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PRELIMINARY SURVEY OF POTENTIAL STOL TERMINAL AREA OPERATIONAL REQUIREMENTS

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16. Abstract

A preliminary survey of potential operational requirements for STOL in the terminal area has been made. The presentation of this survey is in three sections. The first section presents the motivation for the survey, which can be summarized as the necessity for the federal government to have a knowledge of the potential operational requirements of STOL. The second section discusses the markets in which STOL may be found viable. This discussion is limited to those aspects which are necessary to determine the effects of these markets on shaping future STOL operations. The final section consists of a description of terminal area operations as they currently exist, of possible operational changes that may occur exclusive of the introduction of STOL, and then of potential operational requirements of STOL in the terminal area.

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PREFACE

The author gratefully acknowledges the help Mssrs. Thomas Imrich and Joseph P. Tymczyszyn, graduate students at MIT, whose suggestions significantly broadened this survey.

1.0 INTRODUCTION

Government's responsibility with respect to the air transportation system is to provide and maintain an operational environment that is both safe and efficient for each segment of the flying community. The structure of this environment is in the form of operational procedures and certification standards. The introduction of a new subsystem, such as STOL, may require the government to modify the existing operational environment in preparation to receiving the new subsystem. The key to efficiently allocating resources to this preparatory work is a thorough knowledge of the subsystem's operational requirements.

The generation of market oriented operational requirements is normally the responsibility of the airline industry with its market research facilities. The airline industry is presently attempting to establish the viability of STOL in a number of markets. The technical and operational viability of area navigation (3-D RNAV) equipped STOL aircraft for intercity service was shown by the Eastern Airlines' STOL Demonstration in 1968 (Ref. 1) and by the American Airlines' Demonstration in 1969 (Ref. 2). Neither of these tests established the economic viability of STOL in the intercity market. In February 1970, the CAB declared that the establishment of a new intercity air service in the Northeast Corridor utilizing STOL, VTOL, and V/STOL aircraft is both technically and economically feasible (Ref. 3). At present, both American and Eastern Airlines are conducting economic viability studies to determine the attractiveness of and methods of approach for entering the STOL intercity shuttle market in the future. In addition, American Airlines is seeking support for a one year intercity STOL shuttle demonstration to be held in the Northeast Corridor. The other potential STOL markets such as the intraurban shuttle, the regional jetport shuttle, and the intrastate/regional shuttle are presently at the stage that the intercity shuttle was prior to 1968 - some analysis has been done but no demonstrations have been carried out. The Aerospace Corp., under the direction of the Western Conference of the Council of State Governments, studied the operational and economic details of STOL service for specific examples of all these markets (Ref. 4). Like American Airlines, the Aerospace Corp. is presently seeking governmental support for a number of demonstrations. The fact is that the economic viability of STOL remains the key question that must be settled before prospective stolport builders, aircraft manufacturers, and the airlines will have the confidence to invest private capital (Ref. 5).

Large scale STOL operations cannot be considered as an

incremental addition to the existing air transportation system, in which the overall system's procedures and standards can be assumed fixed and the subsystem's requirements for new procedures and standards can be assumed to be simple extrapolations of the existing set. It should be expected that a viable STOL subsystem will strongly interact with existing procedures and standards as well as require new ones. The answers to the operational questions posed by this interaction will influence the outcome of studies concerned with the economic viability of STOL. The output of these studies will in turn, determine the nature of future STOL applications which the ATC system must accommodate. To sum up, government needs a realistic knowledge of STOL's operational requirements to efficiently prepare for STOL service. Complementing this governmental need is the need of the airlines to be able to factor into their STOL planning a realistic picture of how current ATC procedures would be modified to accommodate proposed STOL operations. The roles of government and the airline industry in STOL planning should be carried out in close harmony with the airlines addressing the question of economic viability of proposed STOL applications and the government determining the interaction of these STOL operations with the ATC system.

Although firm requirements have not yet been established, sufficient work has been done to generate a number of potential STOL operational requirements. Since, in the case of STOL, the new subsystem could require major modifications and additions to and interaction with the existing air transportation system, the government should begin work in anticipation of firmly established requirements. Direction of this work should be based on a thorough understanding of these potential operational requirements. The objective of this paper is to present a preliminary survey of these potential requirements with respect to STOL terminal area operations.

This paper consists of three sections. The first section presents a survey of the markets in which STOL may be found viable. This survey does not discuss the actual economic questions of market viability, which is the function of the airline industry, but rather it presents the pertinent aspects of the various markets to the extent necessary to determine their effect on shaping future STOL operations. This will be the basis for establishing such potential operational requirements as the location of stolports and the gross characteristics of future operational STOL aircraft. The various stolport locations will in turn, determine a number of terminal area environments, each with its own set of characteristics, in which STOL may operate. The second section of the paper consists of a description of terminal area operations as they currently exist, of possible

operational changes that may occur exclusive of the introduction of STOL, and then of potential operational requirements of STOL in the various terminal area environments. The last section draws together and emphasizes a number of the potential requirements discussed in the first two sections.

Potential operational requirements for STOL terminal area operations is a broad and involved subject. The limited resources available to this survey dictated that it be of a preliminary nature in that it is incomplete and that much of it is based on uncorroborated and, in some cases, meager documentation. Yet, taken as a whole, this survey does give an understanding of STOL's potential place within the air transportation system and does point to areas in which operational requirements may one day exist.

2.0 SURVEY OF POTENTIAL STOL MARKETS

2.1 Intercity Market

Large volume intercity air travel is the prime market open to STOL, but only if STOL can successfully reduce or avoid the congestion associated with the various large metropolitan jetports. The adverse importance of this lack of airport capacity for both the airlines and the cities involved is illustrated by the following statistics. Eastern Airlines records a $1 - million a week cost associated with nonproductive flying due to air traffic congestion (Ref. 6). In response, the airlines have begun to steer flights away from the cities associated with this congestion. As a result of this shift in airline traffic, the FAA has estimated that N.Y.C. lost over $50 - million in 1970 and will lose over $500 - million annually by 1980 (Ref. 7). This costly congestion is not restricted to N.Y.C. Five metropolitan jetports operated at saturation during peak hours in 1968, and it is estimated that this number will increase to twenty by 1980 (Ref. 8). Intercity air travel is a large, but artificially confined market in search of a method to break the terminal area constrictions.

There are two techniques for increasing the capacity of a metropolitan airport system. Either increase the acceptance rate of the existing runways or establish new runways, either at the local jetport or at some new site. The expected increase in demand for air travel requires that both of these techniques be implemented (Ref. 8). Gone is the day however, when an airport could be located solely for the convenience of either the traveler or the air transportation system. A new jetport, or even the expansion required of existing jetports to permit independent parallel CTOL operations, requires large amounts of additional land. Although the expansion of a metropolitan airport system may offer obvious advantages to the overall metropolitan area, as in the case of N.Y.C., the residential communities adjacent to any proposed expansion site have been seen to present a unified, emotional, vocal resistance to the selection of any such site. This popular resistance is the result of the expectation of increased noise, increased street congestion, increased taxation, and the suspicion of the pervading influence of any large jetport on the future growth of the surrounding residential communities. The statement that there is money to be lost or gained by the overall, surrounding metropolis due to airport congestion is not an effective argument. Community resistance together with land costs tend to keep the selection of an airport site unsettled or to force its final location into

the lightly populated areas outside the very metropolis that the jetport is to serve. STOL could be the solution to the problem of establishing more urban runways. First, since a STOL runway need be only one fifth the length of a commercial jet CTOL runway, the stolport requirement for land is only a fraction of that required for a jetport. The task of finding a site for a stolport in the metropolitan area agreeable to all therefore, should be less difficult. The second fact is that STOL can fly steeper flight path angles and is more maneuverable than a jet transport. In comparison with a jet transport's relatively long, straight, low approach and takeoff, a STOL is more able to fly around noise sensitive areas at relatively high altitudes and then to descend into the stolport in a relatively short distance. All of this implies that a stolport will at least be a less conspicuous, a less dominant member of the community. This is a necessary but not necessarily sufficient condition for community acceptance.

Expectation concerning community acceptance depends on whether the proposed stolport is to be located in the downtown area near the central business district (CBD), the suburbs, or at the existing jetport. In turn, each of these locations will have an effect on the competiveness of STOL with the existing intercity jet shuttle service. For although the introduction of STOL to intercity shuttle service is aimed at increasing the overall capacity of the system, the STOL may not be able to exist solely on the volume of passengers that would have preferred the short-haul CTOL transport, such as the DC-9, but could not find seats. The STOL must be able to hold its own with the short-haul CTOL in passenger appeal. In terms of competition, the CBD stolport offers the well publicized advantage of reduced city center to city center trip time as compared to the jet shuttle. Countering this operational advantage are the apparent difficulties encountered in overcoming community reaction in establishing the stolport and in overcoming the technical difficulties in its construction (Ref. 6). If the experience to date in attempting to establish a stolport along the Hudson River in N.Y.C. is indicative, a system of intercity CBD stolports will be slow in realization and will be nonuniform in result. To break the impasse concerning the CBD stolport, Robin Ransone of American Airlines has suggested that the surrounding community should be brought in as co-owners of the stolport in order to exercise control of its operation and to share in its profits (Ref. 5). In the case of the suburban stolport, the situation tends to be reversed. Stolport sites will be easier to find, although there will be many communities that take exception to this generality, and STOL will now tend to be in more direct competition with the jet shuttle. Potential stolport sites are existing general aviation airports, closed military air bases, and new land in the more sparsely settled sections in suburbia.

Depending on the overall distribution of stolports within a metropolitan area, the stolport could require a rapid transit link with the downtown area that will be suitably attractive to the air traveller. The final possible location for an urban stolport is at the existing jetport. Here there are two possibilities. The STOL runway can either be located as close as possible to the operational jet runway in order to minimize additional land requirements or at the farthest reasonable distance from the jet runway in order to facilitate the achievement of "independent operations" and thus to maximize safety and to simplify ATC. In the case of maximum separation, a high speed ground link with the jet facility may be required. Community reaction to the call for additional land to expand a particular jetport to accommodate STOL will be one of the prime factors involved in determining which of these two schemes is implemented. According to Scott Crossfield of Eastern Airlines, the implementation of stolports at the major Northeast Corridor jetports could be made with a minimal investment (Ref. 6). Countering this apparent ease in establishing a stolport, the STOL would be in direct competition with the short-haul CTOL intercity shuttle. Once the viable STOL markets have been identified, local conditions will determine which of these stolport sites, or combination of sites, will actually come into being in any particular situation.

