Conventional Aircraft Possibilities for Boston–Washington Service

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Vertical-takeoff aircraft will undoubtedly offer much improved block time, especially between city centers, for the passenger of the future. Before applications of the conventional airplane are abandoned, however, we should examine what it might still contribute, especially when designed specifically for short-range operations. Examples are given where profitable, competitive airline operations have resulted in improved service, reduced fares, and dramatic growth in the airline share of the total transportation market. It is toward promoting growth in the airline share of that total transportation market that this paper is directed. Conventional aircraft can be used to penetrate the bus, railroad, and automobile market in the immediate future while we await the VTOL developments of the late seventies.

Introduction

TODAY, we see a Washington–New York–Boston corridor area that covers six states and parts of three others, wherein live almost 50 million people. This area contains roughly one-fourth of the total population of the United States, yet it is only 395 miles long.

All told, there are 28 cities with populations over 90,000 in this corridor area. These cities account for 15 million of the area's 50 million people. The remaining 35 million people can be identified as suburban, small city, or country residents. Undoubtedly this market of potential airline travelers is a prime one if we can offer something to entice them from the auto, the bus, or the train, or to induce them to take trips currently not contemplated. The areas where these people live, exclusive of the large cities, average about 400 people per square mile for the entire suburban, small city, or country area.

W. H. Johnson of Interpublic Inc. made a comment in a recent AIAA paper that is most apropos to our subject when he said, "The airline industry probably knows more about its customers and less about its noncustomers than any major industry in America." With two-thirds of the population in this northeast corridor living outside the large cities, it may well be that we are deluding ourselves when we presume that the future airline traveler cares very much about traveling to and from downtown locations, the requirement that generates the stated need for vertical-takeoff vehicles. Much of the potential airline market undoubtedly would rather drive to an uncluttered perimeter airport with good parking facilites than drive into the heavily congested streets of a large city.

Statistically, the northeast corridor area is unique. The trend data of airline passenger miles as compared with railroad passenger miles in the United States as a whole have seen air travel grow from being equal to rail travel in 1955 to where, in 1965, it was three times the rail passenger miles. The northeast corridor, on the other hand, still has railroad passenger miles leading airline passenger miles by an estimated factor of over two. Obviously, airline travel has not effectively competed with rail travel in the minds of the traveling public in this area.

The goal the airplane or airline industry must have is one of providing the most desirable service possible while retaining good profit ratios. We should sell speed and economy, not accommodations or luxury, if we are to expand our share of the total transportation market. And we must be cost-competitive if we are to entice our customer from his automobile, from the train, the bus, or even from his home.

It is a fact that 50% of the population of the United States is 25 years of age or under, a market group readily eager to move and move quickly. This group has grown up with the jet era. Yet, today, the airline industry still has enticed only 40% of the U.S. population to fly. In any one year this percentage is much lower; for instance, last year about 11% of the total U.S. population flew by commercial airline. In a recent study it was found that, in that year, 52% of the U.S. population did not travel, by any means, a distance of more that 200 miles from home. It has been reported that 60% of the population of the United States has never stayed in a hotel. The young people of this country will greatly change these figures, and historical airline business growth rates are not indicative of what will happen.

Much has been published about the northeast corridor transportation problem of the seventies, about the passenger, and about his travel habits. It is my opinion that the airline business potential for the seventies is enormous and one we can cultivate if we put our best economic foot forward and provide the environment for this market to develop.

