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Final Report

A BACKGROUND PLANNING STUDY OF MICHIGAN'S AVIATION NEEDS

Part III. Growth and Technological Change in Aviation

Section 1. Technological Trends in Aircraft, Air Traffic and Traffic Control.

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FOREWORD

Considered assessment of growth is an essential part of the background of planning. In an area of rapidly changing technology, such as transportation - particularly air transportation - today, this assessment properly includes the study of probably developments in technology and their realization in new equipment, techniques and standards of service. These, in turn, exert significant influences upon the extent and nature of the growth of transportation services. At the present time in aviation, these relationships are of critical importance.

Part III of the comprehensive study of the planning background for Michigan's aviation needs is an evaluation of the influence of technological change in aviation and an estimation of growth in Michigan's air transportation. For convenience in assembly and presentation, this part has been developed in two separate sections.

Section I is devoted to the consideration of technological trends in aircraft, air traffic and traffic control, and to certain conclusions regarding their influence upon aviation planning for Michigan. Because this subject involved specialized knowledge, its development was assigned to the University of Michigan's Department of Aeronautical and Astronautical Engineering; Dr. Harold F. Allen, research engineer and lecturer in the field, assumed responsibility for the preparation of this section of the report.

While the report is presented with full official confidence in the professional competence and integrity of the author, the conclusions are Dr. Allen's and do not bear any institutional authority. It should be added, as a measure of appreciation, that Dr. Allen possesses not only the scientific qualifications for this study, but also, as a licensed pilot and an aviation officer in the U.S. Naval Reserve with rank of captain, a practical viewpoint of inestimable value in such research.

In the presentation of technological considerations, Dr. Allen deliberately adopted an approach which assumed that the reader had little or no specialized knowledge of aviation. To those who have studied in the field, some of the material may seem unduly elementary; to the layman, without such information, the inclusion of simple detail is essential and is considered to add to the general value of the study.

Section 2, which is separately bound, deals with the growth of aviation, nationally and locally, and presents in broad terms an estimate of the future insofar as it seems practical to speculate. This section was prepared by the staff of the Transportation Institute, which is continuously concerned with the study of demands for transportation services rather than the detailed technological bases. While it was independently developed, close attention has been paid to Dr. Allen's phase of the study and careful consideration given to his conclusions.

Both sections are therefore essential to an understanding of the background for the establishment of a rational aviation planning policy for the State of Michigan. Neither alone, nor together, are they intended as a blueprint or rigid guide for any arbitrary plan of airport design and location.

While "scientific" in the sense that rational analysis and statistical relationships have been applied to the information collected, it must be emphasized that the future will be influenced by forces which cannot be entirely anticipated nor precisely measured in advance. Inherently then, the conclusions of this Part III of the report are the result of the collective judgment of the research staff which has attempted to maintain a professional, objective and unbiased view. They are not intended, nor should they be considered as absolute, unqualified predictions.

John C. Kohl
Project Director

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Introductory Notes

The information presented herein is for the purpose of assisting the Michigan Department of Aeronautics in planning for the future. However, in most cases, the information is quite general, and applicable not only to one state, but to the entire country. Types of aircraft, for example, will be no different in Michigan than in other states, while air traffic control, meteorological services, etc., must be provided by agencies which are nationwide, or even international in scope. Frequent references are made to possible Michigan applications, and the generality of the report does not detract from its specific usefulness within the state. Much of the material was obtained from reference 1, and to avoid continuous repetition, this will not be referred to in the report. Some of the material results from personal experience, and is not referenced. Other major sources of material are listed at appropriate points in the report.

For purposes of this report, it is assumed that international conditions will not change significantly during the next ten or twelve years, that there will be no full-scale war and no complete mobilization. However, it is assumed that continuing international tensions will necessitate maintenance of defense expenditures at a high level, providing a continuing base for the civilian economy.

Since 1946, the American economy has been in a state of expansion. Gross National Product, a measure of the total market value of national output, rose about 4% per year from 1947 to 1957, and there seems little doubt that expansion will continue at a similar rate. Since 1950, population has increased by nearly three million per year, and under a prosperous economy, population growth should continue at a rapid rate.

It is assumed that the steady expansion of output and increase of population will create an extremely favorable environment for further growth in air transportation. Total inter-city travel has grown faster than both population and Gross National Product, with growth limited to private automobiles and to the airlines. In 1956, air travel comprised only 3.3% of total inter-city travel and 35.9% of common carrier inter-city travel, so there is still plenty of room for expansion of all forms of air commerce.

It is assumed that the increased demand for air travel will continue to exert pressure on the manufacturers to develop new types of aircraft, and all the accessory equipment and services which they will require. On the basis of past experience, aircraft types have been considered in the light of the technical possibilities for new development within the next ten years. Plans prepared by the Federal Aviation Agency for air traffic control are fairly specific for the next few years, though less definite beyond 1963. These plans are discussed in general terms only, as they apply to the country as a whole.

Except for forecasts of increases in domestic and international airline passenger volume, which are taken from published surveys carried out nationally, the report is qualitative rather than quantitative. The types of aircraft which can be developed within the next ten-year interval can be fairly accurately foreseen, although it is not possible, without far more general surveys than have been undertaken, to estimate the numbers of different aircraft which will be flying at any given date, or indeed, whether such aircraft will exist at all. The fact that it is technologically possible to produce a certain type of aircraft does not imply that it will actually be developed. A need for the type must first be established before its production can be undertaken. Even if a need exists, preoccupation of industry with other types, or lack of facilities or capital may inhibit development until the need has disappeared or been satisfied, perhaps less efficiently, by other means. The report frequently points out the desirability or the technical possibility of developing certain types of aircraft, equipment, or services, but it is often impossible to predict the appearance of the type in significant quantities.

Consequently, the report can be used to estimate technological trends, and types of facilities or services which may be needed, but additional surveys will be required in order to determine quantitative requirements.

Summary

The major portion of the air transport fleet will continue to comprise largely conventional propeller-driven, fixed-wing aircraft, similar to those now in use. There will be a major shift away from the reciprocating engine and toward the turbine type of power plant. Significant numbers of jet aircraft will be used, mainly in the larger sizes (100 or more passengers) and in medium to long haul service. Supersonic transports will not be economically feasible within the next ten years. Transport helicopters or VTOL transports may be used to some extent in heavily subsidized short haul services.

The types of aircraft used for private and business flying are less likely to change in the next ten years than transport aircraft. Piston engines will continue to predominate, as there are few small turbines being developed. Larger private aircraft, and aircraft used for business purposes are more likely to be powered by turbine power plants. Helicopters will not be used in large numbers due to their high first cost and expense of operation, although they will be used for certain special services which only copters can provide. In general, there is not likely to be any great increase in private flying, although flying for business purposes is increasing, and will probably continue to increase.

There is slight possibility that VTOL aircraft or "flying jeep" types, or lighter than air craft will form a significant part of air traffic. There will be considerable military traffic,

but the amount or trend cannot be estimated except by defense agencies.

The seaplane and the STOL aircraft both have considerable potentialities, but an evaluation of their possible future use is difficult, as seaplanes are currently not used to any great extent in Michigan and STOL aircraft are not available at this time. The appearance of successful aircraft of the latter type could result in a demand for many small "skyports" throughout the state, and especially in the metropolitan area. These ports would be small, with runways not over 500 feet in length, so it would not be difficult to find space for them if planning is initiated far enough in advance.

The passenger demand for air travel is expected to double within the next ten years, resulting in approximately double the number of flights. Improved traffic control procedures will result in a larger number of flights for a given airport, but some airports serving the larger metropolitan centers may become saturated, necessitating the construction of additional airports. Aircraft which are currently foreseen will not require runways longer than two miles, under normal conditions. However, the sensitivity of the turbine type of power plant to temperature leads to the possibility that in hot weather, runways should approach three miles in length, if payloads are not to be seriously limited. Approaches at each end of the runways should be one mile in length, with no obstruction above a 1 in 50 glide plane. Aircraft noise, and the threat of danger to nearby residents, will continue to be problems, and this fact, coupled with the size requirements, militates against the location of airports in or near the downtown or residential areas of the large cities which provide nearly all the support for the airports.

Remote location of airports creates a demand for some sort of rapid transport service between the airport and the city proper. This can be by rail, bus, or air, but a very attractive possibility is in the development of STOL aircraft, which can operate economically and quietly from heliports or very small skyports. These can be located within large cities, either beside lakes or rivers, with overwater approaches, on the median strips of express highways, on roofs of low buildings, or other available areas. The helicopter is capable of providing this service, but cannot operate economically, and must be subsidized.

CHAPTER I

Types of Aircraft - 1959-1970

For purposes of this report, the characteristics of an aircraft which are of the greatest interest are those which influence airport size and location, and those which determine the type of service in which the aircraft is used. These characteristics are concerned with the size, performance, type of power plant, and power plant rating. A few significant values are tabulated for airplanes of each type discussed. The size of an aircraft is fairly well established if one knows the wing span, gross weight, and number of passengers (or alternate cargo capacity). Useful performance parameters are cruising speed and altitude, maximum rate of climb, and length of runway required under normal conditions. In certain cases, other information is included, such as hovering ceiling for helicopters. Power plant information includes type, number of engines, and rated power or thrust. Aircraft themselves are classified as transport, general aviation, helicopter, vertical take-off and landing VTOL), and short take-off and landing (STOL). A few representative examples of each type are discussed in the following paragraphs.

Transport Aircraft

It is expected that during the next decade, all but a small portion of the common carrier fleet will be made up of conventional aircraft similar to those currently operating or under construction.

These can be classified as small (50 passengers or less), medium (50-100 passengers), and large (over 100 passengers) aircraft, with reciprocating engines or gas turbine engines, the latter comprising the shaft turbine-propeller (or turboprop) and the turbo-jet types of power plants. In the press and advertising, the shaft turbine-propeller engine is sometimes referred to by the misleading term "prop-jet." This nomenclature will be avoided in this report.

Currently, reciprocating (or piston) engines power all but a small portion of the civil fleet. Engines having ratings from about 80 to 4000 horsepower are now available, and it is not anticipated that larger reciprocating engines will be built because of their bulk, weight, and complexity compared to large turbine engines. No new piston engine transport designs are expected to follow current types, and there will be a major shift to the turbine type of power plant in the larger sizes. However, aircraft powered by reciprocating engines of lower horsepower rating will continue to be built, as the piston engine has better fuel economy than the turbine engine for low speed, low altitude, partial power operation. For this reason, few turboprop engines of less than 750 horsepower are being developed. On the other hand, for high altitude operation at speeds in the 300-450 MPH range, the turboprop has a definite advantage. Also, it can be built in larger sizes with consequent increase in efficiency.

As aircraft speeds exceed 450-500 MPH, the propeller begins to lose efficiency, and at high subsonic speeds and high altitudes, the turbojet power plant becomes more economical than a propeller driven by either a reciprocating engine or a shaft turbine. However, the turbojet is extremely inefficient at low speeds and altitudes, hence jet aircraft are restricted to rather narrow operating limits, necessitating careful flight planning, and strict adherence to flight plans.