The airlines foresee a quiet jetstol, with a passenger comfort equivalent to the short-haul CTOL transport and a 150 passenger capacity, as the most desirable STOL for intercity shuttle service. A jetstol fleet operating into a system of CBD/suburban stolports and metropolitan jetports with facilities for independent STOL operations offers the best chance for favorable passenger acceptance. If the viability of this system can be established on paper, then attention will be focused on a start-up system. The start-up system in turn, will have to hold its own against the short-haul CTOL transport, and could vary from the mature system in two significant ways. A jetstol suitable for a shuttle system can not be ready for service before 1978 (Ref. 5). This is primarily due to the prerequisite work that must be done to reduce the noise level of the fan-jet engine. If it is found desirable to establish an intercity STOL shuttle before that date, a suitable propstol could be available by 1974 (Ref. 5). The second significant difference concerns stolport facilities. At those metropolitan jetports that are found to be necessary to establishing the intercity STOL shuttle system, operations independent of CTOL may not be permitted. This could be a temporary start-up condition, or it may be found that independent operations at each jetport are not necessarily critical to the viability of the overall system.

In summary, both the air carriers and the cities are losing

money from the congestion caused by the lack of airport capacity. Among the air carriers, the short-haul lines suffer the greatest losses since they must necessarily spend a higher percentage of each flight in the congested terminal areas. A large scale market is available to STOL if it can significantly contribute to the required increase in system capacity. If STOL must depend on a system of intercity CBD stolports to provide the added advantage of reduced city center to city center trip time in order to exist in this market, then STOL may well have severe difficulties becoming the large scale system required to contribute to the relief of the growing congestion at the nation's metropolitan jetports.

2.2 Regional Jetport Air Feeder Market

The intercity STOL shuttle market is directed at improving an existing service. There are other potential markets available to STOL that are presently very small scale or nonexistent. The following description of these markets is primarily based on the work done by the Aerospace Corp. for the Western Conference of the Council of State Governments (Ref. 4).

Community reaction and land costs have had an increasing tendency to cause more of the new construction of metropolitan jetports to be located outside of the metropolises they are to serve. This has created a "Regional Jetport Air Feeder Market" in which STOL could be viable. The system would consist of a number of distributed small stolports within the metropolis and some sort of STOL facility at the remote jetport. The example of this type of service, which was studied by the Aerospace Corp., was a system to link the Los Angeles basin with the proposed Palmdale Jetport to be located in the Mojave desert and to be operational by the late 1970's. It was found that the best mix of STOL aircraft for this situation would be a combination of 20 and 50 passenger aircraft. They should be pressurized, turboprop STOLs with a cruise speed of 270 mph.

2.3 Intraurban Market

In addition to travelling to the regional jetport, the inhabitants of the large metropolis are finding an increasing need for a high speed mode of travel within the metropolitan area itself to counter the increasing sprawl and congestion of urban life. One competitor for this "Intraurban Market" is the STOL. The Aerospace Corp. found that the equipment and facilities required to service this market are virtually the same as those required by the regional jetport feeder service. It was determined that an Intraurban Market could be served in the

Los Angeles Basin by the addition of 50 passenger STOLs to the hypothesized Palmdale Jetport feeder system previously described.

2.4 Intrastate/Regional Market

While the city dweller has found himself increasingly restricted in travel due to sprawl and congestion, the country dweller finds himself increasingly isolated due to the curtailment of service. Airlines continue to seek routes connecting the more populous areas while railroad service has practically disappeared, all of which leaves bus service the increasingly dominant mode of transportation outside the metropolitan area. An "Intrastate/Regional Market" is based on a rapid and easily accessible air transportation system which would link the regional centers of business, commerce, government, and the rural community. This type of service could consist of a mixture of profitable routes serving demand and government subsidized routes aimed at inducing community growth or at providing easy access to semi-isolated communities. A significant source of demand for STOL operations may be from those growing cities that have reached the size to require the initiation of large scale, short-haul air service. Today, these cities find that they must pay a costly ante in the form of greatly expanded airport facilities to accommodate the existing short-haul CTOL transport. STOL could postpone this investment until these cities reach the size that requires direct, long range air service. The Aerospace Corp. focused on applying this type of service to relatively low demand, sparsely settled states. It was determined that CTOLs with passenger capacities of ten or less and a cruising airspeed of 250 mph would be sufficient in the three cases studied - Arizona, Idaho and Nevada.

2.5 Recreational Market

Another potential STOL market is the provision of regular shuttle service to isolated recreational areas from their associated regional jetports. A large part of the "Recreational Market" could involve service to mountainous ski areas. In terms of aircraft operations, this would mean flying at high altitudes and spending a relatively large percentage of the time under IFR conditions. The Aerospace Corp. example was based on serving a number of Rocky Mountain ski areas out of Denver. For this case, it was found that a 20 passenger STOL with a cruising airspeed of 270 mph would be a satisfactory aircraft.

2.6 Natural Resource Development Market

The fact that natural resource development occurs in remote regions, which typically lack adequate transportation service,

is the basis for a "Natural Resource Development Market." This market is characterized by large volumes of cargo, heavy bulky equipment, and some mail and personnel transportation. Service would tend to be on-call to a variety of locations under all weather conditions. The requirement for a short runway makes STOL a natural candidate for large scale development operations that can afford to build their own remote runways and for smaller operations that are situated near established runways. This market would be greatly expanded by the development of the air cushion landing system (ACLS) for heavy aircraft. This type of landing system permits an aircraft to land and to take off from any relatively level surface, irrespective of the soil load capacity. The Aerospace Corp. example centered on the Alaskan north slope oil fields. Here they found the need for a heavy lift C-130 type aircraft with an ACLS. A STOL capacity in this particular case was seen as desirable but unnecessary due to the relatively large, level areas at those development sites.

2.7 Potential STOL Terminal Area Environments.

These six potential STOL markets define three terminal area environments, each associated with a particular subset of stolport locations and possessing distinct operational characteristics. The first of these environments is associated with STOL operations into metropolitan jetports. The predominant characteristic of this environment is the high density of existing CTOL traffic. Coexistence with this traffic, while successfully competing with jet CTOL transports, will be the primary influence on establishing STOL operations in this environment. The second environment is associated with STOL operations into CBD/suburban stolports. In general, air access to these sites will be much more restricted than in the case of operating into a jetport. The configuration of the restricted access routes will be based on community reaction to noise and on the required clearance with respect to the structures in the area of the stolports. Coexistence with the air traffic into the area's jetport will be of relatively less importance to STOL terminal area operations in this environment. The third terminal area environment is associated with rural stolport locations. This includes all the possibilities from the remote stolport, associated with the Natural Resource Development Market, to the small city jetport, associated with the Intrastate/Regional Market. The constraints of noise, safety, and coexistence with CTOL traffic will continue to influence STOL operations but on a smaller scale in this less demanding terminal area environment.

3.0 STOL OPERATIONS IN THE TERMINAL AREA

This section contains a description of terminal area operations as they presently exist, of possible operational changes that my occur exclusive of the introduction of STOL, and then of potential operational requirements of STOL in the three terminal area environments.

3.1 General Terminal Area Operations

During an approach, each incoming aircraft must be merged with all other inbound aircraft while going through a number of descents, heading changes, speed changes, and possible delaying maneuvers. These events take place in a particular sequence and in relation to a particular terminal area approach route structure. A representative example, Figure 1, is the structure associated with runway 22L at Boston's Logan International Airport as of January 1, 1971. To complete the structure, the profile of the concurrent back course localizer and nondirectional beacon (NDB) approaches to that runway are shown in Figure 2 (Ref. 9). The following description of the sequence of events that occurs during an approach is a generalization of the sequence described in the FAA Advisory Circular 90-45 (Ref. 10):

Transition Phase - The Transition Phase is a link that connects the enroute structure to the terminal area structure and in which the aircraft begins its descent and adjusts its airspeed as commanded by the appropriate controller.

Holding Feeder Fix - This point marks the end of the Transition Phase and the beginning of the terminal area structure. If the structure is unable to accept an aircraft at its time of arrival, then the aircraft goes into a holding pattern at this point. Logan Airport, Figure 1, has six holding feeder fixes - Millis, Whitman, Duxbury, Skipper, Ipswich and Acton.

Initial Approach Phase - During the Initial Approach Phase the aircraft continues approaching the runway and descends upon command to an altitude close to the one from which the final descent will be initiated. In Figure 1, this phase terminates when the aircraft attains the commanded 3000 ft altitude. The distance associated with this phase is less than 50 miles and in the Logan example is on the order of 20 to 25 miles.

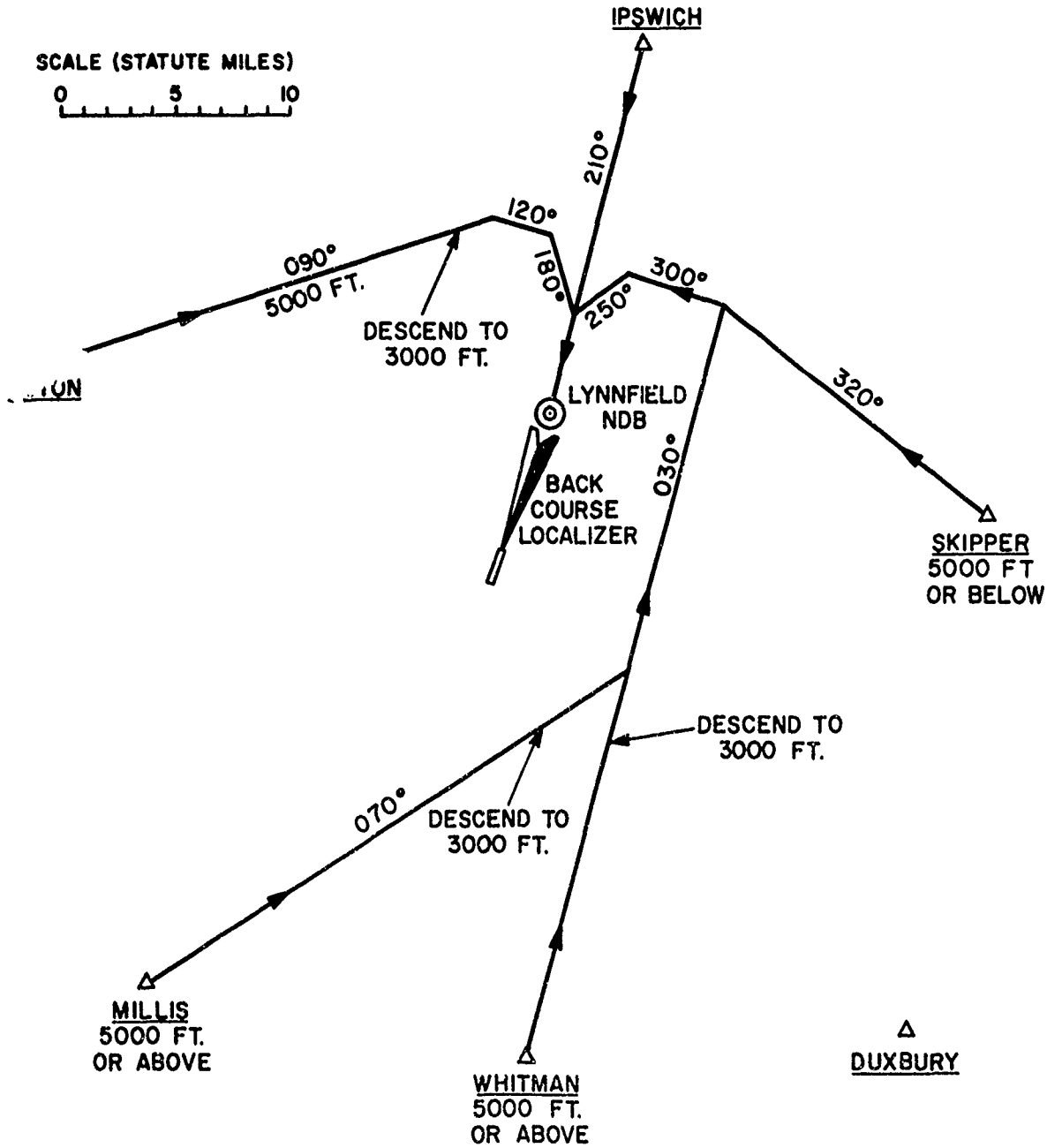


Figure 1 - The Approach Structure Associated with Runway 22L at Logan International Airport as of January 1, 1971

