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# REQUIREMENTS FOR REGIONAL SHORT-HAUL AIR SERVICE AND THE DEFINITION OF A FLIGHT PROGRAM TO DETERMINE NEIGHBORHOOD REACTIONS TO SMALL TRANSPORT AIRCRAFT

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August 1978

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AERONAUTICAL RESEARCH FOUNDATION  
 Division of the Inter-University Research Center  
 for  
 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

REQUIREMENTS FOR REGIONAL SHORT-HAUL  
AIR SERVICE AND THE DEFINITION OF A  
FLIGHT PROGRAM TO DETERMINE NEIGHBORHOOD  
REACTIONS TO SMALL TRANSPORT AIRCRAFT

By

Mr. Kornel Feher, Aeronautical Research Foundation  
Dr. Lynn Bollinger, Aeronautical Research Foundation  
Mr. Jeffrey V. Bowles, NASA Ames Research Center  
Mr. Mark H. Waters, NASA Ames Research Center

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## TABLE OF CONTENTS

|   | <u>Page</u> |
|---|-------------|
| Introduction  | 1           |
| Part I - Status and Requirements of Intraregional Short-Haul Air Service  | 4           |
| Short-Haul Air Service Markets  | 4           |
| Interregional Air Service   |             |
| Intraregional Air Service   |             |
| Historical Review and the Current Status of Intraregional Short-Haul Air Service  | 8           |
| Deterrants: to Earlier Intraregional Air Service  |             |
| Summation of Relevant Helicopter Experience   |             |
| Intraregional Fixed-Wing Commuter Operations  |             |
| Definition of the Requirements for Intraregional Short-Haul Air Service   | 16          |
| Market Requirements   |             |
| Operational and Air Vehicle Requirements  |             |
| The Need for Economic Viability and Environmental Compatibility   | 22          |
| Port Site Locations   |             |
| Policy Constraints to the Air System  |             |
| The Need for a Flight Research Program  | 26          |
| Part II - Definition of an Experimental Flight Research Program to Determine Community Reaction to Small Transport Aircraft | 29          |
| Proposed Region and Field Site Selection for the Experiment   | 29          |
| The Legal Requirements for the Siting of Temporary Airports   | 36          |
| Preliminary Noise Evaluation  | 42          |
| Experimental Aircraft Definition  | 46          |
| Operation of the Experiment   | 58          |
| Preliminary Budget Estimates  | 73          |
| A Modified DHC-6 as the Experimental Aircraft   |             |
| Design Modifications  | 80          |
| Noise Impact Tradeoffs  | 95          |
| Modification Costs  | 107         |

TABLE OF CONTENTS (continued)

|   | <u>Page</u> |
|---|-------------|
| Concluding Remarks  | 120         |
| Recommendations   | 122         |
| Appendix A - A Review of Post Flight Research and<br>Demonstration Programs Related to<br>Short Field, Fixed-Wing Aircraft<br>Operationg in Urban Areas | A1          |
| Appendix B - Design Criteria for STOL and A/STOL<br>Ports (Document prepared by the Calif-<br>ornia Department of Aeronautics)                          | B1          |

## INTRODUCTION

As air transportation has grown and matured, there has been a stronger distinction made between "long haul" and "short haul" air transportation. At the outset of scheduled passenger service in the 1930's, only short haul flight segments existed due to the range capability of the aircraft at that time. Long haul trips were a series of short haul segments, and the time to cross the United States in 1935 by air was approximately 20 hours.

Technology has been a pacing factor in the remarkable growth in air transportation since World War II. Specifically, the combination of the turbojet engine and the swept wing has led to the speed and range of modern air transports. More recently, the high bypass ratio turbofan engine and the wide body aircraft have provided a continued impetus to this growth.

It is noteworthy that in spite of the emphasis on long haul in modern aircraft design, short haul air transportation is the fastest growing segment in U. S. air transportation and, in fact, has become the dominant segment in terms of routes and passenger service. Statistics show that over one-third of the routes flown by the U. S. scheduled Certificated Carriers are five hundred miles or less. Operations of these stage lengths account for almost two-thirds of the passengers and one-quarter of the passenger-miles flown. These proportions would increase when the non-certificated commuter airlines are included.

The conclusion to be drawn from these factors are that the advantage of air travel are mostly pronounced at long ranges due to the dramatic reduction in trip time. Yet, the demand for travel at shorter ranges is so great that the convenience and comfort of air travel has created markets for short haul air service which are continuing to grow and expand at rates faster than air transportation in general. This growth is taking place in spite of the fact that the application of modern aircraft technology has not been oriented toward

short haul air transportation. Many aircraft used today in short haul air transportation represent relatively old technology, and many others are being operated very inefficiently at short stage lengths. Thus, it seems intuitively obvious that modern aircraft technology can produce energy conservation and market growth for short haul just as it has for long haul. Unfortunately, no on aircraft can be defined in terms of size, cruise speed, and field lengths to satisfy all short haul markets in an optimum way, and this lack of definition for specific design requirements coupled with the critical sensitivity to aircraft costs have stymied new developments to date, at least in the U. S.

With this problem in mind, the objective of this report is to explore future requirements for one aspect of short haul air transportation in more detail, specifically, to evaluate the use of aircraft providing scheduled air service at very short ranges of two hundred miles and less. This type of service is termed intraregional air service, and it requires operations into small airports closer to urban and suburban locales as well as feeder operations into major hub airports. Noise, closer proximity to the general public and congestion at the hub airports are all potential constraints which must be considered in the definition of future requirements. These constraints apply to any type of flight vehicle -- rotorcraft and fixed wing aircraft alike. Although, rotorcraft have traditionally been used for this type of service, almost all have been uneconomical. Consequently, emphasis is placed in this study on the use of small fixed wing aircraft, (nominally 15-70 passengers) capable of short field lengths (less than 1000 ft.) as a viable alternative.

Part I of this report is an evaluation of the current status and future requirements of an intraregional short haul air service. To give a clearer perspective of future requirements, the initial section of this part gives

a brief definition of the different types of short haul air service. This will be followed by a historical review of previous attempts to develop short haul air service in high density urban areas and an assessment of the current status. The last three sections of Part I define the requirements for intraregional air service, the need for economic and environmental viability and the need for a flight research program.

Part II is a detailed outline of a research program that would determine urban community reaction to frequent operations of small transport aircraft. Both the operation of such an experiment in a specified region (The San Francisco Bay Area) and the necessary design modifications of an existing fixed wing aircraft which could be used in the experiment are established. In addition, an estimate is made of overall program costs.



## PART I

### STATUS AND REQUIREMENTS OF INTRAREGIONAL SHORT HAUL AIR SERVICE

#### Short Haul Air Service Market Definition

Short haul air transportation is considered in terms of the service offered between cities or regions (interregional) and that offered within a given region (intraregional). The former provides both origin-destination (O-D) type service and connections with other flights, whereas the latter typically operates as an airport feeder although point-to-point service within the region may also be available.

#### Interregional Air Service

Concerning the O-D and connecting flight service provided between cities and regions, it is an over simplification to define short haul air transportation in terms of stage length limit. Five hundred miles is often used as a convenient limit in defining a short haul trip, but considering existing air transportation in the U. S., there are regions in the midwest and southwest with numerous interregional stage lengths of greater than 500 miles. Conversely, in densely populated regions of the U. S., such as the Northeast Corridor from Washington, D. C., to Boston, a preponderance of the short haul trips are much shorter than 500 miles.

In addition to stage length, a distinction must be made for market size in terms of passenger density between city pairs. Passenger densities are generally classified as high, medium, or low density levels. The dividing point between these levels is not well established. However, high density is usually considered to be above 100,000 to 300,000 passengers per year, medium density from 100,000 to as low as 7,000 annual passengers, and low density the remainder.

It is obvious that these markets are quite diverse with many combinations of stage lengths and passenger density to consider when matching an aircraft to a given route structure. In addition, it should be recognized that inter-regional short haul air service is being provided by all classes of airlines -- the trunk airlines for high and medium density markets, the local service airlines for high, medium and a few low density markets, and the commuter airlines for medium and low density markets.

With this diverse market, no one aircraft can be defined in terms of size, cruise speed, and field performance to satisfy all short haul markets in an optimum way. This problem is part of the reason why modern aircraft are not being developed in the U. S. for these markets. The aircraft in use are, in general, either too large (e.g., DC-9, B737) or too old (e.g., DHC-6, DC-3). Several new aircraft are being developed in foreign countries (e.g., DHC-7, SD3-30) and they are finding their way slowly into U. S. air service.

In general, interregional short haul air service is a well established and growing segment of the U. S. air transportation system. In spite of high passenger demand, service is hindered somewhat by the lack of a modern aircraft in the small transport sizes (15 - 70 passengers).

#### Intraregional Air Service

This type of service is the subject of the current investigation, and it refers to aircraft operations limited to a specific urban region. In the past, this type of service has been performed almost exclusively by helicopter airlines operating an airport feeder service. The most prominent of these in recent years were those in the San Francisco Bay Area (SFO), Los Angeles (LA Airways), Chicago (Chicago Helicopter Airways), and New York (New York Airways). Today, only remnants of the earlier New York Airways system is in operation. In contrast, operations within a region using small, fixed wing aircraft are

not nearly as well known, but they do exist unsubsidized as both air taxi operators and commuter airlines.\* Current such service exists in the San Francisco Bay Area (STOL AIR), Los Angeles (Golden West), Dallas (Rio), and Houston (Metro). Similar service using small fixed wing aircraft is also operating between closely spaced large urban areas, e.g., between New York, Philadelphia, and Washington (Ransome), and between Cleveland and Detroit (Wright). In addition, there are several small commuter airlines which are very successful in providing a service over very short stage lengths from major cities to recreational areas. These include Rocky Mountain Airways and Aspen Airlines which fly from Denver to Rocky Mountain resort areas and Catalina Airlines which operates from the Los Angeles basin to Santa Catalina Island.

Thus, commuter airlines do provide a mix of both interregional and intraregional service. If intraurban air service is to grow, it would seem necessary to combine it with air service that goes beyond the given region providing scheduled and/or charter flights to nearby regions to complement scheduled service within the region. In this way, the natural versatility of air transportation can be exploited when competing with ground modes which are confined to fixed guideways and roadways.

In contrast to interregional short haul air transportation, intraregional air service is not well established. As mentioned above, all but one of the airport feeder helicopter airlines have gone out of business in recent years, and the operations with small fixed wing aircraft, although apparently successful (Los Angeles and Houston), are few in number.

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\* By definition from the CAB, a commuter airline offers scheduled service between a given two points with a minimum of five (5) roundtrips per week.

For this type of air service to grow, there is little question concerning the need for modern small transport aircraft which provide a comfortable ride to the passenger at a reasonable cost. In addition, this type of service must operate frequently and be convenient to both urban and suburban locales. As a result, a fundamental aspect of intraregional transportation systems in general and air systems in particular is the acceptance by the public of operations with urban centers and of port locations near both commercial and residential areas. Community noise, the proximity of low flying aircraft and possible property devaluation are all major concerns.

Historical Review and the Current Status  
of Intraregional Short Haul Air Service

Deterrents to Earlier Intraregional Air Service

Immediately following WW II, the CAB was mandated by Congress to establish subsidized short haul regional air services on a five-year test basis. In the resulting operations, existing twin-engine airplanes were employed to provide services between nearby towns and metropolitan centers. The results were not encouraging. The five-year certificates and accompanying subsidies were not renewed.

In most if not all of those short haul operations, the lack of economic justification arose from the disproportionate time/distance lengths between available airports and the passengers' points of origin and destination. Because of inconvenient airport locations, few passengers could attain any significant net saving of time.

A high proportion of the earlier close-in private airports had already been sold for post-war real estate development. Most of the proposed new airports for local flying encountered both economic and neighborhood obstacles. As a result, operators of the war surplus light transport airplanes used in those operations could not find landing areas close enough to the outlying population centers to provide significant time savings vis-a-vis the private automobile in and out of the metro center.

In general, the only significant demand for such air services was found to be into and out of the region's metropolitan air terminal for airline connections. However, in those days of limited airline service with DC-3 aircraft and low traffic volume, that demand was not sufficient by itself to support the service.

By that time, NASA's predecessor, NACA, had already recognized that the large size of the landing area required to serve outlying communities, together with the neighborhood noise objection, constituted the principal deterrent to the development of viable intraregional air services. Accordingly in 1948, NACA commissioned the Aeronautical Research Foundation (a joint MIT/Harvard research entity) to conduct flight tests in the Boston region. The ARF tests employed specially modified utility-type aircraft with variable noise suppression and flight pattern capabilities to determine the feasibility of placing smaller, more acceptable landing areas adjacent to population and commercial centers.

The resulting tests demonstrated the feasibility of both quieting and reducing the landing area requirements of existing utility aircraft designs sufficiently to produce adequate neighborhood acceptance of small close-in strips. This test is discussed in more detail in a later section entitled "The Need for a Flight Research Program."

However, that limited initial exploratory program was inadequate to provide a specific data base from which adequate design criteria could be derived. Such data were needed to guide the necessarily coordinated efforts of aircraft engineers, landing-area planners and regulatory agencies so that such intra-metro-region air services can be established as an integrated and viable system. With increasing traffic congestion since, that need has continued to grow.

The continuing effort planned by NACA and ARF to help fulfill that growing national need was sidetracked by the outbreak of the Korean War.

After that war, the helicopter emerged with powerful military sponsorship as the apparent successor of the fixed-wing airplane to serve all such short haul needs. Public regulations, subsidies, and developmental efforts for the next two decades were based on the expectation that rotary wing aircraft could

economically and acceptably meet the growing national needs for intraregional air services that expectation proved unrealistic.

#### Summation of Relevant Helicopter Experience

Prior to the U. S. military acceptance and initiation of large-scale financing of helicopter development during the Korean War, the Federal Government had recognized and was beginning to support experimentation with commercial helicopter services.

In 1947, barely two years after WW II, Los Angeles Airways (LAA) was the first helicopter operation to be granted authority to carry mail and property. Approval was granted LAA by the CAB under a temporary three-year certificate similar to those issued to local short haul airlines operating fixed-wing aircraft. Concurrently, both types of services were granted air mail subsidies. In 1951, the LAA certification was renewed for five years with added authority to carry passengers.

During most of the two decades following WW II, intraregional helicopter services expanded rapidly -- as did the development of larger, improved helicopters and the output of the helicopter sector of the U. S. aircraft industry. The second federally subsidized operation, Chicago Helicopter Airways (CHA) was certificated as a mail carrier in 1949. In 1952, New York Airways (NYA) was organized and certificated to carry both passengers and mail. CHA thereafter received its expanded passenger authority in 1956.

In November, 1963, the fourth and last CAB certification of an intra-urban helicopter service was granted on a non-subsidy basis to San Francisco and Oakland Helicopter Airlines (SFO). That company operated at a loss until bankrupt in 1965. After 1965, SFP operated under a trusteeship, with airline rebates on interline tickets, loans and free operating assistance. Under

those conditions, SFO succeeded in building the lowest cost, most efficient and relatively successful of the country's intraregional helicopter services.

At the outset in 1947, advocates of helicopter service subsidies pointed to the government's earlier initial three-year subsidy of DC-3 airline service. Thereafter, airline route after route had moved into a self-supporting position. Helicopter services were expected to follow the same pattern.

From 1947 through 1965, proponents of the subsidized helicopter services continued to satisfy Congress that a potentially self-supporting helicopter design was still "just around the corner." First the development of larger helicopters, and then the development of lighter, more efficient turbine powered models was expected to reverse the discouraging year-by-year need for increased subsidies.

Nevertheless, each year the subsidy need still continued to expand. By 1965, the subsidy requirement was reported to have reached 72% of total costs. (It is not clear, however, whether or not the government's contribution to manufacturing costs is included in that total cost.) Regardless, Congress cut off all helicopter subsidies at the end of 1965.

After 1965, the three previously subsidized helicopter services shrank rapidly. Increased airline subsidies through inter-connecting ticket rebates, loans and free supporting services did not suffice. LAA ceased regular scheduled operations in October, 1970. CHA ceased operations entirely from 1966 through 1968.

More recently, CHA re-established some minimal services to Chicago Midway Airport. However, if any such operations still exist, they no longer merit listing in the Official Airlines Guide. Also, during recent years, several other operations, such as the Metroplex Helicopter Airways in Texas, have



been privately financed, evidently exhausted their capital through operating losses and sharply curtailed or completely ceased operations.

In the meantime, NYA with the support and control of Pan American and TWA, has continued to provide limited services to the three principal New York airports. The NYA operation from JFK airport to the top of the Pan Am building has been most conspicuously important. Whether or not NYA will be able to re-establish sufficient traffic to justify continuity following the disastrous accident atop the Pan Am building in 1977 has yet to be determined. Nevertheless, with continuing Pan American and TWA support, NYA appears able to continue some modicum of services indefinitely. If so, NYA may be the last survivor of the previously certificated intra-metro-region helicopter operations.

Despite the discouraging experiences to date, optimism has not disappeared. A New "Los Angeles Helicopter Airlines and Bay Area Helicopter Airlines" is now reported to be awaiting certification to operate small helicopters in the San Francisco Bay Area with plans also to operate in Honolulu and Washington, D. C. In other parts of the country, limited taxi services employing small helicopters still continue to appear and disappear. However, only those providing contract services for premium industrial activities -- such as energy exploration, production and distribution -- have in the course of this investigation been found to be financially successful.

All said and done, such investigations to date have yet to reveal any helicopter operation any place in the world offering regularly scheduled public transportation services that has been able to earn a satisfactory return on its investment. In fact, none are known to have been able to break even over a significant period of time.

Suffice to say, the helicopter as an economic, self-supporting form of public transportation to serve intra-metro-region needs has been tried and found wanting.

## Intraregional Fixed-wing Commuter Operations

The type of service offered by the commuter airlines is quite varied depending upon the region of the U. S. being served, and a NASA sponsored study by the Aerospace Corporation<sup>1</sup> is an excellent reference on Commuter air service. In it, the diversity of the service is highlighted.

In general, commuters have gone through a dynamic period of growth. For example,

- ° The growth rate of commuters is more than double that of the growth rate for all CAB certified carriers.
- ° The number of passengers they carried has increased 75% between 1970 and 1975.
- ° The average annual increase in cargo is 31.2%.
- ° The average annual increase in mail is 17.5%.
- ° The number of carriers in 1964 was 12.
- ° The number of carriers by 1975 was 235.
- ° Of the 970 communities that receive scheduled passenger service, 314 (32.4%) are served exclusively by commuter airlines.
- ° Of the total of 1073 aircraft operated by commuters, only 251 (23.4%) are turbine powered.

Of particular interest in this study is the feeder operation into major airport hubs to provide service to certificated carriers from small communities. It is interesting to note that in the Commuter Air Carrier Traffic Statistics for the year of 1975, the CAB showed that the 25-49 mile category had the largest passenger total (1,258,076) in the distribution of passenger market by mileage

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1. Belina, F. W.; and Bush, L. R.: "A Study of Commuter Air Service," NASA CR-152005, June 1977.

and density. The major reason is that commuter operators such as Golden West in Los Angeles have found that a major market exists within a given metropolitan region utilizing existing airport facilities. Golden West provides service to Fullerton, 26 miles from the Los Angeles International Airport, the Santa Ana/Orange County Airport, Ontario, Palmdale, Riverside and Oxnard, all within the 26 to 60 mile range.

STOL air commuter's role in the San Francisco Bay Region is geared precisely to this hub and spoke pattern, serving communities such as Concord, 30 miles away from the San Francisco International Airport, San Rafael, 22 miles from the San Francisco International Airport, Santa Rosa and Napa/Vallejo, all within the 22 to 56 miles range, well within the region.

Some of these commuters have gained permission to operate outside of the regular airport traffic pattern under VFR conditions, making their service just that much more efficient. However, it must be recognized that in general, fixed wing aircraft are precluded by regulation from flying the "helicopter approach" paths into major hubs, i.e., 500 foot low altitude approach channels below and between the active airlines. It is noteworthy that such operations using small fixed wing, short field aircraft were conducted in trial operations at both Washington National Airport and LaGuardia Airport in New York in 1956. By all accounts, the operations were a technical success and the Flight Safety Office of the CAA (forerunner to the FAA) took the initiation in recommending a permanent approval by the Civil Aeronautics Board (CAB) of the helicopter -- equivalent approach pattern. This recommendation was disapproved for other than technical reasons. Included in Appendix A is a short account of situations that took place leading up to and including the CAB hearings.

The primary thesis of this study is that a major market does exist for short haul feeder operations into hub airports, and that they can be served with fixed

wing aircraft without government subsidy. What better proof is there than the very existence of the many and varied commuter operators which operate under minimal CAB economic regulations, hold no certificate of public convenience and necessity and operate without subsidy or route protection.

Definition of the Requirements for  
Intraregional Short Haul Air Service

Market Requirements

An earlier section outlined a new type of intraregional air service. The service would be dominated by frequent flights to and from the major hub airport(s) within the region. In addition, commuter service would be provided between the locations set up in the route system network within the region. For an established region with set patterns of living and commerce, the market for this point to point service would be small. However, it would grow if the air service could influence changes in these patterns. This prospect is discussed below. Finally, relatively, short interregional air service should be included into the route system of the airlines to take full advantage of the inherent versatility of aircraft versus other modes of transportation.

There appears to be little question concerning the desirability of an air feeder service into hub airports from locations within a given region. As discussed earlier, there have been many attempts at such service since World War II in the U. S., primarily with rotorcraft, but only the feeder services using fixed wing aircraft in Houston and Los Angeles can be considered economic successes. Obviously, the flight origins must be reasonably convenient to the origin of the traveler, and in most regions, Houston and Los Angeles notwithstanding, this requirement has usually meant minimal land area at the port sites. In recent years, this requirement has lead to the use of rotorcraft, but short field fixed wing aircraft have been used for this purpose in the past (Appendix A) and appear to be entirely feasible in the future (Part II of this report).

Concerning commuter service within the region and short haul service to nearby regions, ultimate economic viability is very hard to estimate. To be successful in commuter operations the air system will have to create new patterns

of travel within the region which would take place over a period of years as business relocates and new residential areas emerge. As an example, the whole concept of the suburb evolved out of the widespread development of the automobile. It is unpredictable what effect the air system would have in this regard. Many factors would influence the result such as local geography, types of business and industry within the region that would benefit from decentralization, etc.

Thus, just as in the past, it seems most likely that an intraregional air service would begin by meeting a demand for airport feeder service. The growth of commuter service would evolve over a period of years depending upon the factors listed above. Finally, it would seem that a successful intraregional air service would have to take advantage of the inherent versatility of aircraft in the daytime off-peak hours, nights and weekends. For example, delivering high priority freight and mail, chartered or scheduled service to recreational areas within or near the region, etc.

#### Operational and Air Vehicle Requirements

Aircraft Design.— Many factors must be considered in the design of the aircraft including cruise speed, size in terms of number of seats, range capability without refueling and field length capability. All are important and must be selected carefully to provide an aircraft which would be versatile in meeting all anticipated mission requirements. However, the overriding consideration in this study for fixed wing aircraft is the requirement for short field length -- runways of 500 to 1000 feet -- to allow fixed wing aircraft to operate to and from port sites close to commercial and residential areas much the way helicopters are operated today. The field length criteria follows from the design criteria for STOL and Augmented STOL (A/STOL) ports established by

the California Department of Aeronautics<sup>2</sup> in 1969. This document is reproduced in total and enclosed as Appendix B to this report.

The last section of Part II of this report goes into detail on the design modifications required to achieve safe short field performance with an existing small transport aircraft. An important design modification for this aircraft and for future "ultra STOL" transport aircraft will be the installation of leading edge slats and augmented lateral control devices (spoilers). This is an important design feature to protect against the continuing hostile environment of convective and mechanical turbulence near the ground. Also, the slats and spoilers prevent the loss of control and lift due to wing stall while operating at low speed in heavy gusts or in the lee of obstacles which may produce hazardous vortices or airflows. Such a slat and spoiler arrangement have proved to be very successful in a series of light aircraft built by the Helio Aircraft Company.<sup>3</sup>

One other aspect of field performance for a fixed wing aircraft is the ground roll in a significant cross wind. Research is currently being conducted by the NASA with cross wind landing gear installed on a small transport aircraft. This type of landing gear makes provision for crabbed steering, and it is likely that this would be a design requirement for all future short field transport aircraft since many port sites will have only one runway or at best parallel runways.

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2. Anon, : "Design Criteria for STOL and A/STOL Ports (For STOL Aircraft 12,500 lbs. Gross Weight or Less), California Department of Aeronautics, September 17, 1969.
  3. H-295 Super Carrier (U-10), H-500 Twin Carrier (U-5), H-600B Stallion.

Although emphasis throughout this report is on the use of conventional fixed wing aircraft, future developments of powered lift aircraft for short field or vertical takeoff as well as improvements in the helicopter remains as a distinct possibility. This is due to the continued research and development being conducted by the government -- primarily the military.

Since the first U. S. commercial helicopter service was certificated by CAB in 1947, the U. S. Government has subsidized the development and testing of well over forty types of VTOL configurations. Most of those configurations when conceived and funded were expected to produce practicable passenger-and-cargo utility. None have! Thus, to date, the helicopter appears to be the relatively lowest-cost and most nearly economical form of VTOL vehicle that a legion of dedicated designers have been able to conceive over a quarter of a century of such efforts supported by many hundreds of millions of U. S. Government dollars, and it has been found wanting.

An interesting sidelight on the operational safety aspect is seen in the fact that most military bases using helicopters for continuous operations have installed paved strips commonly 600 to 800 feet in length -- as are also seen at most helicopter factories. Consistently safe helicopter operations evidently call for a ground skimming run to build up a safe auto-rotational speed before climbing out at about the same speed as do the more advanced STOL airplanes.

Air Traffic Control Requirements. -- A complete evaluation of air traffic control (ATC) requirements is beyond the scope of this study, but it is likely that an effective regional ATC system interacting with the air space control into the hub airports will be a pacing technical factor in the development of an effective intraregional air system. The specific programs to consider have



been addressed very well in a study of intraurban transportation systems by The Boeing Company.<sup>4</sup>

In this study, the concept of strategic air space planning is advocated whereby the slot for landing at the next destination of a given aircraft is pre-programmed before its departure. Extensive use of ground based computers is necessary. This concept is effectively used on highly travelled long range routes such as the North Atlantic. In contrast, tactical control resolves conflicts as they occur in real time and is used in domestic airspace because the complexity of traffic is beyond the capability to manually plan strategic flights. The assessment is made in the Boeing study that the advances in airborne avionics and ground based equipment will make strategic control in a high traffic regional environment possible. The great advantage of strategic control is the movement of ATC workload from real time during the flight to fast time before the flight.

The Boeing study also addresses the runway operation rate in terms of aircraft operations (arrivals and departures) per hour. This becomes a critical factor in commuter operations when there is a great demand into or from a given port in the route system. This would be the case in the San Francisco region with the great influx to and from downtown San Francisco. Aircraft approach speed and allowable separation, and the runway occupancy time affect the rate of operations as well as the capability of the strategic ATC to safely monitor the slots. Based on the Boeing study, a runway acceptance rate of 50 - 100 aircraft per hour appears feasible.

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4. Anon, : "Study of Aircraft in Intraurban Transportation Systems San Francisco Bay Area," NASA CR-114347, September 1977.

Concerning the operations at the hub airports, the aircraft would take full advantage of their short field and crosswind capability to land independent of the runways active with large transport operations. Such a situation now exists on both the San Francisco and Oakland airports by STOL AIR airlines and the time saving is quite significant. Obviously, this is the way rotorcraft operate into the hub airports, and it seems mandatory that short field fixed wing aircraft do the same if they are to be effective. The widespread use of Microwave Landing System (MLS) will make this procedure even more feasible.

Concerning weather, it is presumed that the aircraft will be designed with IFR capability, and thus visibility conditions should not influence the system or the location of ports. This was a conclusion of the Boeing study, but there is no question that more research is needed to insure flight safety in all operating conditions and locations.

## The Need for Economic Viability and Environmental Compatibility

The economics of any intraregional transportation system becomes very complex because of the need to evaluate the economic impact on the total community -- land values, commerce development, etc. -- not just the operating revenues and costs of the carrier. Similarly, environmental impact is complex. The net effect of a new or expanded mass transportation system should be to reduce the overall noise, emission and energy consumption for the total region. To do this, the other modes being replaced must be evaluated. There are many assumptions to be made and alternatives to be considered, and obviously no quick definitive answers can be determined from a "Benefit vs. Cost" type study for urban transportation systems. However, the trends are very important, and these studies can be very useful to highlight the strong interaction between the technical, social, and political issues that must be considered.

Two studies, both complementary, have been conducted concerning the operation of an intraregional air service in the San Francisco Bay Area.<sup>5,6</sup> Market demand, operational constraints and a benefit -- cost tradeoff have all been established to a certain degree. Both studies were conducted using inputs from the San Francisco Bay Area Metropolitan Transportation Commission (MTC) concerning growth projections and population shifts.

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5. Eastwood, Stephen, et al: "Operational Evaluation of a Regional Air Transportation System for the San Francisco Bay Area," Institute of Transportation Studies, University of California, Special Report ITS-B-SR-76-3, September 1976.
  6. Haefner, L. E.: "Benefit Cost Evaluation of an Intraregional Air Service in the Bay Area," Department of Civil Engineering, Washington University, St. Louis, Missouri, NASA CR-152084, December 28, 1977.

Future alternatives for ground transportation modes were not considered in either study, a necessary step to make such studies more definitive. However, a great deal of insight into the problem of implementing an intraregional transportation system can be gained from either study. Some of the results are discussed qualitatively in the following sections.

Port Site Locations.- The purpose in establishing an intraregional air service is not only to provide a convenient and fast mode of transportation primarily to the hub airport, but also to other points both within and without the region. Thus, it is obvious that the port sites should be located close to concentrations of population both commercial and residential. However, this poses a dilemma in terms of community acceptance. The environment -- noise and emissions -- and the proximity of aircraft operations are determining factors that must be evaluated.

In the two studies referenced, candidate port sites were located at the centroids of population within the thirty (30) superdistricts within the total region. A mode split analysis was used to determine which of these sites would be used in the air system network. The U. C. Berkeley study adopted a far term approach with 8 - 10 new ports close to population centers; whereas the Washington University study considered several alternatives ranging from the status quo (the use of existing General Aviation airports only) to the addition of five new sites. Both studies included downtown port sites in both San Francisco and Oakland, and it is fairly clear that these sites would be mandatory if the system were to grow to any significant size other than as an airport feeder system.

Policy Constraints to the Air System.- The Washington University study made an evaluation of the impact on capital costs, noise, emissions, energy consumption, and neighboring property values to be anticipated from expansion

of intraregional air transportation systems. Under three different assumptions as to projected population growth, in each case the expanded regional air systems resulted in the following:

- ° Increased capital costs
- ° Increase noise
- ° Reduced emissions
- ° Reduced energy consumption
- ° Increased property values

The increase in noise has been found to be a prime deterrent in energy effort during recent years to establish close in short field air transportation services. Note as made in the Washington University study that the projected increase of noise with expanded activity can be offset by aircraft quieting designs or procedures which involve inconsequential cost penalties. A specific plan-of-action to solve the noise problem is set forth in Part II of this report. Subject to acceptance of the required landing areas by the adjacent community, both of those University studies concluded from their cost/benefit analyses that the net benefits favored an expanded regional air system under each of the system alternatives and population growth projections which were considered.

The U. C. Berkeley study found that the air service would have the best chance to make a profit as strictly an airport feeder system. Neither study made any attempt to quantify the expanded use of the system in off peak hours though both recognized this prospect (longer trips to other regions, carrying of mail and light cargo, etc.). Nor was any attempt made to evaluate the induced demand that could result due to shifts of business and population. No effective way is known to quantify this effect, yet it is obvious from history that the availability of transportation always produces such demographic shifts.

The remaining issues -- emissions, energy consumption and property value all improve with the expansion of the air service. It is interesting to note that the decision theory used in the Washington University study to combine these issues and relate the overall benefits and costs favored the expanded regional air system for each of the MTC growth projections.

## The Need for a Flight Research Program

A fundamental aspect of intraregional transportation systems in general and air systems in particular is the acceptance by the public of operations within urban centers and of port locations near both commercial and residential areas. It is impossible to develop any transportation system that has no objectionable aspects. Thus, the basic problem is "what obtrusiveness will be acceptable when weighed against the public benefit of the transportation system?" Community noise, the proximity of low flying aircraft and possible property devaluation are all major concern.

With one exception, NACA/NASA studies have not adequately addressed any of these concerns; the exception was a series of flight tests with light aircraft which were operated experimentally in the Boston area during 1947-1950. Results of the experiment are reported in NACA TR-1156.<sup>7</sup>

Conclusions reached in this report were generally favorable in terms of acceptable community noise and proximity of low flying aircraft. The anticipated effect on urban property values was evidently not considered seriously, since the majority of property owners concerned thereafter testified in favor of a Bill passed by the Massachusetts legislature authorizing continuing commercial use of the sites tested.

The flight tests in Boston mentioned above are probably the only such tests ever conducted for purely research purposes involving advanced in the state of the art. However, there have been several more recent attempts to conduct similar flight programs to demonstrate at urban port sites the operation of

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7. Elwell, Fred S.: "Experiments to Determine Neighborhood Reactions to Light Airplanes With and Without External Noise Reduction," NACA TR-1156, 1953, conducted by the Aeronautical Research Foundation.

small transport aircraft already in production.

The most widely publicized of these was the "Metro-66" program conducted in Manhattan, New York City, in 1966. Appendix A includes a narrative description of events which took place leading up to and during both flight programs -- the one in Boston and the one in New York. An attempt to conduct a similar program in San Francisco in 1969 is also discussed. Those more recent efforts only serve to reconfirm the fact that throughout the country, communities reject efforts to establish close-in landing areas which require several thousand feet of runway combined with conventional approach and departure patterns and which have no provisions for an acceptable degree of noise attenuation.

It must be concluded that there are no definitive criteria upon which transportation system designers or community planners can evaluate the public reaction to aircraft operations in urban locales. In spite of the partial success of the test program in Boston, it is probable that only limited aspects of those results are valid now due to the generally presumed increase in environmental awareness on the part of the public.

Thus, there is a need to systematically re-evaluate the total community acceptance of intraregional air transportation. Part II of this report defines an experimental program to achieve this goal. The program is patterned after the earlier Boston tests with the San Francisco Bay Area chosen as the candidate region for the flight program. Field sites for the tests have been selected which would be logical sites to be included in a future operational route network. A preliminary assessment of computed noise contours and the population impacted at each site has been made, and a detail plan for the actual operation of the experiment has been defined. Finally, considerable study has been made of the necessary modifications that would have to be made



to a deHavilland DHC-6 "Twin Otter" to be used as the flight test aircraft. There are several options for the modifications, and the total program costs are presented that reflect these different options.

As a final remark concerning the need for a flight test program -- this need exists whether future intraregional aircraft are conventional fixed-wing aircraft, powered-lift STOL, VTOL or rotorcraft. Part of the failure to gain acceptance of STOL aircraft in the late 1960s -- in spite of great enthusiasm by the aerospace industry and the airlines -- can be traced to a lack of effective communication and understanding between aviation advocates and the general public.

The other part of the failure has been the continuing attempt by advocates to sell old "Ford tri-motor" state of the art vis-a-vis short field operations instead of complying with the public demand for less noise and less land use, combined with more safety and more convenient locations. The purpose of the investigation proposed in the following Part II is to provide a "blueprint" that will avoid the mistakes of the past.

The proposed blueprint will include empirically determined new design criteria in terms of acceptable noise levels, flight patterns and operational procedures that are found to be acceptable to inhabitants of areas adjacent to close-in landing strips for Quieted/STOL aircraft. Aircraft engineers as well as community land use planners need such empirically determined criteria upon which to base their designs and operational procedures. Before the engineers and designers can proceed, however, the FAA must have such tests and the resulting documented findings in hand so as to be able to establish updated rules that will regulate the design and operation of advanced short-field aircraft.

Advanced Q/STOL and VTOL technology cannot therefore be applied to growing public transportation needs until the requisite flight research and operational testing have made possible the establishment of standards acceptable to all concerned.

## PART II

### DEFINITION OF AN EXPERIMENTAL FLIGHT RESEARCH PROGRAM TO DETERMINE COMMUNITY REACTION TO SMALL TRANSPORT AIRCRAFT

Part I of this report has provided a background for intraregional short haul air service in terms of an historical perspective and the requirements for the future -- technical, economic, and environmental. The concluding section of Part I has discussed the need for a flight research program which would test the reaction of the community to frequent aircraft operations in urban and suburban locations.

The critical issues are community noise and the proximity of flight operations to the community. It is presumed here that this experimental flight research program would come under the purview of the U. S. Department of Transportation as part of an overall objective to improve urban transportation services within a metropolitan region and for short distances beyond metropolitan regions. Basic research aspects appear consistent with NASA objectives.

Part II defines such a flight research program with the San Francisco Bay Area chosen as the region in question. Candidate field sites have been selected, and an assessment of the legal requirements for the siting of ports and a preliminary evaluation of community noise at each site have been accomplished. In addition, the definition of a candidate research aircraft and preliminary assessments of the operation, the costs and the noise impact of the flight program have been completed. This work is detailed in the following sections.

#### Proposed Region and Field Site Selection for the Flight Experiments

The San Francisco Bay Area was selected for study as the region for the flight research program. It is felt that a flight research program which proposes to test the reaction of the community to aircraft should be conducted in

a region where a future intraregional air service may be implemented. The Bay Area is a natural choice for such an air transportation system due to natural geographical boundaries (the Bay and hilly terrain surrounding the Bay) which channel surface traffic into several congested corridors. In addition, there is an excellent data base of transportation data for the region which has been developed and is maintained by the Metropolitan Transportation Commission (MTC).

The region is comprised of the nine (9) counties and the further subdivision into thirty (30) superdistricts, shown in Figure 1. Figure 2 locates existing general aviation airports now in operation within this region. Although these airports are well spaced throughout the region and reasonably accessible to most of the outlying residential areas in the region, it was decided to go one step further to identify the optimum location of candidate port sites. A brief study was conducted with the Institute of Transportation Studies at UC Berkeley to evaluate an operational intraregional air system in the Bay Area (see Reference 5 in Part I). A mode split analysis was conducted as part of the study, and the resulting network of port sites for the air service is shown in Figure 3. These ports are intentionally located at the centroid of population within a given superdistrict.

The next step was to select candidate sites for the flight research program. The criterion was to find sites as close as possible to the selected sites for the operational system. Surprisingly this posed little or no problem, even in the San Francisco Central Business District (CBD). Seven port sites were selected as candidates for a flight research program out of some thirty sites surveyed.

