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STOL FIGHTER TECHNOLOGY PROGRAM

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ABSTRACT

In recent years, the Air Force has provided additional funds to investigate the technologies and problems associated with providing fighters a Short Take Off and Landing (STOL) capability without seriously degrading today's maneuver, load, and cruise performance. Within the Flight Dynamics Laboratory, this technology thrust has been planned and organized under the title of "Runway Independence."

The thrust is multi-disciplined in that the following technologies are being investigated both singularly and in integrated combinations to quantify their contribution to providing options in solving the STOL design task. These technologies are: aerodynamics, integrated controls, thrust vectoring/reversing exhaust nozzles, landing gear, and cockpit aids and controllers necessary to operate under weather and/or at night.

To help focus these technology efforts and to mature existing technology, the STOL Technology Fighter program was formulated. The objective of the program is to flight validate and mature near-term advanced technologies applicable to providing a STOL capability without sacrificing today's maneuver, cruise or dash performance. Specific technologies to be addressed in this program are: two-dimensional thrust vectoring/reversing exhaust nozzle; integrated flight/propulsion control; advanced high lift systems; rough/soft field landing gear; and cockpit aids and controllers necessary to locate and land a fighter on the usable portion of the runway at night and in weather.

The program will either modify an existing fighter like the F-15, F-16 or F-18 or build a hybrid vehicle like the X-29 with these technologies integrated into the vehicle. The contract will be awarded in 1983 with first flight in late 1987. The end objective of the program is to demonstrate take offs and landings under wet runway conditions of under 1500 feet including dispersion. This paper discusses the integration of these technologies into a total flight program.

INTRODUCTION

The STOL Fighter Technology Program has been structured to investigate, develop and validate through analytical, experimental and flight test methods, five technology areas related to providing current/future high performance fighters a STOL capability without an undue weight or performance penalty. This technology thrust is directed at one facet of the solution to the runway interdiction problem facing our main operating bases in Europe.

The five technology areas to be demonstrated in this program are as follows:

1. Two dimensional thrust vectoring/reversing exhaust nozzle.

2. Integrated flight/propulsion control system

3. High lift system

4. Rough/Soft field STOL landing gear

5. Cockpit displays and controllers required for STOL operations under night/weather conditions

Although the program is directed at providing technology options in the design of the next generation fighter, these technologies may also be incorporated into derivative versions of current fighters. A design requirement and technology driver for this program is to take off with payload and land within 1500 feet, including dispersion under day/night and adverse weather conditions.

BACKGROUND

The current interest in providing fighters with a STOL performance capability stems from the current and projected capability of an aggressor to neutralize the runways of our main operating bases in Europe. This concept of runway denial is based on the payload capability of the aggressor aircraft and the take off and landing distances of our current fighters when operating at night and/or under weather conditions. Numerous studies have clearly shown three advantages of significant reductions in balanced field length. First, the number of sorties required to close a runway increases exponentially with a linear decrease in required runway length (Figure 1). Second, the number of available runways increases as the balance field improves (Figure 2) and the airbase repair time/closure is significantly reduced as required runway length is decreased.

