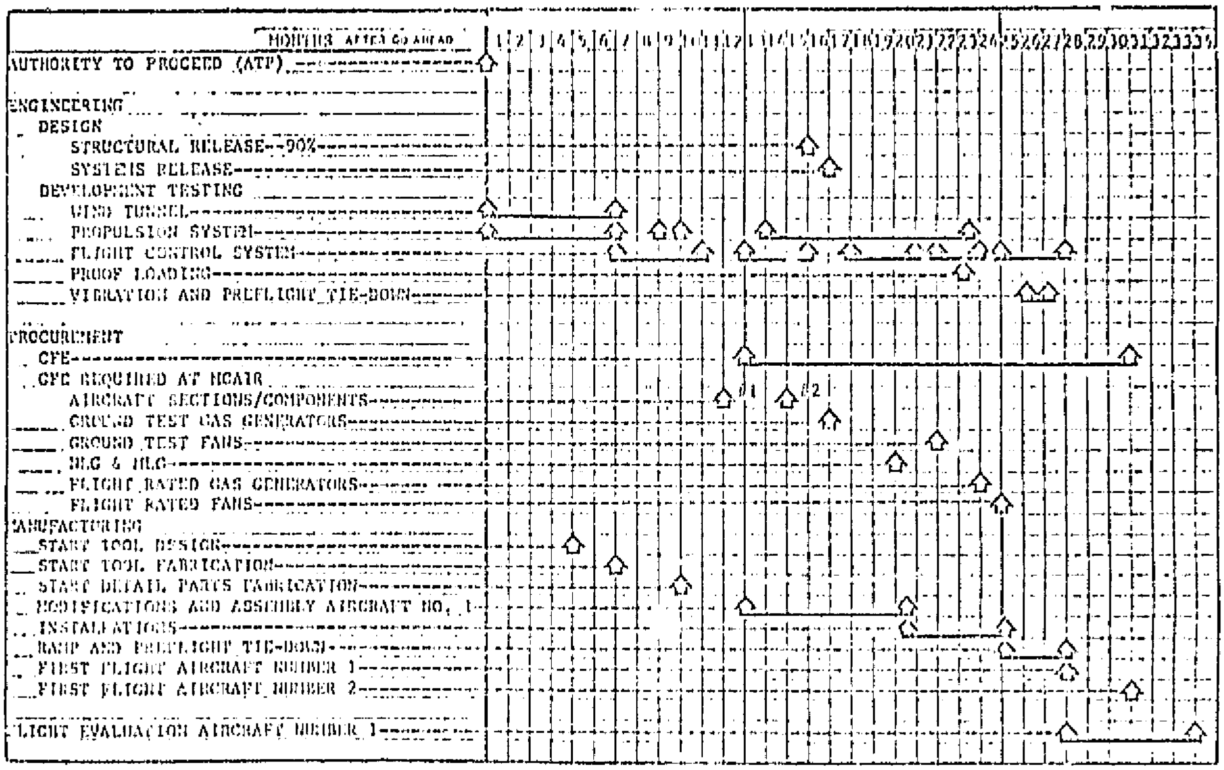
The ground and flight test development programs described briefly in the following paragraphs are those required to develop and evaluate the selected Research Technology Aircraft in the powered lift mode through conversion. Full advantage will be taken of the extensive development work MCAIR has accomplished in the past several years, both independently and under contract to NASA, to reduce the cost of the test program. This work, which is a continuing effort, includes wind tunnel tests of similar designs and development tests of ETaC systems, hot gas ducting, thrust vectoring devices, and V/STOL aircraft control systems.

In order to establish the development program requirements, the following assumptions have been made:

- The engines and fans will have been fully developed before start of the program.
- The MCAIR test program will be limited to a cursory exploration of only the powered lift mode through conversion (200 knots maximum).
- No performance guarantees are to be made.
- Instrumentation will be NASA furnished, and consist of 100 channel PCM tape system including signal conditioners. Eighty measurands will be the maximum to be used. No propulsion system inlet or exit instrumentation will be included.
- A three-degree-of-freedom VTOL test stand will be available GFE at the remote test site.
- One instrumented aircraft will be utilized in the test program. The second aircraft constructed will be used for program backup only and will not be instrumented.
- All wind tunnel model fabrication and testing will be accomplished by NASA with MCAIR design and technical support.

It is anticipated that the ground test program for either the gas or mechanical interconnected aircraft configuration will be of the same scope with only the details of propulsion system testing differing. There are no major differences in the flight test program required for evaluation of either design. The proposed development program schedule, Figure 1, represents a compressed schedule of 27 months to first flight to assure a low cost program.

FIGURE 1
TECHNOLOGY AIRCRAFT DEVELOPMENT SCHEDULE



Differences between the test programs for the gas and mechanical designs are identified in the following discussion.

1.2 WIND TUNNEL TESTS

Maximum utilization will be made of data from the Large Scale Lift/Cruise Fan Powered Model tests in the NASA Ames 40- by 80-Foot Wind Tunnel as well as previous MCAIR tests of designs similar to the Research Technology Aircraft. In addition, a minimum amount of new low and high speed tests will be required. The low speed tests will be conducted in NASA low speed wind tunnels using a 10% scale powered model and an updated version of the Large Scale Powered Model. The high speed tests will be conducted in a NASA wind tunnel at high subsonic speeds using a 4% to 5% scale model. The general objectives of the wind tunnel programs will be to obtain data on low and high speed aerodynamic forces and moments, control powers, propulsion-aerodynamic interaction effects, ground effects, flow field effects on forces, moments, and propulsion system recirculation. During the flow field tests the effects of (a) power setting, (b) aircraft height, attitude, and control application, and (c) forward, aft, and crosswinds will be investigated.

1.3 TURBOTIP PROPULSION SYSTEM GROUND TESTS

As in the case of aerodynamic wind tunnel tests, maximum use will be made of data obtained from various tests which have been accomplished both under contract and independently. In addition, a limited amount of supplementary subscale and full scale tests will be required. The planned subsystem and system integration tests are described briefly in the following paragraphs.

1.3.1 DUCTING - Subscale cold tests of the duct system will be conducted for evaluation of the system's internal aerodynamics. These tests will be followed by subscale hot tests of critical portions of the system to prove its thermostructural design. A schedule for design, fabrication, and development testing of this subsystem is presented in Figure 2.

1.3.2 VALVES - Subscale cold tests of the Energy Transfer and Control (ETaC), shutoff, and isolation valves will be conducted in conjunction with the ducting tests. Full scale hot tests of these valves will be done in conjunction with the complete system integration tests.