The Corridor Today

Figure 1 depicts the major business airline routes today between 11 of the northeastern corridor cities where the an-

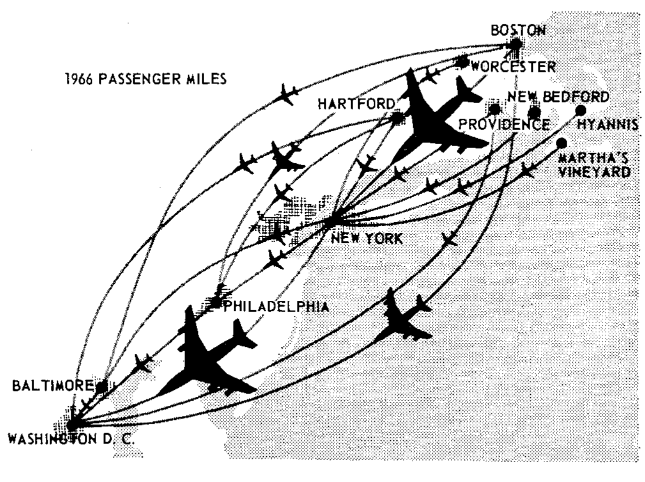

Fig. 1 Business levels—1966 passenger miles.

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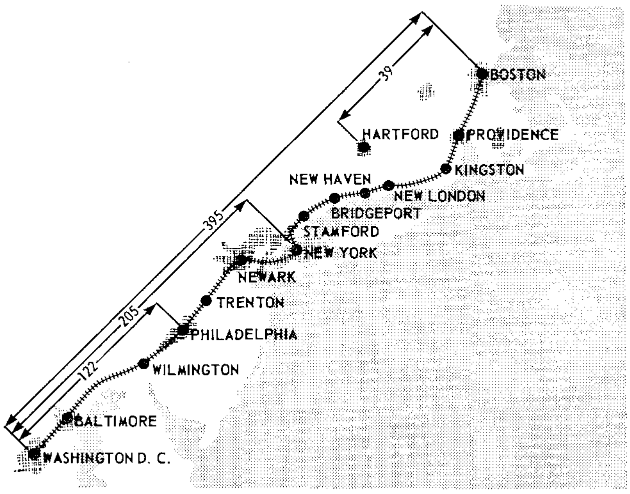

Fig. 2 Northeastern corridor design ranges.

nual passenger miles of business are portrayed by the relative wing span of each airplane. The dominance of the Boston–New York, Washington–New York, and Boston–Washington markets is obvious and, of course, well known to all of us.

Figure 2 shows this same corridor with the city areas, the railroad competition, and some airline distances indicated. In this study we will keep in mind the distances shown on this chart: Boston to Washington is 395 statute airline miles, Washington to New York is 205 miles, Washington to Philadelphia is 122 miles, and Boston to Providence is 39 miles. Also note the present Pennsylvania/New Haven Railroad through-train service from Washington to Boston, with 13 stops en route.

Figure 3 presents a comparison of airplane and train times plotted against range for this corridor. Today's train schedule shows 9 hr and 45 min for the through-train service that includes the 13 stops shown in Fig. 2. The circled point at $2\frac{1}{4}$ hr time from Boston to Washington is what the Department of Commerce says a 200-miles/hr nonstop express train could do. A time of 5 hr is the goal for 1968. Towards this end they are generating momentum for the expenditure of from $\frac{1}{2}$ to \$2 billion. The airline industry should compete for these dollars.

On the other hand, nonstop airline service of but 1 hr is already possible and, if desired, one-stop or multistop service that stays well under the very best targeted railway express times quoted can be offered. Rapid refueling and quick, efficient passenger unloading and loading times are vital, but many short-haul operators have demonstrated time and time again that this can be done.

Figure 4 shows the daily departures available out of Boston for New York, Washington, Philadelphia, Hartford, and Providence by air and by train. In essence, six airlines compete with each other while competing with one railroad. There are 17 airline departures for each train departure. A quick look at this market does not indicate that a larger number of

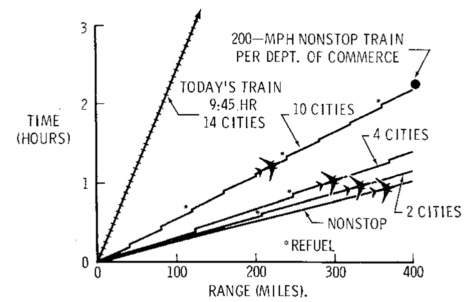

Fig. 3 Time comparison.

