THE PROSPECTS FOR AIR TRANSPORT

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At this time when the immediate concern of every aircraft manufacturer is rapid expansion and production to meet military needs, the future of the air transport industry is taking shape in the back of the minds of research, development and administrative personnel. While the war may bring to a halt commercial development as such, new research and manufacturing facilities and rapid technical development fostered by the war will accelerate the natural growth of the post-war industry.

Transport development problems are normally attacked on a triple front. The research laboratories, aircraft manufacturers and transport operators all contribute to their solution.

The division of labor between these agencies has been fairly well marked. The research laboratories develop the theoretical background and investigate the basic problems of flight. In addition, they provide many of the facilities with which the manufacturers conduct their research. The wind tunnel of the Guggenheim Aeronautics Laboratory at the Institute, for example, has probably been the scene of more commercial development than any other tunnel in this country.

The research conducted by the manufacturers tends towards the solution of the more immediate design problems. Commercial research has, in the past, been concentrated on features which offer promise of early practical application. Under the impetus of the defense emergency, this trend has become more than ever established. In many cases, however, the growth of the industry has recently made possible considerable private investment in long-range research facilties. These investments are evidence of faith in the stability of the industry, and in the dollar value of research.

The transport operators are playing an important part in the develpoment of equipment through their constant work on maintenance and operating problems.

All three of these development groups have been vitally affected by the defense emergency.

The entire attention of the research laboratories and the commercial development staffs is now directed towards military ends, but probably 90 per cent of their work will have direct or indirect application to the transport industry.

". . . when the aircraft industry emerges from the war it will find tremendously expanded research facilities available."
—View of Lockheed's new 300 m.p.h. wind tunnel.

INCREASED RESEARCH FACILITIES

When the aircraft industry emerges from the war, it will find tremendously expanded research facilities available. The huge amounts spent by the German and Italian governments on aircraft research facilities a good many years ago are now being matched in this country. The National Advisory Committee for Aeronautics, whose Langley Field laboratories have been our mainstay of aeronautical research since the last war, is building several new plants, including one for engine and propeller work at Cleveland and an aerodynamics unit at Moffett Field, California. The Army Air Corps' Material Division at Wright Field is being expanded with the addition of a large high-speed tunnel. In peace time, all of the results of the work of these laboratories will be available to the transport industry. There are few industries in which scientific analysis is more essential to growth than it is to aircraft, and the work of the research laboratories is so important that it is hardly to be evaluated in terms of dollars and cents.

The war expansion will have a far-reaching effect upon the ability of the aircraft manufacturer to produce airplanes in quantity. It will likewise influence the materials and methods employed in building future transports.

First, the manufacturer has been forced to learn production methods and assembly line techniques to an extent that would never have been the case except for the vast military requirements. These methods and techniques will be carried over into transport construction and will undoubtedly result in savings in manufacturing costs.

By the time the war is over, a considerable degree of standardization will have been obtained, and more important, its advantages recognized. Heretofore, the industry has been characterized by an almost complete lack of standardization, but under the pressure of the national emergency, this situation can no longer be tolerated. The standardization of purchased parts, for example, will result in a saving in cost and availability. From the operator's standpoint, it will mean much simplification in training of maintenance personnel and a reduction in the quantity of replacement parts that must be carried in stock. Although standardization will never be universal, because of the peculiar requirements of certain specialized aircraft, the trend is inevitable.

The equipment which has been acquired during defense production can be expected to exert considerable influence upon transport design in the future. Machine tools, large presses, assembly jigs and factories themselves have become available to an extent that would previously have been economically unsound. This mass production equipment will make possible design features which, in the past, have been prohibitive. The result will be better ships that can be manufactured less expensively.

EFFECT ON PERSONNEL PROBLEMS

Another influence of "forced draft" production is the effect upon the personnel problem.

The acute need for trained and experienced men is gradually being alleviated. The number of Cal Tech alumni that has been drawn into the local aircraft plants is illustrative of the demand. There certainly need be no fear that the transport industry will suffer for lack of professional experience.

The industry will find that the men who have been trained during the war are familiar with design for production, and their influence will tend to simplify the construction methods used in commercial aircraft. Fortunately, military aircraft design requires an emphasis on performance as well as production. If this were not so, the conditioning of personnel during a war era would have an adverse effect upon the aerodynamic efficiency of commercial designs which follow. Instead, we are developing our ingenuity in producing sound aerodynamic designs that are feasible from a production standpoint.

It is apparent that competition in the commercial aircraft field will be very severe after the war, due to the new factories created during the expansion of the industry and to the fact that many of the military designs developed are readily convertible to commercial types. There will probably be at least eight manufacturers of large commercial equipment in this country alone. All of the above influences indicate that the industry will be capable of producing commercial aircraft faster and more economically.

