NASA/TM-2003-212152
AMCOM/AFDD/TR-03-A-002

XV-15 Tiltrotor Aircraft: 1999 Acoustic Testing – Test Report

Bryan D. Edwards
Bell Helicopter Textron Inc., Fort Worth, Texas

David A. Conner
Joint Research Program Office
Aeroflightdynamics Directorate
U.S. Army Aviation and Missile Command
Langley Research Center, Hampton, Virginia

April 2003

The NASA STI Program Office ... in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers, but having less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results ... even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at ***http://www.sti.nasa.gov***

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA STI Help Desk at (301) 621-0134

- Phone the NASA STI Help Desk at (301) 621-0390

- Write to:
  NASA STI Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320

NASA/TM-2003-212152
AMCOM/AFDD/TR-03-A-002

XV-15 Tiltrotor Aircraft: 1999 Acoustic Testing – Test Report

Bryan D. Edwards
Bell Helicopter Textron Inc., Fort Worth, Texas

David A. Conner
Joint Research Program Office
Aeroflightdynamics Directorate
U.S. Army Aviation and Missile Command
Langley Research Center, Hampton, Virginia

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

April 2003

Available from:

NASA Center for AeroSpace Information (CASI)
7121 Standard Drive
Hanover, MD 21076-1320
(301) 621-0390

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161-2171
(703) 605-6000

TABLE OF CONTENTS

Paragraph **Page**

APPENDICES

LIST OF FIGURES

Page

LIST OF TABLES

Page

1. INTRODUCTION

This report describes noise testing of the XV-15 tiltrotor aircraft conducted by NASA Langley Research Center (NASA LaRC) and Bell Helicopter Textron Incorporated (Bell) during October 1999 at Bell's test site near Waxahachie, Texas. The test was the third in a three-test series directed toward defining low-noise flight procedures for tiltrotors operating in terminal areas.

NASA LaRC, which was responsible for overall test direction as well as for acoustic and meteorological measurements, was assisted by test and analysis teams from Wyle Labs and Lockheed Martin Engineering Sciences. Bell supported the tests by providing the aircraft and its support, test site coordination, and a part of the acoustic measurements. This work was accomplished under Contract NAS1-20094, Task 13. This report describes the test and presents an overview of the measured data. It was prepared under Contract NAS1-00091, Task 4.

1.1 Purpose of Test

Noise impact has been identified as a potentially major obstacle to developing the tiltrotor's full potential within the civil transportation system. If this potential is to be realized, noise reduction must be considered in each new tiltrotor design, and low-noise tiltrotor operating techniques must be defined. The purpose of this test was to develop and demonstrate low-noise flight procedures while maintaining safety and acceptable handling and ride qualities. Testing was planned around the XV-15 aircraft.

The NASA-sponsored 1999 XV-15 acoustic test was the last in a series of tests aimed at understanding and quantifying the noise characteristics of the relatively new tiltrotor aircraft type. This series was conceived and implemented as part of NASA's Short Haul Civil Tiltrotor (SHCT) initiative, and represented a Level 1 Milestone. The timeline of Figure 1-1 illustrates the XV-15 acoustic test history, including this SHCT test series as well as other related tests that contributed to the current understanding of tiltrotor noise characteristics.

In the SHCT tests, the approach flight condition was emphasized. Since this condition influences community noise impact more than any other, an understanding of the noise generating processes could guide the development of low noise flight operations and increase the tiltrotor's acceptance in the community. In turn, this acceptance would allow the tiltrotor to be effectively used to provide emergency medical service, rescue operations, public transport, and to assist in relieving the congestion crisis at major airports throughout the world.

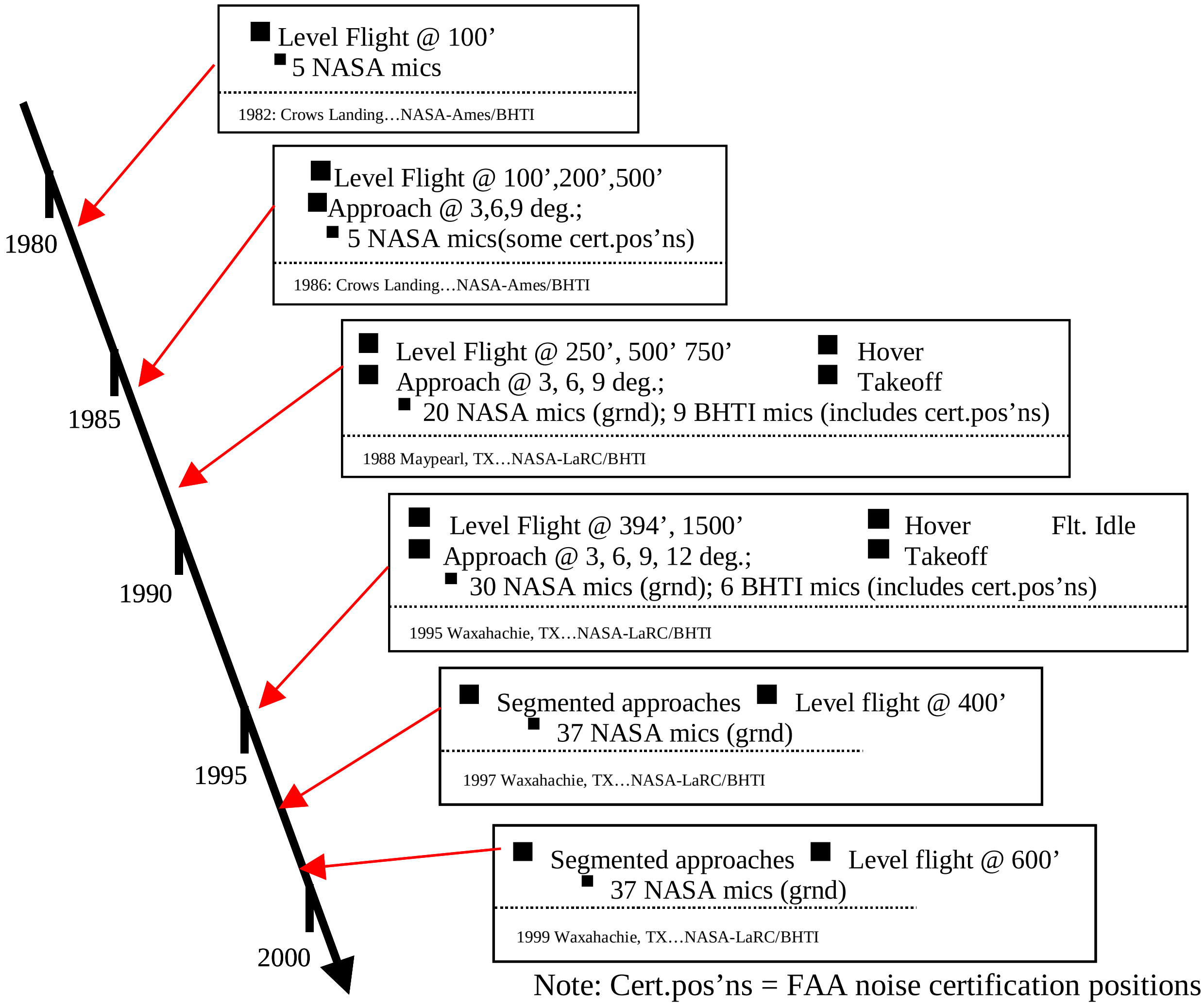


Figure 1-1. Major XV-15 acoustic test history

The SHCT XV-15 acoustic test series was initiated in 1995. It was envisioned in these steps:

- 1995: Define broad characteristics of tiltrotor approach noise at a matrix of operating conditions, provide high-quality dataset for tiltrotor acoustic prediction model validation, and perform a limited set of approaches for preliminary review.

- 1997: Demonstrate approach profiles incorporating Instrument Flight Rule (IFR) handling qualities constraints and tradeoffs with sound. Investigate broad range of approach procedures and develop "short list" of promising ones.

- 1999: Refine the "short list" of approach procedures produced by the previous testing. Fly optimal approaches to develop and demonstrate most practical, quietest flight procedures.

2. TEST DESCRIPTION

Testing consisted of the XV-15 aircraft flying prescribed approaches over a large array of microphones deployed on the ground. The test aircraft, microphone array, test site, instrumentation systems, and test procedures are described in this section.

Aircraft Description - XV-15

The XV-15 tiltrotor aircraft was designed and manufactured at Bell as a joint NASA/Army/FAA project. It was conceived as a proof of concept aircraft and technology demonstrator whose first flight was in May 1977. It has two 25-foot diameter rotors mounted on pivoting nacelles that are located on the wing tips. Each nacelle houses a transmission and a Lycoming T-53 turboshaft engine capable of generating 1800 shaft horsepower. The nacelles are tilted into the vertical position (90° nacelle angle) for vertical takeoffs and landings and rotated to the horizontal (0° nacelle angle) for cruising flight. Each rotor has three highly twisted, square-tip, stainless steel blades that typically operate at 589 RPM during hover and transitional flight modes, and at 517 RPM in cruise, corresponding to 98% and 86% of rotor design speed. The wings have a 6½° forward sweep to provide clearance for rotor flapping. During this test, the nominal vehicle takeoff gross weight was 13,900 pounds, including about 2000 pounds of fuel. During the period of data acquisition, fuel burn resulted in an approximately 10% reduction in the vehicle gross weight. For this test, the vehicle was operated by Bell under contract to NASA. In addition, Bell furnished research pilots, flight test engineers, ground crew personnel, and other necessary support personnel for operation and maintenance of the aircraft and on-board data acquisition system. A detailed description of the XV-15 and its history is available in Reference 1.

The photograph of Figure 2-1 shows the XV-15 in cruise flight, with nacelles tilted full forward (0 degrees). Figure 2-2 shows the same aircraft in hover, with nacelles tilted up to the full 90° position. Only two XV-15 flight vehicles were built, Serial Numbers 702 and 703. Both have been extensively tested to define the capabilities and limitations of the tiltrotor concept, and have successfully demonstrated the practicality of this new aircraft type. Ship Number 703 was used in the tests described in this report.

The XV-15 nominal flight envelope, shown in Figure 2-3, illustrates the combinations of nacelle angle and airspeed necessary to achieve stabilized level flight. The acoustic effects of trading off practical combinations of nacelle angle and airspeed within this envelope provide a way to guide flight operations of the XV-15 (and presumably other tiltrotors) in minimizing external noise (see Reference 2). The present test was designed to extend the body of information available to define these effects, incorporating a balance of operationally acceptable handling qualities.

Figure 2-1. XV-15 in cruise flight

Figure 2-2. XV-15 in hover mode

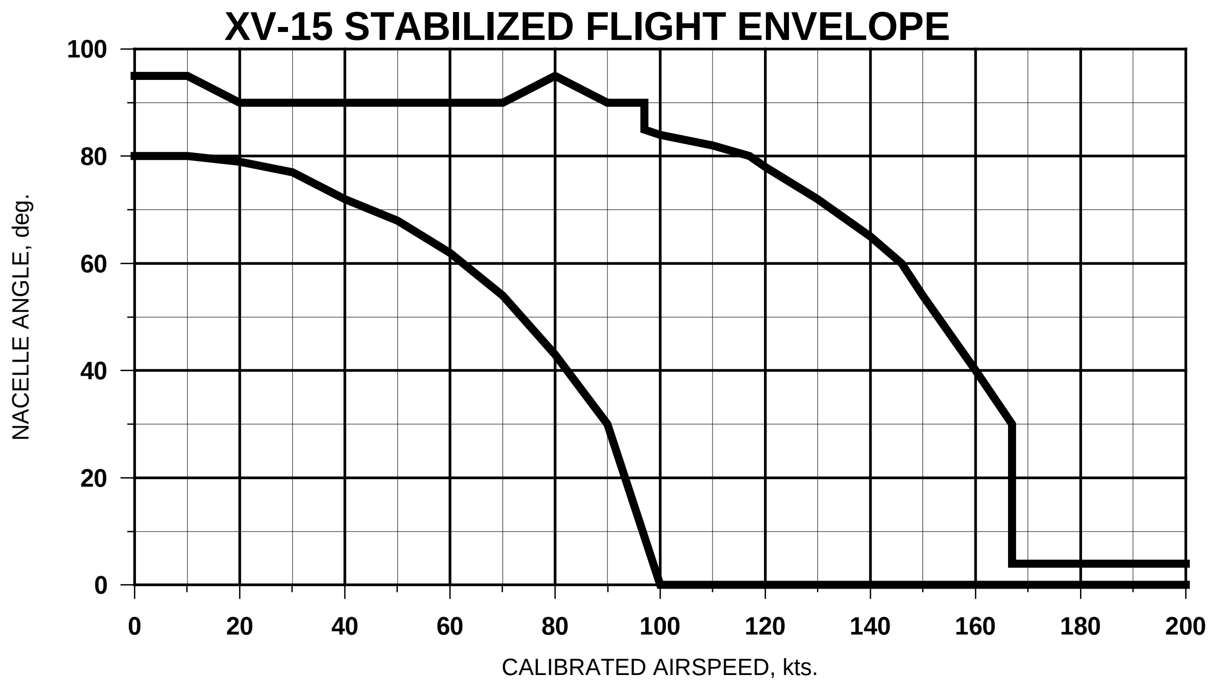
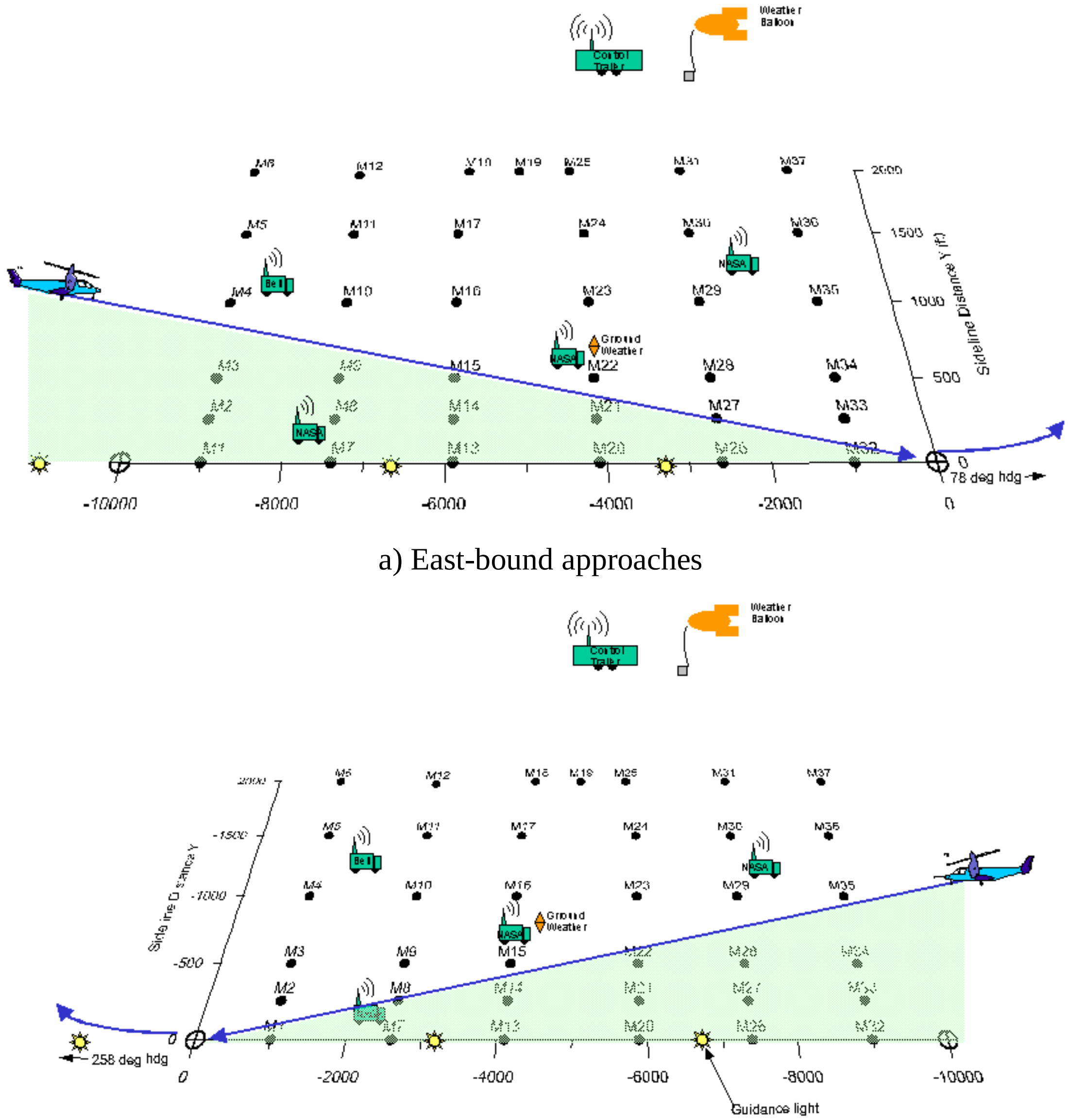


Figure 2-3. XV-15 Stabilized flight envelope, level flight

Test Site

The test was performed in a rural area near the town of Waxahachie, Texas, which is located 20 miles south of the Dallas-Fort Worth area. This site, the same one as used in the 1995 and 1997 XV-15 tests, is sufficiently remote that the ambient noise levels were low, 35-40 dBA, yet near enough to allow flight operation out of Bell's Arlington flight facility. The terrain was flat with few trees, and the ground was covered with short, mowed grass.

The general layout of the test site is sketched in Figure 2-4, with each microphone location illustrated. The flight track was selected so the microphones were positioned in the flattest portion of the terrain, away from trees and accessible by vehicle, resulting in a roughly east-to-west flight track at a heading of 88.2° (True). Depending on wind direction, flights were also conducted in the opposite direction, at a heading of 268.2° (True). Wind conditions at the test site were monitored by onsite test personnel prior to each flight. Aircraft heading for that flight was then selected to maintain a headwind component as much as possible. This dual-heading option was a product of experience from the 1997 test, in which flights could only be made in one direction, and persistent tailwinds adversely affected many of the approaches. To make this dual-heading option feasible, the 1999 microphone array had been laid out symmetrically about a center point on the flight track (Microphone location 19), with target landing sites at either end of the array. The microphones were deployed only on one side of the flight track. As in the previous testing, noise measured on one side of the XV-15 was assumed to be identical to that on the opposite side. The validity of this assumption had been demonstrated in the 1995 test (Reference 3).



a) East-bound approaches

b) West-bound approaches

Figure 2-4. Test site layout and microphone array

NASA LaRC recording equipment was housed in three instrumentation vans such as the one shown in Figure 2-5. Each van supported 10 microphone sites. A Bell van supported an additional seven microphone stations at the westernmost portion of the array. A mobile office located at an elevated site commanded a view of the flight track and served as control headquarters for the test. Figure 2-6 shows the headquarters trailer with test personnel.