At least one major American aircraft manufacturer feels that it would be possible to have a supersonic transport airplane ready for certification by 1965 (Ref 8) and one British manufacturer is shooting for 1970. However, it is not anticipated that supersonic transport aircraft will be actually operating within the next decade, as current experience, which is limited to military types, appears to be inadequate to produce a supersonic aircraft which could be economically competitive with subsonic transports. Consequently, the commercial fleet will continue to comprise principally the above-described types for at least the next ten years. The commercial use of helicopters, STOL aircraft, etc., is limited and will be discussed elsewhere. Brief descriptions of the major transport aircraft are given below, and the aircraft characteristics are found in Table I.

Small Transport Aircraft - Reciprocating Engine

Practically the entire short-haul passenger transport fleet is composed of these aircraft, ranging from DC-3 (and even a few older models) through the current series of Convair and Martin transports. Some cargo aircraft are also of this type. Approximate performance figures for older and newer models are given in Table I.

Aircraft of this type, expecially the more modern models, will continue in use through 1970 in local and non-scheduled passenger and cargo service, as the medium and larger transports in general require longer runways than are available at the majority of airports used in this service. Also, larger aircraft may be too difficult to fill to economic load factors at smaller cities and towns.

Small Transport Aircraft - Turboprop Engine

Aircraft of this type, such as the Vickers Viscount and Fairchild F-27 have started to replace small piston-engine transports in the short-to-medium haul field (under 1000 miles). Typical characteristics are given in Tabl I. These aircraft have good small-field characteristics, and may have a small speed advantage over the more modern small piston-engine transports. They are currently somewhat more expensive, and more sensitive to operating conditions. Consequently, the replacement of the reciprocating engine aircraft will be slow, but inevitable, as no new piston engine transports are being designed. Some airlines are already investigating the possibility of converting existing Convair transports to turbo-prop power plants.

Medium Transport Aircraft - Reciprocating Engine

Aircraft in this class currently comprise the major portion of the entire transport fleet, including both cargo and passenger service. Typical performance characteristics of one of the larger, long-range aircraft are given in Table I. These aircraft will remain in service throughout the next decade, although markedly inferior in passenger-mile capacity to the medium turbine powered transports. As time goes on, they will probably be used less on international passenger flights, and more for domestic passenger and cargo service, medium (500-1500 miles) to short-haul (less than 500 miles), although not in local service, because of the load factor problems and the small airports in the smaller cities.

Medium Transport Aircraft - Turboprop Engines

Aircraft of this type, such as the Lockheed Electra and the Vickers Vanguard are just going into service in the spring of 1959. Typical characteristics are given in Table I. These aircraft have a considerable speed advantage over piston engine aircraft of the same capacity and comparable horsepower, and therefore can produce more passenger-miles per airplane. They are somewhat more expensive in first cost and hourly operating cost, but under proper conditions of operation, the larger passenger-mile capacity results in lower direct operating costs. They may be expected to replace the medium piston engine transports gradually during the next ten years, and to continue in use for medium- to short-haul service for the next twenty years.

Medium Transport Aircraft - Turbojet Power Plant

Typical characteristics of aircraft of this type are given in Table I. Such aircraft as the Comet IV will provide service similar to that of the medium turboprop over the same time period. The turbojet aircraft shows a large cruising speed advantage over the turboprop, and therefore a larger passenger-mile capacity, especially over longer stages. However, its necessity for added runway length and its greater sensitivity to cruise altitude requirements, as well as its greater first cost and higher fuel consumption, will keep the direct operating costs above those of the medium turboprop transport. Its use can therefore be justified only over the longer stage lengths, where it must compete at a disadvantage with the large turbojets. The medium turbojet transport will probably not see very widespread service, and no small turbojet transport may be anticipated, as its probably speed advantage would be lost in the short-haul service, and it would be much less economical than the small turboprop or piston engine transport.

Large Transport Aircraft - Turbojet Power Plant

A large turbojet transport, such as the DC-8 or Boeing 707, (see Table I) can have lower direct operating cost per passenger-mile than medium aircraft of any type over medium and long stage lengths if it can be operated with capacity loads. At lower load factors it can compete only over the long stage lengths where the smaller aircraft can operate only at reduced payload capacity. In general, the large jet aircraft will operate over longer average stage lengths, at higher average block speeds, and can be expected to serve all long routes and a substantial portion of medium length routes during the next ten years. By the end of this period, it may even be used on shorter routes with high traffic density, except where limited by available runway lengths.

The use of jet assist take-offs and decleration devices could permit jet aircraft to operate out of smaller airports, but in the past, such devices have not found favor with passenger carrying airlines, and there is no reason to expect a change in this attitude in the future.

Summary - Transport Aircraft

During the next ten to fifteen years, aircraft of all types listed in Table I will be operated on commercial airlines. Piston engine and turboprop aircraft will serve all cities in Michigan capable of supporting an airline and having runways approximating a mile in length. The larger aircraft will operate only at airports with longer runways and higher traffic densities. Jet transports will probably operate only in and out of Detroit, except that by 1970 or 1975, some of the smaller cities may generate sufficient traffic to permit the profitable use of jet aircraft, if adequate runways are available.

Aircraft speeds will increase somewhat during the next ten years, especially over the long stage lengths, where jet transports will be used. However, no supersonic transports may be anticipated during the same period.

General Aviation

All aircraft types not in the common carrier or military fleets are normally grouped under the above heading. However, it is anticipated that during at least the next ten years, the general aviation fleet will comprise principally conventional fixed-wing aircraft similar to those currently in use. Consequently, only such aircraft will be discussed in this section; and rotary wing aircraft, STOL aircraft, etc., will be taken up separately.

Reciprocating engine aircraft will remain very much in the majority, as turbojet aircraft in the general aviation category are very expensive to purchase and operate, and there seem to be very few shaft turbine engines being developed which are sufficiently small to power single engine and light twin engine aircraft. It is doubtful if any small turbines will appear within the next decade in the mass production quantities necessary to bring prices down far enough for wide acceptance. This is not because of technical infeasibility but on account of the large development costs before the turbines could be produced in sufficient quantities. If any significant use is made of such engines in automobiles, this will probably result in the appearance of similar engines in the aircraft field. Some turboprop engines in the medium horsepower range have been developed abroad, and some are being manufactured under license in this country, but have not been widely used. The characteristics of a number of existing or technically feasible aircraft in the general aviation category are listed in Table II and discussed in the following paragraphs.

Light Single Engine Aircraft

The "light single" is a small, single-engine, fixed-wing airplane, usually two place, and used principally for flight training and private flying. A typical example is tabulated in Table II. Within the foreseeable future, the performance of such aircraft is not likely to improve appreciably. They will continue to be powered principally by reciprocating engines, as it is unlikely that any small turbine engines can be developed which will be economically feasible. The only possibility for a major break-through in the private aircraft market appears to be with the STOL aircraft, which will be discussed separately.

Heavy Single Engine Aircraft

The "heavy single" has higher performance and usually higher capacity than the "light single." It carries two to five passengers, and may range in size and performance from a reciprocating engine aircraft slightly larger than a light single to civil versions of military jet trainers. Frequently, it will have extensive radio, navigation, and instrument flight equipment. Typical examples of existing aircraft or models which could appear within the next ten years are listed in Table II.

A considerable number of heavy single engine aircraft are used in business and commercial flying, such as charter service. Within the next ten years, the reciprocating engine will predominate as in the case of the light single, although a substantial number will be powered with jet engines, and there is a possibility that some use may be made of turboprop engines, as these can be larger than would be required by the light single.

Light Twin Engine Aircraft

The "light twin" is generally larger than the "heavy single" (except military trainers) and carries from five to ten persons.

It offers multi-engine safety, and can carry complete all-weather flight, navigation, and communication equipment. Civil airplanes in this category make up much of the business fleet, and a few of the larger models are used as short-haul transports, or in inter-city service, using small down-town airports such as Detroit City Airport which are not available to the larger commercial transports. Military versions are frequently used for training and administrative flying. Characteristics of three typical light twin engine aircraft are given in Table II.

General Aviation Transport

Aircraft in this category do not constitute a class of aircraft per se, but include aircraft which are used for general aviation purposes but which fall into the classes of transport aircraft previously described, whose characteristics were listed in Table I. They range from 8-12 passenger twin-engine aircraft, such as the DeHaviland "Dove" or Sud Aviation "Diplomatic," through DC-3, Convair and Martin twin engine aircraft, and may include even larger aircraft which are corporation-owned or leased for special purposes. A few firms and a few private individuals operate amphibians, such as the Grumman "Widgeon," which fall into the small transport category.

Helicopters - General

The helicopter has been a subject of investigation since the early days of flying, but the first successful models appeared at the start of World War II. It is a logical outgrowth of the work done on the autogiro during the 1920's and early 30's. The helicopter became a reality when power plants of sufficiently low weight per horsepower were developed, and high strength alloys made possible an efficient system of power transmission, as well as a light weight structure. When the helicopter became physically able to rise and hover under its own power, problems of control and stability were soon solved.

Helicopters, in general, are currently more complicated to fly than conventional aircraft. They are inherently slow, short-range craft, with low ceilings. They are expensive to build, maintain, and operate. On the other hand, the copter has the unique advantage that it can take off and land vertically and can hover over a fixed point.

However, there are disadvantages connected with vertical rising and hovering operation. In the first place, it is a characteristic of the helicopter that the greatest amount of power is needed in level flight at top speed and at zero speed. At medium speed, the least power is needed to maintain altitude, and the most power is available for climbing. It is therefore uneconomical to climb vertically beyond the ground-effect cushion, which usually is considered to extend one wingspan (for conventional aircraft) or one rotor diameter (for copters) above the ground.

In the second place, there is a considerable element of risk during vertical flight in that under these conditions the sole source of lift is the power plant. Engine failure results in immediate loss of lift, which cannot be reestablished until the rotor is changed over from powered operation to autorotation, which involves the loss of a few hundred feet of altitude, so if the copter has less than this amount of ground clearance, power plant failure will result in a crash. The required altitude decreases as forward speed increases, and becomes zero at a certain velocity which is below the cruising speed of the copter.

In the third place, vertical operation in the vicinity of obstacles, especially on windy days, requires a very high degree of pilot skill, so a certain amount of risk of this type is involved in operation out of restricted areas.

As a result, in normal operations, climbing and descent are carried out at moderate forward speed. The copter usually takes off vertically for the first few feet, then proceeds to develop a horizontal velocity before gaining further altitude, and finally climbs out on a slant after the manner of conventional aircraft. This characteristic of helicopter operation has a very important effect on the size of the heliport from which it is to operate. The International Air Transport Association (IATA) recommends cleared approach paths having a 1 in 8 glide ratio (1 vertically to 8 horizontally) and landing strips at least 400 feet in length. This typifies the requirements for safe, economical operation, and does not represent the minimum required. Where necessary, of course, it is possible to operate from an area not much larger than the physical dimensions of the copter itself, with consequent reduction in efficiency and safety.

