Vertical Flight IFR Terminal Area Procedures (VERTAPS) Program Plan

Executive Summary

DOT/FAA/RD-93/51

For: Federal Aviation Administration
Contract DTFA01-87-C-00014
August 1993

NOTICE

Introduction

Advanced vertical flight aircraft, with operational performance exceeding that of the current fleet, are expected to share in the growth of the air travel market in the next century. The vertical landing capabilities of these aircraft will allow them to service significant new segments of the market. However, to realize their full potential, vertical flight aircraft must be integrated with the existing traffic flow, and procedures must be developed that allow them to exploit their unique capabilities. In addition, landing sites specifically designed for vertical flight vehicles will be needed. Currently, this infrastructure is not in place and the instrument procedures needed to reap the full benefits of vertical flight do not exist.

The Vertical Flight IFR Terminal Area Procedures (VERTAPS) program summarized in this document is an important step to resolving this problem. It will identify infrastructure requirements and develop instrument and air traffic control procedures necessary for the integration of vertical flight aircraft into the National Airspace System (NAS). VERTAPS will use piloted simulation and flight test to develop instrument procedures. In developing air traffic control procedures, VERTAPS will draw on the resources of the FAA National Airspace System Simulation Support Facility.

The extensive use of piloted simulation for procedure development, a unique feature of VERTAPS, is intended to validate simulation as a tool for future vertical flight instrument procedure development. This may lead to broader application of simulation in the world of fixed-wing procedure development, providing additional significant cost savings.

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Overview

In response to direction from Congress, the FAA has placed all vertical flight research and development activity under the control of the Vertical Flight Program Office. On receiving this assignment, the Vertical Flight Program Office established specific goals to:

- plan and implement guidelines for design of vertical flight aircraft landing sites,
- improve the efficiency of methods for developing and validating instrument procedures for vertical flight aircraft, and
- develop and demonstrate air traffic control (ATC) procedures to integrate vertical flight aircraft into the NAS.

Advanced vertical flight aircraft are expected to enter the scheduled commercial traffic mix early in the next century. These aircraft will have operational capabilities exceeding those of the current vertical flight aircraft fleet. Current instrument procedures and air traffic control procedures will not allow operators to utilize the unique capabilities that these aircraft provide. The FAA has recognized this and has initiated a project to develop and modify terminal area procedures to enhance vertical flight operations in the future.

The VERTAPS Program Plan represents a cooperative effort by industry and the Federal Aviation Administration (FAA) to develop the infrastructure and procedures required to successfully integrate advanced vertical flight aircraft into NAS.

Under direction of the FAA Vertical Flight Program Office, the VERTAPS Program is being undertaken by Systems Control Technology, Inc., Bell Helicopter TEXTRON, Inc., and Boeing Defense & Space Group, Helicopters Division. The VERTAPS Program Plan, outlining and defining the project, is summarized in this document.

The VERTAPS program will combine a variety of technical initiatives in a structured approach to:

- develop terminal area procedures for vertical flight aircraft through piloted simulation and flight test,
- demonstrate the validity of using high-fidelity, piloted simulation results to augment flight test data in the development of instrument procedures,
- evaluate vertiport characteristics related to terminal instrument operations (e.g., lighting, marking, and dimensions), and
- develop ATC procedures needed to safely integrate vertical flight aircraft into the established air traffic system.

Within VERTAPS, the Bell Boeing V-22 Osprey tiltrotor aircraft will be used for all flight testing. The simulation model of the V-22 will be the starting point for all simulation evaluations. A generic market-responsive civil tiltrotor model will also be developed for additional evaluation of instrument procedures.

Program Description

The proposed VERTAPS program consists of four tasks extending over a five-year period (see figures 1 and 2). The four tasks are interrelated and run concurrently.

Task 1 - develop instrument procedures specific-ally for vertical flight aircraft. Unlike procedures development until now, this effort will employ both flight test and simulation data.

Task 2 - define a configuration for the flight test aircraft and conduct piloted simulation evaluations to collect the data needed for comparison with flight test results.

Task 3 - modify the aircraft and conduct the required flight test evaluations.

Task 4 - develop air traffic control procedures for safe, efficient integration of vertical flight aircraft into the ATC system.