1.3.3 THRUST VECTORING DEVICES - Subscale model tests of the lift/cruise vectoring nozzle will be conducted on a MCAIR nozzle thrust stand to supplement 36-inch fan tests done under contract to NASA Ames. Nose lift fan thrust vectoring louver systems will also be tested subscale in the MCAIR facility. A schedule for the design, fabrication, and testing of these devices is presented in Figure 3.

1.3.4 INLETS - Subscale partial models of fan and gas generator inlets will be tested statically and at forward speed conditions to evaluate their performance. Internal flow will be provided by suction, scaled model fans, or engine simulators.

1.3.5 SYSTEM INTEGRATION TESTS - Fans will be the pacing item in availability of the gas interconnected propulsion system. Therefore, the integration tests will start with J97 gas generators, ETaC valves, ducts, and fixed nozzles to simulate the fans installed in a propulsion system test rig. A second series of development tests will be run on the test rig with a complete aircraft propulsion system including the fans, thrust vectoring devices, and the flight control interface. Operation and performance of each component as it functions in the overall system will be evaluated. The final propulsion system integration tests will be accomplished on the complete first airplane during the ramp tests prior to first flight.

FIGURE 2
ETaC DISTRIBUTION SYSTEM DEVELOPMENT SCHEDULE

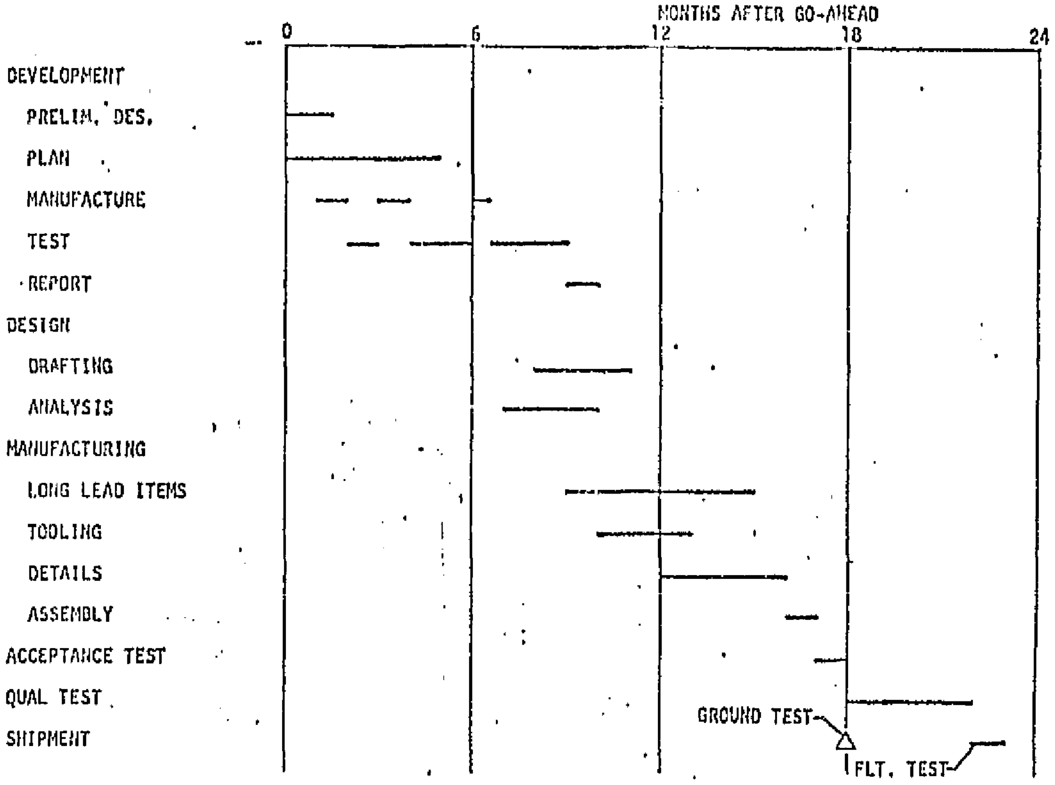
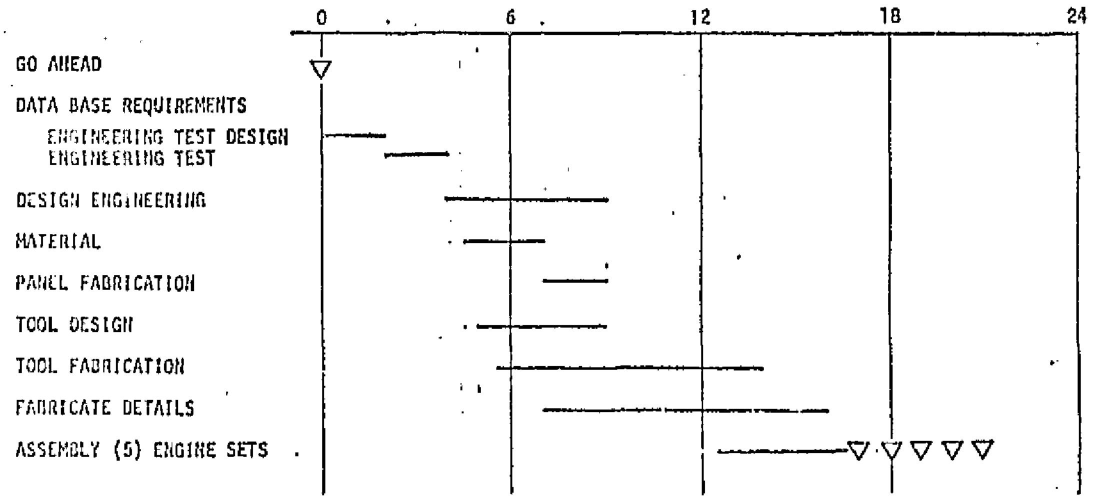


FIGURE 3
THRUST VECTORING HOOD DEVELOPMENT SCHEDULE



1.4 MECHANICAL PROPULSION SYSTEM GROUND TESTS

The planned subsystem and system integration tests for the mechanical propulsion system are described in the following paragraphs.

1.4.1 TRANSMISSION SYSTEM - Development of the shafting, clutches, gearboxes and their lube system will be accomplished by the selected vendor. Component development tests of each item will be conducted separately followed by system evaluation using back-to-back test setups. These system tests will be concluded by endurance and Preliminary Flight Rating Tests prior to delivery to MCAIR. A schedule for a typical system development which has been coordinated with a prospective vendor is presented in Figure 4.

1.4.2 INLETS AND THRUST VECTORING DEVICES - The development of these components for the mechanically interconnected system will be done in essentially the same manner as for the gas coupled system. Design details would, of course, differ but the procedures and schedules for fabrication and testing would be the same as shown in Figure 3.