There are many varieties of helicopters. The rotors may have two, three, or more blades, and there may be one, two, or even more rotors. The rotors may be hub driven by one or more piston engines or shaft turbines, or they may be tip driven by various thrust producing devices, such as rockets, ram jets, pulse jets, or turbo-jets mounted on the wing tips. Compressed air or other gases may be generated in the fuselage, ducted to the rotor tips and discharged through nozzles or burners to generate thrust. The most common copter types are currently those which are hub driven through mechanical transmissions. The earlier copters were of this type, as engines producing jet thrust were not available twenty years ago. Good gear transmissions still require much expensive development, because of the severe vibration problems encountered in mounting extension shafts and gears in a relatively flexible structure. The shaft turbine, with its inherently smooth torque characteristics, can reduce the severity of the problem, but efficient low horsepower shaft turbines are still not available. During the next ten years, most copters in civil use will still be equipped with hub driven rotors, most of the smaller ones being powered by reciprocating engines, and the larger ones by shaft turbines. The turbine is much lighter for a given horsepower, a critical factor in helicopter design, but is available principally in the larger sizes. Also, the turbines are more expensive in first cost than reciprocating engines, their fuel consumption is greater, and their power output declines more in hot weather. The increase in helicopter load carrying ability can justify the use of turbines in larger sizes, but a good, economical, efficient, inexpensive, small turbine has yet to be developed.

The tip-driven rotor system offers some promise for reduction of first cost and complexity of copters, and increase of their performance. Tip-mounted engines can be very simple in design and very light, but the currently used ram jets, pulse jets, and rockets are extremely noisy, and have very high fuel consumption. Currently, they are being developed principally for military applications.

The recent development of efficient small turbojet engines rated between 1000# and 5000# thrust brings up the possibility of mounting engines of this type on the rotor tips of large helicopters. (Ref. 11) Turbojets are quieter and more economical than the pulse jet or rocket engines. A 40-passenger design study is included in Table III. This does not appear to offer weight or speed advantages over existing piston engine craft of equivalent capacity, but eliminates the transmission and gearing required by the hub-driven type, and offers multi-engine safety with reduced complexity.

Helicopters - Private Flying

The initial appearance of the helicopter was hailed from many quarters as the development which would bring about the replacement of the private automobile by the private aircraft, and evoked visions of a copter in every garage (ref. 5). However, the use of helicopters as private aircraft is limited to a few relatively wealthy businessmen, who usually operate them in connection with a business anyway. They often provide their own heliports, usually smaller than the IATA recommended size, and such use as they make of public airports has had and will have very little effect on traffic density, number of airports required, or servicing facilities. The copters used are usually, small, two-place, low performance machines. Until the initial, operating, and maintenance cost of helicopters can be reduced, and the reliability improved, private helicopter flying will remain an almost negligible phase of the overall aviation picture. The development of a low-powered gas turbine suitable for use in small helicopters would materially enhance the future prospects of private copter flying.

Helicopters - Special Services

The helicopter has many advantages for certain specialized purposes. Its wide visibility had its ability to hover over a designated spot make it unexcelled for certain photographic or observation missions. It has been used occasionally in the dismantling or erection of structures. Its low speed and high visibility, coupled with the ability to hover and take off or land vertically from water as well as land areas are powerful tools in search and rescue work, and in the patrol of forests, farms, transmission lines, highways, pipe lines, etc. In crop dusting, it can operate from small open fields or roads adjacent to the crop areas, its excellent visibility is a safety asset, and the downward blast from the rotor improves the distribution of dust or spray. It can provide taxi or charter service, on a short-haul basis, to many points which could not otherwise be reached except by a combination of air and ground, or water transportation. Small, low performance two- to eight-passenger copters are used for the above types of services, but their widespread use is inhibited by inherent high costs. Also, their low ceilings and rates of climb severly limit their usefulness in mountain areas, but the economic factor is the principal bugaboo of the helicopter.

Helicopters - Suburban or Interurban Service

It is frequently proposed to link the downtown areas of cities such as Detroit and Cleveland by means of helicopters. However, such services seldom materialize because of the high costs involved in all phases of the operation, and also because the low speed of the copter limits its usefulness to short-haul operations. Short-haul helicopter passenger service is available in New York, Chicago, and Los Angeles, the three most populous metropolitan areas in the United States with a combined population of nearly 24,000,000. Chicago Helicopter Airways operates only between two points, O'Hare and Midway Airports, while New York and Los Angeles Airways offer passenger services between a variety of points. These airlines operated in 1956 at load factor less than 50% (ref. 4) with fares ranging from nineteen to thirty-six cents per passenger mile. Even at these rates, extensive subsidies are required, amounting to a total of over four million dollars in fiscal 1958.

If such a service could be established in the Detroit area, the most likely route would extend from a hypothetical heliport in downtown Detroit to Wayne County and Willow Run Airports. A meeting of helicopter operators and manufacturers was held in 1956 under the auspices of the IATA and, at that time, the manufacturers were reported as optimistic concerning the possible future development of copters capable to operation with direct operating expenses of ten to twelve cents per passenger mile (ref. 4). It is estimated that for a load factor of 50%, the fare charged in order to break even will have to be about four times the direct operating costs for copters similar to current models, or at least 40¢ per passenger mile. It is estimated that current direct operating costs are from two to three times the value quoted above, so the minimum break-even fare at present would be nearly a dollar per passenger mile. Even at the possible future break-even fare of 40¢ per mile, the trip from downtown Detroit to Wayne County Airport would cost $7.20, and the fare to Willow Run Airport would be $10.80. There are always a few passengers who would be willing to pay this much to save half an hour, but it is unlikely that the 3,500,000 persons in the Detroit Metropolitan Area could support such a service without an extensive subsidy.

Helicopters - Commercial Operation

The operation of copters in connection with businesses is slowly increasing. Aside from the unique services which the helicopter can provide, there are two additional incentives. In the first place, such operations are paid for before taxes; and in the second place, indirect costs are low as there is no necessity to charge overhead for ground operations, advertising, sales, administration, etc. The most extensive use of copters for business purposes is the carrying of personnel and cargo between the mainland and offshore oil drilling rigs in the Gulf of Mexico. Even here, however, the recent trend has been toward chartering the services of fixed base operators, and away from company ownership of the copters. The economics are not greatly changed by this shift, as the usual small, fixed base operator does not have a large overhead. He will usually operate at a better load factor and can thereby show a margin for profit. The ownership and operation of copters by business and industrial firms will probably continue to increase, but not to the extent that appreciable additional capacity will be required of municipal airports, although there may be some pressure for the establishment of downtown heliports in large cities.

The use of copters by fixed base operators will continue to increase, especially if turbine-powered copters in the smaller sizes can be developed. The principal services will be crop dusting, photography, charter services, etc. Municipal, county, and state agencies, such as police, fire, conservation, and highway departments, may prefer to use charter services rather than own their own copters. The use of copters with water landing gear by well-to-do sportsmen appears to be almost a "natural" for a state with as many lakes as Michigan.

Vertical Take-Off and Landing (VTOL) Aircraft

Aside from its high first cost and operating costs, an important drawback of the helicopter is its inherently low speed. Its great advantage of being able to take off and land in small areas is lost if it has to fly any distance. To overcome this advantage, the VTOL aircraft has been investigated as a type which can rise and descend vertically, but can be converted to something resembling a normal fixed-wing aircraft for high speed flight. For this reason, it is sometimes called a convertiplane. At present, the VTOL aircraft is in a very early stage of development. Some military prototypes have been flown, but none are operational or in production. One commercial prototype has been flown in England. It is unlikely that very many VTOL aircraft will be commercially available before 1965, or that very many will be in actual airline service before 1970 at the earliest.

The VTOL aircraft which was developed by Fairey in England is called the "Rotodyne." It uses a helicopter-type rotor for take off, hovering, and low speed flight, and a fixed wing and propellers for high speed flight. In hovering or vertical flight, all the power is applied to the rotor. In cruising flight, all power is applied to the propellers, while the rotor autorotates and supplies a small part of the lift. Performance figures for the Rotodyne are given in Table IV. The speed advantage over the helicopter is not large.

The tilt-wing type of VTOL has also been successfully flown as a military prototype, although no commercial transport of this type is either flying or under construction. The tilt-wing aircraft has its wing at about 90 degrees incidence for take-off and landing. The wing is rotated slowly to near zero incidence for normal forward flight. The characteristics of a design study based on this type (ref. 12) are given in Table IV.

In the supersonic range, it should be possible to build VTOL aircraft having the same gross weight as conventional aircraft for the same speed, range, and payload, using jet engines to provide the lift. The VTOL will, of course, require many more engines but will have lighter wings and landing gear so the gross weights will be comparable. However, the VTOL will have higher first cost and higher operating costs, and also may not be able to exploit its ability to operate from close-in heliports due to the noise problem. At any rate, supersonic transports of any type are many years in the future.

A comparison of VTOL aircraft with conventional aircraft having good small-field capabilities, such as the Fairchild F-27, indicates that, in general, the VTOL aircraft will be heavier, slower, and require more horsepower, in addition to being very much more complex and expensive. The advantage of this type must come entirely from the VTOL feature and must offset poorer performance and higher operating cost by eliminating the ground transportation link between the centers of cities, for example, and the larger airports from which the conventional aircraft must operate. Since the cost of operating the VTOL will be comparable to that of a corresponding helicopter, it is doubtful if very many VTOL aircraft will be operating during the next decade. No additional airport facilities will be required for these aircraft other than helicopter facilities.

Short Take Off and Landing (STOL) Aircraft

The so-called "STOL" aircraft is probably the most neglected category of modern aircraft. Using conventional means of developing high lift, coupled with the use of large diameter, slow speed propellers for high thrust at low airspeeds, aircraft can be built which take off and land with very short ground runs, and climb or glide very steeply, as has been demonstrated through the years by such aircraft as the Curtiss "Tanager," Fieseler "Storch," and Helio "Courier." None of these aircraft were produced in quantity, (except that the Storch was used to some extent by the German Air Force prior to World War II) in spite of the fact that their performance was and is startling. Furthermore, the noise of the aircraft is greatly reduced by the large, slow turning propellers.

Some recent studies based on preliminary designs carried out in 1951 are summarized in Table V and compared with a design study (taken from Ref. 1) using boundary layer control instead of the more conventional means of supplying high lift at low speeds. Design studies A and B use existing small reciprocating aircraft engines geared down to large diameter propellers. This produces high thrust at low speeds for good take off and climb performance and quiet operation. Full span leading edge slats and trailing edge flaps develop the high lift coefficients required for low stalling speeds. Small ailerons are used for lateral control at cruising, and slot interceptor spoilers for lateral control at low speeds. All of these devices have been separately used for many years, and their combination in a single airplane results in superlative short-field performance. An existing prototype using more of these devices is the small Helio "Courier," which is one of the few true STOL aircraft in existence.