They are as follows:

|   |     |
|---|-----|
| San Francisco Central Business District | CBD |
| Palo Alto - Off Page Mill Road          | PAL |

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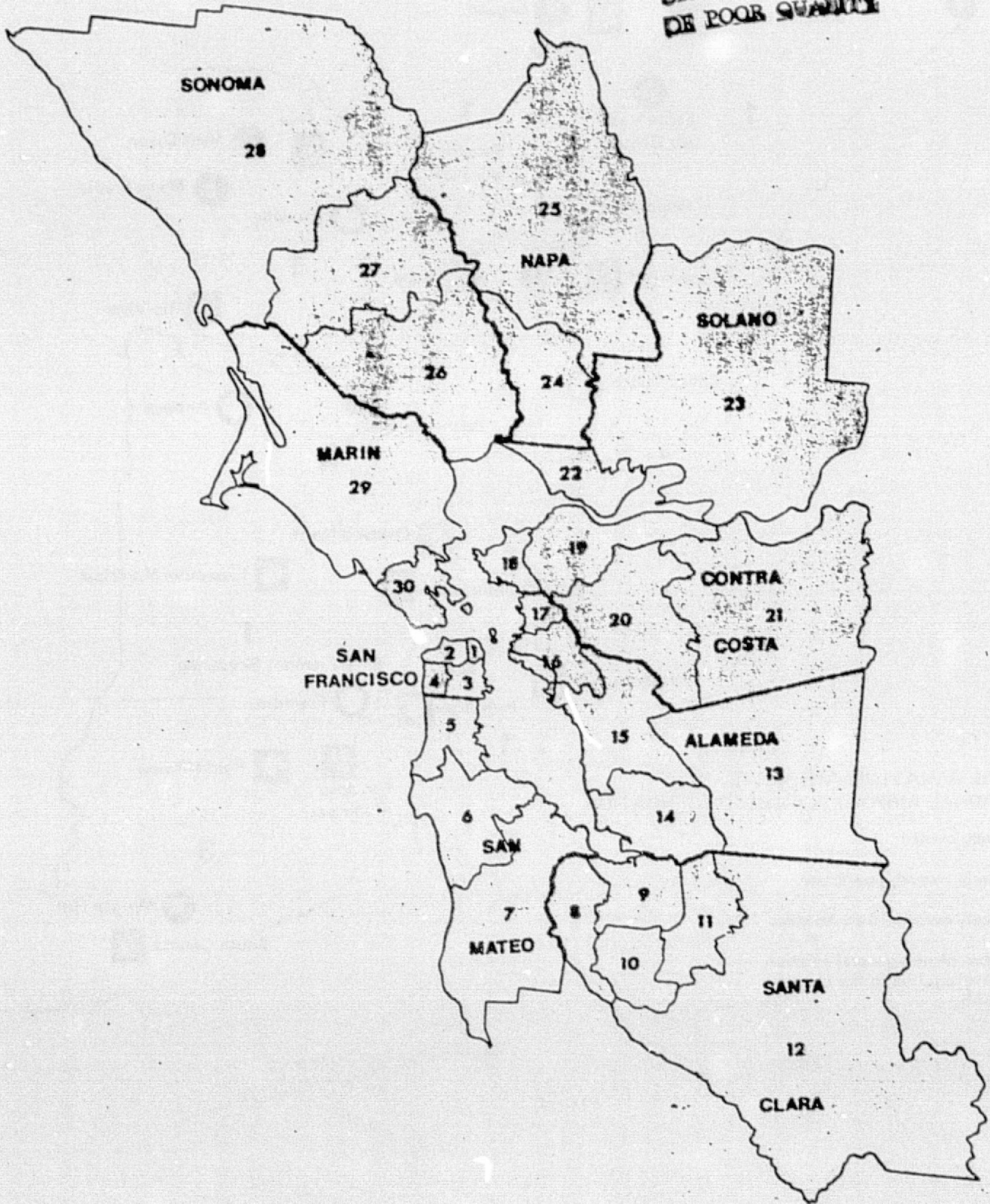
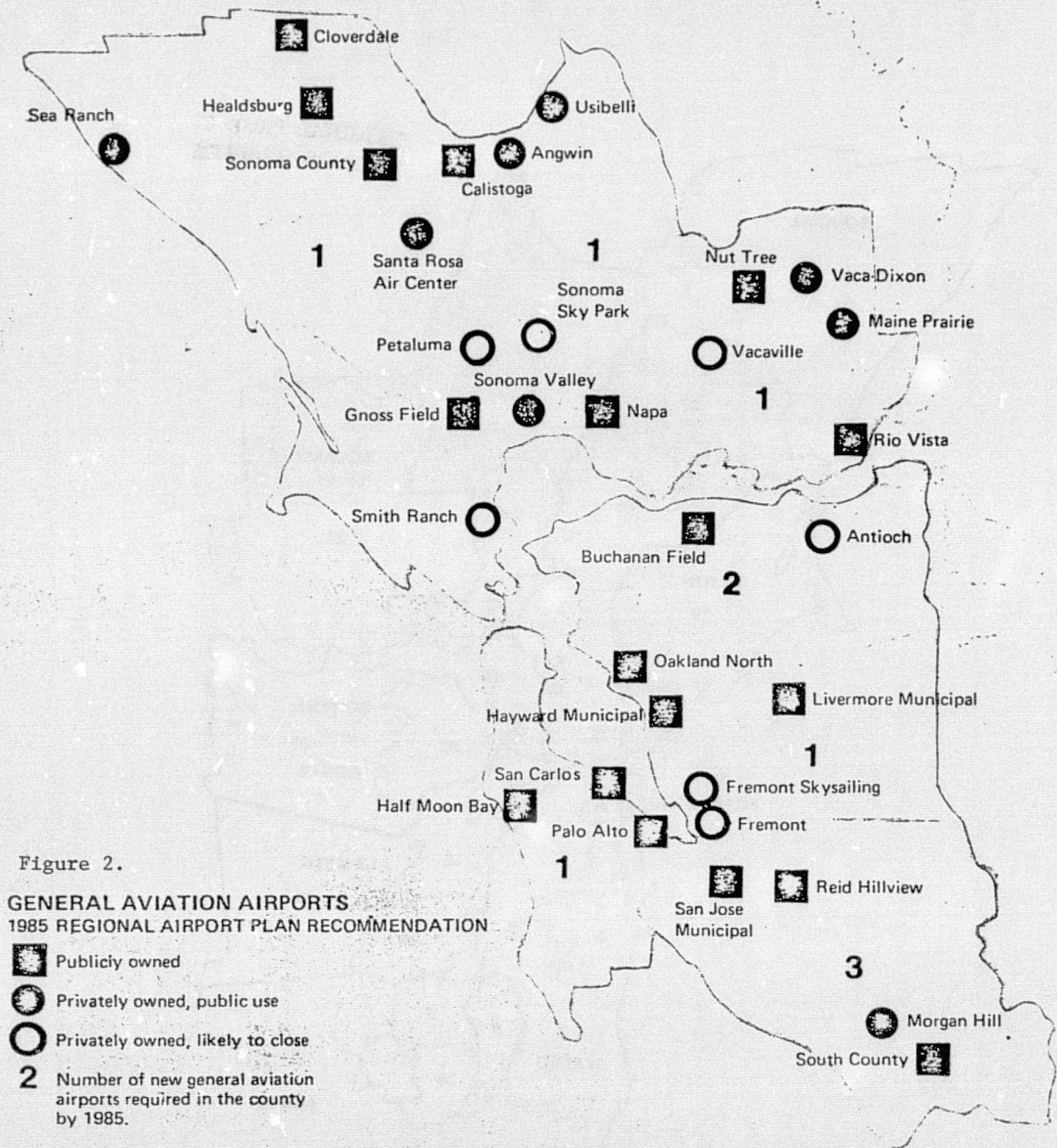


Figure 1. Super Districts for the Nine-County San Francisco Bay Area



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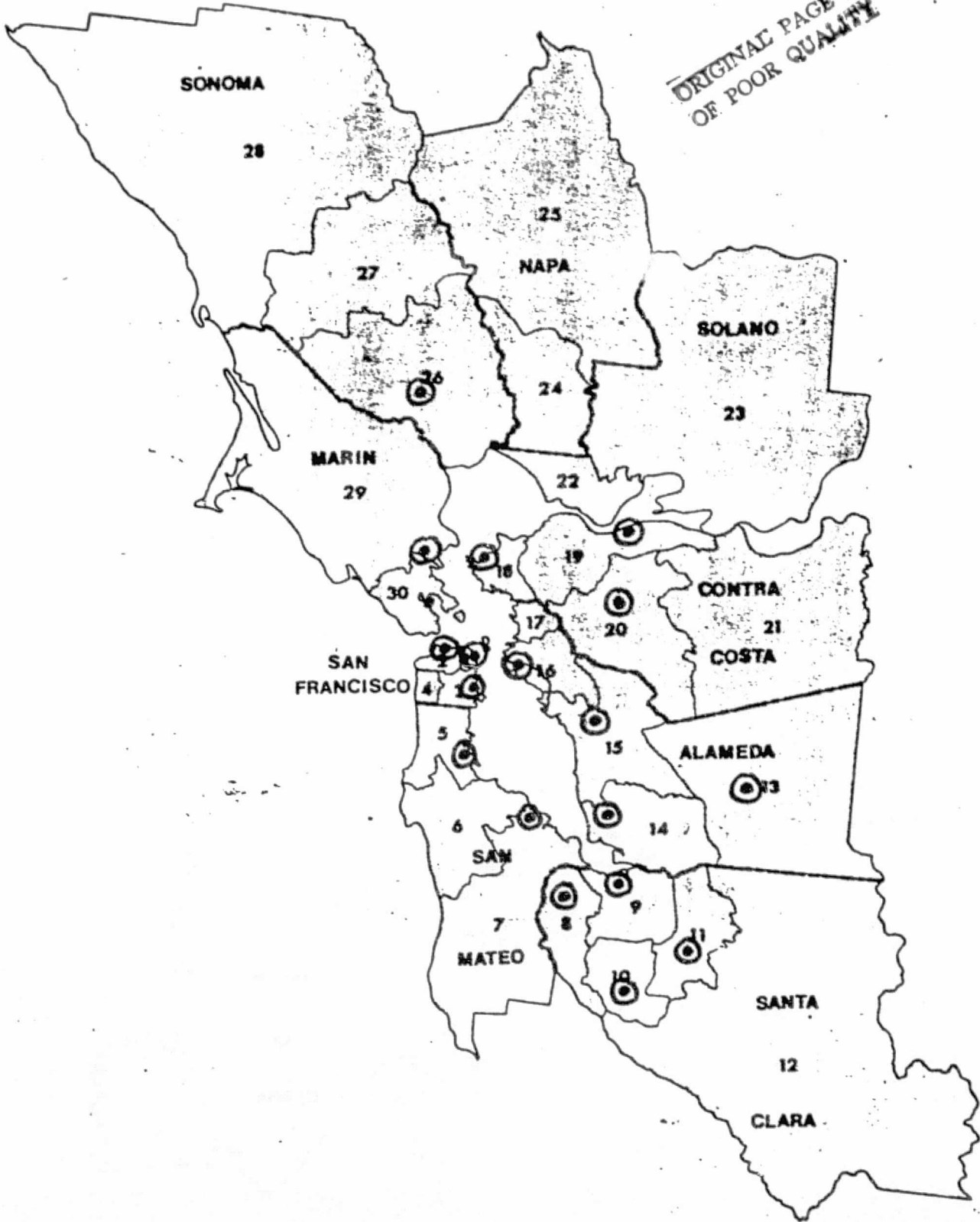


Figure 3. Potential Network of Port Sites for an Intraregional Air Service

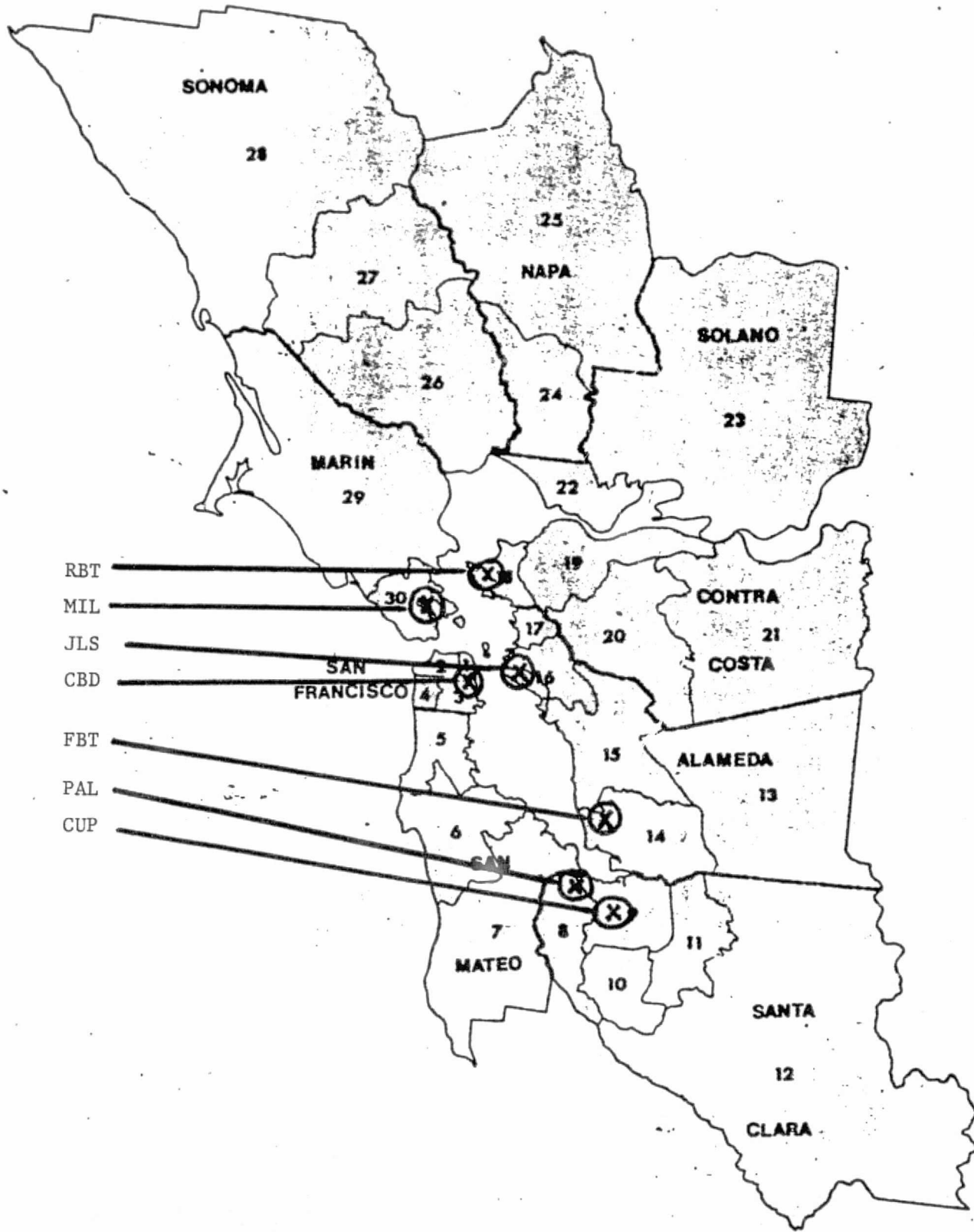


Figure 4. Experimental Port Site Locations

|                                  |     |
|----------------------------------|-----|
| Cupertino - Adjacent to I-280    | CUP |
| Fremont - At BART Terminal       | FBT |
| Oakland - Jack London Square     | JLS |
| Richmond - At BART Terminal      | RBT |
| Mill Valley - Adjacent to US 101 | MIL |

A map of the region showing these seven (7) sites is shown in Figure 4.

The most ambitious aspect of the flight program would be the location of a port site in or near the San Francisco CBD. There are several excellent sites available, as well as the prospect for operations from a barge located off the waterfront. Likewise, the site at Jack London Square is very close to the Oakland CBD. The sites at Fremont and Richmond are not only in the CBD of these smaller Bay Area cities, but both are virtually contiguous with terminus stations of the Bay Area Rapid Transit (BART). The sites in Cupertino and Palo Alto are located as sites which impact residential, commercial, and high technology industrial areas. In addition, the Palo Alto site is very close to the Stanford University campus. Finally, the location of the Mill Valley site is strictly residential.

The following paragraphs describe each site in more detail, and Figures 5-11 show each site on local street maps.

San Francisco (CBD) - Land Sites

Transbay Transit Terminal - The Transit Terminal is the region's major transportation hub. One block south of Market Street, on First Street, it is halfway between BART's Embarcadero and Montgomery Street stations. The building's 1000 foot roof could provide an excellent landing site for a future air transportation system, although its proximity to high rise structures will require a very careful study of approach and takeoff patterns. It is presumed that both



the aircraft and air traffic control systems used would take full advantage of modern aeronautical technology in terms of slatted, wing leading edge devices for lateral control, augmented flight control systems and advanced microwave landing systems with full radar surveillance. As such, maximum aircraft safety could be preserved with curved approach and departure flight paths. This site is located in San Francisco County and is under the jurisdiction of the San Francisco Planning Commission, Air Council and the Board of Supervisors.

South Park-Mission Rock - The proposed site is located at the waterfront between San Francisco Piers 48 through 56. The site is two miles from the San Francisco Central Business District, under the jurisdiction of the San Francisco Port Commission. There is adequate space available for short field aircraft operations and eventual passenger terminal facilities. No relocation of existing structures would be required. Local public transit access is provided by the existing MUNI bus line operating on Third Street with a travel time of six minutes to the San Francisco Central Business District and to the Montgomery Street BART Station. The Southern Pacific Railroad terminal on Fourth and Townsend servicing the Peninsula commuter traffic is a five minute walk away from the proposed site. This site is located in San Francisco County.

South Park - China Basin - Location of the proposed site is in the Central Waterfront District of San Francisco and is adjacent to the Southern Pacific Railroad yard between Third Street and Fourth Street. The site is one-and-one-half miles from the San Francisco Central Business District and is owned by the Southern Pacific Railroad. There is sufficient space available for future ULTRA-STOL aircraft operation and terminal facilities. Public transit access is provided by the existing MUNI bus line operating on Third Street with a travel time of six minutes to the San Francisco Central Business District.

The new Southern Pacific Terminal Building that services the Peninsula commuter traffic is five minutes walking distance. The area is zoned M-2 industrial by the San Francisco Planning Commission. This site is located in San Francisco County.

San Francisco (CBD)-Barge Waterfront Sites

Ferry Building - Located in the San Francisco business district at the foot of Market Street, within walking distance of the greatest concentration of office buildings in the region. There is a high ambient noise level in the area due to traffic on the elevated freeway. If the site is accepted and used for the flight research program, it would perhaps become the most significant link in the chain.

Pier 37 - The proposed site is located directly east of Fisherman's Wharf. The site could either be used with the floating platforms or possibly off the just recently cleared pier that measured 825 ft. along its shortest longitudinal dimension and 200 ft. in width. The availability of the pier has not been checked.

Pier 42 - The pier is near the foot of Second Street and is 936 ft. long and 145 ft. wide. For the total transportation system planning it could offer a fair alternative, but for the flight research program it has no real significance.

Mission Rock - Located two miles from the San Francisco Central Business District, it is under the jurisdiction of the San Francisco Port Commission. It should be considered one of the major possibilities for one of the downtown landing sites. As Pier 42, it could be used effectively as a flight research site, but it is questionable whether this site would be used in an operational system due to its remoteness from nearby populated areas. The location's real value is as a permanent site for a future link in the air transportation system.

### Other Bay Area Sites

Palo Alto (PAL) - Located directly south of Stanford University, it is bordered by the Oregon-Page Mill Expressway on the north and Hanover Street on the east and south. This site is extremely close to Stanford campus and higher income residential areas. Also, light industrial complexes, Hewlett-Packard, Itek are in the immediate vicinity. Two hospitals, Stanford and Veterans Hospital, are within a three-mile radius. This could prove to be a very useful site to obtain a good cross-section of public reaction due to its location of widely different interests. The open space available is approximately 1500 ft. long, 800 ft. wide. Zoning A (open area no development). Santa Clara County.

Cupertino (CUP) - The proposed site is adjacent to Interstate 280 bordered by Stevens Creek Boulevard on the north and Interstate 280 on the south. The site is nestled in a residential area of predominantly single-family dwellings, with a new condominium complex on the east. Basically north-south orientation. The proposed site is approximately 34 acres, 1600 ft. long and 850 ft. wide. No relocation of existing structures is required. There is no available freeway access to the site. Santa Clara County.

Fremont BART (FBT) - There are several choice locations in the immediate area of the BART Station. The site has excellent possibilities both as a location for the flight research program and also as a permanent site for the total air transport system. It is within walking distance of the BART Station, and major shopping center, various condominium complexes, a hospital, and the newly established Fremont Civic Center. This site is ideally located in all respects. Alameda County.

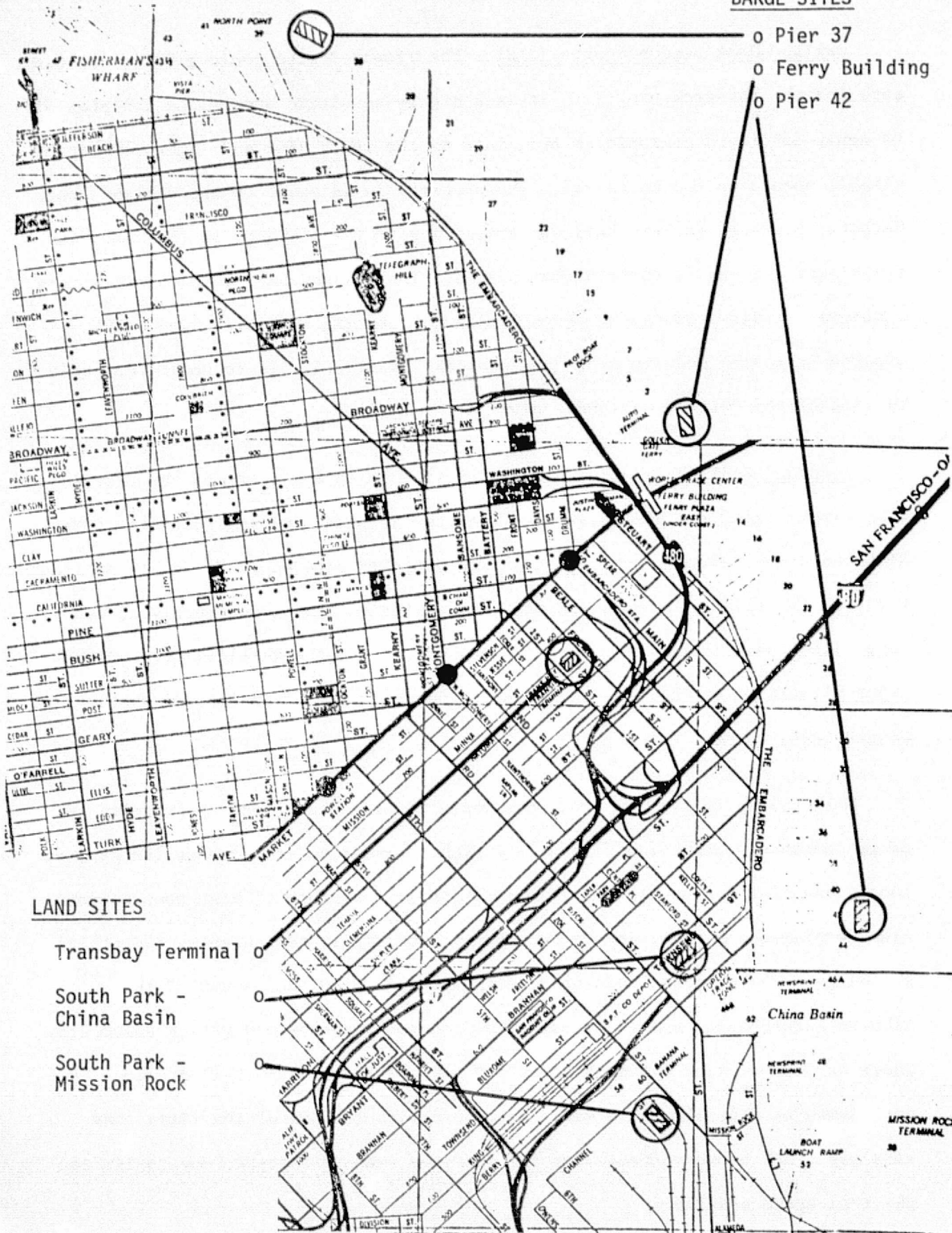
Oakland Jack London Square (JLS) - The proposed site could give invaluable data for the research program. It is a highly sensitive area since its proximity to newly developed condominium buildings on the south side and light commercial establishments on the north end. The property is adjacent to the Oakland Inner Harbor. Southern Pacific Railroad tracks border the property on the east, and the Nimitz Freeway is three blocks beyond. The Oakland BART terminal is within a one-mile radius, and Jack London Square is less than 1/2 mile away. The applicable zoning code is R-80 (residential high rise). It is under the jurisdiction of the Port of Oakland. Alameda County.

Richmond BART (RBT) - The designated site is in the heart of the city in the close vicinity of the BART Station. The area is under the jurisdiction of the Richmond Urban Redevelopment Agency. The proposed site would be highly desirable for both the flight research and the transportation system due mainly to its prime location. There is a question, however, as to the availability and the prior allocation of the site for other purposes in the Urban Renewal Master Plan. Contra Costa County.

Mill Valley (MIL) - An area that would offer an excellent opportunity to gauge community acceptance. This is a highly sensitive area due to its general locale and also due to its specific location in a mixture of high-cost condominium complexes and newly erected commercial buildings, restaurants, and office buildings. The proposed landing site is west of US 101 and south of the Tiburon Interchange, and it is surrounded on two sides by navigation easements. There is a power line directly north and west of the site, but its presence is not viewed as a problem that would interfere with the use of the site. The site might not prove suitable for the ultimate transport system due to limited physical space available.

BARGE SITES

- o Pier 37
- o Ferry Building
- o Pier 42



LAND SITES

- o Transbay Terminal
- o South Park - China Basin
- o South Park - Mission Rock

Figure 5. San Francisco (CBD) - Prospective Port Site Locations

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Page Mill Rd.



Figure 6. Palo Alto (PAL) - Prospective Port Site Location

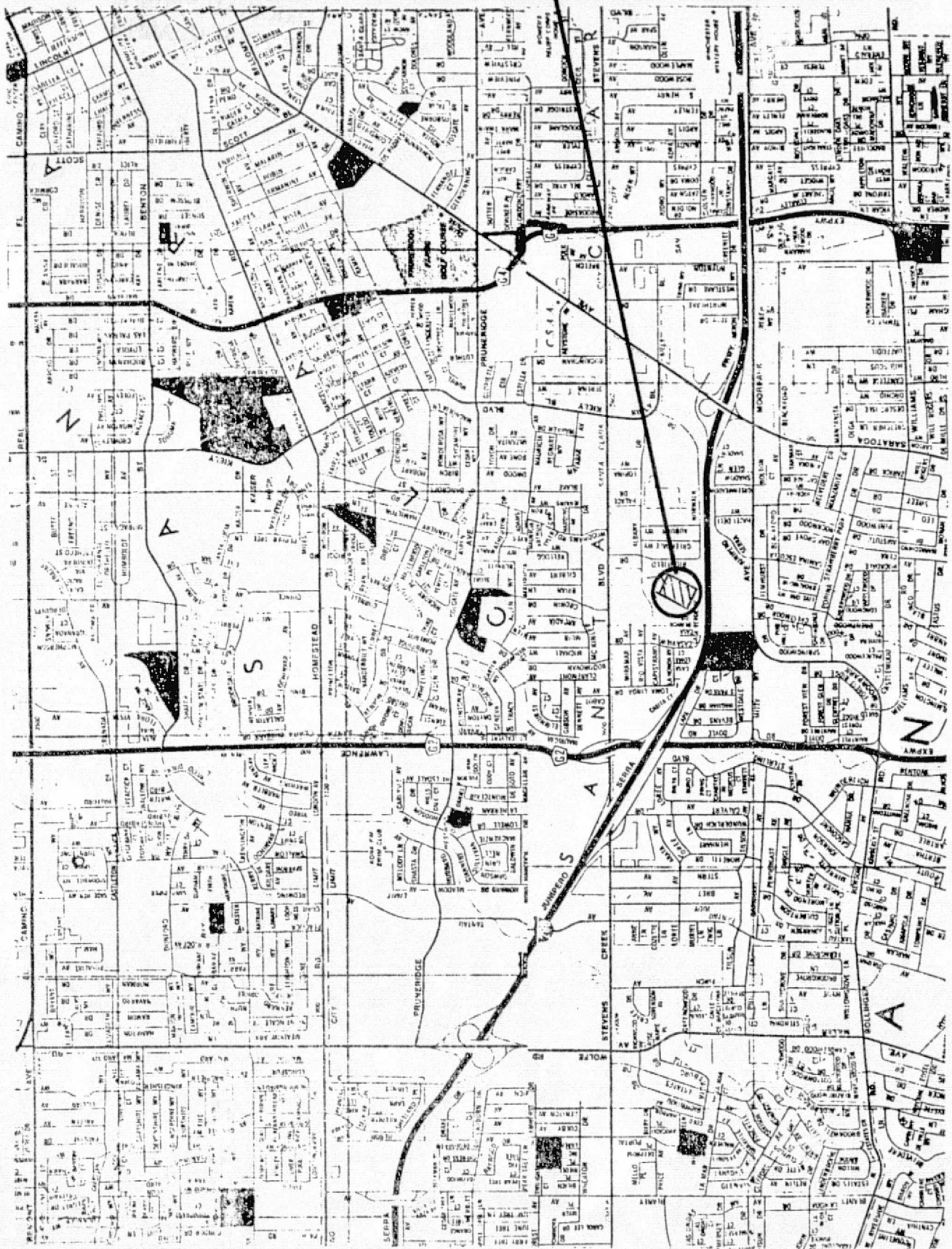


Figure 7. Cupertino (CUP) - Prospective Port Site Location

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BART Station  
(Fremont line terminus)

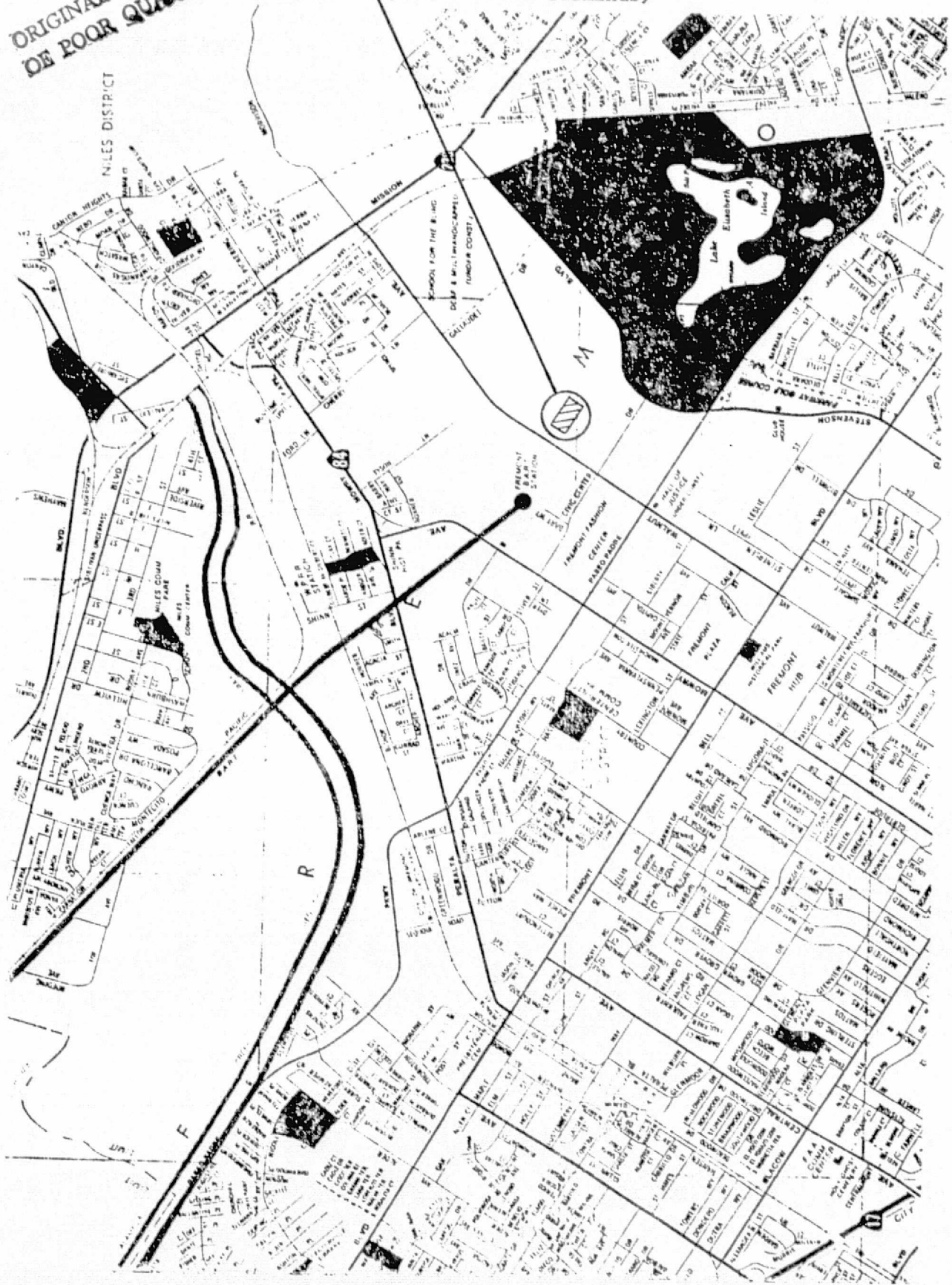


Figure 8. Fremont (FBT) - Prospective Port Site Location



Jack London Square  
(on the Estuary)

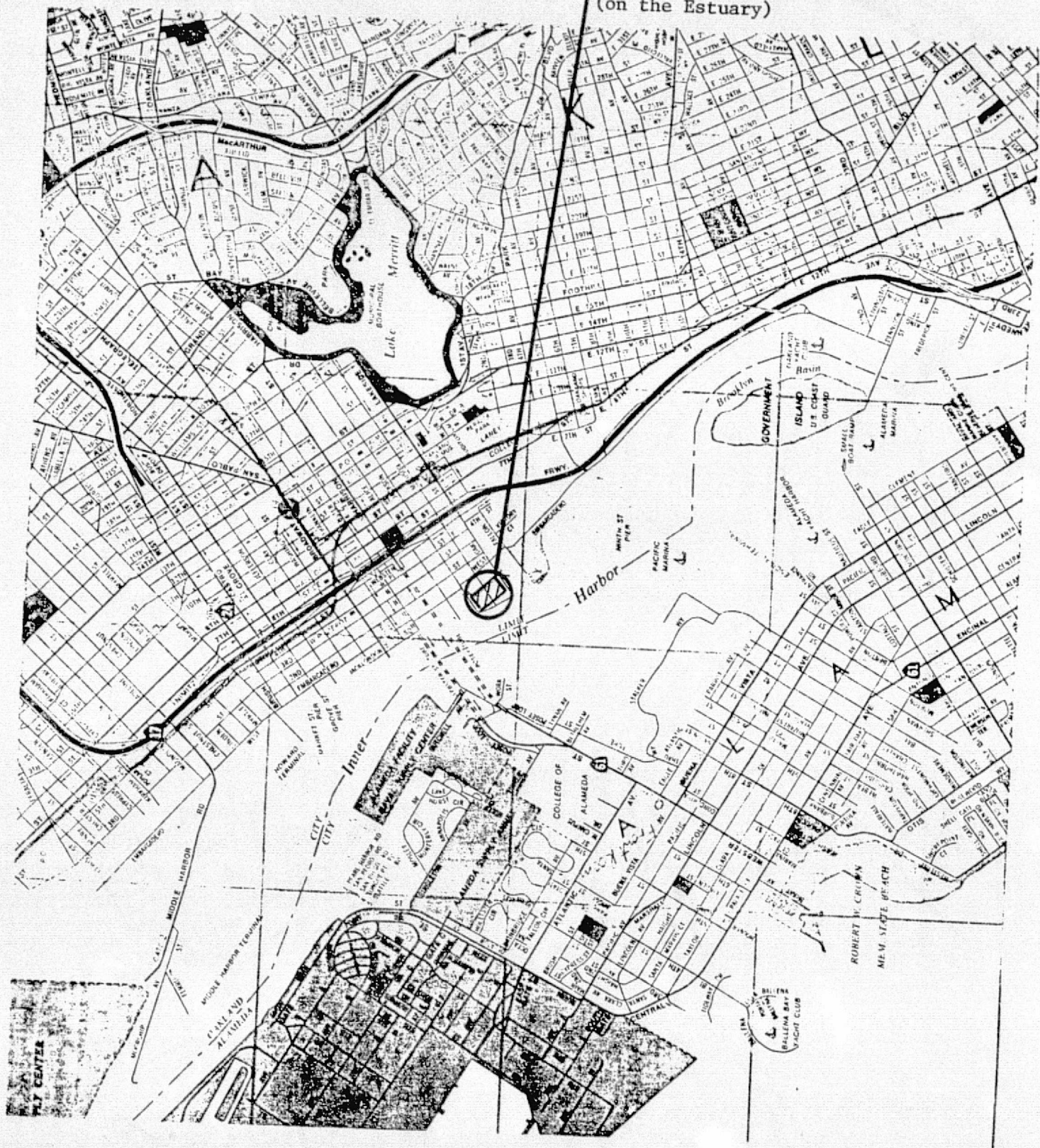


Figure 9. Oakland (JLS) - Prospective Port Site Location

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BART Station  
(Richmond line terminus)

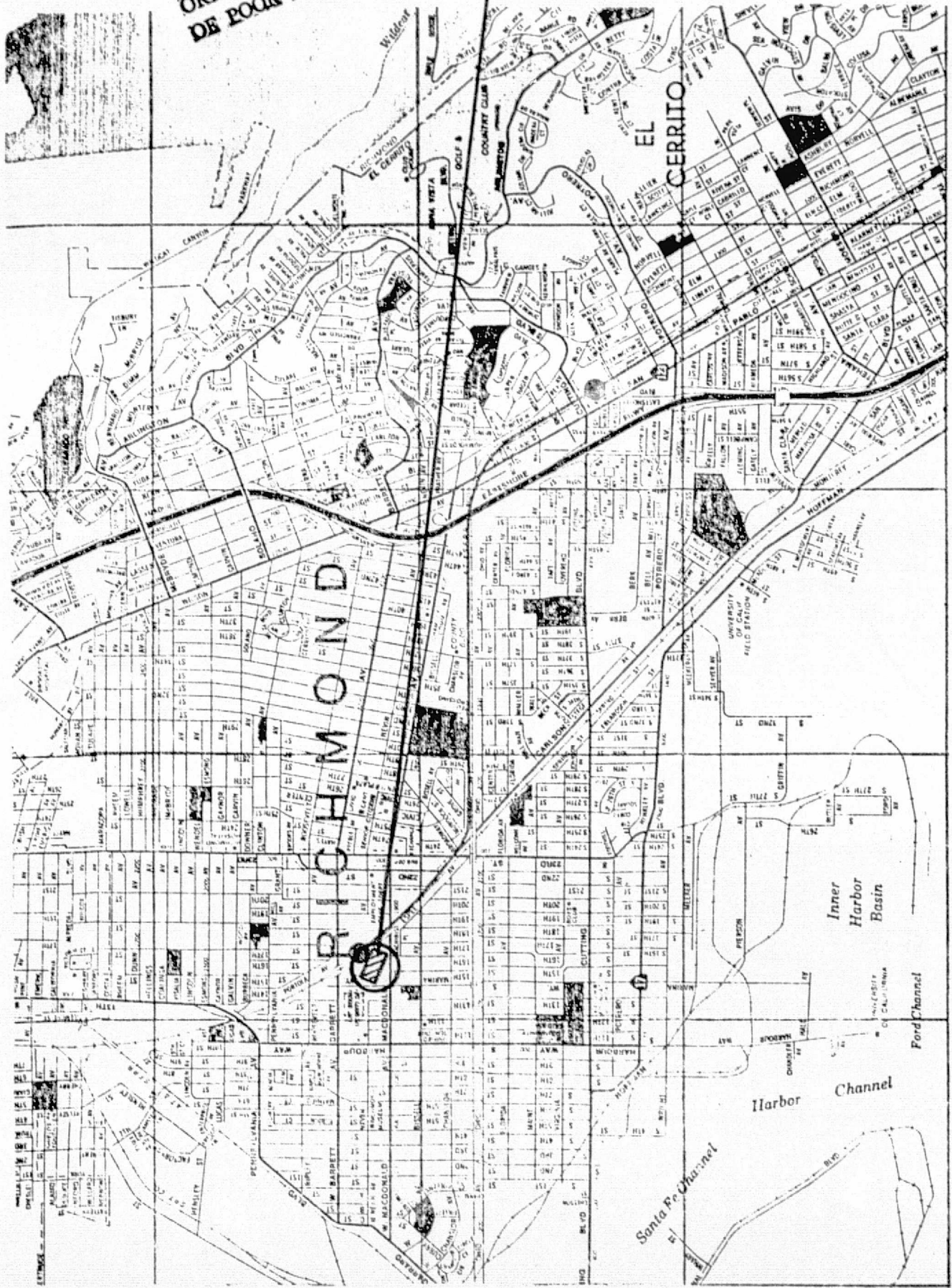


Figure 10. Richmond (RBT) - Prospective Port Site Location

U.S. 101 Causeway

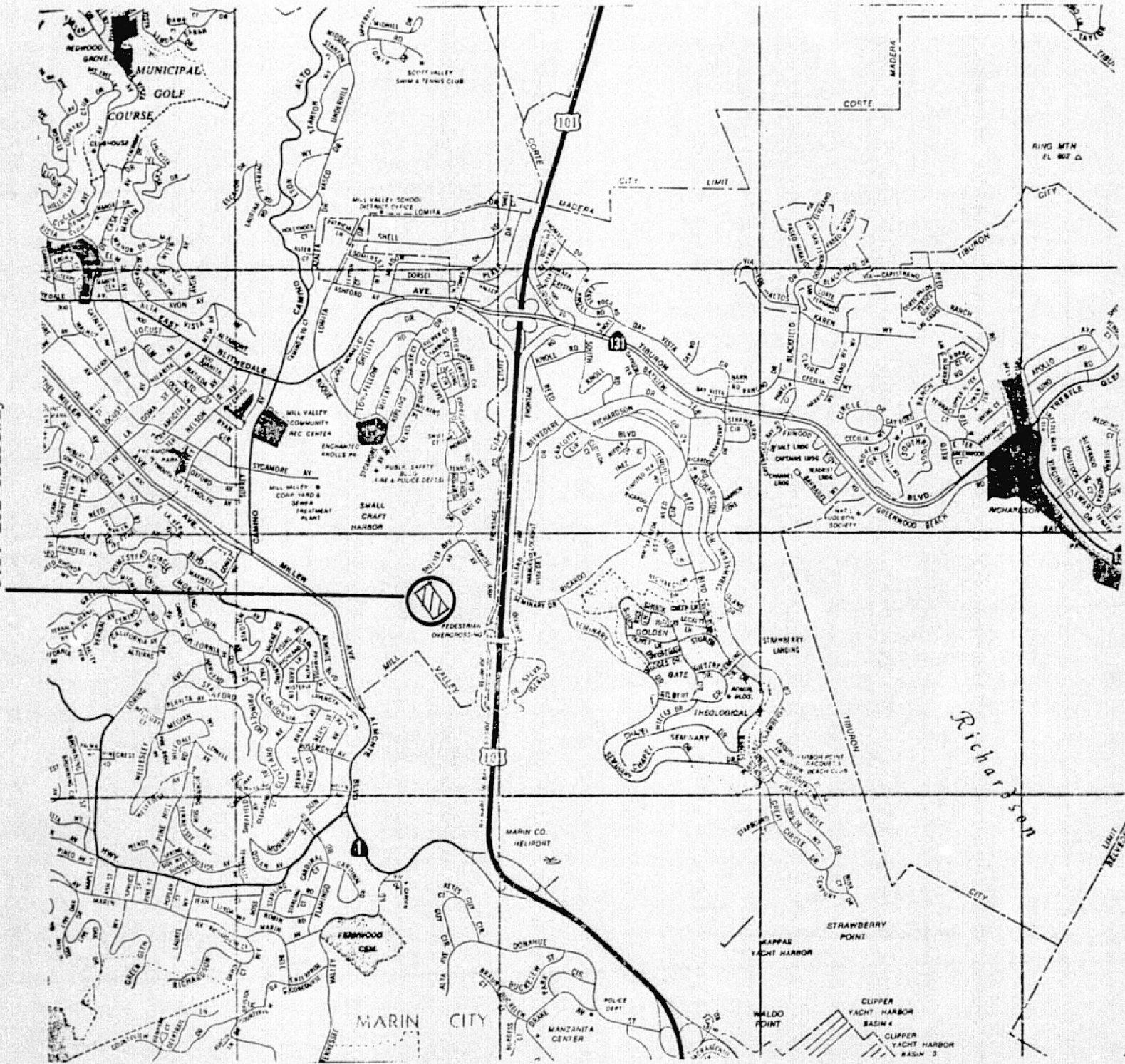


Figure 11. Mill Valley (MIL) - Prospective Port Site Location

## The Legal Requirements for the Siting of Temporary Airports

### Airports on Land Sites

To operate experimental aircraft in the proposed flight experiments, a request for the issue of temporary permits would be submitted to the California Department of Transportation, Division of Aeronautics, in accordance with California Airport Regulations. It appears that this is the easiest and most expeditious way to fulfill current legal requirements. The temporary permits will allow for use of the designated landing sites for a period of not more than 30 days. For the purpose of the flight research program, 30 days is adequate to execute a total of 450 operations from each proposed site. The applicable law is stated in the California Administration Code, Title 4; California Airport Regulations, Subchapter 2; Airports; Article 3, Airport Permits. The following passage is taken from this source:

#### Temporary Permits (for periods not more than 30 days)

(a) Any political subdivision, corporation, company, or private individual or individuals desiring to make aircraft landings and takeoffs from a nonpermitted or nonexempt site must request authorization from the Department of Aeronautics to conduct such operations, if the site if in for a temporary permit may be submitted on the regular Site Approval Application forms or by letter. Information to be submitted with request is as follows:

- (1) Name of proponent (owner and operator).
- (2) Site location (latitude and longitude and other descriptive information which will assist in locating site).
- (3) Local area map with site plotted on map (C.G.S., city map, etc.)
- (4) Type of aircraft to use site.

- (5) Period of operations and expected number of operations (landings and takeoffs).
- (6) Purpose and description of operations.
- (7) Letter or notice of approval from local governing body (city or county).
- (8) Letter or notice of approval from local policing authority (Chief of Police or County Sheriff).
- (9) Letter of approval by Landowner.
- (10) Letter or notice of approval or no objection by the cognizant General Aviation District Office of the Federal Aviation Administration.

- (b) Upon receipt of a temporary permit application, the Department will consult with proponent, coordinate with appropriate officials and issue temporary permit in accordance with request. Temporary sites will be evaluated on the basis of recommended Federal Aviation Administration criteria. Waivers may be granted on this criteria when safety of flight or the interests of the general public are not jeopardized.

The State Department of Transportation has been kept informed on current development of events, and their advice has been sought on these matters. That State Office has shown a strong continuing interest in the program and will assist in every way possible.

In order to obtain temporary use of test landing sites in the metropolitan area, it will be necessary to have cooperation of the local government. State law also requires approval by Division of Aeronautics for such facilities. They would evaluate the proposed sites and provide assistance in obtaining the use of these sites, including the contacts with local government and the FAA offices in the Bay Area.