Figure 2-5. NASA Instrumentation van at test site

Figure 2-6. Headquarters trailer and test personnel

A 75’ × 75’ concrete helipad had been constructed at the test site prior to the 1997 test. Although not used during the 1999 data acquisition, this pad served as an emergency landing site and a convenient hover/touchdown point during the test. Figure 2-7 shows the XV-15 completing an approach at the test site.

Figure 2-7. XV-15 at test site

<u>Personnel/Crew Assignments</u>

NASA LaRC was responsible for the overall test direction and for selecting test points and flight procedures. Dave Conner was the test director and Odilyn Santa Maria was the test Engineer. Test point selections were made with the assistance of handling qualities inputs from Pete Klein of Bell and Bill Decker/Mike Marcolini of NASA. Handling qualities were considered an integral part of the program to ensure that any "low noise" flight operations documented for the XV-15 were practical ones that could realistically be used in a commercial tiltrotor.

NASA LaRC provided equipment and personnel for acoustical support at 30 of the 37 microphone locations. They were also responsible for meteorological measurements during the test, and for overnight analysis of each dataset. The NASA LaRC team included personnel on contract from Wyle and Lockheed Martin Engineering Sciences for technical support in data acquisition and analysis.

Bell supported flight operations of the XV-15, providing instrumentation support to monitor and record rotor RPM, nacelle angle, flap angle, airspeed, radar altitude, and other aircraft parameters. Test site coordination and technical support for the remaining 7 of the 37 microphone stations were also provided by Bell.

Figure 2-8 shows some of the test personnel at the mobile office trailers that served as a control headquarters for the test and with the XV-15 at Bell's Arlington Flight Test Center. A list of personnel involved in the test is given in Appendix A. Each individual's responsibilities during the test are given, along with his home agency.

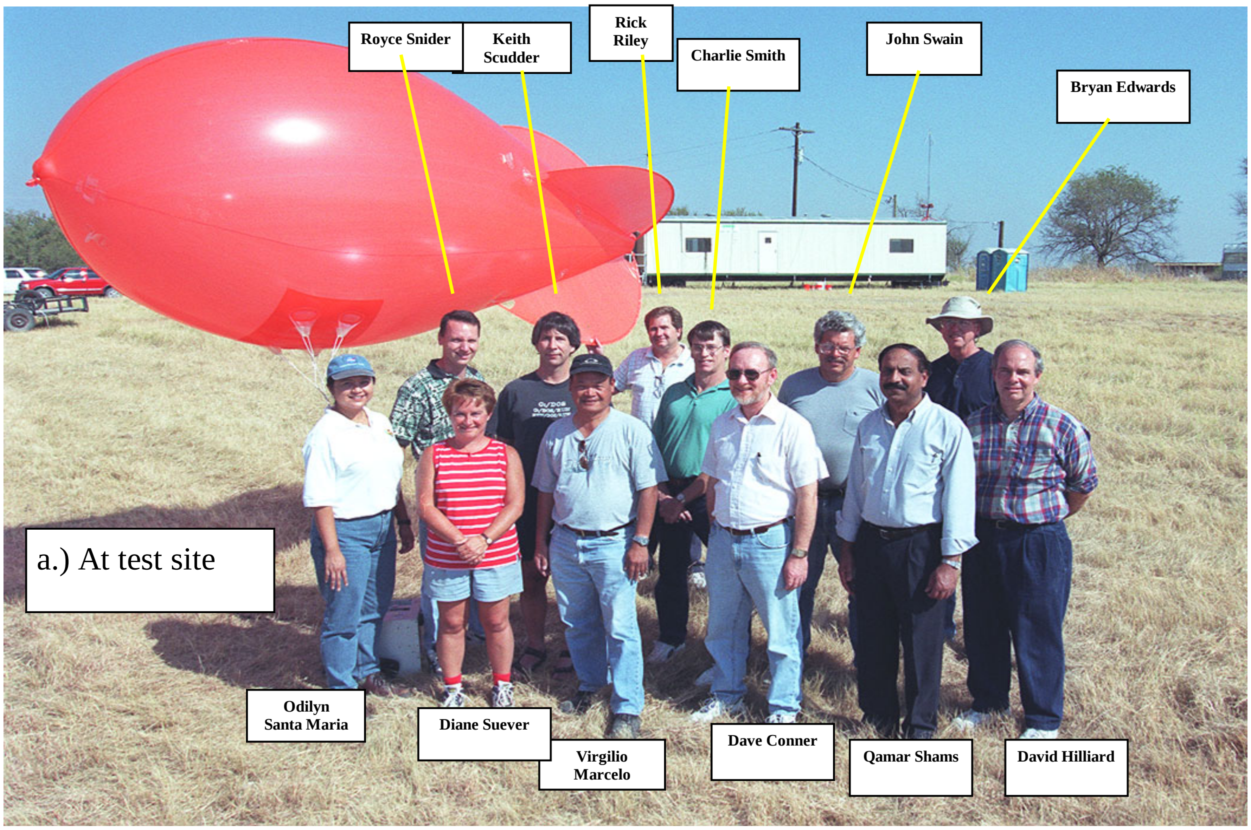


Figure 2-8. Test personnel

2.1 Measurement Systems

Instrumentation systems were provided to measure noise, meteorological conditions, aircraft position, and aircraft flight parameters. Equipment operators were notified by radio as each pass was initiated and concluded. Satellite time code was recorded on each instrumentation system to provide time synchronization for post-test processing.

2.1.1 Acoustic Measurements

For acoustic measurements, four fully instrumented vans were provided, each responsible for up to 10 microphones in the array. Each van housed equipment for recording the time-synchronized microphone signals.

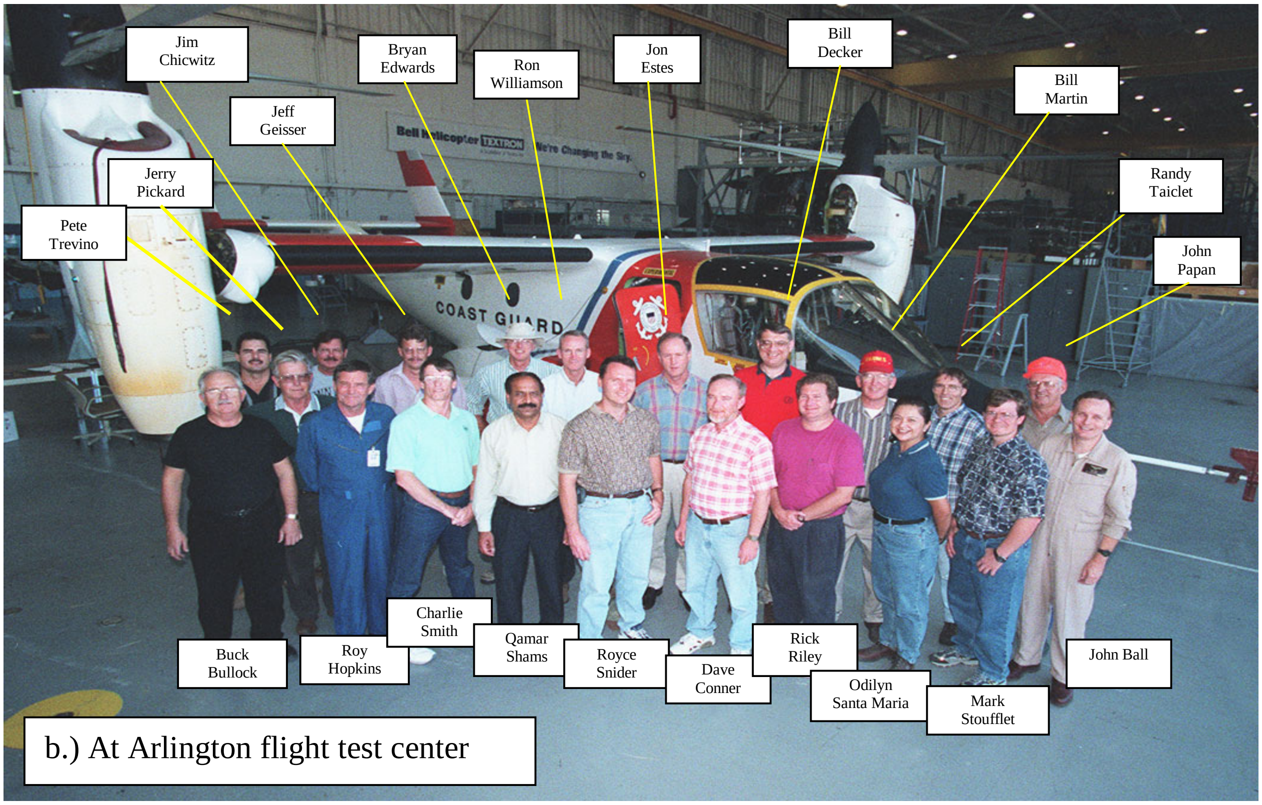


Figure 2-8. Test personnel (Concluded)

The 37 microphones were deployed over a large ground area near the hover pad as previously shown in Figure 2-4. All microphones were mounted on ground planes as indicated in Figure 2-9. Symmetry of the sound field was assumed, so the microphones were located along only one side of the flight track. The array extended 8000 feet along the approach track and 2000 feet to the north side. This extensive array was designed to measure the acoustic effects of specific approach techniques upon noise near a vertiport terminal. Specific measurement positions are tabulated as an X-Y-Z grid and specific latitude-longitude-elevation positions in Appendix B.

2.1.2 Meteorological Measurements

Nominal meteorological guidelines for testing were:

- average surface winds less than 10 knots
- relative humidity less than 95%
- no precipitation
- visibility greater than 3 miles (for flight safety), and
- ceiling greater than 1500 feet AGL (for flight safety).

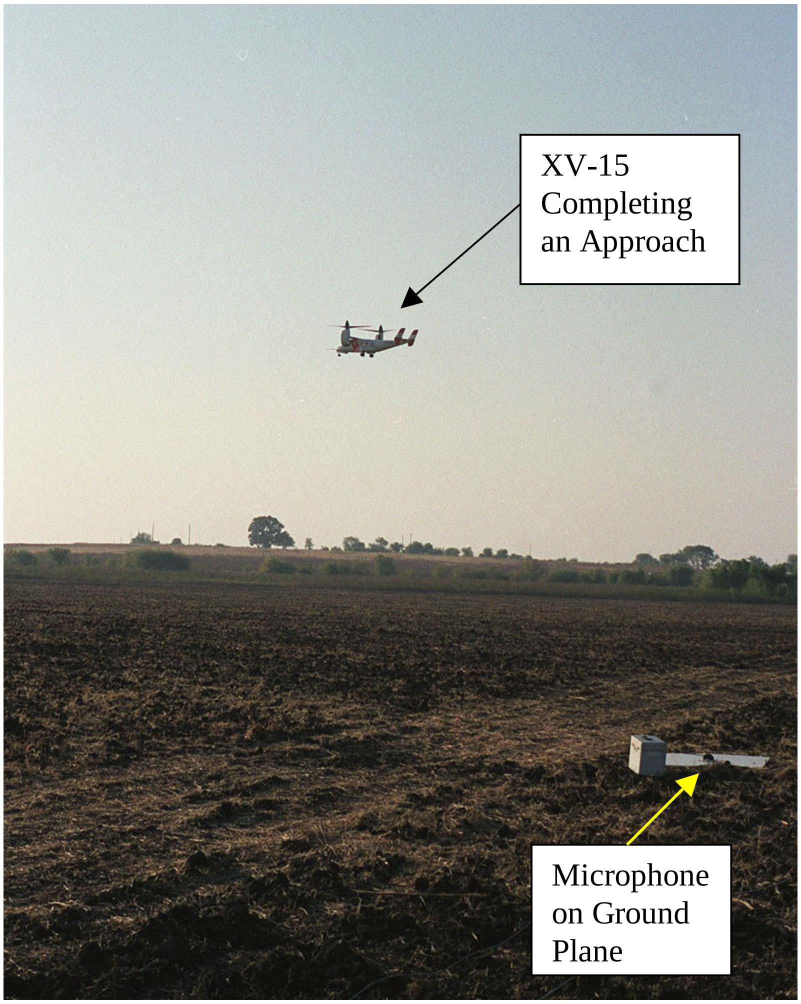


Figure 2-9. Typical ground plane microphone setup during XV-15 approach

Because of the low wind requirements, early morning flights were scheduled. Based on weather information available at 3:00 PM prior to each potential test day, plans for the next day's testing were confirmed.

During testing, surface meteorological data were recorded at a position near the flight track. In addition, a tethered weather balloon, positioned at the control trailer site, monitored conditions aloft. The balloon was raised and lowered, cycling to altitudes of 1000 feet above ground level. Meteorological data were transmitted to the ground and displayed on a laptop computer.

2.1.3 Position Tracking

A Differential Global Positioning System (DGPS) was used for position guidance and tracking. The XV-15 was fitted with a flight director for providing position and aircraft state guidance to the pilot during approach. This system allowed the desired flight path to be flown very precisely. For ground control monitoring, a parallel system in the control trailer displayed the desired flight path for each approach, with the XV-15's real-time position being overlaid as the approach was flown.

In addition to driving the ground-based and aircraft-based real-time display systems, XV-15 position information was also recorded for later analysis. In the recorded data, each position was recorded to an accuracy of ±3 feet, and updated twice each second.

Whether approaches were made from the East or West, the landing point for each approach served as the origin of the positioning grid. Sign convention followed a right-hand rule, resulting in defining a three-axis system in terms of:

X: horizontal distance along the flight track, positive in the direction of flight,

Y: horizontal distance perpendicular to the flight track, positive on the aircraft port side,

Z: vertical distance, positive up.

The sign convention for both approach directions is illustrated in Figure 2-4, shown previously.

2.1.4 Aircraft Parameters

During each flight, aircraft position and a wide variety of aircraft state parameters were recorded on the aircraft. The state parameters include acoustically relevant ones such as rotor speed, nacelle angle, airspeed, and rate of climb/descent. Prior to each flight, an onboard time code generator was synchronized with a satellite-linked time code unit to provide time correlation between airborne and ground based instrumentation systems. During testing, selected safety of flight data were also transmitted from the aircraft to the command post ground station, where it was monitored continuously.

2.2 XV-15 Testing

Data flights were begun 6 October 1999, and continued until 21 October 1999. A total of 15.8 flight hours of data were accumulated during the test. The XV-15 flight operation was based at Bell's Arlington, Texas, Flight Test Center, approximately 25 miles from the test site. Fuel capacity allowed about one hour at the site, during which time 8 to 9 data passes could normally be completed.

2.2.1 Flight Procedures

As in the previous tests, each time the XV-15 arrived at the test site, a level flight pass was made at 60 degrees nacelle and 90 knots airspeed, at a target altitude of 600 feet over the microphones. These passes were conducted to check the day-to-day consistency of measurements. The intent was to perform these "housekeeping" runs at an altitude of 400 feet as in the previous tests, but the profile was inadvertently set for 600 feet instead. The original purpose of the housekeeping runs is served at the 600 ft altitude as well as 400 ft, but a comparison among the 1995, 1997, and 1999 housekeeping runs is less direct.

A library of some 15-candidate flight procedures was developed and programmed into the flight director prior to the test. For each procedure, two separate flight director files were made available – one for the 88° heading and one for the 288° heading. These were numbered sequentially in pairs with the "housekeeping" procedure being 1 and 2, a baseline approach procedure derived from the 1995 test numbered 3 and 4, and potential noise reduction approach procedures being identified as 5 and 6 through 29 and 30. These candidate procedures are listed in Table 2-1 and described more fully in Appendix D. Each was programmed into the XV-15 flight director, which provided not only position guidance, but also cues for airspeed, nacelle angle, flaps, power, and other acoustically relevant parameters. The display used to guide the pilot through these candidate procedures is shown in the photograph of Figure 2-10.

Approaches were conducted nearly identically to the previous (1997) testing except that they did not terminate with the aircraft in an IGE hover over the hover point. Instead, the pilot held the prescribed approach conditions until the aircraft had flared and slowed to about 20 knots at an up-range distance of 200-300 feet and an altitude of 50 to 100 feet. The pilot then radioed, "Prime data off," and immediately performed a climb out to set up for the next data run. A full flare-to-hover was not specified. The microphone array had been positioned slightly up-range of the landing point to capture the portions of the approach which could be affected by flight procedure modifications. A full flare-to-hover was not required in this test, as it had been fully documented in the 1997 test. This modified approach procedure required slightly less flight time, resulting in more data passes per flight hour.

Each approach began approximately 5 miles up-range of the microphone array, at an altitude of 1500 to 2000 feet above ground level. At approximately 3 miles up-range, the desired flight procedure was finalized, and the test director radioed "Prime data on." The XV-15 continued performing the required procedure along the flight track, passing over the microphone array and continuing toward the target landing point.

Data was acquired during 8 data flights throughout the 3-week test period. A sequential list of approaches flown during the test is presented in Table 2-2. Each flight had a specific number, allocated by Bell; this table is repeated in Appendix E with additional notes and background information.