1.4.3 SYSTEM INTEGRATION TESTS - All propulsion system components for this configuration will become available at the same time. Therefore, the initial integration tests will be run with a complete system. This setup will include fans and engines, shafts, clutches, gearboxes, thrust vectoring devices, and the flight control interface. The final integration test will be conducted on the first airplane during the final ramp tie-down tests prior to first flight.

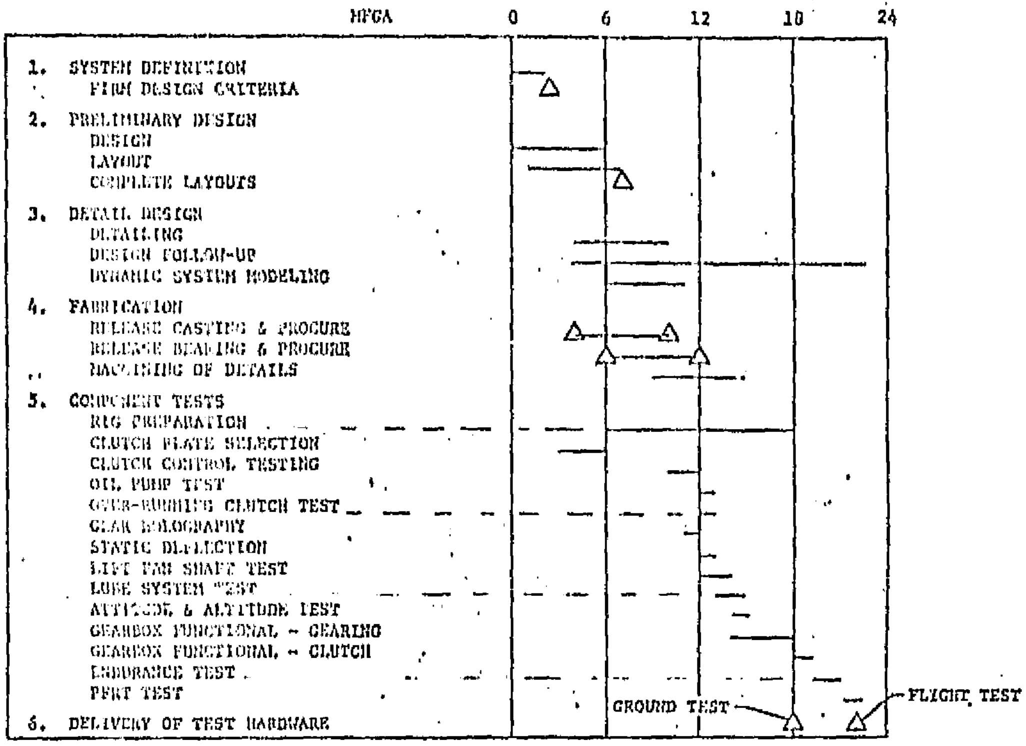
1.5 FLIGHT CONTROL SYSTEM GROUND TESTS

Ground tests of the flight control system will consist of partial and total system development tests and total system integration tests.

1.5.1 PARTIAL SYSTEM INTEGRATION TESTS - Partial system integration tests will be accomplished early in the program to check the stability and response characteristics of some of the basic control loops. These control loops will be made up of individual components using fixed and moving base simulators with various degrees of actual hardware tie-in.

1.5.2 TOTAL SYSTEM INTEGRATION TESTS - These tests will be conducted on the first completed aircraft and in conjunction with proof testing. Overall system stability and performance under load will be evaluated. Closed loop system integration tests will be accomplished in conjunction with preflight ramp tie-down tests with the propulsion system functioning. These tests are used in place of the usual "iron bird" tests with simulated propulsion system inputs. During these tests, aircraft motion will be computed and pilot displays driven

FIGURE 4
MECHANICAL FAN PROPULSION SYSTEM DEVELOPMENT SCHEDULE



by a general purpose digital computer in a manner similar to a fixed-base flight simulation program.

1.5.3 COMPONENT QUALIFICATION TESTS - Qualification test reports for selected off-the-shelf components will be accepted. Minimum qualification tests, commensurate with RTA requirements, will be conducted on new designed components by the vendor.

1.5.4 ACCEPTANCE TESTS - GFE components that are not received immediately after vendor acceptance tests will require minimum functional tests to assure the integrity of the unit.

1.5.5 FUNCTIONAL TESTS - Although the RTA will incorporate a high percentage of developed components and subsystems, a limited number of tests are required to assure proper functioning of these items as installed. The tests, which will be performed as part of the preflight ground test program, will cover the fuel system, hydraulic system, electrical system, avionics, landing gear, and environmental control system.

1.5.6 PHYSICAL TESTS - These will consist principally of tests of critical elements, and proof loading on the first flight article of aerodynamic control surfaces, engine and fan mounts, and thrust vectoring devices.

1.5.7 VIBRATION TESTS - Vibration tests will be performed as part of the ground test program. Critical modes will be investigated using conventional ground vibration test techniques. A simple "soft tire" suspension arrangement will be used to minimize test setup costs.

1.5.8 PREFLIGHT TIE-DOWN TEST PROGRAM - During the normal ramp checkout of the first airplane after completion of assembly, a thorough test of the propulsion and control system will be performed with the airplane tied down. Satisfactory operation of the gas generators, interconnect system, lift fans, thrust vectoring devices, and the ACS will be verified. The closed loop system integration tests mentioned in several prior paragraphs are the final portion of these tests.

1.6 FLIGHT TEST PROGRAM

The MCAIR flight test program will be limited to a cursory examination of the powered lift mode through conversion, and will be conducted with one instrumented aircraft in approximately 45 flight hours over a period of 6 months. A schedule for this program is given in Figure 5. Customer participation is planned on a continuing basis throughout the program.

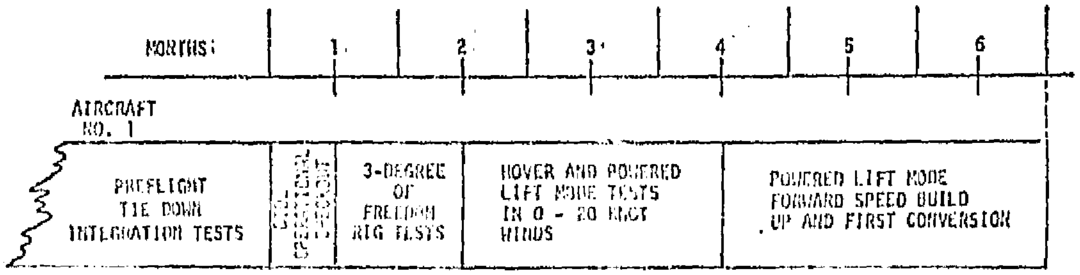
After completion of the preflight tie-down tests, the first airplane will be transported to the remote test facility. Then, following completion of the normal ramp preflight checkout, the aircraft will be flown first in the CTOL mode to a maximum of 200 knots IAS and 25,000 ft altitude. In addition to assuring that the aircraft is operationally safe, these flights will provide some flight operating experience with the fan propulsion system before start of the powered lift mode testing.