### Barge Waterfront Sites

The presence of the Bay has been a major factor in the development of the entire San Francisco Bay Area. The Bay's predominant influence on the region's economic activities, development patterns, and transportation system is highly visible. This large body of water has been a barrier to intraregional transportation because it channels movements into corridors created by the bridges. Any future study should fully explore the potentials to utilize the waterfront as a major gateway to any future transportation system.

The San Francisco Port, which has all but lost its predominance as a major deep sea port, has been using its facilities far below capacity. It appears that at least for the duration of the flight research it would be appropriate to propose the use of some designated landing sites within the jurisdiction of the San Francisco Port Commission. The relatively low cost, the absence of a need for a land acquisition, and the proximity to centroidal areas offers a very attractive alternative to land-based sites, especially in heavily traveled corridors, such as the foot of Market Street at the San Francisco Business District and in the vicinity of Jack London Square in Oakland.

A barge would serve as a floating platform which can be towed. This flexibility could be used very efficiently in several locations (foot of Market Street, Jack London Square, South Bay, Marin County) without costly site preparation. The total platform would consist of four 200-ft. standard barges 60 ft. wide with a 10-ft. freeboard (unloaded). The barge bitts tied together with steel cables and the gaps bridged with 3/4 in. steel plates will provide for a continuous runway length of 800 ft. Non-skid abrasive running surface will provide for the desired surface roughness under all weather operations.

The barges will be equipped with the proper navigation light requirements, anchoring devices, fair leads, and winches. The barges are available in the Bay Area and appear to be well suited for the purpose of the flight research. They are built in the U. S. and are regularly used to service the supply effort of Alaska's North Slope. The return of the barges in mid-September 1977 from Alaska has made them available.

There are no known additional legal requirements for supplemental barge landings other than those already indicated for other governmental agencies on the federal, state, and local levels. However, under certain conditions at certain locations the following agencies have jurisdiction which could impose special requirements. These agencies are the U. S. Coast Guard, the U. S. Army Corps of Engineers, the San Francisco Port Commission, and the Port of Oakland. Specific requirements are as follows:

U. S. Coast Guard - The approval of specific sites, if in navigable water, will have to have the approval of the U. S. Coast Guard Captain whose primary responsibility is the safety of the port. The Captain ultimately will decide how close to the shipping channel anchorage of the barges can be allowed. The Captain is advised by an Advisory Board and the considerable voice of the sea pilots. The Captain of the port has veto power on all safety-related issues. No legal restrictions exist, however. Anchorages and anchorage regulations for San Francisco Bar are listed in 33 CFR Part 1 to 199, Navigation and Navigable Waters. Specifically, Part 1.0.244 applies. This document can be obtained from the U. S. Coast Guard 12th District, 632 Sansome Street, San Francisco, California.

The Army Corps of Engineers - General permits are required for work or structures in all tidal areas. In addition, permits may be required for activities landward of the mean or ordinary high waterline if such work affects the navigable

capacity of the water body. The applicable laws are stated in Section 110 of the River and Harbor Act which was approved March 3, 1899 (30 Stat. 1151; 33 U.S.C. 403). This Act prohibits the unauthorized obstruction or alteration of any navigable water of the United States. Specific requirements that would apply to the locating of barges for the purpose of the flight experiments are as follows:

1. General: "one completed copy of the ENG Form 4345 shall be submitted to the District Engineer having jurisdiction over the location at which the activity is proposed."
2. Fills and Platforms: "If the activity includes the construction of a fill or pile supported or floating platform, the application must specifically describe the structure to be erected on the fill or platform."
3. Hazardous Materials: "If the activity includes the handling, storage or transportation of petroleum and/or other hazardous materials, a spill contingency plan should be submitted with the application."
4. "If the District Engineer believes that granting the permit may be warranted but the proposed activity would have a significant environmental impact, an Environmental Impact Statement will be prepared prior to the final action on the permit application as required by Section 102 (2)(c) of the National Environmental Policy Act of 1969. The Corps will prepare the EIS, but the applicant will be required to submit data and may be assessed for preparation expenses."

San Francisco Port Commission - Preliminary discussion with the San Francisco Port Commission staff states that no additional requirements other than those already required by federal, state, and local governmental agencies will be



imposed. The jurisdiction of the San Francisco Port Commission includes the portion of the Bay between the San Francisco County line on the south to the Marin County line on the north extending to the Pier Head. If flight research activities are to be conducted on the proposed waterfront sites, a number of them will fall under the jurisdiction of the San Francisco Port Commission. Depending on the duration of the research effort, noise and air quality issues could become the subject of special permit requirements. In that event, the San Francisco Port Commission will require the following, as a prerequisite to issuing permits:

1. Environmental Evaluation from the City Planning Commission. In all probability a negative declaration will be obtained if the research effort is of limited duration indicating no impact report requirement.
2. BCDC minor permit. Bay Conservation and Development Commission permit which has jurisdiction of the Bay within 100 ft. of the mean high tide line will impose a minor permit requirements.
3. Army Corps of Engineers permit. (See Army Corps of Engineers)

## Preliminary Noise Evaluation

One of the primary objectives for the projected flight research program is to evaluate the noise impact in the community surrounding each of the experimental port sites. The research aircraft would be operated in different takeoff and landing profiles and at different power settings to create a variety of noise contours around the port site.

To obtain some understanding of the necessary characteristics of the noise contours (shape and intensity), a preliminary study was undertaken to estimate the noise contours at five of the seven proposed test sites. This was done by simulating the operations of both a conventional DHC-6 "Twin Otter" aircraft and a conceptual 20 passenger tilt rotor VTOL aircraft.

The DHC-6 was simulated in its STOL mode takeoff and landing profile as shown in Figure 12, and an estimate of the source noise characteristics (noise in EPNL as a function of distance from the aircraft) was obtained from Reference 8. For the conceptual tilt rotor aircraft, takeoff and landing profiles are an estimate of the source noise was obtained from Reference 9. The aircraft was assumed to operate in a STOL mode as shown in Figure 13. The operations in this mode is with a partial tilt of the nacelles, and by conventional airplane standards, the ground roll is extremely short and the takeoff and landing profiles are quite steep.

- 
8. Bishop, Dwight E., et al; Effective Perceived Noise Level Versus Distance Curves for Civil Aircraft, Bolt, Beranck, and Newman Inc., Report 2747, July 1974.
  9. DeTore, J. A. and Sumbell, K. W.; Conceptual Design Study of 1985 Commercial Tilt Rotor Transports; Bell Helicopter Company, NASA CR 2544, May 1975.

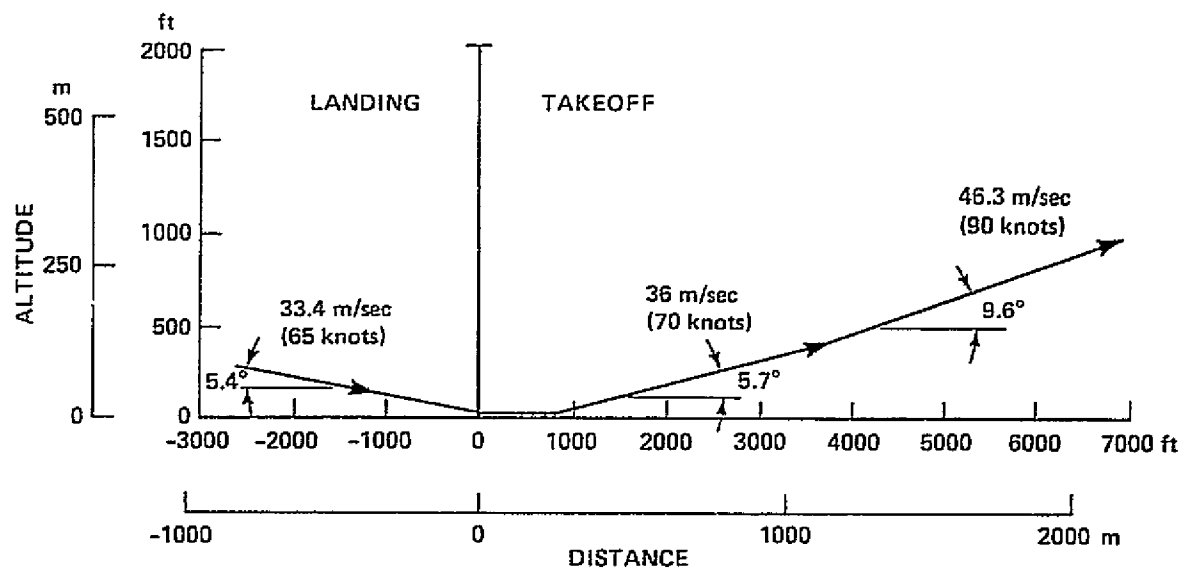


Figure 12. DHC-6 STOL mode Takeoff and Landing Profiles

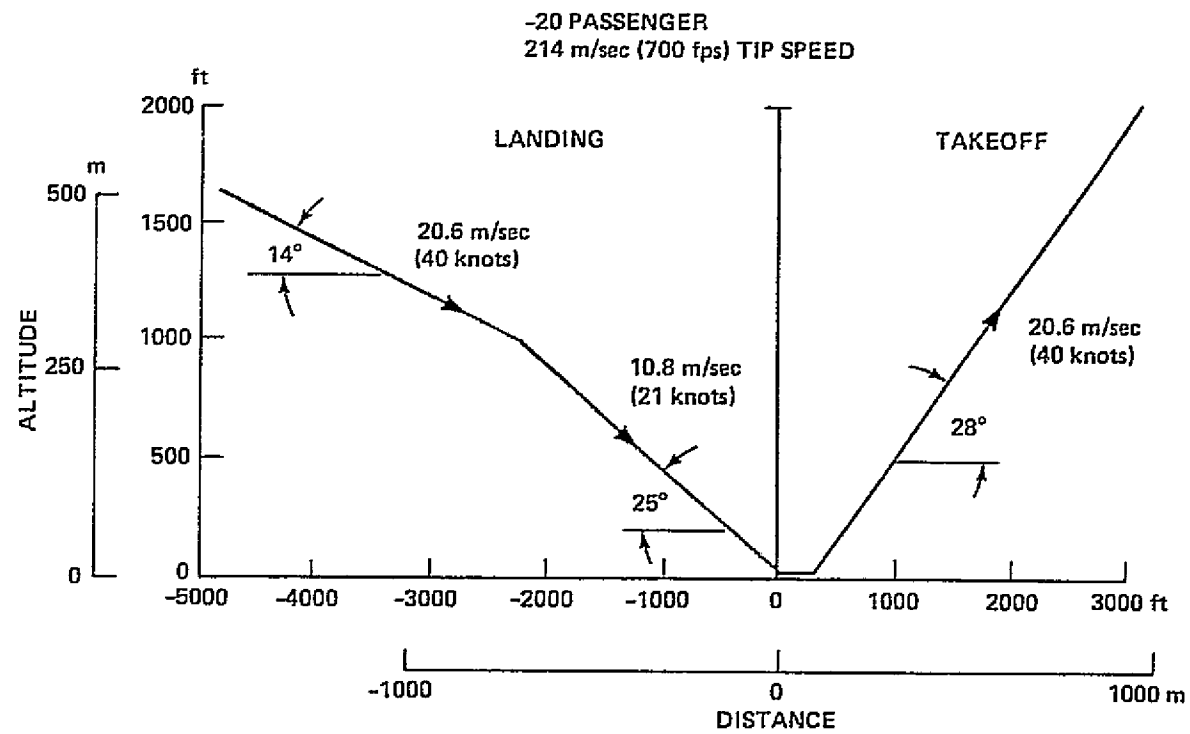


Figure 13. Conceptual Tilt Rotor Aircraft STOL Mode Takeoff and Landing Profiles

With these data, noise contours were generated for both aircraft and are shown in Figures 14 and 15. These are single event contours for both 80 and 90 EPNL. (70 EPNL as well for the tilt rotor aircraft), and the contrast between the two aircraft is quite striking. The Twin Otter has relatively low source noise, but a conventional takeoff and approach path. This results in long and narrow footprints for the noise contours. In contrast, the Tilt Rotor has higher source noise, but a very steep profile which results in short and fat noise contours.

There is no general way to measure abstractly the relative merits of any one specific noise contour shape. This can be done only with an evaluation at a specific site. Using the tilt rotor aircraft data, such an evaluation was done at five of the seven prospective experimental ports sites: CBD, CUP, PAL, JLS, and MIL. To measure the impact of multiple events (takeoff and landings) the Noise Exposure Forecast (NEF)\* was adopted as a measure of noise. The number of operations per day assumed for the five sites (an operation is defined as either a takeoff or a landing) is as follows:

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\*NEF is the total summation (on an energy basis) over a 24-hour period (weighted for time of day) of the effective perceived noise level (EPNL). The correction for time of day simply recognizes the added disturbance of nighttime vs. daytime operations by adding 10 dB to the computed noise for operations after 2200 hours and before 0700 hours. Reference 10 gives an excellent summary of the method used to compute values of NEF.

10. Edge, Philip M., Jr., and Cawthorn, Jimmy M.; Selected Methods of Qualification of Community Exposure to Aircraft Noise; NASA TND-7977, February 1976.

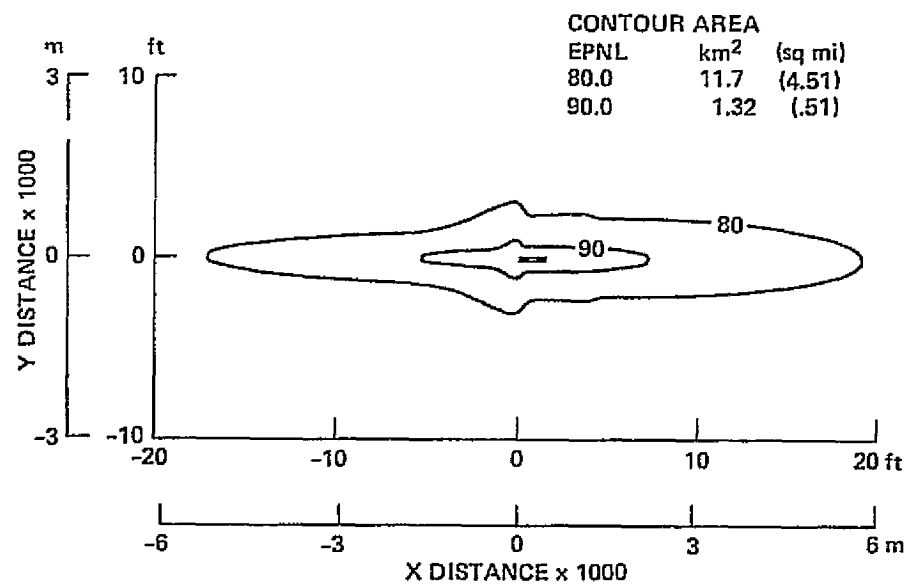


Figure 14. DHC-6 Noise Contours for STOL Mode Operation

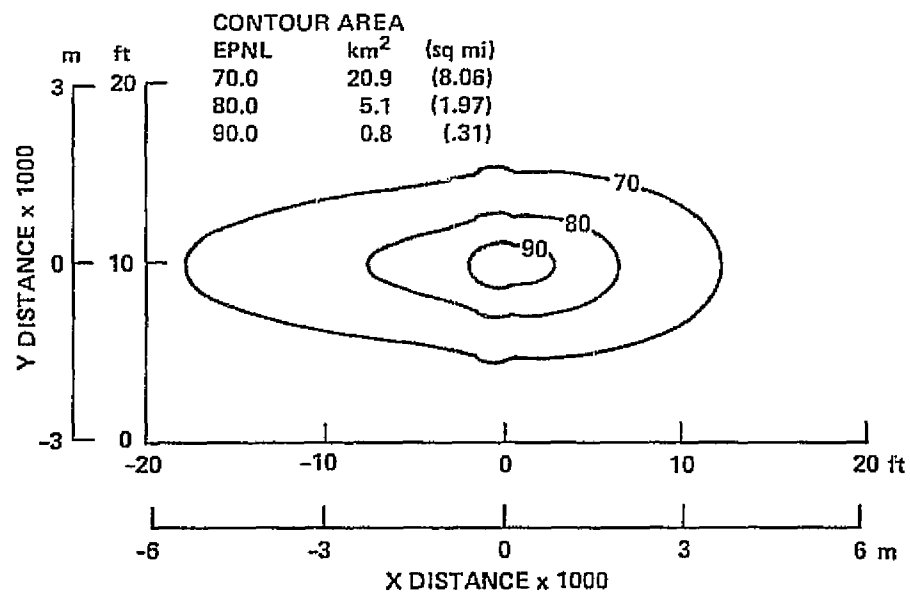


Figure 15. Conceptual Tilt Rotor Aircraft Noise Contours for STOL Mode Operation

|     |                |
|-----|----------------|
| CBD | 275 operations |
| CUP | 130            |
| PAL | 110            |
| JLS | 230            |
| MIL | 154            |

These numbers are based on the study of the operations system given in Reference 5 which accounted for a non-uniform number of operations at each site during the course of a day.

To obtain an estimate of the noise impact on the community surrounding each site, 1970 census tract data were used (Reference 11), and a reaction of the community estimated from the annoyance algorithm developed by the U. S. Department of Transportation (Reference 12). A figure from this report is reproduced as Figure 16. Note that 15 NEF represents virtually no annoyance and 30 NEF represents substantial annoyance.

Between these two extremes, the annoyance is very subjective and unpredictable. One obvious need for the proposed flight research program is reliable test data which will improve methods of predicting annoyance due to noise in different types of neighborhoods.

The results of the study are shown below:

- 
11. Anon; 1970 Census of Housing, Block Statistics, San Francisco-Oakland Urbanized Area; Census Bureau.
  12. Safer, Harvey B.; Community Response to Noise Relative to Percent of Population Highly Annoyed by Noise; U. S. Department of Transportation, Technical Memorandum TM 72-1, June 6, 1972



**COMMUNITY REACTION**

VIGOROUS COMMUNITY ACTION

SEVERAL THREATS OF LEGAL ACTION OR STRONG APPEALS TO LOCAL OFFICIALS TO STOP NOISE

WIDESPREAD COMPLAINTS OR SINGLE THREAT OF LEGAL ACTION

SPORADIC COMPLAINTS

NO REACTION, ALTHOUGH NOISE IS GENERALLY NOTICEABLE

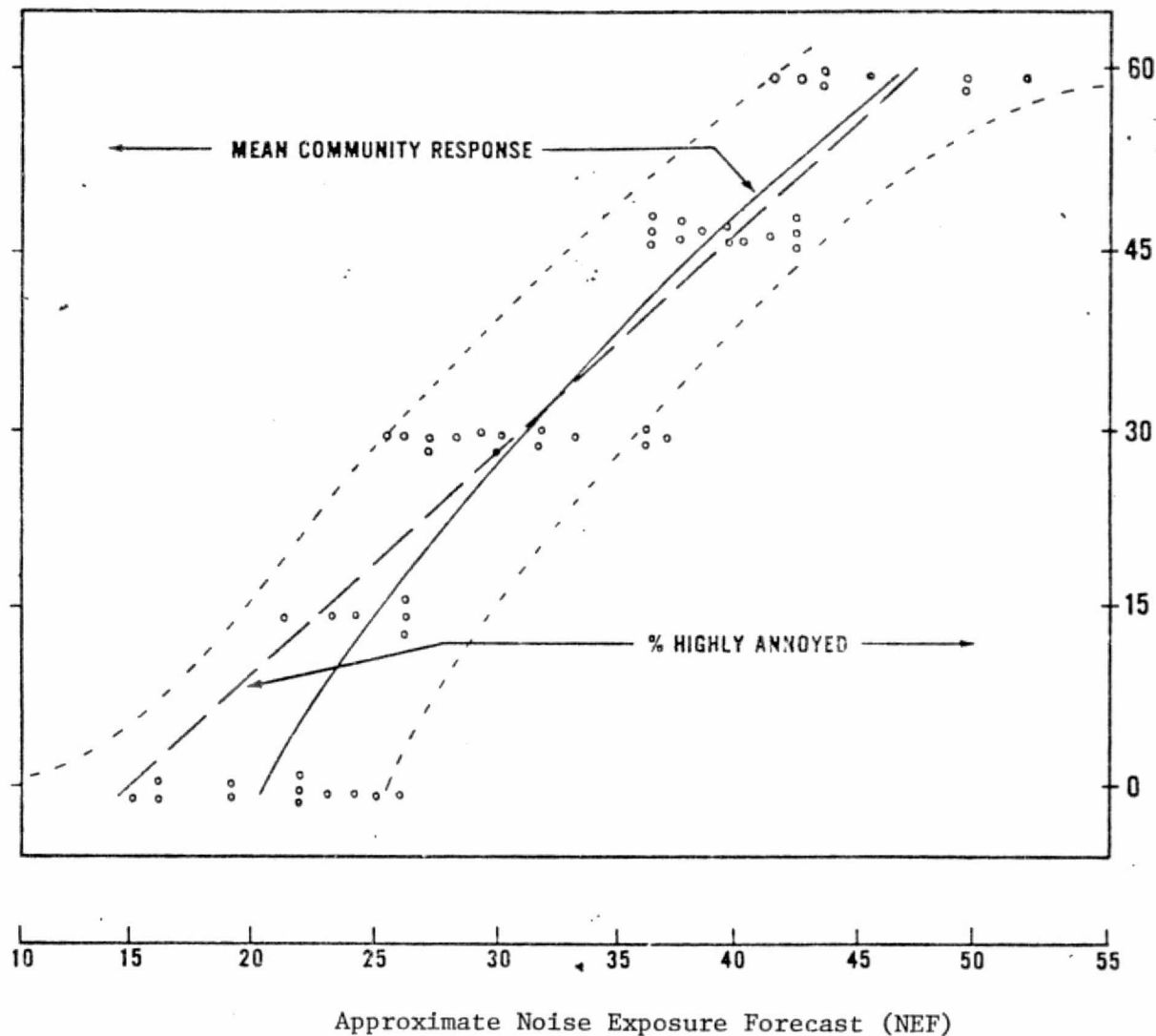


Figure 16. Correlation of Community Annoyance with Noise Exposure Forecast (NEF)

| Location | Control Area |        | People Impacted | % Highly Annoyed |
|----------|--------------|--------|-----------------|------------------|
|          | 15 NEF       | 30 NEF |                 |                  |
|          | Sq. Mi.      |        |                 |                  |
| CBD      | 1.5          | .08    | 6822            | 4.7              |
| PAL      | .69          | .03    | 1591            | 3.4              |
| CUP      | .78          | .04    | 4526            | 8.5              |
| JLS      | 1.27         | .06    | 565             | 2.4              |
| MIL      | .96          | .05    | 491             | 4.0              |

Estimated data derived from a theoretical 20 passenger tilt rotor aircraft (source noise and flight profile) was used throughout and the variation in the NEF values from site to site is a result of the different number of operations. It is interesting to note that at the Cupertino site the estimated noise footprint impacts a relatively large number of people, and indicates the highest estimated percentage for those annoyed. As a result, this would be an excellent choice for a test site for the proposed flight test program.

Figures 17 - 21 are high altitude photos\* which include each of the five sites. The 15 and 30 NEF contours are shown for each, and note that an attempt has been made to find approach and departure paths that would minimize the number of people impacted within the 15 NEF contour. In doing this, a tradeoff exists between the number of people near the flight track on the ground versus the reduced altitude of the trajectory for curved paths. As a result of the study, curved paths were found to be desirable at PAL, CUP, and JLS.

As stated in the title of this section, the analysis of estimated noise impacts was preliminary and was conducted to get some feeling for what noise levels should be created by the research aircraft. A more detailed analysis of the estimated community noise impact is given in the last section of Part II which concerns the design modifications for the proposed research aircraft.

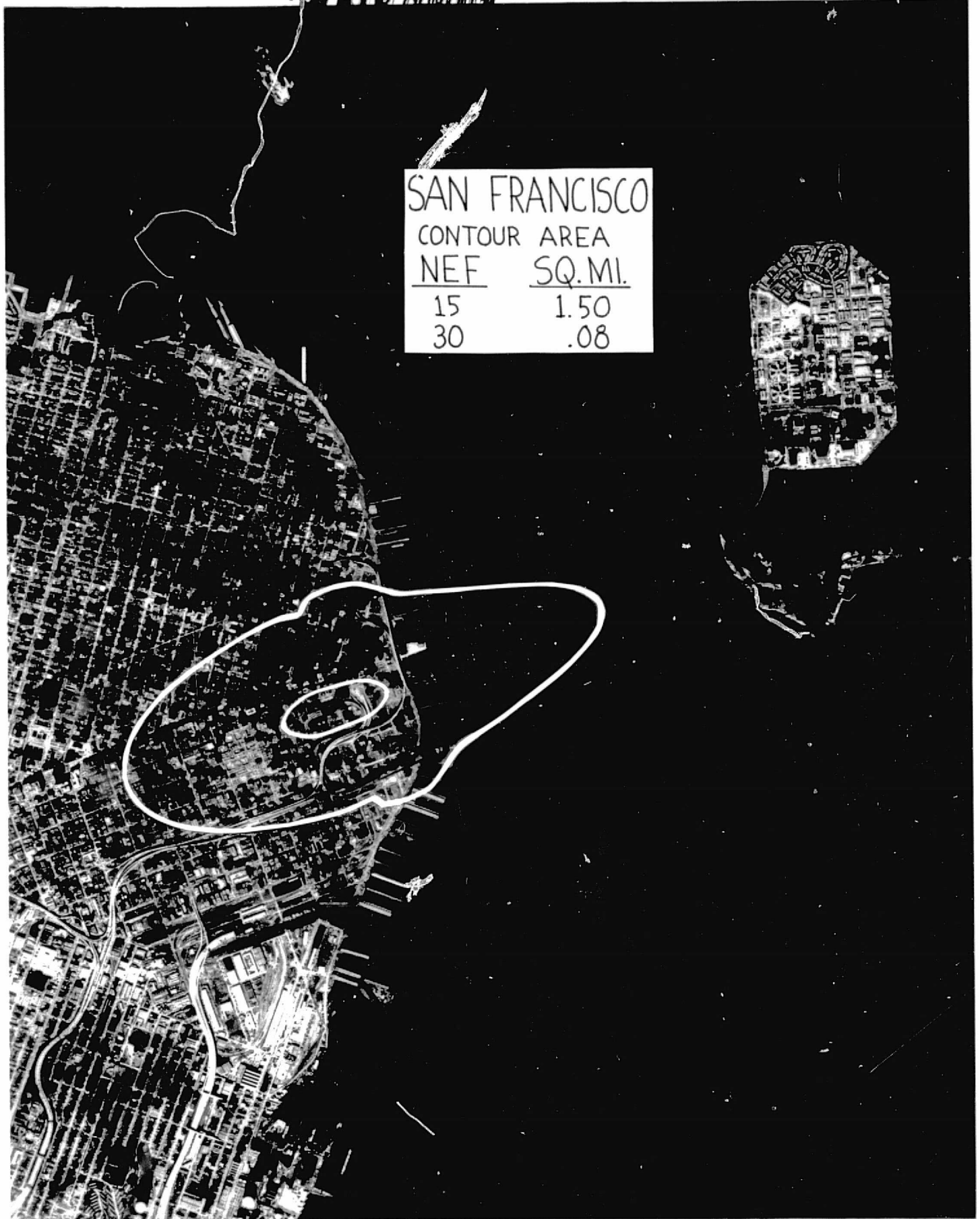


Figure 17. Estimated NEF Contours for Operations of the Conceptual Tilt Rotor Aircraft to and from San Francisco (CBD)



Figure 18. Estimated NEF Contours for Operations of the Conceptual Tilt Rotor Aircraft to and from Palo Alto (PAL)

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Figure 19. Estimated NEF Contours for Operations of the Conceptual Tilt Rotor Aircraft to and from Cupertino (CUP)

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Figure 20. Estimated NEF Contours for Operations of the Conceptual Tilt Rotor Aircraft to and from Oakland (JLS)



Figure 21. Estimated NEF Contours for Operations of the Conceptual Tilt Rotor Aircraft to and from Mill Valley (MIL)

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## Experimental Aircraft Definition

### Candidate aircraft and their characteristics

Candidate aircraft considered for this experimental program represent a wide spectrum, ranging from the single engine Helio U-10 to the twin engine DHC-6 Twin Otter. The criteria for the preliminary selection of candidate aircraft include the predictable takeoff and landing characteristics and the versatility of the aircraft in takeoff and landing operations to create different noise levels near the ports sites. Since not all of the candidate aircraft are in current production, the availability of the aircraft had to be taken into consideration for the evaluation. Specifically, aircraft selection for the flight is based on the following criteria:

1. Performance characteristics of the aircraft prior to modification - Only aircraft with short takeoff and landing characteristics were considered.
2. Availability of the airframe - To maintain a realistic time frame, only aircraft which are currently in production or otherwise available were considered.
3. Availability of suitable powerplant - Only aircraft that can be modified to accept a larger suitable engine were considered.
4. Ease of modification - No aircraft has been proposed for modification that required basic change in configuration.
5. Degree of modification required - Modification requirements resulting from the new powerplant installation including structural changes, larger control surfaces, and new wing lift devices.



6. Adaptability of the aircraft to various noise configurations - Sufficient clearance for larger prop diameters for both fuselage and ground clearance.
7. Future value of the aircraft as a test vehicle - Testing to include flight experiments for landing qualities, community noise impact studies, and cabin interior noise experiments.
8. Potential of the aircraft as a demonstrator in a passenger carrying capacity - Possible utilization of the same aircraft in a subsequent phase of the on-going program.

The following is a narrative summary addressing the eight elements of each of the aircraft considered. A summary of the aircraft performance is given in Table I.

HELIO - COURIER

USAF Designation U10

Performance characteristics of the A/C

The only aircraft among the selected candidates that could fly the experiment without modification. Quieting the A/C is the primary reason for new turbo-prop installation.

Availability of the airframe:

There are a number of A/C available in government inventory easily attainable.

Availability of a suitable power plant:

Allison 250-17B Turboprop belt drive gear reduction. (Current engine is the Lycoming GO-480-G1D6 horizontally opposed piston engine.)

Ease of modification:

Tricycle gear installation. High vision cockpit. No wing modification.

Degree of modification required:

Power plant installation, gear reduction, quieting exhaust and intake.

Adaptability of the A/C to various noise configuration:

No limitations.

Future value of the A/C as a test vehicle:

High performance characteristics of the A/C suggest a good potential for future use.

Potentials of the A/C as a demonstrator in a passenger carrying capacity:

Limited use.

Australian Aircraft Factories

Performance characteristics of the A/C:

Required takeoff and landing performance only at less than maximum takeoff gross weight.

Availability of A/C:

Currently in production.

Availability of a suitable power plant:

No change in power plant is required if V belt driven gear reduction is considered technically feasible.

Ease of modification:

Modification limited to the gear reduction.

Degree of modification:

Since a high degree of stability is present in the initial design, which includes spoiler and 20-degree flap, change required could involve no more than the addition of leading edge devices intake and exhaust modification.

Adaptability of the A/C to various noise configurations:

Propeller diameter could become a limiting factor.

Future value of the A/C as a test vehicle:

At less than maximum takeoff gross weight, the A/C could show versatility.

Potentials of A/C as a demonstrator in a passenger carrying capacity:

Unknown. The A/C could become a viable candidate, further study is required. However, the high minimum noise factor could prove unduly restrictive.

DOMINION - SKYTRADER "800"

Performance characteristics of the A/C:

New power plant necessary to satisfy Flight Experiment requirements.

Availability of A/C:

Type certificate expected 10 months from date. Prototype entering certification flight test. No current production program.

Availability of suitable power plant:

Allison 250-B17 Turboprop should be a suitable power plant. Belt driven gear reduction required.

Ease of modification:

Moving the nacelle outboard may be required to accommodate larger propeller.

Degree of modification required:

Current wing design includes high lift devices. Change in power plant location, however, would require substantial structural modification of the wing. Larger vertical tail and rudder surfaces would be required.

Adaptability of the A/C to various noise configurations:

If nacelles were moved outboard sufficient prop clearance will allow for modification.

Future value of the A/C as a test vehicle:

With new power plants the aircraft could be valuable for subsequent tests.

Potential of the A/C as a demonstrator in passenger carrying capacity:

Unknown.

Note: The unavailability of the A/C precludes all other considerations. The A/C is not in production.

HELIO TWIN-COURIER MODEL H-500

USAF designation U-5A

Performance characteristics of the A/C:

Two new engines required for the Flight Experiment.

Availability of the Airframe:

Airframe is readily available.

Availability of a suitable power plant:

Two Allison 250-B17 Turboprops. Belt drive gear reduction, 10 ft. propeller

Ease of Modification:

The availability of the airframe, tricycle landing gear, complete wing set, requiring no modification, offers a very practical alternative for the Flight Experiment.

Degree of modification required:

Engine nacelle, propeller installation, quieting devices.

Adaptability of the A/C to various noise configurations:

Due to the short, stubby nose configuration, the propeller plane is forward of the nose giving unlimited latitude for any propeller combination.

Future value of the A/C as a test vehicle:

The versatility and advantages of the high power rating could make the aircraft extremely useful.

Potential of the aircraft as a demonstrator in a passenger carrying capacity:

Good if payload capacity is maintained.

N262 FREGATE  
(MOHAWK M-298)

This aircraft was considered at the outset because it was believed to have marked improvements in performance, with the new engine installation. (The original N262 model powered by two Turbomeca BASTAN VI turboprop engines has been re-engined to use two 1120 SHP PT6-45 turboprop engines with five bladed propellers)

There appears to be substantial improvements in noise reduction; however, no substantial field-length improvement is expected. Thus, the aircraft is unsuitable for the proposed Flight Experiment.

BRITTEN - NORMAN ISLANDER

Performance characteristics of the A/C:

New engines are required for the Flight Experiment.

Availability of the airframe:

Currently in production.

Availability of a suitable power plant:

Two Allison 250-B17 engines 400 SHP each. Belt driven gear reduction.

Ease of modification:

Location of the landing gear makes modification with the new turbine engine impractical. (It would put a hump on the wing and possibly cause an excessive change of the aircraft c.g.)

Degree of modification required:

Outboard movement of the nacelle would most likely require an entire new wing.

Adaptability of the A/C to various noise configurations:

If the nacelle were moved outboard, the A/C would be easily adapted to other configurations.

Future value of the A/C as a test vehicle:

Unknown.

Potential of the A/C as a demonstrator in a passenger carrying capacity:

Unknown.

Note: Britten-Norman is developing a turboprop version of the Islander. It will be powered by two 620 ESHP Avco Lycoming LTP 101 engines. Gross weight 7300lbs., 700 lbs. over the standard Islander. Status of the program is not known, but it could be a possible candidate for this program. For reasons of safety, the addition of a leading edge device to the wing is imperative.

TWIN OTTER

DeHavilland DHC-6

Performance characteristics of the A/C:

New power plants may be required to satisfy the requirements of the Flight Experiment.

Availability of the airframe:

Currently under production, and acquisition of a used airframe is a good possibility.

Availability of a suitable power plant:

The availability of the new PT6-45 power plant that is designed with a low speed reduction gearbox makes this aircraft a viable candidate for the modification.

Ease of modification:

Since there is sufficient clearance to accommodate the 11.25 ft. four bladed propeller, there is no requirement for changing the location of the powerplant.

Degree of modification required:

Substantial modification will include changes in the nacelle structure. Changes in the wing structure to accommodate high lift devices and augmented lateral control devices. Structural beef-up on the inboard wing, increased vertical tail and rudder surfaces. Structural reinforcement of the tail cone.

Adaptability of the aircraft to various noise configurations:

No particular problems foreseen.

Future value of the aircraft as a test vehicle:

The aircraft could be valuable in a number of subsequent test programs.

Potential of the aircraft as a demonstrator in passenger carrying capacity:

Due to the aircraft's larger payload capacity, its potential in a subsequent demonstration program would appear greater than any of the aircraft considered.



The DeHavilland DHC-6 "Twin Otter" was selected as the candidate aircraft for the flight research program. The overriding reason for the selection of the DHC-6 is unquestionably its size. If the prime objective of the proposed flight research program is to determine how public acceptance is attainable, it would seem prudent to try to simulate conditions, both with respect to the size of a commuter aircraft and the locations of the landing sites near the community, as closely as possible. Since the DHC-6 offers both size and acceptable performance characteristics, the choice is fairly clear. The aircraft has acceptable performance with the existing PT6-27 engines at a lower gross weights; therefore, modification requirements may not be as costly as for other candidate aircraft.

The option, however, exists to increase power by installing the larger, more powerful -45 engines with 5 bladed propellers to accomplish higher performance at near full gross weight capacity. The aircraft is currently in production. However, acquisition of a used aircraft has been considered as the most economical approach for the program. Suitable power plants for the modification, should the installation become necessary, is easily accomplished since both the -45 engine and the 5 bladed propellers are in production and are a proven combination on existing aircraft now in service.

There is sufficient fuselage and ground clearance for a wide range of possible propeller engine combinations, so the aircraft could be adapted to various noise configurations. A substantial structural modification will be necessary on the wing to accommodate the larger, heavier -45 engine. Changes in the wing structure for the leading edge slats, augmented lateral control and spoiler systems, will be necessary. Structural beef-up of the inboard wing, increased vertical tail, increased rudder surfaces and reinforcement of the tail cone will be required to compensate for desired, lower minimum control speeds.

At the conclusion of the proposed flight experiment, the aircraft could

become a valuable tool for future flight tests. Due to the aircraft's large payload capacity, its potential in a subsequent demonstration program would appear greater than any of the other aircraft considered in this evaluation.

Table I  
AIRCRAFT PERFORMANCE SUMMARY

| Aircraft Type               | No. of Eng. | T.O. GRWT, Lbs. | OWE Lb. | T.O. Run Ft. | T.O. Over 50' Ft. | Land Roll Ft. | Land From 50' Ft. | V Max MPH | Vs MPH | R/C Ft/Min |
|-----------------------------|-------------|-----------------|---------|--------------|-------------------|---------------|-------------------|-----------|--------|------------|
| Single Engine               |             |                 |         |              |                   |               |                   |           |        |            |
| Helio U-10                  | 1           | 3400            | 2080    | 335          | 610               | 270           | 520               | 167       | 30     | 1150       |
| Twin Engine                 |             |                 |         |              |                   |               |                   |           |        |            |
| Nomad N.22                  | 2           | 8500            | 4670    | 700          | 960               | 380           | 690               | 199       | 55     | 1670       |
| Skytrader "800"             | 2           | 8500            | 4950    | 390          | 890               | 310           | 730               | 210       | 39     | 1600       |
| Helio U-5A                  | 2           | 5850            | 3126    | 309          | 600               | 275           | 575               | 185       | 31     | 1640       |
| Frigate N-262 (Mohawk M298) | 2           | 23,500          | 14,909  | 1810         | 3510              | 1050          | 1722              | 260       | 85     | 1200       |
| Britten Norman Islander     | 2           | 6300            | 3550    | 560          | 1090              | 450           | 960               | 170       | 49     | 1050       |
| Twin Otter DHC-6            | 2           | 12,500          | 7320    | 700          | 1200              | 515           | 1050              | 207       | 67     | 1600       |

## Operation of the Experiment

This section is intended as a preliminary plan for the conduct of the flight research program. Previous experience in related programs (see Appendix A) proves very graphically that both the preliminary steps leading up to actual flight tests and the organizational affiliations of the individuals conducting the project are very critical to public acceptance of the program -- what will be accomplished and how! The local citizens must be convinced that government agencies concerned primarily with advocacy of air transportation will not override other community interests.

It was found in the 1947-49 NACA sponsored flight program in the Boston region (Appendix A) that the most effective solution to this problem was to conduct such a program under the auspices of a special-purpose university-based research organization. Accordingly, the Aeronautical Research Foundation, Inc. (ARF) was organized by independent authorities affiliated with Harvard and MIT.\* It conducted the original "good-neighbor" landing site tests in Boston under an NACA grant, working in close cooperation with federal and state aviation authorities. The ARF organization thus provided a degree of objectivity the local community found acceptable. ARF staff assistants were recruited in part from Harvard and MIT but a number of local aviation specialists were also retained. That arrangement sufficed to assure the public that the researchers could be constrained by local authorities to the program's stated (and real) objective of preserving the environmental quality as well as providing improved transportation. A similar arrangement is now proposed.

The remainder of this section addresses three main issues: a) the required interface with authorities; b) the flight operations at the experimental port sites; and c) the methodology and responsibility for data.

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\* The three founding Trustees of ARF were Dr. Killian, President of MIT; Dean David of Harvard Business School and Dr. Bollinger, Professor in Charge of Aviation Research at Harvard. After completing the original NACA-sponsored test program, ARF carried on other government-supported aviation research. It continues to operate now as the aeronautical division of the Inter-University Research Center, Inc., which Dr. Bollinger serves as Director. Mr. Kornel Feher serves as ARF's Director.

## Required Interface with Authorities

State Division of Aeronautics: An absolutely necessary step is to elicit the support and establish close coordination with the State Division of Aeronautics. They must be involved in both the preliminary planning phases of the program as well as the conduct of the flight experiment itself. In the preliminary phase, the State Division of Aeronautics should be asked to help determine the feasibility of the program within the region in question. Specifically:

1. To inspect each proposed test site to ascertain the safety and feasibility of using the ground area in the manner planned and of using the flight pattern with the approach and departure paths planned;
2. To confer with FAA offices concerned to verify their approval of those proposed areas and flight patterns'
3. To advise of any known legal restraints requiring clearance in advance (or of any known permits required) and to accompany the inter-university personnel in their meetings with other governmental authorities involved whenever practicable;
4. To advise on the adequacy of the proposed communication and control procedures vis-a-vis air traffic control requirements; and, whenever possible to accompany inter-university personnel in any meeting required on that subject with FAA and/or military air traffic control personnel;
5. To confer with the inter-university team in advance of the first flight tests at each location as to the adequacy of the procedure for communication with local authorities and key elements of the citizenry concerned; and

6. To review in advance the proposed data collection procedure and to determine the most appropriate contribution thereto that the State Division of Aeronautics may be able to make.

Once the flight program is underway, the Division of Aeronautics must be kept actively involved in as many of the following areas as is practical:

1. assistance in establishing and maintaining adequate communication with public authorities involved in the surveillance of the operations (especially local police and FAA);
2. provision of pilots to maximum extent practicable;
3. help in obtaining and in operating sound measuring equipment;
4. advise and assist on collection of adequate neighborhood response data;
5. review and conference on interpretation of the resulting findings;
6. advice on those landing area requirements such as the size and location determinants, adjacent area characteristics, approach-and-departure procedures and such other landing-area design criteria as the tests may indicate;
7. advise on those aircraft design features such as landing-area run, noise restraints, approach and departure capabilities, minimum safe maneuvering speed, additional safety features and such other aircraft design criteria as may be indicated by the tests;
8. coordination with FAA on the subsequent implementation of such inter-related landing-area and aircraft design criteria into applicable aeronautical regulations; and

9. encouragement thereafter of establishment in California of such intra-regional aircraft operations as may be found to be practicable and needed in the public interest -- including the transmission of helpful technical information thereon to all state and local land-use or transportation planning organizations concerned .