Table 2-1. XV-15 Flight Procedures for 1999 Test

NASA Flight Profile	Flight Profile Number
Housekeeping approach along hdg of 88.24 deg	1
Housekeeping approach along hdg of 268.24 deg	2
Procedure 0 (6 deg) Baseline along hdg of 88.24 deg	3
Procedure 0 (6 deg) Baseline along hdg of 268.24 deg	4
Procedure 1 (3 - 9 deg) E along hdg of 88.24 deg	5
Procedure 1 (3 - 9 deg) E along hdg of 268.24 deg	6
Procedure 2 (3 - 9 deg) F along hdg of 88.24 deg	7
Procedure 2 (3 - 9 deg) F along hdg of 268.24 deg	8
Procedure 3 (3 - 9 deg) rep along hdg of 88.24 deg	9
Procedure 3 (3 - 9 deg) rep along hdg of 268.24 deg	10
Procedure 4 (3 - 9 deg) mod C along hdg of 88.24 deg	11
Procedure 4 (3 - 9 deg) mod C along hdg of 268.24 deg	12
Procedure 5 (9 deg - 750') along hdg of 88.24 deg	13
Procedure 5 (9 deg - 750') along hdg of 268.24 deg	14
Procedure 6 (9 deg) .04 decel along hdg of 88.24 deg	15
Procedure 6 (9 deg) .04 decel along hdg of 268.24 deg	16
Procedure 6 (9 deg) .05 + 90 decel along hdg of 88.24 deg	17
Procedure 6 (9 deg) .05 + 90 decel along hdg of 268.24 deg	18
Procedure 7 (3 deg) along hdg of 88.24 deg	19
Procedure 7 (3 deg) along hdg of 268.24 deg	20
Procedure 7 (3 deg) B along hdg of 88.24 deg	21
Procedure 7 (3 deg) B along hdg of 268.24 deg	22
Procedure 7 (3 deg) C along hdg of 88.24 deg	23
Procedure 7 (3 deg) C along hdg of 268.24 deg	24
Procedure 4 (3 - 9 deg) mod C (2) along hdg of 88.24 deg	25
Procedure 4 (3 - 9 deg) mod C (2) along hdg of 268.24 deg	26
Procedure 0 (6 deg) Baseline (B) along hdg of 88.24 deg	27
Procedure 0 (6 deg) Baseline (B) along hdg of 268.24 deg	28
Procedure 5 (9 deg - 1000') along hdg of 88.24 deg	29
Procedure 5 (9 deg - 1000') along hdg of 268.24 deg	30

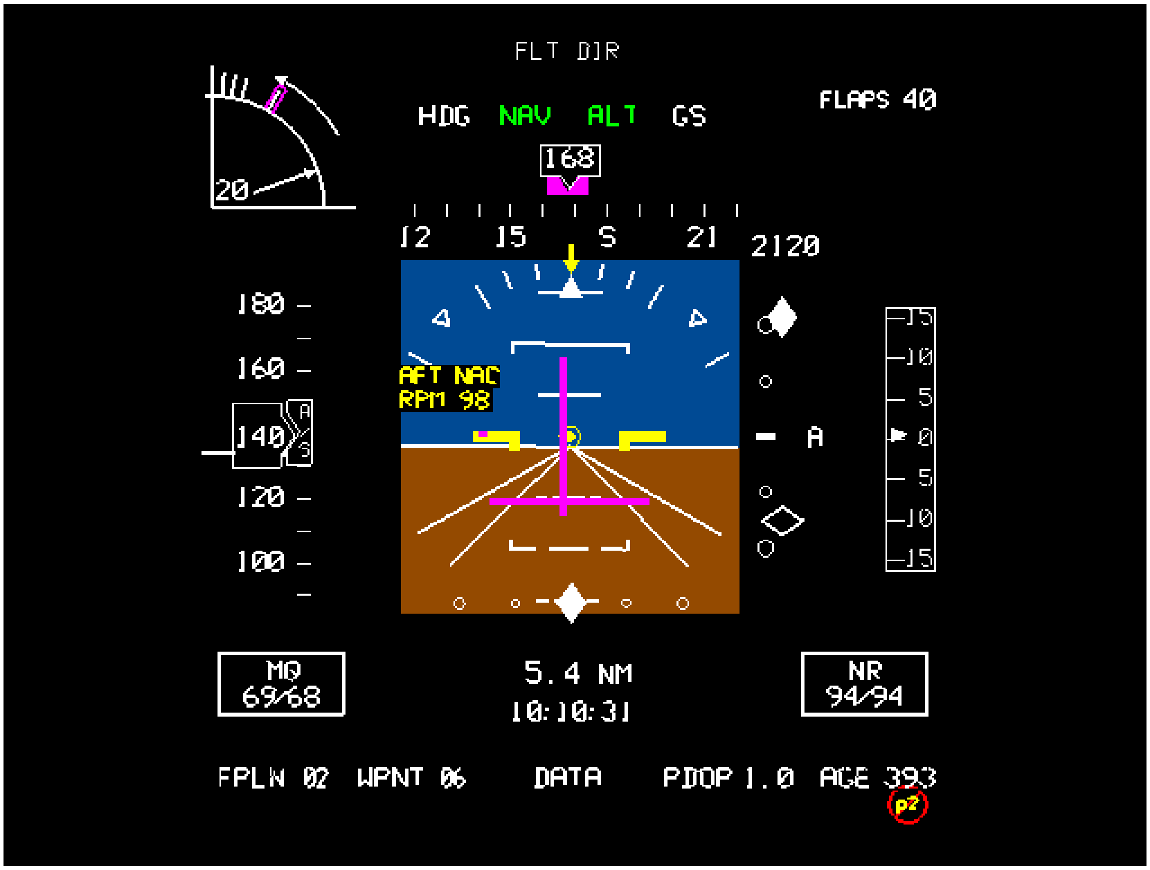


Figure 2-10. XV-15 flight director display

Since information on handling qualities for each of the approach procedures was desired, the pilot was requested to comment as to the handling qualities of each pass. An on-board video recorder had been installed to record the flight director screen during the entire test, and pilot comments were recorded on the audio track of this recorder. These have been transcribed, and are presented in Appendix F.

2.2.2 Results and Discussion

The results of this test concerning tiltrotor operational procedures during approach and their effects on noise have been presented in previous reports and in public forums (References 3-11), and are summarized below. These results include a discussion of data repeatability, approach procedures, noise data in the form of Sound Exposure Levels deltas, noise “footprints,” and relative benefits of using specific noise abatement flight procedures. This information is primarily given in terms of trends and deltas rather than specific amplitudes.

Table 2-2. Sequential List of Test Conditions Flown

XV-15-99 Test Log

Test Date	FLT	RUN	Profile	Ship Rec #	Description
10/6/99	409	106	1	4	Housekeeping
10/6	409	107	3	5	6° Approach
10/6	409	108	3	6	6° Approach
10/6	409	109	3	8	6° Approach
10/6	409	110	13	9	9° Approach
10/6	409	111	13	10	9° Approach
10/6	409	112	13	11	9° Approach
10/6	409	113	13	12	9° Approach
10/7	410	114	1	2	Housekeeping
10/7	410	115	1	5	Housekeeping
10/7	410	116	3	6	6° Approach
10/7	410	117	3	7	6° Approach
10/7	410	118	3	8	6° Approach
10/7	410	119	5	9	3-9° Approach
10/7	410	120	5	10	3-9° Approach
10/7	410	121	5	11	3-9° Approach
10/7	410	122	19	12	3° Approach
10/7	410	123	13	13	9° Approach
10/8	411	124	1	8	Housekeeping, Eastbound
10/8	411	125	19	9	3° Approach
10/8	411	126	19	10	3° Approach
10/8	411	127	9	11	3-9° Approach
10/8	411	128	2	15	Housekeeping, Westbound
10/8	411	129	10	16	3-9° Approach, Westbound
10/8	411	130	10	22	3-9° Approach, Westbound
10/8	411	131	12	23	3-9° Approach, Westbound
10/8	411	132	12	24	3-9° Approach, Westbound
10/11	412	133	1	2	Housekeeping, Eastbound
10/11	412	134	17	3	9° Approach
10/11	412	135	17	4	9° Approach
10/11	412	136	15	5	9° Approach
10/11	412	137	15	6	9° Approach
10/11	412	138	7	7	3-9° Approach
10/11	412	139	7	8	3-9° Approach
10/11	412	140	9	9	3-9° Approach

Table 2-2. Sequential List of Test Conditions Flown (Concluded)

Test Date	FLT	RUN	Profile	Ship Rec #	Description
10/12	413	141	1	2	Housekeeping
10/12	413	142	9	3	3-9° Approach
10/12	413	143	9	4	3-9° Approach
10/12	413	144	9	5	3-9° Approach
10/12	413	145	9	6	3-9° Approach
10/12	413	146	9	7	3-9° Approach
10/12	413	147	23	8	3° Approach
10/12	413	148	23	9	3° Approach
10/13	414	149	2	9	Housekeeping, Westbound
10/13	414	150	26	10	3-9° Approach
10/13	414	151	26	11	3-9° Approach
10/13	414	152	4	12	6° Approach
10/13	414	153	6	13	3-9° Approach
10/13	414	154	6	14	3-9° Approach
10/13	414	155	8	15	3-9° Approach
10/20	416	156	2	2	Housekeeping, Westbound
10/20	416	157	28	3	6° Approach
10/20	416	158	28	4	6° Approach
10/20	416	159	30	5	9° Approach
10/20	416	160	30	6	9° Approach
10/20	416	161	14	7	9° Approach
10/20	416	162	2	8	Nacelle Conversion
10/20	416	163	2	9	Nacelle Conversion
10/20	416	164	24	10	3° Approach
10/20	416	165	2	19	Housekeeping, Westbound
10/20	416	166	28	20	6° Approach
10/20	416	167	10	21	3-9° Approach
10/20	416	168	6	22	3-9° Approach
10/20	416	169	24	23	3° Approach
10/20	416	170	24	24	3° Approach
10/20	416	171	20	25	3° VFR
10/20	416	172	2	26	Nacelle Conversion
10/21	417	173	2	2	Housekeeping, Westbound
10/21	417	174	2	3	Nacelle Conversion
10/21	417	175	28	4	6° Approach
10/21	417	176	24	5	3° Approach
10/21	417	177	24	6	3° VFR
10/21	417	178	10	7	3-9° Approach
10/21	417	179	26	8	3-9° Approach

2.2.2.1 Data Repeatability

To examine the repeatability of the data acquired during this test program, Figure 2-11 illustrates the comparison of the sound exposure levels (SEL) for all the housekeeping runs and 6° approaches. The data shown were acquired during the 1997 test (Ref. 8) from the most densely populated line of microphones located 3750 feet up-range. The figures show that, as expected, the maximum sound exposure levels occur on the flight path centerline and the levels decrease rapidly with increasing sideline distance. For the housekeeping runs of Figure 2-11a, the SEL variation for the centerline microphone and all microphones up to 1000 feet to the sideline are ±0.6 dB or less. The largest SEL variations are approximately ±1.6 dB for the microphones located 1500 and 2000 feet to the sideline. Figure 2-11b shows that the SEL variation for the 6° approaches was ±2.3 dB or less for all microphones except the farthest out microphone located 2000 feet to the sideline, which had a slightly greater variation of ± 2.8 dB. These variations are consistent with what has been measured in previous XV-15 acoustic flight tests.

As noted in Table 2-1, a total of eight different approach profiles were flown, in addition to the 6°-baseline approach. The 6°-baseline approach profile tested in 1999 was, for all practical purposes, identical to the one flown during the 1997 test (Ref. 8).

Two low noise approaches profiles have been selected for comparison with the baseline approach; the 3° approach and a 3° to 9° segmented approach. Each of these approaches was flown six times during this test and the acoustic data presented are the average values over the six runs. These approach profiles were selected because the 3° profile provided significant and uniform noise reduction over the entire measurement area while the 3° to 9° profile provided the greatest noise reductions at the farther up-range areas. The approach conditions and the average noise footprints are presented followed by comparisons to the 6°-baseline approach.

While the approach profiles for the six averaged runs were nearly identical, slight variations did exist. Comparison of the six runs showed that altitude variations were generally less than ±25 feet, airspeed variations were generally less than ±3 knots, and variations of less than ±100 feet in the up-range distance at which nacelle angle changes were initiated. For the 1999 approaches, the initial glideslope was intercepted at a distance of 18,000 feet up-range of the landing point. All were flown with a headwind component of between 5 and 15 knots.

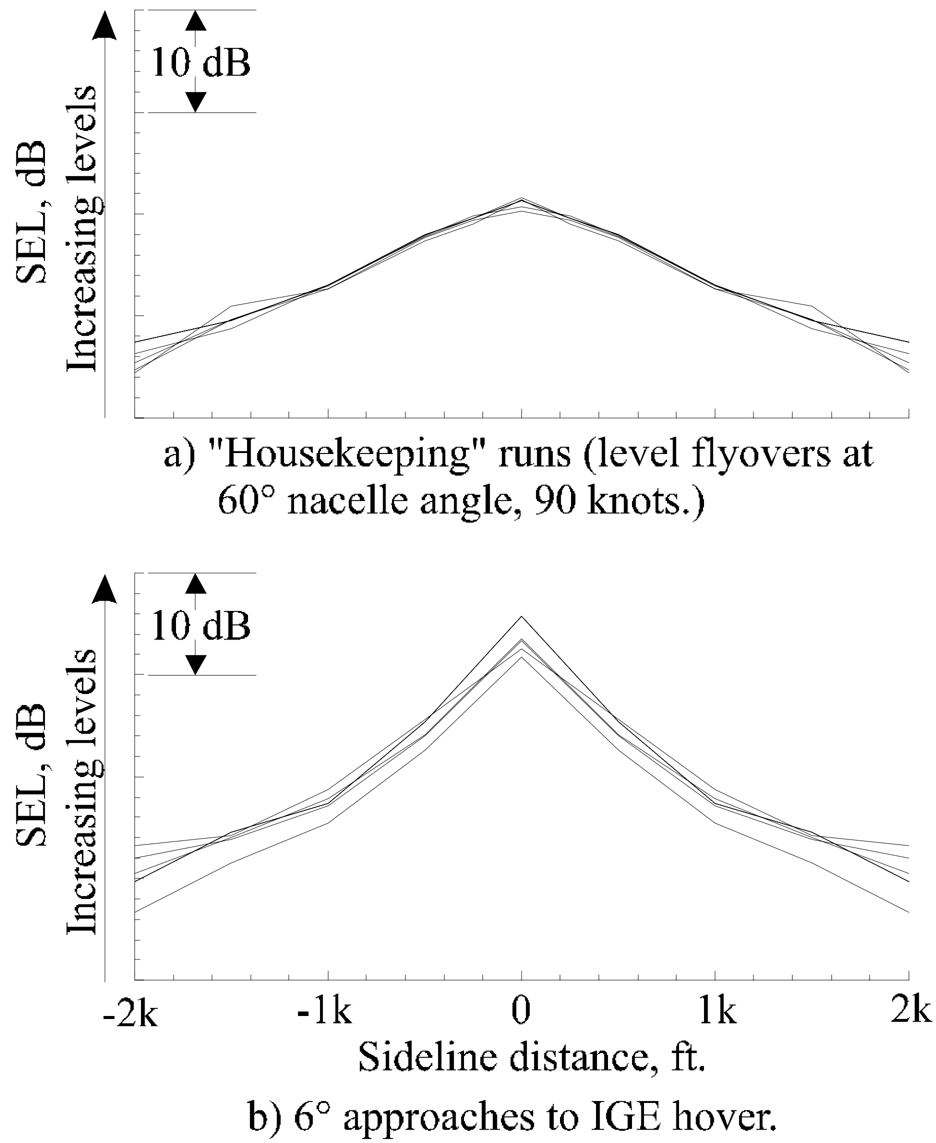


Figure 2-11. Sound exposure levels for multiple runs at same flight conditions as measured during 1997 test at line of microphones 3750 feet up-range of landing point

2.2.2.2 Approach Profiles

Measured altitude, airspeed, and nacelle angle schedules for one run for the baseline and the two-selected approach profiles are shown in Figure 2-12.

Each part of the figure presents the altitude, airspeed, and nacelle angle as a function of the up-range distance for a single approach. A dash-dot line indicates the intended or desired flight path. It should be noted that while the approach profiles were designed using airspeed, they were flown using ground speed.

For the baseline 6° approach profile (Figure 2-12a), the aircraft intercepted the 6° glideslope at an altitude of about 1900 feet with approximately 60 knots airspeed and a nacelle angle of 85°. The 85° nacelle angle, 60 knots condition was maintained until the aircraft was approximately 3300 feet up-range, where the nacelles were rotated to 90° and a deceleration to 40 knots was begun. At about 1800 feet up-range the aircraft began a final deceleration that would be required to achieve an IGE hover at the landing point. The approach was terminated at an up-range distance of about 300 feet when the aircraft was at an altitude of about 75 feet and airspeed of about 25 knots. As mentioned earlier, the pilot considered this to be a very comfortable approach.

The 3° approach profile characteristics are presented in Figure 2-12b. The aircraft intercepted the 3° glideslope at an altitude of about 950 feet with a nacelle angle of 60° and airspeed of about 95 knots. This nacelle angle and airspeed were maintained until the aircraft was about 7000 feet up-range, where the nacelles were rotated to 75° and a nearly constant deceleration rate, sufficient to achieve a hover condition over the landing point, was initiated. The nacelles were rotated in 5° increments to 80, 85, and 90° at up-range distances of about 4600, 3200, and 1200 feet, respectively. The approach was terminated at an up-range distance of about 300 feet when the aircraft was at an altitude of about 50 feet and airspeed of about 25 knots.

The 3° to 9° segmented approach profile characteristics are presented in Figure 2-12c. This approach had a glideslope intercept of the initial 3° glideslope at an altitude of about 1400 feet with airspeed of 93 knots and a nacelle angle of 60°. At a distance of about 7000 feet up-range the nacelles were rotated to 75° and a deceleration to about 55 knots was initiated. The nacelles were then rotated to 80° at an up-range distance of about 5000 feet, followed by the 9°-glideslope intercept at an up-range distance of about 4000 feet. At about 2500 feet up-range, the nacelles were rotated to 85° and the final deceleration to a hover condition was initiated. The final nacelle rotation to 90° was initiated at about 1800 feet up-range of the landing point. The approach was terminated at an up-range distance of about 300 feet when the aircraft was at an altitude of less than 100 feet and airspeed of about 10 knots.

As is evident from a comparison of the figures, the nacelle angle/airspeed schedules are very similar for these two quiet approaches, each being significantly different from the baseline approach.