Following these CTOL flights the airplane will be installed on a simple three-degree-of-freedom VTOL test stand for an initial look at the hovering mode handling characteristics. Upon satisfactory completion of these tests, the remainder of the program will be conducted starting with the free-flight investigation of the powered lift mode in calm wind hover. Translating flight will then be evaluated, building up to the speeds required for conversion. The program will then be concluded with the first full conversion from the powered lift mode to the conventional flight mode and return.

The following areas will be evaluated during the flight test program:

- Aircraft Performance will be investigated during vertical takeoff, hover, transition to and from conventional flight, and landing.

FIGURE 5
TECHNOLOGY AIRCRAFT
FLIGHT TEST PROGRAM



Specific attention will be given to evaluating the expected high induced lift characteristics for vertical and very short takeoff distances.

- o Stability and Control as provided by the ACS will be evaluated at selected airspeeds, altitudes, gross weights, and cg's in both the powered lift and conventional modes to determine: handling qualities at several fuselage pitch attitude angles and angles of attack; and longitudinal, lateral, and directional stability. The ACS integration with the propulsion control system will be investigated. Adequacy of the autopilot functions of the ACS will be checked.
- o Propulsion System Performance will be evaluated with regard to adequacy of gas generator, fan, and duct/valve or shaft/gearbox/clutch installation; gas generator and fan operation including one-gas-generator-out conditions; and fuel system operation.

This 45 hour flight test program is consistent with a low cost approach; however, it is recommended that the 210 hour flight test program discussed in report MDC A3440 be used so that the RTA can proceed smoothly into the research program.

2. RESEARCH TECHNOLOGY AIRCRAFT BUDGETARY ESTIMATES

Based on the aircraft description and data base summary presented in Volume I of this report and the development program described in Section 1, budgetary estimates were prepared in CY 1976 dollars for a two aircraft program for both the turbotip RTA and the mechanical RTA, Figures 6 and 7. The estimates were based on an experimental shop operation which included the following features:

- Specification compliance not a requirement
- Performance goals <u>only</u>; not specified guarantees
- Weight not a prime factor
- Minimum documentation
- Layout type drawings only
- Vendor test results accepted
- Rigidly controlled in-house test program
- Only select personnel assigned
- Project co-located with final assembly area
- Manufacturing establish true experimental shop
- Program manager reports to MCAIR president and has absolute program authority.

In addition, detailed cost matrices were prepared for the mechanical transmission system, the turbotip transmission system and the thrust vector hoods and yaw doors. These budgetary estimates are presented in Figures 8, 9 and 10 respectively.

FIGURE 6
TURBOTIP RTA BUDGETARY ESTIMATE

2 AIRCRAFT PROGRAM MILLIONS OF CY 1976 DOLLARS

	DESIGN & MODIFICATION			GROUND TEST			FLIGHT TEST	TOTAL
	A/F	PROP	CONT	OTHER	PROP	CONT		
ENGINEERING	13.2	5.21	4.30	2.88	2.19	2.55	2.38	32.71
MANUFACTURING	10.43	8.55	1.63	.10	.13	.15	.90	21.89
PROCUREMENT	.55	.52	7.76	.06	.05	.71	.46	10.11
OTHER	.91	.49	.23	.14	.11	.12	.29	2.29
TOTAL	25.09	14.77	13.92	3.18	2.48	3.53	4.03	67.00

FIGURE 7
MECHANICAL RTA BUDGETARY ESTIMATE

2 AIRCRAFT PROGRAM MILLIONS ~~THOUSANDS~~ OF CY 1976 DOLLARS

	DESIGN & MODIFICATION			GROUND TEST			FLIGHT TEST	TOTAL
	A/F	PROP	CONT	OTHER	PROP	CONT		
ENGINEERING	14.05	3.92	4.21	2.08	1.94	2.55	2.33	31.93
MANUFACTURING	11.22	7.18	1.63	.10	.08	.15	.90	21.26
PROCUREMENT	.61	3.28	6.71	[illegible]	3.10	.71	.64	15.11
OTHER	.96	.38	.22	.14	.09	.12	.29	2.20
TOTAL	26.84	14.76	12.77	3.13	5.21	3.53	4.21	70.50

FIGURE 8
MECHANICAL TRANSMISSION COST MATRIX

2 AIRCRAFT PROGRAM THOUSANDS OF CY 1976 DOLLARS

	DATA BASE	DESIGN & MFG	COMP. TEST	UNIT QUAL. TEST	SUPPT. MCAIR FLIGHT TEST	TOTAL
COMBINER BOX						
ENGR LABOR	20	335	1014	229	330	1978
MFG LABOR	0	1472	848	0	0	2320
MAT'L & PURCH. ITEMS	0	482	270	0	0	752
OTHER	0	10	0	0	0	10
TOTAL	20	2349	2132	229	330	5060
SHAFTING						
ENGR LABOR	1	26	26	7	0	60
MFG LABOR	0	374	44	0	0	418
MAT'L & PURCH. ITEMS	0	54	5	0	0	59
OTHER	0	1	0	0	0	1
TOTAL	1	455	75	7	0	538
GRAND TOTAL	21	2804	2207	236	330	5598

FIGURE 9
TURBOTIP TRANSMISSION COST MATRIX

2 AIRCRAFT PROGRAM THOUSANDS OF CY 1976 DOLLARS

	DATA BASE	DESIGN & MFG	COMP. TEST	UNIT QUAL. TEST	TOTAL
ENGR LABOR	50	500	100	150	800
MFG LABOR	0	500	10	200	710
MAT'L & PURCH. ITEMS	5	50	5	20	80
OTHER	-	-	-	-	-
TOTAL	55	1050	115	370	1590

FIGURE 10
THRUST VECTOR HOODS & YAW DOOR COST MATRIX

2 A/C PROGRAM THOUSANDS OF CY 1976 DOLLARS

	DATA BASE	DESIGN & MFG	COMP. TEST	UNIT QUAL. TEST	TOTAL
ENGR LABOR	294	289	40	113	736
MFG LABOR	0	2889	57	0	2946
MAT'L & PURCH. ITEMS	0	82	2	0	84
OTHER	3	90	2	3	98
TOTAL	297	3350	101	116	3864

3. PROGRAM COST VARIANTS

The turbotip RTA and the mechanical RTA defined in Volume I of this report reflect a minimum cost approach utilizing a large number of GFE components as well as an austere development program. A significant program cost reduction would seriously jeopardize the research value of the program or unacceptably increase the risk.