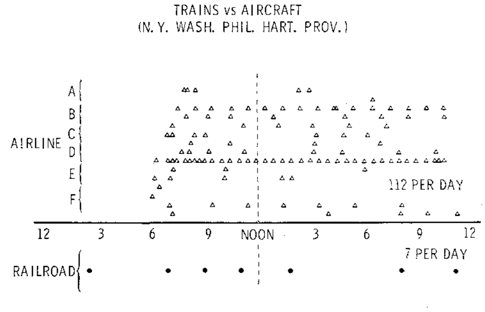

Fig. 4 Boston departures.

airline departures would increase the airline share of the market. Conversely, fewer departures by fewer airlines and to more destinations (by adding stops) could be in the best interests of a large part of the traveling public, if fares were reduced at the same time.

Figure 5 shows a plot of fare per trip divided by airline-trip distance, or cents/passenger mile, against trip distance, shown as range. The distances between the same city pairs noted earlier are indicated on the abscissa. One-way coach fares between these city pairs are compared for today's airplane and train. Note the large rise in airline fare/mile at the shorter distances. Obviously, the actual fares shown for today's conventional aircraft are not competitive with rail

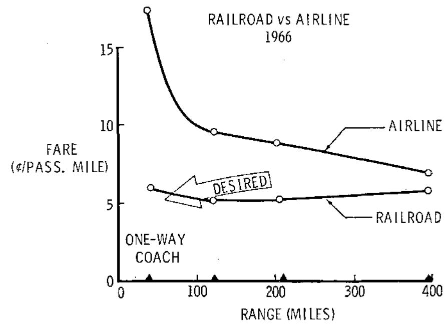

Fig. 5 Fare variations.

fares except at the longer ranges. A more desirable fare variation for airlines is depicted by the large arrow. If the fare/mile can be held constant or moved in the direction shown by the arrow, speed can be offered for free, as compared with the train. This should be our objective in air transportation. How then can we improve our fare offering?

Reference Studies

Recently, the Massachusetts Institute of Technology, under the sponsorship of the Department of Commerce, completed a study on short-haul air transportation as foreseen for the 1970's. The initial study results, copied directly from the MIT report, are shown in Fig. 6. Five basic types of vehicles, all carrying 80 passengers, were compared for various design ranges. The air-maneuver and ground-maneuver times for

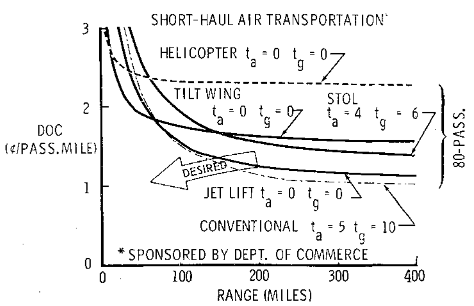

Fig. 6 MIT study.

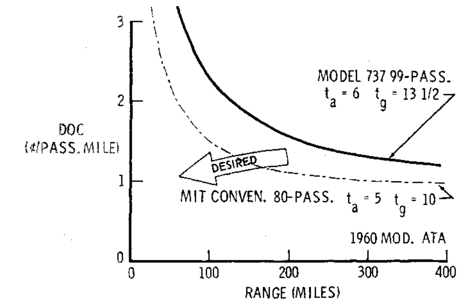

Fig. 7 Model 737 vs MIT conventional.