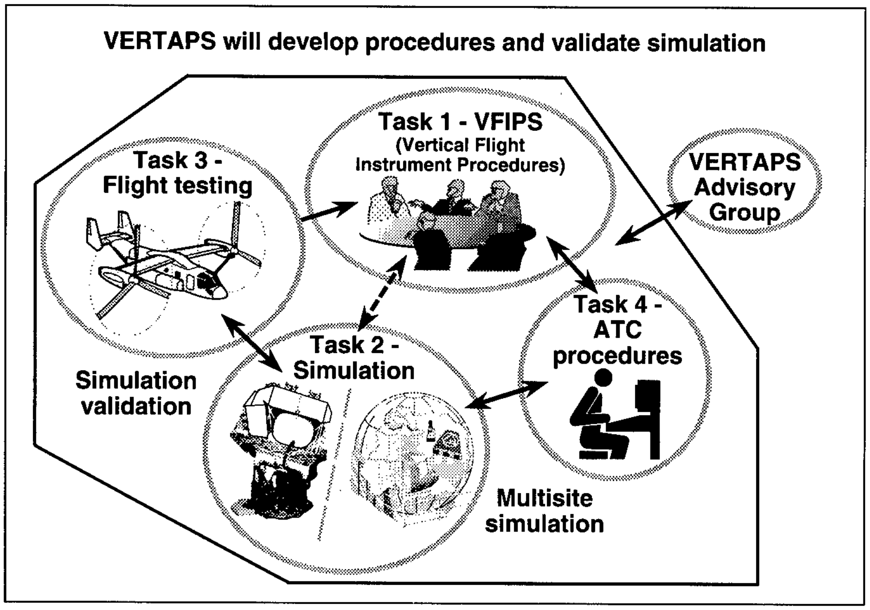


FIGURE 1 VERTAPS PROGRAM SUMMARY

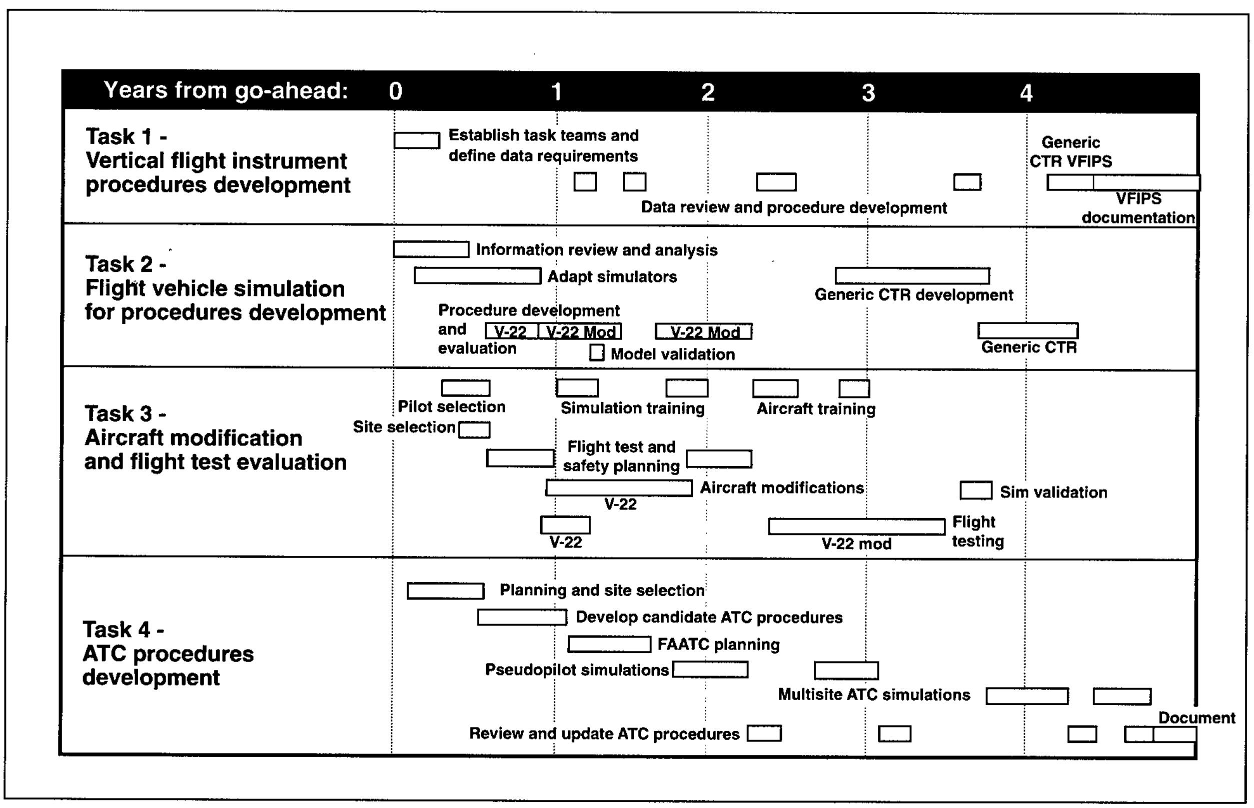


FIGURE 2 VERTAPS PROGRAM SCHEDULE

VERTAPS Advisory Group

The VERTAPS Advisory Group will provide program visibility and direction at the executive level. This group consists of three representatives from government, three from industry, and three from operators. They will meet three times a year throughout the program. Members will promote and support the program within their home organizations and review procedures and documents generated by the task teams. Further, they will coordinate with other organizations and consider other studies in advancing the development of vertical flight infrastructure. They will focus the goals of the VERTAPS program as necessary to support vertical flight objectives.

Task Team Formation

Four teams will be formed to conduct specific tasks within the VERTAPS program (see table 1). Government, industry, and operator participation is planned for each team in accordance with the nature of their responsibilities. The FAA is heavily represented on task teams developing operating procedures, while the VERTAPS contractors are heavily represented on the pilot and site selection teams.

TABLE 1
VERTAPS TASK TEAM DEFINITION

Team	Representation			Responsibilities	Meetings
	Government	Industry	Operators		
VFIPS development team - task 1	**8**	**4**	**2**	• Data requirements definition • Review of task 2 and 3 results • Monitor procedure development • VFIPS development	**15 (3 meetings per year)**
Pilot selection team for tasks 2 and 3	**3**	**4**	**2**	• Selection criteria development • Candidate selection • Candidate disqualification	**4**
Flight test site selection team for task 3	**2**	**6**	**--**	• Definition of required site attributes • Reduction of candidate field • Site inspections • Site selection	**4**
ATC procedure development team - task 4	**8**	**4**	**2**	• ATC site selection (for simulation) • Procedure development • Simulation test plan development • Data requirements definition	**15 (3 meetings per year)**

TASK 1 - Vertical Flight Instrument Procedures (VFIPS) Development

Three aspects of terminal area operations require definition in order to develop vertical flight instrument procedures (see figure 3). They are:

- landing minima (ceiling and visibility restrictions),
- obstacle clearance (minimum clearance allowable between flight paths and structures in the terminal area), and
- procedure design rules (guidelines for defining specific procedures with regard to aircraft flight paths, speeds and operations)

Traditionally, such information is extracted through data gathered from 300 to 500 test flights accomplished by numerous pilots. Any deviation from the desired course is measured during the exercises and used to determine the airspace necessary for the instrument procedure. The VERTAPS program differs from this traditional approach in that it will use both simulation and flight test for obtaining data. Procedures will be developed through simulation and later evaluated in flight test. This is expected to demonstrate that simulation can provide much of the data currently obtained only through flight testing.