A comparison of STOL possibilities with a currently operating helicopter are carried out in Table VI. This clearly indicates that a conventional aircraft can be built which will be able to operate from a heliport adequate for normal operation of the equivalent helicopter. The STOL aircraft is not capable of taking off and climbing vertically but can carry more passengers at higher speeds on less horsepower. Furthermore, it is a less complicated machine than the copter, so will have lower first costs and maintenance costs, as well as lower operating costs and improved safety.

The Army has recently become interested in STOL aircraft, but there are few existing commercial models, none being produced in significant numbers. Because of its relative simplicity, a STOL aircraft could be designed and placed in production within a year or two if a demand should arise. If successful small or medium size aircraft with true STOL capabilities should appear, a demand for small, close-in airports to accommodate them will also arise. Cognizance should be taken of this possible demand during long-range civic planning.

The factor of usefulness is an important one for aircraft.

The automobile did not begin to appear in quantity until it became useful to a large number of people. The STOL aircraft appears to offer the best chance for an aircraft to become useful to the average individual in the near future. It cannot replace the automobile, but it can be operated out of small fields which can be located much nearer the individual's home than existing aircraft, yet its first cost and operating costs should be comparable. The possible use of STOL transport aircraft for short-haul service is discussed in Chapter II.

Aircraft with excellent short-field performance are coming into use abroad (Ref. 10) although none of these appear to exploit all the possibilities of STOL aircraft. Scottish Aviation's "Pioneer" models are used extensively in the jungles of Malaya, and the high-performance single-engine Dornier DO-27 has been ordered in large numbers by the Luftwaffe. A two-seater French design, the Morane-Saulnier "Epervier" (Sparrow Hawk) powered by a 650-750 H.P. shaft turbine takes off from a grass field over a 50-foot obstacle in 800 feet and has a 205 m.p.h. top speed. It uses full span fixed slots and long conventional landing gear. The British are developing the "jet flap," in which air is ejected through narrow slots over a trailing edge flap. In common with boundary layer schemes being studies in this country, large amounts of air are required, necessitating auxiliary power and extensive ducting with cross-overs and multiplication for engine-out safety. Jet flap or boundary layer control (BLC) prototypes are not likely to appear in the near future, but could be flying within the next ten years, although they do not appear to offer substantial improvement in performance over more conventional STOL types.

To summarize, STOL aircraft are not currently in use in significant numbers; but if sufficient demand were to arise, they could appear in a very short time, due to their relative simplicity and the ease with which they could be designed and produced. Such a type would be almost ideal for farm use, patrol applications, or short-haul passenger and cargo service and, at the same time, would be much more useful for purposes of private or business flying. STOL aircraft could fly out of heliports constructed to IATA standards, with much greater economy than helicopters. Long range planning should reserve space in residential areas as well as in downtown city areas for possible use as small "heliports" or "skyports," as discussed in Chapter IV. Such skyports would be less objectionable in residential areas than the usual airports, as STOL aircraft, using large diameter, slow-speed propellers, are inherently quiet, and the usual airport noise problem is greatly reduced.

Miscellaneous Aircraft

The shrouded propeller, or ducted fan, can produce higher static thrust than a free propeller or rotor for the same diameter and power imput (Ref. 9). It has, therefore, been given consideration as a source of lift for vertically rising or hovering vehicles of the type frequently referred to as the "flying jeep."

This type of vehicle is usually intended to operate near the ground as a means of crossing terrain which would be impassable for ground vehicles, although it is sometimes regarded as a future private aircraft (ref. 5). Several firms in this country and Canada are working on projects of this nature, using two to four rotors driven by one or more engines. Only one has flown extensively at this time, although others may be flying in the very near future. The major difficulty encountered has been one of stability in horizontal flight. The machines appear to hover fairly well a short distance above the ground or move slowly about, but high speed has not yet been attained. These vehicles are in a very early stage of development, and are not expected to be used in numbers, except possibly by military agencies, within the next ten years.

Another type of vehicle being studied both in this country and abroad (ref. 18) is the "minimum ground-pressure" vehicle, which glides on a cushion of air and does not exceed an altitude of a few inches. Its movement is not restricted by mud, snow, ice, water, or other surface conditions which impede the movement of wheeled vehicles. Prototypes has "flown" both over water and over smooth terrain. This may or may not be classed as an aircraft, but is in an early stage of development and will not appear in significant numbers within the next decade. A vehicle of this type being developed in Canada has possibilities of forward flight at greater altitudes, but is also in a very early stage of development.

Lighter Than Air

Lighter-than-air craft form an insignificant fraction of the aircraft industry, except for non-rigid craft, or "blimps" used for military purposes principally by the Navy. However, many years ago, when the present air transport system was in its infancy and even before it was born, there were successful passenger-carrying services using rigid airships, or "dirigibles," and the future of such craft seemed assured. Adverse publicity accompanying an unfortunate series of military accidents to dirigibles climaxed by the fiery crash of the Hindenburg in full view of hundreds of people speeled the doom of the dirigible, and none are now in existence. However, the technical know-how for the construction of dirigibles still exists, and improved types could be built at any time if a demand should arise. At this time, there is no indication of such a demand, and no probability that dirigibles will be constructed, but the possible future of the dirigible is discussed more fully in Chapter II.

Table I. Transport Aircraft

Aircraft	Small Transport-Piston Engine		Medium Piston Engine Transport	Turboprop Transport		Turbojet Transport	
	Old (DC-3)	Late		Small	Medium	Medium (DC-9)	Large
Wing span, ft.	95	105	150	93.5	99	94	131
Gross weight, lb.	31,000	49,100	156,000	58,500	106,700	120,000	250,000
Passengers	25	44-52	58-94	40	66-85	68-92	109-125
Cruising speed, mph	173	288	313	313	405	580	575
Cruising altitude, ft	5,000	up to 18,000	22,600	10-20,000	22,000	35,000	30,000
Normal runway required	4,900 (max)	4,700	6,500	4,700	5,250	6,000	9,000
Max. rate of climb, fpm	1,000	1,000	1,080	1,200	2,500	--	6,500
No. of engines	2	2	4	4	4	4	4
Type	Reciprocating	Reciprocating	Reciprocating (Turbine Compound)	Turboprop	Turboprop	Turbofan	Turbojet
Total horsepower or thrust	2,400 (max)	4,800	13,600 (max)	5,600 (max)	15,000 (max)	33,000 lb.	--

Table II. GENERAL AVIATION AIRCRAFT

Aircraft Type	Light Single	Heavy Single: Piston Engine	Heavy Single: Design Study	Heavy Single: Jet Engine
Wing Span	33 ft.	33 ft.	33ft.	33 ft.
Gross Weight	1450#	2750#	2905#	4360#
No. Places	2	5	4-5	2
Cruising Speed	92 MPH	178 MPH	230 MPH	230 MPH
Cruising Altitude	5000 ft.	10,000 ft.	15,000 ft.	25,000 ft.
Normal Runway Req'd.	1500+ ft.	1500 ft.	1500 ft.	3500 ft.
Max. Rate of Climb	500 FPM	1300 FPM	2900 FPM	2700 FPM
No. Engines	1	1	1	1
Type	Recip.	Recip.	turboprop	Turbojet
Total Horsepower or Thrust	85 HP	413 HP	413 HP	900#
Range	400 mi.	700 mi.	700 mi.	350 mi.

Aircraft Type	Military Trainer	Light Twin: Piston Engine	Light Twin: Turboprop	Light Twin: Turbojet
Wing Span	38 ft.	44 ft.	---	33 ft.
Gross Weight	15,000#	6000#	---	7500#
No. Places	2	5	8-12	4
Cruising Speed	495 MPH	200 MPH	320 MPH	357 MPH
Cruising Altitude	25000 ft.	10,000 ft.	10,000+ ft.	20,000 ft
Normal Runway Req'd.	5500 ft.	1600 ft.	1200 ft.	5000 ft.
Max. Rate of Climb	3400 FPM	1600 FPM	---	2500 FPM
No. Engines	1	2	2	2
Type	Turbojet	Recip.	Turboprop	Turbojet
Total Horsepower or Thrust	5000#	540 HP	1520 HP	1800#
Range	1000 mi.	1100 mi.	1250 mi.	900 mi.

Table III. Helicopters

Type	Light	Medium	Heavy		
	(S-55)	(H21-B)	(H-16)	"Westminister"	Design Study
No. of rotors	1	2	2	1	1
Diameter, ft.	53	44	82	--	115
Gross weight, lb.	6,495	15,061	46,750	--	60,000
Passengers	7	24	40	42	40
Cruise speed, mph	85	98	130	150	138
Cruise Altitude, ft.	5,000	--	5,000	--	--
Max. rate of climb, fpm	1,040	730	860	920	--
Speed of best climb, mph	52	79	93	--	--
No. of engines	1	1	2	2	4
Type	Reciprocating	Reciprocating	Reciprocating	Turbine	Turbojet
Total horsepower	600	1,425	3,300	5,210	7,700
Range, mi.	340	233	166	448	230
Hovering ceiling, ft.	8,200	1,400	--	--	6,000 (95°F)
Vertical rate of climb, fpm	720	130	--	--	--

Table IV. VTOL Aircraft

Type	Fairey Rotodyne	Tilt-Wing Design Study
Gross Weight	39,000#	60,000#
No. of Passengers	40	50
Cruise Speed	184 MPH	460 MPH
No. of Engines	2	4
Type	Turboprop	Turboprop
Total Horsepower	5210	16,000 (plus auxiliary jet engines for pitch control)
Range	300 mi.	1040 mi.

Table V. STOL Aircraft

	Design Study A	Design Study B	Design Study C
Wing Span	50 ft.	100 ft.	131 ft.
Gross Weight	6500#	18,000#	63,000#
Passengers	10	40	50
Cruising Speed	161 MPH	155 MPH	300 MPH
Normal Runway Req'd.	400 ft.	400 ft.	400 ft.
Max. Rate of Climb	1600 FPM	1000 FPM	3500 FPM
No. of Engines	2	4	2
Type	Recip.	Recip.	Turboprop
Total Horsepower	520	1040	9600
Range	900 mi.	260 mi.	100 mi.
Hi Lift Devices	Flaps, slats	Flaps, slats	BLC (auxiliary power required)

Table VI. Comparison of STOL Aircraft and Helicopter

	Design Study A	S-55*
Wing Span (rotor diameter)	50 ft.	53. ft.
Gross Weight	6500#	6495#
No. of Passengers	10	7
Cruising Speed	161 MPH	85 MPH
Cruising Altitude	5000 ft.	5000 ft.
No. of Engines	2	1
Type	Reciprocating	Reciprocating
Total Horsepower	520	600
Range	900 miles	340 miles
Max. Rate of Climb	1600 FPM	1040 FPM
Speed of Best Climb	94 MPH	52 MPH
Vertical Rate of Climb	---	620 FPM
Take Off Ground Run	150 ft.	0
Total Take Off Run Over 50 ft. Obstacle	440 ft.	455 ft. (normal operation)

* Used by New York Airways in local passenger service.