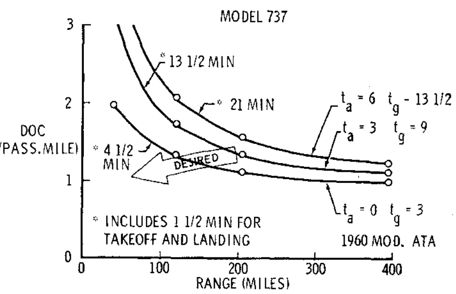

Fig. 9 Effect on DOC of air- and ground-maneuver time.

these vehicles, as used in these studies, are noted: the helicopter, tilt-wing aircraft and jet-lift vehicle were assumed to be able to operate with no air- or ground-maneuver penalities on block time; the STOL (short takeoff and landing vehicle) was assumed to require 4-min air-maneuver and 6-min ground-maneuver time; and the conventional vehicle was assumed to require 5-min air-maneuver and 10-min ground-maneuver time. The helicopter presented here is a 1975-technology vehicle incorporating dramatic improvements over today's engine and airframe maintenance, in addition to other improvements. All told, the operating costs forecast for the 1975 helicopter, when corrected for vehicle size, are 40% of those experienced by today's commercial operators. It must be recognized that much work lies ahead to accomplish the economic level depicted here, and that the 1975 time goal may be premature. To indicate the improvement that must be accomplished, the direct operating costs of today's helicopters run about 11 cents/available seat mile for a 40-mile trip.

The obvious conclusion from a comparison of the five vehicles studied by MIT is that the vertical-takeoff machines could be cost competitive with conventional vehicles at ranges below 100 to 150 miles. We challenge this conclusion if conventional aircraft are developed fully.

The arrow shown on the previous plot of fare/mile vs range (Fig. 5) has been carried over to this chart and converted to an equivalent direct operating cost level. It may be argued, and correctly so, that the relationship between fare and direct operating cost is not linear with range. Inasmuch as this paper is to represent what we as manufacturers can influence, we are assuming that, if direct operating costs can be reduced, we could expect a corresponding reduction in fares. The arrow labeled "desired" indicates the goal of direct operating costs. The direct operating costs seem to run about 20% of the fare rates at the northeastern corridor ranges.

Existing Aircraft

Figure 7 shows a typical short-range conventional airplane of today, a 99-passenger airplane, compared with the 80-passenger vehicle of the MIT study. The direct operating cost (DOC) calculation is based on 6-min air-maneuver time and $13\frac{1}{2}$-min ground-maneuver time per the 1960 Air Transport Association (ATA) cost formula. The MIT conventional aircraft DOC calculation assumes 15 min. In addition, 737 economics incorporates today's engine technology rather than the advanced engine technology of the reference MIT study. The increased passenger capacity of the 737 tends to offset the influences of time and technology as used in the MIT study. It can be seen that both the conventional aircraft curves have the same general characteristics vs range. The desired operating cost trend arrow is again carried over and is shown as a target.

Maneuver Times

Several years ago Boeing began to realize the tremendous impact that ground and air-maneuver times could have on short-range-aircraft operating economics. Accordingly, several surveys were undertaken wherein each Boeing traveler was asked to note the pertinent items relating to ground times for each flight taken.

Figure 8 depicts the results of the most recent study. It shows the variable to be the airport business level rather than the airplane gross weight, which is the variable in the ATA cost method. Ground-maneuver times at both origin and destination, including takeoff and landing times, are shown plotted against five categories of airports. These categories range from category I, the airports of large hubs such as New York, Washington, and Boston, at each of which over 3% of all U.S. airline passengers are handled, down to category V, which represents airports at which less than $\frac{1}{20}$ of 1% of U.S. airline passengers are handled. Of the 28 cities in the northeast corridor area with populations over 90,000 three cities fall in category I, one in category II, two in category III, one in category IV, and the majority, 21, in category V.