Possible Role of NASA during Test Phase: It would be desirable to have NASA serve as the custodian of flight equipment during the program. Since the use of existing US Government owned aircraft appears to be feasible, the bailment of such equipment by NASA to the contractor for the duration of the tests is suggested. However, if NASA (or any other governmental entity concerned) might prefer instead to have the legal responsibility for flight operations on close-in and neighborhood sites placed solely on the shoulders of the contractor, transfer of aircraft title to the contractor for the duration would appear to be a feasible alternative.

(During the earlier NACA supported flight tests of a similar type, both the government and the cooperating universities preferred to have ownership of the "experimental" aircraft together with full responsibility for the equipment modification and the off-airport landing site operations concentrated solely in the hands of the foundation which conducted the program.)

In either event, the basing and physical support of the flight equipment with NASA is recommended as being the most desirable alternative. If for any reason such support is not found to be practicable, then the support services of the State Division of Aeronautics will be sought on the second best alternative.

Role of Other Governmental Agencies: Apart from the contracting authority and the surveillance to be exercised by the Federal DOT and NASA, the principal governmental authority that will be responsible for the safety and control of the proposed flight operations is the FAA (supplemented by the State Division of Aeronautics, as noted in the preceding section).

In addition, many local and regional planning bodies have a long-range interest in the application of findings from the current investigation. Perhaps the foremost among these in the San Francisco Bay Area is the Metropolitan Transportation Commission (MTC).

However, neither the MTC nor any of the other regional planning groups, land use commissions, etc., would appear to have any direct authority or immediate participative role in the specific fact-finding activities of this investigation. Their subsequent evaluation of the findings will, of course, be of real importance.

Accordingly, any further systematic communications with such public planning bodies would appear best deferred until after the total feasibility of intra-regional flight operations have been determined and the landing-site design criteria have been established. Thereafter, informative conferences in addition to a distribution of findings to those planning bodies may be desired by NASA and DOT. At present, however, such full blown inter-agency communications would appear both premature and beyond any project work-statement now extant or under consideration.

The land use and growth planning institutions listed below will, therefore, be kept advised of the pending investigation but asked only to volunteer such guidance and counsel as they may deem appropriate. The principal reason for seeking to maintain that level of coordination and liaison during the test period



is their potential importance in the subsequent implementation of any Bay Area intra-regional air transportation plans that might develop as a result of the current investigation.

In addition to the Metropolitan Transportation Commission (MTC) already referenced, those institutions most concerned with regional land use planning include:

1. The Bay Conservation and Development Commission (BCDC) has jurisdiction over construction along the shoreline of San Francisco Bay;
2. The Central and Northern Coastal Commission which has jurisdiction over development along the ocean shoreline;
3. The Local Agency Formation Commissions (LAFCO) in each of the nine counties which are trying to define the limits and jurisdictions over growth in newly developing areas;
4. And, finally, the primary responsibility for planning of land use which falls to city and county governments and their associated local planning commissions.

All of the above land use planning bodies have been reported by the MTC in its published 1974 Regional Transportation Plan to be participants in the development of "The Regional Land Use Plan" as prepared by the Association of Bay Area Governments (ABAG). That Plan calls for "a city-centered pattern of development with functionally integrated communities, shorter journey-to-work times, and conservation of open space."

Other governmental agencies whose specific standards and authority must be determined and taken into account during the next interim planning phase of this

investigation include the Environmental Protection Agency (EPA), the Bay Area Air Pollution Control District (BAAPCD) and the California Air Resources Board (ARB).

Role of Public and Private Local Organizations: Since no physical structures, commercial operations or continuing land use will be involved in the currently proposed test program, few, if any, requirements for official permits or permission from local land-use planning bodies are anticipated for the proposed flight operations. On privately owned land, permission of the land owner together with an FAA clearance obtained through the offices of the State Division of Aeronautics had sufficed for the earlier flights in the Boston program provided no public nuisance or other infractions produce undue local pressures. In California, temporary permits are now provided, as discussed in the previous section entitled "The Legal Requirements for the Siting of Temporary Airports".

To acquire access to public land, however, the precise path is not always predictable. Earlier experience showed that formal written applications for permissions from local authorities as the first step seldom generated affirmative action. A generally more effective initial approach was found to be to issue an informal invitation for key members of the controlling public boards (or councils) to witness on their property (for their convenience) the type of quietness, safety, and potential service standards on which their evaluation is desired.

Even then, the Board (or Council) members were not asked to give any formal permit but only to withhold possible objections until their friends and neighbors also had been given a chance to evaluate the cost-benefits and to express their judgments. Such permissive inaction (i.e., the withholding of any objections) was found to be much easier to obtain than was a formal act of permission, per se. Although a letter of approval must now precede the first actual touchdown, simulated approach and departure patterns may provide adequate initial response.

Following such a series of "flight demonstration" (i.e., tests, but never so termed in communications with local officials) then, many local spokesmen are to be asked to consider, and to advise whether or not they would approve future commercial use of the site in question, and why. Their action-oriented response (after completion of the flight tests) will then become a valuable part of the program's response data.

Obviously, no rigid pre-determined pattern can eliminate the need for a polite but purposefully persistent approach tailored to the inevitable variations in each local situation. For example, although little purpose would appear to be served by protracted sessions with the many long-range planning bodies nominally concerned, some of those groups which have little direct authority -- such as the San Francisco Bay Area Council -- nevertheless may be so influential with others as to merit special consideration and conferences.

By contrast, earlier experience indicates that the employment of Federal and State aviation authorities should be restrained and judicious when seeking an open-minded response on the part of local officials and residents. The initial intervention of spokesmen representing high state and federal aviation authorities has been found often to engender defensive reactions at the local level. Such spokesmen were often found to be perceived by local residents as being special interest promoters.\*

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\*An example of the importance of avoiding such defensive reactions was evidenced when, during the earlier NACA supported ARF investigation, the Massachusetts State Director of Aeronautics, Arthur H. Tully, Jr., tried to be helpful in persuading community groups to cooperate on those "good neighbor" landing site demonstrations (i.e. acceptance tests). Such efforts were generally rebuffed and counter-productive.

Subsequently, Mr. Tully resigned as State Director, becoming instead a member of Harvard's staff and Associate Director of the Aeronautical Research Foundation. In that new role, his identical presentations to local groups produced open-minded acceptance and productive results -- even though his previous status as a government official remained well known.

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The importance of non-governmental organizations that have local constituencies and spokesmen within the proposed test areas will also be more precisely determined during the interim planning phase of this investigation. Specific plans for on-going communication procedures with those groups will also be established during that planning phase. Such groups include private environmental entities such as the Sierra Club, consumer organizations, real estate developers, local banks, PTA (where schools are contiguous) and those other civic groups that may be active in the area and interested in the proposed type of air services.

Practical time and space constraints do not permit elaboration of the careful preliminary exploration, the informal diplomacy and the quiet "educational" work with group leaders in each community that was found requisite in the earlier tests before the town authorities directly responsible for approving the landing-area permit were requested to act. During that preparation time, actively interested leaders in local real estate, in adjacent educational, hospital or other institutions, in one or more local business and most especially the local Chief of Police required careful indoctrination. Similar preparation is again expected to be a requisite.

The offices so indoctrinated are again expected to serve both to stimulate and to receive neighborhood response. The most important office from the standpoint of both receiving and placating the initially startled and frightened neighborhood response is that of the Chief of Police. The understanding and cooperation of

his troops has been found to be of utmost importance. (On that count, a few "observations" trips with intrepid local police during the airborne observing was found to be a great help).

#### Flight Operations on Proposed Sites

As with the previous section, the method and plans for conduct of the proposed tests are built on an experience-base that starts with the earlier NACA Project, "Experiments to Determine Neighborhood Reactions to Light-planes With and Without External Noise Reduction," during 1947 - 1950 by the Aeronautical Research Foundation.

That experience-base has been considerably augmented since by participation in other test programs such as Metro '66 sponsored by FAA on Manhattan Island in 1966, the NORCAL STOL Project in the San Francisco Bay Area together with many hundreds of flight demonstrations and operational missions with STOL aircraft, both quieted and unquieted, on small neighborhood sites during the intervening years (see Appendix A). However, because the earlier NACA Project is the only one that proposed significant data with regard to the impact of noise reductions on neighborhood response, that project will be used as the principal reference point in discussing the similarities and variations in the methods now proposed.

The earlier NACA Test Program covered a period in excess of three years. The extended duration was occasioned largely by the extensive modifications and the varied configurations of the several aircraft used in test flights, both with and without external noise reduction. By contrast, in the now proposed program, use of only one airplane is planned. Moreover, no purpose would appear to be accomplished by proving once again that the aircraft would be objectionable with no noise suppression. Accordingly, it will be flown only with the noise reduction and full safety equipment installed.

Any of the several airframes now being considered for modification and quieting

as proposed, are to be equipped so as to be usable on strips varying from 600 to a maximum of 900 feet in length. They are also to be configured for operation with varying degrees of noise emission down to the lowest level believed practicable at the present state of the art.

In the earlier Boston area tests, ten sites were found to be adequate for the range of determinations needed. However, for present purposes in the San Francisco area, because of the unique importance of waterfront sites, the objective is to run tests on ten land-based sites and on up to five shoreline locations utilizing barges as the landing platform. The proposed budget appears adequate to cover all such proposed operations. Nevertheless, in order to make allowances for possible contingencies and unforeseen added expenses, the number of sites and number of flights proposed includes a margin between the optimum desired and the minimum that was deemed essential. The minimum deemed essential is seven on land and not less than three contiguous to the shoreline. In all probability, all the shoreline operations will utilize barges. However, the utilization of shore-attached structures, such as piers, may in some locations prove to be more practicable.

Because of the present California Airport Regulations only make provisions for temporary permits for periods of not more than 30 days, the proposed operational plan-of-action is at present is being conscribed by that time limit. Consequently, operations will be concentrated largely on one site for each 30-day period, but with as much overlapping operation on the preceding and on the subsequent landing site as may prove practicable.

The proposed daily span-of-time to be covered by tests is from 7 a.m. to 11 p.m. Those are not only the hours in which most of the economically practical traffic is expected to be concentrated, but also constitute the probable limits of intrusion

into sleeping hours that previous experience indicated may prove tolerable. The principle emphasis during the test will be placed on the more sensitive time periods. The two most sensitive hours within that span were previously found to be between 7 a.m. and 8 a.m. and between 10 p.m. and 11 p.m. (The greatest protest arose during those hours in which the head of the household was trying to sleep, but was intermittently awake.)

The frequency of flights and the length of test periods will be varied in relation to the number, type, and intensity of complaints. Within the practical limits imposed by the 30-day time period at each site -- taking into account reasonably predictable weather and mechanical delays -- realistic objective appears to be to accomplish not less than twenty landing/takeoff sequences on each day of the week. Also, each day of the week (i.e., Sundays, Mondays, et. al.) is to be tested at least twice. The minimum number of flights thus sought on each site is 300, (that minimum being above the number found essential during the earlier Boston tests). On most of the potential land-based sites, it is believed practical.

#### Methodology and Responsibility for Data

Each neighborhood will have similar but differing organizations that can systematically assist in determining and influencing neighborhood reactions. Among these are the PTA, the League of Women's Voters, church groups, Rotary, etc. Such organizations -- and most especially the local police -- will probably continue to be found to be the principal channels for significant complaints -- hopefully also for positive support.

Each complaint is to be classified by time, place, "plaintiff" characteristic, flight path, noise ambient at that point, etc. Each such plaintiff will also be

sent a letter and a short questionnaire. However, the most dependable source of complaint analysis has been found to be by direct interview and in public hearings. Therefore, insofar as practicable, each complaint will be followed up with a carefully structured interview. Initially, the experienced senior members of the research team will conduct the interviews, with selected local university students participating. When found adequately prepared, those students will then be used for continuation and expansion of the interview process.

In advance of and during the flight tests, the Federal FAA will be expected to check each site, flight path, and operational plan concurrent with a similar check by California DOT Aeronautics personnel. Thereafter, the California DOT has advised that their pilots and technicians will be willing and able to provide surveillance and spot checks on the flight operations, noise measurement procedure and other techniques involved. However, the state DOT also advises that they do not have sufficient personnel to be able to supply regular and continuous pilot or mechanical services, noise monitoring, or systematic interviewing.

For such purposes, the contractor will retain professional talent available in the area for aircraft operation (utilizing NASA personnel wherever possible). To monitor the ground equipment, to follow up complaints, to conduct interviews and to process the data thereafter, the contractor will take full responsibility for selecting, supervising, and training the staff, utilizing graduate students insofar as practicable. Also, as has been done on the traffic analysis to date, the professional capabilities of local university faculty and staff will be similarly utilized in the subsequent data analysis and interpretation. A maximum of talent for such temporary work at a minimum of cost has been found thus usually best available from local universities.



At the conclusion of the flight test program in each locality, either a formal or a simulated "public hearing" will be scheduled. Local authorities will be asked to vote, at least nominally, their approval of the establishment of the proposed type of intra-regional air service within their community. All known opponents and advocates of such a service will be invited to attend those hearings and will be given a carefully prepared "ballot" (i.e. a questionnaire) upon which to express their views and reasons.

At this point, emphasis should be placed on an important fact that emerged during the earlier Boston investigation. That is, that the part of the investigative procedure which simply registers and investigates complaints produces only a negative picture. The objective of the current investigation, however, is positive. It is to determine how elimination of the maximum objections possible may then permit the desirable features of this type of air service to be accepted. Consequently, the investigation and presentation must also emphasize positive aspects and present effectively to the groups involved, by letter and in conference, the advantages of such air service to the community in general and to each individual concerned. Obviously, without so presenting the desirable aspects and their directly applicable benefits to the individuals concerned, the only thing more desirable than a quiet, safe airplane in the vicinity will be found to be no airplane!

The ultimate purpose of the program being that of making possible a new type of air service that will benefit the community, both economically and environmentally, the collection of complaints must concurrently be counter-balanced by a pro rata dissemination of the positive aspects.

When the "votes" at the end of the proposed hearings, and through the other questionnaires and surveys have been completed, the local university staff will

be retained to classify, analyze and tabulate the resulting findings. Concurrently interested aeronautical offices in California DOT and in FAA will be called on to evaluate the operational experience and findings as they may bear on establishment of flight parameters, noise standards and other resulting criteria that can be utilized to guide future regulations for intra-regional air transport operations.

The final report will then seek to present a complete and practical plan-of-action setting forth the design criteria for new aircraft that will be acceptable in terms of noise suppression, safety, flight characteristics, size and economic characteristics, etc. to provide optimum intra-regional flight services for the San Francisco Bay Area. Those design criteria and performance parameters for the aircraft will be matched by design criteria and parameters for landing areas and for the local flight patterns to guide future engineers and planners of such facilities.

The proposed contract time period for the testing phase is 18 months plus or minus 90 days. The preliminary budgets for the test program, under varying assumptions as to the nature of the flight equipment selected, are summarized in a following section of this report. The final selection of the test aircraft by NASA and DOT will appreciably affect related aspects of the budget but should not affect the required testing time appreciably.

Note should be made of the fact that the currently proposed program will have the full benefit of guidance and advice by the key participants in the team that organized and directed the earlier successful Boston program. In particular, Dr. Lynn L. Bollinger, then Professor in Charge of Aviation Research at Harvard and Director of the Aeronautical Research Foundation, Inc. will continue such guidance for the proposed project in his present role as Director of the Inter-University Research Center, Inc. (within which the Aeronautical Research Center now functions as its aviation division).

### Preliminary Budget Estimates

There are two major cost items reflected in the budgetary requirements of the proposed demonstration program. Costs that are related to the acquisition, engineering, modification and testing of the research aircraft, and those related to the actual flight demonstration phase of the program.

For the purpose of the preliminary cost estimate, and to maintain a viable alternative, three aircraft were considered as candidates for modification and subsequent flight demonstration. The Helio U-10, the Helio U-5, and the De Havilland DHC-6. For primarily budgetary reasons the modification of more than one aircraft has been ruled out, except in the case of the much smaller, single engine Helio U-10, where modification and simultaneous use of two aircraft would be planned.

The flight research program will be conducted on temporary landing sites which are limited in use to a maximum of 30 days. This limiting time factor will necessitate an accelerated operating schedule requiring 20 days of operations for every selected landing site. The program calls for operations out of ten pre-selected landing sites\* and operations at 5 water-based landing sites using especially outfitted barges as landing platforms.

There are 450 landings scheduled for each landing site for a given 30 day period. A somewhat different schedule has been planned for the water based sites. A higher utilization of the barges will require 300 landings at each site within a 20 day period.

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\*Only seven sites were discussed in the earlier section entitled "Proposed Region and Field Site Selections for the Experiment", however, costs are estimated assuming ten sites as stated.

*C-2*

## Cost Elements

To estimate a total program budget, the project is divided into two phases - aircraft procurement and flight operations - with costs broken down into the following elements:

### Research Aircraft Procurement

Aircraft Acquisition

Aircraft Modification (including engineering & flight test)

### Flight Operations

Fixed Costs for Port Site Developemnt

Land Based Sites

Water Based Sites

Aircraft Operating Costs

Each element is outlined in greater detail in the following section.

### Aircraft Acquisiton Costs

Both the Helio U-10 and the DHC-6 are available from commercial sources at the following prices:

|            |          |
|------------|----------|
| Helio U-10 | \$30000  |
| DHC-6      | \$400000 |

All existing U-5 aircraft are in the U.S. Government inventory and therefore, no attempt is made to estimate an acquisiton cost. However, it is likely that the aircraft could be obtained at no cost presuming availability. This was confirmed in several telephone conversations with the Government Services Administration (GSA) in San Francisco.

### Aircraft Modification Costs

The estimates given below for aircraft modifications necessary to prepare the aircraft for short field, quiet operations during the research program include engine and propeller changes, modifications to the wing and empennage, and increased strength in the fuselage.

Concerning engine changes, the Allison 250 B-17 Turboprop engine offers the best alternative to replace the existing Lycoming piston engines for both the U-5 and the U-10 aircraft. The cost of this engine is \$60000. For the DHC-6, there is the possibility of replacing the existing PT6-27A turboprop engine with the updated PT6-45 at a cost of \$150,000 per engine.

A detailed cost breakdown for the prospective airframe modifications for the DHC-6 are given in a following section entitled . Overall costs which include the engineering labor costs are as follows:

| Aircraft                                       | U-10     | U-10     | U-5      | DHC-6     |
|--|----------|----------|----------|-----------|
| Number Modified                                | 1        | 2        | 1        | 1         |
| Cost of Engine Changes                         | \$ 60000 | \$120000 | \$120000 | \$ 300000 |
| Total Modification Costs<br>(w/o engine costs) | \$365000 | \$530000 | \$590000 | \$ 808000 |
| Total Modification Costs<br>(w/engine costs)   | \$425000 | \$650000 | \$710000 | \$1103000 |

### Fixed Costs for Port Site Development

Land Sites: It is estimated that the research program will last for eighteen months. A bulk of the fixed costs will go for personnel salaries; however, costs for port site preparation and data processing are also factors. A breakdown of the fixed costs over the eighteen months is as follows:

|   |                 |
|---|-----------------|
| Port Site Preparation and Private Rental        | \$ 38000        |
| Ground Attendants, Site Security, Staff Support | \$ 67000        |
| Ground Support Equipment Rental                 |                 |
| Office Rental and Personnel                     |                 |
| Data Processing                                 | \$ 55000        |
| Research Personnel                              | \$120000        |
| Accounting, Audit, Legal                        | \$ 54000        |
| Travel and Per Diem                             | \$ 48000        |
| Allowance for Insurance and Miscellaneous       | \$ <u>36000</u> |
| Total Fixed Costs (Land Sites Only)             | \$418000        |

Barge Sites: It is assumed that operations from barges will take place within a 100 day period in order to hold down costs. Costs directly related to the barge include lease cost, insurance, towing, anchors, fairleads and accessories. In addition there would be additional fixed costs due to added personnel and equipment. The costs estimates to cover the 100 day period are as follows:

| Aircraft                                  | U-5      | U-10     | DHC-6    |
|---|----------|----------|----------|
| Number of Barges Required*                | 5        | 5        | 8        |
| Fixed Costs - Barge Direct                | \$95000  | \$95000  | \$152000 |
| Fixed Costs - Personnel & Equip.          | \$65000  | \$65000  | \$ 65000 |
| Total Added Fixed Costs<br>Due to Barges  | \$160000 | \$160000 | \$217000 |
| <u>Total Fixed Costs for the Program:</u> | \$578000 | \$578000 | \$635000 |

\* As discussed in the previous section entitled "Port Site Development", the barges are attached together to provide the necessary length and width for takeoff and landing.

## Aircraft Operating Costs

The approach used to estimate the aircraft operating costs over the course of the program was simply to determine the number of flight hours required to conduct the experiments at the ten land sites and the five barge sites and then to apply the hourly cost of flying the aircraft. In addition, salary and insurance for the pilot are included as an aircraft operating cost.

The breakdown to compute flight hours for both the land sites and the barge sites are as follows:

### Land Sites

|   |         |            |
|---|---------|------------|
| Landings per site                                 | 450     |            |
| Time for one landing cycle                        | 15 min. |            |
| Experimental Flight Time/Site                     |         | 112 hours  |
| Operating days/site                               | 20      |            |
| Round trips/site                                  | 40      |            |
| Average Transit Time                              | 30 min. |            |
| Transit Time/Site                                 |         | 20 hours   |
| Total Flight Time/Site                            |         | 132 hours  |
| Number of Land Sites                              |         | 10         |
| Experimental Flight Time                          |         | 1320 hours |
| Miscellaneous Test & Demonstration<br>Flight Time |         | <u>120</u> |
| Total Flight Time for Land Sites                  |         | 1440 hours |

### Barge Sites

|                            |         |
|----------------------------|---------|
| Landings per site          | 300     |
| Time for one landing cycle | 15 min. |

|                               |         |           |
|-------------------------------|---------|-----------|
| Experimental Flight Time/Site |         | 75 hours  |
| Operating Days/Site           | 14      |           |
| Round Trips/Site              | 28      |           |
| Average Transit Time          | 30 min. |           |
| Transit Time/Site             |         | 14 hours  |
| Total Flight Time/Site        |         | 89 hours  |
| Number of Barge Sites         |         | 5         |
| Experimental Flight Time      |         | 445 hours |

The hourly operating costs and the resulting aircraft operating costs for the program are shown in the following table. Also shown are the costs for pilot salary and insurance.

| Aircraft                              | U-10  | U-5    | DHC-6  |
|---------------------------------------|-------|--------|--------|
| Hourly Operating Cost (\$)            | 28    | 43     | 95     |
| Program Flight Hours                  |       |        |        |
| Land Sites                            | 1440  | 1440   | 1440   |
| Barge Sites                           | 445   | 445    | 445    |
| Total                                 | 1885  | 1885   | 1885   |
| Aircraft Operating Costs              | 52780 | 81055  | 179075 |
| Pilot (Salary, Insurance for 18 mos.) | 36000 | 36000  | 36000  |
| Total Operating Costs                 | 88780 | 117055 | 215075 |

#### Total Program Costs

A preliminary estimate of total program costs is given in Table II which summarizes the cost elements outlined previously. Provisions in the costing is made for program costs with and without the cost of new engines for the modified aircraft.



Table II  
Preliminary Budget Estimates

\$ Thousands

|                                      | U-10  |      | U-10  |      | U-5   |      | DHC-6 |      |
|--------------------------------------|-------|------|-------|------|-------|------|-------|------|
|                                      | 1 a/c |      | 2 a/c |      | 1 a/c |      | 1 a/c |      |
| a. Modified A/C Engines GFE          |       |      |       |      |       |      |       |      |
| b. Modified A/C Engines Purchased    | a     | b    | a     | b    | a     | b    | a     | b    |
| Aircraft Acquisition                 | 30    | 30   | 60    | 60   | 0     | 0    | 400   | 400  |
| Aircraft Modification                | 365   | 425  | 530   | 650  | 590   | 710  | 808   | 1108 |
| Fixed Cost for Port Site Development | 578   | 578  | 578   | 578  | 578   | 578  | 635   | 635  |
| Total Operating Costs                | 89    | 89   | 89    | 89   | 117   | 117  | 215   | 215  |
| Total Program Costs                  | 1062  | 1122 | 1257  | 1377 | 1285  | 1405 | 2058  | 2358 |

## A Modified DHC-6 as the Experimental Aircraft

### Design Modifications

To simulate the operation of STOL and V/STOL aircraft in an urban environment for assessing public acceptance criteria, a study was undertaken to identify those modifications of a deHavilland DHC-6-300 Twin Otter that would be required to model the field length performance capabilities of projected STOL and V/STOL aircraft. These field length performance characteristics include short takeoff and landing field length (800 ft. to 1200 ft.), and steep climbout and approach flight path angles. As an experimental aircraft, the modified Twin Otter would be operated without passengers. However, a 3500 lb. payload design constraint was also imposed.

The first option considered was operating the standard DHC-6-300 aircraft at off-loaded gross weights without any structural modifications. Operated in the "STOL Mode," the Twin Otter has excellent short field performance at gross weights up to 12,500 lbs. The second option consisted of the addition of ground spoilers, similar to those on the DHC-6-300s. The addition of spoilers would shorten the ground roll distances for landing and the braking portion of the accelerate-stop distance. The third modification option was the addition of leading-edge devices (LED) to the wing. The LED would provide a lower stall speed, (higher  $CL_{max}$ ) which is important for reducing both the takeoff and landing distances. The LED's real value, however, is to provide an essential increase in safety.

The most essential need for the LED is thus to eliminate the otherwise high risk of losing control during slow-speed approaches in turbulence closer to vortex-producing obstacles than is required for final approach to a conventional

airport. The earlier Boston tests on such short strips revealed that the LED eliminated the stall-spin risk, but that conventional ailerons then became inadequate to prevent the airplane from side-slipping into the ground and striking a wing when such turbulence was encountered. (A high proportion of the famous German Fliessler-Storch STOL airplanes which are also equipped with LED have been demolished in that manner -- though seldom with serious personal injury, due to the low touchdown speed.)

To eliminate such an unacceptably high incidence of aircraft demolition in slow-speed touchdowns, the Helio Aircraft Corporation adopted and improved an earlier experimental British device called an auto-slat interceptor. This is in effect a sugar-spoon type of spoiler mounted directly behind the trailing edge of the automatic leading-edge slat so that it partially blocks air flow through the slat. It thus produces added roll control when the slat opens at high angles-of-attack.

The Helio patent of combination involving that uniquely effective control system has now expired. ARF personnel are familiar with and can appropriately utilize the technology involved. The incorporation of such augmented-lateral-control as part of the DHC-6 modification is thus both feasible and essential for safe operation in the types of confined areas proposed for use.

A somewhat more extensive modification would involve a new larger vertical tail unit along with the addition of spoilers and LED described above. The larger tail would allow for lower minimum control speeds, ( $V_{mc}$ ), i.e. yaw control for an engine-out condition. The new tail would permit safe operation of the aircraft at lower speeds during the landing and takeoff maneuver.

The final minimum power-plant modification considered is the replacement of the existing propulsion system with Pratt and Whitney PT6A-45 turboprops employing 9.25 ft. diameter 5-bladed Hartzell propellers.\* This is the propulsion system currently used on the Shorts 3D3-30 aircraft. The PT6A-45 engine has a shaft horsepower of 1120 SHP at 1700 RPM. That engine/propeller modification would produce an approximate 50% increase in the Twin Otter's static thrust to reduce takeoff distances and to improve climb performance. That modification requires a larger vertical tail to counter the increased engine-out yawing moment.

Serious question must be raised, however, as to whether the resulting noise reduction would be acceptable in the more critical outlying neighborhoods where such testing is especially important. The earlier Boston tests strongly indicate that this noise level may be rejected. More recent FAA-sponsored tests on proposed 2000-foot strips (less close-in than now contemplated) also confirm that indication.

Regardless, the limiting of the proposed experimental research airplane to the moderate degree of noise reduction already employed by conventional aircraft now in service would not be consistent with the research objective of testing the acceptability of those lowest noise limits practicably attainable with present-day technology. The employment of a lower engine-to-propeller gear ratio is clearly called for. Then, to maintain takeoff and climb efficiency a larger propeller diameter may be needed. Unless significantly reduced noise levels can be so produced and tested at an acceptable cost with the preferred DHC-6 aircraft, use of the Helio twin-engine U-5 C/STOL may prove more practicable.

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\* The existing propulsion system consists of Pratt and Whitney PT6A-27 turboprop engines and 8.5 ft. diameter 3-bladed Hartzell propellers.

The field lengths initially considered for the test program ranged from 500 to 1200 ft. The definitions of the required takeoff and landing distances described below differ from those defined in FAR Part 23 or SFAR 23 in that only the ground roll portion is considered. The airborne portions of the takeoff and landing did not need to be included in the calculation of the field lengths. The field length performance of a modified DHC-6 airplane was computed for a range of gross weights from 9000 to 12500 lbs. (maximum of 12,300 lbs. for landing). On that basis, an 800-foot field length was selected.\*

The required landing run is defined as the distance from the touchdown point to a point where the aircraft speed has been reduced to a taxi speed of 10 knots. The required landing field length is then computed as the landing distance divided by a dispersion factor of 0.6. Existing rules include:

1. Approach speed, equal to 1.3 times stall speed, must be greater than or equal to the minimum control speed (VMC) down to 50 ft. altitude.
2. Speed at touchdown equal to 110% of stall speed, with engines idle.
3. 1.0 second delay after touchdown before any braking action taken.
4. Reverse thrust not to be used in calculating the ground roll-out.

Important to note is the fact that the landing-field length now calculated for the proposed program is based on full compliance with current safety regulations for conventional airplanes having no LED. For that reason the required approach speed is 30% greater than the stalling speed ( $V_S$ ). By contrast, with the proposed wing modified to incorporate both LED and augmented lateral-control,

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\* The required takeoff field length is determined by the engine-out performance. Two takeoff distances are computed: 1) the accelerate-stop distance and 2) the distance to lift-off after having incurred an engine failure. The aircraft is assumed to accelerate with all engines operating to the decision speed  $V_1$ , whereupon an instantaneous engine failure occurs. The pilot then elects to stop the aircraft, or continue the takeoff and accelerate to the lift-off speed. A time delay of 2.0 seconds is allowed for engine failure recognition before braking action. The longer of the two required distances is the takeoff field length. The rotation speed is the greater of stall speed or minimum control speed.

the normal  $V_S$  of that airfoil in its "naked" mode ceases to be the determinant of minimum safe flying speed. At the normal stalling speed, such modified airplanes remain fully controllable. The coefficient-of-lift will actually continue to increase with further increase in the angle-of-attack. That capability makes possible safe approach speeds slower than would be permissible with conventional airplanes.

Then, by using moderate amounts of power, much steeper and more controllable approach flight paths are practicable. Consistently controllable touchdowns can thus be made at speeds less than the normal  $V_S$  of the naked-wing section. In such operations, the throttle is normally not fully closed until the wheels touch down.

The proposed flight test will seek to amass sufficient operational data to permit the FAA to determine whether commercial operations on such short close-in strips can be safely permitted under new rules that will allow shorter, steeper approaches and lower velocity touchdowns than would be permissible with improved aircraft under present-day approach and landing rules. This will allow the establishment of new standards for such Q/HE (quieted/helicopter equivalent) operations requiring appreciably less landing area and controlled air space than is now being specified for the test program.

(That ultra-short field technique has been used for years without difficulty with the approximate 200 Helio C/STOL (Controllable) aircraft employed by the U.S. government during the Vietnamese episode. It has also been used safely for a longer period by the approximate 500 civilian operators of such C/STOL throughout the world.)

## Landing Field Length

Ground roll distances are presented in figure 22 as a function of touchdown speed and gross weight for various modification options. Using the 0.6 landing field length factor, the required landing distances for 800, 1000 and 1200 ft. field length are 480, 600, and 720 ft., respectively. For the standard DHC-6-300, only braking and flap retraction during the ground roll are used. With the flaps deflected to the landing approach setting, the aircraft has a high lift coefficient during the ground roll. This removes a significant portion of the weight from the wheels, resulting in diminished braking effectiveness. This results in the lighter aircraft requiring longer stopping distances for the same touchdown speed.

Because the flaps can be retracted only very slowly (1.2 degrees per second from a landing setting of 40 degrees) the addition of ground spoilers was considered. The estimated performance of the DHC-6-300S ground spoiler system was approximately 10 percent loss in ground roll lift coefficient. The ground spoilers produce a moderate reduction in the stopping distance, with the trend of longer stopping distances at lighter gross weights exhibited by the unmodified aircraft.

The use of reverse thrust during the ground roll produces appreciable reduction in the stopping distance for the aircraft equipped with either the standard PW PT6A-27 or the new PT6A-45. The use of reverse thrust results in the lighter aircraft requiring a shorter stopping distance. For normal operations, the use of reverse gives approximately 50 percent reduction in ground roll.

The required touchdown speeds are presented in figure 23 as a function of gross weight for various design field lengths. The touchdown speed constraint of 110 percent of stalling speed is superimposed on these plots. The higher lift

coefficient of the LED leads to a significant reduction in the stall speed. Also, with the stalling speed a function of gross weight, the lower the weight, the lower the touchdown speed.

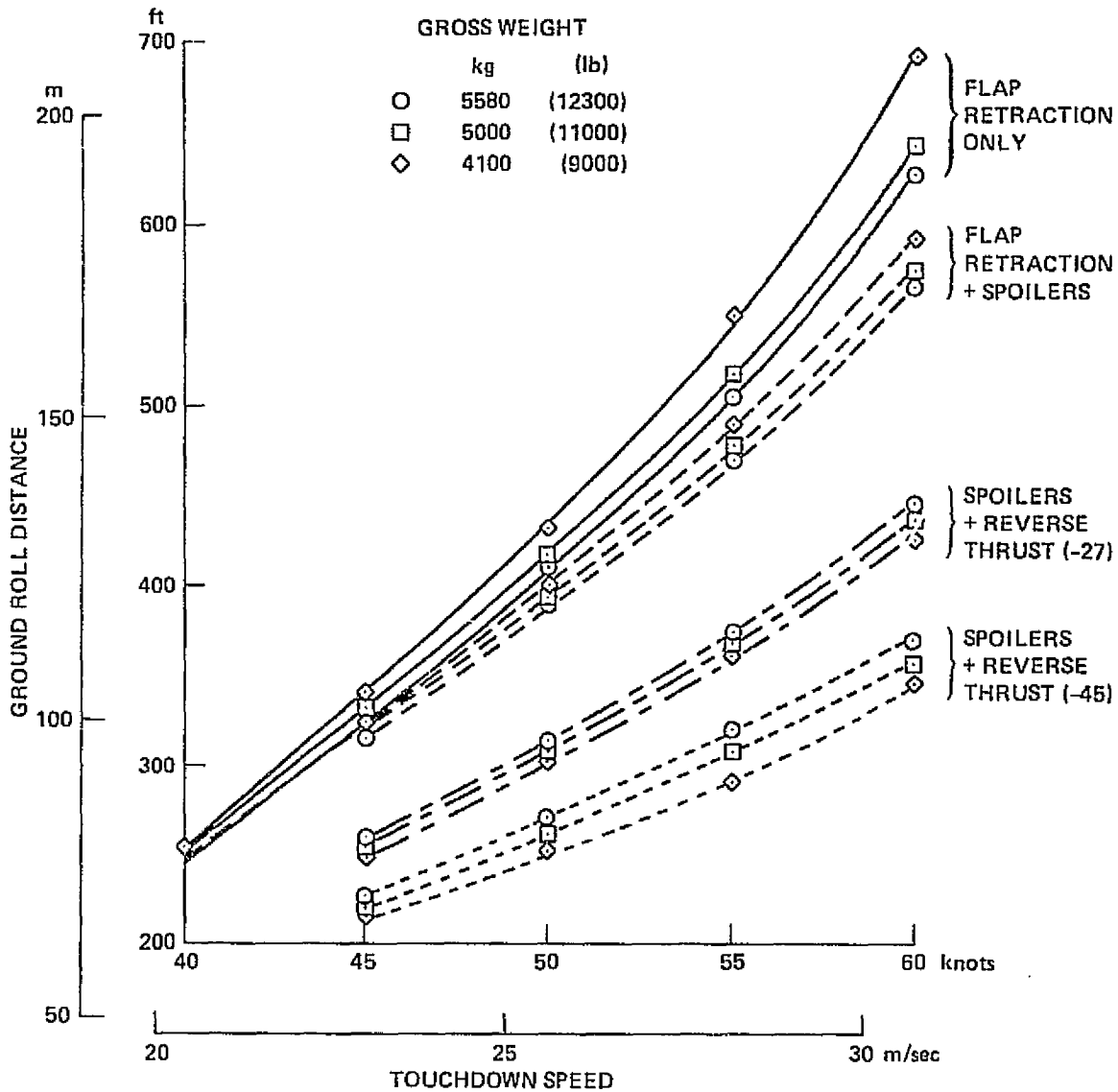
Referring to the 800 ft. field length, figure 23a, the unmodified aircraft is able to satisfy the field length requirement only at a gross weight less than 9000 lbs. (approximately 8700 lbs.). The addition of ground spoilers allows gross weights of up to 9300 lbs. to meet the 800 ft. requirement. If the aircraft is equipped with LED, gross weights of up to 11,000 lbs. are permitted. The use of reverse thrust permits higher gross weights with no limit with the -45 engine and no limit with the -27 engine combined with LED. However, reverse thrust is not assumed in determining the field length. Longer design field lengths result in higher allowed landing gross weights for the spoiler and spoiler/LED modifications.

The effect of relaxing the touchdown speed constraint is shown in figure 24. This operational technique may be permissible for aircraft equipped with LED, which tend to improve the low speed performance of the aircraft. With the trend of shorter stopping distances with lower touchdown speeds, the spoiler/LED mod aircraft can meet the 800 ft. field length requirement at full gross landing weight (12,300 lbs.) at a touchdown speed of  $1.03 V_{\text{stall}}$

From the landing performance calculations, the spoiler and LED modifications will be required to allow a sufficient range of aircraft gross weight to meet shorter field length requirements.



