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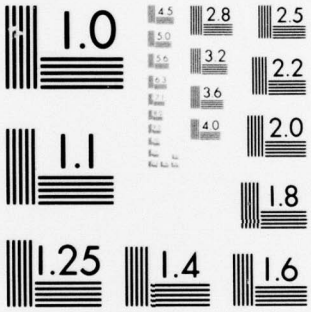

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Technical Memorandum

FLIGHT CONTROL TESTING OF THE

VAK-191B AIRCRAFT

by

Mr. R. L. Traskos

Strike Aircraft Test Directorate

24 May 1977

NAVAL AIR TEST CENTER
PATUXENT RIVER, MARYLAND

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The U.S. Navy/Federal Republic of Germany Joint Flight Test Program, using the VAK-191B aircraft, was conducted to expand the base of VSTOL technology. During the flight program, an integrated test block approach was considered mandatory for the acquisition of the required data in the limited flight time available. Ground and captive rig tests were used, when applicable, to supplement data acquisition. In spite of the configuration of the captive rig, which precluded its use in the documentation of engine exhaust flow, it was considered a valuable tool in control system and engine test, and for pilot familiarization.

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PREFACE

From June 1974 to October 1975, the U.S. Navy and the Federal Republic of Germany conducted a Joint Flight Test Program using the VAK-191B jet VSTOL aircraft for the purpose of expanding the data base for VSTOL technology. NAVAIRTESTCEN involvement in the program was executed under NAVAIR AIRTASK A03P-03PA/053B/5F41-411-006 of 24 July 1974. One of the major purposes of the program was the development of testing techniques for VSTOL aircraft in jetborne flight. This technical memorandum is the result of the experience gained during the VAK-191B program. The paper was prepared for presentation on 7 June 1977 at the AIAA/NASA Ames VSTOL Conference in Palo Alto, California. Included are the problems encountered and solutions used for the acquisition of aircraft and control system data through a blend of flight, ground, and aircraft captive rig tests.

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FLIGHT CONTROL TESTING OF THE VAK-191B

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Abstract

The U.S. Navy/Federal Republic of Germany Joint Flight Test Program, using the VAK-191B aircraft, was conducted to expand the base of VSTOL technology. During the flight program, an integrated test block approach was considered mandatory for the acquisition of the required data in the limited flight time available. Ground and captive rig tests were used, when applicable, to supplement data acquisition. In spite of the configuration of the captive rig, which precluded its use in the documentation of engine exhaust flow, it was considered a valuable tool in control system and engine test, and for pilot familiarization.

I. Introduction

During the period of June 1974 to September 1975, the U.S. Navy and Federal Republic of Germany, Ministry of Defense, *conducted a joint flight test program using the* VAK-191B lift plus lift-cruise VSTOL aircraft. The intent of the program was to extend and expand the technical data base for VSTOL technology. The primary Navy interests in the program were to:

a. Provide a basis for developing new prediction techniques for VSTOL aircraft based on the comparison of full scale test data with predicted analytical characteristics.

b. Investigate the VAK-191B aircraft technology relating to the lift plus lift-cruise concept.

c. Evaluate the adequacy of present VSTOL specifications.

d. Develop testing techniques for VSTOL aircraft.

e. Disseminate this information to the aeronautical community.

The test program was conducted at the German flight test facility at Manching, (Erprobungstelle 61) including 60 flights (8.5 flight hours) and 45 ground tests (30 hours). The technical disciplines investigated during the program were:

a. *Aircraft temperature and velocity footprint.*

b. Jet induced effects in and out of ground effect.

c. Handling qualities in jetborne and semi-jetborne flight.

d. Aircraft/engine performance.

e. Propulsion systems.

f. Acoustic environment.

g. Flight control system and hydraulics.

h. Control of ground environment with flat and parallel ribbed surfaces.

i. Integrated logistics assessment.

Due to the fact that the VAK-191B was a research aircraft with a total of less than 6 hours of flight time at the start of the joint test program, many of the tests were conducted at conditions not flown prior to the program. As a result, many of these conditions were approached with buildups to the test points, and some of the data originally required were not obtained due to the aircraft limitations and flight safety.