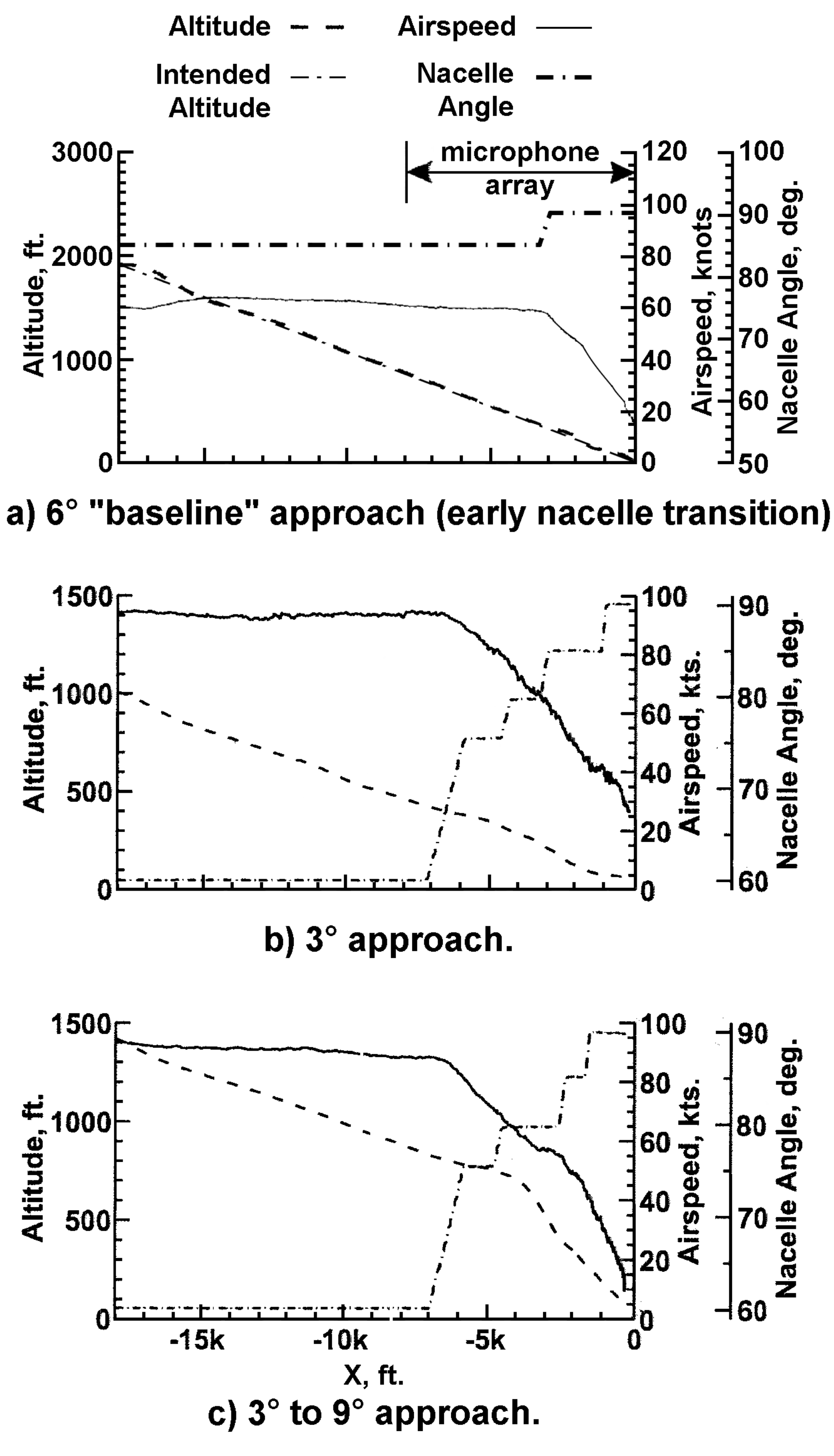


Figure 2-12. Altitude, airspeed, and nacelle angle schedules for baseline and two "quiet" approaches

2.2.2.3 *Ground Contours*

Figure 2-13 shows the characteristics of the resulting noise footprints for the same three approaches presented in Figure 2-12. The separation in the contour levels is 5 SELdB and the contour levels are labeled from A to G with A representing the lowest SEL, shown as black in the figure, and G representing the highest SEL, shown as white in the figure. The contour scales for all parts of the figure represent equal values to allow for direct comparisons. Each footprint extends from 9000 feet up-range to 1000 feet up-range of the landing point and spans up to 2000 feet to either side of the landing point, covering an area of more than 735 acres. The XV-15 approached from the left in the figure, along a line at Y = 0, and held the desired approach conditions until reaching a point approximately 300 feet up-range of the landing point, at which point the data run was terminated. The noise footprints are most useful in providing a qualitative assessment of the noise abatement potential of the different approach profiles. The contour data will be presented in other formats in this section to provide a more quantitative assessment.

The noise footprint for the 6° "baseline" approach is illustrated in figure 2-13a. The highest SEL contour is located along the flight path approximately 1000 and 3500 feet up-range of the hover pad ($-3500 \leq X \leq -1000$) and extends about 150 feet to the sidelines. In general, the maximum levels are located along the flight track and decrease rapidly with increasing sideline distance and with increasing down-range distance. The F contour level extends about 8500 feet up-range and about 400 feet to both sidelines. Each successively lower SEL contour is a little larger, extending a little further to the sides of the flight track. For the contour levels of E and below, the contour "tails" extend up-range beyond the area of the measured noise footprint.

The noise footprint for the 3° approach is presented in Figure 2-13b. The highest SEL contour (G) is located along the flight path between approximately 1000 and 3700 feet up-range of the landing point and extends about 200 feet to the sidelines at its widest point that was located at the line of microphones 2600 feet up-range. This "hot spot" is just ahead of the aircraft location where the nacelles were moved from 80° to 85° and is likely due to the occurrence of blade-vortex interactions at this airspeed/nacelle angle/descent rate combination. In general, the levels decrease rapidly with increasing sideline distance. The contour levels decrease least rapidly along the flight path. More specifically, the F contour level extends about one mile up-range with a maximum width of about 700 feet while the E contour extends nearly 8000 feet up-range with a maximum width of about 1100 feet. The D and C contour levels appear to extend well beyond the furthest up-range measurement location.

The noise footprint for the 3° to 9° segmented approach is presented in Figure 2-13c. The maximum contour level (G) extends to 2600 feet up-range and the width of this contour increases with decreasing up-range distance. The F, E, and D contour levels extend to about 3800, 5200, and 7700 feet up-range, respectively, while the C contour level extends beyond the furthest up-range measurement location.

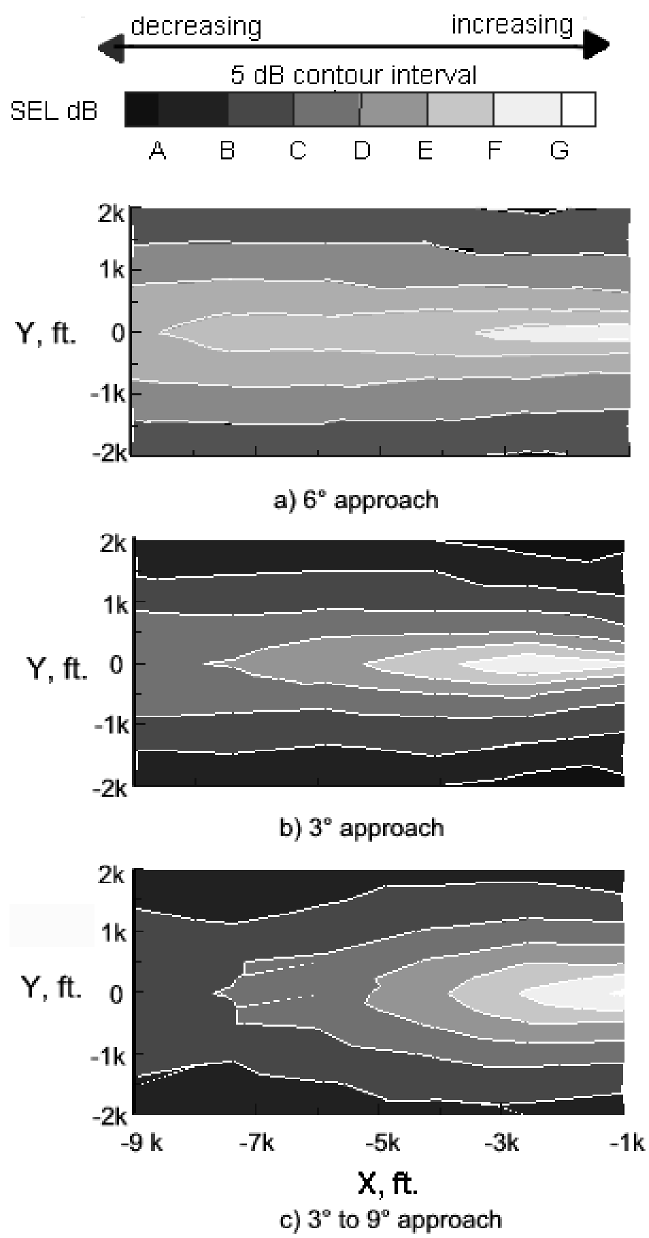


Figure 2-13. SEL ground contours

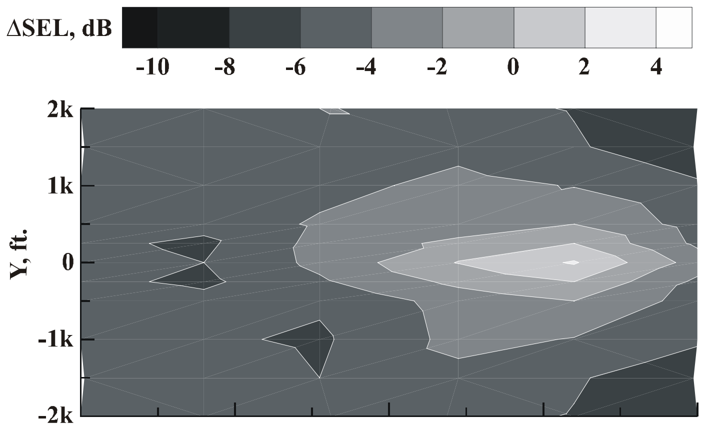
Figure 2-14 presents contours of the SEL difference from the average 6°-baseline approach levels. Four runs were used in the calculation of the average SEL values for the 6°-baseline approach. A negative contour level indicated a reduction in the noise level compared to the 6°-baseline approach while a positive value indicates an increase in the noise level. Because noise measurements were made directly beneath and to one side of the aircraft flight path only, these noise footprints should be symmetric about Y = 0. However, these footprints are not exactly symmetric due to the linear interpolation scheme used by the plotting program. Slight variations arise because the program handles negative numbers differently than positive numbers. Each noise footprint in these two figures extends from 1000 feet to 9000 feet up-range of the landing point and span to 2000 feet to either side of the landing point, covering a measurement area of 735 acres. The XV-15 approached from the left in the figure, along a line at Y = 0, and held the desired approach conditions until reaching a point approximately 300 feet up-range (X = -300 feet) of the landing point.

Figure 2-14a shows an area along the flight path between about 1900 and 4200 feet up-range, with a maximum width of 500 feet, where the levels are as much as 2 SELdB higher than measured for the 6°-baseline approach. A very small area directly beneath the flight path at 2600 feet up-range shows an increase of greater than 2 SELdB. Around this pocket of increased noise levels is an area where the levels have decreased by as much as 4 SELdB. The majority of the area contained in this footprint shows a noise reduction of between 4 and 6 SELdB with small pockets showing reductions of greater than 6 SELdB.

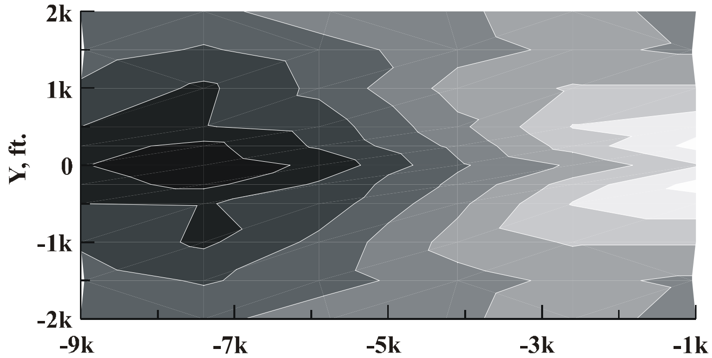
Figure 2-14b presents a footprint of the average SEL difference between the 3° to 9° segmented approach and the 6°-baseline approach. The figure shows areas of increased noise levels between 1000 and 3500 feet up-range, centered along lines 500 feet to either side of the flight track centerline. The level of noise reduction increases with increasing up-range distance with the maximum noise reductions occurring along the flight path centerline. A maximum noise reduction of greater than 10 SELdB is shown along the flight path centerline between about 6300 and 8800 feet up-range.

2.2.2.4 <u>*Average Sound Exposure Levels*</u>

A more quantitative assessment of the noise reductions is presented in Figure 2-15. This figure presents the difference between the average SEL for the 6° approach and the average SEL for the two "quiet" approach profiles of Figure 2-10, for a number of different microphone groups, as labeled directly beneath the bar graph. A negative ΔAVGSEL means that the average SEL has been reduced compared to the 6°-baseline approach. Compared to the 6°-baseline approach, the 3° approach provides nearly 4½ SELdB noise reduction and the 3° to 9° approach provides about 3.8 SELdB noise reduction when averaged over all the microphones used during this test (far left bars, labeled "All"). Moving from left to right in the figure, the next pair of bars show that the 3° to 9° approach provides the greatest noise reduction along the centerline, almost 6 SELdB, compared to about 2.5 SELdB for the 3° approach. Averaging the centerline microphones located between 4000 and 9000 feet up-range, the 3° to 9° approach provides nearly 9 SELdB noise reduction while the 3° approach provides only 3.7 SELdB noise reduction. The next four pairs of bars show the average noise reduction starting at the far end of the noise footprint (9000 feet up-range), progressively including areas closer to the landing point with each successive pair. The first pair averages the SEL from the microphones in the two farthest up-range lines of microphones, located 9000 and 7400 feet up-range. Each of the next three pairs progressively includes the next line of microphones closer to the landing point (5800, 4200, and 2600 feet up-range). This set shows the trend of decreasing noise reduction with increasing area when starting at the end of the noise footprint farthest from landing point. The 3° to 9° approach provides an average of 7.4 SELdB noise reduction when including the area from 7400 to 9000 feet up-range,



a) 3° approach.



b) 3° to 9° approach.

Figure 2-14. Contours of the difference from the 6°-baseline approach SEL

and 4.7 SELdB noise reduction when including the area from 2600 to 9000 feet up-range. The 3° approach shows the same trend as the 3° to 9°approach over these same areas, but provides less noise reduction, decreasing from 5.2 SELdB to 4.3 SELdB noise reduction. The next set of four pairs of bars is similar to the previous set, except that it includes the areas starting closest to the landing point and progressive includes areas farther from the landing point, as indicated in the figure. The first pair, which includes the area from 1000 to 2600 feet up-range, shows that the 3° approach provided 4.2 SELdB noise reduction while the 3° to 9° approach had a slightly increased noise level. Noise reduction provided by the 3° to 9° approach increased with increasing up-range area with about 3.2 SELdB noise reduction over the area from 1000 to 7400 feet up-range. The 3° approach held a relatively constant noise reduction of about 4 SELdB over all the areas included in this set.

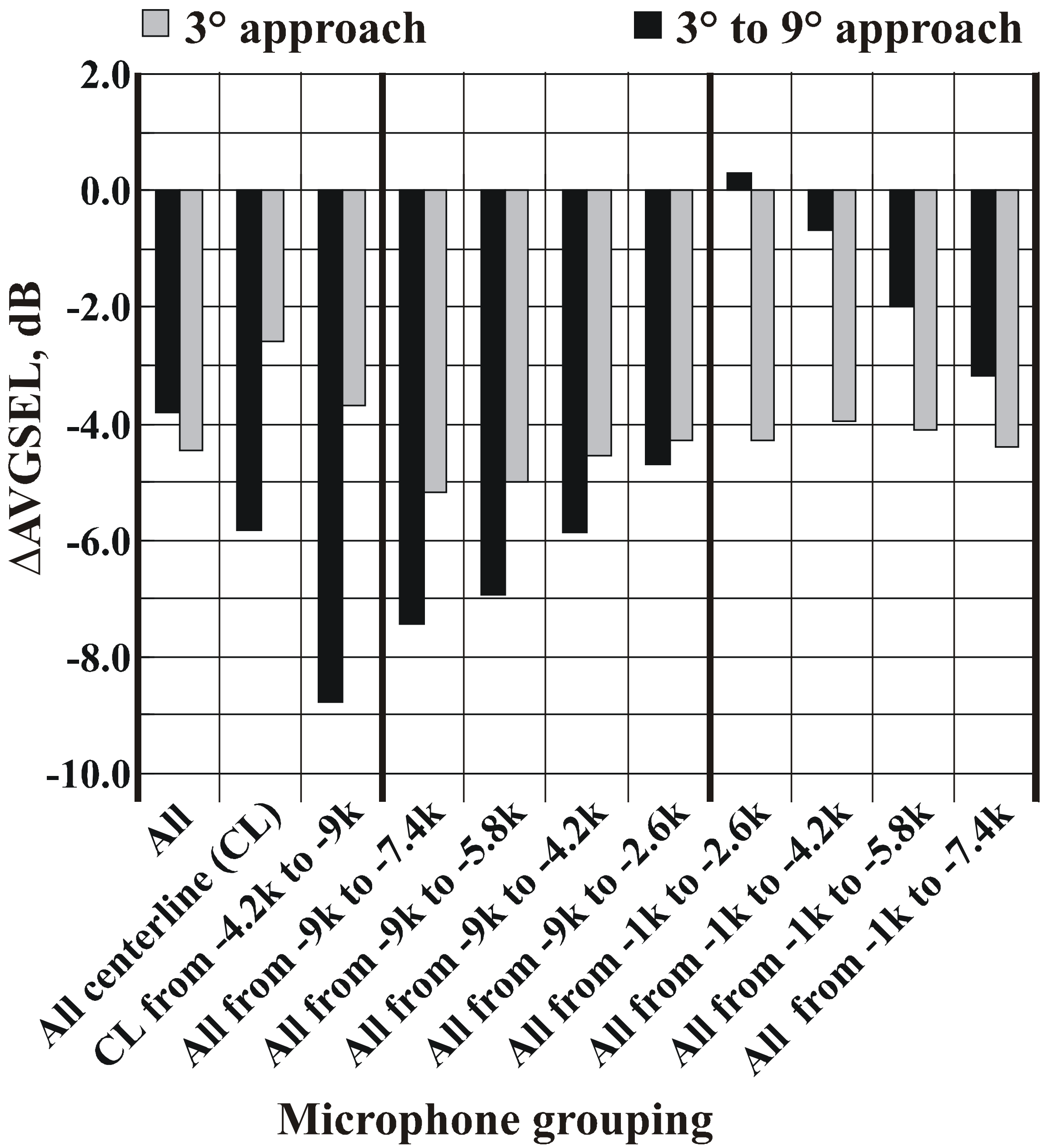


Figure 2-15. Contours of the difference from the 6°-baseline approach SEL

3. CONCLUSIONS AND RECOMMENDATIONS

Tiltrotor aircraft, with their unique capability to fly at relatively high cruise speeds like an airplane while maintaining the ability to takeoff and land vertically, provide a potential alternate means of transportation that could link major cities and alleviate some of the demand on airport runway usage. However, noise generated by large tiltrotors is a potential barrier issue for civil market penetration. To address the issue of noise reduction, NASA initiated an effort with the goal of reducing the overall tiltrotor approach noise within a 40-acre vertiport by 12 dB relative to then-current (1995) technology. The goal was to obtain half the noise reduction through design and half through operations. A series of three XV-15 acoustic flight tests have been conducted by a NASA/Army/Bell Helicopter team to evaluate the noise reduction potential during terminal area operations by altering the nacelle angle/airspeed/altitude schedule. The 1999 test described in this report was the third in this three-test series.