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NOTE: 1) DECELERATION FROM TOUCHDOWN SPEED TO 5.1 m/sec (10 knot) TAXI SPEED  
 2) IDLE THRUST AT TOUCHDOWN  
 3) ONE SECOND DELAY AFTER TOUCHDOWN BEFORE BRAKING ACTION

Figure 22. Ground Roll Distances

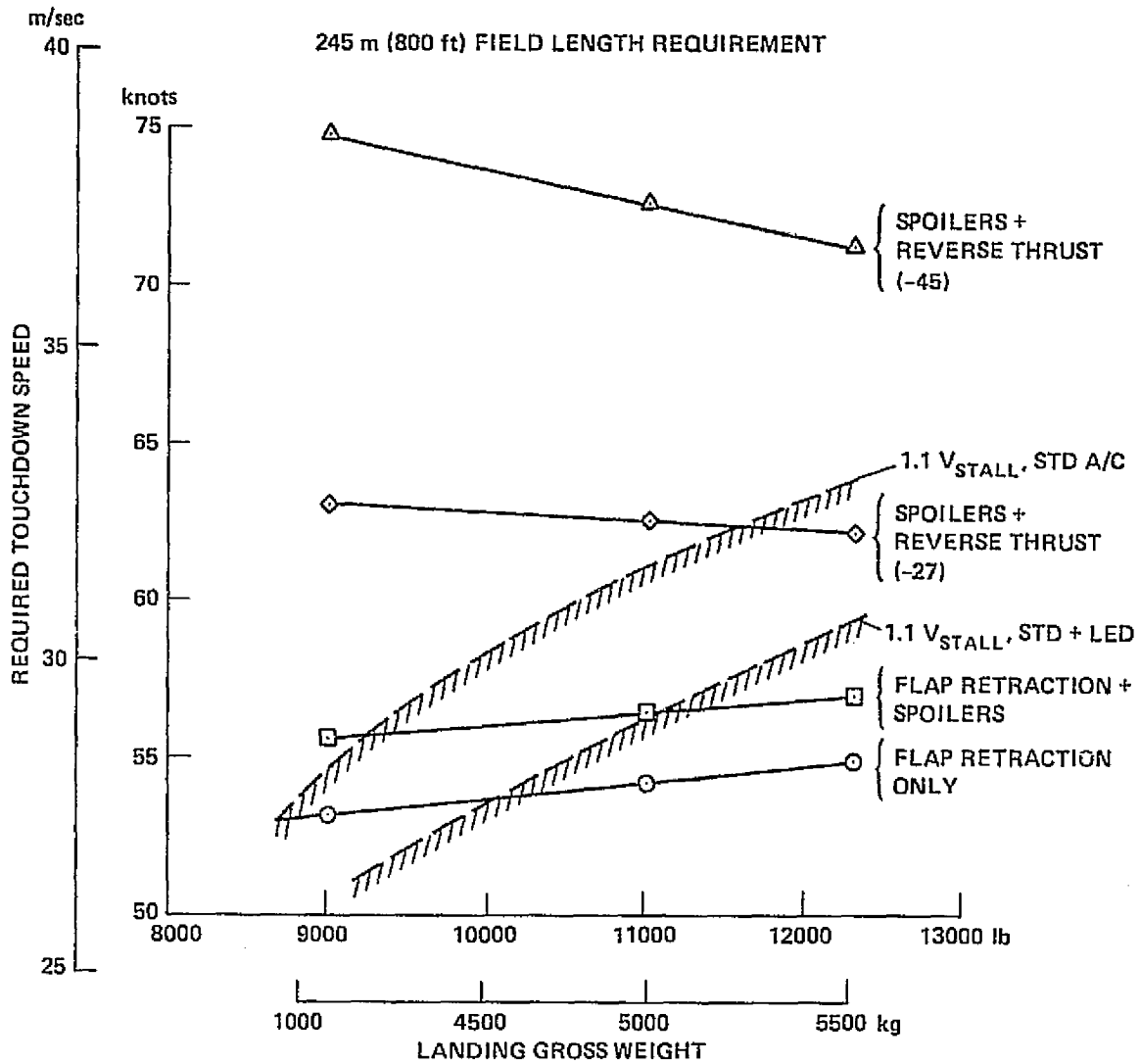


Figure 23 (a). Required Touchdown Speeds for 800 Ft. Field Length

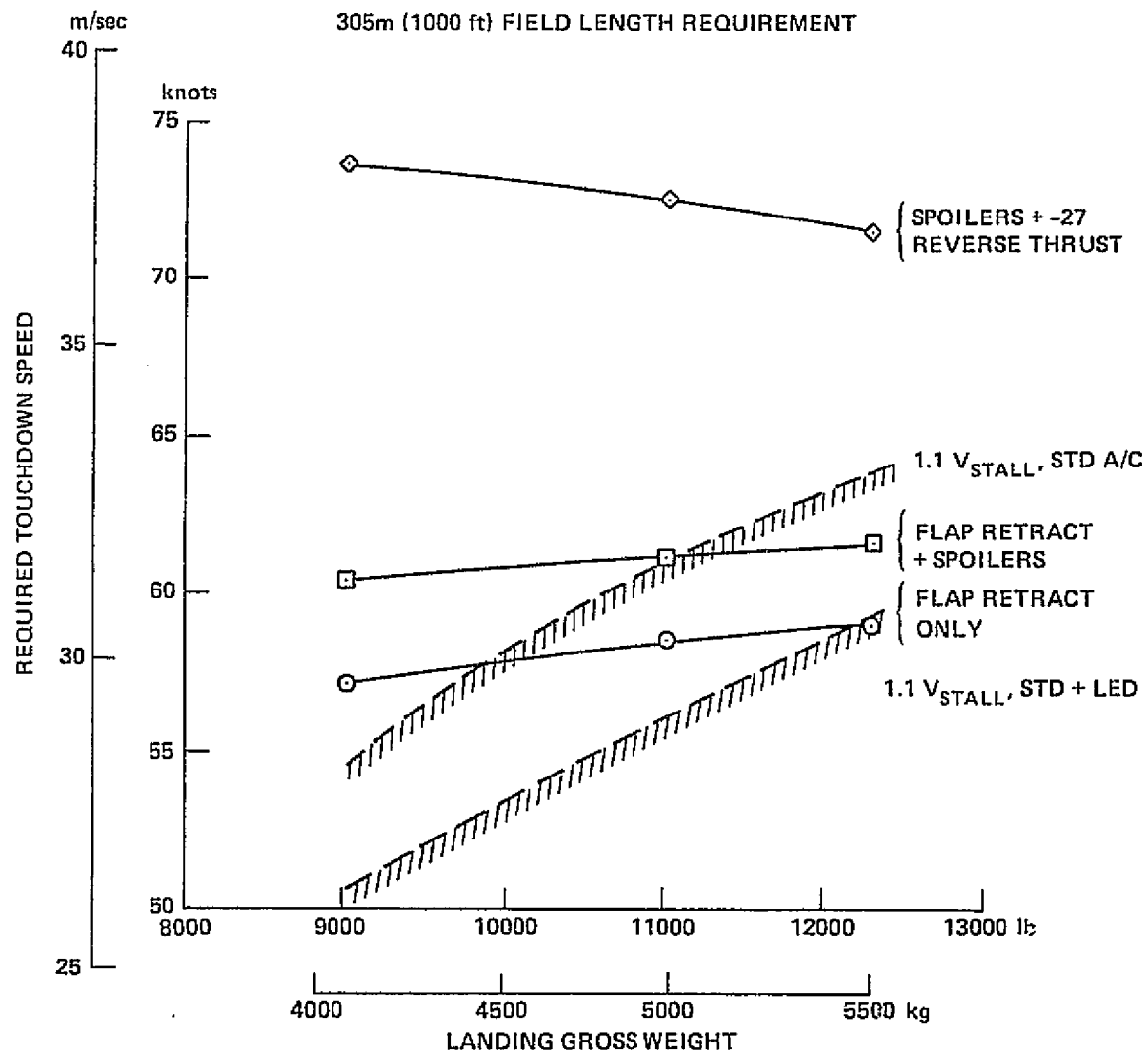


Figure 23 (b). Required Touchdown Speeds for 1000 Ft. Field Length

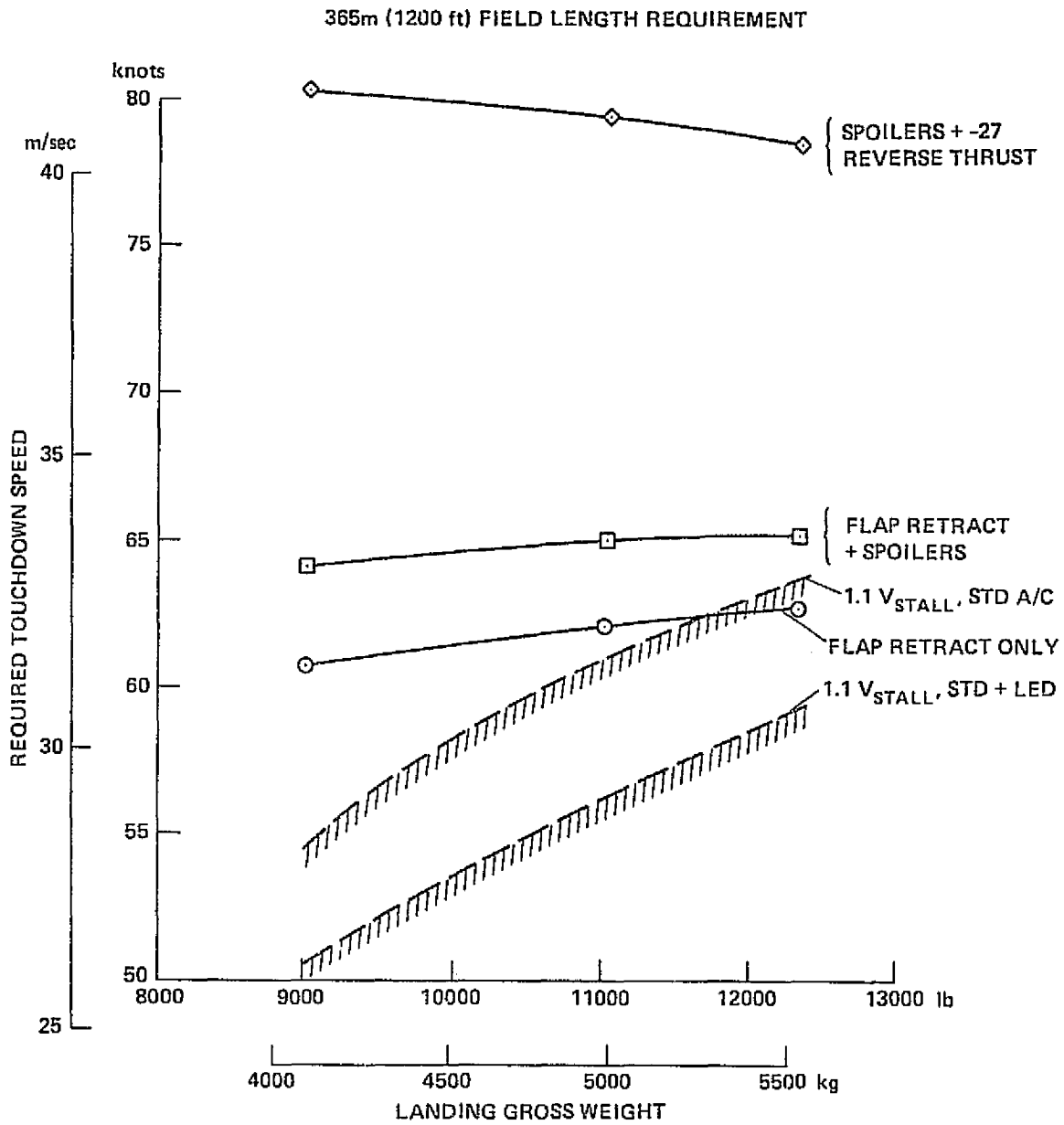


Figure 23 (c). Required Touchdown Speeds for 1200 Ft. Field Length

AIRPLANE GROSS WEIGHT = 5580 kg (12300 lb)

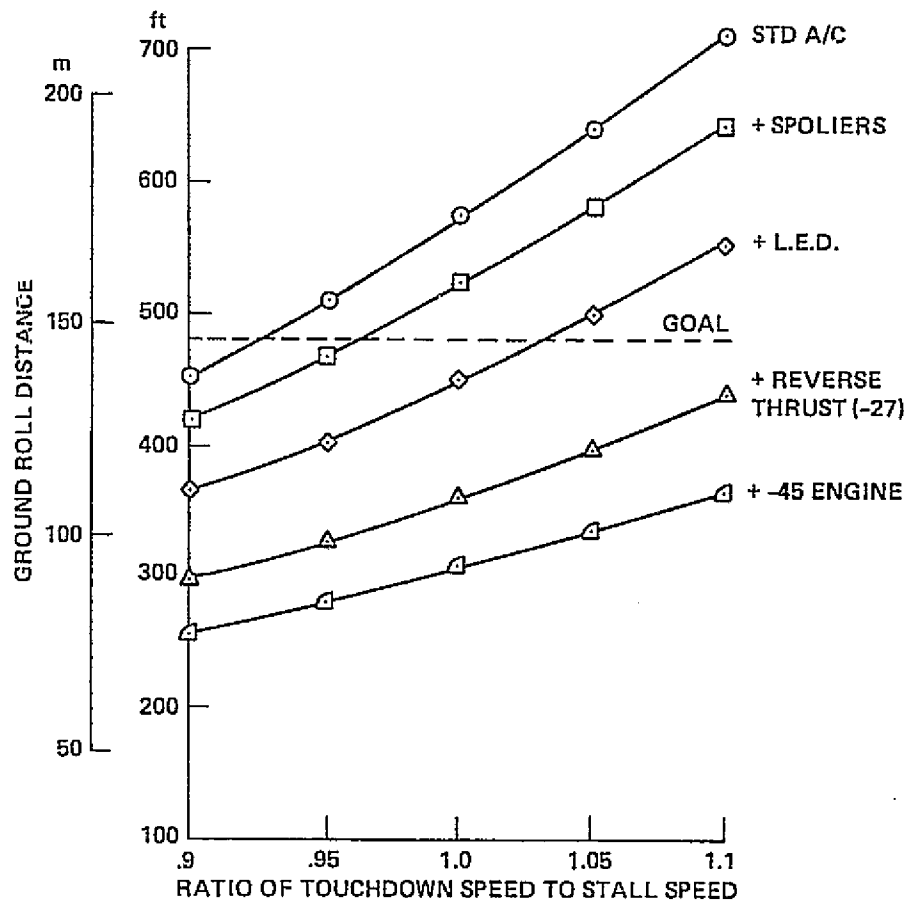


Figure 24 (a). Effect of Reduced Touchdown Speeds on Ground Roll - Aircraft Gross Weight = 12300 lbs.

AIRPLANE GROSS WEIGHT = 5000 kg (11000 lb)

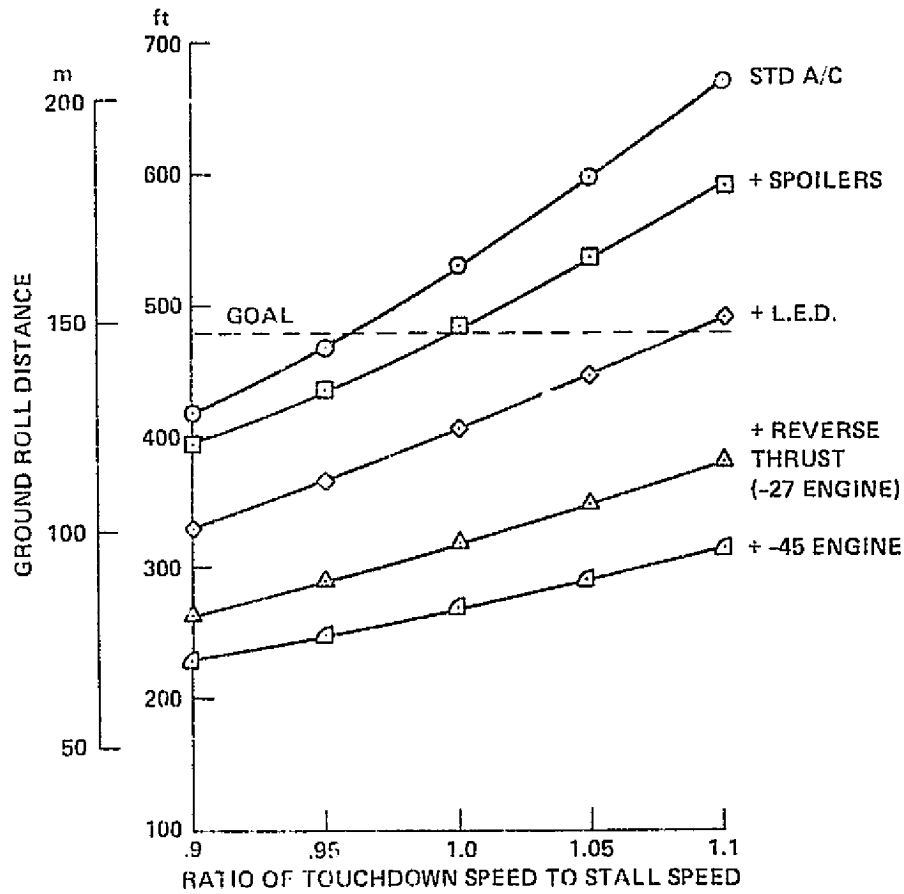


Figure 24 (b). Effect of Reduced Touchdown Speeds on Ground Roll - Aircraft Gross Weight = 11000 lbs.

AIRPLANE GROSS WEIGHT = 4100 kg (9000 lb)

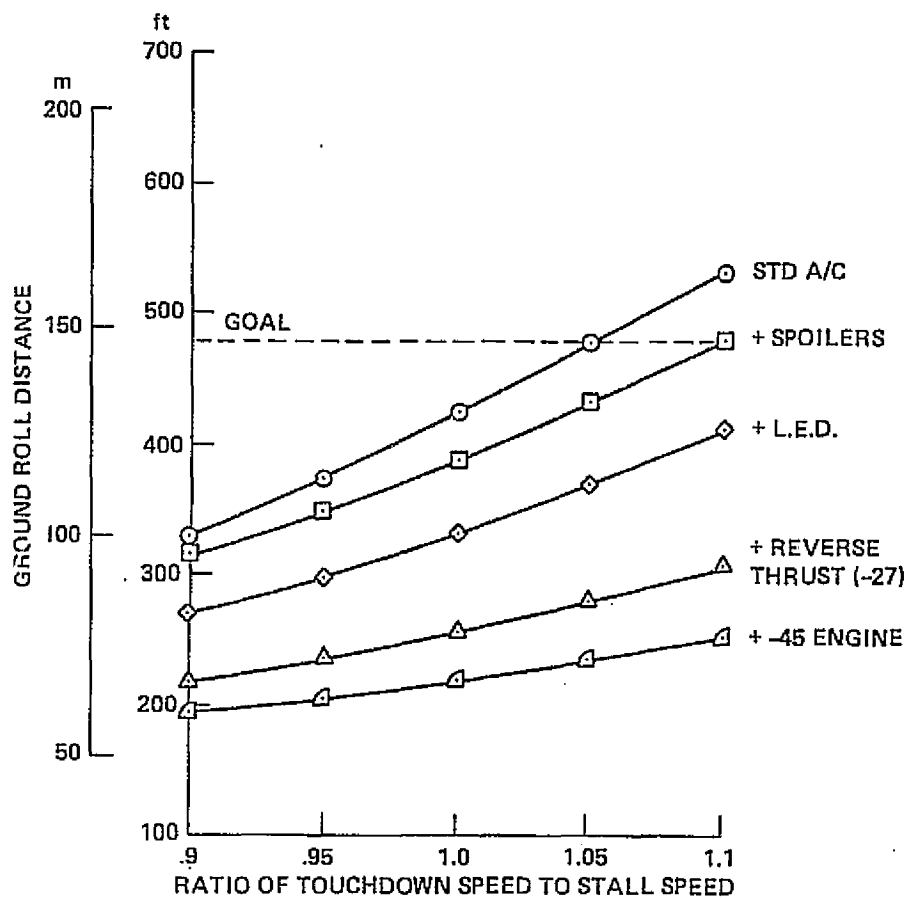


Figure 24 (c). Effect of Reduced Touchdown Speeds on Ground Roll - Aircraft Gross Weight = 9000 lbs.

## Takeoff Field Length

The engine-out takeoff distances are presented in figure 25a for the new tail/spoiler/LED equipped aircraft as a function of engine failure speed and gross weight. The higher the gross weight, the longer the required distance. As the engine failure speed is increased, the distance to lift-off decreases and the accelerate-stop distance increases. The intersection of the accelerate-stop curve and lift-off distance curve yields the minimum takeoff field length and its associated engine failure speed. For the results shown in figure 25, the vertical tail size has been increased from 100 ft<sup>2</sup> to 160 ft<sup>2</sup> to counteract the engine-out yawing moment during ground roll. The effect of vertical tail size on field length performance will be discussed in the following section.

Shown in figure 25b are the takeoff distances for the Twin Otter equipped with spoilers, LED and the PT6A-45 engine. The trends are similar to those of the PT6A-27 aircraft. The distance to lift-off for the -45 aircraft is less than that of the -27 aircraft due to the higher installed thrust. However, the accelerate-stop distances are comparable. For the -27 aircraft, the heavier the aircraft, the longer the required accelerate-stop distance. In contrast, the heavier the -45 aircraft, the shorter the required accelerate-stop distance. This results from the fact that the accelerate-stop distance for the -27 aircraft is dominated by the all-engine acceleration distance, while the -45 aircraft accelerate-stop distance is dominated by the braking portion of the rejected takeoff (i.e. the lighter the aircraft, the less the effective wheel braking).

The design takeoff field lengths (accelerate-stop distances equal lift-off distance) are shown in figure 26 as a function of gross weight. For the -45 equipped aircraft, the required takeoff distance is substantially less than any of the design landing field lengths considered. For the -27 engined aircraft,



also equipped with spoilers and LED, two curves corresponding to different vertical tail sizes are shown. For the larger vertical tail, the 800 ft. field length requirement can be satisfied for gross weights to 11400 lbs.

Presented in figure 27 are the takeoff climb-out flight path angles at optimum flap deflection as a function of gross weight. As the gross weight is decreased, the climb-out angle for both aircraft increased due to the higher thrust-to-weight ratios at the lighter weights. The -45 modified aircraft exhibited higher climb-out flight path angles due to its higher installed thrust.

From the landing and takeoff field length calculations presented above, modification of the standard DHC-6-300 with spoilers, LED and a new larger tail will permit the aircraft to be operated down to field lengths of 800 ft. with gross weights up to 11000 lbs. This gross weight corresponds roughly to the desired payload capability of 3,500 lbs. (See section on Aircraft Balancing). If it is desired to simulate the very steep climb-out angles associated with V/STOL aircraft, then the final modification of the -45 engine would be required (figure 27).

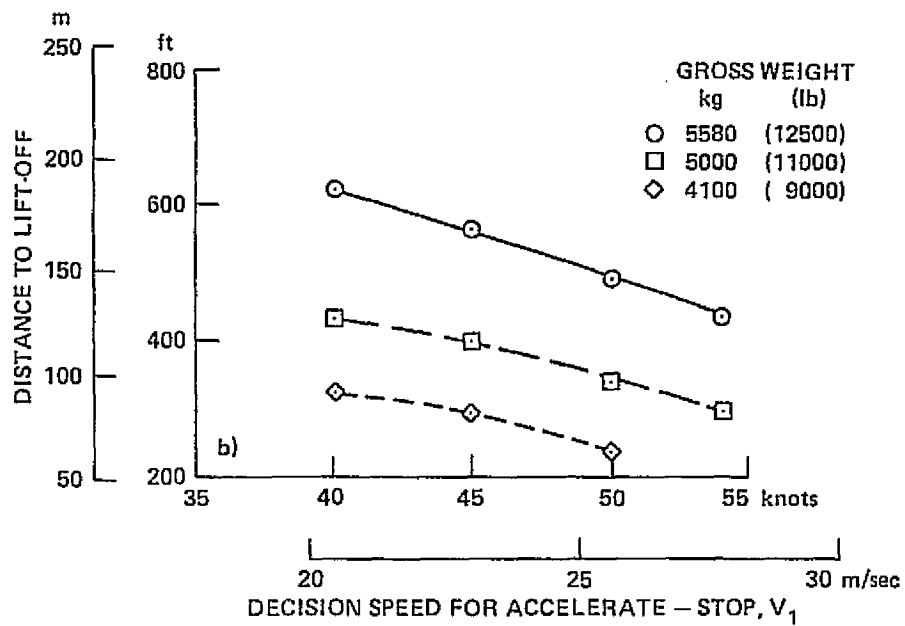
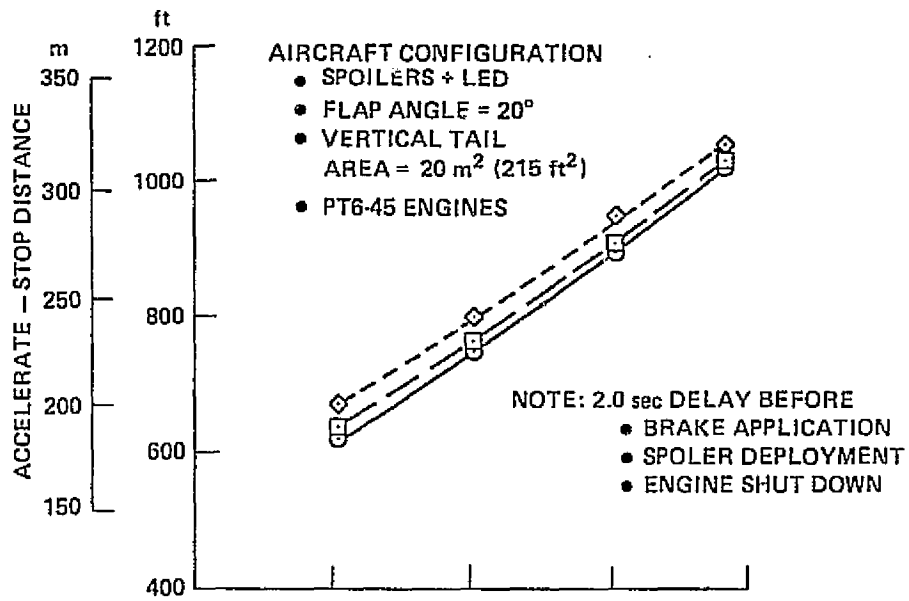


Figure 25 (a). Engine-Out Takeoff Distances and Accelerate-Stop Distance - PT6-27 Engines

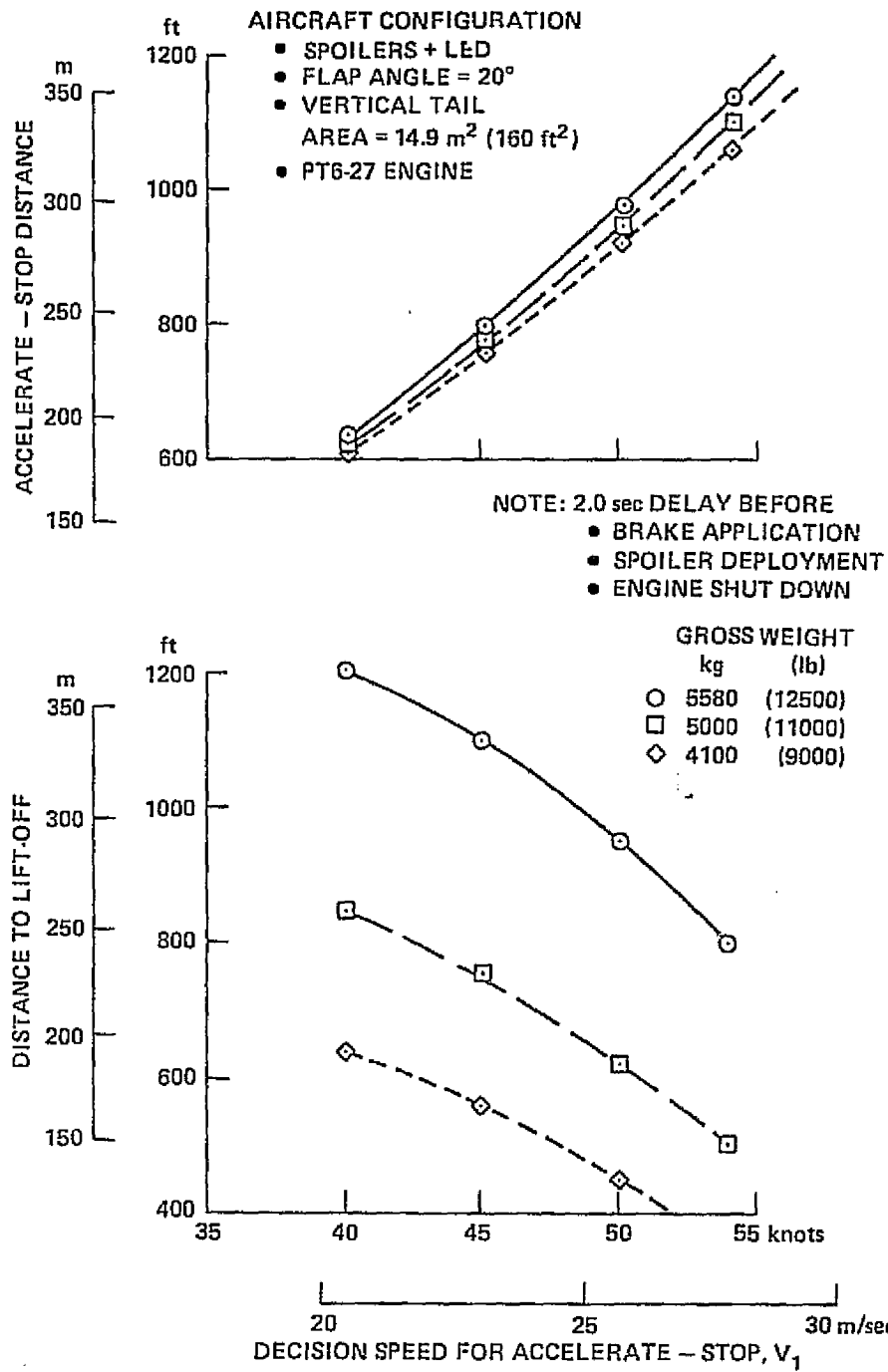


Figure 25 (b). Engine-Out Takeoff Distances and Accelerate-Stop Distance - PT6-45 Engines

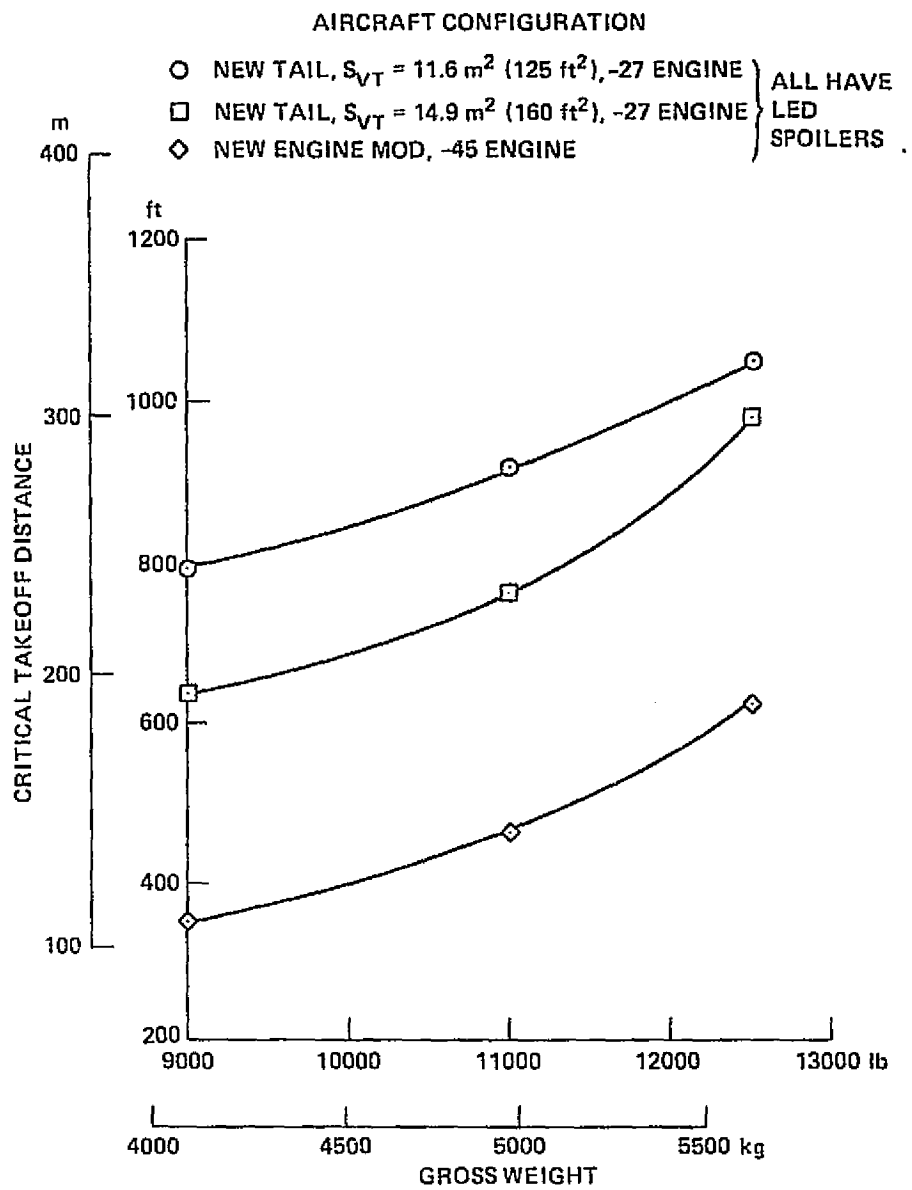
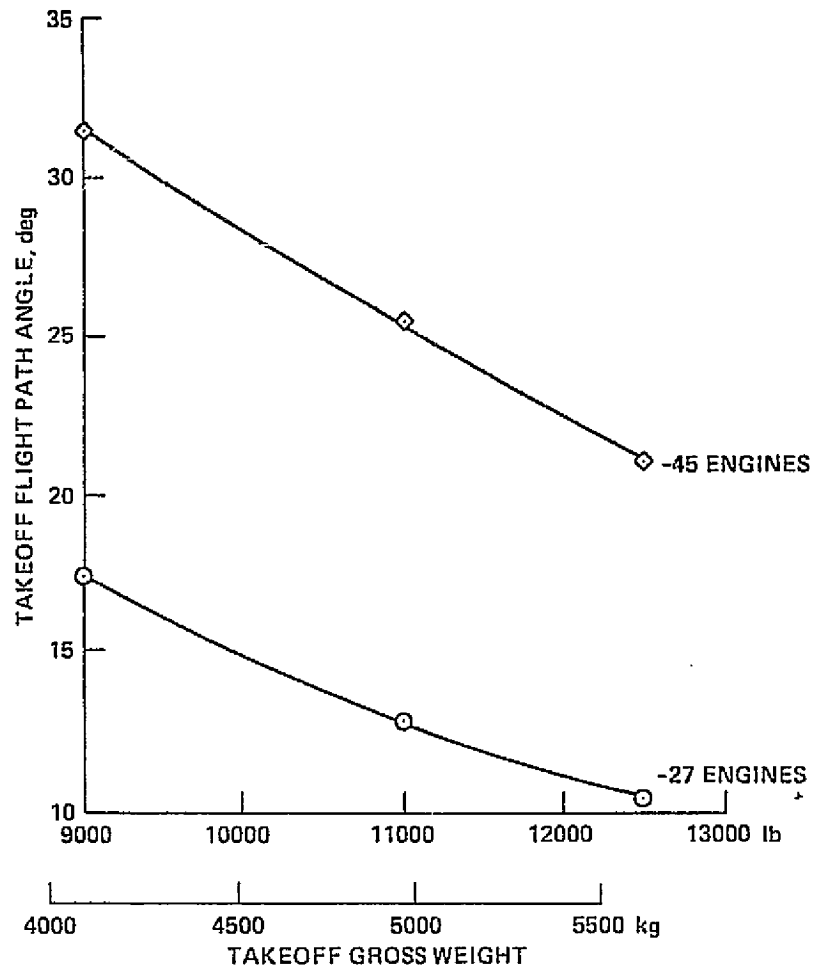


Figure 26. Design Takeoff Field Length



(ALL COMPUTATIONS AT OPTIMUM FLAP SETTING)

Figure 27. Climb-Out Flight Path Angles

## Vertical Tail Sizing

A key design parameter for an aircraft is the minimum control speed, i.e., that speed at which there is just enough vertical tail area to counter the yawing moment in an engine-out situation, with the remaining engine(s) at full power. This engine-out condition can occur during both the takeoff and during the approach for landing. The larger the vertical tail, the slower the minimum control speed. Hence, the size of the vertical tail will impact the field length performance of the aircraft.

Shown in figure 28 is the yawing moment coefficient as a function of airspeed for the -27 and -45 aircraft. Due to its higher prop and jet thrust, the -45 aircraft exhibits a larger moment coefficient. Based on the published VMC speed of 66 knots for the DHC-6-300, a maximum vertical tail lift coefficient,  $CL_{VT}$ , was determined. For the -45 engine modification, the  $CL_{VT}$  was held constant.

The required design vertical tail area as a function of airspeed is presented in figure 29 for the two engines. The -45 engine option would require a considerably larger tail for a fixed minimum control speed, due to its higher yawing moment coefficient.

For this study, a preliminary requirement that the approach speed to 50 ft. altitude ( $1.3 V_{stall}$ ) should not be less than the minimum control speed was adopted. At the lightest gross weight considered, 9,000 lbs., with a stalling speed of 46 knots (with LED) the minimum control speed of 59.5 knots was selected. In addition, this speed corresponds to the touchdown speed ( $1.1 V_{stall}$ ) for the maximum gross weight aircraft, 12,300 lbs. Flying the aircraft at less than the minimum control speed on approach below 50 ft. altitude was judged to be safe. The pilot would be committed to landing the aircraft below 50 ft. Above

50 ft., minimum control speed (or higher) would be maintained and hence an engine-out go-around could be executed.\*

The impact of vertical tail size on nose wheel steering requirements and rotation speed (hence minimum control speed) is shown in figure 30a for the -27 engined aircraft. Two curves at gross weights of 9,000 and 12,500 lbs. are shown corresponding to the nose wheel on the ground situation (allowing nose wheel steering for countering the engine-out yawing moment) and for the rotated attitude (implying that all yawing control must be produced by the vertical tail). The heavier aircraft has higher loads on the nose wheel, hence more steering force is available and less vertical tail force required. This results in smaller design tail areas at higher gross weights. The minimum required tail area is that which corresponds to the maximum engine failure speed  $V_1$ . This speed for a required field length of 800 ft. is 45 knots, and for the 9,000 lb. aircraft a  $140 \text{ ft}^2$  vertical tail would be required. With this area fixed, the minimum rotation speed is also determined (approximately 58 knots). However, at this rotation speed, the maximum allowable gross weight at takeoff would be approximately 10,000 lbs. (See figure 30c) For takeoff weights up to 11,000 lbs., a rotation speed of about 55 knots would be required. Hence the selected vertical tail area for the spoiler/LED/new tail modification is selected to be  $160 \text{ ft}^2$ . This gives a minimum control speed of 54 knots. (See figure 29).

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\*For  $V_{MC} = 59.5$  knots, a vertical tail area of 125 sq. ft. would be required for the -27 aircraft while 215 sq. ft. would be needed for the -45 engined aircraft.

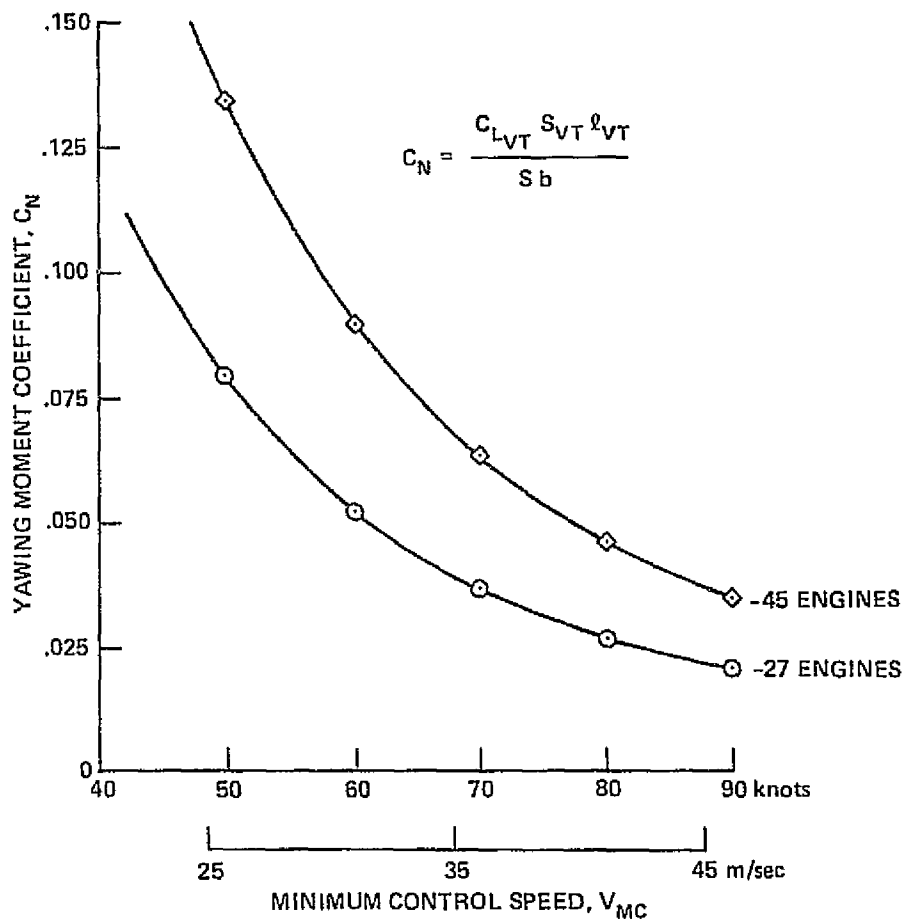


Figure 28. Yawing Moment Coefficient



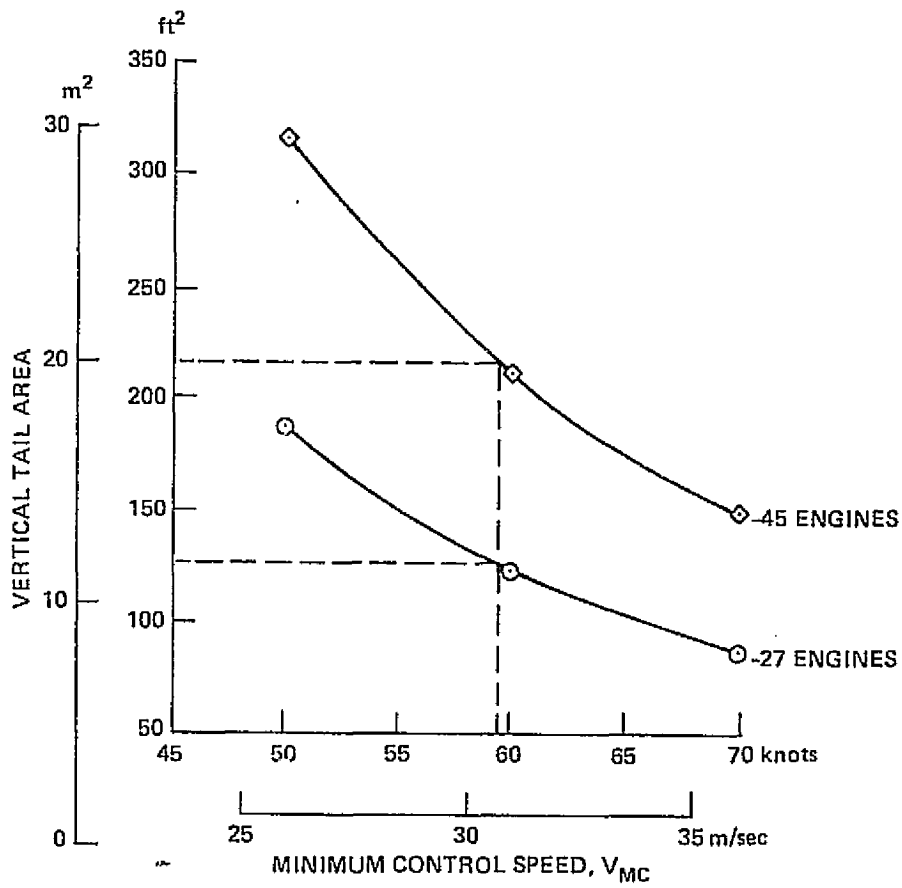


Figure 29. Effect of Minimum Control Speed on Vertical Tail Area

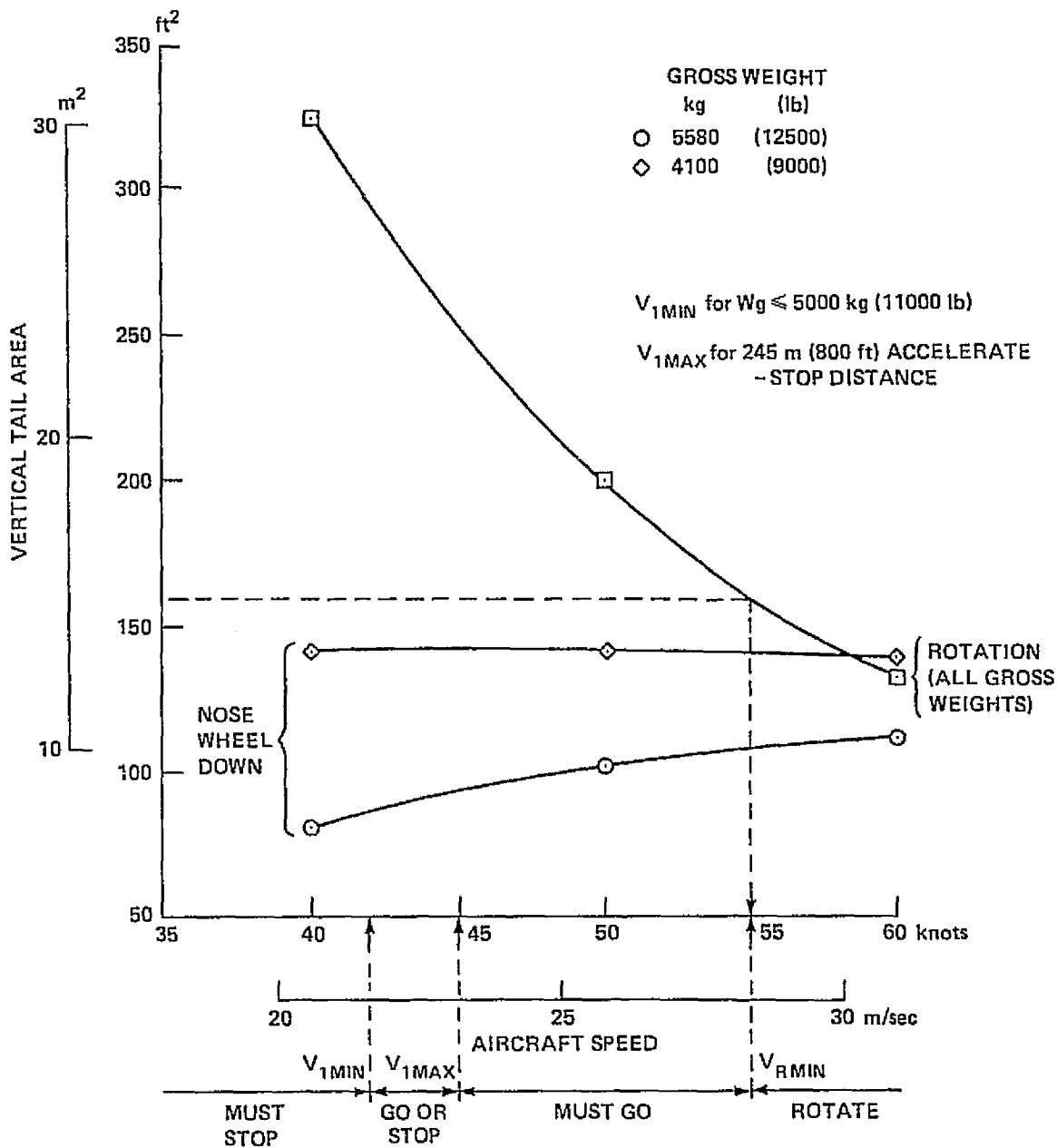


Figure 30 (a). The Impact of Nose Wheel Steering and Rotation Speed on Vertical Tail Requirements - PT6-27 Engines