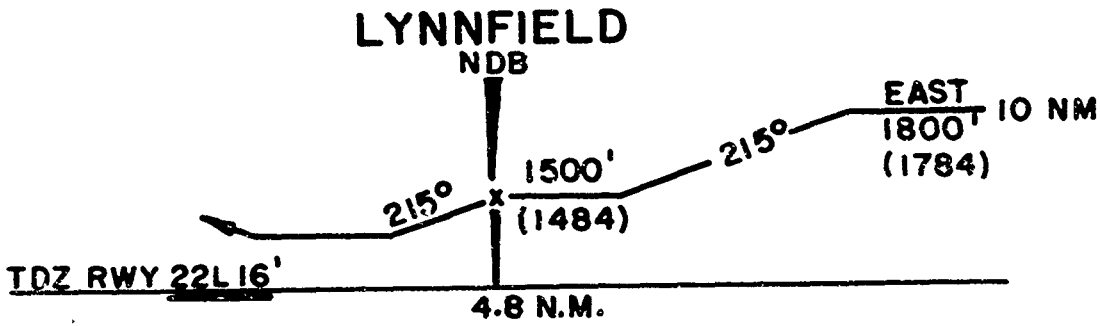


Figure 2 - Profile View of the Back Course Localizer/Nondirectional Beacon (NDB) Approaches to Runway 22L at Logan International Airport as of January 1, 1971

Intermediate Approach Phase - During the Intermediate Approach Phase the aircraft goes through its configuration change and attains its approach airspeed. In Figure 2, it is seen that the aircraft has continued its descent from 3000 ft to 1800 ft. The distance associated with this phase is from 5 to 15 miles.

Final Approach Phase - In the Final Approach Phase the aircraft makes its final descent to touchdown, Figure 2. Just prior to touchdown the flare maneuver is executed decelerating the aircraft to its final landing airspeed and rate of descent. This phase has an associated distance of 10 miles or less.

Let us shift from the viewpoint of the pilot to that of the ATC controllers, who have the task of merging all the incoming traffic into a single queue. During the Transition Phase, all the incoming air traffic from a particular sector is directed to converge on the associated holding feeder fix while maintaining vertical separation. The inbound aircraft enter the holding fix at the directed altitudes. The controller then meters the aircraft from the bottom of the stack with proper spacing. This sequence is somewhat informally called the laddering process (Ref. 11). During the initial and intermediate phases, the queues of the air traffic approaching from the various holding fixes are in turn, metered and spaced together to form the final landing procession. The merging structure for the Logan example can be seen in Figure 1.

The terminal area departure sequence is simpler and consists of the:

Takeoff Phase - The initial climb to gain 2000 to 5000 ft of altitude for safety and noise considerations.

Area Departure Phase - The post takeoff maneuvering to clear the terminal area and to enter the enroute structure via established procedures.

Large scale STOL operations will not necessarily be introduced into the existing terminal area as it has just been described. These operations are years off, and the terminal area is an evolving environment. Four FAA programs may play a part in this evolution. Three of these programs are concerned with increasing the safety of terminal area operations. One difficulty with the present method of handling aircraft in the terminal area is the relatively large number of near midair collisions that occur between high performance controlled aircraft and uncontrolled aircraft in the airspace below 8000 ft. AGL (above ground level) and within 30 miles of the airport.

The FAA programs that address this situation are the:

"Keep-Em-High" Program - which is directed at segregating turbojets from other aircraft by means of vertical separation whenever possible. This will be done by keeping the arriving IFR turbojets at an altitude above dense traffic as long as possible before descent and by permitting the departing IFR turbojet aircraft to make maximum rate climbs (Ref. 12). This program will be implemented at major jet terminals in the next several years.

"Terminal Area Control" Program - requires that all aircraft within a specified airspace surrounding an airport be controlled. As an example, Figure 3 shows the configuration of the terminal controlled airspace (TCA) recently put into operation at Atlanta (Ref. 13). This program too will be implemented at major jet terminals over the next several years.

"Safety Corridor" Program - The TCA configuration, as typified by Figure 3, contains airspace normally unused in terminal area operations. The most utilized airspace tends to be aligned with the airport runways. This program explores the consequences of reducing the TCA to a system of arrival and departure corridors in which turbojet and large turboprop aircraft would be confined. This concept is to be evaluated at Boston's Logan International Airport this year. Figure 4 (a) shows the preliminary configuration of the corridor and Figure 4 (b) of the system of corridors to be evaluated at that time. Arriving turbojets and large turboprops will enter the corridor at their cruising altitudes or 10,000 ft. MSL (mean sea level), whichever is lower. Upon departure these aircraft will remain in the corridor until reaching cruising altitude or 10,000 ft. MSL, whichever is lower (Ref. 14). Figure 4 (b) indicates that the existing holding feeder fixes would be shifted further out from the airport and that the approach structure, Figure 1, would be shifted to some higher altitude and would terminate at the entrance of the approach corridor. The price for this increase in terminal area safety is an increase in block time for those aircraft that must climb in a corridor in a direction away from the desired course and maneuver to enter a corridor on approach. Also, the longer common path may cause a reduction in airport capacity via the "funnel effect" (Ref 11).

In addition to these programs, the FAA has a broad program addressed to increasing the capacity of the ATC system by means of evolutionary stages of automation. The portion of this program directed to terminal area operations is called the Air

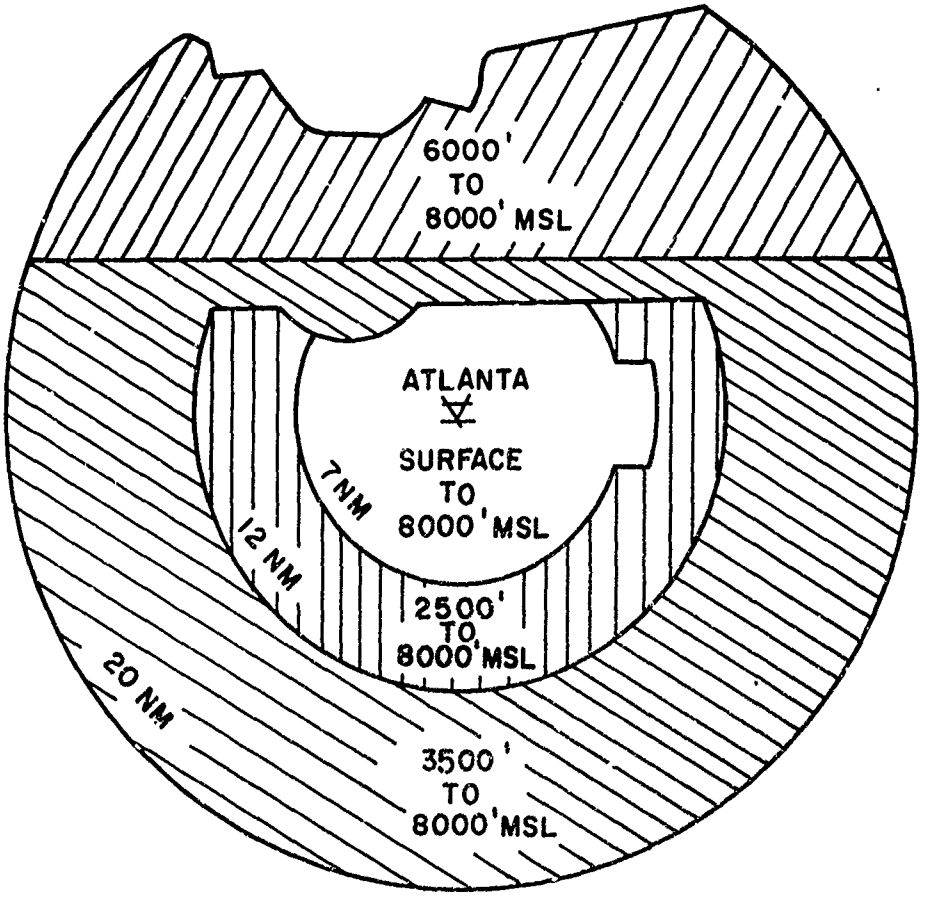


Figure 3 - Plan View of the Atlanta Terminal Control Area

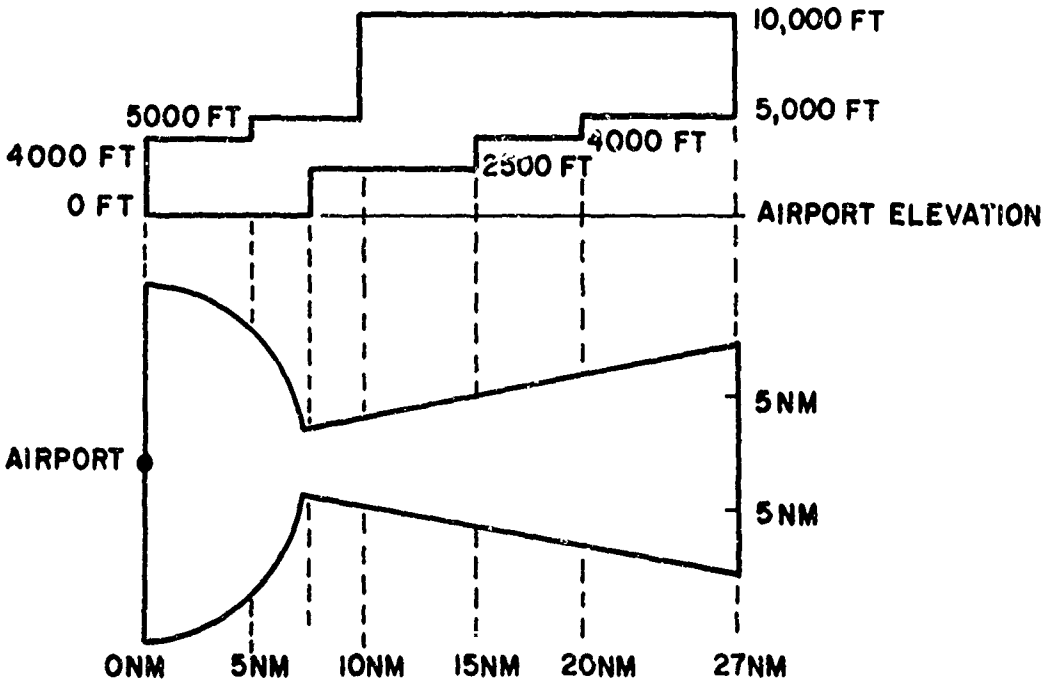


Figure 4 (a) - Preliminary Configuration of the Safety Corridor to be Evaluated at Logan International Airport