The approach profiles from the 1997 test that provided the greatest noise reduction were optimized and fully integrated with handling qualities considerations for testing during the 1999 test. In addition, the Rotorcraft Noise Model (RNM), a rotorcraft noise prediction tool developed by NASA, was linked to an optimizer to develop additional approach profiles. All of the approach profiles were designed to function as IFR approaches with the goal of achieving a handling qualities rating of three or better, which is sufficient for commercial passenger operations. The purpose was to demonstrate an integrated system approach and to quantify the noise reductions provided by these approach profiles. The use of a 75° flap setting was found to greatly improve the XV-15 handling quality characteristics during the steep, low-powered descent conditions that occurred during many of the approach profiles. This relatively high-angle setting had not been commonly used prior to this test, but shows promise as a way to achieve an acceptable pitch attitude during steep approaches. It may also allow the nacelle angle to be reduced somewhat, resulting in reduced noise level. Compared to the 6° baseline approach profile, the 3° approach profile provided a relatively uniform 4 to 6 SELdB noise reduction over much of the measurement area. The 3° to 9° approach profile provided the greatest noise reductions on the flight path centerline and for the farther up-range measurement areas. Nearly 6 SELdB noise reduction was measured when averaged over all the centerline microphones (between 1000 and 9000 feet up-range) while almost 9 SELdB noise reduction was measured when averaged over the centerline microphones located between 4200 and 9000 feet up-range. Greater than 10 SELdB noise reduction was measured on centerline for a small area between 6300 and 8800 feet up-range. More than 6 SELdB noise reduction was measured for much of the measurement area beyond 5000 feet up-range of the landing point. As a summary of the entire test series, this noise reduction and the associated flight procedure modifications are illustrated in Figure 3-1.

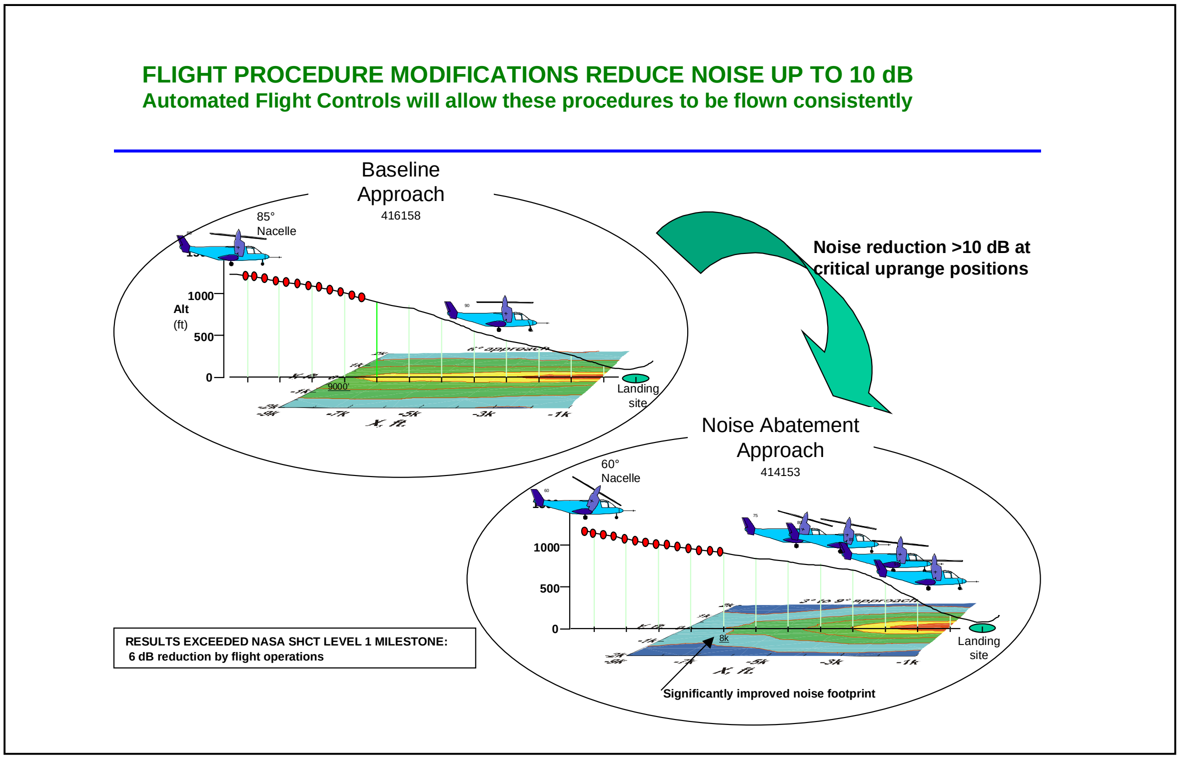


Figure 3-1. Illustration of noise reduction due to flight procedure modification

These tests indicate that there is no one single approach profile that is best for all landing sites. Rather, the approach profile can and should be tailored to the type of landing site. For instance, if the landing site is located on the top of a building in the center of a city, it might be appropriate to use a 3° approach profile since it provides the most uniform noise abatement over the entire noise footprint. However, if the landing point has a 2000 to 3000 foot buffer zone which is surrounded by a noise-sensitive area, then a 3° to 9° approach profile may be more appropriate, as it provides the greatest noise reductions beyond the buffer zone even while generating increased levels within the non-noise-sensitive buffer area.

In this and the 1997 test, the profiles were flown as "Instrument Flight Rules" (IFR) approaches using the newly developed flight director. This allowed much more repeatable, precise profiles, but ones that were necessarily limited by the pilot's IFR workload. To allow enough time for the pilot to assimilate the flight director's visual cues and translate them into control inputs, a 5 second time delay, or buffer, had to be allowed for after each pilot instruction. This buffer produced elongated approaches compared to “Visual Flight Rules” (VFR) approaches, where the aircraft can remain in the relatively quiet Low-nacelle flight regime until very near the landing point. In the next few years, as advanced DGPS based guidance systems are directly coupled to the aircraft control systems thus reducing the pilot workload, precise, repeatable approaches will be possible in a shorter time/distance interval, as illustrated in Figure 3-2. This will allow approaches that *tend* more toward the shorter VFR-type approaches. Civil tiltrotor operations will make use of the information derived from both VFR- and IFR-type acoustic testing to combine handling qualities and acoustic constraints in a highly efficient manner, thus allowing the noise reduction potential of the tiltrotor to be applied in precise, repeatable approaches, providing environmental benefits to the public.

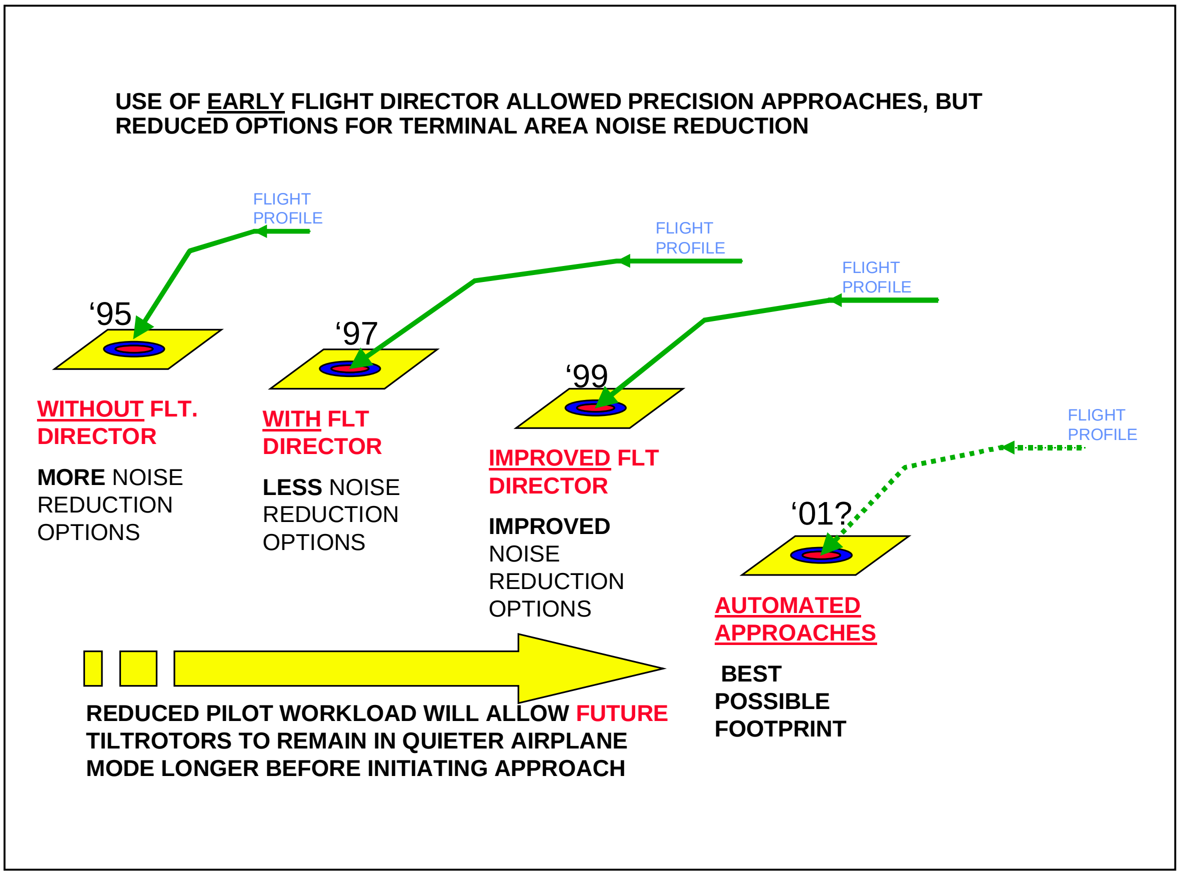


Figure 3-2. Evolution of flight director and its effects on flight profile and noise abatement

Recommendations

Since the conclusion of this test series in 1999, the XV-15 has been fitted with the capability of performing automated approaches. This capability, while still in the developmental stage, now allows the direct control coupling discussed above. It is now possible to program a noise abatement approach into the XV-15 flight control computer. An additional XV-15 flight test would demonstrate the acoustic benefits and reduced pilot workload that will characterize future tiltrotor operations.

With a focus on tiltrotor operations at airports, the test would include Short Takeoff or Landing (STOL) operations and transient maneuvers as well as the automated approach operations. This one final XV-15 test would take advantage of this premier testbed aircraft in its most advanced configuration, providing acoustic data most representative of the low-noise potential of future tiltrotors. Due to budgetary constraints and XV-15 availability, it is unlikely that this test will be conducted.

4. REFERENCES

1) Maisel, M. D., “XV-15 Tiltrotor Aircraft Research Aircraft Familiarization Document,” NASA TMX-62, 407, January 1975.

2) Edwards, Bryan D, “External Noise of the XV-15 Tiltrotor Aircraft,” NASA Contractor Report 187463, May 1991.

3) Edwards, Bryan D, “XV-15 Low-Noise Terminal Area Operations Testing,” NASA Contractor Report 206946, February 1998.

4) Klein, P.D., and Nicks, C.O., “Flight Director and Approach Profile Development for Civil Tiltrotor Terminal Area Operations,” Presented at the American Helicopter Society 54th Annual Forum, Washington, DC, May 1998.

5) Decker, W. A., “Piloted Simulator Investigations of a Civil Tilt-Rotor Aircraft on Steep Instrument Approaches,” AHS 48th Annual Forum, Washington, DC, June 1992.

6) Gray, D., Wright, K., and Rowland, W., “A Field-Deployable Digital Acoustic Measurement System,” Presented at Technology 2000 (Proceedings published as NASA CP 3109, Vol.2), Washington, DC, November 27-28, 1990.

7) Lucas, M.J., and Marcolini, M.A., “Rotorcraft Noise Model,” Presented at the AHS Technical Specialists’ Meeting for Rotorcraft Acoustics and Aerodynamics, Williamsburg, VA, October 28-30, 1997.

8) Conner, David A., et al., “XV-15 Tiltrotor Low-Noise Approach Procedures,” presented at the AHS 55th Annual Forum, Montreal, Quebec, Canada, May, 1999.

9) Conner, David A., et al., “NASA/Army/Bell XV-15 Tiltrotor Low Noise Terminal Area Operations Flight Research Program,” AIAA-2000-1923, presented at the 6th AIAA/CEAS Aeroacoustics Conference, Lahaina, Hawaii, June 12-14, 2000.

10) Edwards, Bryan D., “NASA/Army/Bell XV-15 Tiltrotor Noise Abatement by Modified flight Procedures,” AHS Tiltrotor/Runway Independent Aircraft Technology and Applications, Arlington, Texas, May 20, 21, 2001.

This page intentionally left blank

APPENDIX A

LIST OF TEST PERSONNEL

Table A1. Tiltrotor Noise Test Personnel

October 1999 @ SSC, Waxahachie, Texas

Association	First Name	Last Name	Responsibilities During Test
Bell	Royce	Snider	Acoustics
Bell	Sandy	Liu	Acoustics
Bell	Rick	Riley	Acoustics
Bell	Kelly	Spivey	Data Operations
Bell	Mark	Stoufflet	Data Operations
Bell	Jim	Wilson	Dynamics
Bell	Bill	Martin	Flight Test Engineer
Bell	Alan	Adamson	Instrumentation
Bell	Helmuth	Koeltzer	Handling Qualities
Bell	Jerry	Pickard	Military Tech Support
Bell	John	Ball	Pilot
Bell	Roy	Hopkins	Pilot
Bell	Ron	Williamson	Project Engineer - Flight Test
Bell	Bryan	Edwards	Project Engineer -Acoustics
Bell	John	Papan	XV-15 Support Crew
Bell	Harry	Aurand	XV-15 Support Crew
Bell	Buck	Bullock	XV-15 Support Crew
Bell	Randy	Taiclet	XV-15 Support Crew
Bell	Jim	Chicwitz	Quality
Lockheed	Charlie	Smith	NASA- LaRC Data Analysis
NASA-Ames	Bill	Decker	Handling Qualities
AMCOM-JRPO	David	Conner	Project Manager/Engineer
NASA-LaRC	Michael	Marcolini	Advisor
NASA-LaRC	Odilyn	Santa Maria	Project Engineer
Wyle Labs	Tom	Baxter	NASA Acoustic Instrumentation
Wyle Labs	Nicholas	Karangelen	NASA Acoustic Instrumentation
Wyle Labs	Virgilio	Marcelo	NASA Acoustic Instrumentation
Wyle Labs	Keith	Scudder	NASA Acoustic Instrumentation
Wyle Labs	John	Swain	NASA Acoustic Instrumentation
Wyle Labs	Diane	Suever	NASA Acoustic/Weather Instru.

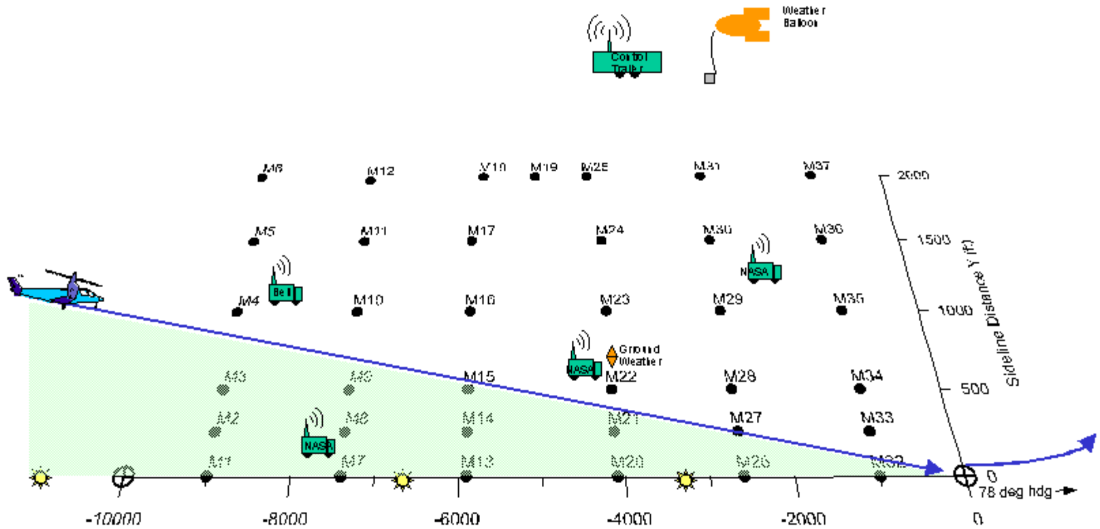
APPENDIX B

MICROPHONE LOCATIONS – SURVEYED POINTS

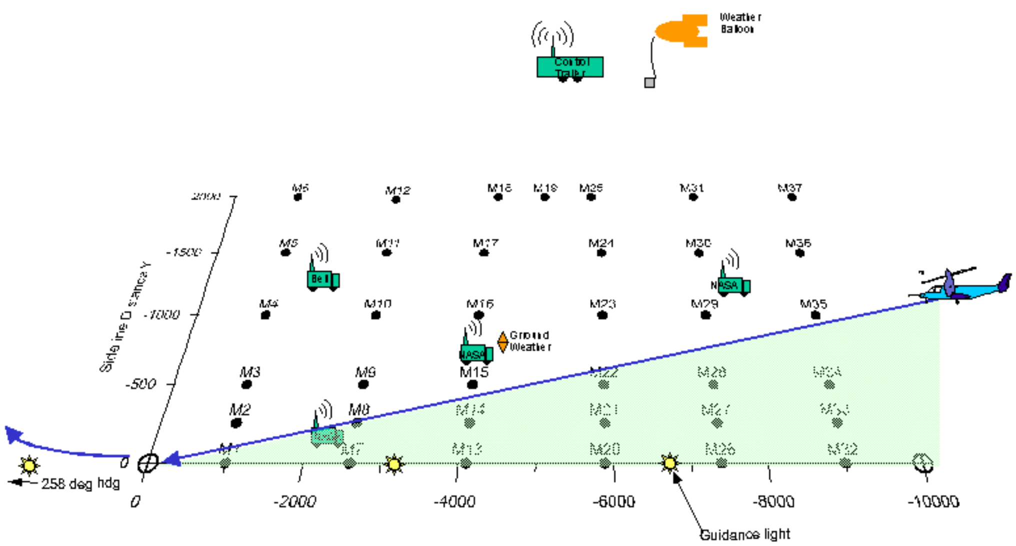
Table B-1. Microphone Positions And Test Site Coordinates