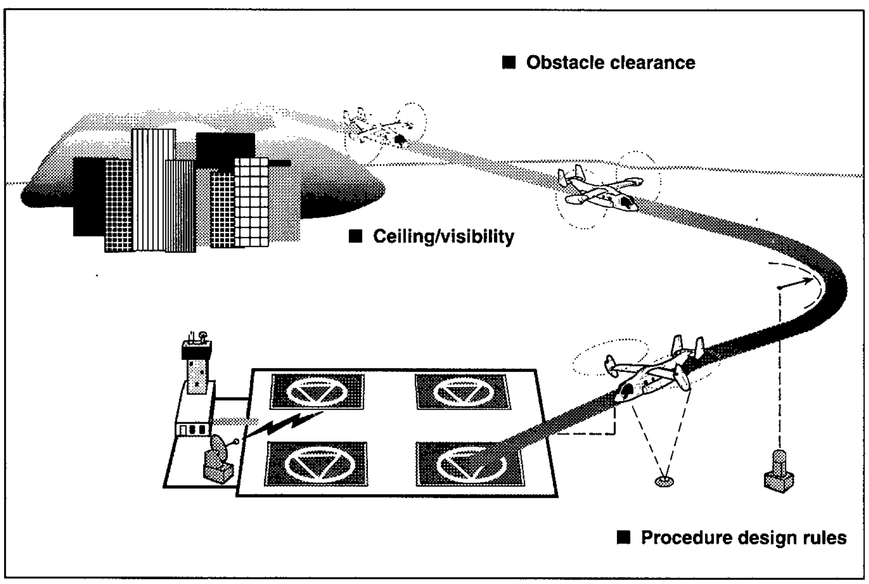


FIGURE 3 VERTICAL FLIGHT INSTRUMENT PROCEDURES (VFIPS) DEVELOPMENT

TASK 2 - Flight Vehicle Simulation for Procedures Development

Figure 4 presents a summary of the flight-vehicle simulation task. This effort, *through simulation,* will:

- develop and evaluate vertical flight instrument procedures,
- determine the control system and avionics modifications necessary to use the V-22 tiltrotor to demonstrate safe, accurate 9° glideslope approaches, and
- investigate the use of vertical flight instrument procedures for a market-responsive civil tiltrotor.

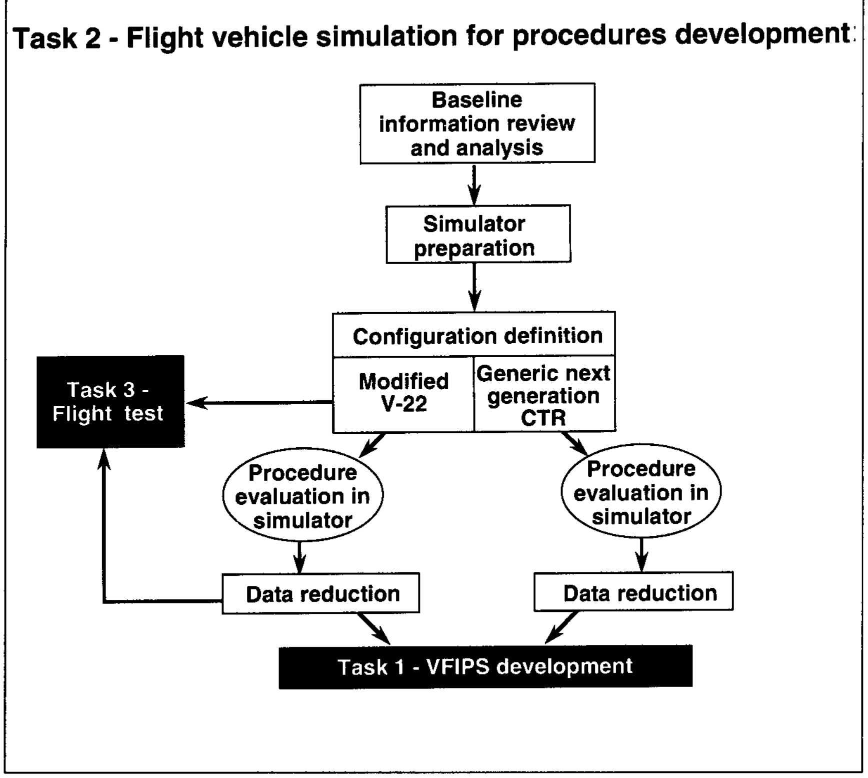


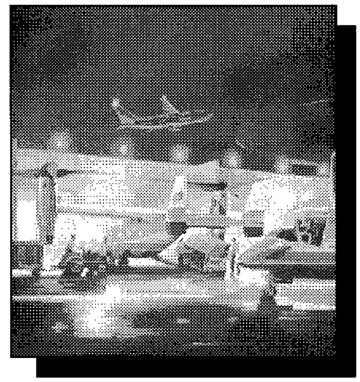
FIGURE 4 VERTAPS TASK 2 SUMMARY

Baseline Information Review and Analysis

VERTAPS contractors will study current regulations to insure that the procedures developed during the program conform to FAA requirements. The review will cover the current procedure development process, noise regulations, and any other areas of concern relating to vertical flight instrument procedures. The capabilities of the V-22 aircraft will then be reviewed and analyzed in order to develop candidate flight profiles for simulation and flight test evaluation.

Simulator Preparation

VERTAPS requires that the simulation provided be as realistic as possible with regard to pilot workload and crew interaction. Simulation vertiport imagery - the view seen by the crew during simulation - will conform to the lighting and marking requirements of "Vertiport Design" FAA Advisory Circular 150/5390-3. Navigation and communication selection features will replicate the function of the avionics interface in the aircraft. Navigation and guidance sensor models and external noise analysis models will be added to the simulations. A conceptual noise model is shown in figure 5.