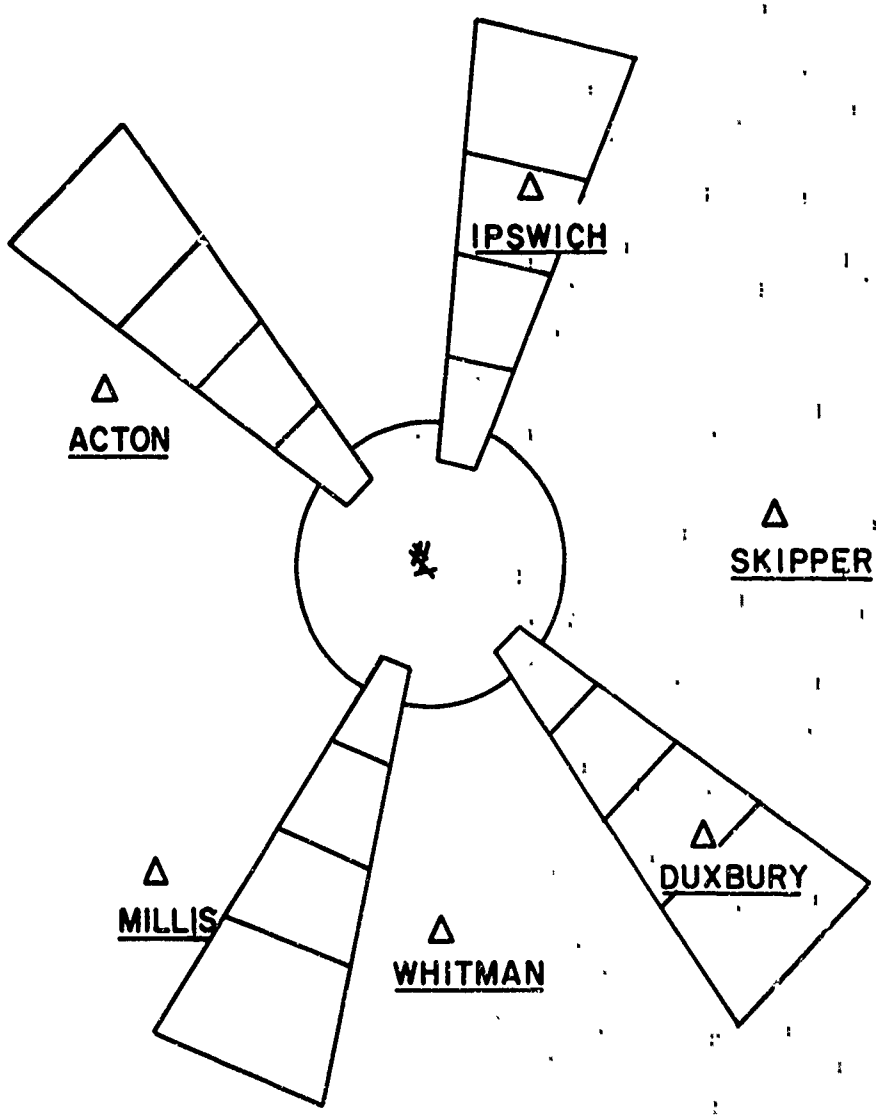


Figure 4 (b) - Preliminary Layout of the Safety Corridor System to be Evaluated at Logan International Airport

Route Traffic System (ARTS) Program. Although ARTS will have significant consequences concerning STOL operations in the terminal area, an examination of this situation is beyond the scope of this survey.

3.2 STOL Operations Into A Metropolitan Jetport-Stolport

At present, STOL operations into metropolitan jetports are small scale, local affairs that predominantly utilize the 19 passenger DeHavilland Twin Otter. Typically, the Twin Otters are mixed with the incoming CTOL traffic and use CTOL approach speeds onto a common runway. The alternative procedure of permitting STOL to make the final approach at its low design approach speed would reduce the acceptance rate of the runway by creating large gaps in the landing sequence whenever a slow STOL followed a fast CTOL (Ref. 15). However, replacing a CTOL by a STOL in the landing sequence is in itself an inefficient utilization of STOL's potential to increase jetport capacity. As stated in Section 2.1, in the case of large scale STOL operations, capacity can be increased by separating the STOL from the CTOL traffic and conducting parallel operations into parallel runways. This section is devoted to the description of these operations.

To tie the following discussion to an illustrative example, a set of representative STOL approach/departure paths is presented. This example of parallel operations into a metropolitan jetport is based on the approach/departure paths generated for use in the 1968 Eastern Airlines' STOL Demonstration flights into Logan International Airport. The STOL runway configuration used for the demonstration is shown in Figure 5. The entire set of approach paths is shown in Figure 6, and the accompanying set of STOL departure paths are presented in Figure 7. In the last two figures the dashed tracks are those of paths available but not flown, while the solid tracks represent those that were flown during the demonstrations. The STOL operating patterns for the entire demonstration were worked out with the objective of carrying out the STOL operations with a minimum of conflict with the parallel CTOL operations and of being compatible with safe operating practices and community acceptance. All planning was done on an IFR basis and the flight program was conducted under simulated IFR conditions whenever the existing criteria for traffic separation was met. The final form of these operating patterns were the result of a coordinated effort involving Eastern STOL pilots, the FAA, and the various Port Authorities.

During the demonstrations, wind conditions were such that the STOL landing and takeoff operations into Logan, Figure 5, consisted of five operations into runway S/4L, one operation into S/22R, and one operation into S/36. Figures 8 (a), (b),

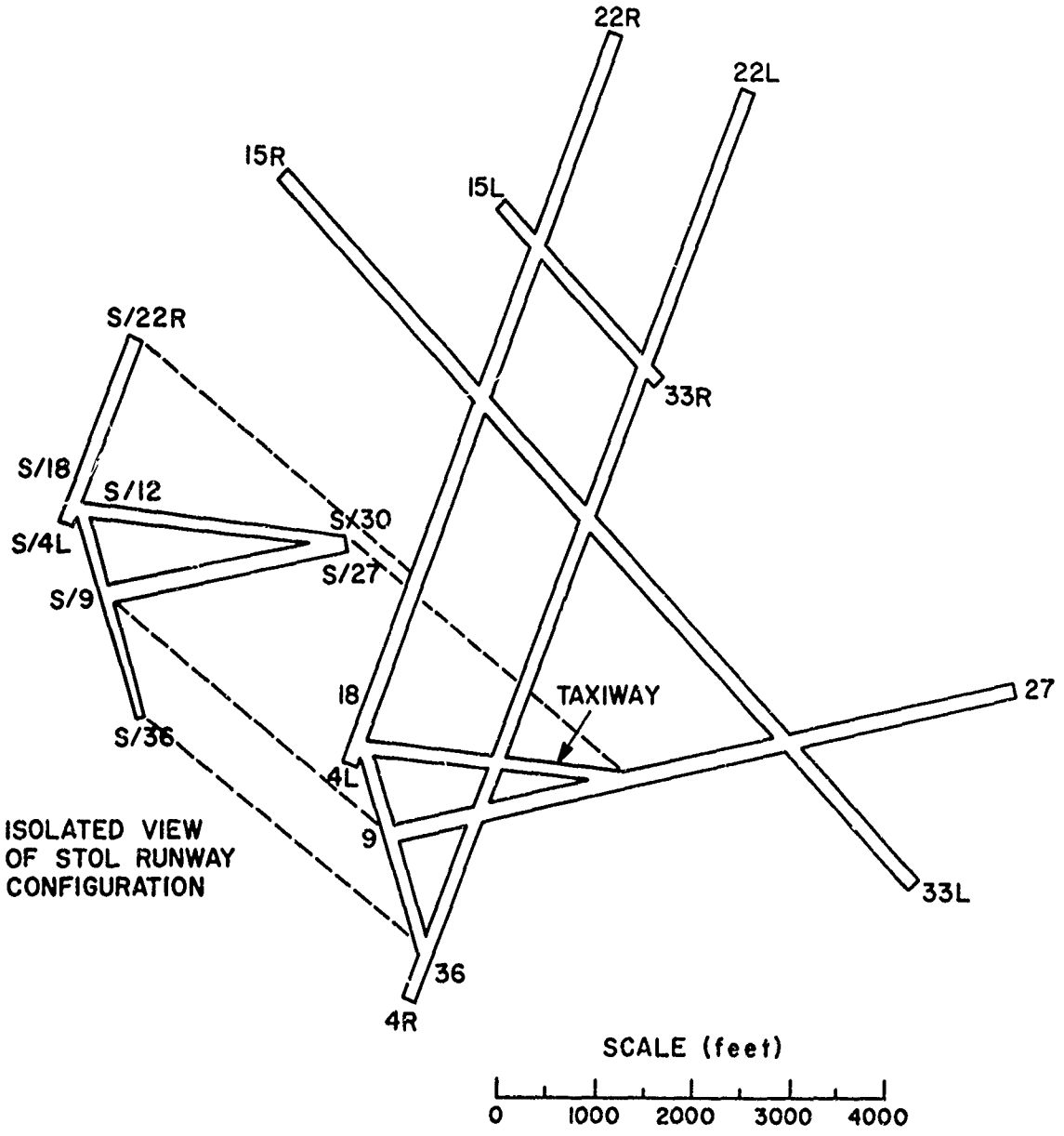


Figure 5 - The Runway Configuration at Logan International Airport Showing the STOL Runways Used for the Eastern Airlines' STOL Demonstration in 1968