CHAPTER II

AIR TRAFFIC

Commercial Air Transport

The major portion of the passenger air traffic in and out of Detroit is interstate (some international) rather than intrastate; and consequently, the traffic trends will be closely linked with nationwide and worldwide air traffic. The CAA (not FAA) has estimated (ref. 1) that between 1959 and 1970, the number of domestic air carrier revenue passengers will increase nearly linearly from about 60 million annually to 118 million, a 96% increase. Aircraft passenger-carrying capacity of newer models can be expected to increase, so the number of flights required to handle the domestic passenger traffic at any given city will be somewhat less than double the number of flights currently operated. At the same time, the number of international passengers is expected to increase, also linearly, from about 5.5 million in 1959 to 11.5 million in 1970, or more than double. This traffic will use a proportionately larger number of big civil jet aircraft; so again, the number of flights at any given airport will not quite double. However, there is every indication that air cargo and mail service will experience an even greater percentage increase than passenger service; so it is quite likely that by 1970 or very shortly thereafter, the average large American city, such as Detroit, which generates interstate and international air passenger and cargo commerce, can expect that the number of flights required will approximately double. Whether this increase can be handled by existing airports or will require the establishment of additional airports can be determined only by specific studies of the situation at the city under consideration, with consideration being given to such factors as increased runway length requirements for jet aircraft, and increased traffic handling capacity of proposed new traffic control systems.

Cities outside of the Detroit metropolitan area which are severed by shorter flights, frequently intrastate flights, also generate interstate passenger traffic, which can be expected to follow the trends discussed above. Surveys of intrastate traffic as such are not available, but presumably are included in the CAA surveys. Consequently, it can be anticipated that the number of commercial flights to be handled at city airports other than those in the Detroit area will also double by about 1970. The necessity of additional airports or airport capacity at these points can be determined only by local surveys.

Types of aircraft expected for international and interstate passenger traffic will include the large turbojet transports which will require runways approaching two miles in length under normal conditions, and possibly as much as three miles under high temperature conditions, if the aircraft are not to be penalized by take-off weight restrictions.

Types of aircraft expected for intercity service between the larger cities within the State probably include medium turboprop aircraft, requiring runways at least a mile in length, and may include medium turbojets requiring a runway at least 8,400 feet long under normal conditions. Runways of this length will be required in order to attract the larger national airlines.

Airports at the smaller cities probably will not be used extensively for commercial air travel unless STOL aircraft are developed which can be operated economically for short-haul passenger, mail, and cargo service. Such aircraft can also be used for local service within the metropolitan area, such as aerial "limousine" service between large airports and small skyports in the downtown area. Such service could also be used to serve a large airport centrally located with respect to a number of smaller cities, neither of which alone could support such an airport. Helicopters could also be used for such services, except that, as noted in Chapter I, substantial subsidies will be required.

General Aviation

General Aviation can be classified under the headings of private and commercial flying, with commercial flying further subdivided into business flying where a company operates aircraft for purposes connected with the business and fixed base operation where an operator, located at an airport, operates charter, flight training, crop dusting, aerial mapping, or other services. Business flying may be for the purpose of transporting executives or employees of the business, or for specialized services such as aerial photography, flight testing of company products, transmission line or other patrol purposes. Government agencies may own and use aircraft for forestry patrol, fire fighting, traffic or agricultural surveys, etc., or they may charter such services from fixed base operators.

In general, post-war private flying has not increased to the extent that was originally predicted. This may be due to the high cost of flying, and also to the inconvenience involved in maintaining an airplane at an airport which may be miles from the owner's residence. Until the usefulness of aircraft becomes compatible with the inconvenience and expense involved, private flying cannot be expected to increase to any great extent. The best hope of private flying appears to be the development of small, quiet aircraft having STOL characteristics, so that they can be operated from very small fields located near or in residential areas. The appearance of such aircraft in appreciable numbers could result in a widespread demand for many small fields, or skyports, and renewed public interest in pleasure flying.

Private flying in helicopters is too expensive for all but the very well-to-do, and the "flying jeep" is in too early a stage of development to be considered. Aside from the possible development of STOL aircraft in the near future, private flying cannot be expected to increase markedly, and existing facilities may be adequate for the next ten years.

Characteristics of the small two- and four-place aircraft used for private flying and flight training are not expected to change markedly in the next decade. As stated in Chapter I, most will still be powered by piston engines with possibly a few turbo-prop types, and performance will be similar to existing models with maximum runway lengths of about 1500 feet required. This applies to the light twin-engine aircraft as well as the singles, as shown in Table II.

The use of aircraft for business purposes will probably continue to increase, as long as the tax laws are not radically revised. Four- or five-place light twins and heavy singles will probably be most commonly used, with a few heavier aircraft and possibly a few jet aircraft. The latter will be more expensive to operate and maintain and will probably require longer runways, as shown in Table II. Such aircraft can be owned only near cities which can support airports with runways a mile or more in length. A few corporation-owned helicopters mayappear, but the numbers will be small and will have little effect on airport requirements.

The seaplane deserves some special attention because of the wonderful opportunities for seaplane flying which exist in the State of Michigan. It is difficult for an old "water pilot" to understand why the seaplane is so rare in a state that calls itself the "Water Wonderland." With lakes everywhere, ringed with summer cottages and permanent homes, and lakes or rivers adjacent to nearly all cities of importance, the seaplane would appear to be the ideal type for private flying. It offers unparalleled convenience to those who live near or on a lake during the summer months. Its safety exceeds that of the landplane, as in an emergency it can land anywhere than a landplane can and will suffer less damage from a landing on very rough terrain than the landplane. Besides, there is water within normal gliding distance throughout most areas of the State. The opportunities for pure pleasure flying place seaplaning in a class with sailboating or water skiing.

Seaplanes are usually normal aircraft with the landing gear replaced by pontoons, or floats. Amphibian types have never been very successful, and are rare compared to the float seaplane. The addition of floats to the average small or medium private airplane produces a surprisingly small change in performance. The average seaplane enthusiast usually installs the floats as soon as the ice going out in the spring, and reluctantly removes them after the first autumn snowfall. Maneuvering a float plane on the water is a bit tricky at first, but the art is soon mastered. Seaplanes can be gassed from the average motor boat service dock, if the required grade of gasoline is available, and can be moored out, beached, or operated from a small ramp. A person who lives by a body of water can have his airplane as accessible as his automobile or boat, and it is not necessary to drive to an airport before flying. It is entirely possible that some day, the Michigan flying fraternity will "discover" the seaplane just as the general public recently "discovered" the small boat, and this could result in a sudden demand for seaplane facilities.

Some cities already have seaplane facilities on lakes or rivers in the heart of the city, which makes for very convenient access to the downtown areas. A quarter of a century ago, the writer landed at a seaplane ramp at the foot of Wall Street, New York City, a five-minute walk from the financial district, and has landed at boat docks in many other cities in this country and Canada. The provision of seaplane handling and servicing facilities in some of the larger Michigan cities could result in aconsiderable increase in seaplane activity. Seaplane ramps require a very small amount of waterfront, and can easily be established at marinas with aircraft storage in depth back from the waterfront, as seaplanes can be handled or taxied on the ground with very simple beaching gear.

A drawback of the seaplane is the fact that the floats are rather expensive, as one company has enjoyed a monopoly in this field for many years. Also, of course, the seaplane cannot be used during the winter months, as the lakes and rivers are frozen during this period.

Local Passenger and Cargo Service

Local passenger service is considered to involve the transportation of airline passengers to and from the airports, commuters from suburban residential areas to urban commercial and industrial centers, and interurban passengers between cities which may be less than fifty miles apart. There appears to be less and less demand for local common carrier service as more and better highways are built. With points as far distant as northern Michigan only a few hours drive from Detroit, for instance, passenger service must be very fast, very convenient, and very economical in order to compete with the private automobile.

Local common carrier passenger traffic is currently handled largely by buses, as the railroads appear to be doing their best to get out from under what is currently, and for several complicated reasons, a losing business (ref. 13). Aircraft are not used to any appreciable extent, except for longer haul interurban service. Helicopters are used for local service in three metropolitan areas, but must be subsidized.

Bus transportation by public highway is probably the most flexible means of service in that pickup and delivery points can be provided in a large number of places, and these points can easily be relocated as future situation changes develop. Operating costs are low, as public rights of way are utilized, and the tax burden is not commensurate with the costs of providing and maintaining such rights of way. Equipment costs are low, as buses are mass produced for widespread service. Fuel costs are probably as low as for most other forms of transportation, and manpower requirements are also near a minimum.

On the other hand, even with super-highways, bus service is slow, most buses are cramped and uncomfortable, and the presence of trucks and private automobiles on the same highway introduces an element of hazard which tends to reduce the overall safety and results in delays when traffic is heavy.

A rail rapid transit system is capable of transporting passengers at higher speeds and with greater comfort and safety than in the case of buses. It is also less subject to service interruption during bad weather or rush hour traffic. Equipment and fuel costs should approximate those of buses, and operating manpower requirements should be extremely low, as the operation of trains can be automatic or remotely controlled. Drone aircraft, which operate in three dimensions, are routinely taken off, flown, and landed without a human being on board; and there is no valid reason why trains, which operate in a single dimension, cannot be completely automatic with no compromise of safety, although there may be objections from organized labor.

The rail system has the disadvantage that it requires a private right of way with its large first cost and maintenance and, in addition, it is necessary to pay taxes on the property. Elevated structures, such as would be required by a monorail, could be constructed above existing railroads or highways and subways could be installed below them, greatly increasing the capacity of the original right of way, but the cost of elevated structures or subways would tend to offset this advantage. It is therefore unlikely that efficient rapid transit systems can be provided without some form of subsidy, or else the overhauling of outmoded labor policies and an antiquated tax structure. It should be pointed out that bus lines receive an indirect subsidy in their use of public highways, while airlines are similarly subsidized indirectly.

If large cities are to exist in the future in substantially their present form, some sort of rapid transit system appears highly desirable, and buses operating on the public streets is only a makeshift solution to the problem. Large municipalities may find it desirable to subsidize a rapid transit system rather than suffer the slow dispersion of industry and commerce to suburban or even more remote areas. However, if such a rapid transit system is to be provided, whether it be a general system or a specific line to serve an airport, so many contingencies and ramifications are involved that years can pass in frustrating negotiations so that if and when the system finally becomes possible, its potential usefulness may well have evaporated.

There is a solution to the problem of rapid transfer of airline passengers between downtown cities and airports and also to certain general rapid transit problems, which can be applied in the near future and which appears to be economically feasible. This is the use of STOL aircraft operating from small fields within the city, small riverside or lakeside airstrips in the downtown area, rooftop skyports, or between the lanes of express highways. At the airport, these craft could land between the runways, on taxiways or parking ramps, or on small auxiliary airstrips.

At first glance, the use of helicopters for such a service would appear to be almost ideal. Existing copters can handle up to 40 or more passengers at speeds of 100 MPH, and can surely provide the rapid, convenient service required. However, the copter is inherently a complicated, expensive machine with high operating costs, maintenance costs, and fixed charges. As a consequence, passenger service is not economically feasible except by subsidy in the very largest cities; and even there, only a few passengers can afford it and the majority must rely on buses, limousines, taxis, or private automobiles. VTOL aircraft, such as the Rotodyne, will have similar disadvantages for short haul runs, but may be more nearly feasible on longer intercity runs.