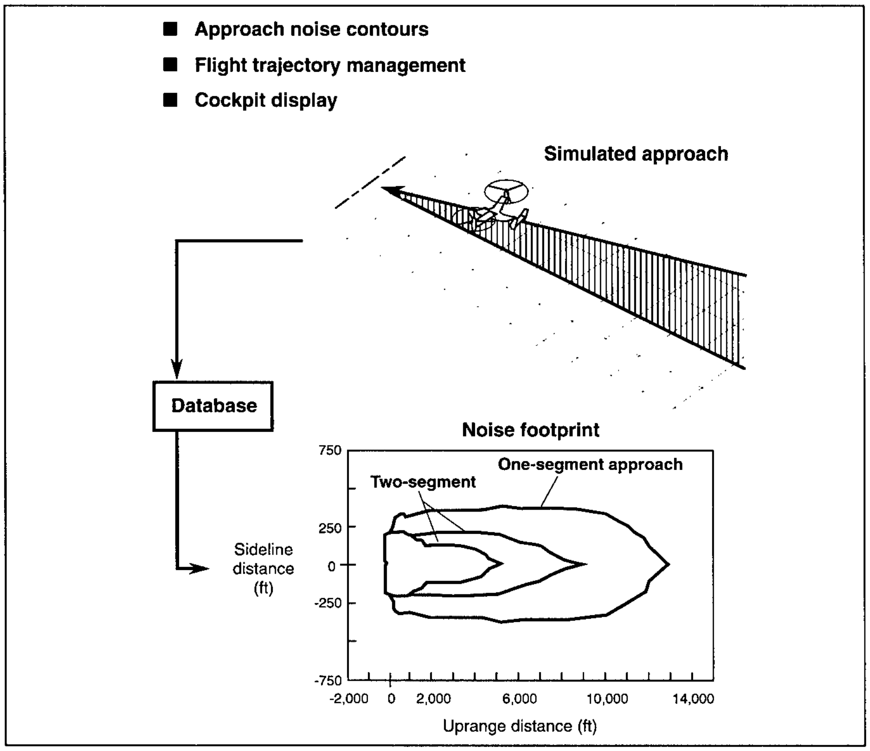


FIGURE 5 VERTAPS ACOUSTIC MODEL FOR PROCEDURE EVALUATION

Simulation Configuration Development and Procedure Evaluation

Baseline Evaluations - With regard to procedure development, current regulations will serve as a starting point. Candidate flight profiles will be developed based on the current capabilities of the V-22. These profiles will then be evaluated in the simulator by pilots regularly employed by the contractors, after which a short flight test program will be conducted. Following that, the simulators will be checked against flight results and fine tuned as necessary.

Modified V-22 - It is anticipated that certain modifications to avionics and flight control systems will be required to allow pilots to perform safely the steep approaches required by VERTAPS in the V-22 aircraft. Simulation evaluations will be used to identify those modifications. The anticipated flight test configuration is shown in table 2. The configuration includes both microwave landing system and differential global positioning system receivers to demonstrate compatibility with either approach system. Flight director nacelle cueing and partial to full automation of nacelle control will be examined in simulation as a means of reducing pilot workload during steep approaches. Other modifications, including autoflap and automatic flight control systems gain modifications, will be examined in simulation to determine if they are required.

TABLE 2
V-22 MODIFICATIONS TO CONDUCT VERTAPS RESEARCH

FSD aircraft		Modified FSD aircraft
3° Precision	6° Non-precision	6- to 9-degree precision
ILS receiver	Inertial navigation system	• Microwave Landing System (MLS) receiver • Differential Global Positioning System (DGPS) receiver • MLS and DGPS flight director approach mode guidance processing - straight - segmented - curvilinear • Control Display Unit (CDU) interface for variable glideslope selection • Flight Control System mods to reduce pilot workload • Nacelle control alternatives • Flight director nacelle cueing

Evaluations by the contractor pilots (pilots regularly employed by the VERTAPS contractors) will define the VERTAPS V-22 flight test configuration. Once this configuration is defined, the simulation models will be frozen to insure the integrity of simulation results when compared to flight test results.

Using the modified V-22 simulation, contractor pilots will establish the flight parameters required for safe, effective terminal area procedures. These parameters include decision and safety speeds, approach slope angle, critical decision points, and fuselage attitude. Procedure development will consider the noise impact on communities and sensitivity to weather conditions.

Vertical Flight Instrument Procedures Evaluations - Contractor pilots, along with 15 additional evaluation pilots selected for the VERTAPS program, will judge the procedures planned for the modified V-22. Procedures will be evaluated for acceptability in terms of aircraft performance, flight crew performance, and pilot workload. Flight path deviation data will be gathered during all formal simulation evaluations to permit development of vertical flight instrument procedures criteria, and to allow validation of simulation results against flight test data. Data to be collected during simulation includes flight path deviation, handling qualities ratings, pilot comments and assessments of pilot workload, aircrew performance, crew coordination, and situational awareness.

Vertiport Design Evaluations - Vertiport design issues such as physical size, marking, and lighting will be evaluated. The "Broken Wheel" configuration described in "Vertiport Design", FAA Advisory Circular 150/5390-3, will be evaluated. The general layout required is as shown in figure 6. The heliport instrument lighting system and helicopter approach lighting system (HILS and HALS), along with a visual glideslope indicator as described in the advisory circular, will be included in one configuration. A second marking and lighting configuration will be identified by the FAA for evaluation during the program.

Design recommendations for size of the final approach and takeoff area, the touchdown and liftoff area, and taxiway clearances will be developed from data obtained during the simulation evaluations.

Generic Civil Tiltrotor - Following flight test evaluation of the modified V-22, a simulation math model will be developed to represent an advanced market-responsive, commercial passenger tiltrotor. This will be used to develop and evaluate instrument procedures in further piloted simulation. This simulation may feature advanced display concepts, flight control system modifications, nacelle and thrust controller modifications, and increased engine ratings. Before incorporation of the generic civil tiltrotor modifications, the math model will be correlated to the results of the flight test program. The pilots will evaluate the aircraft configuration and assess the impact of configuration improvements on vertical flight instrument procedures.