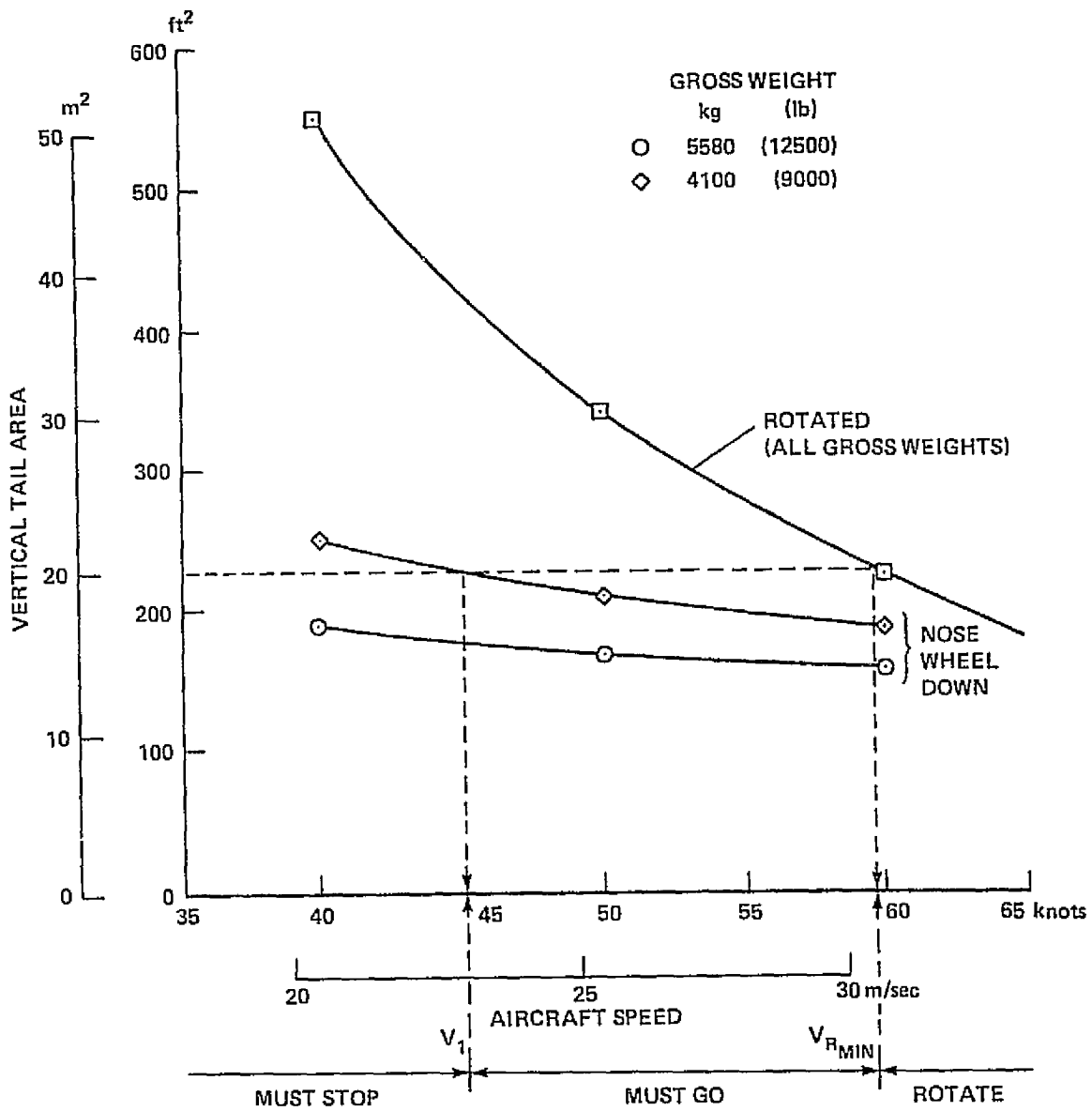


Figure 30 (b). The Impact of Nose Wheel Steering and Rotation Speed on Vertical Tail Requirements - Pt6-45 Engines

245mm (800 ft) FIELD LENGTH  
23m/sec (45 knots) ENGINE FAILURE SPEED

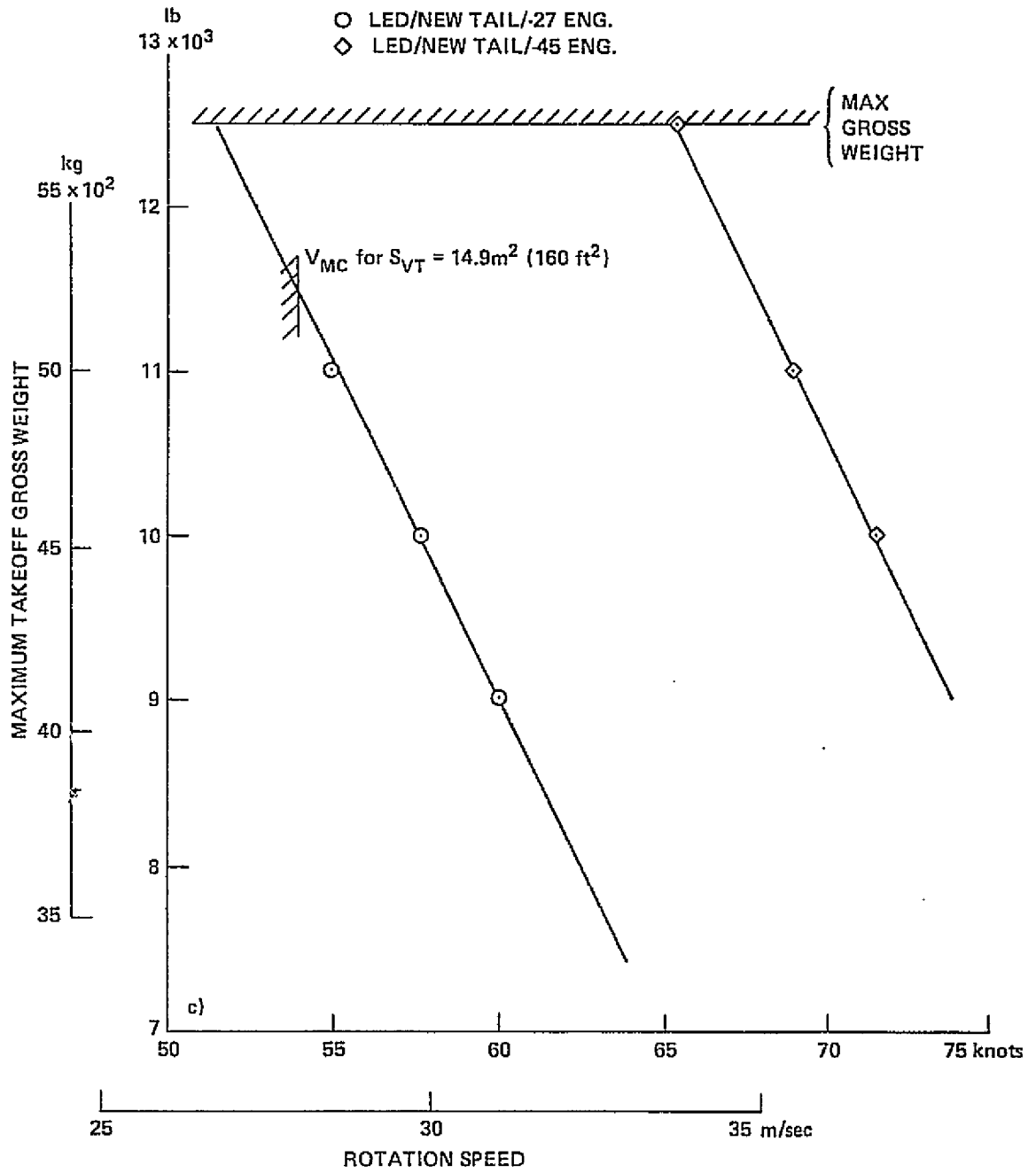


Figure 30 (c). Effect of Rotation Speed on Maximum Takeoff Gross Weight

For the -45 modified aircraft, the takeoff tail sizing criterion is shown in figure 30b. For a vertical tail area of  $215 \text{ ft}^2$ , determined by the minimum control speed requirement of  $1.3V_{\text{stall}}$  (59.5 knots), a minimum rotation speed of approximately 60 knots could be used. This would easily meet the 800 ft. takeoff field length rotation speed requirement (figure 30c). However, at 9,000 lbs. gross weight, the resulting engine failure/decision speed,  $V_1$ , (approximately 47.5 knots) would exceed the maximum  $V_1$  speed, 45 knots, for the 800 ft. accelerate-stop distance. Hence, an increase in vertical tail area to  $225 \text{ ft}^2$  is required. The associated rotation speed equal to the minimum control speed, would be approximately 59 knots.

In summary of this section, the new tail/spoiler/LED modification for the standard aircraft with the -27 engine would have a vertical tail area of  $160 \text{ ft}^2$ , sized by the takeoff rotation speed requirement. Corresponding to this tail area, the aircraft would have a minimum control speed of 54 knots. For the -45 modified aircraft, including spoilers and LED, the design vertical tail area would be  $225 \text{ ft}^2$ , sized by the engine-out takeoff decision speed for the 800 ft. field length requirement, and have a minimum control speed of around 59 knots. For the landing approach, both aircraft could be operated at air speeds less than 1.3 times the stalling speed and remain above the minimum control speed.

## Aircraft Balancing

With the large vertical tail modification, the aircraft must be rebalanced. It was specified that the wing should not be moved. Hence the same forward and aft C.G. limits for the standard DHC-6-300 were used (figure 31). To balance the new heavier tail, ballast was added in the nose cone baggage compartment (limited to 300 lbs.). The estimated vertical tail weight and required tail cone beef-up weight are shown in figure 32. Table III shows the added-on items for the complete aircraft modification - their weight and relative location from the aircraft reference point, and Table IV shows all the fixed items which are unchanged by the modification. The sum of the weights in these two tables is the gross weight of the Aircraft.

A maximum fuel load of 946 lbs. is to be carried in the forward fuselage belly tank. The required nose ballast weight was computed using the aft C.G. limit with the fuel tank empty, and then the forward C.G. location determined with the fuel tank full. The resulting nose ballast weight as a function of minimum control speed is depicted in figure 33. For the -27 equipped aircraft with a VMC of 54 knots, approximately 50 lbs. of nose ballast would be required. For the -45 engine aircraft with a VMC of 59.0 knots, no ballast would be needed. The heavier propulsion system for this option tends to offset the larger tail. Shown in figure 34 are the estimated minimum gross weights (with fuel) as a function of minimum control speed. For the -27 engine aircraft (with spoiler/LED/new tail), the gross weight (less payload) would be approximately 8,000 lbs. For the -45 engine modification (including spoiler/LED/new tail), a minimum gross weight would be approximately 8,850 lbs.

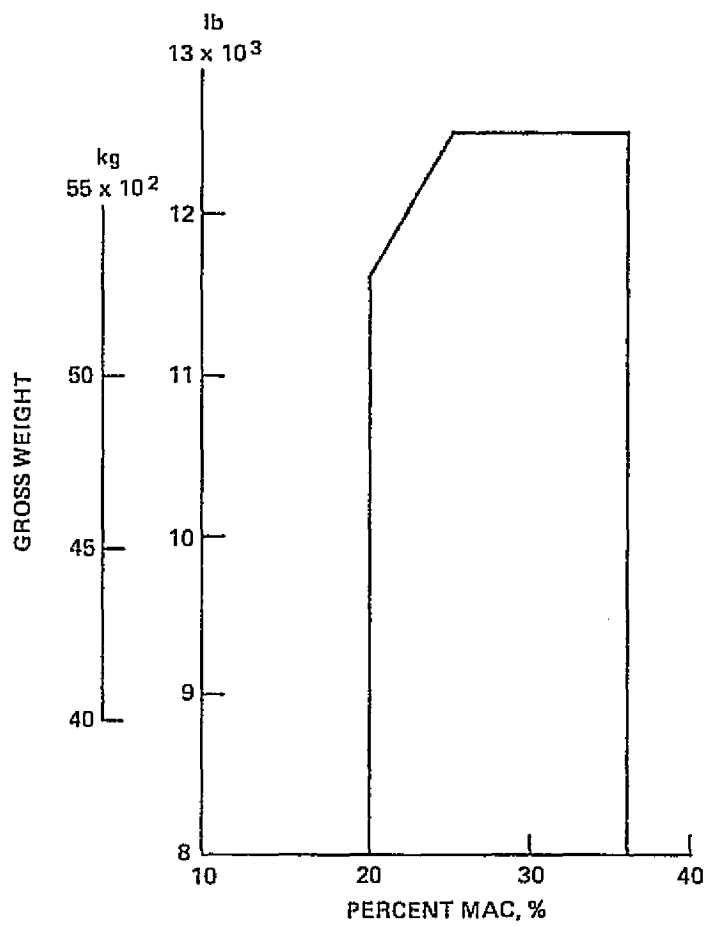


Figure 31. Forward and Aft Center of Gravity Limits

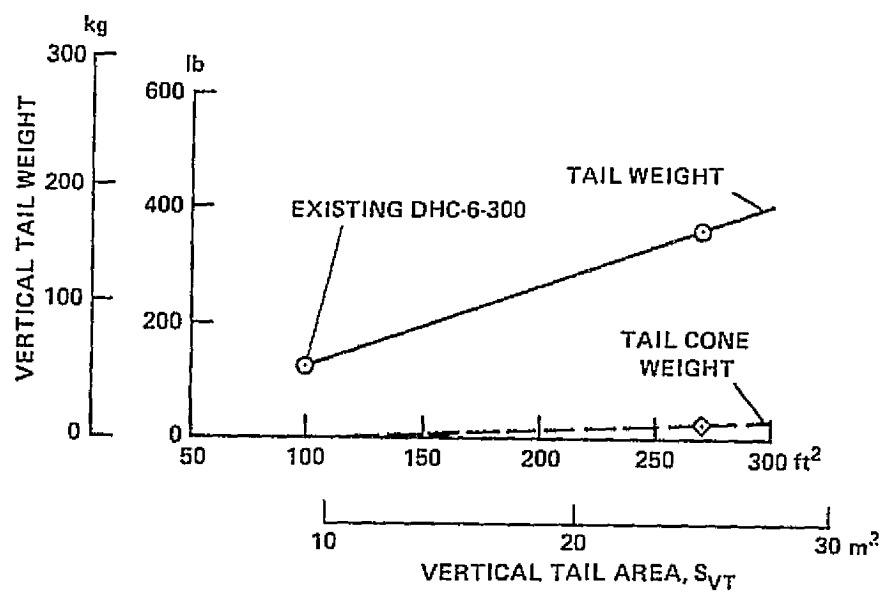


Figure 32. Vertical Tail Weight and Tail Cone Weight for the Modified Aircraft



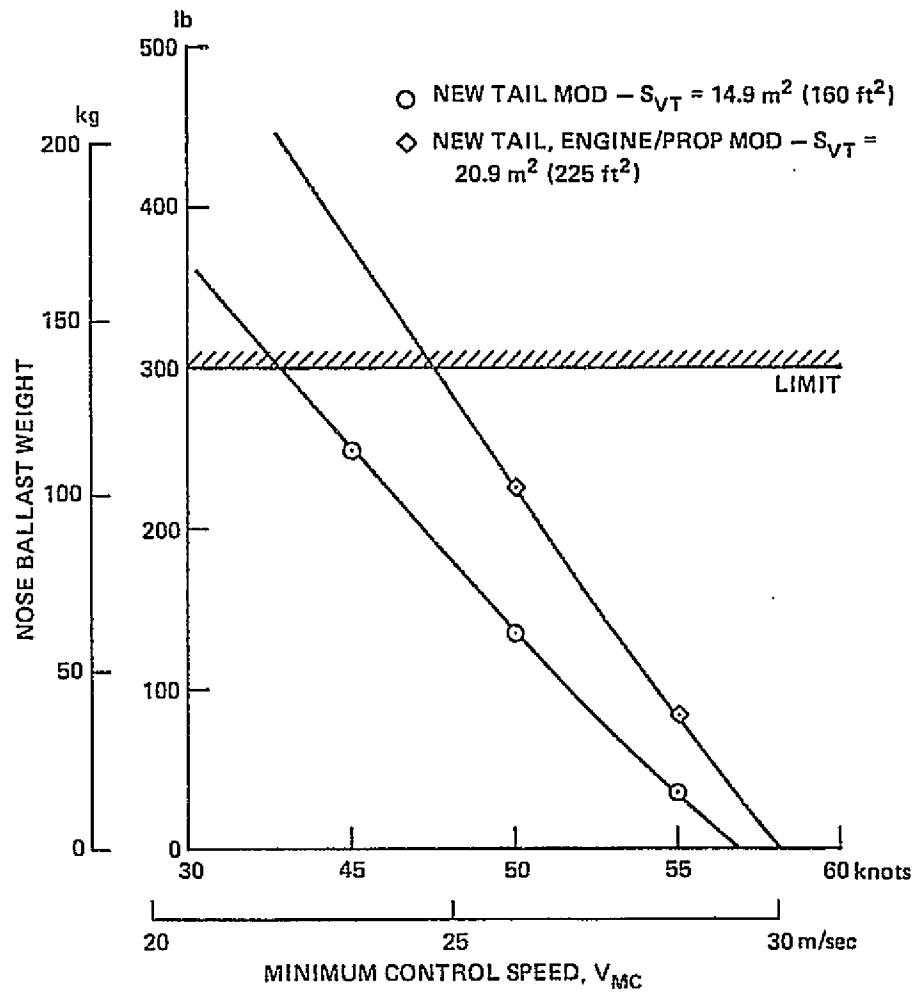


Figure 33. Nose Ballast Weight Requirements

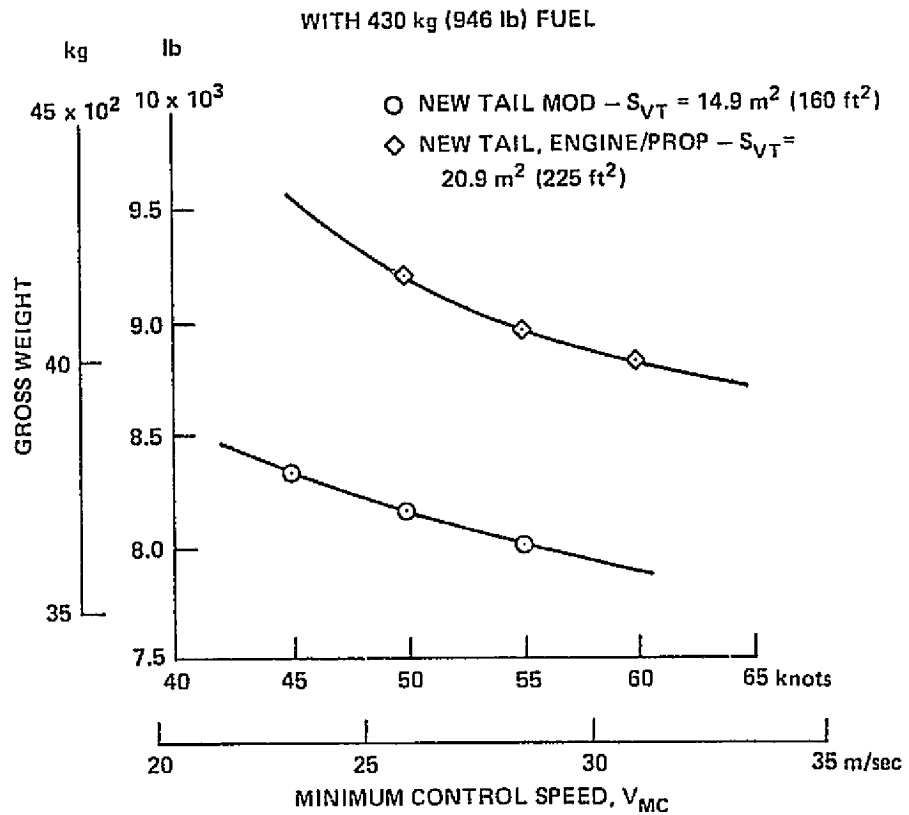


Figure 34. Effect of Minimum Control Speed on Minimum Gross Weight (empty weight plus fuel weight, but no payload)

TABLE III

## Added Items for DHC-6 Modification

| <u>Item</u>                 | <u>Increase In<br/>Weight - lbs.</u> | <u>Location<br/>from Nose - in.</u> |
|-----------------------------|--------------------------------------|-------------------------------------|
| New Tail                    | f(S <sub>VT</sub> ) (fig. 32)        | 548.5                               |
| Wing Structure              | 180                                  | 206                                 |
| Tail Cone Beef-up           | f(S <sub>VT</sub> ) (fig. 32)        | 576                                 |
| Nacelle Structure           | 85                                   | 171.8                               |
| PT6-6-45 Engines            | 465                                  | 154.6                               |
| New 5-Bladed Propellers     | 193                                  | 122.5                               |
| Ballast (in nose)           | ≤ 300                                | 25                                  |
| Fuel (in forward tank only) | 946                                  | 162.5                               |

Table IV

## Fixed Items for the DHC-6

| <u>Item</u>                       | <u>Weight - lbs.</u> | <u>Location from<br/>Nose - inches</u> |
|-----------------------------------|----------------------|--|
| Wing Structure<br>(including LED) | 1391.6               | 219.46                                 |
| Horizontal Tail St.               | 176.6                | 523.8                                  |
| Fuselage Structure                | 1667.8               | 223.3                                  |
| Landing Gear                      | 606.0                | 200.1                                  |
| Surface Controls                  | 143.7                | 187.2                                  |
| Instruments                       | 55.47                | 88.9                                   |
| Hydraulics                        | 43.26                | 103.42                                 |
| Electrics                         | 328.7                | 240.93                                 |
| Electronics                       | 14.17                | 63.6                                   |
| Furnishing<br>(minus seats)       | 511.67               | 208.65                                 |
| Heating & Vent.                   | 103.52               | 143.5                                  |
| Eng.                              | 16.99                | 167.7                                  |
| Ext. Primer                       | 14.20                | 216.71                                 |
| Trapped & Unusables               | 89                   | 183.2                                  |
| Pilot & Equipment                 | <u>200</u>           | 105                                    |
| Total                             | 5362.68              |  |

## Summary

The desired short field performance can be attained with the purely aerodynamic and structural modifications, including spoilers, leading edge devices and larger vertical tail. With these modifications, a gross weight of up to 11,000 lbs. can be attained, with a corresponding payload (not including fuel) of almost 3,500 lbs. For higher gross weights and steep takeoff climbout flight path angles, approaching those of V/STOL aircraft, the addition of the more powerful PT6A-45 engine must be made.

In all cases, the existing FAR design and operational requirements have been met in considering these modifications. It should be noted, however, that the type of leading edge device investigated in this study is operational with an existing aircraft. Based on this experience, it may be feasible to reduce both approach and touchdown speeds lower than allowable by the FAR's\* with no compromise in flight safety. This would have strong implications on the ground roll distance for the aircraft.

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\*Current FAR Part 23 or 25 require the approach speed at the 50 ft. screen height be 1.3 times stall speed and that touchdown speed be 1.1 times stall speed.

## A Modified DHC-6 as the Experimental Aircraft

### Noise Impact Tradeoffs

Structural and propulsion system modifications to the Twin Otter DHC-6 aircraft necessary to simulate the short field performance capabilities of a V/STOL aircraft have been presented, and two different modifications of the DHC-6 have been proposed. The first would modify the wing to install slats on the leading edge of the wing and to install ground spoilers as in the design of the DHC-6-300S. In addition, the empennage and fuselage tail cone would be modified to provide for the necessary increase in the vertical tail size. This modification will be designated as mod-A throughout this section. In the second modification, the wing would be modified as described above plus the engines would be changed to the PT6A-45 model having a 5 bladed Hartzell propeller. The change to the empennage and tail cone would be more extensive because of the larger required increase in the vertical tail size. This modification will be designated as mod-B.

In this section, determination of the noise characteristics of both modified Twin Otter aircraft will be presented, and they will be compared with the predicted community noise impact characteristics of the conceptual 20 passenger tilt rotor aircraft introduced in the section entitled, "Preliminary Noise Evaluation."

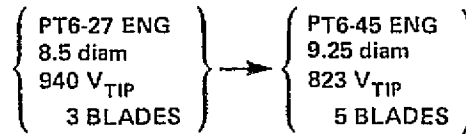
### Modified Aircraft Noise Calculations

The baseline noise data for the standard DHC-6-300 aircraft were obtained from Reference 8. The data consisted of effective perceived noise level (EPNL) as a function of the slant range distance for the takeoff and landing approach configuration. These curves were then adjusted to reflect changes in the propeller noise due to variations in absorbed power, propeller diameter, tip speed, and aircraft speed.

The changes in the propeller perceived noise levels (PNL) were computed using the Hamilton Standard propeller noise prediction methodology. Changes in propeller noise levels at takeoff power setting associated with the -45 engine bladed prop modification are presented in Figure 35. The increase in noise level with higher installed horsepower is offset by the reduction in blade loading with added blades and increased diameter. The lower tip speed of the PT6-45 modification produces the most significant reduction in the propeller noise. The net result is that the mod-B aircraft is approximately 5 PNdB quieter than the standard DHC-6-300.

Propeller noise was found to dominate all other noise sources for the aircraft. Even during the landing approach with reduced power settings and propeller RPM, the propeller noise was computed to be 15 to 30 dB higher than the engine core, gear box, or airframe noise levels. Hence, variations in the total aircraft noise level were solely determined by the corresponding change in the propeller noise. The total aircraft EPNL value is the sum of the maximum PNL value during the fly-by plus a tone correction factor and a duration correction factor. For the same observer distance and aircraft speed, the tone correction factor and the duration factor of the modified aircraft were assumed to be the same as that of the baseline DHC-6-300. As a result, a lowering of 1 dB in the PNL value produced a corresponding reduction of 1 dB in the EPNL value. Thus, the noise versus slant range curves of the modified aircraft were determined by vertically shifting the baseline noise curves the amount corresponding to the change in the propeller noise level.

The takeoff and approach power EPNL versus slant range curves are presented in Figure 36 for the baseline DHC-6-300 aircraft at maximum gross



| PARAMETER CHANGE | BLADE NUMBER          | PROPELLER DIAMETER    | TIP SPEED @         | HORSEPOWER | HELICAL MACH NUMBER | NET CHANGE |
|------------------|-----------------------|-----------------------|---------------------|------------|---------------------|------------|
|                  | @ CONSTANT HORSEPOWER | @ CONSTANT HORSEPOWER | CONSTANT HORSEPOWER |            |                     |            |

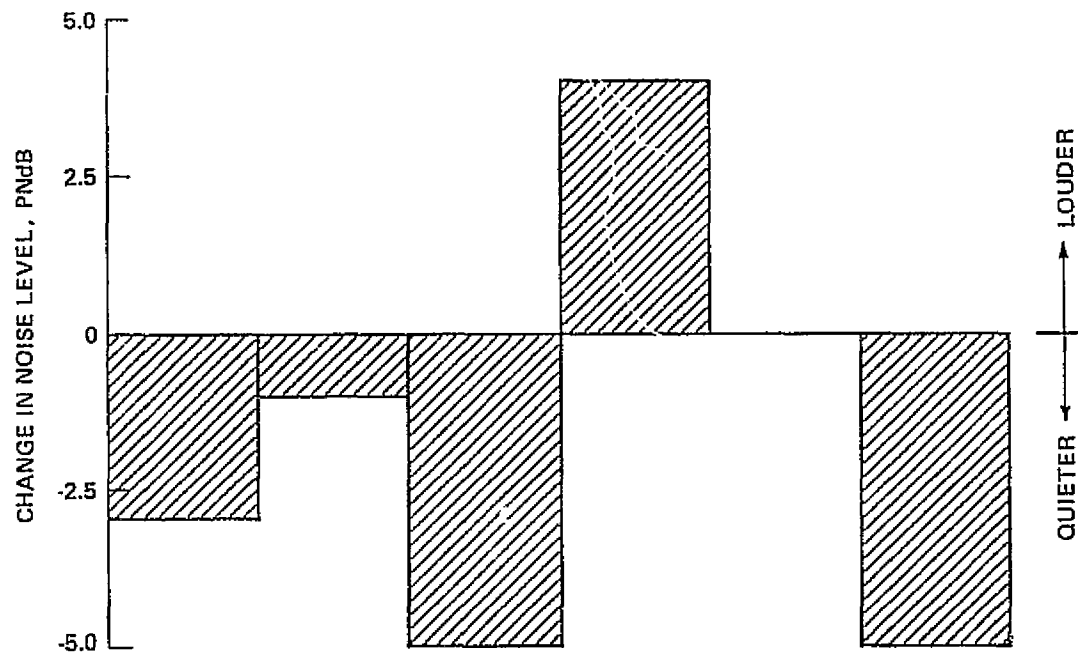


Figure 35. Effect of the Propulsion System Changes on Noise Level



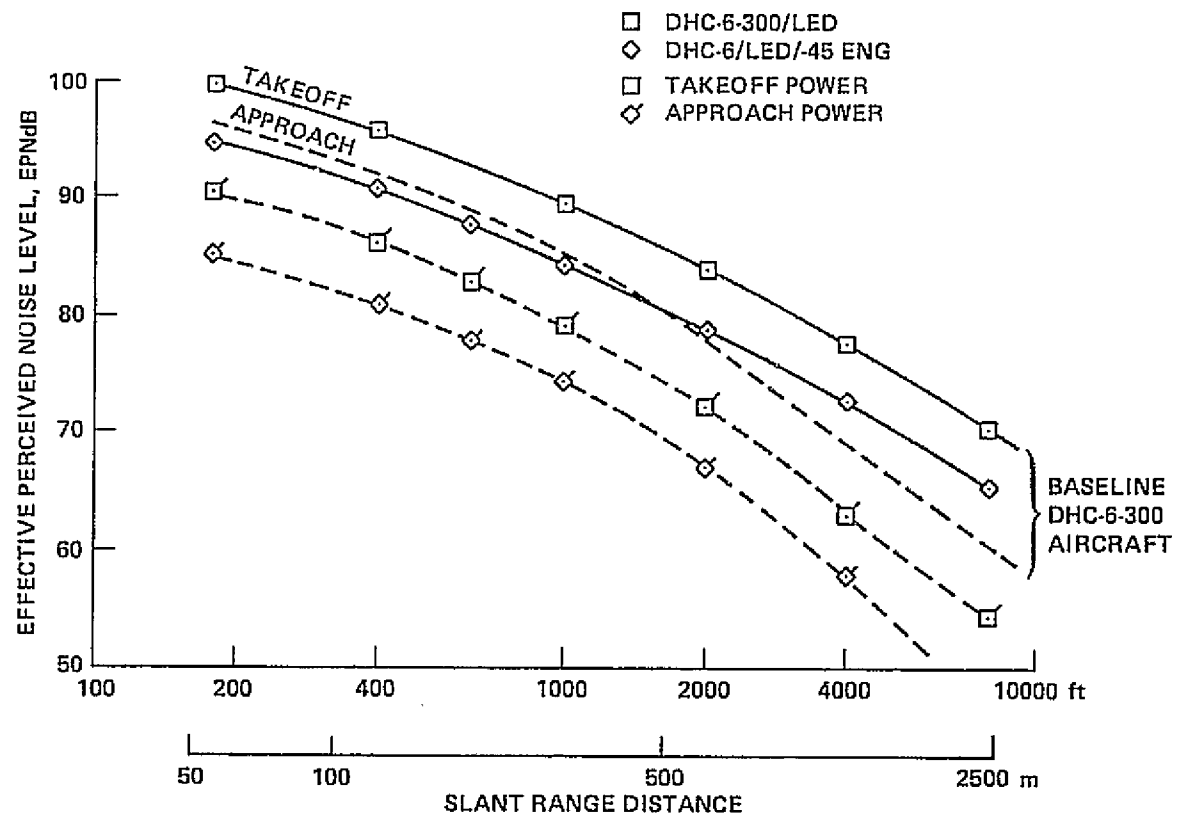


Figure 36. Noise vs. Slant Range for Takeoff and Approach Power Settings

weight and for the two modified versions: mod-A at 8000 lbs gross weight and the mod-B at 8700 lbs. gross weight. Because the mod-A aircraft employs the same engine/prop system as the baseline DHC-6-300, its takeoff power noise curve is identical to that of the baseline aircraft. However, the approach power noise curve is shifted vertically downward approximately 6 dB to reflect the lower power setting carried on the steeper approaches used by the modified aircraft operated in the STOL landing mode. The takeoff power noise curve for the mod-B aircraft is 5 dB below the baseline takeoff curve as discussed above. For the modified aircraft, the approach power noise curves shown were computed assuming 85 percent engine speed, which is somewhat lower than the percent speed used by the baseline aircraft on a standard 3 degree approach glide slope. The noise curves were also adjusted for flight speeds differing from the baseline values to account for changes in the duration factor.

#### Flight Profiles

Presented in Table V are the takeoff and landing profiles for various aircraft used in the single event noise analysis. For the standard DHC-6-300, the STOL mode operational profiles at maximum gross weight of 12,500 lbs. were used. For the tilt rotor aircraft, the STOL mode procedures presented in Reference 9 were used. Estimated gross weight for the 20 passenger configuration tilt rotor is 28,288 lbs.

The takeoff profiles for the modified Twin Otter aircraft were computed using "ultra STOL" flight procedures. The aircraft was rotated at 10 degrees fuselage angle per second upon reaching the stall speed (a function of the takeoff gross weight) or the minimum control speed  $V_{MC}$ , whichever was greater.

TABLE V

## TAKEOFF AND LANDING FLIGHT PROFILES

| Aircraft<br>(Gross Weight)                           | Maneuver | Segment<br>Length<br>(Feet) | Flight Path<br>Angle<br>(Degree) | Tip<br>Speed<br>(Fps) | Average<br>Velocity<br>(Knots) |  |
|--|----------|-----------------------------|----------------------------------|-----------------------|--------------------------------|--|
| Standard DHC-6-300<br>STOL Mode<br>(12,500 lbs.)     | Takeoff  | 800                         | 0.0                              | 940                   | 70                             |  |
|  |          | 4,000                       | 5.70                             | 940                   | 70                             |  |
|  |          | 100,000                     | 9.60                             | 940                   | 90                             |  |
|  | Landing  | 500                         | 0.0                              | 845                   | 40                             |  |
|  |          | 100,000                     | 5.40                             | 845                   | 65                             |  |
|  |          |                             |                                  |                       |                                |  |
| Tilt Rotor<br>20 Passenger<br>(28,288 lbs.)          | Takeoff  | 300                         | 0.0                              | 700                   | 40                             |  |
|  |          | 100,000                     | 28.0                             | 700                   | 40                             |  |
|  | Landing  | 100                         | 0.0                              | 700                   | 25                             |  |
|  |          | 2,200                       | 25.0                             | 700                   | 25                             |  |
|  |          | 100,000                     | 14.0                             | 700                   | 40                             |  |
|  |          |                             |                                  |                       |                                |  |
| DHC-6-300/LED/New Tail<br>(8000 lbs.)                | Takeoff  | 301                         | 0.0                              | 940                   | 54                             |  |
|  |          | 284                         | 13.4                             | 940                   | 59                             |  |
|  |          | 1,489                       | 20.5                             | 940                   | 59.2                           |  |
|  |          | 100,000                     | 20.8                             | 940                   | 59.5                           |  |
|  | Landing  | 290                         | 0.0                              | 800                   | 37                             |  |
|  |          | 100,000                     | 6.0                              | 800                   | 57                             |  |
|  |          |                             |                                  |                       |                                |  |
|  |          |                             |                                  |                       |                                |  |
| DHC-6-300/LED/New Tail/<br>-45 engine<br>(8700 lbs.) | Takeoff  | 263                         | 0.0                              | 823                   | 63                             |  |
|  |          | 271                         | 14.6                             | 823                   | 73                             |  |
|  |          | 100,000                     | 33.7                             | 823                   | 73                             |  |
|  | Landing  | 270                         | 0.0                              | 700                   | 39                             |  |
|  |          | 100,000                     | 5.7                              | 700                   | 60                             |  |
|  |          |                             |                                  |                       |                                |  |

Incremental load factors as high as 1.0 were permitted. For the mod-A aircraft, the flaps were retracted from a takeoff value of 20° to a 10° degree setting, corresponding to best climb gradient configuration. For the mod-B aircraft, takeoff and climbout were executed with constant 10° flaps deflection. The aircraft performed the climbout portion of the takeoff at the best gradient climb speed (approximately  $V_{STALL} + 10$  knots). Fuselage attitude angles greater than 30 degrees were allowed during the climbout.

The landing flight profiles for the modified aircraft were computed using the Twin Otter STOL mode approach procedures. Flap setting for the approach is 37.5 degrees. A constant rate of sink, 600 fpm, is maintained at 130 percent of the aircraft stalling speed (a function of gross weight) or at minimum control speed, whichever is greater. During the approach, engine speed is held at 85 percent design speed. At this engine rpm, approximately one second is required to spool the engine up to maximum speed, providing adequate response time for an emergency go-around. At 50 ft. altitude, the engine power setting is reduced to idle and the aircraft flared to a touchdown at 110 percent of the stall speed.

#### Single Event Noise Levels

Presented in Figure 37 are the takeoff noise levels as a function of gross weight for the DHC-6-300 and the modified aircraft. The estimated takeoff noise of the 20 passenger tilt rotor at its maximum gross weight is also shown. Observer location for the takeoff noise calculation was 1.0 n.m. from the end of the runway and directly under the flight path. The trend of higher noise levels at higher gross weights is due to the longer ground roll distance and shallower flight path angle of the heavier aircraft. The mod-A aircraft is somewhat quieter than the baseline, due to its slightly higher altitude

MEASURED AT 1852 m (1.0 n. mi.) FROM END OF RUNWAY  
UNDER TAKEOFF FLIGHT PATH

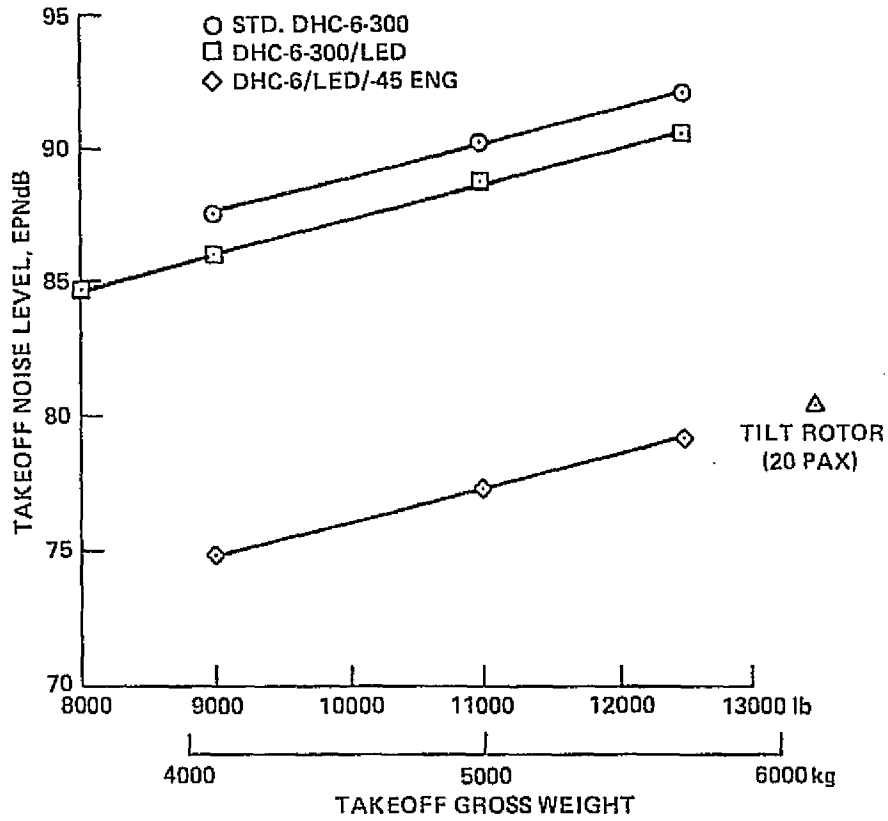


Figure 37. Effect of Gross Weight on Takeoff Noise Levels

(approximately 300 ft.) during flyover of the observer. This difference in altitude is a result of the lower lift off speed (hence, shorter ground roll distance) and steeper initial climb angle resulting from the higher transition load factors permitted for the modified aircraft. The mod-B aircraft noise level is significantly below that of the baseline, due to its lower inherent noise level (lower tipspeed) and better takeoff and climb performance. At maximum gross weight, the takeoff noise level of the mod-B aircraft is comparable to that of the tilt rotor aircraft.

Approach noise levels as a function of gross weight are shown in Figure 38 for both modified Twin Otter aircraft. Also presented is the approach noise level for the tilt rotor aircraft at maximum gross weight. The observer was located under the approach flight path 1.0 n.m. from the end of the runway. The general trend is for increasing approach noise levels with increasing gross weight. With the approach rate of sink fixed at 600 fpm, and the approach speed a function of the aircraft gross weight ( $V_{APP} = 1.3 V_{STALL}$ ), the approach flight path angle decreases with gross weight. Hence, the heavier aircraft are lower over the observation point and carry higher power settings. The mod-A aircraft is somewhat quieter than the standard DHC-6 due to its lower tipspeed on approach and slightly steeper approach angles. The mod-B aircraft fly the same approach angle as the mod-A aircraft, but produce less noise due to the lower tipspeed used on approach. At the approach observer location, the mod-B aircraft at maximum gross weight has a comparable noise level to that of the tilt rotor.