It has been brought out in Chapter I that it is entirely possible to build fixed-wing aircraft which can operate from heliports which are constructed to IATA standards, and which have lower first cost, operating costs, and maintenance costs, and at the same time improved safety and reliability when compared to the helicopter or VTOL aircraft. These aircraft would be simple to design and construct, and can use engines similar to those used in considerable quantities for light aircraft. First costs should be comparable to those of the larger private and executive type aircraf, and maintenance should be at a minimum. Fuel consumption at cruising settings results in a figure of nearly 75 passenger miles per gallon of fuel, which is similar to that of buses and private automobiles.

A minimum crew of two will be required, as against a single driver for buses. However, the number of passenger miles per vehicle per day is much larger, as the greater speed of the aircraft permits more trips for the same crew and vehicle than for the bus and driver.

The place to start an aerial passenger system would probably be in a service between the central areas of cities and the airports which serve those cities as, in general, airports can seldom be located for convenient access to city centers. For example, aircraft similar to those in Table V could make a trip from downtown Detroit to Willow Run Airport in 10 minutes flight time at 160 MPH. Because of the ability of the STOL aircraft to fly safely at very low air speeds and because of its multi-engine safety feature, it is assumed that it will be possible to obtain authorization for such aircraft, whenoperated in scheduled service, to utilize traffic patterns below those of conventional transport aircraft, to avoid mutual interference, and eliminate approach delays. It is further assumed that the STOL will be authorized to land off the runways at the big airports and near the loading ramps so that taxi time can be reduced to a minimum. It is therefore estimated that about five minutes will be required for taxi-take-off, approach, and landing. The trip from Detroit to Willow Run Airport can then be made in a total time of 15 minutes as against 50 minutes by bus. Assuming 10 minutes for loading in each case, it is possible for the aircraft to make more than twice as many round trips as the bus in a given length of time, transporting more than twice as many passengers. The air crew will be more expensive per man hour, so the direct operating costs per passenger mile will probably be slightly larger for the airplane. Maintenance costs and fixed charges will also be higher, so an unsubsidized "flying limousine" service will not be quite as economical as the bus line, but the difference will not be large and, for a substantial number of airline passengers, the convenience and the saving of valuable time will more than offset the small price differential. The slower and much less economical helicopter could not successfully compete with the buses over the same distance without a substantial subsidy.

Such a means of rapid and economical transfer of passengers from city to airport can also make it possible for cities which are too small to support a large commercial airport capable of attracting the large national or international airlines to combine with neighboring cities to build an airport serving several cities through the medium of an aerial rapid transit, or "limousine" service. This service can be logically extended to become an interurban network with intermediate airport stops, carrying mail and express as well as passengers.

All large cities have commuter troubles. Railway commuter services are losing money for reasons not likely to be corrected in the foreseeable future and are attempting, fairly successfully, to wash their hands of the business by making the service as unattractive as possible. In the words of a noted author (ref. 19), "When I first moved to the suburbs, our local railroad was a means of transportation. Today, — and I gather from the public prints that the same is true of almost every commuters' railroad in the country, — the seats are filthy, the washrooms detestable, the conductors sullen, the fares outrageous, the schedules lies, and the passengers helpless victims of the whole miserable system." Bus service, especially during the rush hours, is slow and uncomfortable; and so the majority commute by private automobile, suffering the annoyance of the accompanying traffic and parking problems. Express highways leading into the centers of some of our largest cities have speeded up automobile commuting, but it is still likely that there are a large number of persons who would prefer to commute by common carrier if the service were sufficiently convenient and attractive, and comparable in expense to operating an automobile.

Consider the case of one small city on the outskirts, but not really a suburb of a nearby city. It is estimated that approximately 1200 persons commute daily from Ann Arbor to Detroit, a distance of about 40 miles. Approximately 85 use rail transportation and a similar number uses buses, while at least 1000 or more use private automobiles. Station-to-station rail service requires 45 minutes, bus service requires one hour and 37 minutes, while, during the rush hours, autos require about an hour to reach a point in downtown Detroit.

An aerial commuter service with STOL aircraft using the existing Ann Arbor airport and an assumed skyport in downtown Detroit, an airline distance of 37 miles, would require 14 minutes flying time at 160 MPH plus an assumed five minutes for ground and approach time, or a total of 19 minutes. This is less than half the time required by rail, about one-fifth of the time required by bus, and less than a third of the time required by automobile. A small skyport located close in to Ann Arbor would reduce the local ground transportation time, and could make an aerial commuter service more convenient than any existing means of transportation. It has already been pointed out that STOL aircraft can be operated at direct operating costs per passenger mile which are comparable to those of buses.

In conclusion, the demand for local common carrier passenger service appears to be decreasing as improved highways increase the utility and speed of the private automobile. However, it is likely that a really fast and convenient passenger service could find a sizable market if it can also approach buses and private cars in economy. Helicopters can provide fast, convenient service over short stage lengths, but cannot compete with surface transportation except by means of a considerable subsidy. However, it is possible for STOL aircraft to operate from small fields, substantially the same size as heliports, with direct operating costs only slightly higher than for buses. Such aircraft are not available at present, but could be designed and produced quickly if a need should arise. Their appearance could result in a demand for many small skyports in urban areas. These could be rooftop or riverside strips, or could use the parkways between lanes of express highways. This possibility should be kept in mind when plans are drawn for future space utilization in large cities, as well as smaller cities and towns.

Military Flying

Characteristics of future military aircraft, the composition of the military fleet, and the nature of military flying are highly classified and not available to the general public. Most military flying, of course, will continue to be carried out from strictly military bases, and the occasional military aircraft which lands at a civilian airport will not cause undue problems at such airports. The major problems presented by military flying involve separation of military traffic from civilian traffic. This is under the cognizance of the FAA, which is developing traffic control procedures which will take this factor into account. Future bases, or expansions of existing bases, can be predicted only by defense agencies.

Missiles and Rockets

Missiles and rockets, including rocket-powered aircraft, are and will remain principally under the cognizance of government agencies. Defensive missile firing sites, such as the existing Nike installations, can be expected to increase in number and scope as long as the international situation remains in its disturbed and uncertain state. The extent of such possible future missile activity cannot be anticipated by civil agencies.

Rockets for research purposes are usually fired from established firing ranges, none of which exist in Michigan. The smaller research rockets, such as those used for upper atmosphere investigation, can be fired from temporary sites, and require rather small ranges, although dispersion is a problem if the experiment is to be carried out near populated areas. Such rockets could be fired safely over water from many places in Michigan, although at present there is no known requirement for such firings. If this problem ever arises, it should not be difficult to establish ad hoc procedures for safety and coordination with air and water traffic.

Rocket firings of this nature would be carried out by responsible agencies, usually government activities such as the Army or the Weather Bureau, who would be expected to take every possible precaution to insure that everyone who could be even remotely concerned would be kept advised of developments, and no planning is required at this time. However, it should be borne in mind that makeshift rockets have, in the past, been constructed and fired by less responsible parties, and the Michigan Department of Aeronautics should inquire into its responsibilities with respect to the regulation of such groups.

Lighter Than Air

Lighter-than-air a[illegible] an ap[illegible] in air traffic for many years. Blimps are a very useful military took, especially in anti-submarine warfare, where the craft's ability to hover or to cruise for long periods of time without landing enables it to perform long-range search and patrol missions over the ocean. An occasional blimp is used commercially for advertising purposes, but these operate with minimum crews out of small fields, and place no strain on existing facilities.

However, the lighter-than-air people, both in this country and in Germany, are firmly convinced that rigid aircraft, or "Dirigibles," withdisplacements up to several times that of the Hindenberg or Graf Zeppelin have great possibilities as aerial freighters (ref. 20). Such ships could be built fairly inexpensively, and with boundary layer control, could cruise economically at about 125 MPH. They would have great lifting power, extremely long range, and cargo space approximating that of 25 boxcars. Since more than 99% of all cargo still travels by surface carriers, there is a vast field for expansion of air cargo services if an economical carrier, such as the dirigible, could be developed.

If such a service were to be undertaken, the aircraft could be produced and be operative within about three years. The first ships would be diesel or diesel electric craft, but the next logical step would be the installation of nuclear power plants. The tremendous lifting power of the lighter-than-air craft would enable it to lift the heavy nuclear reactor and associated shielding with ease, whereas the difficulty of shielding has been the major stumbling block in the attempt to use nuclear power in heavier-than-air aircraft. Furthermore, the dirigible does not expend power in order to provide the necessary lift, as does the HTA aircraft. Power is needed only in order to move from place to place. Nuclear-powered dirigibles might appear within ten years, if dirigible freight services were to be undertaken in the near future.

Such a freight service could probably be started as an intercontinental freight line except that, unlike ocean vessels, the dirigible would not be limited to seaports but could take on and discharge cargo at any city in the world. It would not attempt to operate out of existing commercial airports with their dense traffic of HTA aircraft. Techniques currently in use for Navy blimps would enable the dirigible to be handled by a small number of persons with a few tractors. Any small field with access to highway or rail facilities for cargo forwarding would be adequate. The dirigible would never need to be placed in a hangar except at long intervals for overhaul purposes. If nuclear-powered, it need not even be refuled between overhauls. It would normally fly at low altitudes and would have little or no effect on airway traffic densities at altitudes normally used by HTA transport aircraft.

Just as in the case of ocean freighters, a few passengers could be accommodated in unbelievable luxury, spaciousness, and comfort. Facilities would be provided for landing helicopters or STOL aircraft aboard the dirigibles in order to transfer the passengers to or from skyports at their destinations or points of origin, or to HTA airline connections at commercial airports. International flights would be met at sea by customs officials; and all customs formalities would be completed very conveniently by the passengers while still in flight, effecting a considerable saving of time. No passengers need be handled at the small fields where the cargo is transferred.

A fact often overlooked is that, in spite of numerous accidents to military dirigibles in the past, commercial dirigibles had an enviable safety record. In nearly three decades of commercial operation, including international service between Europe, North America and South American at a time when intercontinental services in HTA aircraft did not exist, no paying passenger ever was killed until the unfortunate Hindenburg disaster, the only fatal accident to a commercial dirigible. Even in this case, it is remarkable that so many passengers escaped. The use of helium instead of the inflammable hydrogen would eliminate the major factor leading to the Hindenburg accident. When properly handled, dirigibles have been able to survive storms of great violence, but normally avoid storms by means of their great range and endurance. Lighter-than-air transport could well be safer than any other form of common carrier transportation service.

In spite of the attractive picture painted above, a dirigible freight or passenger service, like the possible STOL passenger service, is not likely to be established until an actual need is recognized and financial backing is forthcoming. Such services may be kept in mind for possible planning purposes, but their actual appearance cannot be predicted with certainty.