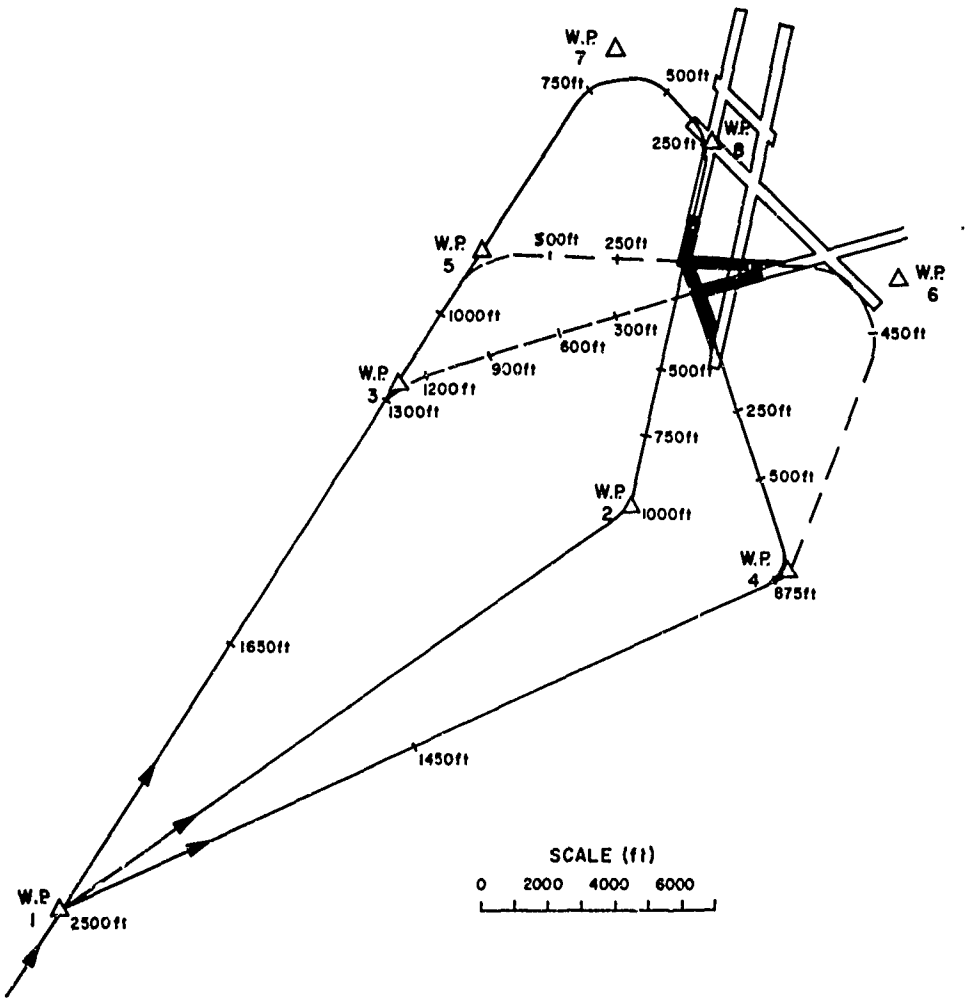


Figure 6 - The Set of Approach Tracks with Representative Altitudes Used for the Eastern Airlines' STOL Demonstration at Logan International Airport

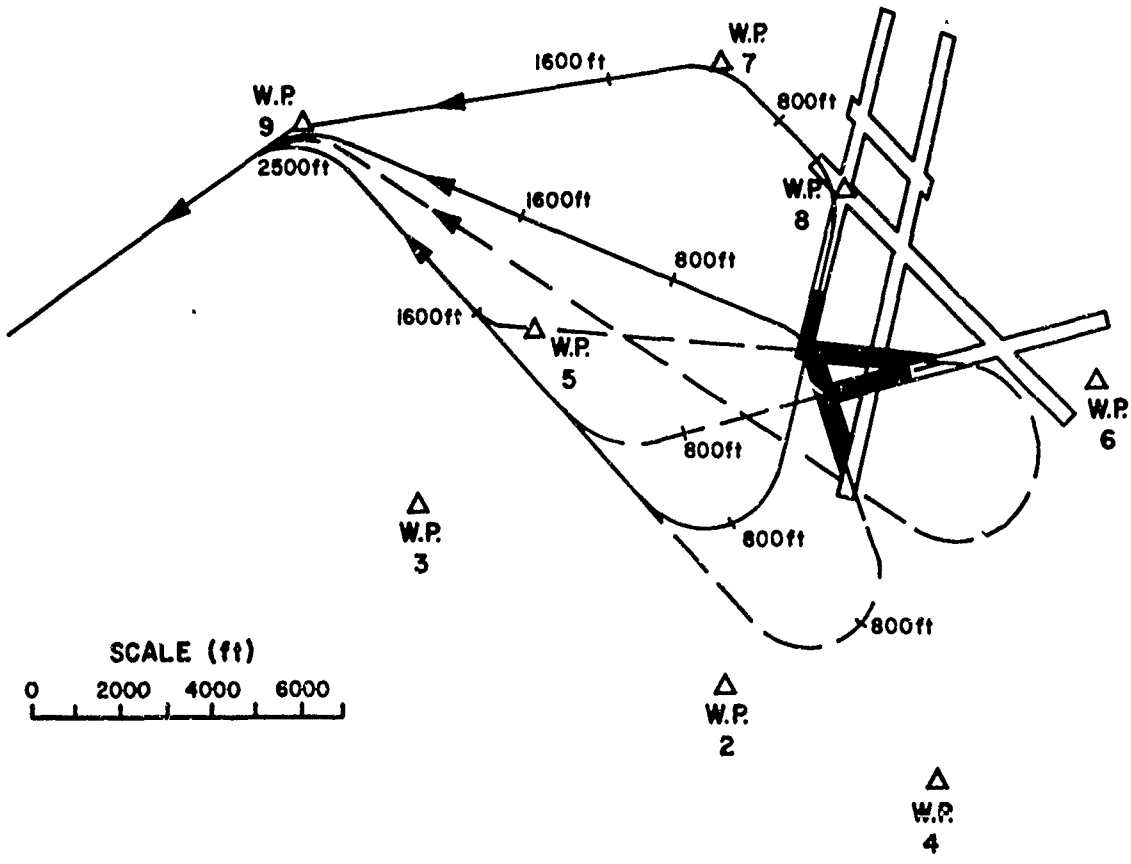


Figure 7 - The Set of Departure Tracks with Representative Altitudes Used for the Eastern Airlines' STOL Demonstration at Logan International Airport

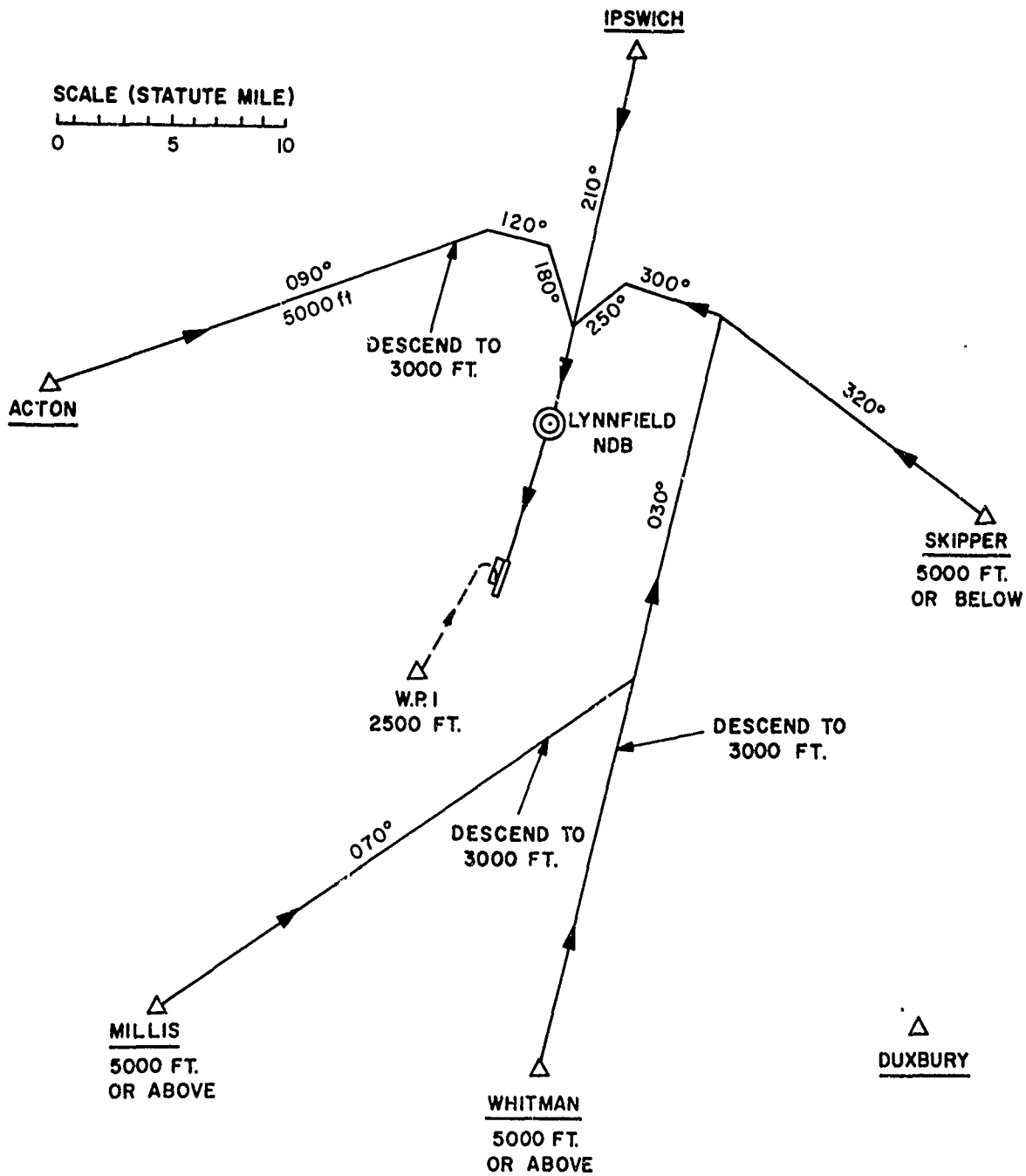


Figure 8 (a) - STOL Approach to Runway S/22R Made During the Eastern Airlines' STOL Demonstration Shown with a Representative Parallel CTOL Approach Pattern to Runway 22L