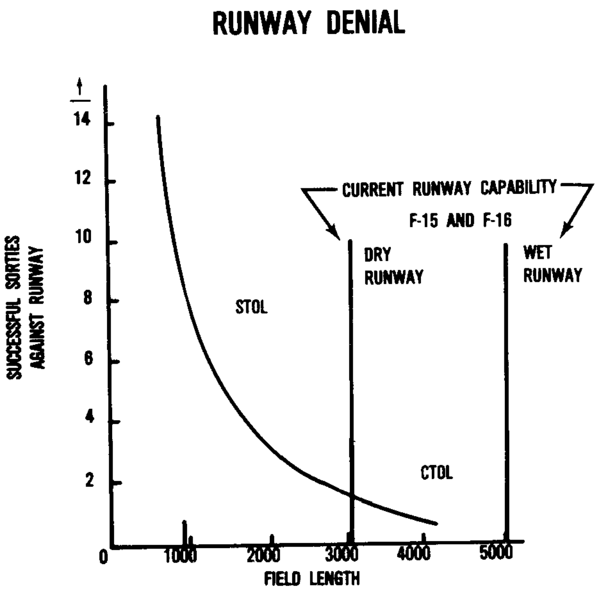

FIGURE 1

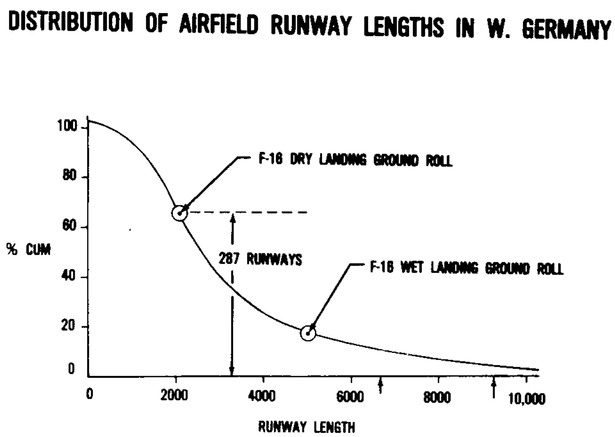

FIGURE 2

This threat caused HQ AFSC to direct the research laboratories to pursue emerging technologies that have application for STOL to current and future systems. Within this direction, the Flight Dynamics Laboratory has developed a runway independence technology roadmap and this effort is a key part of that roadmap (Figure 3). It is recognized that these five technologies are not the only solution to the runway denial problem or STOL; however, successful validation of these technologies will provide the designer with options he does not enjoy at this time because of real and perceived risks. So the thrust of this effort is threefold: 1) to individually validate these technologies for any possible applications; 2) integrate these technologies to provide a STOL capability to a fighter without sacrificing today's cruise, maneuver or payload performance; 3) to provide the data to assess the payoffs versus life cycle costs associated with systems application of these technologies.

OBJECTIVES

With this background and the results of additional operational studies, it was determined that the near term objectives would be to investigate technologies that would provide a STOL capability of approximately 1500 feet without sacrificing any of today's maneuver, cruise or maximum speed capability. Toward this end, several studies were initiated to identify these technology areas and industry was surveyed to determine the technologies that were being incorporated into their advanced designs. Out of these efforts were identified the five technology areas that form the core of this advanced development program (Figure 4). Application of these technologies was bounded by the requirement that they be flight demonstrated by fiscal year 1987 in order to be considered design options for the next fighter. The remainder of the paper will discuss both the total system requirements and the technology requirements that form the STOL Fighter Technology Program.

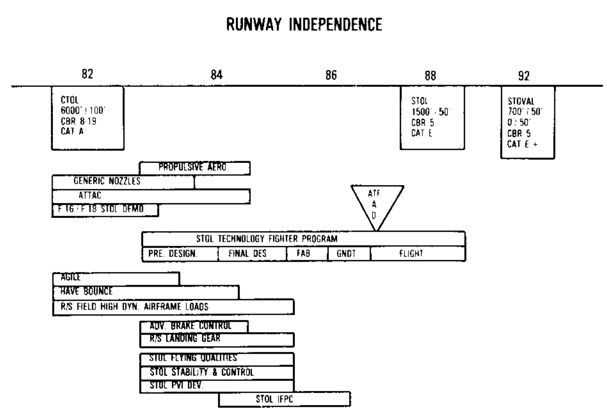

FIGURE 3

PROGRAM TITLE: STOL FIGHTER TECHNOLOGY
PROGRAM ELEMENT: 63245F / 63205F
PROJECT: 2682 / 2506

OBJECTIVE:

- DEVELOP, INTEGRATE AND FLIGHT TEST A SET OF TECHNOLOGIES THAT PROVIDE STOL CAPABILITY WITHOUT SACRIFICING MANEUVERING PERFORMANCE
  - 2-D THRUST VECTORING / REVERSING NOZZLE
  - INTEGRATED FLIGHT / PROPULSION CONTROL
  - SOFT / ROUGH FIELD GEAR
  - ADVANCED HIGH LIFT SYSTEM
  - STOL MODE GUIDANCE, CONTROL & PVI

POTENTIAL APPLICATION:

- ALL NEXT GENERATION FIGHTER AIRCRAFT

MILITARY WORTH:

- REDUCE TAKE OFF DISTANCE BY 40%
- REDUCE LANDING DISTANCE BY 80%

RISK:

- 2-D NOZZLE-MODERATE
- IFPC-HIGH

SOFT / ROUGH FIELD GEAR-LOW
HIGH LIFT SYSTEM-MODERATE
COCKPIT DISPLAYS, PVI-MODERATE

COORDINATION REQUIRED:

- ASD - EN, XR, SPO
- AEDC, AFFTC, APL
- NASA - LeRC, LaRC, ARC, DFRF

FIGURE 4

SYSTEM REQUIREMENTS

The five technologies will be incorporated into a current or hybrid fighter to provide the following STOL capability. Take off and landing distance of 1500 feet under the following conditions:

a. The usable runway width is 50 feet.

b. The runway surface friction coefficient is 0.1 when tires are not hydroplaning.

c. The runway surface roughness corresponds to Have Bounce Category E repairs without spacing or location restrictions.

d. Crosswinds have a cross-runway component gusting to 30 knots and turbulence as specified in MIL-F-8785C.

e. Atmospheric conditions are standard sea level day.

f. Lift-off and touchdown speeds are not less than 1.2 V_{min}.

g. The loading for take off is full internal fuel plus a 6000 lb external payload plus internal weight equivalent to gun and full ammo.

h. The loading for landing is no external payload, and a fuel load that will be the larger of 5% of usable internal fuel or sufficient fuel for 20 minutes of loiter.

The aircraft shall be capable of taxi on a soft field with a California Bearing Ratio of 5 for 5 passes on a field no larger than 8000 feet by 150 feet with the same loading conditions for take off and landing. It will be capable of STOL operations under night/weather conditions of 1/2 mile visability and a 200 foot ceiling. The test aircraft shall have maneuverability capabilities comparable to current fighters such as the F-15, F-16, and F-18. In addition, it shall be capable to operate to at least Mach 1.5 at 26,000 feet altitude.

TWO DIMENSIONAL THRUST VECTORING/REVERSING

A two dimensional thrust vectoring/reversing nozzle (Figure 5) is a major contributor towards meeting the STOL performance goal. The nozzle shall have a vector capability of ± 20 at dry and augmented conditions at or below 300 PSF dynamic pressure and approximately ± 5 above 300 PSF.

NOZZLE OPERATING MODES T.O. & L.

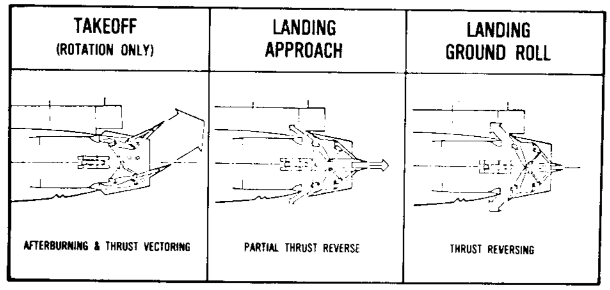

FIGURE 5

The thrust reverser shall be capable of providing at least an effective 50% reverse thrust in the dry mode on the ground. In addition, it shall be deployable in the air to provide a speed brake function.

The nozzle shall be designed so that an infinite variation in flow split between reverser and vectoring functions is possible within mechanical limits. This feature will allow the nozzle to provide longitudinal, lateral and directional control functions to augment the aerodynamic control surfaces both in the air and on the ground. In order to accomplish these functions, the reversing systems shall be capable of actuation from the approach mode to full reverse or to maximum forward dry thrust in less than a second. The vectoring rate will be determined by its use as part of the flight control system.

During the take off roll, the vectoring function will be used to lower the nose gear unstick speed. Typically, maneuver and cruise conditions size the tail area, and rotation and lift-off speed are accepted as a compromise. This results in a longer take off distance than is necessary since the aircraft can attain flight speed in a shorter distance but cannot rotate to a flight altitude. Vectoring will be used to rotate the aircraft to its flight altitude at its minimum control speed. This will reduce take off distance by approximately 40%.

During the approach phase, the engine will be at maximum dry power and the thrust will be spoiled by using the reverser and normal exhaust areas to provide thrust modulation. The requirement for the engine to be at maximum dry thrust stems from the reversing requirements to meet the 1500 foot landing requirement. Full reverse thrust must be available in less than a second after wheels contact the ground in order to meet the landing requirements under wet conditions. The fact that the engine is at military power also solves the transition and go-around criteria for night/weather operations. Once on the ground, the reverser ports, along with differential braking and nose wheel steering will provide directional control.