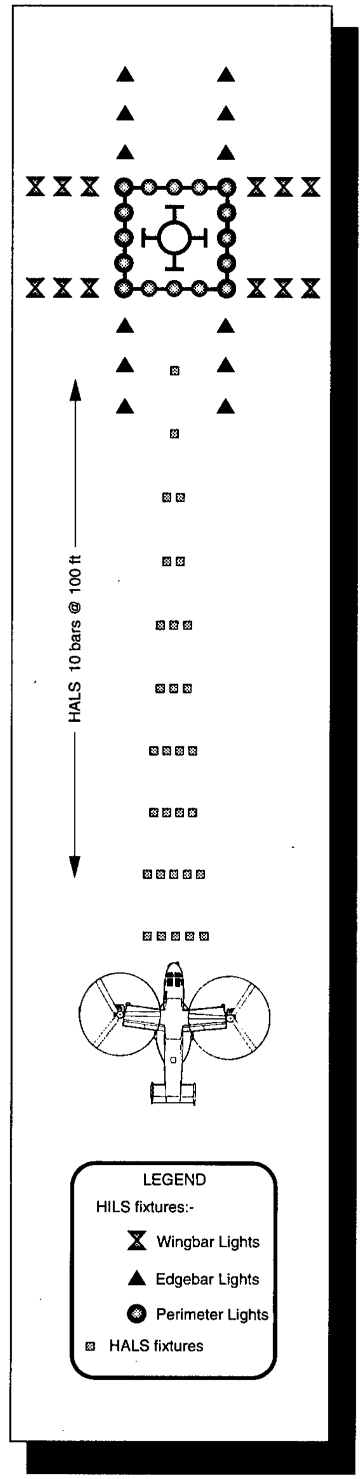
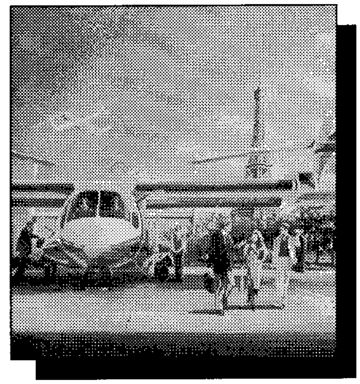


FIGURE 6 VERTIPORT MARKING AND LIGHTING SCHEME

Task 3 - Aircraft Modification and Flight Test Evaluation



This task, in preparing for and conducting flight testing, will:

- modify the V-22 flight vehicle to allow safe, reliable, steep precision approaches using microwave landing system and differential global positioning system guidance,
- train fifteen evaluation pilots for vertical flight instrument procedures simulation and flight test evaluations,
- collect statistical flight path data required for simulation validation and vertical flight instrument procedure development, and
- evaluate vertiport marking and lighting for comparison to simulator results.

Figure 7 presents the general flow of tasks in the VERTAPS aircraft modification and flight test program.

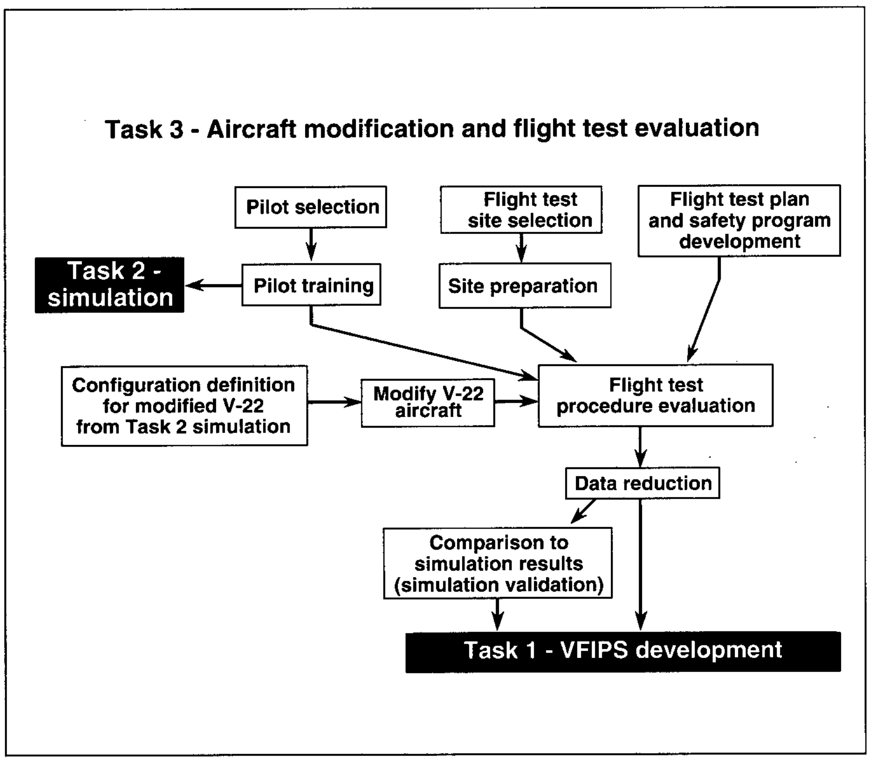


FIGURE 7 VERTAPS TASK 3 SUMMARY

Evaluation Pilot Selection

Pilots will be chosen to represent a cross section of the pilots likely to fly tiltrotor aircraft in commercial or private transport service. They will be selected from a pool established by the FAA to include FAA test and evaluation pilots, NASA test and evaluation pilots, commercial airline pilots, and helicopter pilots.

Pilot Training

Evaluation pilots will be trained to fly the V-22 Osprey tiltrotor aircraft. The training will enable pilots to fly instrument procedures in both the simulator and the aircraft and will be timed to lead simulation and flight test evaluation events. During actual flight, a contractor pilot will serve as pilot-in-command while permitting the evaluation pilot to perform the required instrument procedures.