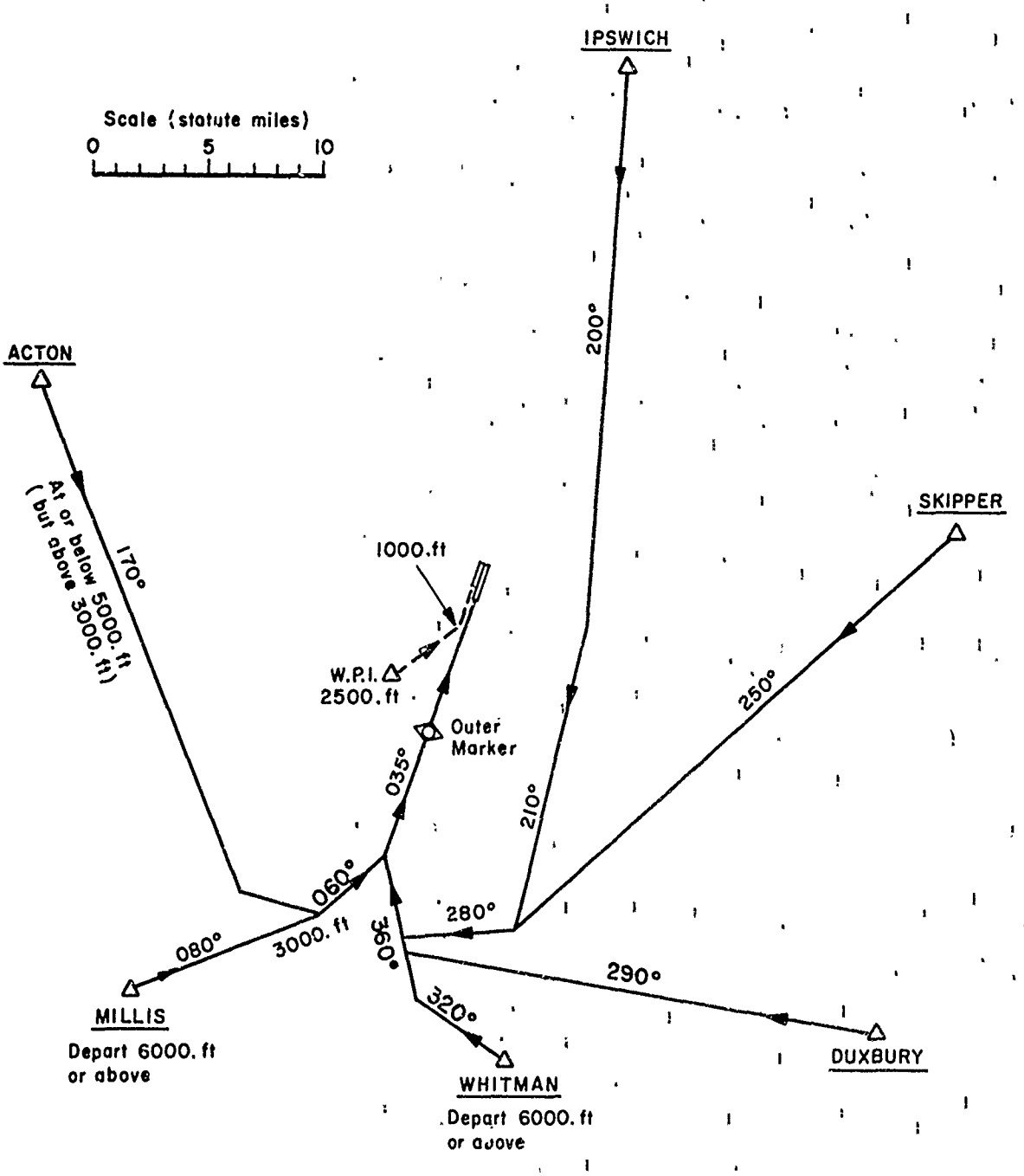


Figure 8 (b) - STOL Approach to Runway S/4L Made During the Eastern Airlines' STOL Demonstration Shown with a Representative Parallel CTOL Approach Pattern to Runway 4R

and (c) show each of the three STOL approach paths flown in relationship to representative approach paths of the parallel CTOL operations. The small number of STOL operations during the demonstration misrepresents the amount of effort and coordination that went into making these approach/departure paths representative of full scale STOL operations. It was concluded from the demonstration that dependent parallel air carrier operations into existing STOL runways at the demonstration airports could be conducted safely on an interim basis (Ref. 1).

Initial/Intermediate Approach Phases - The primary economic concern of the airlines in the terminal area is to minimize the flying time between the enroute structure and the gate. STOL, being more maneuverable than CTOL, may be able to operate into a STOL holding feeder fix considerably closer to the airport than the corresponding CTOL fix. This could reduce the average time required for STOL terminal area maneuvering resulting in a reduction in STOL block times (Ref. 1). The STOL terminal area approach structure would be similar to the existing CTOL structure except that it would be contracted with the holding feeder fixes more tightly grouped around the jetport. This tendency can be seen in the Logan example, Figure 8 (a), by comparing the STOL fix, WP1, with the CTOL fixes. In part, the proximity of the set of STOL feeder fixes to an airport will be determined by the volume of traffic that can be efficiently handled by the STOL approach structure. This efficiency will be determined by the percentage of STOL traffic held at the feeder fixes thereby causing an increase in STOL block times. The greater the volume of STOL traffic at a particular airport the farther from the airport will the STOL holding feeder fixes be located.

The superior climb/descent gradient capabilities of STOL as compared with CTOL can be used to increase operational safety by permitting the STOL traffic to operate at some vertical distance above the CTOL traffic within the terminal area. This would take place in the high density air traffic hub within some radius of the jetport. As the air traffic fans out with distance from the jetport, a point would be reached at which the two aircraft types would exist together, depending solely on horizontal separation. If safety warrants vertical separation, it would be initiated at some point in the Initial Approach Phase at which the incoming STOL traffic would reduce or terminate its rate of descent while the CTOL traffic continued to descend. Low flying, local STOL aircraft that operate into the jetport would probably coexist with the incoming CTOL traffic at lower altitudes before merging with the incoming STOL traffic. The Keep-Em-High Program will reduce the maximum practical radius from the jetport at which vertical separation could be initiated between the two aircraft types.

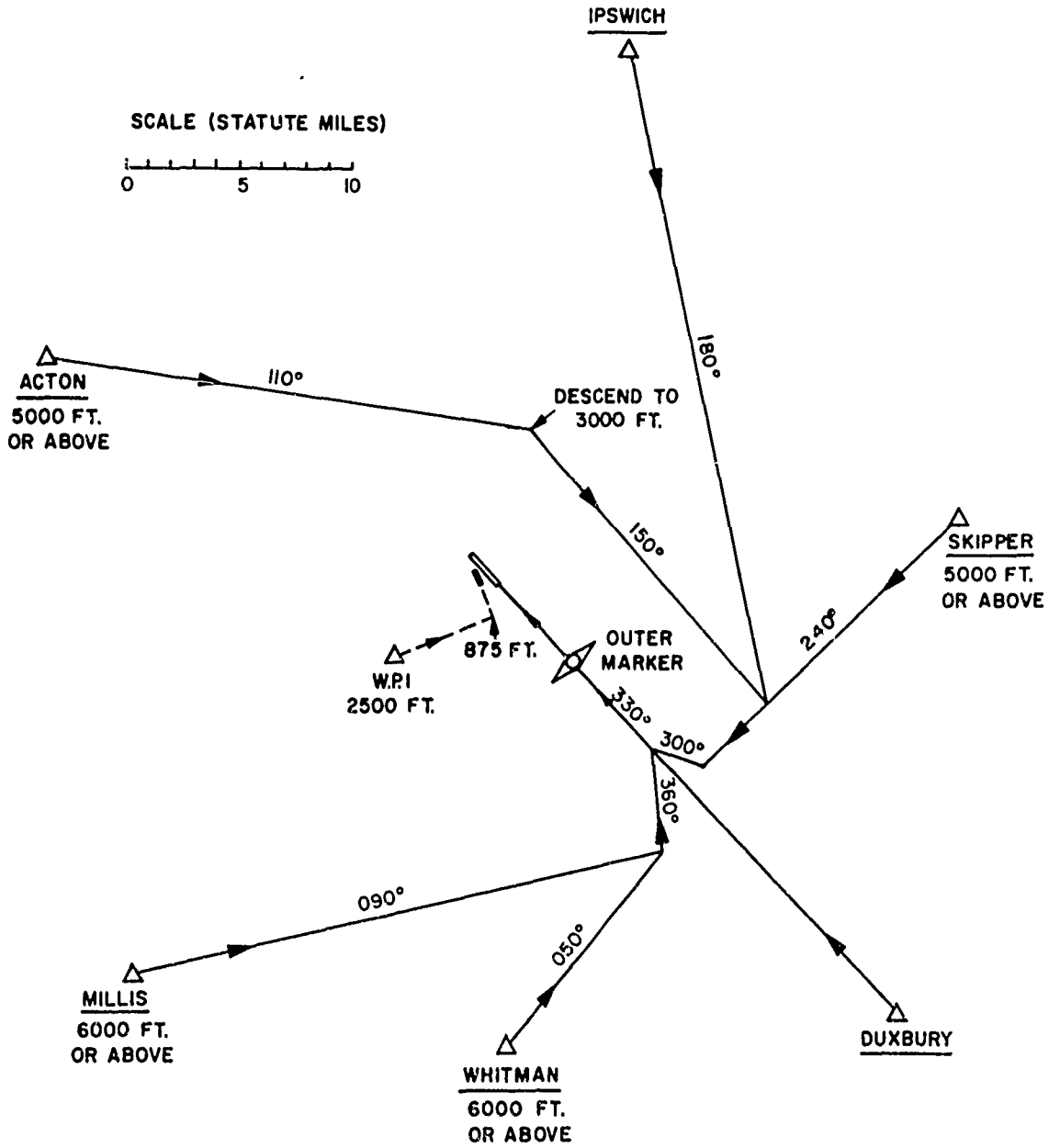


Figure 8 (c) - STOL Approach to Runway S/36 Made During the Eastern Airlines' STOL Demonstration Shown with a Representative Parallel CTOL Approach Pattern to Runway 33L

Final Approach Phase - A number of factors will directly influence operations in this phase - safety, economics, noise, and the location of the STOL runway. Safety will be in terms of insuring that the probability of one aircraft type violating the other's approach airspace is satisfactorily small. Economics will be in terms of the ever present airline need for efficient operations, and noise will be in terms of keeping within the limits of community acceptance. All of these will be influenced by the relationship of the STOL runway to the operational CTOL runway and their relationship to the surrounding community.