INTEGRATED FLIGHT/PROPULSION CONTROL

In order to fully utilize the reversing and vectoring capabilities, it requires that these systems be functionally integrated with the flight control system. This will require the forging of new control design methods and review of traditional divisions of responsibility between airframe and engine companies (Figure 6). With the exhaust nozzle part of the flight control system, the engine control can no longer be developed as a separate entity. It will now not only have to monitor normal engine functions, but also protect the engine from the vectoring/reversing functions. In addition, the nozzle actuators will now have to satisfy the rates and redundancy requirements of the flight control system. This includes consideration of the nozzle in estimating time and phase delays. In order to accomplish these tasks, a higher degree of integration and mutual resolution of design problems between airframe and engine companies will be required.

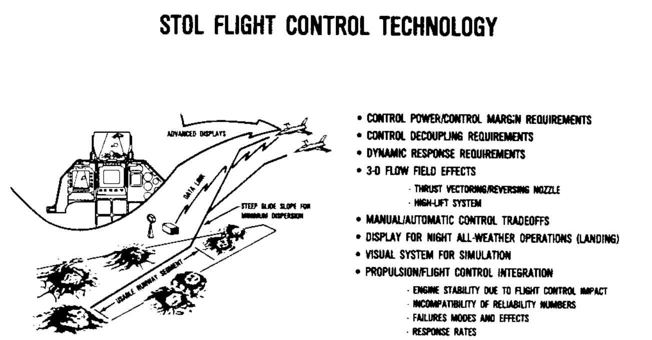

FIGURE 6

The control system will satisfy the intent of MIL-F-8785C, Flying Qualities of Piloted Airplanes and MIL-F-9490D Flight Control Systems, Design, Installation and Test. Specific area of interest is the terminal approach phase including semi-automated precision touchdown mode for pinpoint landings under a wide range of conditions including gusts and poor visibility. The control system shall be designed for precise manual control in all axes to provide good inner-loop stability. The system shall be a digital, fly-by-wire system to provide flexibility, precision and fault tolerance.

PILOT VEHICLE INTERFACE

The cockpit displays and controllers shall be modified or replaced to allow STOL operations at night/weather with visability of 1/2 mile, 200 foot ceiling. The goal is to allow a pilot of average skill to operate the aircraft in a STOL mode with a low to moderate workload. The near term solution is to provide information on a HUD in order for the pilot to precisely land the aircraft (Figure 7). Types of information that may be presented include rate of sink, airspeed, ground speed, and distance to touchdown. Exact information will have to be determined by extensive use of simulators. In order to provide this information, some form of ground aid will be necessary in the near term. However, if advances in the designation of ground targets continue, it may be possible to use the attack radar to locate and land on the usable portion of the bomb damaged runway.

HIGH LIFT SYSTEM

The high lift system shall be designed to lower the approach speed of the demonstrators to approximately 115 knots under landing load conditions. In order to accomplish this task, the high lift system may incorporate some of the advanced high lift systems currently being investigated like the vortex flap concept or other spanwise blowing concepts. Most of the advanced leading edge concepts are more applicable to highly swept configurations so that their demonstration on a current aircraft may not be feasible. However, some form of blown trailing edge flaps may be necessary in order to lower the approach speed without major modification to the wing of the demonstrator aircraft. In addition, the payoff versus penalty in weight and complexity of some of these concepts only becomes attractive when the landing requirement is below 1000 feet. Above 1000 feet, more wing area coupled with mechanical high lift systems and simple blown devices appear to be the more efficient solution.