II. Test Program Technical Approach

The approach taken during the test program was to obtain a maximum amount of the data requested in the test matrix within time and safety restraints. In order to maximize efficiency of the acquisition of data in the jetborne flight regime, an integrated test block (ITB) approach was taken. The ITB approach consists of combining various disciplines into a series of sequential tests. This approach has been taken in several recent programs (such as the F-14A Navy evaluations) to reduce flight time. The ITB philosophy was considered necessary in the VAK-191B program in order to complete the required tests in the flight time available. During the program, an average of 5.5 minutes of flight time per jetborne flight made the efficient acquisition of data mandatory.

With the ITB approach, many of the test disciplines of stability and control, performance, propulsion system, and induced forces in semi-jetborne flight, could be combined into a single flight profile (figure 1).

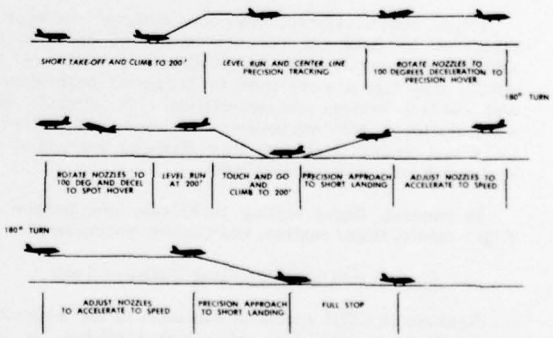

Figure 1 VAK-191B STOL Flight Profile

This was possible in that the test airspeeds of 20, 40, 80, and 120 kt were used for these disciplines. The tests were conducted over the 11,000 ft runway at the test site. The tests were combined in that the takeoffs, level accelerations and deceleration, and steady level runs were sequenced in a manner that each change of flight condition was also a test. For example, the decelerations at the end of a level run were conducted with a step input (short term dynamics) and held until a hover was attained (deceleration and attitude system characteristics). The hover turns at the end of the runway were also step inputs, thus reducing the need for test time for this specific maneuver.

In addition, flight tests were supplemented by ground and captive rig tests whenever possible. Ground tests were used whenever possible or when safety of flight limited testing for known hazardous tests. The captive rig (pedestal) was used to check engine performance, document flight control system, and pilot familiarization prior to test flights.

III. Stability and Control Testing

Testing was conducted to document the stability and control characteristics primarily in the slow airspeed semi-jetborne flight regime of the aircraft (V 120 kt). Major emphasis was placed on:

a. Acquisition of data for comparison with scale model, windtunnel, and simulator test results.

b. Acquisition of data to be compared with pilot rating data for inclusion into the investigation of present VSTOL design guidelines and specifications [1, 2].

Tests to document the aircraft for comparison with windtunnel data were conducted at 0, 40, 80, and 120 kt in the attitude command mode of the AFCS. The testing techniques used were derived from normal helicopter and fixed wing methods [3, 4]. Testing techniques in the hover were essentially those used in helicopter stability and control testing. Standard fixed wing techniques were used above a flight speed of 160 kt. However, due to blend of hover and aerodynamic characteristics in slow airspeed flight (40 kt$<$V$<$160 kt) exhibited by the aircraft, standard testing methods were modified to isolate parameters of interest. For example, as airspeed increases, directional stability varies from negative to positive. The testing method to obtain the directional stability data changed from a slow doublet input at slow speed to normal sideslip maneuvers at airspeeds above 60 kt.

Flight control system laws also dictated the type of inputs to be used for the acquisition of data. In the attitude command/attitude stabilization mode of the AFCS, step inputs were used to document both aircraft and control system characteristics. In aircraft with acceleration or rate controller, test inputs are limited to pulse and doublet inputs at slow airspeed because of the restricted safe attitude envelope.

In general, flight testing techniques are dictated by flight safety, flight regime, and control system laws.

IV. Closed Loop Handling Qualities Tests

Because the ITB approach was used in the acquisition of quantitative data, little time was available for pilot rating of the aircraft during tasks normally associated with jetborne flight. As a result, a series of tests were conducted toward the end of the program to obtain pilot ratings of the aircraft during hover and slow airspeed pilot-in-the-loop precision tracking and hover tasks.