Flight Test Site Selection

The test site will be selected for convenience and efficiency. In determining an acceptable flight test location, the team will consider air traffic control facilities, landing area, guidance equipment, landing zone lighting and marking, and communications and tracking equipment as shown in figure 8. In addition, emergency equipment availability, air traffic density, hangar and maintenance facilities, weather, and data reduction access will be considered.

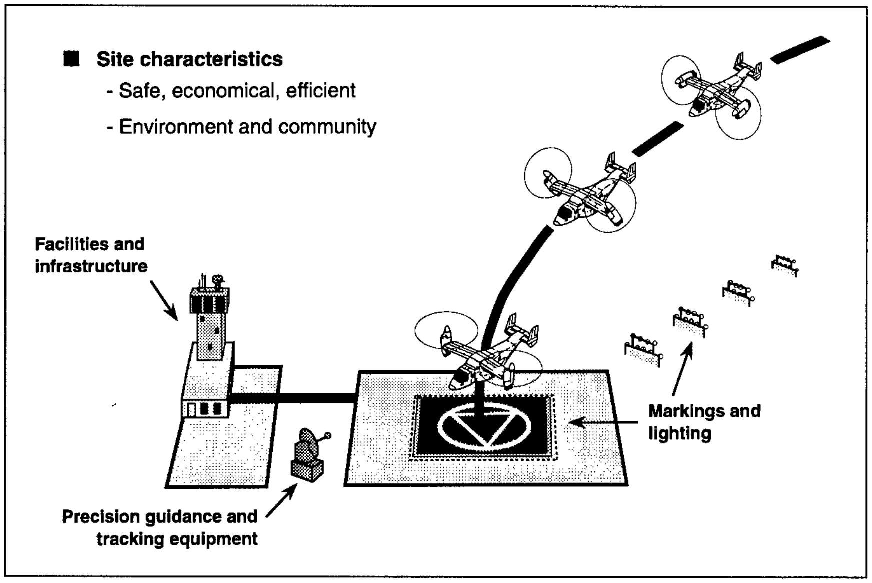


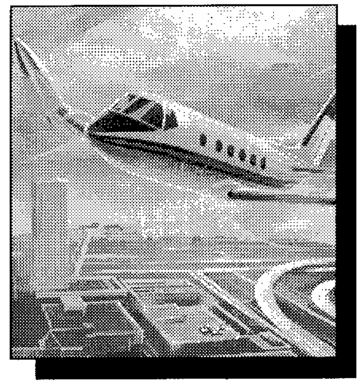
FIGURE 8 FLIGHT TEST SITE SELECTION

Aircraft Modifications

Modifications to incorporate a microwave landing system (MLS) and a differential global positioning system (DGPS) constitute a large part of the aircraft modifications required for the VERTAPS program. VERTAPS will demonstrate that both MLS and DGPS guidance can be used in the execution of vertical flight instrument procedures. This is desirable since the eventual predominance of one guidance system in the NAS is expected. In addition, flight director steering cues and the aircraft control system will be modified if required.

Flight Test Program

Flight tests will be conducted in accordance with accepted flight test practices. Existing aircraft limitations will be observed during all testing. Maneuver abort criteria will be established and adequate support facilities will be available to insure a safe program.

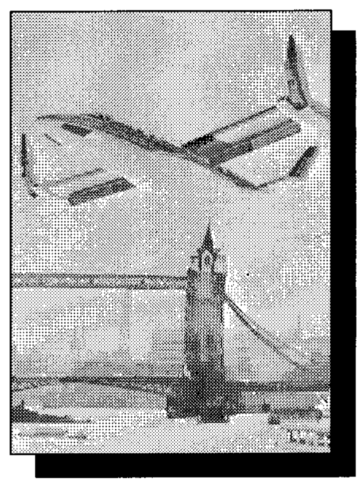


Initial Evaluations - Approximately 40 hours of flight will be conducted by contractor pilots in an unmodified V-22 Osprey tiltrotor aircraft. VERTAPS contractors will conduct this testing at their own facilities to support the initial correlation and verification of simulation results. Evaluations will be limited to flight paths that the unmodified aircraft can fly safely. An initial evaluation of vertiport lighting and marking will be included.

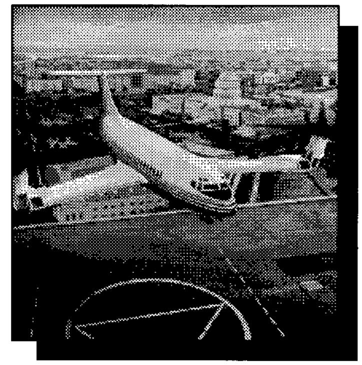
Vertical Flight Instrument Procedures Flight Evaluations - A 240-hour flight test program will be conducted at the site chosen by the Site Selection Team. During this period, each of the evaluation pilots will evaluate up to four different procedures in the flight vehicle. At least one of the procedures will be a steep approach at 9 degrees (V-22 performance and safety considerations limit the glideslope on approach to no more than 9 degrees). As an additional safety precaution, evaluation pilots will fly approaches only in visual meteorological conditions.

Data Reduction and Simulation Validation

Pilot comments and handling qualities ratings will be collected from the evaluation pilots. Post-flight debriefings will be conducted to obtain detailed information on pilot activity and workload. Onboard data recording will obtain aircraft and avionics information (including aircraft rates and attitudes, control positions, and flight deviations) as displayed to the pilot. Ground tracking system data will be integrated with the aircraft data to provide actual flight path deviation information. An acoustics array under the approach path will record data for comparison with estimates based on simulation profiles.



Flight path deviation information will be reduced to flight technical error (a measurement of the deviation of the aircraft from the desired flight path) for computation of procedure tolerances and comparison with simulation results. All data will be reviewed by the Vertical Flight Instrument Procedures Task Team. Flight test results will be compared to simulation results to determine the validity of using simulation for procedure development (see figure 9). The characteristics of the simulators used for these evaluations will provide a benchmark for establishing the requirements of simulators intended for procedure development.