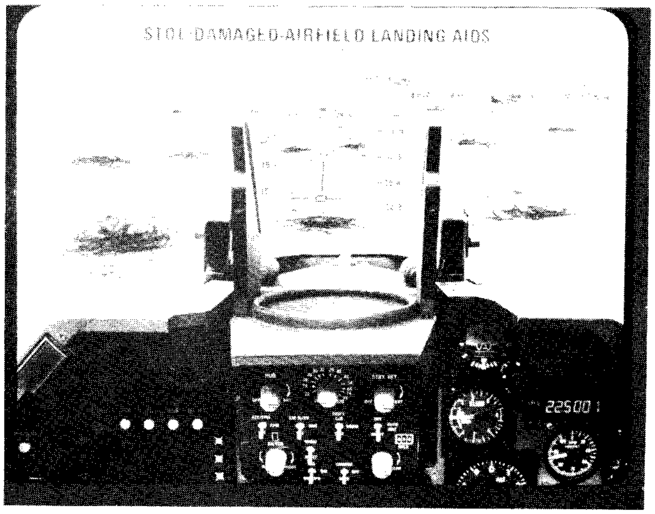

FIGURE 7

LANDING GEAR

The landing gear on the demonstrator shall be capable of rough/soft field operation. In addition, the landing gear will be coupled with the flight control system to provide directional control under wet/icy, crosswind landing conditions. Figure 8 shows the problems faced when trying to operate from an airbase after an attack. The effective area of damage is not only the crater but also the scattered debris which causes a FOD problem. Figure 9 is a graphic illustration of the total problem after an airbase attack.

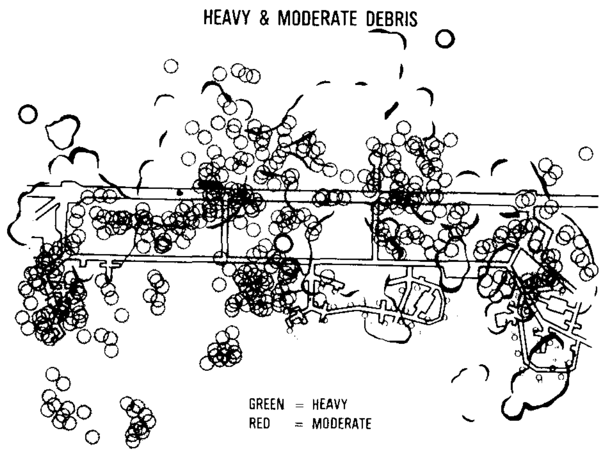

FIGURE 8

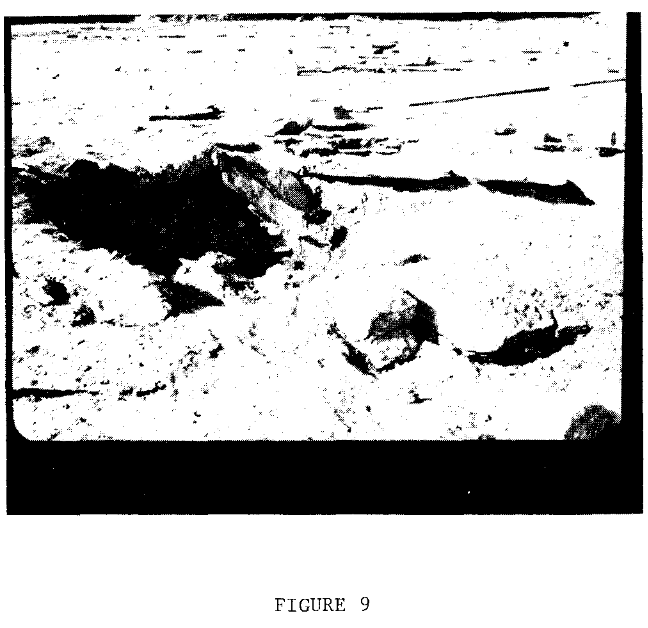

FIGURE 9

In order to operate from this base after the attack, several craters must be filled and repair mats placed over the craters. This repair technique creates bumps in the taxi and runway areas. Gear capable of rough/soft field operation will minimize the post attack recovery operations by allowing aircraft to be independent of concrete and be able to withstand the structural loads caused by the repair mats.

Figure 10 provides the criteria for describing the rough/soft field conditions. For the STOL Program, demonstrating a gear capable of taxi on a soft field at CBR 5 and Category E repairs on paved surfaces is a requirement.