The hover tests were conducted over an aircraft parking area (figure 2). The size of the area (80 ft X 600 ft) was approximately the size of an LPH flight deck.

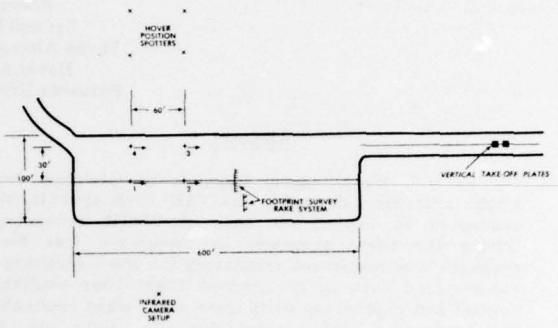

Figure 2 Hover Testing Area

Following a vertical takeoff, the aircraft was translated to position 1 and a steady precision hover was attained. The aircraft was then moved to positions 2, 3, and 4 while maintaining aircraft height and direction. The tests were repeated at different aircraft heights and wind magnitudes and directions. Precision of the task as well as pilot activity was monitored during the tasks. Pilot opinion of the tasks was recorded for various heights and surface wind effects.

A second sequence of tasks was conducted in the semi-jetborne flight regime to obtain pilot opinion of the aircraft during slow airspeed operations such as short takeoffs and slow approaches and landings. The sequence was conducted in a similar manner to the profile shown in figure 1. The difference was that the pilot was required to complete given tasks such as deceleration to hover over a given spot or slow landing to a given touchdown point.

One of the maneuvers conducted is shown in figure 3.

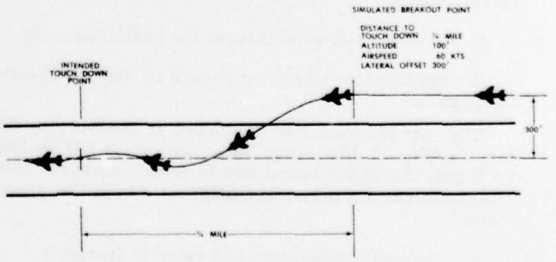

Figure 3 Lateral Correction Maneuver

The task shown is a sidestep maneuver simulating an off-center breakout from IFR conditions at 1/4 mile and 100 ft altitude. The test was conducted into the wind and then repeated with crosswinds of as much as 10 kt. Results of these tests indicated that this maneuver could not be completed due to the limited bank angle command ($\pm$15 deg) available in the attitude mode of the flight control system. Normally, the flight path shown in figure 3 was the result, with the pilot having to extend the approach past the intended landing point, or to land off-centerline or not lined up with the runway.

These closed loop flight profiles were designed with AGARD Report No. 577 Volume 2 [5] as a guideline and were conducted to allow the pilots to rate the aircraft during each of the tasks by answering the questions contained in the AGARD Report. These sequences used in conjunction with the questions posed in that report allow evaluation of a VSTOL aircraft during most of the tasks associated with the operational use of the hover and slow airspeed flight regimes.

V. Flight Control System Testing

In order to fully document the flight control systems characteristics in the hover mode of the AFCS, tests were conducted using the aircraft captive rig (pedestal) at the test site which allowed "off the ground" testing of the aircraft in both a fixed and free mode. The pedestal consisted of a single post (hydraulic lift) which was attached to the aircraft in a manner to allow freedom of movement about the center of gravity in the pitch, roll, and yaw axes. Attitudes available in the aircraft free mode were ±15 deg in pitch and roll and 360 deg in yaw. Cables attached to the extremities of the aircraft were used to hold the aircraft in a fixed position (figure 4).