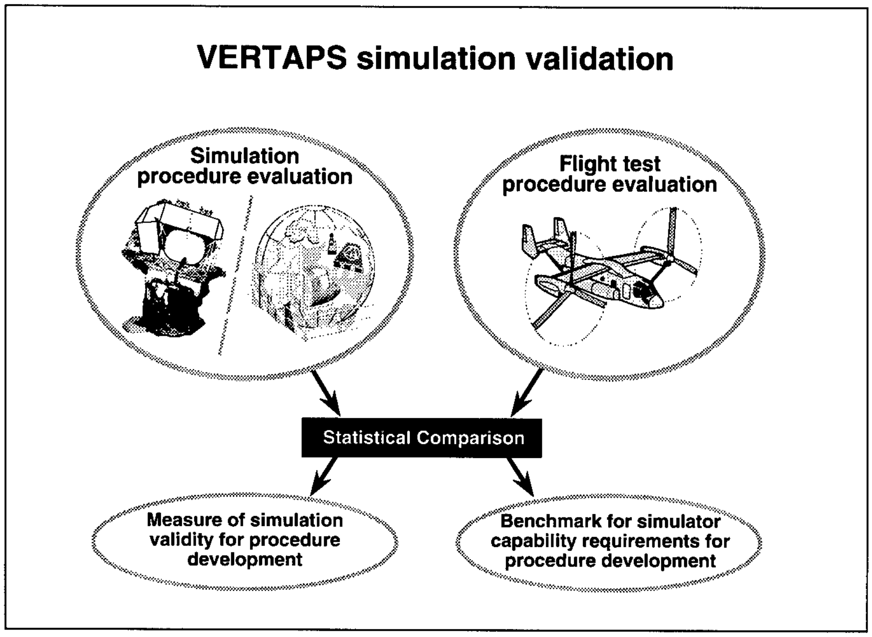


FIGURE 9 VERTAPS SIMULATION VALIDATION

TASK 4 - Air Traffic Control Procedure Development

Simulation will be used to evaluate air traffic control procedures designed to integrate vertical flight aircraft into the NAS. Procedures will be developed to allow operators to safely exploit the operational advantages of the civil tiltrotor without conflicting with existing air traffic and procedures.

Terminal Area Flight Path Analysis

Initially, timing and spacing requirements for vertical flight aircraft in the terminal area will be investigated using a simple flight path analysis model (see figure 10). The model will calculate spatial and temporal separation and identify conflicts between flight paths. Ineffective air traffic control procedures will be eliminated from further consideration.

- **Contractor simulation**
  - Visualization tool for timing / spacing analysis
  - Traffic conflict evaluation

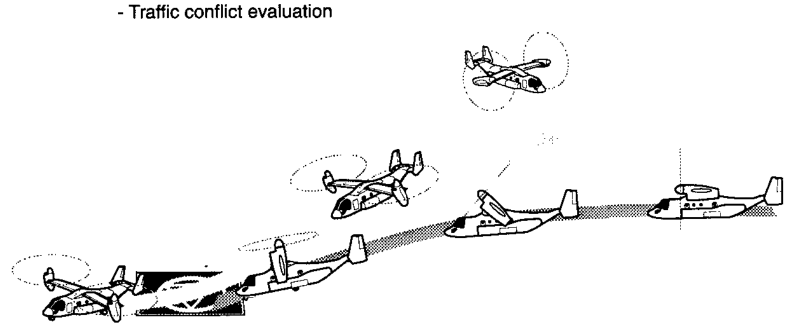


FIGURE 10 VERTAPS TERMINAL AREA FLIGHT PATH ANALYSIS

Federal Aviation Administration Technical Center Simulation Preparation

The NAS Simulation Support Facility will be prepared for VERTAPS work by developing vertical flight aircraft models for the Target Generation Facility, obtaining and analyzing traffic information from the site selected for air traffic control simulation, and training the pseudopilots and controllers in vertical flight air traffic procedures (see figure 11). Pseudopilots are individuals with no aviation background, but who are specifically trained for the air traffic control simulation. They control a simple point-mass computer model that drives an air traffic control target. Like real pilots, pseudopilots respond to directions from air traffic control. One pseudopilot can control a number of airborne targets, providing a target-rich air traffic environment for evaluation.

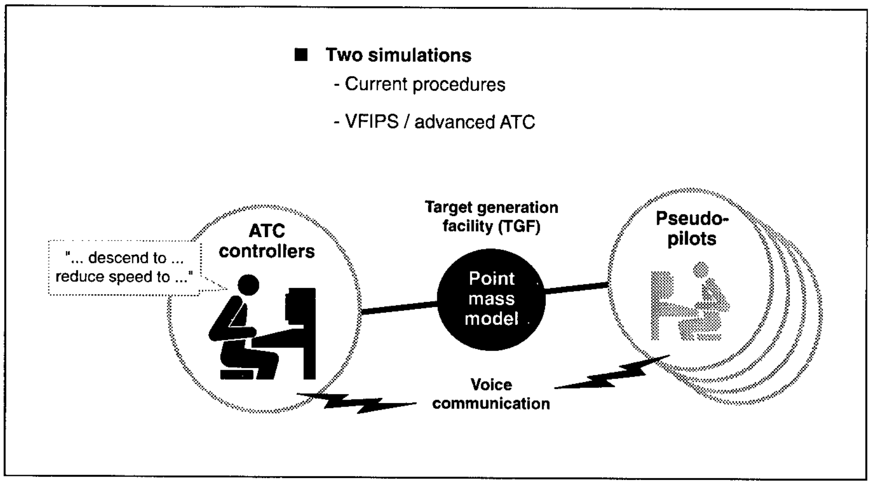
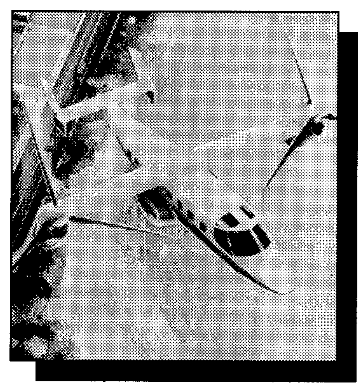