One item is very significant here: it is readily apparent that ground-maneuver times of 4 to 5 min should be possible at all airports in the northeast corridor if the few large airports were changed to accommodate short-haul operations or to simulate low-density airports. The large airports could simulate low-density airports by several means. Special gate positions adjacent to midpoints of the long runways would be beneficial. Special onload/offload ramps, possibly coming up from underground out near the runway, would be advantageous. Use of

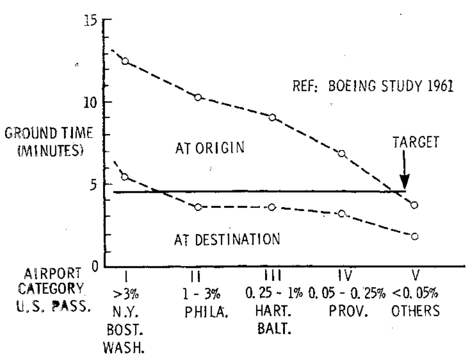

Fig. 8 Ground-maneuver-time survey.

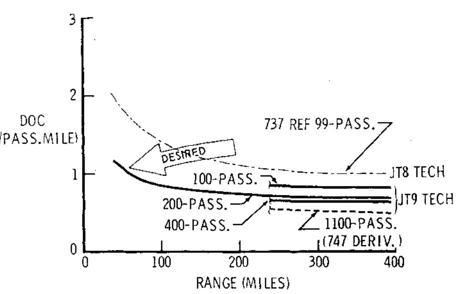

Fig. 10 Effect on DOC of engine technology and passenger capacity.

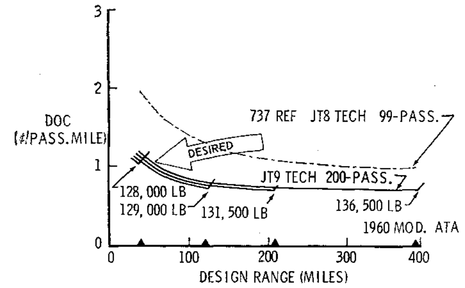

Fig. 11 Effect on DOC design-point range.

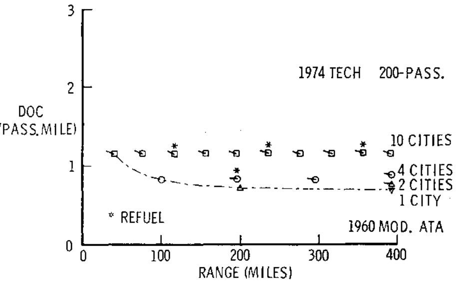

Fig. 12 Effect on DOC of multihop service.

midpoint runway takeoffs or greater use of shorter runways could be considered.

Airplane gross weight did not show up in our studies as a significant variable and is therefore not shown here. As a passing comment, it is interesting that jet aircraft had significantly shorter maneuver times than propeller-driven aircraft for all classes of runways, primarily because of the lack of engine runup time.

Many operators, emphasizing short-haul operations and seriously working to minimize operating costs on these short-haul routes, have been able to make significant reductions in block time penalities. Civil Aeronautics Board Staff Rept. 4, published in August 1965, analyzed in depth the San Francisco–Los Angeles market in which three major trunk carriers and one intrastate carrier compete. This report stated that one airline, Pacific Southwest Airlines (PSA), has always been able to demonstrate 10-min-shorter flying times in identical equipment than the competitive major carriers and that this is attributable to quicker control-tower confirmation, use of "intersection" or short-field takeoffs, and operation under visual flight rules whenever possible. PSA depends on this type of short-range business in order to make a profit for its system. It has had to make this operation as efficient as possible and its record shows it has successfully accomplished this objective. The outstanding response by the public to this total competitive airline market is a matter of record: all carriers have benefited, the public has benefited, and the manufacturers have benefited.

Figure 9 shows how important minimum maneuver-time penalites can be. The use of the ATA formula without additional modification may not be completely correct, but the effect of minimum maneuver times is still believed to be valid. If the total maneuver time of 21 min, as used in the 1960 ATA format for a conventional short-haul transport, can be reduced to the targeted time of 4 or 5 min, the direct operating costs at 60-mile ranges can be reduced as much as 47% or almost in half. At the longer ranges, of 400 miles or more, it is obvious that this influence is much less important. Prudent control is important, of course, at the longer ranges, but the success or failure of airline economics does not depend on maneuver penalities. On the other hand, the data indicate that the success or failure of a short-range operation depends on careful control of maneuver penalties.