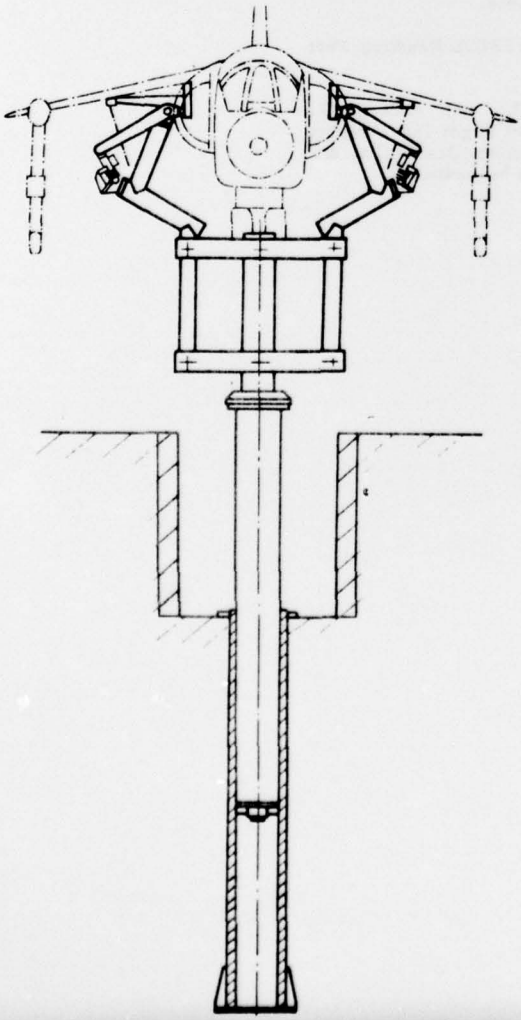

Figure 4 VAK-191B on Aircraft Pedestal

Aircraft control system characteristics in the hover mode of the AFCS were obtained by conducting frequency response tests in the pitch, roll, and yaw axes. Inputs of a constant magnitude and frequency were made electrically into the AFCS computer simulating the output of the cockpit control potentiometers of the fly-by-wire system. Inputs were conducted with the frequency varying between 0.1 and 5.0 Hz and magnitude of 15, 30, and 50% control authority. The tests were conducted in the aircraft fixed mode of the pedestal with the flight control system feedback loop disconnected and in the aircraft free mode of the pedestal with the total AFCS functional in order to document both the forward and feedback loops of the flight control system. These tests were conducted on the pedestal because attempting these tests in flight was putting the aircraft in an unsafe condition for an excessive period of time. The results of these tests compared favorably with data obtained from normal flight methods such as step and pulse inputs.

Control power data were not gathered during the pedestal test due to the lack of instrumentation on the rig. Force and moment information would greatly enhance the usefulness of the pedestal in aircraft and control system documentation tests.

One degrading feature of the pedestal was the configuration (center mounted post) which coincided with the central fountain of the jet exhaust flow (figure 5). This negated the use of the pedestal in the documentation of the jet exhaust and ground flow patterns of the aircraft.

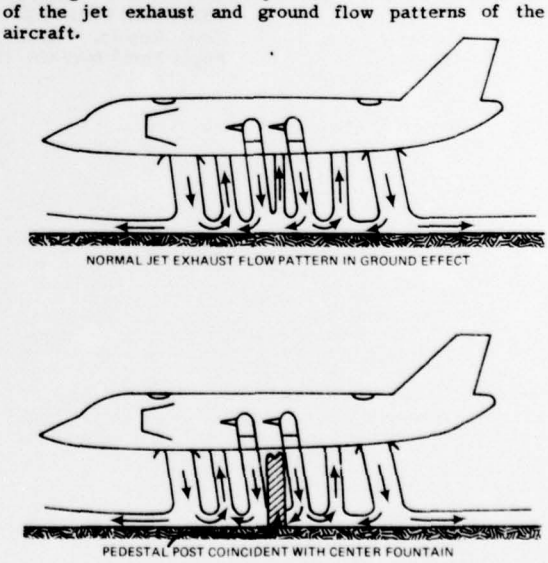

Figure 5 Jet Exhaust Patterns Inflight and on Pedestal

Notwithstanding the limitations of the pedestal, the facility provided a safe efficient means of pilot familiarization, engine checkout, and control system optimization and testing.

A complete description of these and other flight and ground tests conducted during the VAK-191B flight test program are contained in Volume 2 of the VAK-191B Flight Test Program Final Report [6].

VI. Conclusions

Tests conducted in the semi-jetborne flight regime are sufficiently restricted by flight time available to require the use of an integrated test block approach in which several tests are integrated into a single flight sequence.

Testing techniques are dictated by flight safety, flight regime, and flight control system control laws.

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