The maximum takeoff sideline noise levels are presented in Figure 39 as a function of aircraft gross weight. The noise levels, measured at 500 ft. sideline distance, are generally independent of gross weight and

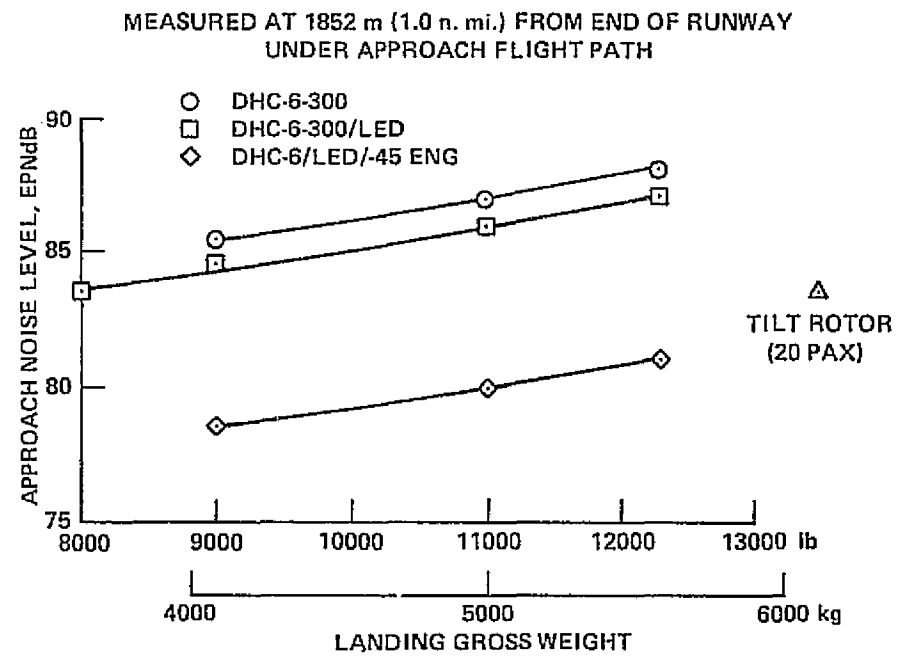


Figure 38. Effect of Gross Weight on Landing Noise Levels

MEASURED AT 15.2 m (500ft) SIDELINE ON TAKEOFF

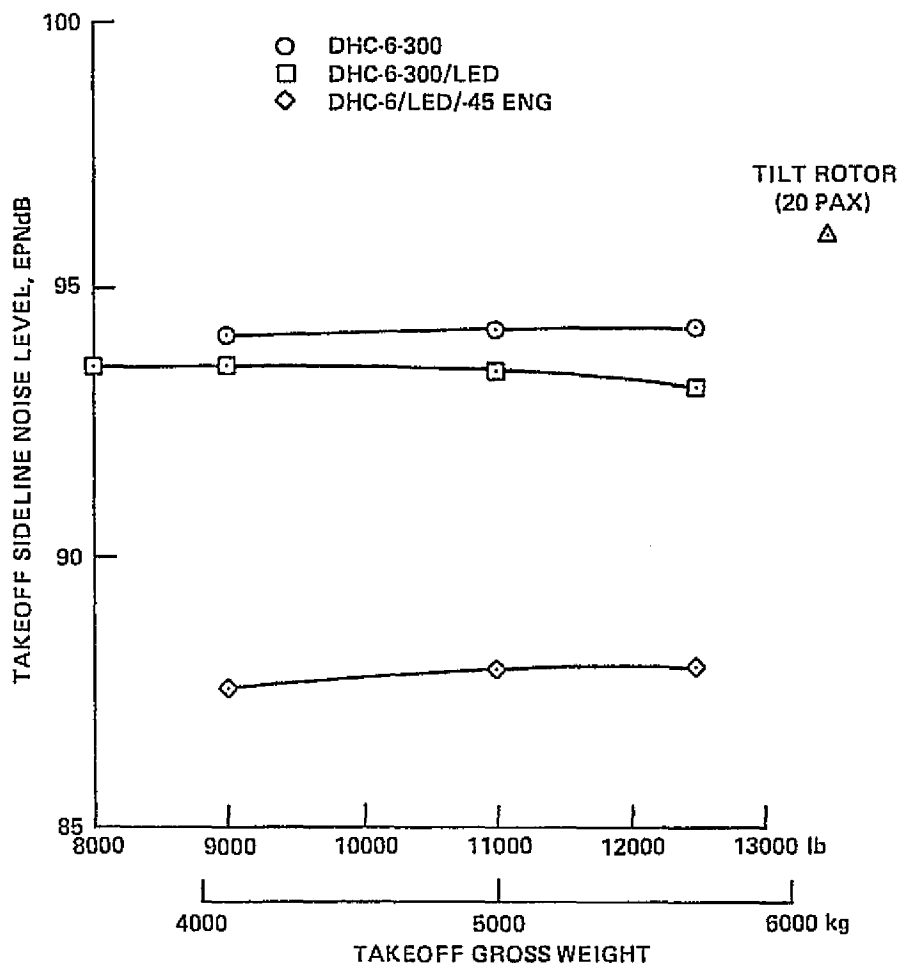


Figure 39. Effect of Gross Weight on Sideline Noise Levels



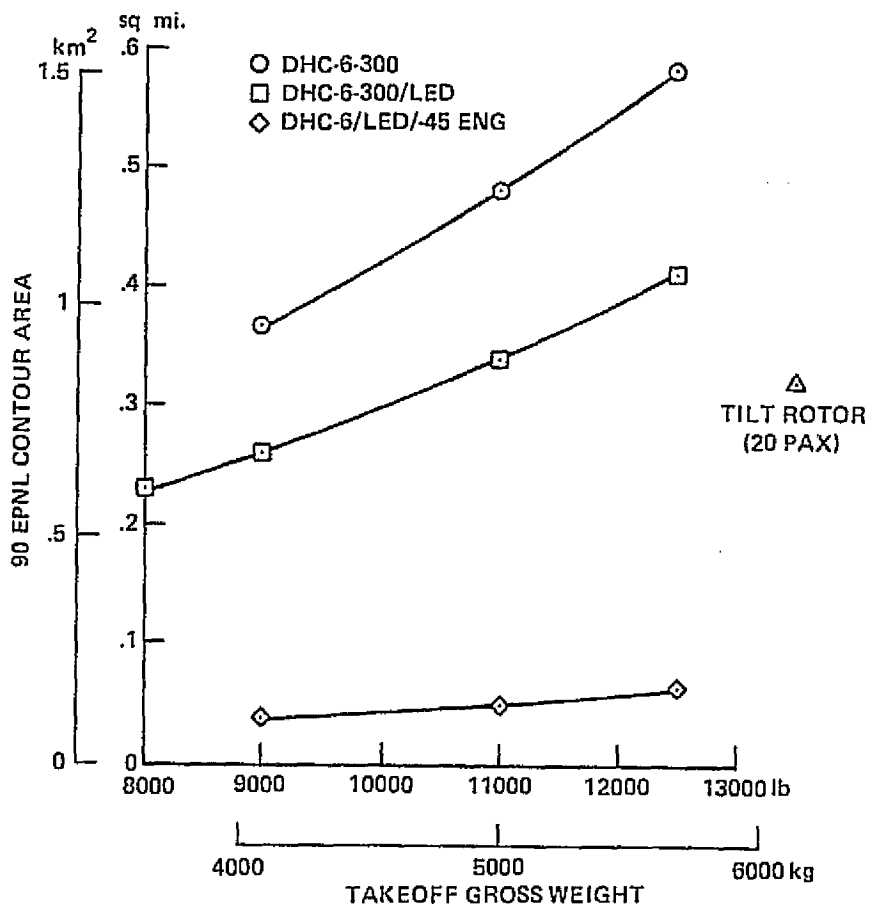


Figure 40. Effect of Gross Weight on the 90 EPNL Noise Contour Area

follow the relative trends exhibited by the takeoff flyover noise levels. All of the aircraft have sideline noise levels less than that of the tilt rotor.

The 90 EPNL noise contour area is plotted in Figure 40 as a function of gross weight. As the gross weight increases, the contour area grows due mainly to the smaller takeoff and landing flight path angles associated with the heavier aircraft. The relative ranking of contour area for the various aircraft is a reflection of the takeoff, sideline and approach noise levels discussed above.

The outlines of the 80 EPNL contours are shown in Figure 41 for the standard Twin Otter and 20 passenger tilt rotor at maximum gross weights, and the modified aircraft at their experimental gross weights. The mod-A contour has a similar lateral dimension to that of the baseline DHC-6-300 contour, but a much shorter length, due to the steeper climb angles of the modified aircraft. The mod-B contour is again smaller due to even lower noise levels. The general proportions of the takeoff portion of the noise contour is similar for the mod-B and the tilt rotor aircraft. However, the landing part of the contours is markedly different due to the steeper angles and higher power settings employed by the tilt rotor on approach.

#### Community Noise Impact

To assess the noise impact upon a community by aircraft operations, the accumulative daily exposure level measured by the Noise Exposure Forecast (NEF) is determined. The NEF level is computed using the single event noise level (EPNL) combined with the number and time of day of the aircraft operations. As the number of operations is increased, the NEF value increases

80 EPNL CONTOUR

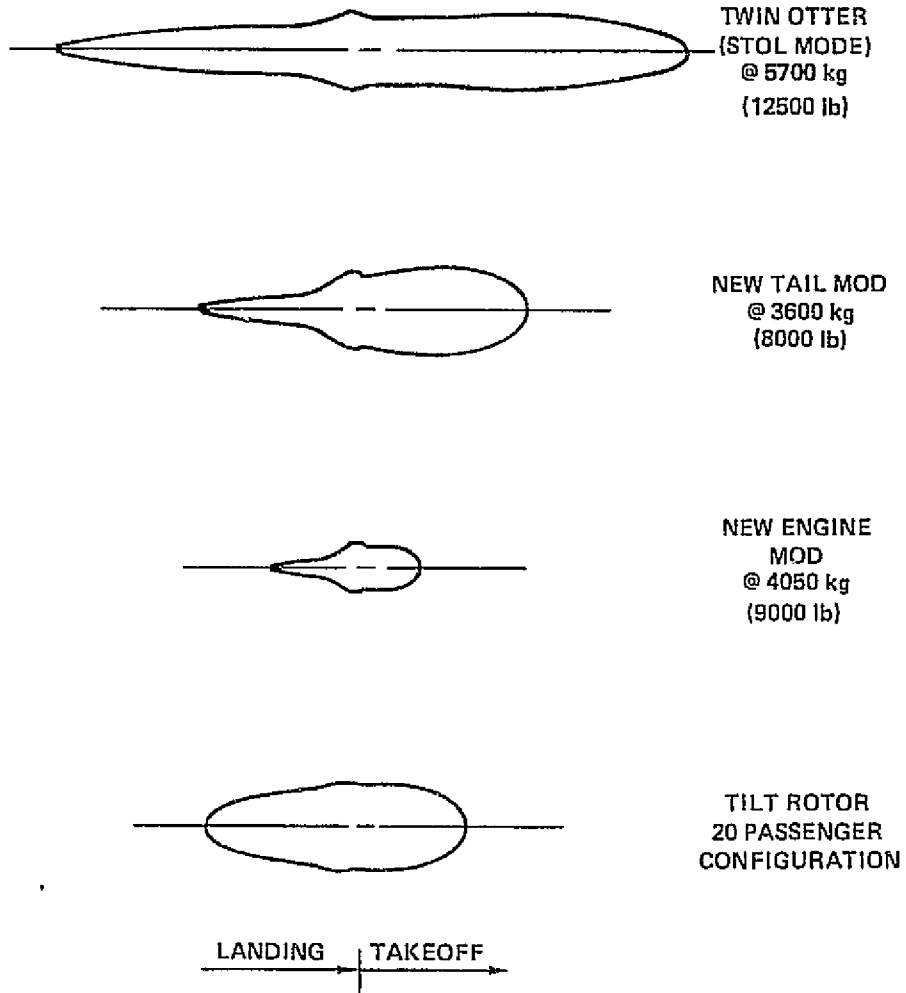


Figure 41. Relative Noise Contour Sizes and Shapes

logarithmically. Community reaction, measured in percent highly annoyed (PHA), is then modeled using the NEF vs. PHA algorithm of Reference 12. This model indicates no community annoyance below a 15 NEF level. As the NEF level is raised, the PHA value increases. At a 40 NEF level, approximately 50 percent of the exposed population is highly annoyed. The distribution of NEF levels is combined with the census tract data for each particular site and the total population exposed and number highly annoyed computed.

Presented in Figures 42 through 45 are potential community noise impact measures for four proposed urban STOL port sites. The area of the 15 NEF (annoyance cutoff contour), total population exposed and the percent highly annoyed is computed as a function of the number of operations of the modified DHC-6 aircraft. As the number of operations is increased, all the noise impact parameters increase. The aircraft were operated in the "ultra STOL" mode for takeoff and landing at each site. For all of the sites, the mod-B aircraft has no community impact, in terms of population exposed or PHA, below a certain number of operations. Also, shown are the predicted noise impacts of the 20 passenger tilt rotor aircraft operating at the proposed site. The number of tilt rotor operations at each site corresponded to the number of required operations determined by the travel-demand analysis given in the earlier section entitled, "Preliminary Noise Evaluation." Note that even though the 15 NEF "cutoff" contour area is the same for a given number of operations, the number of people exposed and percent highly annoyed varies markedly from site to site. This results from the particular population distribution around each individual site.

The community impact of the tilt rotor at each site can be easily simulated by the mod-A aircraft flying a moderate number of daily operations.

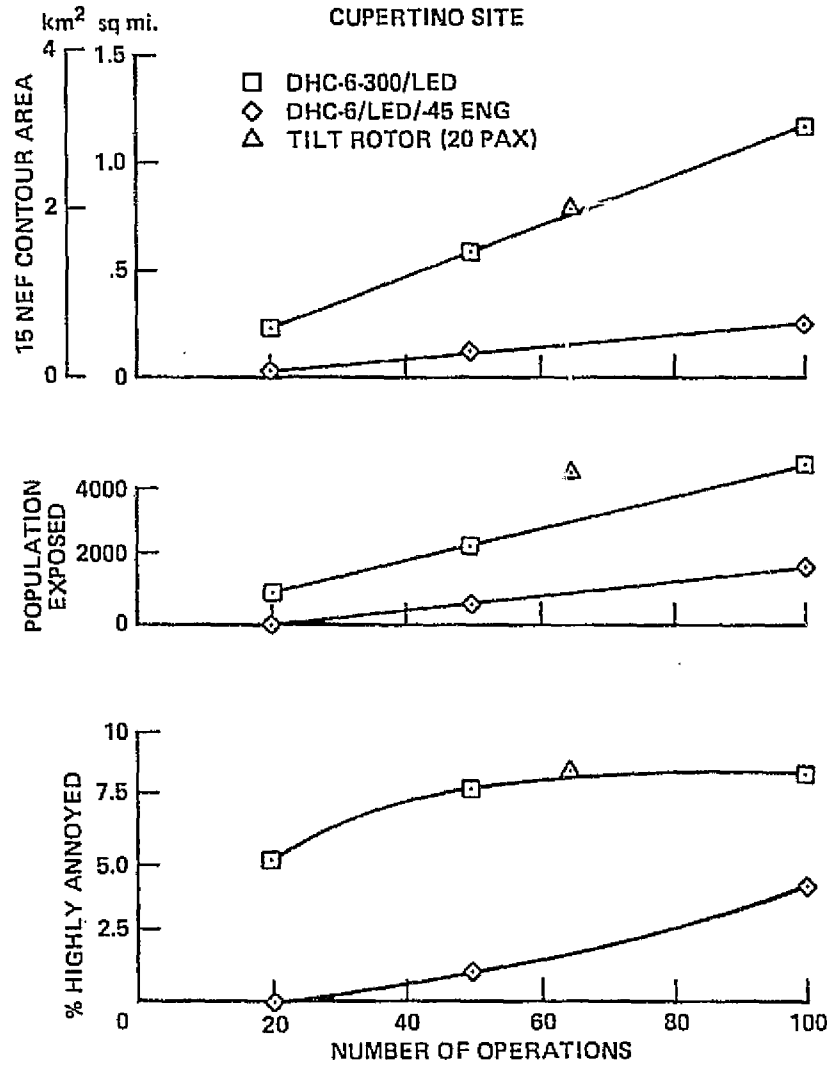


Figure 42. Impact of Increased Operations on Noise - Cupertino Experimental Port Site

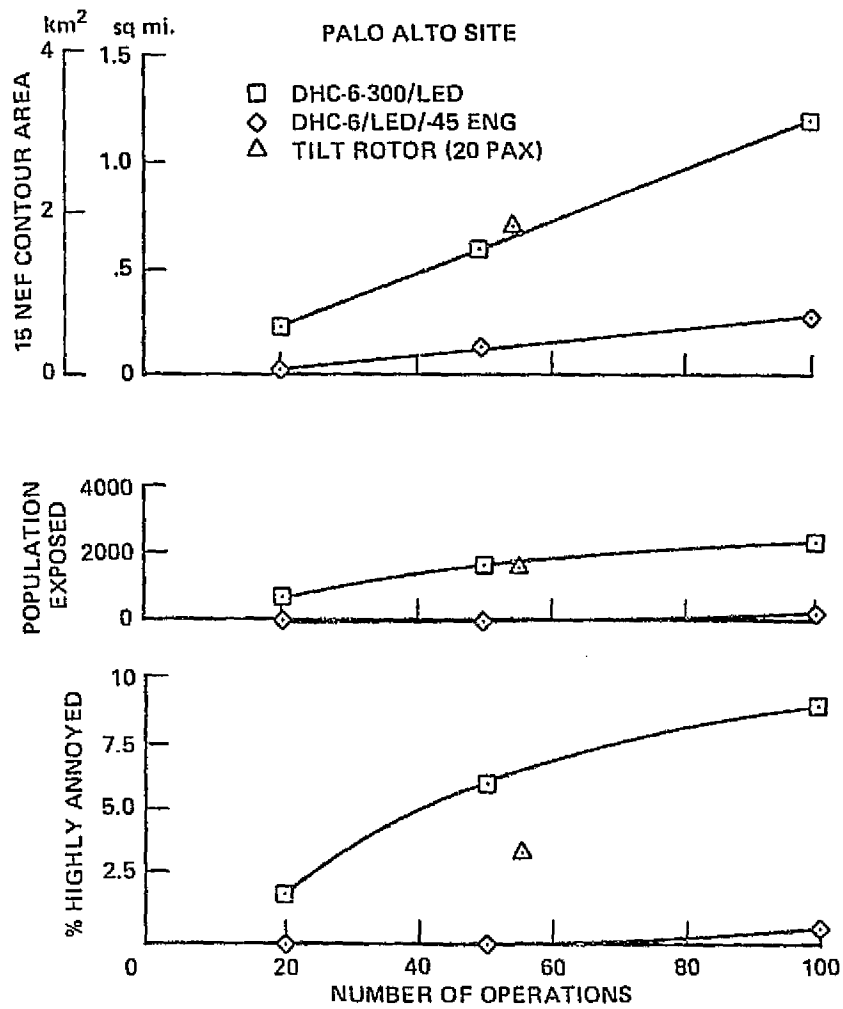


Figure 43. Impact of Increased Operations on Noise - Palo Alto Experimental Port Site

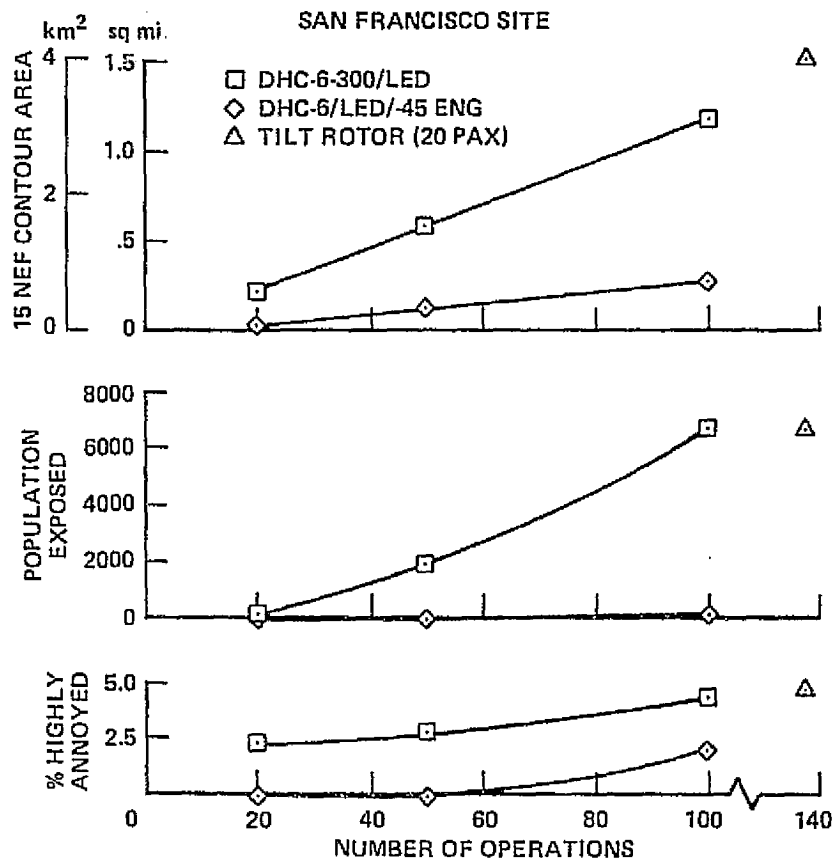


Figure 44. Impact of Increased Operations on Noise - San Francisco Experimental Port Site

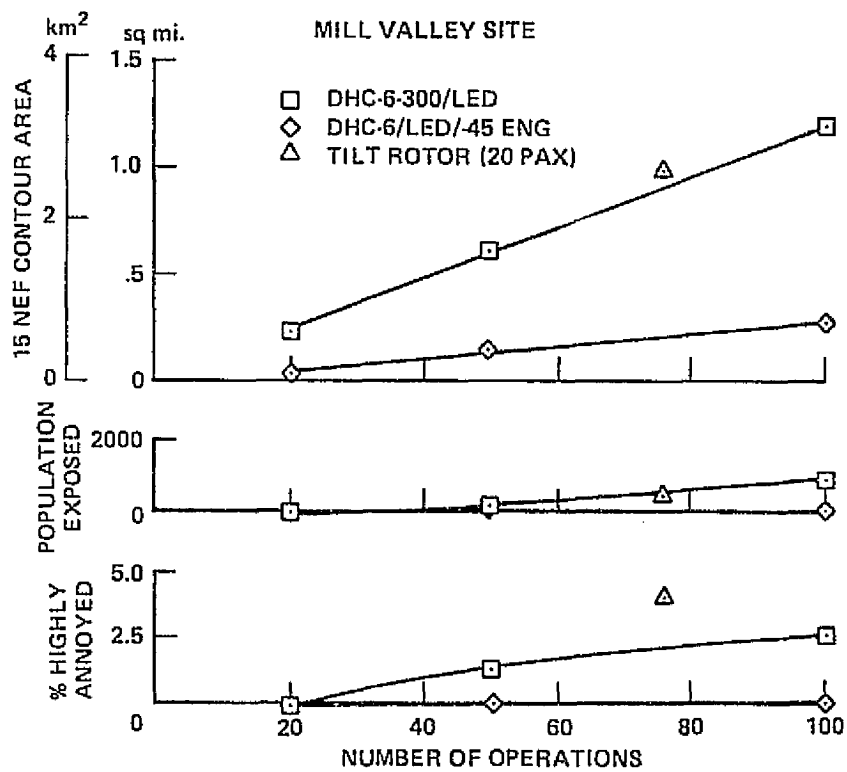
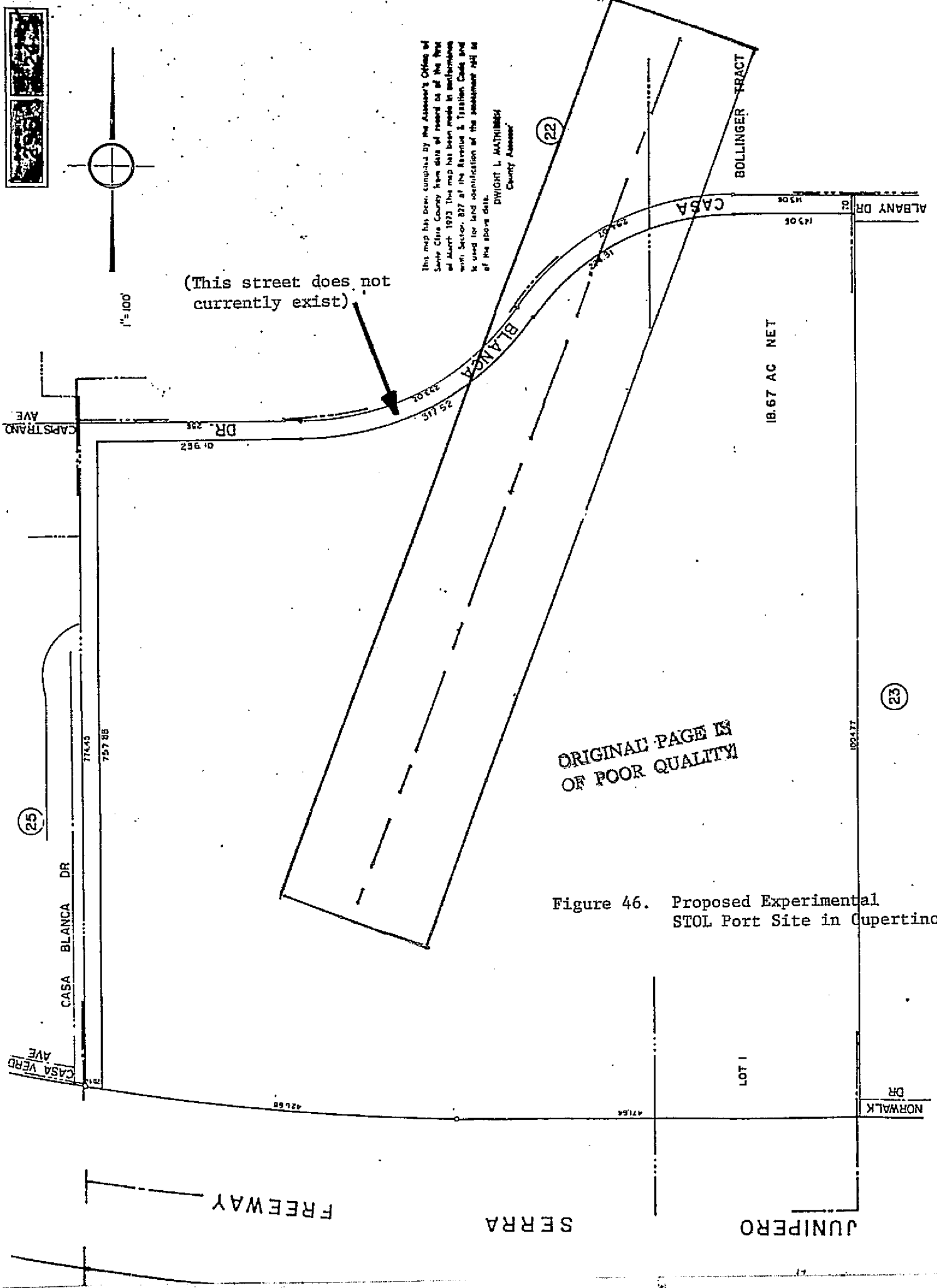


Figure 45. Impact of Increased Operations on Noise - Mill Valley Experimental Port Site





This map has been compiled by the Assessor's Office of Santa Clara County from data of record as of the first of August, 1973. This map has been made in accordance with Section 827 of the Revenue & Taxation Code and is used for land identification of the assessment roll as of the above date.

DWIGHT L. MATTHEWS  
County Assessor

(This street does not currently exist)

ORIGINAL PAGE IS  
OF POOR QUALITY

Figure 46. Proposed Experimental STOL Port Site in Cupertino

For the mod-B aircraft, a large number of daily operations would be required to produce an equivalent community noise impact to that of the tilt rotor. Only at the Cupertino site can the mod-B aircraft produce significant noise impact in terms of population exposed and PHA with a moderate number of daily operations.

For the proposed STOL port site in Cupertino (Figure 46), a more detailed analysis was conducted to investigate the possible extent of community noise impact obtainable with the modified aircraft. The Cupertino site is located in a high density residential area, with both single unit family dwellings and apartment houses. The proposed site is also adjacent to a major highway, implying a relatively high ambient background noise level. The number of aircraft operations was held constant (65 operations, corresponding to the project number of tilt rotor operations). Various flight operational procedures were then studied and their effect on the community noise impact evaluated.

To produce the highest noise impact, both modified Twin Otter aircraft were operated in a CTOL takeoff and landing mode at maximum gross weight. Takeoff and climbout profiles were constrained by rotation speed, load factor and fuselage attitude angle limitations. For approach, the aircraft were constrained to fly a standard three degree flight path angle.

The second flight procedure considered corresponded to the ultra-STOL profiles used in the previous community noise impact analysis. The aircraft were flown at maximum climb gradient speed, and used a 600 fpm rate of sink on approach. Both aircraft were operated at their experimental gross weights.

The third procedural option consisted of flying the aircraft on a noise

abatement takeoff profile. The takeoff profile was optimized to produce the minimum 80 EPNL contour area using a power cutback procedure and optimized climb speed. The power setting is cutback to approximately 85 percent engine rpm upon attainment of 400 ft. altitude -- corresponding to flap retraction altitude. This power reduction produces a lower climbout flight path angle, but also gives a substantial reduction in propeller noise (7 PNdB for the mod-A aircraft and 6.5 PNdB for the mod-B aircraft). The optimized climb speed was approximately 16 knots higher than the best gradient climb speed for the mod-A aircraft, and 10 knots higher for the mod-B aircraft. The higher climb speed resulted in a lower climb angle (but higher rate of climb), but a reduction on the EPNL level due to a smaller duration correction factor. The combination of power cutback and higher aircraft climb speed produced roughly a 50 percent reduction in climbout flight path angle, but resulted in significant noise level reduction. As in the ultra-STOL takeoff profile, the flap setting was optimized to produce best climb performance. Both aircraft were operated at their associated experimental gross weights. For the landing approach, the 600 fpm approach at  $1.3 V_{STALL}$  profile was used.

The final noise impact option consisted of tailoring the ground tracks of the takeoff and approach procedures to avoid high concentrations of people. The takeoff procedure adopted consisted of a straight out departure to the northwest along Highway I-280 combined with the power cutback profile. Rather than a straight-in approach, a curved flight track was used. The aircraft approached from the northwest along Saratoga Avenue, and turned to a final approach flight track over Highway I-280. Again, both aircraft were operated at their corresponding experimental gross weights.

Presented in Figure 47 are the noise impact levels for the various operational procedures at the proposed Cupertino site. The area of the 15 NEF contour, total population exposed and percent highly annoyed are shown for both modified Twin Otter aircraft. The impact levels of the mod-B aircraft are lower than that of the mod-A aircraft, reflecting the lower single event noise characteristics of the re-engined aircraft. There is a marked reduction in contour area for both aircraft in going from the CTOL operation to the curved flight track options. However, the reduction in population exposed is not as substantial for the mod-A aircraft. For the mod-B aircraft, a significant reduction in population exposed can be achieved with the optimum and curved flight path options. With the highest concentration of people living under the takeoff flight path, the curved approach flight track did not produce significant reduction in people exposed. The results obtained for percent highly annoyed can be attributed to the particular population distribution around the Cupertino site. Only the 15 NEF contour area trends with the various options can be applied in general to the other sites. Population exposed and percent highly annoyed trends will vary at each site, depending on the particular population distribution around that site.

#### Summary

The general noise impact characteristics of the tilt rotor aircraft can be simulated with the LED/New Tail modified DHC-6-300 aircraft (mod-A) using a comparable number of projected operations. However, the lateral noise distribution (reflected in noise contour shape) and the aircraft/community proximity relationship (reflected in flight path characteristics) of the tilt rotor can be more closely reproduced using the re-engined PT6-45 modified aircraft (mod-B). With the similarity in shape between the tilt rotor

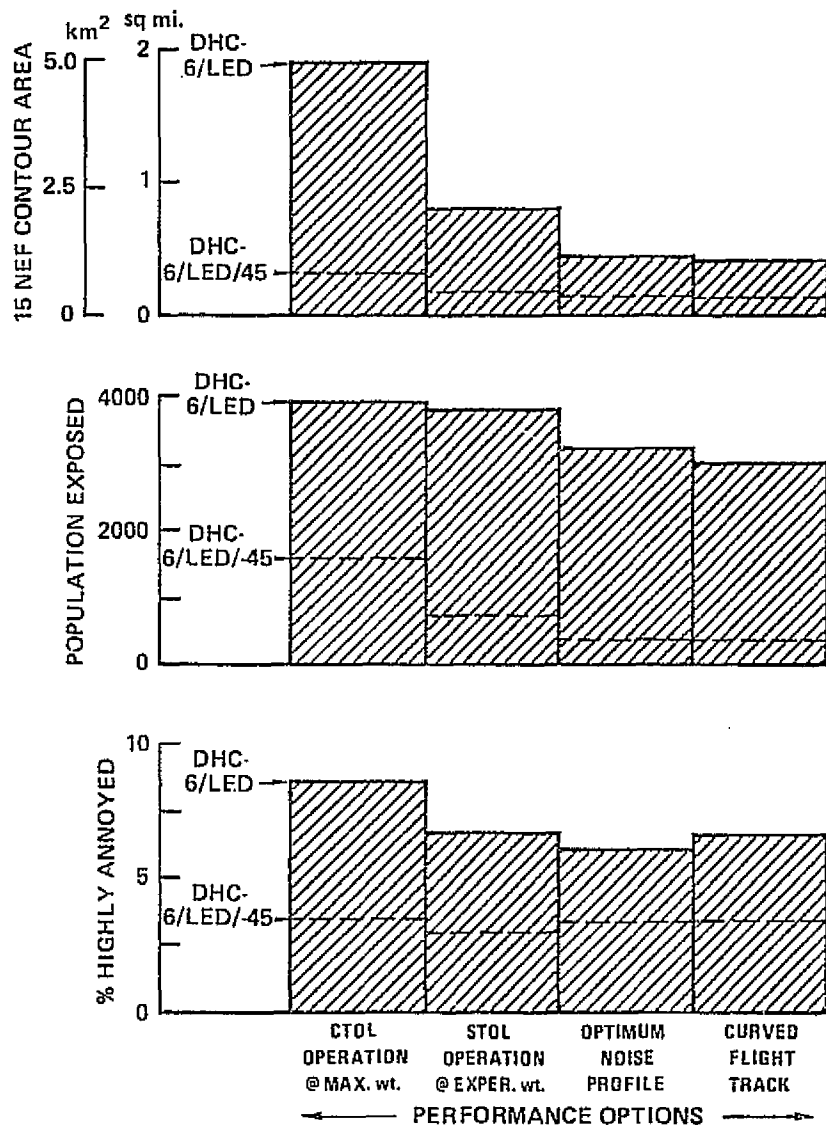


Figure 47. Effect of Modified Operational Procedures on Noise in the Cupertino Port Site Community

and mod-B single event contour (at least on takeoff), the mod-B NEF contour can be "blown up" to the same general dimension as that of the tilt rotor by using more flight operations of the mod-B aircraft. By using approximately four mod-B aircraft flights for every one projected tilt rotor flight, the community noise impact characteristics of the tilt rotor aircraft can be closely approximated.

## A Modified DHC-6 as the Experimental Aircraft

### Modification Costs

A detailed estimate of prospective modification costs for the DHC-6-300 was conducted for both proposed modifications. Recall that mod-A would install leading edge slats and ground spoilers in the wing and increase the size of the vertical tail which would also require a beef-up of the fuselage tail cone. Mod-B would change the engines to the PT6-45 model and have new 5-bladed Hartzell propellers as well as provide for the mod-A changes, but with an even larger vertical tail. The elements of the aircraft considered for either or both of these modifications are listed in Table VI along with the necessary flight tests.

Engineering and manufacturing hours and the need for purchased parts and services were estimated for each element. Both hours and costs are summarized in Tables VII and VIII for mod-A and mod-B respectively. Total costs to modify the aircraft, which include \$400,000 for the purchase of a production DHC-6-300 aircraft, total \$1,011,392 for mod-A and \$1,511,797 for mod-B. The difference reflects the purchase price of the new engines and propellers along with the design modifications to the nacelles needed for mod-B.

This latter cost can be compared directly with the preliminary budget estimates shown earlier. In Table II, the aircraft modification costs for the DHC-6 was estimated to be \$1,108,000 for a modified aircraft with engines purchased adding \$400,000 for the purchase of the basic aircraft increases the total to \$1,508,000 which compares remarkably well with the estimate of \$1,511,797 given here.

Using the data from Table II for port site and operating costs, total program costs for the aircraft modification and flight test program can be

TABLE VI  
 AIRCRAFT ELEMENTS CONSIDERED FOR THE DHC-6-300  
 DESIGN MODIFICATIONS & FLIGHT TEST

PROPULSION

- |   |   |
|---|---|
| 1. Nacelle Upper Assem. (Incl. Jig)           | 23. Eng. Air Inlet Lip Assem. & Form Die      |
| 2. Nacelle Upper Skin (Cres)                  | 24. Eng. Air Inlet Duct Fwd. Frame & Form Bl. |
| 3. Nacelle Upper Installation                 | 25. Eng. Air Inlet Duct Aft Frame & Form Bl.  |
| 4. Nacelle Rear Mount Yoke                    | 26. Eng. Air Inlet Fwd. Duct Assem.           |
| 5. Nacelle Front Mount Yoke                   | 27. Eng. Air Inlet Aft Duct Assem.            |
| 6. Nacelle Fwd. Fire Seal Blkd.               | 28. Eng. Air Inlet Vane Assem.                |
| 7. Nacelle Center Fire Seal Blkd.             | 29. Engine Air Inlet Duct Shell (Fiber-glass) |
| 8. Nacelle Aft Fire Seal Blkd.                | 30. Eng. Air Inlet Duct Aft Blkd. & Form Bl.  |
| 9. Nacelle Split Longeron (Jig & 8 tubes)     | 31. Oil Cooler & Duck Instal.                 |
| 10. Nacelle Top Center Line Longeron (4 hats) | 32. Oil Cooler Scoop Assem.                   |
| 11. Nacelle Split Longeron Fitting            | 33. Oil Cooler Scoop                          |
| 12. Nacelle Firewall Blkd. Assem.             | 34. Oil Cooler Aft Duct Assem. & Form         |
| 13. Nacelle Upper Fire Wall Blkd. Assem.      | 35. Oil Cooler Fwd Duct Assem. & Form         |
| 14. Aft Nacelle Upper Longeron                | 36. Engine Fuel Control Linkage               |
| 15. Aft Nacelle Lower Longeron                | 37. Propeller Control Linkage                 |
| 16. Aft Nacelle Assem. (Fiberglass lay-up)    | 38. Exhaust Elbow Assem.                      |
| 17. Nacelle Lower Shell Assem. (Uses -2 Skin) | 39. Exhaust Pipe Extension                    |
| 18. Lwr. Nacelle Fwd. Fire Seal Frame         | 40. Engine Build-up                           |
| 19. Lwr. Nacelle Center Fire Seal Frame       | 41. Engine Aft Mount Details                  |
| 20. Lwr. Nacelle Aft Fire Seal Frame          | 42. Engine Fwd. Mount Details                 |
| 21. Engine Air Inlet Scoop Assem.             | 43. Engine Air Inlet Vane Actuator            |
| 22. Engine Air Inlet Duct Assem. (Incl. Jig)  | 44. Engine Air Inlet Duct Damper Assem.       |
|   | 45. Engine Mount Lower Yoke                   |



TABLE VI (Cont.)

EMPENNAGE

Empennage External Loads & P.D.

Empennage Internal Loads

1. Vertical Tail Installation
2. Vertical Fin Assem. Out'bd.
3. Vertical Fin Rear Spar Assem.
4. Vertical Fin Front Spar Assem.
5. Vertical Fin Leading Edge Assem.
6. Vertical Fin Rib Details
7. Vertical Fin Hinge Fittings
8. Vertical Fin Attach Fittings
9. Rudder Assem. - Out'bd. (Fwd. Sec.)
10. Rudder Vert. Spar Assem (6)
11. Rudder Leading Edge Assem.
12. Rudder Hinge Fittings (18)
13. Rudder Rib Details
14. Rudder Drive Assem.
15. Rudder Tab Installation
16. Rudder Tab Assem.
17. Rudder Tab Hinge Fittings
18. Rudder Tab Drive Assem.
19. Rudder Tab Linkage Details
20. Rudder Tab Control Installation
21. Rudder Balance Wt. Installation
22. Rudder Aero. Balance Tip

Main Vert. Fin Modification

1. Tie Rod Installation
2. Tie Rod Fittings
3. Vortex Generator Installation
4. Outbd. Rudder Control Installation
5. Main Rudder Tab Assembly
6. Main Vert. Fin Reinf.
7. Main Rudder Modification
8. Main Rudder Tab Hinge Assembly

Stabilizer Modification

1. Tie Rod Fitting Installation
2. Outbd. Fin Attach Fitting Installation
3. Outbd. Fin Attach Fittings
4. Stabilizer Tip Assem.
5. Rudder & Tab Control Installation
6. Elevator Modification
7. Elevator Horn Assem.
8. Stabilizer Reinforcement

TABLE VI (Cont.)

WING

Wing & Flap External Loads

Wing & Flap Internal Loads

1. Wing Leading Edge Outbd. Assem.  
Includes Lateral - Blkd.
2. Wing Leading Edge Outbd. Skin Panel
3. Wing Leading Edge Rib Modif.
4. Wing Leading Edge Actuator Rib
5. Wing Leading Edge Actuator Fitting
6. Wing Leading Edge Installation
7. Wing Inbd. Front Subspar Installation
- 7a. Wing Inbd. Front Subspar Ribs
8. Wing Leading Edge Inbd. Assem.
9. Wing Leading Edge Inbd. Skin Panel
10. Wing Leading Edge Installation - Inbd.
11. Wing Flap Inbd. Assem.
12. Wing Flap Inbd. Installation
13. Wing Flap Leading Edge Assem.
14. Wing Flap Leading Edge Ribs
15. Wing Flap Slat Assem.
16. Wing Flap Slat Ribs
17. Wing Flap Slat Hinge Brkt.
18. Wing Flap Hinge Brkt.
19. Wing Flap Slat Link Assem.

Wing Spoiler Installation

1. Wing Spoiler Assem.
2. Wing Spoiler Drive System
3. Wing Spoiler Hyd. Drive System

TABLE VI (Cont.)

SYSTEMS

|   |                               |
|---|-------------------------------|
| Engine Oil System Installation            | Engine Vibration Survey       |
| Power Plant Elect. Installation           | Ground Vibration Survey       |
| Power Plant Drain System                  | Fuselage Torsion Test         |
| Propeller Installation                    | Flutter & Whirl Mode Analysis |
| Power Plant Instrum. Installation         | Fire Control System Test      |
| Engine Air Inlet Scoop Installation       | Far 23 Compliance Anal.       |
| Nacelle Lower Afterbody Installation      | Hyd. System Function Test     |
| Engine Bleed Anti-ice System Installation | Elect. System Function Test   |
| Hydraulic System Installation             |                               |
| Engine Exhaust Overwing Shroud            |                               |
| Aft Fuse Shell Reinf.                     |                               |
| Ldg. Gear Fail-Safe Anti-Skid Brakes      |                               |
| Rig & Function Test Engine Controls       |                               |
| Rig & Function Test Flt. Controls         |                               |
| Rig & Function Test Ldg. Edge             |                               |
| Rig & Function Test Spoilers              |                               |
| Rig & Function Test Rudder System         |                               |
| Fuel Flow Test                            |                               |
| Engine Temp. Survey                       |                               |
| Engine Air Inlet Pres. Survey             |                               |

TABLE VI (Cont.)

FLIGHT TESTING

Taxi Testing

Pwr. Run-up (Brake Holding)  
 Anti-Skid Brake Function  
 Engine & Prop. Control  
 Prop Reverse Function

Flight Testing

Handling (Stability & Control)

Pwr. Off Stalls

Full Flap & Spoilers  
 Clean  
 Take-Off Flaps

Pwr. On Stalls

Take-Off Flaps (2 Eng.)  
 Clean (2 Eng.)  
 Balked Landing (2 Eng.)  
 Take-Off Flaps (1 Eng.)  
 Balked Landing (1 Eng.)  
 Clean (1 Eng.)

Air Speed Calibration

Stall Speeds Pwr. Off

Clean  
 Full Flap & Spoilers  
 Spoilers Extended

Stall Speeds Pwr. On

Clean (2 Eng.)  
 Take-Off Config. (2 Eng.)  
 Full Flap & Spoiler (2 Eng.)  
 Clean (1 Eng.)  
 Take-Off Config. (1 Eng.)  
 Balked Ldg. Config. (1 Eng.)