Future Design Possibilities

There are other ways that vary the basic airplane economics per available seat mile can be varied. Two of the most usual ways are by changing passenger capacity or engine technology. Figure 10 shows a plot of DOC against range in which the reference conventional short-range airplane, with reduced maneuver times, JTS engines, and 99-passenger capacity, is compared with a 100-passenger JT9 technology new design. This latter design would incorporate reduced specific fuel consumption, improved thrust-to-weight ratio in the engine, and slightly improved drag as compared with the 737. A reduction in direct operating cost of approximately 14% could result. This is a good reduction but not nearly as large as the reduction possible through reduced maneuver times.

If, at the same time, the passenger capacity could be increased to about 200 passengers, a total reduction of about 20% could be realized, as compared with the reference conventional jet transport of today. Additional study results have been included wherein passenger capacities of 400 and even 1100 have been exercised over these same routes. In general, these larger capacities provide less than favorable results. Major gains seem to be realized somewhere near a capacity of 200 passengers. Strange as it may seem, body shape seems to be the dominant variable after this capacity is reached. It can be noted that the "desired" level of economics that will enable airplanes to compete with trains at short ranges (shown by the arrow) is being met.

Another variable, design-point range, which has historically been under the control of the manufacturer, for long-range aircraft has a significant impact on basic operating economics. Figure 11 shows the results of selecting as design-point ranges, distances to match the city pairs mentioned earlier. Four individual airplanes were designed, one for the 39-mile distance between Boston and Providence, another for the 50-mile distance between Washington and New York, etc. Each curve depicts a single airplane with the takeoff gross weight for the design-point range shown. The economics of each design, when operated at off-design ranges, is also shown. The operating economics for the 136,500-lb design at 395 miles, for example, is shown when operated at shorter ranges, down to and including the 39-mile point. Also shown is the sharp break upwards for this design when it is operated beyond the design-point range and must trade available seats for fuel.

This study reveals a very interesting fact: at ranges of 400 miles or less, little if any reduction in direct operating cost can be realized by decreasing the design-point range. This has not been true for airplanes of 2000- to 4000-mile design ranges. Figure 11 shows that, for short-range applications, design ranges of less than 400 miles should not be considered.

Multihop Operations

Looking at the 200-passenger aircraft with the good off-design range economics, it is possible to construct a curve as shown in Fig. 12. This curve shows a way of replotting the curve of Fig. 11. This chart emphasizes the fact that multihop operating costs are additive and that two 200-mile trips would be as shown, or ten 40-mile trips would likewise be as shown.

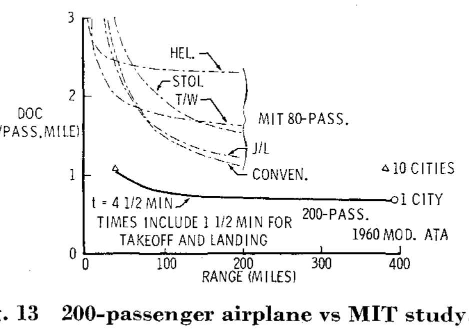

Fig. 13 200-passenger airplane vs MIT study.

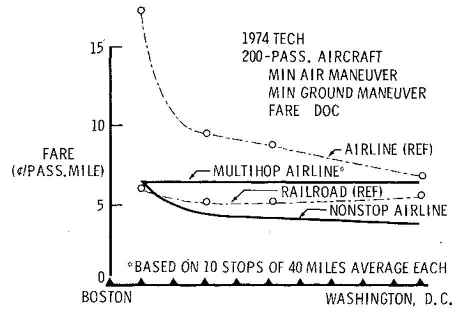

Fig. 14 Possible airline fare structures—northeastern corridor.