FIGURE 11 SUMMARY OF FAATC PSEUDOPILOT SIMULATIONS

Preparation of Cockpit Simulators for Air Traffic Control Simulation

Piloted simulators at multiple remote sites will be prepared for ATC simulation by establishing required communications links to the NAS Simulation Support Facility. Simulators that may be used for ATC simulation include:

- V-22 simulator at Boeing Defense & Space Group, Helicopters Division, Philadelphia, PA;
- V-22 simulator at Bell Helicopter TEXTRON, Fort Worth, TX;
- Vertical Motion Simulator at NASA Ames Research Center, Moffett Field, CA; and
- Manned Flight Simulator at the Naval Air Warfare Center, Aircraft Division, Patuxent River, MD.



Federal Aviation Administration Technical Center Air Traffic Control Simulations

Pseudopilot Simulations - Two air traffic control simulations will be conducted using pseudopilots only. The first will explore the conflicts likely to be associated with mixing vertical flight aircraft with fixed-wing aircraft under existing procedures. The second will provide an initial evaluation of new procedures designed to integrate vertical flight aircraft with other traffic in the NAS. The impact of the new procedures on terminal area operations, traffic flow, air traffic control system efficiency, and controller workload will be assessed.

Multisite Linked Simulation - The final air traffic control simulation will link remote, high-fidelity piloted simulators with the Federal Aviation Administration Technical Center simulation facility for online, real time, interactive simulation of vertical flight operations in a realistic traffic environment (see figure 12). Computer generated targets controlled by pseudopilots will provide additional air traffic. Under these conditions, having actual pilots fly simulators in response to air traffic controller instructions will increase realism; real pilots may respond to controller instructions differently than pseudopilots with no actual aviation experience. Piloted simulations also provide more realistic aircraft performance than the point mass models used by pseudopilots.

Candidate air traffic control procedures will be evaluated for feasibility and system operability. System delay, controller workload, and traffic flow will be analyzed. A questionnaire will be developed to obtain controller and pilot opinion information. The air traffic control procedures developed during these evaluations will enhance integration of vertical flight aircraft into the air traffic control system and the NAS.

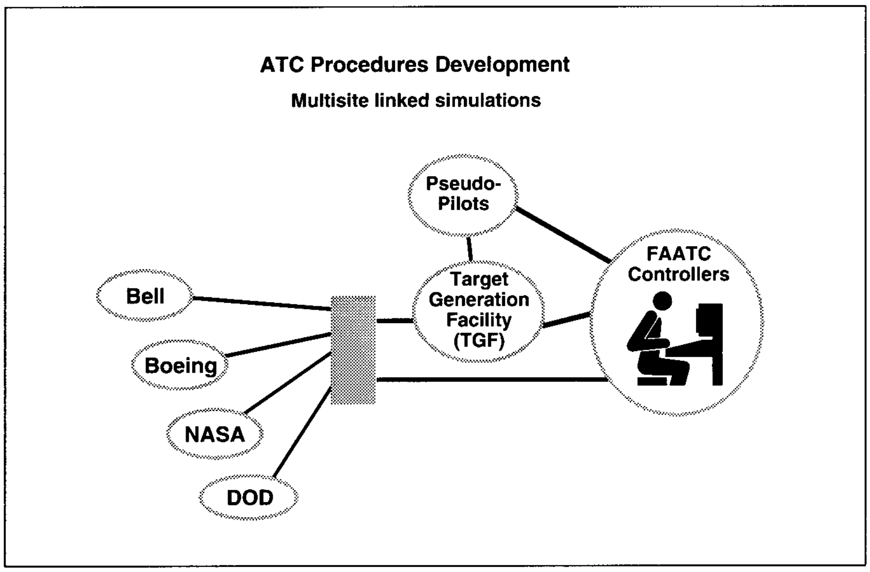


FIGURE 12 SUMMARY OF MULTISITE LINKED SIMULATIONS

Summary

The VERTAPS program provides an opportunity for the FAA, the manufacturers, and prospective operators to understand and utilize the potential benefits of vertical flight aircraft. By developing instrument procedures and ATC procedures, VERTAPS represents a critical step to understanding the infrastructure required for the integration of vertical flight aircraft into the NAS. Instrument procedures and ATC procedures developed under the VERTAPS program will be designed to utilize the unique capabilities of vertical flight aircraft while avoiding conflicts with fixed-wing traffic patterns, expanding the capacity of the NAS for all users.

The value of simulation for evaluation of aircraft characteristics has long been recognized. VERTAPS will be the first FAA program to draw on the power of simulation to develop and evaluate instrument procedures. Validation of simulation for instrument procedures development will provide a continuing benefit for the FAA in procedure development programs. This benefit may extend beyond vertical flight aircraft to the development of instrument procedures for fixed-wing transport aircraft. The potential cost savings of this application could be significant.

Completion of the VERTAPS program prior to the introduction of advanced vertical flight aircraft will increase the confidence that these vehicles can be successfully introduced and utilized to the benefit of the traveling public.

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7. Abstract

The Vertical Flight IFR Terminal Area Procedures (VERTAPS) Program Plan was developed by Systems Control Technology, Inc., Boeing Defense & Space Group, Helicopters Division, and Bell Helicopter TEXTRON. The plan describes tasks to be performed in a five year program to develop vertical flight instrument procedures (VFIPS) and air traffic control (ATC) procedures to integrate advanced vertical flight aircraft into the National Airspace System. The plan proposes the development and evaluation of instrument procedures using high-fidelity, piloted simulators and flight test. VERTAPS is intended to produce usable VFIPS and ATC procedures, and validate simulation as a valuable counterpart to flight test in instrument procedure development.

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