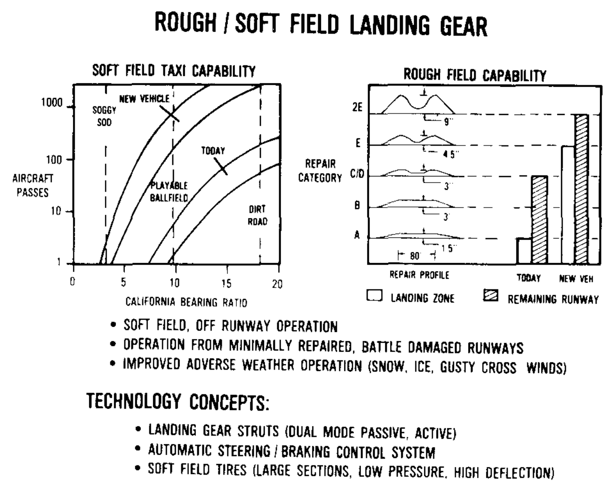

FIGURE 10

The second part of the landing gear effort concerns keeping the aircraft on the runway and under control during wet, crosswind operations. Figure 11 is an example of the hazards of wet runway operation. The Flight Dynamics Laboratory, in conjunction with industry, is investigating various control schemes to provide additional directional control to aircraft on the ground. One of these efforts is called the Advanced Brake Control System wherein nose wheel steering and a heading hold feature are used to keep the aircraft from wheathercocking into the wind and going off the runway (Figure 12). Simulations were conducted in the LAMARS facility validating this concept and additional work is planned. Figure 13 shows the potential payoff in this area. A version of this concept will be flight tested on the demonstrator aircraft. However, the level of control integration will be higher in that nose wheel steering, differential brakes, control surfaces, and reverse efflux will be used to provide directional control on the ground.

By using the vectoring capability, the maneuver performance can be retained and in some areas even enhanced.