Program cost reductions were identified for two approaches: (1) a one aircraft program and (2) use of a dual CAS flight control system. Use of a one aircraft program could seriously impact the program if an accident occurred. The dual CAS flight control system, described in Appendix A, represents a reduction in aircraft safety whereby a single failure could result in loss of the aircraft. Furthermore, the dual CAS system does not represent any advancement in flight control technology or total system integration.

Budgetary estimates were prepared for each of these variants and are presented below.

RTA PROGRAM VARIANT COST EFFECTS

CY 1976 Dollars

	Turbotip RTA	Mechanical RTA
One Aircraft Program	-$5.58M	-$5.93M
Dual CAS System		
2 A/C Program	-$3.89M	-$3.73M
1 A/C Program	-$3.45M	-$3.30M
Cost of 1 A/C Program with Dual CAS	$57.97M	$61.27M

APPENDIX A

ALTERNATE FLIGHT CONTROL SYSTEM FOR RTA COST REDUCTION STUDY

1. INTRODUCTION

The RTA flight control system has been identified as a candidate area for potential cost reduction of the RTA program. A study was therefore initiated beginning with a review of the RTA design goals from which the major design ground rules of Figure A-1 were established. Considering the first two ground rules, it becomes apparent that reduced system flexibility by nature implies less flight research capability and therefore an appropriate compromise is needed. However, the allowance of degraded performance following a single failure has an identifiable cost reduction provided that the level of degradation remains acceptable. This approach resulted in the definition of an alternate RTA flight control system as described in this section.

FIGURE A-1
RTA ALTERNATE FCS
DESIGN GROUNDRULES

- V/STOL FLIGHT RESEARCH CAPABILITY
- REDUCED FLEXIBILITY PERMITTED
- NASA DESIGN GUIDELINES
  (+ AGARD R577 AND MIL-F-83300)
- DEGRADED PERFORMANCE FOLLOWING SINGLE FAILURE
- SAFE LANDING FOLLOWING SINGLE FAILURE
  (VERTICAL, SHORT, OR CONVENTIONAL)

2. CONTROL CONCEPTS AND REQUIREMENTS

Control of the reduced cost program RTA is the same in most respects as the Research Technology Aircraft described in Volume I of this report. Therefore, the major emphasis of this description is on those aspects in which control of this RTA differs. The control capabilities have been determined and are compared to the minimum recommended control performance of the NASA study guidelines.

2.1 BASIC CONTROL CONCEPTS

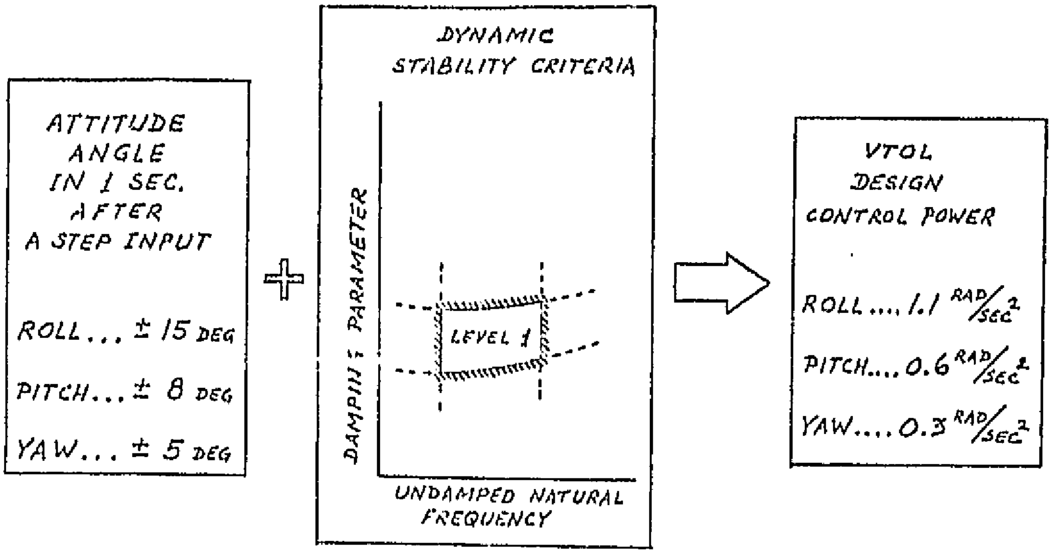
Control of this RTA aircraft is identical in basic concept to that described in detail in Section 5.1 of Volume I. Stabilator, aileron, and rudder control surfaces provide aircraft pitch, roll, and yaw control within the conventional aerodynamic flight envelope and airspeed dependent partial control within the powered lift flight envelope.

The powered lift controls for VTOL and STOL operation generate attitude control moments by thrust modulation and vectoring and height control by modulation of gas generator power.

2.2 CONTROL REQUIREMENTS

The control design requirements were established to insure good maneuvering capability and, also, to provide sufficient forces and moments to stabilize the aircraft and to control disturbance and cross-coupling effects. The VTOL control power design guidelines which are a composite of the maneuver control power requirements and the aircraft stability requirements are indicated in Figure A-2. The two are interrelated in that the characteristics of the stability augmentation system, which satisfy the aircraft stability requirements, affect the installed control power requirements.

FIGURE A-2
VTOL DESIGN CONTROL POWER



3. ANALYSIS OF TURBOTIP RTA USING ALTERNATE FCS

Thrust modulation using the alternate FCS differs from that described for the baseline triplex, hybrid AFCS in Volume I. In order to be compatible with the reduced cost program single failure performance goal, a modulation technique which takes advantage of high T/W capability to minimize control time lags in the event of a control system failure is employed. As shown in Figure A-3, pilot ratings for pitch and roll control in hover are generally satisfactory for time lags below 0.2 second. This is consistent with the NASA control design guidelines for desired control response.