The relationship of the STOL runway to the operational CTOL runway determines the safety inherent in the parallel operation. Ideally the inherent safety of the combined operations will be sufficient to permit the independent operation of each runway. At present this requires that the parallel runways be separated by at least 5000 ft. If this condition is not met, then the parallel runway operations must be coordinated. It should be expected that coordinated or dependent operations will exist temporarily and perhaps permanently. Many of the dependent operations classified as temporary could be relatively long term. One case in which this could occur is at those existing jetports which have parallel runways that are separated by a distance over 2500 ft but less than the required 5000 ft. To these jetports the Alexander Report (Ref. 8) holds out the possibility that one day area navigation equipped aircraft, landing at airports equipped with scanning beam microwave ILS, will be handled independently into parallel runways separated by as little as 2500 ft. This could be a factor in the willingness of these jetports to build new STOL runways that meet the present standards for independent operations. In the event that the parallel runways are less than 2500 ft apart or that the runways intersect, vortices from large CTOL transports may dominate the operation of the STOL runway (Ref. 16). As an example, controllers presently require at least a two minute interval before an arrival flight can cross a runway used by a departing jet with a maximum takeoff gross weight of over 300,000 lbs (Ref. 17). Wake turbulence could be a problem for STOL even in the event of independent parallel operations. The situation in which a heavy intercity STOL is followed by a relatively small STOL many prove operationally analogous to the existing case for CTOL. The minimum longitudinal separation allowed between the two aircraft is increased.

In addition to the lateral separation between the runways, the touchdown points of the parallel runways may be separated longitudinally from one another - i.e. staggered, Figure 9. Longitudinal separation will normally exist between the parallel approach paths resulting from the 7.5 degree STOL glideslope as

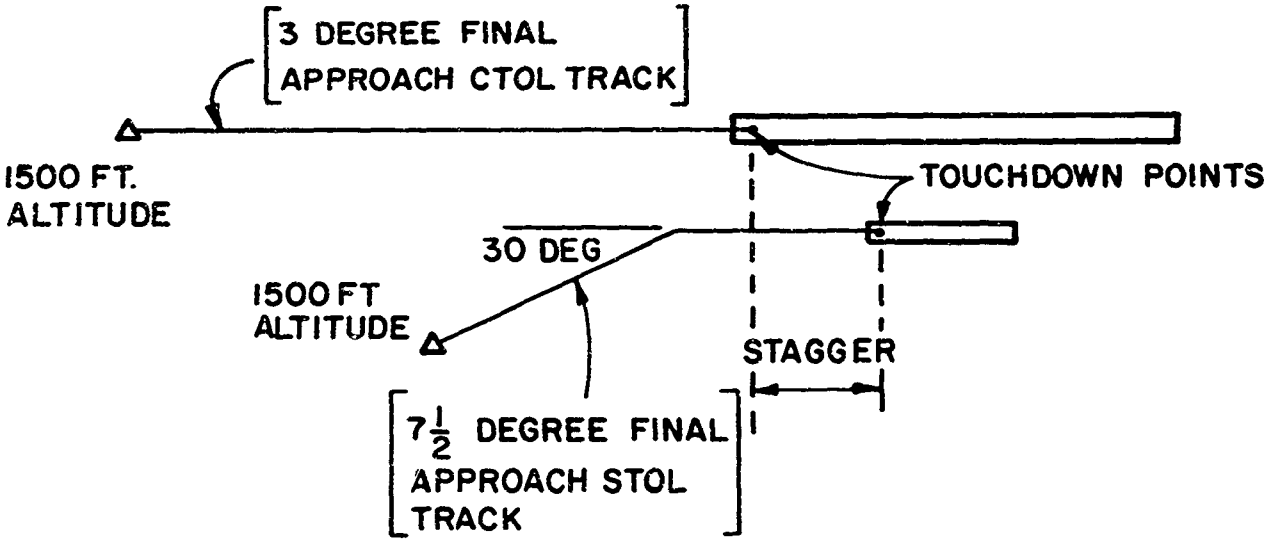


Figure 9 - Plan View of Parallel CTOL and STOL Runways Illustrating Stagger and a Final STOL Approach Containing a Heading Change

compared to the 3 degree CTOL glideslope. If the parallel touchdown points are not staggered, then the longitudinal separation between the two approach paths at any particular altitude will be approximately half the range to touchdown of the point on the CTOL approach path associated with that altitude. Operational safety will be increased if the basic longitudinal separation is increased by proper staggering of the runways.

The layout of the runways establishes the basic lateral and longitudinal separation of the parallel final approach paths. If safety requires additional separation for the critical runway centerline capture maneuver, then the STOL maneuver can be executed at some altitude above that of the CTOL capture maneuver. The NAFEC simulation study concerning the introduction of VTOL and STOL traffic into the Los Angeles International Airport used a vertical separation of 1000 ft to increase the operational safety of already independent operations (Ref. 18). One additional variation may be possible to increase operational safety. Lateral separation between the final approach paths can be increased by having the STOL final approach course angled to the runway centerline, Figure 9. In this case, a tradeoff affecting safety would exist in that STOL would execute the final runway alignment maneuver with less separation from the CTOL airspace. This situation could be particularly critical in the event of a STOL missed approach.

The relationship of a runway to the surrounding community can restrict and, in some cases, prevent its use. This is the case at Logan International Airport, runway 22R, which is normally restricted for landings from the present generation of relatively unmaneuverable CTOL air carriers. The more maneuverable STOL may be able to fly other than straight-in approaches operationally in order to be acceptable to the community. One example of such an approach is shown in Figure 8 (a). The 180 degree final descent path was used to open the normally restricted Logan runway, 22R.

The coordination of parallel operations is the responsibility of a controller. In independent operations into a runway, a controller meters and spaces the incoming aircraft. This coordination task is most difficult at runways operating near or at saturation. In the case of dependent operations into a set of runways, the controller has the additional task of coordinating the coupled operations. 4-D guidance, either ground-based or airborne, can greatly increase a controller's powers of coordination by giving the controller a direct means of controlling each aircraft's position with respect to time. Whether STOL proves to be viable or nor, the pressure of the continuing growth of CTOL operations into the metropolitan

jetport will one day require the coordination that 4-D guidance can provide. If STOL is successful in establishing large scale operations into the metropolitan jetport, the need for and demands on this coordination will indeed be even greater.

Takeoff and Area Departure Phases - The takeoff capability of the Breguet 941 has been established by flight tests conducted by NASA/Ames. The aircraft is capable of a 12 degree climb angle while maintaining an airspeed of 80 kts. In a spiral takeoff, the aircraft is capable of initiating a 20 degree bank angle at 150 ft altitude, resulting in a spiral diameter of less than 4000 ft, while maintaining 80 kts. It was concluded from these flight tests that these takeoff maneuvers were easy and comfortable to make (Ref. 19). Assuming that this takeoff performance is representative of future, commercial STOL aircraft,this steep climb-turning capacity will be used to satisfy a number of constraints. Safety can be increased by promptly providing increased lateral and vertical separation with respect to departing CTOL traffic, particularly heavy transports with their potentially dangerous wakes. Noise complaints can be reduced by gaining the initial 2000 ft altitude quickly and by avoiding particularly noise sensitive areas. Finally, reduced block times are possible by promptly turning to the direction of destination. Representative terminal departure routes are shown in Figure 7. The NAFEC Los Angeles International Airport study concluded that the steep climb capability of STOL aided in formulating efficient control procedures and in the integration of STOL traffic in the terminal area (Ref. 18). As in the case of landing, takeoff operations may be dominated in certain situations by the wakes of heavy STOL and CTOL transports.

3.3 STOL Operations Into a CBD/Suburban Stolport

The availability of metropolitan stolport sites, particularly near the downtown central business district (CBD), will be restricted. This condition is due to stolport site requirements for access to a ground transportation system and for access through the surrounding structures to the airways, as well as being due to the community-based arguments summarized elsewhere. The capacity of STOL to safely operate into stolports with restricted access will directly affect the number of sites that can be considered from the already limited number available within each metropolitan area.

Stolport access will tend to be in the form of corridors. The bounds on these access corridors will be defined in terms of various constraints. First, obstacle clearance must be achievable and maintainable in an environment that has undergone and continues to undergo vigorous vertical growth. Second,

community reaction to aircraft noise varies with the type of community, but it has been found that virtually all noise complaints cease for an aircraft operating at and above 2000 ft. The noise characteristic of the aircraft considered was 100 PNdb at 250 ft (Ref. 20). However, it is to be noted that a large, quiet aircraft operating at low altitudes may still excite complaints from the community due to the "scare" effect of its closeness. Noise and clearance constraints will define a corridor primarily associated with the 2000 ft descent to and ascent from the stolport. The constraint that STOL traffic in this terminal area environment not interfere with the air traffic into the local jetport(s) has the potential, in the extreme case, of extending these corridors to the limits of the metropolitan area. One extreme case is New York City, with its overhead air traffic from three major jetports. A study of this situation, in which four CBD/suburban stolports were hypothesized in and around Manhattan, was made by the Aircraft Instruments Laboratory under contract to the FAA and used by the Alexander Committee (Ref. 8). In this example, overhead traffic restricted STOL operations to the airspace over the Hudson River and below 2000 ft until they were well outside the Manhattan area. In the event that intraurban STOL traffic existed in such a situation, it possibly would be restricted to corridors for its entire operation. The general necessity for this type of extensive corridor system is unkown. Whatever the requirement however, the Keep-Em-High Program, the Terminal Area Control Program and the Safety Corridor Program could reduce it by reducing the number of and by concentrating the distribution of low flying jet aircraft in the jetport terminal area environment.

Initial/Intermediate Approach Phases - Examples of the terminal area structure for a large scale, mature STOL system, consisting of a number of stolports distributed throughout a metropolitan area, are not available. However, as in the case of the jetport, the terminal area structure will have to permit metering and spacing, delay, missed approaches, and the overall efficient handling of the traffic. If extensive corridors are present, then some or all of these functions would take place within the corridor system. Low altitude operations over any metropolis, particularly around the downtown areas, will require increased precision in flight path control. Precise flight path control requires accurate knowledge of aircraft position. However, the existing source of navigational information, the VOR signal, can exhibit degraded performance over metropolitan areas and can be restricted by line of sight considerations below 2000 ft altitude. Large scale STOL operations in this environment may require an upgraded navigational signal.