LOCATION	XGRID	YGRID	ZGRID	<<<<<<<LATITUDE >>>>>>>>>				<<<<<<<< LONGITUDE >>>>>>				ELEV	XGRID	YGRID	ZGRID
NUMBER	(ft)	(ft)	(ft)	DIR	DEG	MIN	SEC	DIR	DEG	MIN	SEC	(ft)	(ft)	(ft)	(ft)
	EAST TO WEST APPROACHES												WEST TO EAST APPROACHES		
WestPad	0	0	0	N	32	19	03.696	W	096	56	5.247	667	-10000	0	0
M1	-1000	0	0	N	32	19	04.000	W	096	55	53.600	651	-9000	0	0
M2	-1000	-250	0	N	32	19	06.473	W	096	55	53.689	658	-9000	250	0
M3	-1000	-500	0	N	32	19	08.945	W	096	55	53.779	662	-9000	500	0
M4	-1000	-1000	0	N	32	19	13.890	W	096	55	53.958	665	-9000	1000	0
M5	-1050	-1500	0	N	32	19	18.850	W	096	55	53.554	671	-8950	1500	0
M6	-1000	-2000	0	N	32	19	23.780	W	096	55	54.316	666	-9000	2000	0
M7	-2600	0	0	N	32	19	04.486	W	096	55	34.965	657	-7400	0	0
M8	-2600	-250	0	N	32	19	06.958	W	096	55	35.054	655	-7400	250	0
M9	-2600	-500	0	N	32	19	09.431	W	096	55	35.144	655	-7400	500	0
M10	-2600	-1000	0	N	32	19	14.376	W	096	55	35.322	660	-7400	1000	0
M11	-2600	-1500	0	N	32	19	19.321	W	096	55	35.501	660	-7400	1500	0
M12	-2600	-1975	0	N	32	19	24.019	W	096	55	35.671	652	-7400	1975	0
M13	-4100	0	0	N	32	19	04.941	W	096	55	17.495	663	-5900	0	0
M14	-4100	-250	0	N	32	19	07.413	W	096	55	17.584	661	-5900	250	0
M15	-4100	-500	0	N	32	19	09.886	W	096	55	17.673	660	-5900	500	0
M16	-4100	-1000	0	N	32	19	14.831	W	096	55	17.852	667	-5900	1000	0
M17	-4100	-1500	0	N	32	19	19.776	W	096	55	18.030	673	-5900	1500	0
M18	-4250	-2000	0	N	32	19	24.766	W	096	55	16.461	675	-5750	2000	0
M19	-5000	-2000	0	N	32	19	24.993	W	096	55	7.726	649	-5000	2000	0
M20	-5900	0	0	N	32	19	05.486	W	096	54	56.530	650	-4100	0	0
M21	-5900	-250	0	N	32	19	07.958	W	096	54	56.619	650	-4100	250	0
M22	-5900	-500	0	N	32	19	10.431	W	096	54	56.709	651	-4100	500	0
M23	-5900	-1000	0	N	32	19	15.376	W	096	54	56.887	659	-4100	1000	0
M24	-5900	-1500	0	N	32	19	20.321	W	096	54	57.065	670	-4100	1500	0
M25	-5750	-2000	0	N	32	19	25.220	W	096	54	58.990	672	-4250	2000	0
M26	-7400	0	0	N	32	19	05.939	W	096	54	39.060	646	-2600	0	0
M27	-7400	-250	0	N	32	19	08.411	W	096	54	39.149	647	-2600	250	0
M28	-7400	-500	0	N	32	19	10.884	W	096	54	39.238	648	-2600	500	0
M29	-7400	-1000	0	N	32	19	15.829	W	096	54	39.416	649	-2600	1000	0
M30	-7400	-1500	0	N	32	19	20.774	W	096	54	39.594	654	-2600	1500	0
M31	-7400	-2000	0	N	32	19	25.719	W	096	54	39.771	656	-2600	2000	0
M32	-9000	0	0	N	32	19	06.422	W	096	54	20.425	641	-1000	0	0
M33	-9000	-250	0	N	32	19	08.894	W	096	54	20.514	642	-1000	250	0
M34	-9000	-500	0	N	32	19	11.367	W	096	54	20.602	645	-1000	500	0
M35	-9000	-1000	0	N	32	19	16.312	W	096	54	20.780	647	-1000	1000	0
M36	-8950	-1500	0	N	32	19	21.242	W	096	54	21.540	650	-1050	1500	0
M37	-9000	-2000	0	N	32	19	26.202	W	096	54	21.135	655	-1000	2000	0
EastPad	-10000	0	0	N	32	19	06.723	W	096	54	8.778	650	0	0	0
Control HQ				N	32	20	06.293	W	096	54	54.365	723			
NASA Van1	-8025	-1255	0	N	32	19	18.540	W	096	54	32.227	656	-1975	1255	0
NASA Van2	-5675	-695	0	N	32	19	12.291	W	096	54	59.399	648	-4325	695	0
NASA Van 3	-3100	-130	665	N	32	19	05.668	W	096	55	28.956	665	-6900	130	665
Bell Van	-1250	-1100	650	N	32	19	15.321	W	096	55	49.330	650	-8750	1100	650
Light 1	800	0	0	N	32	19	03.453	W	096	56	14.564	672	-10800	0	0
Light 2	-3400	0	0	N	32	19	04.728	W	096	55	25.648	667	-6600	0	0
Light 3	-6600	0	0	N	32	19	05.697	W	096	54	48.378	663	-3400	0	0

NOTE: POSITIVE X IS IN DIRECTION OF FLIGHT
POSITIVE Y IS PORT SIDE (Right Hand Rule)
POSITIVE Z IS UP (Right Hand Rule)



a) East-bound approaches



b) West-bound approaches

Figure B-1. Test site layout and microphone array

This page intentionally left blank

APPENDIX C
METEOROLOGICAL CONDITIONS

Table C-1. Weather for XV-15 Testing

				Balloon-based Meteorological Data								Ground-based (17 ft AGL)		
				BALLOON ALTITUDE			PRESS	TEMP	RH	WIND		WIND		TEMP
Test Date	FLT	RUN	Ship Rec #	min ft	avg ft	max ft	in Hg	°F	%	speed kt	direction deg	speed kt	direction deg	°F
10/6	409	106	4	499	512	528	28.85	66	44	11	113			
10/6	409	107	5	361	381	407	28.98	67	41	13	119			
10/6	409	108	6	20	481	1204	28.95	67	50	11	177			
10/6	409	109	8	718	808	902	28.55	67	39	10	143			
10/6	409	110	9	764	835	895	28.52	67	40	11	100			
10/6	409	111	10	466	534	604	28.83	69	38	9	122			
10/6	409	112	11	157	222	289	29.15	71	35	10	142			
10/6	409	113	12	112	119	121	29.25	72	33	10	125			
10/7	410	114	2	361	366	374	28.83	61	46	19	135	7	75	53
10/7	410	115	5	695	737	768	28.45	64	41	15	153	6	93	57
10/7	410	116	6	797	810	827	28.38	64	39	18	143	6	119	59
10/7	410	117	7	725	743	768	28.44	64	40	16	142	6	123	60
10/7	410	118	8	636	655	676	28.53	64	43	15	142	8	131	61
10/7	410	119	9	466	500	544	28.69	64	46	14	135	8	138	62
10/7	410	120	10	279	317	351	28.88	62	46	13	139	7	143	63
10/7	410	121	11	89	125	161	29.08	63	46	7	115	7	139	64
10/7	410	122	12	184	261	335	28.94	62	46	8	154	6	136	65
10/7	410	123	13	548	598	643	28.59	64	42	14	156	7	143	66
10/8	411	124	8	-	-	-	-	-	-	-	-	3	251	61
10/8	411	125	9	-	-	-	-	-	-	-	-	2	215	62
10/8	411	126	10	-	-	-	-	-	-	-	-	2	213	63
10/8	411	127	11	-	-	-	-	-	-	-	-	4	238	63
10/8	411	128	15	331	502	672	30.87	69	65	6	316	4	217	70
10/8	411	129	16	505	762	948	28.37	71	61	8	309	3	165	72
10/8	411	130	22	544	580	617	28.55	74	58	6	305	4	122	79
10/8	411	131	23	210	244	269	28.89	77	55	5	53	3	85	79
10/8	411	132	24	138	208	279	28.93	77	54	5	49	5	38	79

Table C-1. Weather for XV-15 Testing (Continued)

				Balloon-based Meteorological Data									Ground-based (17 ft AGL)		
				BALLOON ALTITUDE			PRESS	TEMP	RH	WIND			WIND		TEMP
Test			Ship Rec	min	avg	max				speed	direction		speed	direction	
Date	FLT	RUN	#	ft	ft	ft	in Hg	°F	%	kt	deg		kt	deg	°F
10/11	412	137	6	0	32	102	29.41	72	73	5	67		-	-	-
10/11	412	138	7	554	668	781	28.80	71	69	10	115		-	-	-
10/11	412	139	8	738	824	905	28.56	71	66	12	86		-	-	-
10/11	412	140	9	203	305	403	29.08	71	72	7	82		-	-	-
10/12	413	141	2	492	549	607	28.86	71	64	14	145		5	25	67
10/12	413	142	3	0	20	79	29.44	66	85	4	38		5	27	67
10/12	413	143	4	171	262	351	29.21	70	75	8	136		5	32	68
10/12	413	144	5	827	903	981	28.56	71	65	11	153		5	42	69
10/12	413	145	6	361	449	528	28.95	71	67	12	145		5	54	69
10/12	413	146	7	161	241	321	29.23	71	72	6	132		5	63	70
10/12	413	147	8	761	823	889	28.63	71	64	12	163		5	71	71
10/12	413	148	9	551	621	689	28.78	70	67	13	153		5	91	72
10/13	414	149	9	538	637	728	28.67	75	51	17	261		7	246	75
10/13	414	150	10	0	26	98	29.33	74	57	8	291		6	258	75
10/13	414	151	11	768	872	984	28.52	76	49	13	241		7	235	76
10/13	414	152	12	561	663	761	28.64	76	49	15	253		6	253	77
10/13	414	153	13	0	40	154	29.26	75	52	11	282		6	254	78
10/13	414	154	14	338	444	544	28.99	75	52	11	261		8	244	79
10/13	414	155	15	951	1050	1122	28.38	76	47	12	250		7	233	80
10/20	416	156	2	282	552	820	29.20	59	35	8	330		-	-	-
10/20	416	157	3	479	739	1004	28.78	59	33	3	28		-	-	-
10/20	416	158	4	0	116	262	29.59	55	48	12	314		-	-	-
10/20	416	159	5	479	711	941	29.02	58	35	6	330		-	-	-
10/20	416	160	6	1027	1204	1328	28.36	58	30	4	70		-	-	-
10/20	416	161	7	144	437	728	29.07	59	35	6	309		-	-	-
10/20	416	162	8	102	316	538	29.43	58	40	12	319		-	-	-
10/20	416	163	9	722	887	1007	28.77	59	31	2	87		-	-	-
10/20	416	164	10	305	458	695	29.09	59	34	5	333		7	297	58

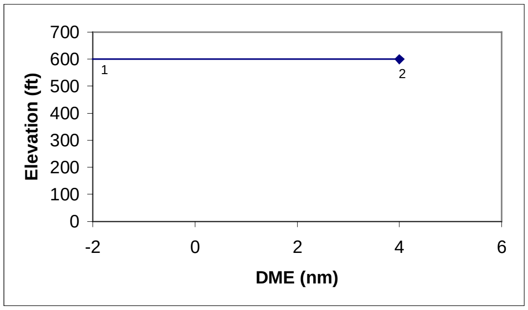
Table C-1. Weather for XV-15 Testing (Concluded)

				Balloon-based Meteorological Data								Ground-based (17 ft AGL)		
				BALLOON ALTITUDE			PRESS	TEMP	RH	WIND		WIND		TEMP
Test			Ship Rec	min	avg	max				speed	direction	speed	direction	
Date	FLT	RUN	#	ft	ft	ft	in Hg	°F	%	kt	deg	kt	deg	°F
10/20	416	170	24	-	-	-	-	-	-	-	-	3	237	68
10/20	416	171	25	-	-	-	-	-	-	-	-	4	169	68
10/20	416	172	26	-	-	-	-	-	-	-	-	3	114	68
10/21	417	173	2	197	208	223	29.30	61	31	22	232	4	232	51
10/21	417	174	3	197	206	226	29.30	60	31	20	229	5	227	52
10/21	417	175	4	194	206	220	29.31	61	30	22	231	4	229	53
10/21	417	176	5	210	217	230	29.29	60	31	21	233	5	237	54
10/21	417	177	6	213	226	239	29.29	60	31	21	235	5	226	55
10/21	417	178	7	230	239	253	29.27	60	31	21	232	5	228	55
10/21	417	179	8	213	253	269	29.25	60	29	21	229	5	226	56

APPENDIX D

CANDIDATE FLIGHT PLANS

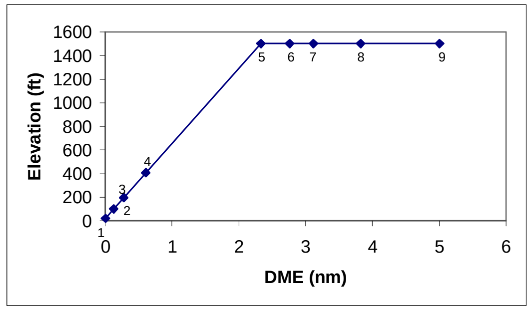
Note: Flight Plan numbering system corresponds to “profile” number in appendix E test log.



Flight Plan 1 / 2
Housekeeping

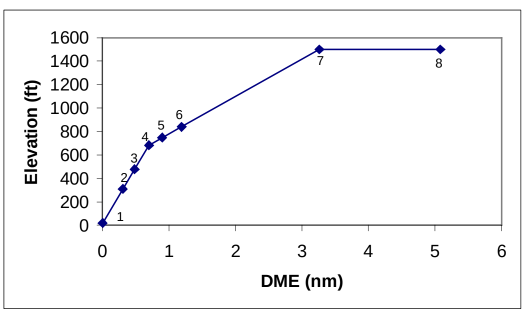
Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
2	4.0	60	90	Initialize at 60 deg, 90 kts, 20 deg flaps
1	-2.0	60	90	

Note: DME stands for Distance Measuring Equipment. For all the plots of Appendix D, DME represents the distance to the target landing point.



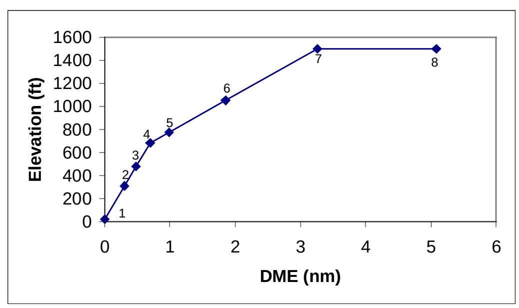
Flight Plan 3 / 4
6 deg Baseline

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
9	5.0	60	110	Initialize at 60 deg, 110 kts, 40 deg flaps
8	3.8	75	90	Begin decel to 90, convert to 75 deg
7	3.1	80	80	Begin decel to 80, convert to 80 deg
6	2.8	85	70	Begin decel to 70, convert to 85 deg
5	2.3	90	70	Transition to 6 deg, convert to 90 deg
4	0.6	90	50	Begin decel to 50
3	0.3	90	30	Begin decel to 30
2	0.1	90	0	Begin decel to 0
1	0.0	90	0	



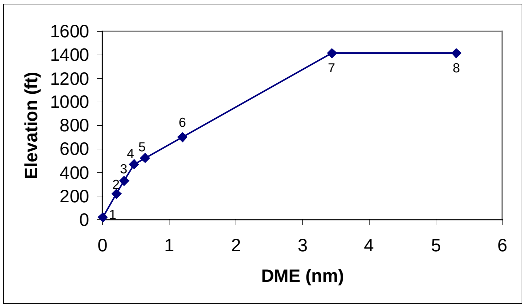
Flight Plan 5 / 6
3 to 9 deg version E

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
8	5.1	60	90	Initialize at 60 deg, 90 kts, 40 deg flaps
7	3.3	60	90	Transition to 3 deg
6	1.2	75	75	Begin decel to 75, convert to 75 deg
5	0.9	80	70	Begin decel to 70, convert to 80 deg
4	0.7	80	70	Transition to 9 deg
3	0.5	85	50	Begin decel to 50, convert to 85 deg
2	0.3	90	0	Begin decel to 0, convert to 90 deg
1	0.0	90	0	



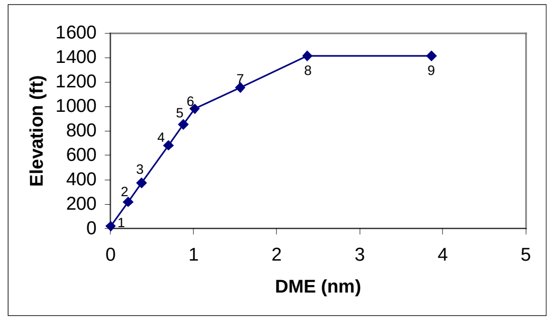
Flight Plan 7 / 8
3 to 9 deg version F

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
8	5.1	60	90	Initialize at 60 deg, 90 kts, 40 deg flaps
7	3.3	60	90	Transition to 3 deg
6	1.9	75	80	Begin decel to 80, convert to 75 deg
5	1.0	80	70	Begin decel to 70, convert to 80 deg
4	0.7	80	70	Transition to 9 deg
3	0.5	85	50	Begin decel to 50, convert to 85 deg
2	0.3	90	0	Begin decel to 0, convert to 90 deg
1	0.0	90	0	



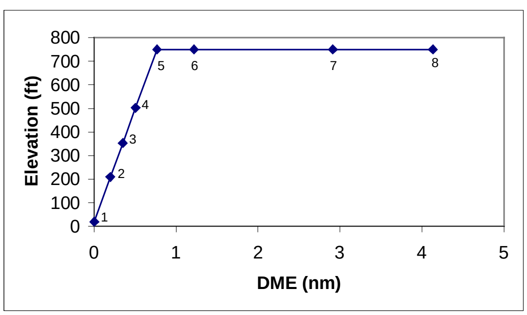
Flight Plan 9 / 10
3 to 9 deg rep

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
8	5.3	60	80	Initialize at 60 deg, 80 kts, 40 deg flaps
7	3.4	60	80	Transition to 3 deg
6	1.2	75	55	Begin decel to 55, convert to 75 deg
5	0.6	80	48	Begin decel to 48, convert to 80 deg
4	0.5	80	48	Transition to 9 deg
3	0.3	85	39	Begin decel to 39, convert to 85 deg
2	0.2	90	0	Begin decel to 0, convert to 90 deg
1	0.0	90	0	



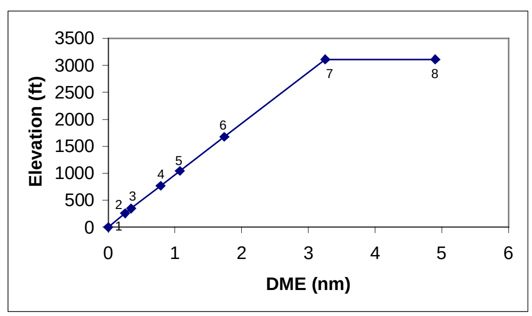
Flight Plan 11 / 12
3 to 9 deg mod C

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
9	3.9	60	100	Initialize at 60 deg, 100 kts, 40 deg flaps
8	2.4	60	100	Transition to 3 deg
7	1.6	75	80	Begin decel to 80, convert to 75 deg
6	1.0	75	80	Transition to 9 deg
5	0.9	80	70	Begin decel to 70, convert to 80 deg
4	0.7	85	60	Begin decel to 60, convert to 85 deg
3	0.4	85	50	Begin decel to 50
2	0.2	90	0	Begin decel to 0, convert to 90 deg
1	0.0	90	0	