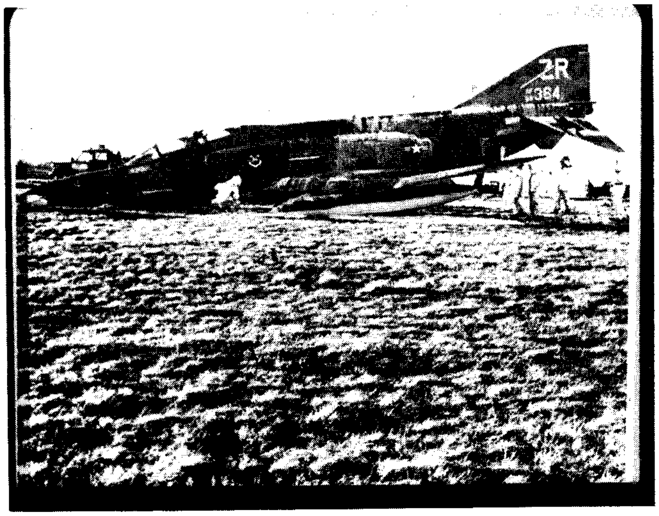

FIGURE 11

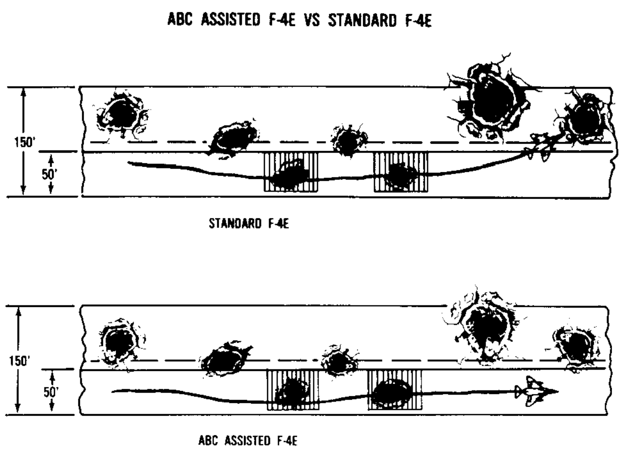

FIGURE 12

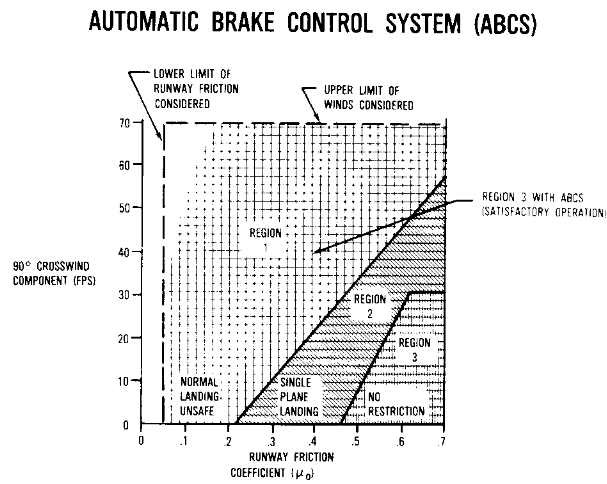

FIGURE 13

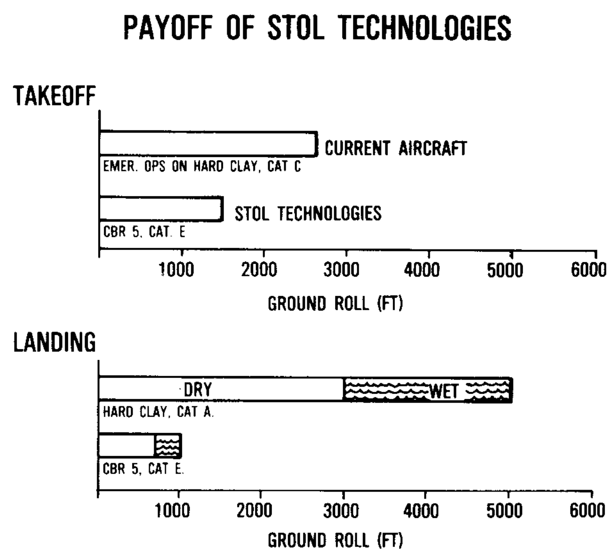

FIGURE 14

INTEGRATED STOL CAPABILITY

Integrating these technologies on a current generation fighter will reduce the take off distance by approximately 40% and the landing distance under wet conditions by 80%. In fact, several studies have shown that the landing distances could be reduced to below 1000 feet if these technologies were incorported on a production airplane (Figure 14). The penalty associated with these technologies is weight. Incorporating these technologies will add approximately 2000 pounds to the empty weight of the aircraft. However, the effect of this weight penalty is minimized by using the vectoring capability to rebalance the aircraft thereby providing a better trim drag polar. The rebalancing opportunity also affects the maneuvering performance. A goal of this program is not to reduce the maneuvering capability of the STOL fighter.

TECHNOLOGY TRANSITION

Equally important to demonstrating these technologies is the requirement to provide the confidence necessary for government and industry to accept and incorporate these technologies into future operational systems. Specific tasks in this program are designed to accomplish this transition. A few of these tasks are outlined below.

a. Determine the effects of a thrust vectoring/reversing exhaust nozzle on the aircraft's performance, control, and handling qualities throughout the operational envelope, especially during STOL operations, and compare these data with analytical and experimental results and current military specifications.

b. Provide full scale engine and two dimensional exhaust nozzle loads, sealing and cooling requirements and subsystems loads at all critical points in the operational enevelope. Validate structural design criteria, cost, and weight estimates.

c. Develop the design criteria for an integrated flight propulsion control for STOL operations for fighter class aircraft.

d. Provide design criteria for cockpit displays and controllers to facilitate routine all-weather STOL operations and provide criteria for selecting degree of automation required for STOL operations.

e. Validate computer models and design methods for rough/soft field landing gear.

PROGRAM SCHEDULE

Shown in Figure 15 is the program schedule. A single contract will be awarded in late FY 83 to modify a current fighter aircraft. A cost plus incentive fee/award fee contract is proposed. The incentive fee will be based on cost only and the award fee based on technical and management incentives. First flight is scheduled for FY 87 with the flight test phase lasting 18 months. During the course of the program, periodic industry reviews, workshops, and symposiums will be used to transfer the developed technology to industry and other government organizations.

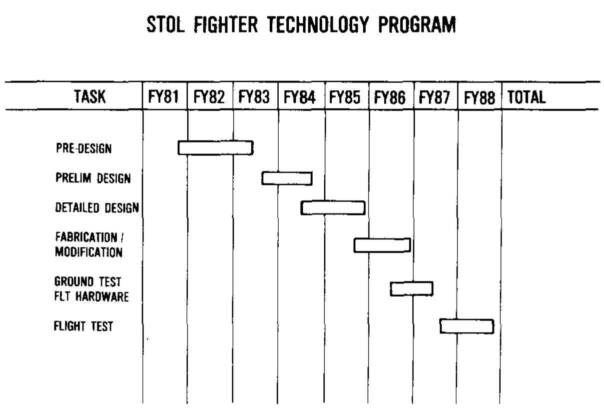

FIGURE 15