3.1 THRUST MODULATION CONTROL

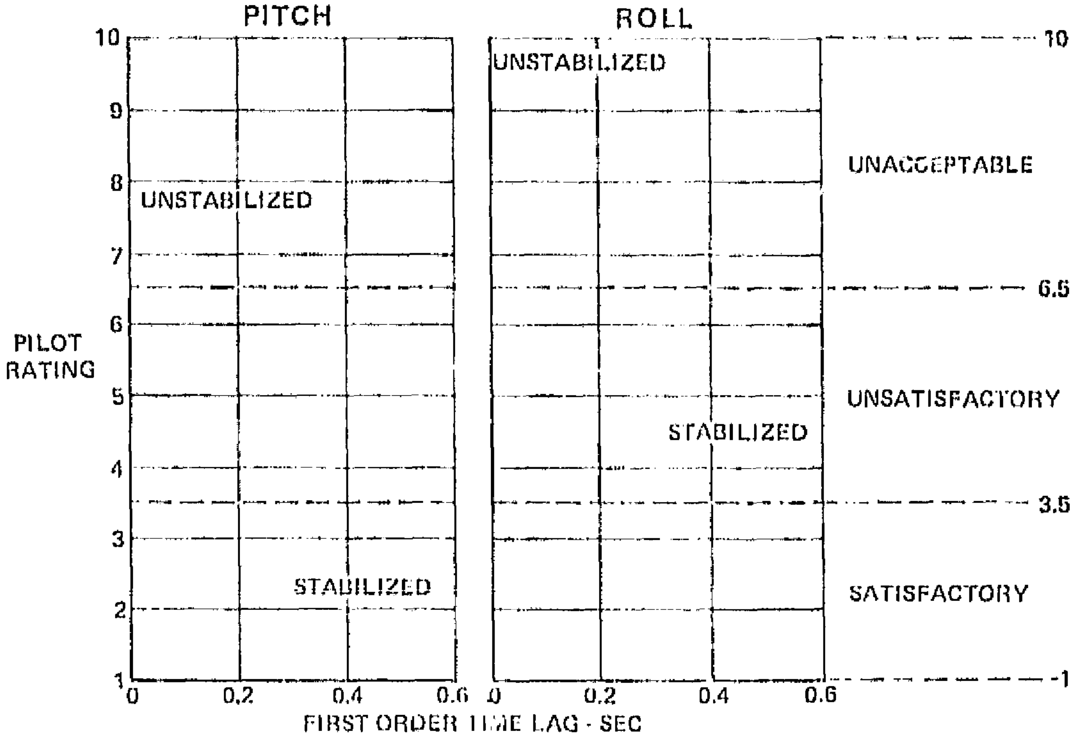
Because of the high T/W ratio of the RTA, it is possible to preset the Thrust Reduction Modulation (TRM) system at a 10% level so that the actual power output corresponds to a T/W = 1.1, whereas the effective thrust corresponds to a T/W = 1.0. By means of this TRM preset, attitude control may be accomplished by reducing thrust at a fan by means of TRM and initially increasing thrust at another fan by reducing the TRM preset. This technique assures fast control response following the loss of stability augmentation which would require the pilot to stabilize and control the aircraft using open loop control. For control inputs above the 10% thrust modulation level, the effective time constant is slightly increased. An example of attitude response with TRM preset is shown in Figure A-4. As can be seen in the figure, the use of TRM at the lift fan serves to produce the initial thrust increase and is washed out exponentially as the fan thrust, resulting from rpm change, approaches the commanded level.

3.2 CONTROL DURING NORMAL OPERATION

The turbotip RTA was analyzed to determine thrust modulation requirements. Attitude control power requirements in hover were determined to be more demanding of thrust modulation than control in transition or STOL and are identical with those of the baseline turbotip RTA.

Available thrust modulation levels are defined by the 3 second 1600°F EGT temperature limit and other practical considerations. The VTOL control requirements are shown superimposed on a graph of available control power in Figure A-5. The power setting for an effective T/W = 1.0 with the 10% TRM preset is increased corresponding to a T/W = 1.1 in actual power output. The control power required to meet Level 1 guideline control criteria is below the practical design goal of 25% modulation and well below the temperature boundary. The combined attitude

FIGURE A-3
EFFECT OF TIME LAG ON CONTROL IN HOVER



Ref: AGARD Report No. 577 Part II

FIGURE A-4
CONTROL RESPONSE EXAMPLE-TRM PRESET

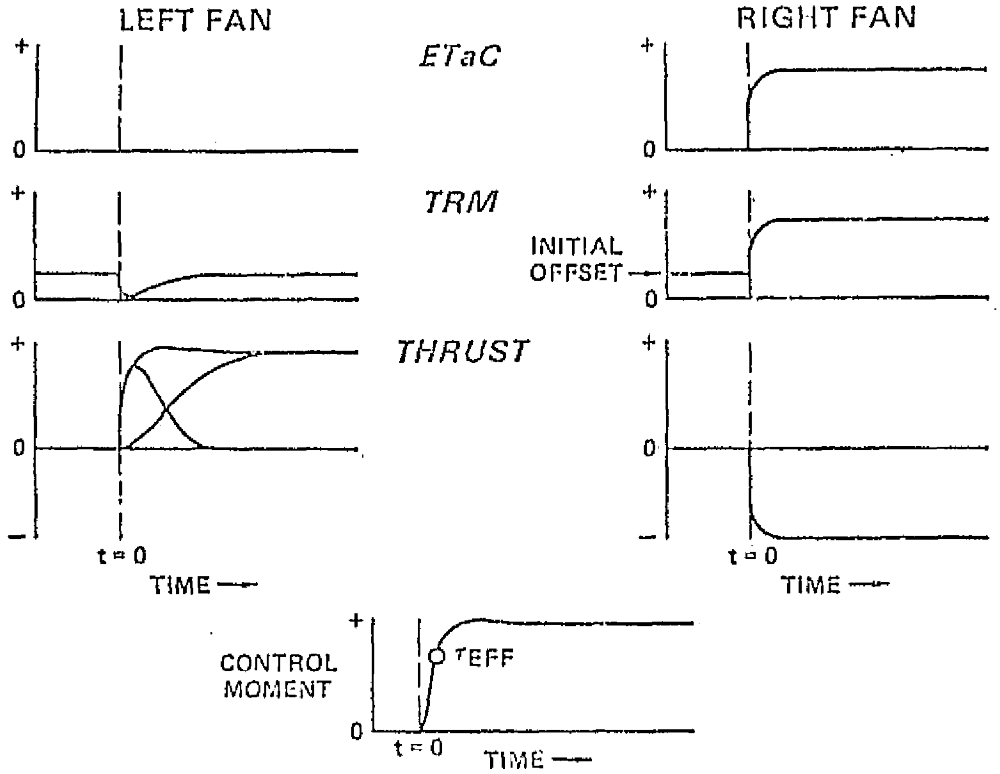
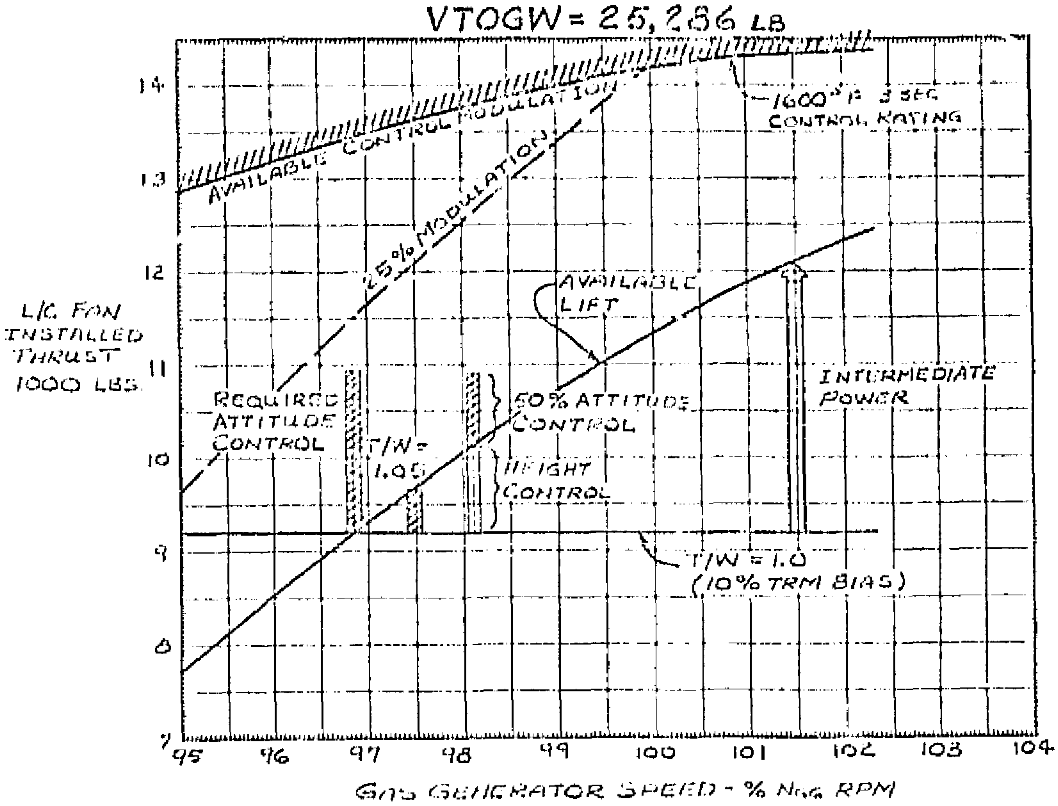