It is a way of showing the average direct operating costs of serving one city, two cities, four cities, or even ten cities. The economics are attractive, even with multihop service, and conceivably could allow fares competitive with trains. The main overriding assumption is that the airline/airport interface can be exercised to minimize airplane ground- and air-maneuver time penalties.

Summary

We believe that much can be done to improve the competitive economic offering of today's conventional airplane in short-haul operations. In addition, there may well be room for the development of another short-range conventional jet transport before VTOL aircraft become available. Figure 13 shows a summary of what has been studied here. It in essence concludes the following.

General

1) Ground- and air-maneuver times are all-important in very-short-haul air transportation. 2) Advanced engine technologies and increased passenger capacities offer improved economics. 3) An airplane designed for a 400-mile range is economically competitive with an airplane designed for a 40-mile range. 4) Conventional aircraft have economic advantages over VTOL designs if special considerations are provided for the conventional aircraft. 5) Conventional airplanes can offer multihop service without prohibitive increases in operating cost.

Northeast Corridor (See Fig. 14)

1) Airline fares that match rail fares can be offered at ranges as low as 50 miles if the industry can make maximum use of the basic economics inherent in large, high-speed aircraft. 2) Airline passengers can enjoy a speed advantage over railroad passengers even in multihop airline operations. 3) A new 200-passenger airplane designed for Boston-to-Washington service offers very attractive economics. 4) The VTOL designs will require much hard work if they are to be economically competitive with what can be offered by conventional designs. 5) Special considerations should be given short-haul operations at the major terminals of New York, Boston, Washington, Philadelphia, Baltimore, and Providence to enable competitive economics to be realized, or consideration should be given to special airports for the short-haul operators for integration into the total transportation system.

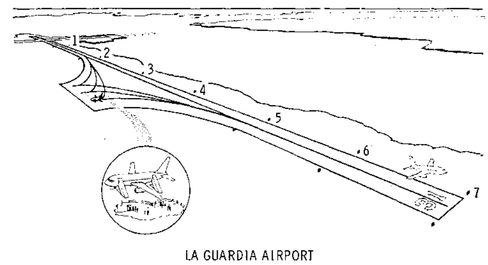

Fig. 15 Rapid air transit.

Outlook

It is envisioned that, before commercial VTOL machines take over the airline business in the notheast corridor, another conventional, 600-miles/hr aircraft will be developed that could allow airlines fares to be directly competitive with railroad fares. Hopefully, fewer airlines will be operating larger aircraft. They will operate multihop services from Boston to Washington, including regular stops at cities such as Providence, Hartford, New Haven, and Baltimore, matching directly the train service available today. For those passengers traveling to downtown areas, an interface with either a rapid transit system or a VTOL service to a satellite port will be provided.

At the large hubs it will be necessary to provide special handling of short-haul airplanes in order to offer the public the economics inherent in the vehicles. If this is not done, new airports will have to be provided. Saving time is the key to short-haul economics. Seconds count.

Figure 15 is an artist's sketch of the main runway at LaGuardia Airport. It depicts what can be done to provide special services for short-haul operations. The terminals are located adjacent to the midpoint of the runway. An underground tunnel to the three terminal loading points provides passenger access to the runway terminal. The curved runways shown are designed to minimize wasteful ground-maneuver time in both takeoff and landing. Landing and takeoff will be in the same direction and only half the length of the runway will be used for each maneuver. Where takeoff length is not critical, the airplane will wait at and take off from the loading pad, accelerating along the curved runway line shown. This is an extension to the optimum degree of the rolling takeoff technique. A constant $\frac{1}{3}\,g$ lateral acceleration was used in defining this particular rapid landing and takeoff area. In landing, after decelerating to 20 mph along the curved path, the airplane will make a constant turn to the loading area. Speed limits will undoubtedly be posted, and the pilot will probably need a ground speed indicator.

This type of specialized treatment is not unrealistic if the airline industry is truly interested in offering the public the best transportation for the least cost. There is still much to do in the field of conventional aircraft to provide air rapid transit.