CHAPTER III

Air Traffic Control and Air Safety

The control of air traffic is the responsibility of the Federal Aviation Agency (FAA), formerly the Civil Aeronautics Authority (CAA). This agency has, by law, the sole responsibility for the establishment and operation of a common civil-military federal airway system comprising air traffic control, navigation, and flight information services. The establishments which the FAA will operate in Michigan and its control over aviation within the state are not the only aspects with which the Michigan Department of Aeronautics should be concerned. The future plans of the FAA and the mechanics by which it expects to implement these plans are of interest to all persons connected in any way with aviation. These plans (ref. 2 and 3) will be briefly summarized in the following paragraphs.

Air traffic in general is a short haul business as indicated by the fact that over 50% of the instrument flight rules (IFR) flight plans went less than 200 miles; and this situation is not expected to change in the foreseeable future. There are a number of indices for air traffic operations in good weather (VFR), but a good indication of VFR usage of both terminal and enroute airway facilities is the number of itinerant aircraft operations (air carrier, general aviation, and military) handled by airports with FAA traffic control service. Recent trends indicate that the number of such operations will double in the period from 1958 to

1970. It is expected that the number of instrument approaches will triple during the same period of time. It is interesting to note that in 1957 general aviation accounted for less than 10% of these instrument approaches, using tax-supported facilities. Military aircraft accounted for 27%, and air carrier aircraft for the remainder.

The present federal airway system includes a widespread net of visual and electronic aids to navigation and landing, extensive air-ground and point-to-point communications, dissemination of weather information and notices to airmen, and the control of air traffic at airports and in designated airspace which, as of December 1957, includes all airspace above an altitude of 24,000 feet over the continental United States.

The system serves both civil and military traffic. At civil and joint civil-military airports, it includes the terminal navigation aids and traffic control devices. At military air bases, airport traffic control and often approach control is exercised by the military agencies. However, these bases generate traffic to be accommodated by the federal airway system, and therefore are tied in with the air route traffic control (ARTC) centers for the clearance of traffic into and out of the system.

The expected increase in air traffic is coupled with an ever-increasing divergence of aircraft performance characteristics. Today aircraft using the federal airways have speeds ranging from 100 MPH to over 600 MPH, and fly at altitudes up to 40,000 feet and more. Current standards of separation require that the block of protective airspace which must be provided around an aircraft traveling at 360 MPH is ten miles wide, 1000 to 2000 feet thick, and 60 to 90 miles long, depending on the altitude and the available navigation aids. The length of the block severely limits the number of such aircraft which can be accommodated at a given altitude on a single airway. Aircraft flying at different speeds present the problem of overtaking, and the air traffic controller must place increasing reliance on lateral separation through the use of multiple tracks, or airways, and radar procedures. The higher general level of current aircraft speeds is a further complicating factor, as earlier action must be taken in a given case to eliminate potential traffic conflicts.

The need for immediate improvements is being met by the Federal Airway Plan which extends through 1936 and uses elements of the existing federal airway system, with expanded and improved facilities integrated into the system as they become available. The first elements of automation are already in operation at some of the ARTC centers. The Airways Modernization Board (AMB) was created by the Congress in 1957 to accomplish the planning and development of the new devices which will be needed to cope with traffic in the years beyond the scope of the present plan. The FAA and the AMB are cooperating to insure that the immediate improvements which are being planned by the FAA to meet current and near-future traffic requirements will be compatible with what the AMB will be developing for the less imminent future.

Expansion of the air navigation network is based on two objectives: increased traffic capacity, and extension of navigation coverage. The planned expansion includes additional long-range radar, airport surveillance radar, airport surface detection equipment, precision approach radar, airways traffic control radar beacon system (secondary radar, i.e. transponder equipment in the aircraft), new air route traffic control centers, direct controller to pilot, air/ground radio communications, automatic flight data processing, airport traffic control service, direction-finding equipment, air traffic communication stations, point-to-point commubications, international air traffic communication stations, VORTAC short-range navigation system, ILS instrument landing system, approach lighting systems, sequenced flashing lights for approach systems, and other facilities. None of these will be described here.

Before the end of 1962, the FAA expects to be able, through application of radar and other advanced techniques, to provide positive control and separation for each aircraft movement above 15,000 feet altitude within the continental United States, regardless of weather conditions. Despite the tremendous increase in facilities that must be provided for this plan, it is the firm belief of the FAA that this is the only practicable way in which the very difficult problem of collision avoidance at jet aircraft speeds and high altitudes can be solved in the near future.

The plan was developed in recognition of increasing military and civil requirements for additional air traffic control service for aircraft traveling at speeds and altitudes which make avoidance of collision by the "see and be seen" principle a difficult and doubtful procedure. There does not seem to be any hope for the development of automatic collision warning devices within the foreseeable future (ref. 7). The plan also recognizes the need for additional flexibility in the selection of tracks by high speed, high altitude aircraft, and the desirability of more direct flight between terminals for these aircraft.

A relatively limited number of high altitude navigation aids will be employed for the high altitude traffic control plan, and a route structure for flights above 27,000 feet, the ceiling of the federal colored and Victor (omnirange) airways, is specifically designed for high speed, high altitude operations. These high altitude facilities are used to delineate a system of high altitude tracks called "jet routes," which are depicted on USAF charts available to civil users through the Coast and Geodetic Survey.

The FAA is currently installing a VHF/UHF air/ground communication system which will provide direct pilot-controller radio communication throughout the airspace above 15,000 feet over the entire domestic U.S.A. This will enable the controller to have a more accurate idea of the pilot's position at any instant so that the time separation of aircraft along the airways can be reduced, and more aircraft can be flown over a given runway.

As more and more aircraft are enabled to use the airways, terminal facilities will become more crowded and the instrument landing procedures will present bottlenecks to the smooth flow of traffic. The use of dual runways can permit simultaneous landing and take-off operations with minimum spacing between departing and arriving aircraft, to permit "wave off," or "missed approach" procedures without undue danger of collision with aircraft taking off. The use of high intensity approach lights will reduce the number of missed approaches, and further increase the number of aircraft that can be landed in a given period of time. Existing types of instrument landing systems, such as ILS and GCA, will continue to be used, and new types which may be developed in the next ten years will not involve extensive changes in airports, or the planning therefor.

Long-range radar with altitude identification for enroute traffic control, with surveillance and approach radar for area control, will enable the controllers to maintain minimum separation of aircraft along the airways, permitting more aircraft to use the airways.

Such procedures may saturate existing airports serving large cities such as Detroit, and may necessitate the use of multiple airports withlocal shuttle service. As discussed in Chapter II, this could be provided by subsidized helicopter service or by unsubsidized STOL aircraft. Both of these offer the possibility of operation without interference with the normal transport traffic.

The characteristics of turbine engines, both the turbojet and the shaft turbine, are such that aircraft using this type of power plant will normally cruise at altitudes considerably exceeding those at which piston engine aircraft normally operate, and cannot economically depart from the optimum operating conditions. This relative inflexibility places particular emphasis on pre-flight planning, so that accurate meteorological information must be available for higher altitudes. The introduction of turbine-engine aircraft is taking place in a period of phenomenal growth in air traffic. Weather is and will continue to be a major factor affecting airspace and airport utilization. The safe and efficient operation of the number of aircraft to be accommodated will call for improved meteorological services for all phases of aircraft operation. The dependence of turbojet and turboprop take-off thrust on temperature reduces the tolerance on temperature prediction. Forecasts of upper air wings, jet streams, and tropopause heights will assume new importance, and forecasts of cloudiness, turbulence, hail, icing, etc., will require increased accuracy. New methods of gathering data, and new instruments may have to be developed for the measurement of such elements as gustiness and vertical motion in the atmosphere, and the collection of basic data, its evaluation, and dissemination must be accelerated. The entire forecase responsibility may have to be reallocated, with greater centralization, increased automation, and improved facsimile communication, ultimately linking with outlying territories and states, and certain foreign meteorological offices.

The question of obstructions, such as chimneys, water tanks, transmission lines, etc., in the vicinity of airports has long plagued the airport planners. Under future conditions of high traffic density and flat trajectory aircraft, such obstructions cannot be permitted above the 1 in 50 glide plane discussed in Chapter IV. New airports will have to be located in outlying areas so as to avoid such obstacles, or legal processes for the elimination or relocation of the obstacles must be provided.

In areas more distant from airports, tall radio or television towers are frequently encountered, which are not easy to see from the air in normal weather conditions and are extremely difficult to detect under conditions of low visibility. The presence of suchtowers is indicated on navigational charts, but an out-of-date chart or a small error in navigation can place an aircraft in a dangerous position.

Regulatory action should be taken to reduce the hazard by requiring the use of modern high-visibility paints or other means of increasing visibility during daylight hours, as well as adequate night lighting. The foregoing should apply both to towers and to such guy wires or other wires which may be attached to the structure. Maximum permissible heights for such towers should be established by law, and the future construction of any structure whatsoever which extends above the minimum permissible flight altitude should be permitted only after exhaustive investigation into the need for the structure as against the hazard to flight. In the absence of national regulation, it may be advisable for individual states to assume leadership.

CHAPTER IV

Airport Planning

Metropolitan Airports

Airport planning is to be discussed from the overall point of view of size, location, and access, with less attention to details such as arrangement, runway or taxiway capacity, etc. Individual studies of particular airport or airport requirements will be necessary for detailed planning. Major city airports must be able to handle the transport aircraft used by commercial airlines, so airports must be geared to the aircraft of the future which will some day use them. Airport planning is not a function of local of state agencies alone, but these agencies must coordinate their plans with the FAA.

The size of an airport is determined primarily by the lengths of runways and approach paths required. It will be seen from Table I that aircraft currently used or in prospect may require runways nearly 10,000 feet long under normal operating conditions. However, it is necessary to take into consideration the fact that future large aircraft will tend toward the gas turbine type of power plant, which is much more sensitive to operating conditions than the reciprocating engine. For a 10° F. increase in ambient temperature, the piston engine loses 1% in power, the jet engine loses 3%, and the turboprop loses 4% to 5%, although these figures are reduced when water injection is used (ref. 2). The effect of power loss, aggravated by the effect of air density on lift, is to decrease the rate of climb and increase the take-off distance as temperature increases, or to require a decrease of take-off weight in order to keep within existing field dimensions. The larger effect of temperature on the turbine engine is accounted for in recent changes to theCivil Air Regulations (Special Regulation 422). At standard temperatures, normal gross weights, and field altitudes of 1000 feet or less, no turbine-powered transport currently available or under development requires more than 10,000 feet of runway. However, on hot days, with gross weights permissible under Special Regulation 422, certain aircraft under development may require runways between 14,000 and 15,000 feet long at a temperature of 100° F. Such a temperature is occasionally encountered in Michigan during the summer months. If runways approximating three miles in length cannot be provided, at least provisions for future extension to this length should be included in any adequate airport plan.

For airport planning purposes, theobstacle plane, according to existing FAA criteria, has a slope of 1 in 50, starting at a point 200 feet from the end of the runway, although aircraft designed to SR-422 may have a flatter take-off slope under high temperature and high load conditions. Therefore, an object 100 feet in height could not be located closer than one mile from the end of the runway. Runway length plus obstruction-free distance adds up to a minimum diameter of five miles for the airport. This, of course, does not mean a five-mile square or circle, as compromises usually must be made for terrain or other problems at particular locations.