FIGURE A-5
TURBOTIP RTA
LEVEL 1 CONTROL REQUIREMENTS
WITH 10% TRM BIAS



requirement, height control with 50% attitude control, and the T/W = 1.05 effective sustained thrust capability are all below the intermediate power rating.

Compliance with Level 1 guideline control criteria based upon 25% thrust modulation for pitch and roll attitude control; and, 4° and 8° thrust deflection angles for yaw control at the lift fan and lift/cruise fans, respectively, are identical to the baseline RTA.

3.3 CONTROL POWER CAPABILITY FOR RESEARCH

The excess control margins for future research in the area of control power requirements are lower for the low cost alternate FCS than for the baseline described in Volume I. The shift in operating point to a higher power setting, as required by the use of the 10% TRM bias, and the convergent nature of the available lift and the 3 second 1600°F available thrust modulation curves result in a 20% reduction in the maximum excess control power as defined by the temperature boundary. The remaining excess margins, however, still provide adequate research capability. This control margin reduction applies to roll and pitch attitude control only as the yaw attitude control is obtained by thrust vectoring which remains unchanged.

3.4 CONTROL WITH ONE ENGINE OUT

Under the single failure performance guideline, the control power capabilities of this RTA are identical to the one engine out capabilities of the baseline RTA. The 10% TRM preset used to provide adequate control response in the event of a control system failure can be removed, although the Level 2 T/W = 1.03 effective sustained thrust power level is approximately intermediate power with the TRM preset.

4. ANALYSIS OF MECHANICAL RTA USING ALTERNATE FCS

The control concept for this Mechanical RTA is identical to that of the baseline Mechanical RTA described in Volume I of this report. The thrust modulation requirements to achieve compliance with the control design guidelines are unchanged. As discussed in Section 5.3 of Volume I, the engine company data provided for this study was sufficient to determine available control margins with respect to the RTA's operational gross weights at constant maximum permissible fan RPM only. The available fan thrust margin for attitude control at VTOGW T/W = 1.0 is nearly twice the guideline requirement providing that a reduction of stall margin is permitted.

5. ALTERNATE FLIGHT CONTROL SYSTEM

The basic aircraft configurations of the turbotip and mechanical versions of the reduced cost program RTA and their respective control concepts are very similar. Only the methods of thrust modulation for aircraft attitude and height control, stemming from the means of energy distribution and transfer, are different between the two systems. This allows a common definition of the flight control system outside of the specific thrust modulation techniques.

5.1 CONTROL SYSTEM FUNCTIONAL REQUIREMENTS

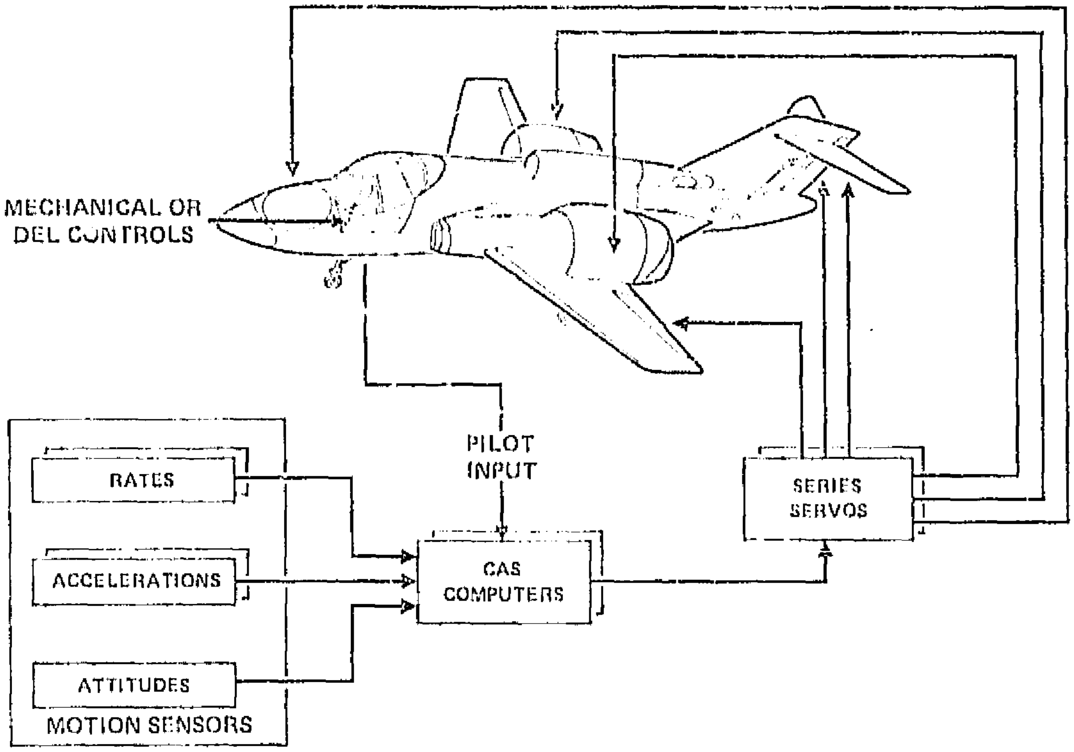
The control system functional requirements of the reduced cost program RTA are identical under normal operation to the baseline system described in Section 5.4 of Volume I. The major difference between the two control system requirements is based upon the reduced cost program performance and reliability goals which permit an in-flight degradation of handling qualities following a single major control system failure.