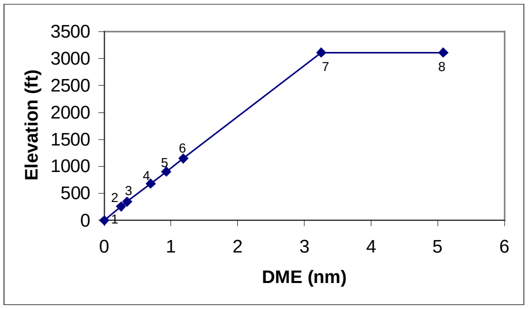
Flight Plan 13 / 14
9 deg from 750 ft

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
8	4.1	60	110	Initialize at 60 deg, 110 kts, 40 deg flaps
7	2.9	75	85	Begin decel to 85, convert to 75 deg
6	1.2	80	70	Begin decel to 70, convert to 80 deg
5	0.8	80	70	Transition to 9 deg
4	0.5	85	60	Begin decel to 60, convert to 85 deg
3	0.4	90	50	Begin decel to 50, convert to 90 deg
2	0.2	90	0	Begin decel to 0
1	0.0	90	0	



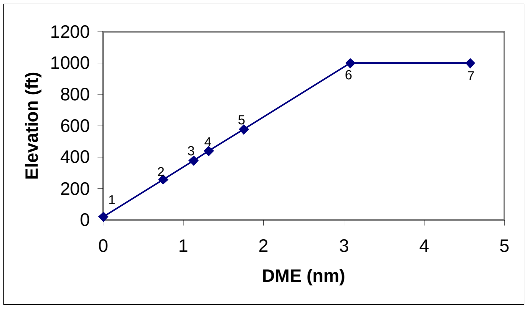
Flight Plan 15 / 16
9 deg .04 decel

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
8	4.9	60	100	Initialize at 60 deg, 100 kts, 40 deg flaps
7	3.3	60	100	Transition to 9 deg
6	1.7	75	80	Begin decel to 80, convert to 75 deg
5	1.1	80	70	Begin decel to 70, convert to 80 deg
4	0.8	85	50	Begin decel to 50, convert to 85 deg
3	0.3	90	50	Convert to 90 deg
2	0.3	90	0	Begin decel to 0
1	0.0	90	0	



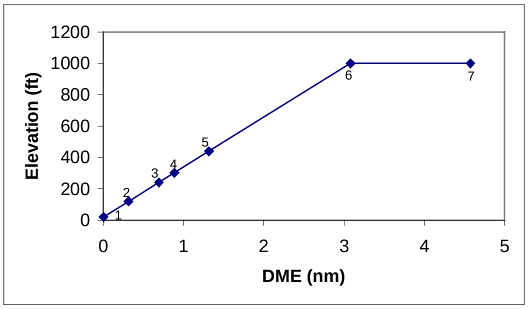
Flight Plan 17 / 18
9 deg .05 decel

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
8	5.1	60	90	Initialize at 60 deg, 90 kts, 40 deg flaps
7	3.3	60	90	Transition to 9 deg
6	1.2	75	80	Begin decel to 80, convert to 75 deg
5	0.9	80	70	Begin decel to 70, convert to 80 deg
4	0.7	85	50	Begin decel to 50, convert to 85 deg
3	0.3	90	50	Convert to 90 deg
2	0.3	90	0	Begin decel to 0
1	0.0	90	0	



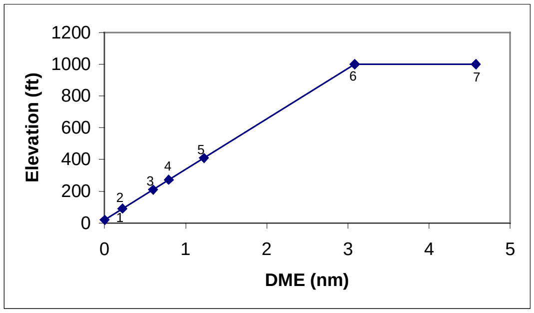
Flight Plan 19 / 20
3 deg

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
7	4.6	60	100	Initialize at 60 deg, 100 kts, 40 deg flaps
6	3.1	60	100	Transition to 3 deg
5	1.8	75	80	Begin decel to 80, convert to 75 deg
4	1.3	80	70	Begin decel to 70, convert to 80 deg
3	1.1	85	50	Begin decel to 50, convert to 85 deg
2	0.7	90	0	Begin decel to 0, convert to 90 deg
1	0.0	90	0	



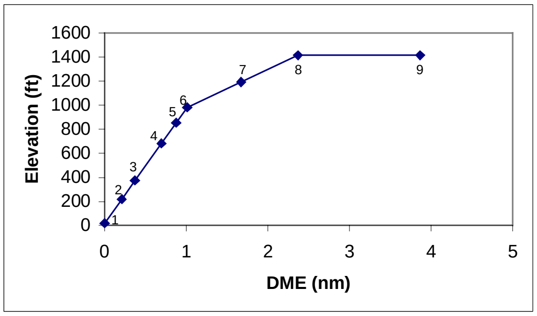
Flight Plan 21 / 22
3 deg B

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
7	4.6	60	100	Initialize at 60 deg, 100 kts, 40 deg flaps
6	3.1	60	100	Transition to 3 deg
5	1.3	75	80	Begin decel to 80, convert to 75 deg
4	0.9	80	70	Begin decel to 70, convert to 80 deg
3	0.7	85	50	Begin decel to 50, convert to 85 deg
2	0.3	90	0	Begin decel to 0, convert to 90 deg
1	0.0	90	0	



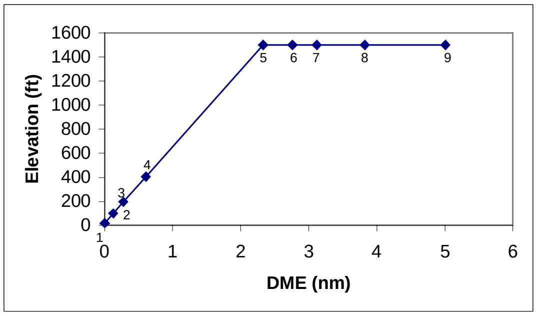
Flight Plan 23 / 24
3 deg C

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
7	4.6	60	100	Initialize at 60 deg, 100 kts, 40 deg flaps
6	3.1	60	100	Transition to 3 deg
5	1.2	75	80	Begin decel to 80, convert to 75 deg
4	0.8	80	70	Begin decel to 70, convert to 80 deg
3	0.6	85	50	Begin decel to 50, convert to 85 deg
2	0.2	90	0	Begin decel to 0, convert to 90 deg
1	0.0	90	0	



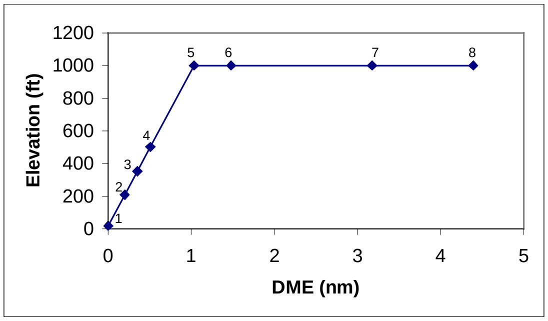
Flight Plan 25 / 26
3 to 9 deg mod C (2)

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
9	3.9	60	100	Initialize at 60 deg, 100 kts, 40 deg flaps
8	2.4	60	100	Transition to 3 deg
7	1.7	75	80	Begin decel to 80, convert to 75 deg
6	1.0	75	80	Transition to 9 deg
5	0.9	80	70	Begin decel to 70, convert to 80 deg
4	0.7	85	60	Begin decel to 60, convert to 85 deg
3	0.4	85	50	Begin decel to 50
2	0.2	90	0	Begin decel to 0, convert to 90 deg
1	0.0	90	0	



Flight Plan 27 / 28
6 deg Baseline (B)

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
9	5.0	60	110	Initialize at 60 deg, 110 kts, 40 deg flaps
8	3.8	75	90	Begin decel to 90, convert to 75 deg
7	3.1	80	80	Begin decel to 80, convert to 80 deg
6	2.8	85	70	Begin decel to 70, convert to 85 deg
5	2.3	90	70	Transition to 6 deg
4	0.6	90	50	Begin decel to 50, convert to 90 deg
3	0.3	90	30	Begin decel to 30
2	0.1	90	0	Begin decel to 0
1	0.0	90	0	



Flight Plan 29 / 30
9 deg from 1000 ft

Wpt.	Range (nm)	Nacelle (deg)	Gnd. Spd. (kts)	Comments
8	4.1	60	110	Initialize at 60 deg, 110 kts, 40 deg flaps
7	2.9	75	85	Begin decel to 85, convert to 75 deg
6	1.2	80	70	Begin decel to 70, convert to 80 deg
5	0.8	80	70	Transition to 9 deg
4	0.5	85	60	Begin decel to 60, convert to 85 deg
3	0.4	90	50	Begin decel to 50, convert to 90 deg
2	0.2	90	0	Begin decel to 0
1	0.0	90	0	

This page intentionally left blank

APPENDIX E

SEQUENTIAL LIST OF FLIGHTS CONDUCTED – TEST LOG

XV-15

Table E-1. Test Log – Sequential List of Test Conditions

Test Date	Flight	RUN	Profile	Ship Rec	Description	Comments	Sec from midnight, GMT Start	Sec from midnight, GMT Stop	Local Time Start hr	Local Time Start min	Local Time Start sec	Local Time Stop hr	Local Time Stop min	Local Time Stop sec
10/6/99	409	106	1	4	Housekeeping	Eastbound	56471	56662	10	41	11	10	44	22
10/6	409	107	3	5	6° Approach	Van 99 Jaz Drive locked up halfway through; M12 lost (Bell)	57015	57195	10	50	15	10	53	15
10/6	409	108	3	6	6° Approach	Van 99 and Van 71 Drives locked up; Swap drive to external in 99	57503	57665	10	58	23	11	1	5
10/6	409	109	3	8	6° Approach	All good except M12	58534	58758	11	15	34	11	19	18
10/6	409	110	13	9	9° Approach	M12 iffy	59010	59214	11	23	30	11	26	54
10/6	409	111	13	10	9° Approach		59457	59645	11	30	57	11	34	5
10/6	409	112	13	11	9° Approach		59881	60066	11	38	1	11	41	6
10/6	409	113	13	12	9° Approach	Van 71 locked up towards end of run	60334	60525	11	45	34	11	48	45
10/7	410	114	1	2	Housekeeping	Guidance iffy; AC sent back to refuel while troubleshooting	45919	46111	7	45	19	7	48	31
10/7	410	115	1	5	Housekeeping	60 Hz noise on M12 (Bell)	49275	49494	8	41	15	8	44	54
10/7	410	116	3	6	6° Approach	M26 failed, M12 noisy but 10 dB down	49788	50017	8	49	48	8	53	37
10/7	410	117	3	7	6° Approach	Van 71 has problems with Jaz Drv, recording on hard drive, 60 Hz+Birds on M12	50302	50530	8	58	22	9	2	10
10/7	410	118	3	8	6° Approach	M4 Overdriven (V71), M26 trouble light on (V72), M12 still has birds--Brian out to scare them off	50794	51019	9	6	34	9	10	19
10/7	410	119	5	9	3-9° Approach	M26, M19 (V72) bad on boxes but ok in Labview	51323	51507	9	15	23	9	18	27
10/7	410	120	5	10	3-9° Approach	Same problem w/ V72; Bell replace M12 cable, 60 Hz noise went down 5-6 dB	51819	52011	9	23	39	9	26	51
10/7	410	121	5	11	3-9° Approach	Van 72--Problems with M19, M20, also M26 but M26 okay on scan	52282	52497	9	31	22	9	34	57
10/7	410	122	19	12	3° Approach	M19 bad (V72), M13 overdriven (V99)	52780	52956	9	39	40	9	42	36
10/7	410	123	13	13	9° Approach	M19 bad, M20 had dropouts (V72)	53234	53423	9	47	14	9	50	23
10/8	411	124	1	8	Housekeeping, Eastbound	M5 (Bell) had dropouts	46037	46246	7	47	17	7	50	46
10/8	411	125	19	9	3° Approach	Van 71 Overdriven at end, M7 (V99) overdriven, pickup truck near Bell mics at end of run	46551	46779	7	55	51	7	59	39
10/8	411	126	19	10	3° Approach	M21 (V72) Overdriven	47056	47280	8	4	16	8	7	60
10/8	411	127	9	11	3-9° Approach	M23 Overdriven at end (V72)	47558	47810	8	12	38	8	16	50
10/8	411	128	2	15	Housekeeping, Westbound		51653	51890	9	20	53	9	24	50
10/8	411	129	10	16	3-9° Approach, Westbound	Aborted, origin not shifted in guidance			9	31	55	9	34	55
10/8	411	130	10	22	3-9° Approach, Westbound	Jet A/C in vicinity during run	56507	56759	10	41	47	10	45	59
10/8	411	131	12	23	3-9° Approach, Westbound		57109	57306	10	51	49	10	55	6
10/8	411	132	12	24	3-9° Approach, Westbound	Chip indicator on	57592	57787	10	59	52	11	3	7
10/11	412	133	1	2	Housekeeping, Eastbound		49795	50012	8	49	55	8	53	32
10/11	412	134	17	3	9° Approach	Bird noise on M12	50323	50514	8	58	43	9	1	54
10/11	412	135	17	4	9° Approach	Lost M17 (Van 99) about halfway through	50807	51016	9	6	47	9	10	16
10/11	412	136	15	5	9° Approach		51326	51524	9	15	26	9	18	44
10/11	412	137	15	6	9° Approach		51846	52051	9	24	6	9	27	31
10/11	412	138	7	7	3-9° Approach	Mic 7 Overdriven (V99), Birds on M12	52354	52567	9	32	34	9	36	7
10/11	412	139	7	8	3-9° Approach	Birds on M12	52856	53068	9	40	56	9	44	28
10/11	412	140	9	9	3-9° Approach		53353	53593	9	49	13	9	53	13

Table E-1. Test Log – Sequential List of Test Conditions

Test Date	Flight	RUN	Profile	Ship Rec	Description	Comments	Sec from midnight, GMT		Local Time					
									hr	min	sec	hr	min	sec
							Start	Stop	Start			Stop		
10/12	413	141	1	2	Housekeeping	Talking heard on M35 (V71)	48743	48963	8	32	23	8	36	3
10/12	413	142	9	3	3-9° Approach	Abort, bad TM			8	41	24	8	44	24
10/12	413	143	9	4	3-9° Approach	Mic 3 (Bell) out, will replace	49475	49703	8	44	35	8	48	23
10/12	413	144	9	5	3-9° Approach	75 Flap; Hammering on Mics 18,19,24,25 (V72) at beginning of run	49984	50221	8	53	4	8	57	1
10/12	413	145	9	6	3-9° Approach	40 Flap; Birds on M12 (Bell)	50512	50759	9	1	52	9	5	59
10/12	413	146	9	7	3-9° Approach	75 Flap; 1 dropout on M12 (Bell)	51038	51274	9	10	38	9	14	34
10/12	413	147	23	8	3° Approach		51574	51769	9	19	34	9	22	49
10/12	413	148	23	9	3° Approach		52064	52250	9	27	44	9	30	50
10/13	414	149	2	9	Housekeeping, Westbound	Fixed wing noise at beginning of run (Bell)	52141	52391	9	29	1	9	33	11
10/13	414	150	26	10	3-9° Approach		52736	52930	9	38	56	9	42	10
10/13	414	151	26	11	3-9° Approach	Birds on M12	53445	53638	9	50	45	9	53	58
10/13	414	152	4	12	6° Approach	Fixed wing noise at beginning of run (Bell)	53955	54178	9	59	15	10	2	58
10/13	414	153	6	13	3-9° Approach	**Birds on M12**	54494	54708	10	8	14	10	11	48
10/13	414	154	6	14	3-9° Approach	Birds on M12	55034	55261	10	17	14	10	21	1
10/13	414	155	8	15	3-9° Approach		55578	55781	10	26	18	10	29	41
10/20	416	156	2	2	Housekeeping, Westbound	Light AC in beginning (Bell)			8	33	20	8	36	20
10/20	416	157	28	3	6° Approach				8	41	53	8	44	53
10/20	416	158	28	4	6° Approach		49857	50090	8	50	57	8	54	50
10/20	416	159	30	5	9° Approach	Some fixed wing noise in the beginning (Bell)	50375	50587	8	59	35	9	3	7
10/20	416	160	30	6	9° Approach		50878	51099	9	7	58	9	11	39
10/20	416	161	14	7	9° Approach		51411	51615	9	16	51	9	20	15
10/20	416	162	2	8	Nacelle Conversion	Van 99 system went down	51956	52092	9	25	56	9	28	12
10/20	416	163	2	9	Nacelle Conversion		52454	52594	9	34	14	9	36	34
10/20	416	164	24	10	3° Approach	OD M7, M8, M13 (V99)	52915	53116	9	41	55	9	45	16
10/20	416	165	2	19	Housekeeping, Westbound		63461	63642	12	37	41	12	40	42
10/20	416	166	28	20	6° Approach	**Flaps at 75 (supposed to be 40)**	63965	64188	12	46	5	12	49	48
10/20	416	167	10	21	3-9° Approach		64499	64728	12	54	59	12	58	48
10/20	416	168	6	22	3-9° Approach		65027	65233	13	3	47	13	7	13
10/20	416	169	24	23	3° Approach	Fixed wing at end, Way off on lateral near end	65532	65708	13	12	12	13	15	8
10/20	416	170	24	24	3° Approach		66021	66207	13	20	21	13	23	27
10/20	416	171	20	25	3° VFR		66523	66692	13	28	43	13	31	32
10/20	416	172	2	26	Nacelle Conversion	Pilot abort, wrong altitude			13	36	4	13	39	4
10/21	417	173	2	2	Housekeeping, Westbound	Slight left crab, slight crosswind	46912	47122	8	1	52	8	5	21
10/21	417	174	2	3	Nacelle Conversion	M13 (V99) overdriven, Trucks on road @ beginning	47454	47597	8	10	54	8	13	17
10/21	417	175	28	4	6° Approach		47910	48142	8	18	30	8	22	22
10/21	417	176	24	5	3° Approach	M22 (V72) overdriven, M5 drove by at end (Bell)	48451	48636	8	27	31	8	30	36
10/21	417	177	24	6	3° VFR		49153	49360	8	39	13	8	42	40
10/21	417	178	10	7	3-9° Approach		49656	49891	8	47	36	8	51	31
10/21	417	179	26	8	3-9° Approach	Broke off before 100' AGL	50172	50357	8	56	12	8	59	17

This page intentionally left blank

APPENDIX F

PILOT COMMENTS

Pilot Comments Concerning Handling Qualities of Approaches

(Recorded immediately after each approach was completed)

Flight #/Run #

409106: Good approach. Everything within good restraints. Work load reasonable.