Final Approach Phase - Noise and clearance constraints will tend to keep the incoming STOL traffic above at least 1500 ft for as

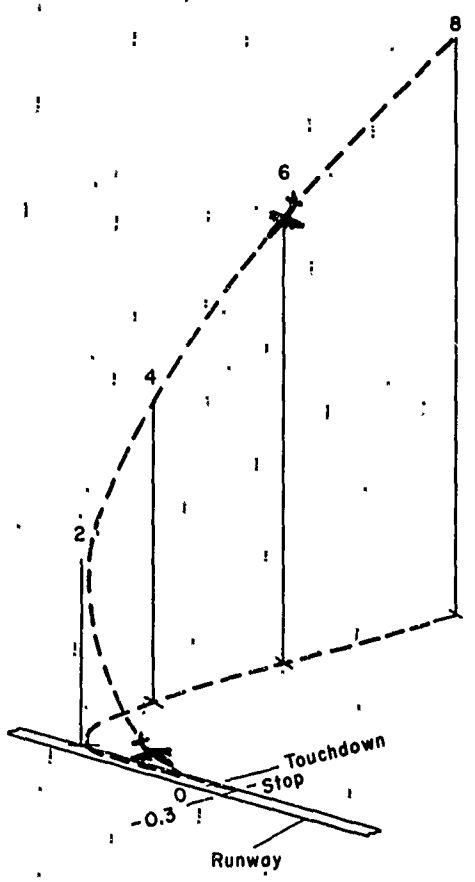
long as possible during the approach. For simplicity, it would be ideal if the final approach could always be of the straight-in, 7 1/2 degree glideslope variety. However, STOL may be required to operate into stolports with various categories of restricted access. A knowledge of STOL's ability to do this is critical to the original question as to which sites can be considered for stolport locations.

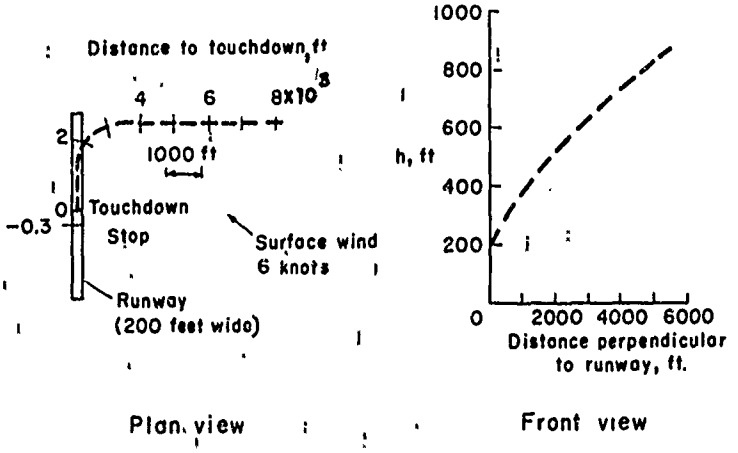
A number of variations on the straight-in approach exist. The simplest and probably the most common situation would be the one in which a heading change is required during the final descent. A heading change of 20 degrees has been found to be operationally acceptable by the FAA, provided that it is executed after breakout at or above 200 ft (Ref. 21). A 90 degree VFR approach, Figure 10, was conducted by NASA/Ames during a series of Breguet 941 flight tests (Ref. 19). It was concluded that this was an acceptable approach if the alignment maneuver was made at 300 ft altitude. Executing the turn at 200 ft did not permit sufficient time for the pilot to make final corrections before touchdown. Another possibility is that the final descent corridor may not have sufficient length to permit a standard 7.5 degree approach from 1500 ft altitude. If the available approach range is only somewhat shorter than the approach range required for a 7.5 degree descent, then the ability of STOL to execute a steeper approach or a segmented glideslope approach are two possibilities to be explored. In cases in which the approach length for the final descent is greatly abbreviated, the ability of STOL to execute a maneuver similar to the 360 degree turn maneuver shown in Figure 11 would be necessary. Although the chance that this maneuver would be found operationally feasible in the foreseeable future is remote, it was flown under VFR conditions by NASA/Ames during their series of Breguet 941 flight tests (Ref. 19). The primary problem in executing this approach was correcting for crosswinds.

Takeoff and Area Departure Phases - Departures will be with respect to the same demanding environment as described for arrivals. The steep climb-turn capacity of STOL will be used to get the departing STOL traffic to 1500 ft as soon as possible while following a ground track that avoids noise sensitive areas and obstructions. Again in certain situations, STOL traffic may be required to operate in a corridor system.

3.4 Overall STOL Operations In The Metropolitan Area

If STOL realizes its potential in the four major urban-based markets, there will be a profusion of STOL traffic criss-crossing the airspace above each metropolis. How will this number and variety of STOL operations in conjunction with the area's CTOL operations be accommodated within the confines of a





Plan view

Front view

Figure 10 - A Low Altitude 90° Turn Final Approach

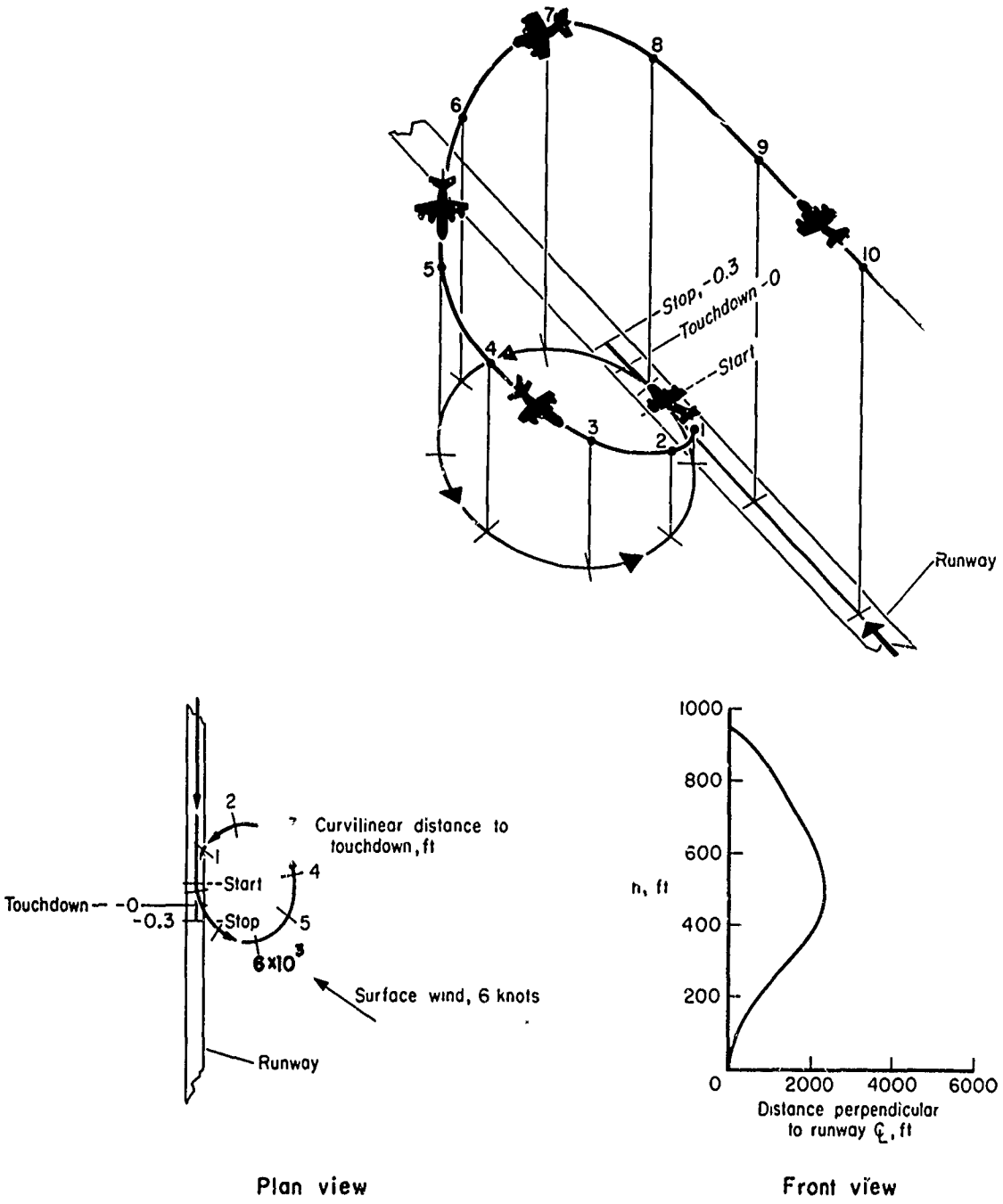


Figure 11 - A 360° Turn Final Approach

single, major metropolitan area? The air congestion that STOL seeks to relieve by making more runways available to intercity air traffic may be more than accounted for by the amount of air traffic generated in servicing these other markets.

The accommodation of the ATC system to efficiently handle these potentially numerous and diverse operations within a single metropolitan area should be stated within the context of the FAA programs to upgrade the ATC system, primarily through the ARTS Program. The determination of potential operational requirements of STOL in this particular terminal area environment is beyond the scope of this survey.

3.5 STOL Operations Into A Rural Stolport

The rural stolport, with its relatively light air traffic densities and modest noise and clearance constraints, will be the least demanding of the three terminal area environments. As such, the introduction of STOL into this environment should cause no general operational difficulties. In the event that STOL is to operate into a rural jetport, the STOL traffic would be mixed with CTOL traffic and would approach the common runway at near CTOL airspeeds. In two situations, navigational problems may exist. Both the Natural Resource Development Market and the Recreational Market, with their demands for all weather operations in remote and mountainous regions respectively, would require precise guidance in areas that may be expected to have low quality navigation signal coverage.

4.0 PARTIAL LIST OF POTENTIAL OPERATIONAL REQUIREMENTS OF STOL IN THE TERMINAL AREA

To highlight the potential operational requirements discussed in the previous two sections, Figure 12 is presented. This figure is to be understood in the context of the last two sections and is not meant to be self-explanatory. Its purpose is to emphasize a number of potential operational requirements, the situations in which they may occur, and to present a number of terminal area maneuvers that could, if shown to be feasible, be used to accommodate these requirements.

The list of potential markets available to STOL is shown on the left of Figure 12. If the economic viability of large scale STOL service is established in any one of these potential markets, the airlines will have an operational requirement to operate STOL into one or more of the stolport locations listed in Column I. In the case which the proposed application requires large scale STOL operations into a metropolitan jetport-stolport, the airlines must further determine whether the economic viability of the proposed application permits mixed operations or requires STOL operations to be conducted in parallel with the CTOL operations; and if parallel operations are required, can they be dependent or must they be independent of the CTOL operations. The introduction and sustainment of large scale STOL operations in the various terminal areas may encounter significant operational constraints. Coping with these constraints, listed in Column II, may influence the economic viability of proposed STOL applications and presents a set of potential operational requirements. Column III presents a set of possible operational maneuvers that may permit STOL to cope with the operational constraints listed in Column II. These maneuvers are based on STOL's basic maneuverability and ability to fly steep gradients. A knowledge of the practicality of these maneuvers and the feasibility of modifying current ATC procedures to incorporate them will, in turn, be useful to the airlines in their determination of the original question as to the actual economic viability of their various proposed STOL applications.

With time, each of these potential operational requirements will be found to be indeed a requirement, or to be an operational preference, or to be of no operational consequence. Estimating the final gradation of these potential operational requirements and seeking out the remainder not found by this survey are candidates for a follow-on effort.

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