Min. Control Speed Air

Take-Off Config.  
 Full Flap, Spoiler & L. Edge  
 Full Flap & Spoiler

Min. Control Speed Ground

Take-Off Config.  
 Take-Off Gnd. Run (2 Eng.)  
 Take-Off Gnd. Run (1 Eng.)  
 Field Length RTO  
 Landing Gnd. Run (2 Eng.)  
 Landing Gnd. Run (1 Eng.)  
 Decent Gradient-Ldg.  
 Engine-Out Climb Perform.  
 Cross Wind Performance

TABLE VII

## COST ESTIMATE FOR MODIFICATION A\*

| Hours                 | <u>ENGINEERING HOURS/COSTS</u> |                      |                        | <u>MANUFACTURING HOURS/COSTS</u> |                 |                  |
|-----------------------|--------------------------------|----------------------|------------------------|----------------------------------|-----------------|------------------|
|                       | Design & Drafting              | Analytical & Testing | Supervisory & Checking | Mfg. Labor                       | Quality Control | Mfg. Supervisory |
| Propulsion            | 0                              | 0                    | 0                      | 0                                | 0               | 0                |
| Empennage             | 3680                           | 1790                 | 1585                   | 4360                             | 700             | 610              |
| Wing                  | 1520                           | 1065                 | 685                    | 2780                             | 500             | 275              |
| Systems & Ground Test | 1220                           | 2945                 | 1045                   | 3520                             | 685             | 1010             |
| Flight Test           | -                              | 810                  | -                      | -                                | -               | -                |
| Sub Total             | 6420                           | 6610                 | 3315                   | 10660                            | 1885            | 1895             |
| TOTAL                 | 16345                          |                      |                        | 14440                            |                 |                  |
| <hr/>                 |                                |                      |                        |                                  |                 |                  |
| Costs (\$)            |                                |                      |                        |                                  |                 |                  |
| Sub Total             | 118,770                        | 122,285              | 61,327                 | 159,990                          | 28,275          | 28,425           |
| TOTAL                 | 302,382                        |                      |                        | 216,600                          |                 |                  |
|                       | 518,982                        |                      |                        |                                  |                 |                  |

Total Engineering &  
Manufacturing Costs

\*Modification A includes wing leading edge Slats, ground spoilers in the wing, and an increase in the size of the vertical tail

## TABLE VII (Cont.)

## COST ESTIMATE FOR MODIFICATION A

SUBCONTRACT SERVICE & MATERIAL COSTS (\$)

|                       |        |
|-----------------------|--------|
| Propulsion            | 0      |
| Empennage             | 6,620  |
| Wing                  | 5,940  |
| Systems & Ground Test | 37,850 |
| Flight Test           | 12,000 |
|                       | <hr/>  |
| TOTAL                 | 62,410 |

TABLE VII (Cont.)  
 COST ESTIMATE FOR MODIFICATION A

TOTAL AIRCRAFT COSTS (\$)

|                                     |         |           |
|-------------------------------------|---------|-----------|
| Total Engineering and Manufacturing |         | 518,982   |
| Subcontract Services and Materials  |         | 62,410    |
| Purchased Parts                     |         | 400,000   |
| DHC-6-300 Aircraft                  | 400,000 |           |
| Engines                             | 0       |           |
| Propellers                          | 0       |           |
| Insurance                           |         | 30,000    |
| <hr/>                               |         |           |
| Total Cost of Modified Aircraft     |         | 1,011,392 |

TABLE VIII

## COST ESTIMATE FOR MODIFICATION B\*

| HOURS                                   | <u>ENGINEERING HOURS/COSTS</u> |                      |                        | <u>MANUFACTURING HOURS/COSTS</u> |                 |                  |
|---|--------------------------------|----------------------|------------------------|----------------------------------|-----------------|------------------|
|   | Design & Drafting              | Analytical & Testing | Supervisory & Checking | Mfg. Labor                       | Quality Control | Mfg. Supervisory |
| Propulsion                              | 3085                           | 955                  | 1210                   | 4480                             | 500             | 760              |
| Empennage                               | 3680                           | 1790                 | 1585                   | 4360                             | 700             | 600              |
| Wing                                    | 1520                           | 1065                 | 685                    | 2780                             | 500             | 275              |
| Systems & Ground Test                   | 1220                           | 2945                 | 1045                   | 3520                             | 685             | 1010             |
| Flight Test                             | -                              | 810                  | -                      | -                                | -               | -                |
| SUB TOTAL                               | 9505                           | 7565                 | 4525                   | 15140                            | 2385            | 2655             |
| TOTAL                                   | 21,595                         |                      |                        | 20,180                           |                 |                  |
| <u>COSTS (\$)</u>                       |                                |                      |                        |                                  |                 |                  |
| SUB TOTAL                               | 175,842                        | 139,952              | 83,712                 | 227,100                          | 35,775          | 39,825           |
| TOTAL                                   | 399,507                        |                      |                        | 302,700                          |                 |                  |
| Total Engineering & Manufacturing Costs |                                |                      | 702,207                |                                  |                 |                  |

\* Modification B includes the changes in modification A plus new PT6A-45 engines installed in the aircraft



TABLE VIII (Cont.)

## COST ESTIMATE FOR MODIFICATION B

SUBCONTRACT SERVICE & MATERIAL COSTS (\$)

|                       |        |
|-----------------------|--------|
| Propulsion            | 17,180 |
| Empennage             | 6,620  |
| Wing                  | 5,940  |
| Systems & Ground Test | 37,850 |
| Flight Test           | 12,000 |
|                       | <hr/>  |
| TOTAL                 | 79,590 |

TABLE VIII (Cont.)

## COST ESTIMATE FOR MODIFICATION B

TOTAL AIRCRAFT COSTS (\$)

|  |         |           |
|--|---------|-----------|
| Total Engineering and<br>Manufacturing |         | 702,207   |
| Subcontract Services and<br>Materials  |         | 79,590    |
| Purchased Parts                        |         | 700,000   |
| DHC-6-300                              | 400,000 |           |
| Engines                                | 250,000 |           |
| Propellers                             | 50,000  |           |
| Insurance                              |         | 30,000    |
| Total Cost of Modified Aircraft        |         | 1,511,797 |

estimated as follows:

| Modification | Total Program Costs |
|--------------|---------------------|
| A            | \$1.86 M            |
| B            | \$2.36 M            |

### CONCLUDING REMARKS

The primary theme to be drawn from this study is the need for a flight research program to test and evaluate the reaction of the community to the frequent operation of transport aircraft at urban and suburban port sites. Emphasis in this study has been placed on small fixed wing conventional aircraft designed to operate from very short runways. However, the need exists independent of the aircraft concept -- conventional STOL, powered lift STOL, VTOL or rotary wing. There is a considerable research data base, both past and present, concerning the technical design of such aircraft. But, there is very little information concerning the reaction of the public to their operation close to business or residential communities. Thus, aircraft and airport designers lack dependable criteria to guide their use of available technology.

Noise is the most obvious concern, but the physical proximity of flight operations to the community may pose an even more vexing problem. If these problems continue to be avoided or ignored by those who advocate the development of these various aircraft concepts for urban markets, then the implementation of such aircraft concepts is likely to fail.

There have been previous attempts to operate flight research and demonstration projects in urban regions. In general, these attempts have failed due to a concern on the part of the public that the environmental quality of the community would be degraded with the introduction of scheduled air service. Yet, this is precisely the reason for undertaking such a research

program! That is, what type of aircraft operations are required to preserve environmental quality and safety, and are they feasible? Past experience proves that the public must be educated as to purpose before they can be effectively involved in this type of research. Unfortunately, government agencies (at any level) and industry are suspect at the outset, and a way must be found to reach the public with the image of protecting their environmental rights. One solution may be the use of a university based research team to conduct and report the experiments.

In order to be specific, this study has planned for such a flight research program for the San Francisco Bay Area. Port sites were found at locations which would be consistent with a future operational system. Even short term operations near the San Francisco central business district look very feasible, although it may be more desirable to operate from barges on the waterfront in a future operational system. Potential legal constraints were investigated for each site, and there appear to be no insurmountable problems if operations at a given site are limited to a thirty (30) day continuous period. The San Francisco Bay Area has a high degree of awareness when it comes to environmental questions, and thus it can be assumed that such a flight program would be feasible in virtually every metropolitan region in the United States.

With an existing production aircraft used as the flight test vehicle, the cost of the program is estimated to be quite low. Provided the objectives of the program can be carefully stated and presented to the public, this type of program would be an excellent investment for the future development of short haul air transportation.

## RECOMMENDATIONS

It is strongly recommended that the Federal Government sponsor a flight research program to test the reaction of urban and suburban communities to the frequent operation of transport aircraft. Such a program logically falls under the purview of the Department of Transportation. However, joint participating of the NASA is strongly recommended --- particularly in the conduct of the flight operations and evaluation of the results. To avoid the stigma of technology advancement for its own sake, the pattern followed by the NACA in sponsoring similar flight tests in the Boston area is recommended. This involved contracting directly with a non-profit research foundation which utilized university based teams for data collection and evaluation processes.\*

Concerning the specific operation of conventional aircraft in short field operations (conventional means no use of power life for takeoff and landing), careful examination of the applicability of FAR Part 23 and 25 is required. The type of leading edge wing device investigated in this study is operational with an existing aircraft, and based on this experience, it may be feasible to reduce both approach and touchdown speeds lower than allowable by the FARs with no compromise in flight safety. This would have strong implications on the ground roll distance for the aircraft. It is recommended that the NASA consider a wind tunnel and/or flight research program to better understand low speed handling problems in general and the operation of these leading edge wing devices in particular.

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\* The Aeronautical Research Foundation (ARF) was the contractor in the Boston Area Flight Tests. Now a division of the Inter-University Research Center, ARF remains constituted for this type of program and is committed to strong interaction with qualified Universities for the conduct of research.

## APPENDIX A

### A Review of Past Flight Research and Demonstration Programs

This Appendix provides a significant review of past flight research and demonstration programs related to short-field, fixed wing aircraft operating in urban areas. The Appendix is divided into the five following sections:

1. 1947-1949 NACA Sponsored Program in Boston and Subsequent Development of Small STOL Aircraft
2. Operations of Small STOL Aircraft at LaGuardia and Washington National Airports: 1956-1957.
3. The Counterproductive Results of the "Metro 66" Program STOL Test.
4. An Attempt at a Flight Demonstration Program in San Francisco - Failure of the NORCAL/STOL Program in 1969-1970.
5. An Assessment of Past Failures - The Non-Technical Aspects of Flight Research Programs Operating in Urban Areas.

1. 1947-1949 NACA Sponsored Program in Boston and Subsequent Development of Small STOL Aircraft

Shortly after World War II, the Congress passed legislation directing the Civil Aeronautics Board (CAB) to establish a number of regional short-haul services to be operated under a five-year subsidy. In New England, the CAB awarded the Regional Air Service subsidy to E. W. Wiggins Airways, Inc. In 1946, a New York investment banking firm agreed to finance the aircraft procurement needs of Wiggins Airways. The bankers' initial step was to retain a technical-and-economic advisory team composed to specialists from Harvard Business School and MIT. That team, under the direction of Dr. Lynn Bollinger (then Director of Aviation Research at Harvard) was given the assignment of selecting the most economical airplane available to serve New England short-haul routes.

The findings were an unpleasant surprise to all concerned -- including the investigators. They found that no existing airplane could produce an economically justified air service on the authorized routes. They concluded that the value of the resulting air service to the public would not be sufficient to justify the CAB's continuing to subsidize the operation after the initial trial period. Nevertheless, the investment bankers decided to proceed. Unfortunately, developments proved that the findings of the HBS/MIT team were correct.

The reason for the predictable failure of that short-haul experiment was the inadequacy of available airports -- both as to number and even more as to



location. The proportion of the regional populace for whom the existing airports could provide sufficient advantages in terms of time and convenience was insufficient to make scheduled air service practicable.

The professors did not confine their findings to the initial negative conclusions. By combining the economic and technical knowledge of the Harvard and MIT participants, they found that it was even then feasible to build economically fixed-wing aircraft which could use much shorter and hence much more conveniently located landing strips. Moreover, they concluded that already well-proven techniques could be employed to eliminate neighborhood objections to noise. With such aircraft operating on close-in strips, they believed sufficient traffic could be generated to produce self-supporting operations within a five-year period.

Those findings led to NASA's predecessor, NACA, sponsoring a test program in the Boston area to determine the real nature of neighborhood objections and the feasibility of applying corrective design features to short-haul aircraft. After a series of consultations with an interested NACA group the team of Harvard/MIT aviation authorities decided to form the Aeronautical Research Foundation (ARF) to work under NACA sponsorship.

The primary reason for the independent non-profit research corporation (ARF) being established to conduct the Boston neighborhood tests (as recommended originally by the NACA University Contract Office in Washington, early in 1947) was to protect both the government and the participating university groups from the risks and liabilities of operating experimental aircraft in congested metropolitan areas. Elimination of university constraints as well as overhead charges has been found to be a by-product advantage.

The subsequent summation of test results from experiments with aircraft modified to accomplish quieter and shorter landing area operations, as then submitted to NACA by ARF, included the following observations:

"Two light airplanes (a Piper Cub and a Stinson Voyager) modified by reduction gears, four-blade propellers, and exhaust silencers were flown in comparison with two standard airplanes at a number of short sites of the type that might be useful as close-in landing strips within the metropolitan area of Boston, Mass.

The findings indicate that at the ten sites tested within metropolitan Boston the degree of noise reduction found to be aerodynamically and structurally feasible did eliminate substantially all neighborhood objections to noise."<sup>(1)</sup>

That summation also reported that the findings "were not extensive enough to determine whether other manifest objections such as fear of low flying aircraft and possible property devaluation would result in sustained objections (in the event continuing operations were to be proposed)."

Consequently, in furtherance of the end objective, which was to determine the total criteria for establishment of an economically viable intraregional air

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(1) These tests and results were initially reported in "NACA, TN2079, 1950" by Professors Leo L. Beranek, Fayette C. Taylor, and Messrs. Fred S. Elwell and John P. Roberts. The concluding Technical Report No. 1156 was submitted to NACA in 1953 by Fred S. Elwell. (The above conclusions were repeated in essentially the same form in each of those reports.)

transportation system, ARF's trustees authorized a continuing investigation that was privately supported. The on-going objective was to determine realistically whether the ten test neighborhoods would accept continuous commercial air operations. The keystone in that on-going investigation was the sponsorship by a cooperating Massachusetts State Senator of a legislative Bill authorizing the Aeronautical Research Foundation to install and operate public landing areas -- but only for aircraft complying with the performance and quietness standards already demonstrated -- at the sites previously selected and tested under the NACA sponsored project (each of those sites being on state-owned properties adjacent to public thoroughfares).

It was not really anticipated that the proposed Bill would be approved by both of the State legislative bodies and then be signed by the Governor. The original purpose was only to determine realistically -- through public hearings predicated on the "threat" of continuous operations -- whether or not the noise suppression and flight patterns as demonstrated in the limited tests were sufficient to create an encouraging degree of acceptance.

The results were a great surprise to all involved. After extended and well attended hearings that lasted for well over a month, public support for the proposed close-in air services so overwhelmingly exceeded the few objections that both of the State legislative bodies did approve the Bill. It was signed by Governor Bradford and became public law.

As a result several aircraft manufacturers announced publicly their plans to produce aircraft that would comply with the noise, safety, and performance standards demonstrated in the NACA sponsored ARF tests. Specifically, Fairchild Aircraft Corp., under the leadership of Adm. L. B. Richardson (ret.) and Aeronca

Aircraft Corp. under its president John Lawler, announced respectively their plans to produce a Fairchild multi-engine short-haul light-transport and an Aeronca single-engine four-place model. In addition, several participants in the earlier ARF work formed a private R&D organization known as Helio Corporation. The Helio team's first task was that of providing technical assistance to Fairchild and Aeronca on proposed new commercial STOL aircraft designs.

Unfortunately, the Korean War soon thereafter forced both of those corporations to drop their STOL aircraft plans and to concentrate all capabilities on military aircraft. Thus, the impetus generated initially by the NACA sponsored flight tests in Boston and accelerated greatly by the State of Massachusetts was lost.

## 2. Operation of Small STOL Aircraft at LaGuardia and Washington

### National Airports: 1956-1957

Early in 1956, when the first approximate 20 Helio Couriers with their ultra-short-field landing capabilities began operating on the East Coast, both the Port of New York Authority and the Federal CAA took the initiative in establishing special permits and sponsorship to encourage their use on existing helicopter landing pads at terminal airports.

The still valid objective of that effort was two-fold: first, to eliminate the interference between jet airliners and slow-flying local air-taxi airplanes in airport approach-and-departure patterns; second, to provide a more economically viable substitute and extension of the excessively costly helicopter services which were already contracting -- prior to their inevitable collapse as intra-regional public carriers.

Following extensive tests by CAA Flight Safety Office and trial operations at Washington National Airport (which were paralleled by Port of New York Authority aviation office at LaGuardia Airport in New York), the 500 foot low-altitude helicopter approach channels below and between active airlines and the helicopter landing pads at both airports were officially approved for Helio/STOL commercial operations. The approval also applied to any other STOL aircraft incorporating safe, slow-speed (non-stallable) maneuverability and ultra-short landing/takeoff capabilities equivalent to those demonstrated by the Helio Courier. Such operating privileges were granted under the "equivalent safety" exemption practice then allowed through the CAA Office of Flight Safety.

Early in 1957, to provide a more assured long-term incentive for private investment in such publicly desirable STOL short-haul services -- which were already attracting nationwide interest -- the Flight Safety Office of CAA then took the initiative in recommending a permanent approval by the Civil Aeronautics Board of the helicopter-equivalent approach pattern. Understandably, prospective investors remained somewhat reluctant to proceed with the establishment of STOL services and facilities under an administrative ruling as to "helicopter equivalency" which might at any time also be subject to an administrative reversal.

At the resulting CAB hearings, to the surprise of all other parties concerned, the light aircraft manufacturing representatives in the Aircraft Industry Association as well as the helicopter spokesmen (as anticipated) joined in unanimously opposing the incorporation of the CAA Flight Safety Office recommendation into existing regulations.

Their argument was two-fold. First, they maintained that the helicopter should be given a chance to prove its economic viability with the next generation of presumably more economical designs, which were "just around the corner." Second, the spokesmen for conventional light-plane manufacturers protested that it was unfair to them for the CAB to establish a privilege that only one company was prepared to utilize.

They also maintained that any such action would discourage the introduction of a number of even more promising new STOL designs that were allegedly even then rapidly approaching the production state. Thus, the state-of-the-art was at that time changing too fast, they insisted, to justify changing the regulation at the point based on what only one small manufacturer had already put on the market.

As a result of those presentations, which history has since proven were false, the CAB decided not to change the underlying regulation. That decision made it obligatory that the CAA withdraw its existing exemption after it had been in effect so ruled contrary to the public interest. Presumably any such exemption for one STOL design would deter the important technical advances with even more advanced models that industry spokesmen implied would soon be ready for public introduction. But, twenty years later, none of those then "immediately pending" major new developments has yet appeared on the market!

### 3. The Counterproductive Results of the "Metro 66" Program STOL Test

In the early 1960's, a large number of private self-supporting air-taxi services were developed to serve related metropolitan area needs. Those air-taxi operations then served at least some small part of the still increasing public need for short-haul services into metropolitan airports from community centers that were more than about 15 to 20 miles distant.

However, the resulting air traffic congestion and interference between small slow air-taxi aircraft and jet airliners on terminal airport runways -- and most especially at the greater New York airports -- then led Mr. John Wiley, Aviation Director of the Port of New York Authority (PNYA) to turn to the original NACA/ARF research team in the Boston area for a possible solution to the problem, namely a renewed effort to develop small, twin engine STOL transport aircraft. Modifications to existing aircraft were to be considered as well as a new aircraft design.

The regional air-taxi operators, who were then questioned by the PNYA, were found willing and able to so convert those existing twin-engine models that were amenable to such modification. Thereupon, the Port Authority installed (paved and lighted) a 900 foot STOL strip on the western perimeter of LaGuardia Airport to accommodate such modified aircraft. That STOL strip location permitted non-conflicting egress at low altitudes over the adjacent Bowery Bay.

Region I FAA Flight Safety personnel were found to be no longer concerned by CAB's temporary and by then obviously discredited earlier (1957) reasons for not authorizing the continuation of such STOL flight patterns in the Washington area. Accordingly, the Region I FAA Office once again issued a "helicopter-equivalent"



exemption ruling for such STOL aircraft. Pending the anticipated STOL modification of twin-engine air-taxi, the several industrially owned Helio-Couriers in the New York area immediately began using the approved helicopter approach pattern at 500 feet in and out of that STOL-pad on LaGuardia Airport. The industrial owners, the LaGuardia Air Traffic Controllers, the FAA Flight Safety Office and the Port Authority were all highly pleased with the resulting operations. There were no known safety or operational complaints.

Shortly thereafter, when President Johnson vetoed continuation of the increasingly heavily subsidized helicopter services, the demonstrated feasibility of the new STOL-pad on LaGuardia Airport generated a wave of new interest in STOL not only within the New York area but nationwide. The FAA Director of Region I, Mr. Oscar Bakke, in particular, developed a deep interest. It led directly to his initiation of a widely publicized STOL demonstration program in 1966 on Manhattan Island. That program was known as "Metro 66."

The Metro-66 program was commendably motivated, and its apparent initial success led to nationwide replication. Mr. Oscar Bakke then left his Regional Administrative post to become the Associate Administrator for Plans in the FAA Washington Headquarters. His office then became the chief sponsor and supporter of the subsequent nationwide STOL demonstrations. That office deserves credit for much of the resulting tide of temporary enthusiasm.

Understandably, existing aircraft manufacturers had a strong desire to have their existing production models accepted unchanged on any and all such pending new "STOL landing areas. Equally understandable was the impact on Mr. Bakke and his FAA associates of their strong consensus and unified industry voice-of-authority. With the benefit of hindsight, it is now obvious that the well-intentioned Metro-66 test was thereby both misguided and misinterpreted.

The first error in the Metro-66 test was an attempt to mislead the public. The sponsoring FAA Office quietly announced to key aviation participants in advance that to avoid public opposition they were going to disguise the project's real intent. Thus, a program designed to prove the feasibility of on-going commercial STOL operations was at first represented to be public as principally "to demonstrate that prompt assistance could be provided by air to a stricken metropolitan core area during an emergency.

That representation backfired in two ways. The most obvious repercussion was the local resentment and opposition engendered when the ploy later became obvious. However, the most serious long-run consequence arose from the manner in which the perpetrators thereby deceived themselves.

Because public observers at first accepted as valid the purported "emergency relief" objective of the temporary tests, they did not then protest the noise and questionably safest approach patterns. As a result, the majority of the industry participants misinterpreted the absence of public protest as connotating a willingness to accept continuing operations. They thus convinced the FAA to ignore thereafter the noise suppression and other requirements found to be essential in the earlier NACA/Boston tests.

Far more difficult to understand is the reason for those manufacturing being able also to persuade the FAA to establish 2000 feet as the design criteria for close-in STOL landing areas. The earlier 1,500 foot requirement for Class I light-plane airports had already been found to be more than could be maintained near most populated metropolitan areas. Moreover, the Metro-66 exercise clearly indicated the impracticability of installing any landing strip of that length on Mahattan Island.

During those Metro-66 exercises, two categories of landing areas were tested. One category was the public park area having 2,000 feet or more of open grass. However, such park areas were known by all concerned not to be available for continuing flight operations. The other, more widespread, category consisted of private hard-surfaced areas of about 1,000 foot length. These included industrial parking and loading areas as well as pier tops (Pier 26 in the Hudson River being the one tested).

The first day of the Metro-66 tests brought exceptionally favorable weather -- smooth, cool air with a light east breeze not exceeding 9 knots. All those participating aircraft that incorporated light wing and power loadings -- such as the Canadian deHavilland Twin Otter, turbo-Beaver, and the U.S. Helio Courier -- were able to use the smaller sites, including Pier 26, with ease. The heavier deHavilland Buffalo was the only airplane confined to the longer areas that day.

The second day was still good, with the wind in a more customary westerly quadrant, starting out at 9 knots and building up to a moderate 18 knots by mid-morning. Even in the moderate turbulence so induced, the airplanes that depended solely on light wing and power loadings without any form of effective boundary-layer control (such as leading-edge slats) or of augmented lateral-control could no longer operate safely on the smaller sites -- namely, the type of sites that might realistically have been acquired for on-going commercial use. Instead, the conventional aircraft were largely confined to use of public park areas -- which by the end of those two days was already arousing adverse public reactions.

The only airplane that could operate in compliance with FAA flight safety rules on the smaller -- commercially available -- type of landing areas that day was the one equipped with those non-proprietary slow-speed safety devices that were

shortly thereafter incorporated in jet airliners to make possible their operation on smaller airports such as LaGuardia and Washington National -- principally, wing leading-edge slats (or equivalent) and augmented lateral-control.

(One conventional airplane did succeed in making a landing on Pier 26 early in the second day, but only in a hazardous manner violating the FAA's approach safety rule. No repetition was permitted).

The evidence even then thus strongly indicated that the commercially available landing areas of around a 1,000 foot length could be used on a regular basis only if well-proven safety devices were added to the aircraft's wing to permit slower and more controllable approaches under turbulent conditions. Experience in other areas as well also indicated that adequately positioned areas of 2,000 foot length would be extremely difficult if not impossible to acquire for on-going STOL operations within any major metropolitan area.

Nevertheless, the manufacturers of conventional "naked-wing" aircraft persuaded Mr. Bakke's FAA office to define a STOL landing area as being 2,000 feet long. Also, despite the nationally recognized need for noise attenuation, it was slighted. The admitted purpose was to try to give existing aircraft in unmodified form a close-in access to such city centers. This was an understandable even though unrealistic industry objective. For public officials to "play ball" with such industry pressures reflected the regulatory mores of that era -- an era now past.

Before making that ill-fated effort, the FAA team did ask for -- but then ignored -- the relevant findings from earlier NACA sponsored "good neighborhood" landing area tests in the Boston area. The attempt by the FAA thereafter to sell metropolitan communities on STOL services with conventional, unquieted aircraft

requiring 2,000 foot strips was a conspicuous failure in all other parts of the country as well as in New York.

The compromised promotional effort shattered the then widespread and inherently valid public expectation that STOL aircraft could bring a new era of unobstrusive intraregional air services. By calling old conventional airplanes "STOL" and then seeking 2,000 foot strips for their use in communities that had already rejected the earlier 1,500 foot "Class I" type of airports for private planes, the FAA Office of Plans in its otherwise commendable effort to promote existing airplanes unfortunately discredited bona fide STOL potentials.

4. An Attempt at a Flight Demonstration Program in San Francisco -  
Failure of the NORCALSTOL Program in 1969-1970

A well considered design criteria for an advanced type of STOL air services was promulgated by California's Department of Transportation (DOT) in September 1969 (see Appendix B). A category of flight operation designated as "Augmented/STOL" was then authorized "to make possible helicopter-equivalent approaches and departures" on 1,000 foot runways.

In contrast to the Metro-66 effort that has ignored the need for improved design criteria, the California standards gave careful consideration to the findings of the earlier NACA sponsored neighborhood tests in Boston. They also investigated carefully other relevant experience, including the FAA approved demonstrations of the helicopter-equivalent capabilities of advanced STOL designs on Washington National and LaGuardia Airports in 1956-57.

Consequently, stall-suppressing devices and augmented lateral-control were specified in the 1969 California criteria. However, because of the very high ambient level at the prime (pier top) location then being sought, the importance of noise suppression at other locations was evidently overlooked.

Encouraged by that state action, a group of substantial citizens in the San Francisco area (unaffiliated with any of the earlier eastern STOL advocates) raised funds and developed plans for STOL flight operations to connect a downtown San Francisco pier top site with a number of outlying strips.

Unfortunately, despite the state sponsored STOL standards, establishment of flight operations in the proposed downtown site encountered overwhelming opposition from two other governmental levels. The reason was apparently more political than either technical or economic.

Local authorities -- having been ignored by the state officials in the earlier phases of the STOL planning -- then received their initial indoctrination from hostile local aviation groups whose existing investments were either in helicopter or in light aircraft operations. The city authorities thus entered the fray in the role of attackers fighting outsiders in behalf of local friends -- friends who were, moreover, existing employers as contrasted to "financial interests."

While struggling to defend themselves from the flank attack, the prospective investors in the proposed new STOL service encountered an even more discouraging obstacle -- one that appeared to be a result of the failure to involve FAA authorities in the earlier planning stage.

The local FAA Flight Safety Officials would not accept post-facto the STOL standards established by the state office. Neither did they appear to either the local or to state sponsors to be willing to consider the proposed flight patterns on the basis of logic and safety, per se. The fact that the proposed new type of STOL flight operations did not comply with existing air control rules produced irreconcilably rigid opposition.

Subsequent dispassionate reviews by independent investigators of the stated reason by FAA officials for rejecting the proposed flight patterns revealed no real technical or safety problem. The underlying difficulty appears to have been primarily one of communication and cooperation.

When the sponsors of the proposed STOL operations were then confronted with FAA opposition on top of that of city authorities, they dropped their efforts. No further serious attempts are known to have been made since to take advantage of the advanced STOL standards that were promulgated independently and

solely by the California state authority. Regardless of their unquestioned technical validity, the unilateral manner in which the California STOL criteria were developed appears to have assured their rejection.



5. An Assessment of Past Failures - The Non-Technical Aspects  
of Flight Research Programs Operating in Urban Areas

First hand observations starting with the 1947-49 NACA tests in Boston and continuing into the 1970's, have revealed that most landing area promotions initiated by a federal or state government representative tend to produce an almost automatic wave of public opposition within the adjacent community. "Don't bother us with the facts, we are against it" typifies the initial community response to such efforts -- a response that has been found hard to change thereafter.

Such reactions suggest that the local citizenry feel the dice are loaded against them when so confronted with "the heavy hand" of anyone who appears to be a powerful governmental advocate of aviation. Technical facts quoted in support of the project then tend to be either discounted or discarded. A graphic example of such a situation was the attempt on the part of American Airlines in 1970 to operate a flight demonstration program with a floating STOL port on the Hudson River adjacent to the Chelsea district in Manhattan (Reference 13). This attempt was met with strong, well organized and effective opposition on the part of the public who perceived a threat to their quality of life.

Therein may lie a lesson of continuing import. That is, future design criteria for any new category of intraregional air service to be practicable may need to be promulgated in a manner that involves interested federal, state, and local officials in a participatory role before those criteria are finalized and promoted. Moreover, the less any one governmental participant appears to be assuming superior authority, the more likely the cooperation of the others.

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13. Ransome, Robin K., "Chelsea STOLport - The Airline View, SAE Paper 760523,"  
May 1976.

In addition, public neighborhood acceptance has been found to be somewhat similarly dependent upon the submission of alternatives to local groups and their spokesmen for a genuine evaluation of the cost-vs-benefits to them prior to public advocacy by an external governmental agency. Premature advocacy by any external power has commonly been found to produce adverse reaction and rejection rather than intelligent reflection and receptivity.

For those reasons, a technically qualified university-affiliated group serving in an investigatory and advisory role -- rather than as an "external power" -- may provide a more effective way to involve local groups in a manner that will produce the required consensus. This, in fact, was the procedure followed in the successful NACA sponsored tests in Boston in 1947 - 1950.

Some of the specific steps that have been found conducive to community acceptance include briefing in advance the local newspapers as well as the spokesmen for politically influential groups. Only after recognized local leaders become supportive do the local police also tend to become allies in the effort. They have been found to be especially helpful in converting initial neighborhood protests into useful research findings. By contrast, efforts to obtain approval from key local functionaries, such as the Chief of Police, prior to the informal acquiescence of key community leaders can be counter-productive.

In past successful efforts, the first step in establishing community cooperation has commonly been for the participants to establish their credibility with a leading local banker or other widely respected community figure. Local banks have also been found dependable sources of information with regard to the identity of important local power groups and the names of their leaders. Personal introductions and implied endorsements as to the integrity of the proposed effort usually results.

The balance of power and prestige that needs to be taken into account differs in each community. Consequently, too much emphasis should not be put on any one procedure or prescribed sequence of actions. Psychological and attitudinal factors have been found equally essential. To attain ready acceptance, for example, the project representative must be sufficiently authoritative to inspire confidence, but not authoritarian. He must appear to be neither uncertain of his facts nor a rigid advocate.

There are no pat formulae, no substitutes for sensitivity, experience, and quiet conviction. Adequate feel and understanding for the task is perhaps attained only by trial and error. Although difficult to transmit verbally, the requisite technique has been found readily communicable through teamwork and demonstration.

## CALIFORNIA DEPARTMENT OF AERONAUTICS

DESIGN CRITERIA FOR STOL AND A/STOL PORTS  
FOR STOL AIRCRAFT OF LESS THAN 12,500 LBS GROSS WEIGHT

## I

## Introduction

1. Purpose. This regulation sets forth minimum dimensions for various classes of "STOL Ports" and "AUGMENTED STOL Ports", for aircraft of less than 12,500 pounds, to meet requirements for a California STOL port permit. In accordance with California Public Utilities Code, Section 21663, a permit is required for any aircraft landing facility which will serve the public.
2. General. FAA design guide criteria have been adopted as required standards for meeting permit requirements for heliports and utility airports. Existing FAA regulations contain interim design guide criteria for STOL ports; however, they do not provide any basis for restricting the use of STOL ports to aircraft which can safely use them. STOL aircraft have not been officially designated as such by FAA. These aircraft are with us now and much planning for their efficient use is being done. It is urgent that criteria for runway design be set so that planning for smaller airports, with restricted airspace, in convenient locations, may be encouraged. These criteria do not depart from FAA regulations, but are an extension of them. When federal criteria are set for these classes of STOL ports, the Department of Aeronautics will utilize them.
3. Terminology. STOL is a term generally accepted to refer to an aircraft with unusually "short take-off and landing" capabilities. It is used in that sense here to refer to fixed wing aircraft with those capabilities. The term A/STOL as used in this regulation means "AUGMENTED STOL". This class of aircraft, described later, is fixed wing with augmented lift and lateral control devices to permit safe maneuvering while flying low and slow in restricted airspace.

## II

## Standards for STOL ports, aircraft, and pilots

1. General. STOL ports are designed for aircraft which are essentially no different from standard utility aircraft except that they have relatively light wing and power loading and probably extra large wing flaps to provide extra lift at low speeds. No low speed maneuvering below 500' should be attempted with these aircraft; therefore, approach/departure slopes, and clearances at STOL ports are the same as for utility airports. Essentially the only difference between STOL port and utility airport criteria is in runway length.

2. Aircraft capability requirements for STOL category. The manufacturer of an aircraft proposed for use on STOL ports must certify as to the capability of the aircraft to meet the qualification set forth below and must submit engineering/test data in substantiation thereof satisfactory to the State Department of Aeronautics.

a. The distance to land and takeoff over a 50' barrier with the stipulated STOL gross must be not more than the length of the proposed runway.

b. The landing roll at maximum gross weight for STOL operations must be not more than 40% of the proposed runway length.

c. The takeoff roll at maximum STOL gross must be not more than 60% of the prescribed runway length.

3. Pilot qualification for using STOL ports. Pilot authorization by name for STOL operations will require a certificate of qualification for each type of STOL aircraft the pilot proposes to operate on STOL ports. The certificate of qualification will be issued by either the manufacturer or a flight instructor approved by the California Department of Aeronautics. In either case, the STOL training and tests will follow the procedure prescribed in a manual supplied by the manufacturer and approved by the California Department of Aeronautics.

4. Minimum dimensional standards for STOL ports.

| <u>Item</u>                         |  |
|-------------------------------------|--|
| Runway length                       | <u>1500'</u> (see footnote)                                    |
| Runway width                        | <u>75'</u>   |
| Landing strip length                | <u>Runway length + 200'</u>                                    |
| Landing strip width                 | <u>150'</u>  |
| Primary surface length              | <u>Runway length + 400'</u>                                    |
| Primary surface width               | 250'   |
| Taxiway width                       | 40'  |
| Runway C/L to taxiway C/L           | 200'   |
| Taxiway C/L to A/C parking area     | 75'  |
| Runway C/L to building setback line | 200'   |
| Taxiway C/L to obstruction          | 50'  |
| Clear zone width at start           | 250'   |
| Clear zone length                   | 1000' (or to where approach surface reaches 50' above terrain) |
| Clear zone width at end             | 450' (at 1000' from start)                                     |
| Approach surface width at start     | 250'   |
| Approach surface length             | 3000'  |
| Approach surface width at end       | 350'   |
| Approach surface slope              | 20:1   |
| Transitional surface slope          | 7:1  |
| Transitional surface minimum height | 100'   |

Note: This is minimum length. See requirements for STOL aircraft above to determine required lengths for specific aircraft.

Standards for A/STOL (AUGMENTED STOL) ports, A/STOL aircraft, and A/STOL pilots.

1. General. A/STOL (AUGMENTED STOL) standards serve two inter-related objectives.
  - a. To permit the safe use of smaller runways closer to obstacles and consequently more conveniently located, which have already been demonstrated as being practicable when, but only when, advanced safety-and-control devices are added to conventional short-field type airplanes.
  - b. To make possible helicopter-equivalent approaches and departures within congested area control-zones at low (500') altitudes below and between the heavily congested approach patterns within which conventional airplanes are operating.

With regard to FAA regulations, the proposed A/STOL standards in no way depart from or attempt to change the generalized all-purpose air-worthiness standards set forth by FAA. The existing FAA regulations, however, do not attempt to prescribe the minimum size runway that general aviation can use nor to provide any basis for restricting the use of small runways to only those airplanes that can demonstrably use such runways safely.

Therefore, staying within the existing FAA rules, the proposed A/STOL standards provide the definitive added criteria needed to regulate operations in specific confined areas. The A/STOL standards thus seek to match the present-day performance capabilities of the STOL state-of-the-art with the minimum size runways that can be used safely.

At the present state of STOL development, it is neither necessary or realistic to expect that these standards need be perfect or "ultimate" but only that they establish a reasonable and practical set of bench marks so that aircraft designers, STOL port operators, and local public authorities can proceed on a coordinated basis.

The safety-and-control characteristics required to meet the A/STOL standards are broadly defined in terms of capabilities rather than specific devices in order to give aircraft designers latitude to choose between a number of well proved non-proprietary devices already in wide spread use. Most conventional light aircraft now in production that have been designed to land with less than a 400' roll can be readily modified to meet the A/STOL requirement.

Minimum runway lengths are expected to vary for different categories of A/STOL aircraft with the probability that shorter runway lengths may be proved feasible at a later date when the state-of-the-art has been developed further. The Department of Aeronautics regulatory objective at the present time is to establish immediately needed local standards for those advanced A/STOL types of aircraft which are already certificated and in production. When and as the FAA established nation-wide standards for confined airspace STOL landing areas together with an up-to-date delineation of the specific added safety features needed to offset the long recognized hazards of the low/slow maneuvering within such confined airspace, then the federal regulations will naturally take precedence.

2. Aircraft capability requirements for A/STOL category. The manufacturer of any model of aircraft proposed for use on A/STOL runways must certify as to the capability of the aircraft to meet the qualifications set forth below and must submit engineering/test data in substantiation thereof satisfactory to the California Department of Aeronautics.

To qualify for the A/STOL category an airplane must have the following safety and control features:

- a. One or more of the well proved stall-suppressing devices must be incorporated to prevent loss of control and lift due to wing stall while operating at low speed in heavy gusts or in the lee of obstacles that may produce either hazardous vortices or up flows. This includes the risk of wing-tip vortices drifting from nearby jet aircraft take-off patterns. The wing of an A/STOL airplane must, therefore, not be subject to air-flow separation such as to cause a decrease in total wing lift at less than a total angle-of-attack equal to the angle-of-attack required to attain, at full A/STOL gross weight, the speed recommended by the manufacturer for over-the-50'-barrier-tests plus either:
  1. 10° angle-of-attack, or
  2. The additional angle-of-attack induced at that speed by a sharp edged vertical gust of 10 feet per second.
- b. To prevent loss of lateral control in low speed down wind turns, or during the airplane's approach and departure maneuver in the lee of turbulence producing hazards, the airplane's lateral-control system must be capable of producing not less than a 10' per second average wing tip rate of vertical displacement as measured from a 30° bank in one direction to a 30° bank in the opposite direction when rolling against engine torque.

(For uniformity of tests, the roll should be started by the pilot from not over a 45° bank, at 1.1 times VSO, or at any lesser speed recommended by the manufacturer for over-the-50'-barrier tests.)

- c. The distance required to land or take-off over a 50' barrier with the maximum stipulated A/STOL gross must be not more than 1000' (without use of reverse thrust in landing).
  - d. For multi-engine aircraft engaged in air-taxi or in other public air transportation for hire; if the aircraft is not capable of clearing a 50' obstacle in the event one engine fails any time after attaining V1 speed, then the manufacturer must present satisfactory engineering and test substantiation as to the aircraft's ability to continue take-off safely. Its one-engine-out rate of climb must permit the aircraft to clear adequately any obstacles in the flight path at that specific STOL-strip for which a permit to operate is requested.
  - e. The landing-roll at the maximum gross weight stipulated for A/STOL operations must be not more than 40% of the prescribed runway length (i.e. 400'), without use of reverse thrust.
  - f. The take-off roll at maximum stipulated A/STOL gross must be not more than 60% of the prescribed runway length (i.e. 600').
  - g. Control of the path over the ground for approach and departure patterns must be such as to make possible the aircraft's following a prescribed path involving 360° turns in either direction within a 600' radius without exceeding a 30° bank or deviating more than 100' either laterally or vertically from the prescribed flight path.
3. Pilot qualifications for using A/STOL ports. Pilot authorization by name for A/STOL operations will require a certificate of qualification for each type of A/STOL aircraft the pilot proposes to operate on A/STOL ports. The certificate of qualification will be issued by either the manufacturer or a flight instructor approved by the California Department of Aeronautics. In either case, the A/STOL training and tests will follow the procedure prescribed in a manual supplied by the manufacturer and approved by the California Department of Aeronautics.



4. Minimum dimensional standards for A/STOL ports.

| <u>Item</u>                         |   |
|-------------------------------------|---|
| Runway length                       | 1000' (see footnote)  |
| Runway Width                        | 75'   |
| Landing strip length                | Runway length + 200'  |
| Landing strip width                 | 150'  |
| Primary surface length              | Runway length + 400'  |
| Primary surface width               | 250'  |
| Taxiway width                       | 40'   |
| Runway C/L to taxiway C/L           | 200'  |
| Taxiway C/L to A/C parking area     | 75'   |
| Runway C/L to building setback line | 200'  |
| Taxiway C/L to obstruction          | 50'   |
| Clear zone width at start           | 250'  |
| Clear zone length                   | 1000' (or to where approach surface rises to 50' above terrain) |
| Clear zone width at end             | 450' (at 1000' from start)                                      |
| Approach surface width at start     | 250'  |
| Approach surface length             | 2000'   |
| Approach surface width at end       | 650'  |
| Approach surface slope              | 10:1  |
| Transitional surface slope          | 4:1   |
| Transitional surface minimum height | 100'  |

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Note: This is minimum length. See requirements for A/STOL aircraft above to determine required lengths for specific aircraft.