409107: "Overall performance better than yesterday (practice flight). Made a difference. I did a fairly adequate job keeping the cues lined up. Primary workload was power and roll not so much power today as it was. Sensitivity issue in command bar. Overall performance pretty good. Most objectionable part of approach was the last .1 mile. I got a nose up command and a lower power command. I didn't like the lower power command I was about 100 feet at that point and that's when I turned the data off. I thought it was not something I would have wanted to do….it helps if turn coordination was a little bit tighter if it was I would minimize my side slip which translates into an error."

409108: "same comments on that approach….Some side slip hurts me once I get below about 60 knots. My workload goes up with roll. I could see the effects in some of the crosswinds as we got lower. The intensity of crosswinds change dependent upon altitude. I could see how the corrections made in roll could compensate for that. Again didn't like from about .15 to about .2 to bring nose up is a command to lower the power. I would leave the power exactly where it is to control the rate of sink coming in to a hover."

409109: "same comments…except overall work load was up about a ½ HQR on this display I thought on the research display my accuracy level was improved. The size had something to do with it for one thing and I think I was picking up the drift a little better on the research display."

409110: "initially I don't know why it increased speed to what it did…picked up off the glide slope and then I was surprised it immediately put me into a pretty healthy rate of sink up to maybe 1500 ft a minute. Then it took it right back out so it was that initial amount that was very obvious. But at the bottom it wasn't quite as pat as I thought it would be. It called for a power increase and it slowed me down on my vertical rate of sink a little bit."

409111: "I stayed on top of the cues a little better that time but there's still a power reduction required. Any time you get that low you can hear the governor working and you can feel some buffeting vibrations increase in the aircraft. I think the pitch work load goes up a little more when we're in situations like this as well. Both times I've ended up short. That last tenth of a mile needs to be smoothed out. They have come up short of the truck (landing point)."

409112: They said they wanted to do another one. They weren't set up well for that one.

409113: “Oscillatory response on power lever and the last few tenths of a mile and raising that nose to slow down. We’re fairly nose high when we come in there slowing down and the arresting the closure rate and just from a comfort rate its dynamic quality is pulling…its not the most desirable way to shoot this approach. Overall: rushed too much. Too much work load on the power. Having the attitude system on does improve the turn coordination but there’s other issues with that attitude system that is somewhat negative as well that we need to tune out, but it did improve the turn coordination.”

410115: “Comfortable reference point work load HQR 3 and all constraints easily met. Biggest workload was due to drift correction and that would be a roll axis. Other than that everything was real nice.”

410116: “Very comfortable taking it to 50 ft. Everything seemed to be a little bit quieter. It was the air quality. Need to work more in roll because the cross wind not getting the turbulence and the pitch axis which impacts the vertical cueing. Everything was pretty well regulated right up to the bottom it was very comfortable down to 50ft today.”

410117: “Same comments. Workload was a little bit, but it wasn’t too objectionable. The highest work load was the roll and drift control. Right there at the bottom, I wish the sink rate was a little bit more. There is a command that is given to take a little bit of power off and I don’t think we should be doing that… I think we should be increasing it a little bit and cutting that sink rate more predictably down into a hover. I got off on cueing about 50 feet today.”

410118: “Only thing I don’t like on that approach is that from a couple tenths in when they start giving the command to raise the nose, I don’t like that rate of sink. Coming in it tends to start picking up we should be adding a little bit of power at some point to bring it a little bit more control to the rate of sink.”

410119: “The first part of the approach was very controlled, nice and easy that initial 3 degrees. HQR3 right in that area. Then that’s a very sharp 9 degree portion. Which it looks like the highest work load was again drift because the crosses that we got. But I ended up short. I was surprised at how quickly it was decelerating me. Once I started the 9 degree approach it was not a very smooth transition from the beginning of the 9 degree all the way to the bottom there was a lot of power influence, and a lot of pitch attitude influence and pretty much I was on cues I thought. And you definitely brought me up short.”

410120: “Again I appreciate you cutting down on that closure rate for me. That part is very comfortable. But you decel me in not a very smooth manner and I end up short.”

410121: "No new comments on that. Need to look at the smoothing on the 9 degree portion of the approach and the fact that it decelerates pretty short repeatably three times."

410122: "Approach profile was incorrect. Prompts come too close together and by being so close together you get a tremendous down power command which raises the work load tremendously. Have to recompensate for that in the 6th or 7th rate of sink. Only thing decent about that was that I felt so comfortable with the rate of sink that I didn't really look up till I was about 30 feet."

410123: "That one brought me up a little bit short too. Right at the very bottom I got that nose up command and again it told me to take the power off. We need to smooth these out at the very bottom and it would be a whole lot better."

411125: "That approach decelerated us rather abruptly and we ended up pretty much in an air taxi from several tenths in. The command cues were fairly much centered. The raw data was off a little, I was slightly below it. At the end of the approach they came together.

411126: "similar results. Really tends to slow you down too much. My perspective, I would never VFR approach that way because of the excessively high nose attitudes of the nacelle position."

411130: "I didn't care too much for the entire approach."

411131: "I got off quite a bit on the glide slope I had a step command on the glide slope and I was compensating on the power because I had one indication to take it off and the raw data to tell me to do something else then all of the sudden I got a step input, I'm not sure what was right….some bad data there."

411132: "for a VFR approach I didn't like that because the nose high attitudes coming in and the rapid decel we had a step jump in the glide slope again when we hit that 9 degree. And I was again having to compensate for the raw data on the glide slope to keep from overshooting it. And then when we got that step jump the error magnified."

412134: "First part of the approach (other than the buffeting) from a handling quality standpoint, had plenty of time from 60° nacells we were slowing down and the attitude was in reasonable limits. Again buffeting was the worse part of that it was probably HQR3 forgetting the buffeting. Then the first in the cell prompt really came and the workload magnified tremendously because the next several prompts were close enough together where you really have to stay on top and we ended up building up a pretty good sink rate. Then at the very bottom of that approach I had to do a lot of compensation and I used the raw data to keep from getting too far below and above the glide slope. The work load from point number 6 inbound is 1.2 increased significantly….I'd give it an HQR5 on the last part of that approach."

412135: "decel points are a little bit close together so my work load really goes up. It tends to get me a little bit too slow around points on the initial points 4 and 5. I ended up having to compensate a little bit to stay on the glide slope….maintained a little more accuracy than I could do with the power cues command bars."

412136: "That was considerably better I like that approach pretty much all the way down. The spacing was a whole lot better…I was able to control the perimeters a whole lot better…The overall work load was down considerably because I had time to shoot the approach the aircraft responded better as well it had time to do the natural deceleration. That's more what these approaches should be like. I wasn't overloaded at all and the spacing was pretty good. I had a view of the path the entire approach. That was probably the best attitude we've had on these approaches. HQR 3 until down HQR4"

412137: "I like that approach other than the last couple of points tend to slow you down a little too much. I think we get just a hair nose high a couple degrees nose high and that tends to slow her down when you're already slow and the last tenth or so inbound I'm flying pretty much raw data because the raw data is telling me I'm on glide slope and yet the power bar is telling me to lower the power. So same HQR 3 down to number 4 then goes up to a 4 three in."

412138: "a pretty good approach. Pretty comfortable all the way down due to the spacing of the decels everything looked good at the very bottom I ended up flying the raw data to increase the accuracy for you there. HQR 3 at the beginning and the very bottom I'd give it an HQR 4 due to the compensation required to stay on glide slope the last tenths of a mile or so."

412139: "no additional comments on that. The glide slope change and sometimes I don't always ignore the question like I should as we go through the transition. If we could fix that it would be a whole lot better"

412140: "a significant improvement over the previous one with 40 degree flaps. From a handling quality standpoint, buffeting standpoint, and a pitch attitude standpoint everything was a vast improvement. It helps at the 9 degree point if I completely ignore the raw data at that point and then use the raw data when it goes through its speed of light jump it helps to compensate there. I'm learning how to use this thing."

413141: "this is the one that we aren't going to like. This one is going to be nose high and it looks like we're going to be about 2000 feet on that one."

413142: went back to do another test. Aborted this one.

413143: “when I reached a certain point. Initially it looked like I was on course. The queuing was telling me to go right, and when I followed that queuing, that brought me back to the left, I don’t follow what went on there.”

413144: “overall that was an improvement from an attitude standpoint, I thought I made a couple degrees difference. Vibration wise today, the buffeting was still there but it was possibly not quite as intense or as sharp today. There was more today than yesterday when we first looked at 75 flaps. Handling quality wise it was an overall improvement. But not to the degree that I saw yesterday. HQR 1 improvement. I thought it was probably more than that yesterday.”

413145: “I think I’ll stick with an HQR 6 on that approach. Extensive compensation’s required at all axes on that approach. Both, power and also a certain amount of lateral as well which occur at predictable points on that approach.”

413146: “again I think when that flaps at an improvement it knocks the attitude down a little bit. There is however some buffeting, it may not be quite as harsh as it is at 40 flaps and I still have that lateral joggle when I get near the bottom as if there was a shift big shift in wind component. I notice that in two different places, it’s very repeatable on the approach. And that’s what increases my work load goes up. I have to make a lateral correction right in there. I’d give that approach for both those 75 degrees in flaps an HQR 5. Really no problem with the spacing on the cell prompts. I think that’s probably okay for that approach. Again the attitude is still on the high side 40 flaps and also 75 degree flaps even though I think the work load is slightly lower at 75 degrees.”

413147: “overall I kind of liked that approach. Good attitude all the time and those prompts were probably right. You have to stay on top of it. It comes rather quick but spacing was better than what we’ve seen. Initially I thought one of them might be off but when I looked at the distal I looked up I realized we really needed that speed. I would not consider an air taxi at all.”

413148: “It’s a good approach. I got a pretty constant speed schedule all there was down. Workload increases at the very bottom with the very quick prompts but it’s doable. HQR 4 for the last portion of the approach.”

414149: I didn’t hear anything.

414150: “we’re going to like that approach. Attitude was excellent all the way down. All cues very manageable….chip light was out.”

414151: “liked the attitudes all the way. Everything was very controllable… only negative on that approach we’re a little bit fast on the last prompt. Our speed was a little bit on the high side and I’d put a little bit of a flare in order to make a landing spot and I had to compensate a little bit with power after our last cell prompt. Overall profile looked good except the last cell prompt and we were a little bit on the fast side. The glide slope control on the 3 degree HQR 3 and on very lower portion of the approach HQR 4 and the initial portion at 9 degrees was HQR 3 but right at the bottom was a little fast and I had to compensate that's where the HQR 4 comes in.

414152: "it started out nice then we got, I thought, too nose low and work load went up a bit and the pitch axis. The decel profile was not strong enough at the bottom and we ended up with quite a bit of ground speed coming over the truck. It was a little bit slow working. It started with and had the right intentions and started to bring the nose up but we should have done it further out we should have never started with such a nose low attitude. HQR 3 on first part of the approach then workload increased to an HQR 4 when we started going too nose low."

414153: "overall the approach looked pretty good. Attitude control was well controlled was 3 degrees initially the back to a level attitude on the important part of the approach when I'm about ready to break out then getting close to the landing sight. Overall workload wasn't too bad I had to do quite a bit of power compensation at the very bottom but other than that the approach was pretty good. You might have tried to decel us just a little too much at the very bottom."

414154: "pretty good approach up until we got with two tenths of a mile that where .1 of the deceleration profile was too steep. Of course the usual power compensation of the glide slope was HQR 3 then down towards the bottom turns into an HQR 4."

414155: "similar to others…decel cues was pretty strong at the very bottom with using the pitch attitude you loose sight of the pad. And we really commanded nose up and a lot of power compensation at the bottom."

416157: "overall good approach HQR 3. Good spacing between points. Good nose down attitude all the way. Good glide slope control and laterally we had a little drift correction but overall it was a pretty comfortable approach. The last 10th of a mile I didn't think it was going to slow us down enough but it eventually did. I probably would have flown it down with just a little bit more nose up attitude if I was going to bring it to an IFR Hover type situation. But that was a great approach."

416158: "same comments on that approach HQR 3. Overall good control and minimum compensation required. Very comfortable in every respect. Just a hair fast on the last 10th of a mile."

416159: "raising the altitude on that approach helped a little bit but still those prompts were way .4 are right after one another there with those higher rates of sink we get with a nine degree glide slope. That's a rather rapid robost. Almost too quick and large power reductions. High workload on power and a slight increase laterally as well along with the power reduction. To maintain following glide slope cues I had to compensate quite a bit at the very bottom in order to stay on the glide slope. If I would have just followed the cues, I would have undershot considerably because the lags with such a dynamic approach. HQR 5."

416160: "same comments. I had to do a lot of compensation at the very bottom. Followed to keep the raw data aligned on the glide slope and along with that is some more lateral compensation required as well on the raw data as apposed to the horizontal guidance of the flight director. HQR 5 a lot of work load and trust axis as well in fact that was the predominate one."

416161: "HQR 5. This lower cues come pretty fast a lot of work load on the trust axis. A couple of points were very close together at the very bottom. Over all workload was high everywhere, you can't concentrate on any one axis because you get off on the other one really quick and again with some of those rates of sink you get a little bit of vibration and buffeting and a little take pitch isolation."

416162: "that worked out pretty good."

416165: "turbulence was minimal. Slight buffeting 60 nacelle at 40 knots of course we were on 40 flaps we were only at about 85 knots with 7 or 8 nose up at times."

416166: "I had to make some corrections to maintain a line up. I'm not sure what the wind is doing right now I don't think there is much of it in any direction. We did have some good changes on the glide slope appeared to balloon up a couple of times it may just be the atmosphere. It was stable we were nose down the whole way down even on the final we only came level so that's a pretty nice program."

416167: "uncomfortably nose high. Lots of buffeting and some pitch motion at some times."

416168: "a little more comfortable on the 9 degree glide slope as I mentioned I think the 90 cell came in a little too early for some reason we had the same response as the last approach where we ended up a 10th of a mile below 30 knots and pretty much air taxied from then on."

416169: "a number of nacelle changes one right after another on final I'm not sure if we had stabilized the glide slope after one before we're in the next one and of course they all wanted a big power reduction and it built up to quite a distance above the glide slope and we had to take the power off to get down in short time. And we came over short tree line and we still had a nice transition to the pad to a three degree."

416170: “turned out a little better it seemed to hold the glide slope a little easier that time. We had some thermal activity with all the sun today. I made an effort to keep the power down when it called for it about 2 tenths. And that kept us on the glide slope and kept us at 85 nacelle going forward on the low 3-degree glide slope. We crept right up to what should have been a nice approach.”

416171: “had speed up a little too fast on final. Probably would have wanted to use 95 on that short final just for another deceleration. But other than that it was pretty comfortable.”

417174: “worked out really well. Air speed was right on that time coming in the alignment was just right altitude was really good and air quality was real nice.”

417175: “had a little alignment problems the cross component changes coming down, but we got that under control. I like the nose down at 85 on the bulk of the glide slope at the end our speed was still up. Coming in on short final to the pad we were still almost 40 knots and we were pitching nose up to decel and I’m still not sure if we would have stopped right over the pad at that rate. HQR 4 because of the alignment today there was a slight cross over.”

417176: “still had to make some alignment corrections because of the cross during the glide slope. Quite comfortable HQR 3 until the cell changes. They come pretty close so we had some power reductions especially he cell changes. This one worked out pretty well we would have touched down to the pad.”

417177: “a little better than yesterday. Really nice closure rate on file still didn’t need nose up it went to 90 decel in about ½ mile and a nice slow deceleration from there on in.”

417178: “initial portion was HQR 3. Had a little problem with the power changes again from transitioning 3 to 9 forgot to ignore the glide slope for a few moments. At 75 decel 3 degrees nose up should have been at 80 it would have been a little more comfortable. The decel profile at the end looks good just a little fast at the end.

417179: “had a glitch at the bottom. Apparently I missed cell movement only got to 85 and never did give me another cell command even though we did fly over the pad.”

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.			
1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE April 2003	3. REPORT TYPE AND DATES COVERED Technical Memorandum	
4. TITLE AND SUBTITLE XV-15 Tiltrotor Aircraft: 1999 Acoustic Testing - Test Report			5. FUNDING NUMBERS WU 576-03-15-10 WU 727-03-15-10
6. AUTHOR(S) Bryan D. Edwards and David A. Conner			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) NASA Langley Research Center Hampton, VA 23681-2199 U.S. Army Aviation and Missile Command Aeroflightdynamics Directorate Joint Research Programs Office NASA Langley Research Center Hampton, VA 23681-2199			8. PERFORMING ORGANIZATION REPORT NUMBER L-18264
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001 and U.S. Army Aviation and Missile Command Moffett Field, CA 94035-1000			10. SPONSORING/MONITORING AGENCY REPORT NUMBER NASA/TM-2003-212152 AMCOM/AFDD/TR-03-A-002
11. SUPPLEMENTARY NOTES Edwards: Bell Helicopter Textron, Inc., Fort Worth, TX; Conner: JRPO, Aeroflightdynamics Directorate, AMCOM, Langley Research Center, Hampton, VA.			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified-Unlimited Subject Category 71 Distribution: Standard Availability: NASA CASI (301) 621-0390			12b. DISTRIBUTION CODE
13. ABSTRACT *(Maximum 200 words)* XV-15 acoustic test is discussed, and measured results are presented. The test was conducted by NASA Langley and Bell Helicopter Textron, Inc., during October 1999, at the BHTI test site near Waxahachie, Texas. As part of the NASA-sponsored Short Haul Civil Tiltrotor noise reduction initiative, this was the third in a series of three major XV-15 acoustic tests. Their purpose was to document the acoustic signature of the XV-15 tiltrotor aircraft for a variety of flight conditions and to minimize the noise signature during approach. Tradeoffs between flight procedures and the measured noise are presented to illustrate the noise abatement flight procedures. The test objectives were to support operation of future tiltrotors by further developing and demonstrating low-noise flight profiles, while maintaining acceptable handling and ride qualities, and refine approach profiles, selected from previous (1995 & 1997) tiltrotor testing, to incorporate Instrument Flight Rules (IFR), handling qualities constraints, operations and tradeoffs with sound. Primary emphasis was given to the approach flight conditions where blade-vortex interaction (BVI) noise dominates, because this condition influences community noise impact more than any other. An understanding of this part of the noise generating process could guide the development of low noise flight operations and increase the tiltrotor's acceptance in the community.			
14. SUBJECT TERMS Tiltrotor; Acoustics; Noise; Flight procedures; Noise abatement; Aircraft; Rotorcraft; SHCT; Short haul civil tiltrotor; Operations			15. NUMBER OF PAGES 68 16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z-39-18
298-102