Airports which will be adequate under any conditions to handle the large transports which may appear within the next ten years should therefore be planned with sufficient space for accommodating runways and approaches at least five miles in length. Such airports will require on the order of 20 to 25 square miles of surface area, and therefore cannot be located near the centers of large cities which provide the traffic to support the airlines which will operate these new planes.

Community opposition to aircraft noise has been and will continue to be a serious problem to airport expansion or relocation. Our largest city is now having noise problems in connection with jet operations out of its international airport (ref. 15). Population growth in recent years has been concentrated almost entirely in the large metropolitan areas which originate and terminate more than 98% of airline traffic. At such high density airports, the density of traffic will probably prevent the use of the special low-noise flight procedures (ref. 14). The newer transport aircraft will be inherently more noisy than existing aircraft because of the higher speeds and larger power plants. It is likely that these aircraft may require larger traffic patterns in the vicinity of airports due to their higher speed and consequent larger turning radius. This may vastly increase the apparent dimensions of an airport by surrounding it with a "noise" area where population density should be low. The NASA and the British are carrying out basic research on aircraft noise generation and reduction. The noise of a high speed aircraft can be reduced somewhat, but at a cost level which the airlines are not likely to accept, and which may not be acceptable to residents in areas adjoining airports. Barring a major breakthrough, the noise problem will remain an important factor in airport planning, and will tend to force airports even father from the centers of the large cities which can support them.

The advent of the new jet powered transports will bring to the air passenger a level of comfort and speed which should accelerate the rate of growth of air traffic. It has been estimated the the number of domestic air carrier revenue passengers will double between 1959 and 1970, while the number of international revenue passengers will more than double during the same period. By 1970, 10% of all passengers will be carried on international flights, which will use large, high-speed aircraft which must operate from the large airports discussed above.

New traffic control precedures planned for the future were discussed in Chapter III. These will permit more aircraft to use the federal airways, and also will speed up the process of taking off and landing so that the capacity of a given airport may be expected to rise; and unless a given airport is currently operating far below capacity, it may easily become saturated within the next decade and additional entirely new airports may be required for some of the larger metropolitan areas. In this event, the question of possible overlapping traffic patterns may arise if airports are located too close together. Turning radii of future high-speed aircraft will increase the size of such traffic patterns, and it is not too early to consider the possibility of supersonic aircraft, even though these may not appear within the next ten or more years.

If this expected increase in air travel is to develop, it must be kept in mind that the airport-to-airport flight in the fast modern plane is but one of three phases of the entire trip from point of origin to destination. A second phase concerns ticketing, baggage handling, terminal waiting, check-in, and boarding procedures. It is disheartening to make a quick flight over thousands of miles, then be required to walk an interminable distance along a drafty corridor, stand in line before an over-worked agent, and then find no place to sit while waiting for a connecting flight. Airport terminals should be designed for the most efficient handling of passengers and baggage, automatic machinery can speed the ticketing procedure, while buildings and waiting rooms should be adequate, comfortable, and esthetically satisfactory.

However, the passenger must still accomplish a third phase of the transportation system, namely his trip from the city to the airport and the corresponding trip at his destination. Through the years, there has been consistent improvement in aircraft speed and comfort, but the ground transportation to the airport has shown little improvement. The passenger must view air travel or any other kind of travel from an overall point of view; from place of origin to final destination. With the great increase in speed and comfort which the jet liner will bring, long and tedious trips between airport and city will appear increasingly unreasonable. The initial and final phases of the air transport system, the passenger's trip from city to airport and return, should receive the same imaginative treatment that the aircraft and the airport terminal should receive in the jet age.

Many passengers arrive at the airport terminal in their private automobiles and are at once faced with the parking problem. Airport planners, in common with city planners, seldom appear to realize the extent to which the average citizen depends upon his automobile or to comprehend the magnitude of the space required for its storage when he is not using it. One may decry the volumetric inefficiency of the modern automobile, but its existence is a fact which must be reckoned with, and valet parking at fancy rates is not the answer as far as the average airline passenger is concerned. Adequate parking space, multi-level if necessary, should be provided close to the terminal, with enclosed access corridors or subways leading to the terminal. Such parking can be provided at rates which existing parking structures have shown that the public will accept, and provisions for its expansion in future years should be included.

The common carrier passenger also requires better treatment. Since the airport of the future will probably be remote from the city it serves, it is up to the planners to consider the provision of fast, frequent, convenient, and comfortable transportation between all the airports serving a given city and as many points as practicable within the city. This can be done in a number of ways. It can be ground or air transportation and may or may not be integrated into other transportation nets not primarily for the purpose of serving the airports. Ground transportation can be by rail or highway, and air transportation can be by VTOL aircraft, helicopters, or conventional aircraft with STOL capabilities.

The separate possibilities are discussed in detail in Chapter II, where the conclusion is drawn that the major percentage of passengers using public transportation to the airport will probably continue to arrive in buses or limousines during the next decade. This service will be speeded up somewhat as new "super highways" are built, but it is still the slowest and least comfortable phase of the traveler's journey.

However, as pointed out in Chapter II, the most logical way for the prospective airline passenger to reach the airport in the "air age" is by air, and it is entirely possible that this can be done speedily and economically by the use of STOL aircraft operating from small heliports, or "skyports" strategically located throughout the area served by the large airport. It is further pointed out that these aircraft, due to their inherent characteristics, could operate in and out of airline terminals without interfering with normal airline traffic. Such a service could cut the time required to travel from downtown Detroit to Willow Run airport to one-third of its present value, and at rates which can seriously challenge the buses. The STOL aircraft would have to be designed and placed in production, whereas existing helicopters could do the job although only by means of a substantial subsidy. However, no heliports exist, and by the time these could by ready, the STOL aircraft could be ready and the service could be established without subsidy.

The establishment of such aerial limousine service at reasonable rates will bring the third phase of the airline passenger's point-to-point journey up to date and in tune with the swift intercity link which he will enjoy in the jet age. Since the airport cannot be brought to the passenger, the passenger must be brought to the airport, and plans for future airports as well as the expansion of existing ones should consider the encouragement of such services by providing for the needed satellite fields in the area to be served.

Heliports, or Skyports

The planning for extremely small fields to be used by helicopters or STOL aircraft will be discussed from the standpoint of the existing helicopter, since adequate heliports will require little or no modification to serve the STOL aircraft. A heliport may be considered to comprise four elements:

1. A pad, or pads, where the copter actually comes to rest and takes off.
2. An obstruction-free area where forward speed may be reduced for landing, or acquired for climb-out. This corresponds to the runway of a conventional airport.
3. Access areas where obstructions are limited in height to permit let-down and climb-out flight paths.
4. A service area for parking helicopters, for a terminal building, etc.

The size of the pad is variously recommended (ref. 4). Sikorsky recommends a square area with sides equal to $1\frac{1}{2}$ times the main rotor diameter as a "minimum size for an occasional landing under ideal conditions." For the Sikorsky S-55 helicopter, used by New York Airways, this requires an 80-foot square which is the size adopted by the New York Port Authority for routine operations. If two or more helicopters are to use the heliport simultaneously, there must be a corresponding number of individual pads separated by a reasonable distance to eliminate dangerous air currents between aircraft. The pad should be paved to provide a surface free of loose particles subject to rotor blast.

The size recommended for the obstruction-free area, or runway, ranges from 200 x 400 feet to 200 x 800 feet. The IATA recommends a length of at least 400 feet. However, the S-55 copter requires 455 feet to clear a 50-foot obstacle after take-off, so 500 feet appears to be a reasonable length for current requirements.

Access areas should provide obstruction-free flight paths with clearance-plane slopes of 1 in 8. The access areas should also include some open spaces for emergency landings. These can be parks, golf courses, rivers, lakes, parkways with wide center strips or adjacent space, or other open areas.

The service area needed will vary widely, depending on the amount and type of activity at the heliport. Space will be needed to park one or more helicopters, a small building will be required as a terminal building, and fire extinguishing equipment will be essential. Auto parking must be available in the vicinity.

All in all, an adequate heliport uses or affects a sizable land area, and is difficult to locate in a large city where no open spaces exist, unless it can be placed adjacent to a river or lake, with all approaches made over water. By this means, access and obstruction-free areas over land can be virtually eliminated, and the heliport reduced to its minimum dimensions. For example, the New York Port Authority heliport at West 30th Street occupies an area 400' x 70' along the water front, with two 80' x 80' pads, each extending about 40' over the water. The pads are supported by piles. Such a heliport would not be adequate for use by STOL aircraft.

It is often suggested that heliports be located on rooftops. This has many advantages, including the possible elimination of access and obstruction-free areas, due to the height of the heliport itself. Also, the heliport can be located at or near major sources of potential passengers. However, on tall buildings the provision of adequate structural support, except for small two or three place copters, will be a major problem. Access to and from the street level must be provided, and there are problems of fuel supply, difficulty in handling disabled copters, and inaccessibility from municipal emergency equipment. Such heliports would probably have to be limited to the landing pad alone, which is scarcely adequate for commercial operation.

In the case of low buildings covering a relatively larger area, such as warehouses or parking structures, it is easier to provide the structural strength for operation of transport helicopters, and also simpler to provide passenger access to the street, terminal facilities, etc. There is adequate space for multiple copter operation and copter parking, and handling facilities for disabled copters, emergency equipment, etc. Such buildings, especially parking structures, would be excellent sites for rooftop heliports.

Other possible sites for heliports could be located on the center strips of parkways or superhighways, or adjacent to such highways. However, this means that space for the heliport must be provided during the planning for and design of the highway. Relocation of traffic lanes of existing highways to provide more space in the center strip would be difficult. If heliports are also to be used for STOL aircraft, few changes are required. The STOL aircraft could not use the absolute minimum heliport, where only a landing pad is provided, but aircraft of the type listed in Table V can operate out of heliports constructed to the IATA recommendations and from even smaller areas at reduced load. For example, Design Study B, with 10 passengers instead of 40 can take-off over a 50 foot obstacle in 222 feet with a ground run of less than 100 feet. With corresponding wing loadings and power loadings, STOL aircraft of any required capacity can be built to operate from areas of similar size.

Since the helicopter is currently such an uneconomical machine, and will remain so within the foreseeable future, its widespread use of unlikely except for certain specialized purposes. It is therefore recommended that any heliports which may be planned for the next ten years be designed to IATA standards, so that these heliports may be used by STOL aircraft if desired.

Intermediate Airports

The huge airports required for existing and future jet aircraft and the small skyports for STOL aircraft and helicopters have been discussed above. Much of what was said about the large airports applies qualitatively to the smaller airports serving cities of intermediate size. The passenger must be brought to the airport expeditiously, and his comfort and convenience must be served after he has arrived. The capacity of the various airport facilities and the lengths of the runways are elements which must be tailored to fit the requirements of the particular city or cities to be served. Quantitative requirements can be determined only by careful local study of the individual case under consideration, and a determination of the type of aircraft to be accommodated.

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