5.2 ALTERNATE FLIGHT CONTROL SYSTEM DESCRIPTION

The alternate reduced cost program flight control system is illustrated in Figure A-6. The control laws for the alternate FCS are very similar in concept to those for the baseline system. Only the implementation is different. The stability and augmentation control laws are programmed in dual CAS computers. The aerodynamic control surfaces are connected to pilot control inputs by direct mechanical links and CAS inputs are made via dual high-authority integrated series servos. The powered lift controls use a quadruplex direct electrical link (DEL) for high reliability. Free play, friction, control routing and associated design problems of mechanical powered-lift controls are thereby eliminated. The signals from the CAS computer are comparison monitored and then summed with the DEL signals.

The two CAS computers are cross-channel monitored for failure detection. The failure of a motion sensor, computer, or servo results in the disengagement of the stability augmentation of the affected axis and the pilot then controls the aircraft in an open loop fashion by means of mechanical links to the associated aerodynamic control surfaces, and unaugmented DEL inputs to the powered lift actuators.

FIGURE A-6
TECHNOLOGY AIRCRAFT FLIGHT CONTROL SYSTEM
ALTERNATE



5.3 ALTERNATE FLIGHT CONTROL SYSTEM EVALUATION AND RECOMMENDATIONS

The dual CAS flight control system concept is predicated on the assumption that acceptable handling qualities are retained following a failure of the stability augmentation system. It is only because of the RTA's single failure performance goals, which permit degradation of handling qualities following such a failure, that the in-flight loss of stability augmentation could be considered permissible. Therefore, the effect of the loss of stability augmentation on handling qualities has been extensively investigated in the general evaluation of the soundness of this flight control system concept.

The inherent aerodynamic stability of a V/STOL aircraft decreases with reduction in airspeed approaching hover such that an in-flight loss of pitch or roll stability augmentation results in low frequencey divergent oscillatory pitch or roll modes which do not meet Level 2 design guidelines as shown in Figure A-7. Recent RTA flight simulation tests conducted by MCAIR on the FSAA under contract to NASA/Navy reinforce the VTOL requirement for attitude stabilization. The results of stability augmentation failure tests during this simulation program, as reported in report MDC A4439, are summarized in Figure A-8. Conclusions based on these results point strongly to the fact that loss of roll axis stability augmentation during hover, or pitch axis stability augmentation during transition and conversion, is particularly critical. These failures result in control characteristics which are unacceptable and dictate mandatory improvement for safety of flight. Therefore, the reduced cost program dual CAS flight control system concept, under which single control system failures leading to loss of roll or pitch stability augmentation are possible, falls short of the desired fail safe performance and is not recommended.

The most direct approach to achieve the desired fail safe performance level is through the addition of a third control channel. This very significant conclusion substantiates MCAIR's recommendation of a triplex control-by-wire flight control system for the RTA as described in Volume I.

FIGURE A-7
COMPLIANCE WITH STABILITY CRITERIA

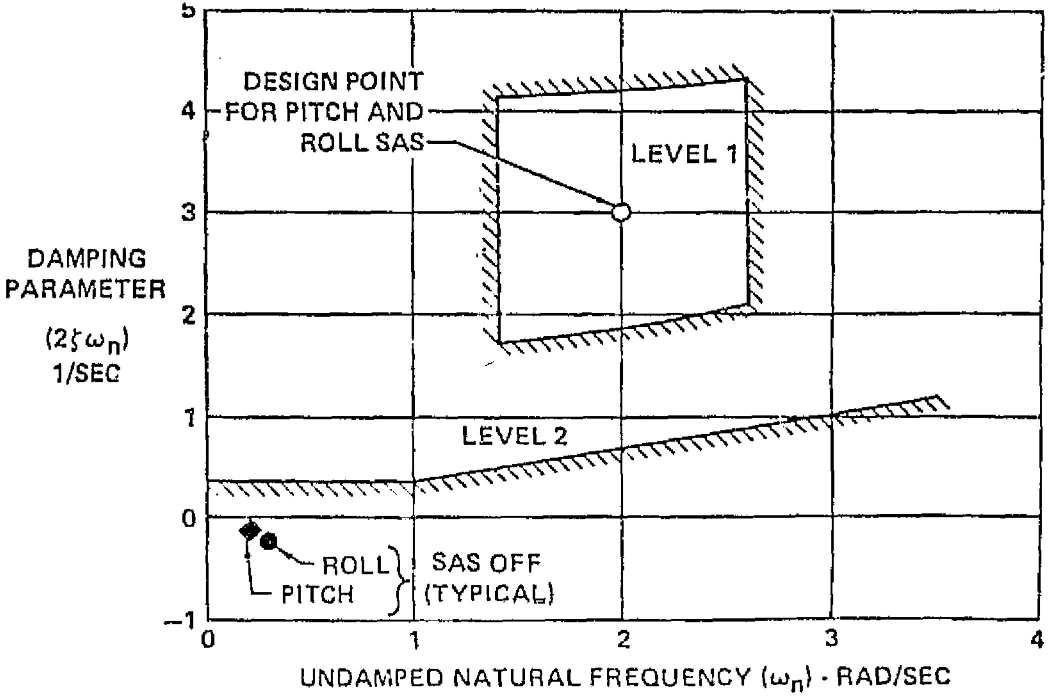


FIGURE A-8
REDUCED COST ALTERNATE FCS
SEPT '76 FSAA SIMULATION RESULTS

		SATISFACTORY WITHOUT IMPROVEMENT	ADEQUATE PERFORMANCE/ WORKLOAD TOLERABLE	IMPROVEMENT MANDATORY
CAS OPERATING				
COMPOSITE RATING		X		
CAS FAILED				
HOVER	ROLL			X
	PITCH		X	
	YAW		X	
TRANSITION & CONVERSION	ROLL		X	
	PITCH			X
	YAW		X	