Like the laboratories and factories, the airlines are having their share of national defense-bred troubles. Many pilots have Reserve Commissions and have been called into active service. Equipment is difficult to replace and expand. Although these shortages are becoming acute, domestic airline operators are continuing to enlarge their services and improve their efficiency of operation.

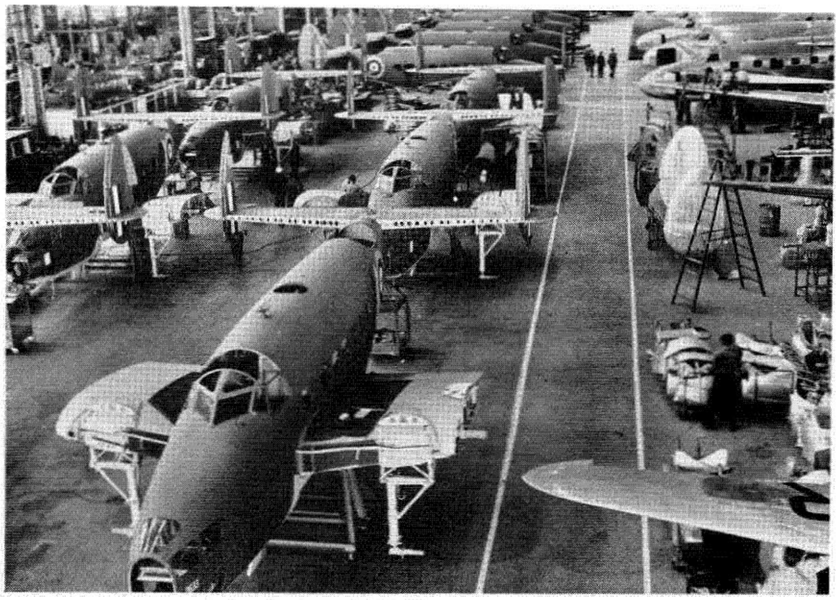
The hard-pressed British government has considered its airlines sufficiently important to their communications systems to maintain operations under difficulties which must make our problems seem trivial. It is reported that the Empire airlines are operating at 90 per cent of their peace time activity, in spite of the war. In this country also, it appears that an effort is being made to see to it that the airlines are not throttled. The tremendous growth in route mileage, passenger miles and cargo carried during the past year represents unusual effort on the part of the operators and is indicative of the commercial expansion that may be expected after the war.

TECHNICAL DEVELOPMENTS

In spite of the growth of factories and laboratories, the transport industry would be hopelessly handicapped if technical development lagged behind that of other countries.

Fortunately, there are similarities between the requirements of a good bomber and a good commercial transport. Both must be light, fast, simple, easy to maintain. The developments that improve the bomber in these respects will also improve the transport. The light, powerful, compact power plant that makes possible today's bomb load and range will make possible tomorrow's low passenger fares. The new airfoil that means another ton of bombs today will mean ten more passengers tomorrow.

Thus, much commercial technical development is the outgrowth of military studies. Nevertheless, commercial development is being directed primarily towards improvement in three



". . . The manufacturer has been forced to learn production methods and assembly line techniques."—Lockheed "Hudson" Bomber final assembly lines.

non-military factors, economy, safety and reliability. (Reliability, as used here, refers to the regularity of completion of scheduled trips.) These three factors are of great importance in determining the extent that air transport is used.

Improved economy can be attained by reduced manufacturing costs, increased aerodynamic efficiency and increased useful load. As we have seen, reduced manufacturing costs will follow directly as a result of the war expansion. Increased aerodynamic efficiency and increased useful load are the subject of intense study at this time in connection with military development. The lesson learned will be directly applicable to commercial development when the time comes.

Several particular design features currently under scrutiny show promise of contributing to increased transport economy. One such feature is the pressure cabin, which is coming into use for operation above eight or ten thousand feet. This device will see more use as cruising altitudes increase. High altitude flight is attractive for a number of reasons. Greater aerodynamic efficiency results from the reduced air density and higher speeds are possible. The air is likely to be smoother and therefore, the flight more comfortable. Pressure cabin airplanes can carry their passengers over the top of storms that are severe enough to make operation at low altitudes impractical. Unfortunately, however, there are a number of disadvantages. First, the useful load that can be carried is less because of the weight of the additional equipment required and the structure necessary to resist the pressure. Particularly in large airplanes where the gauges of sheet metal employed depend upon the loads imposed and not upon the minimum gauges that can be readily handled, the structural penalty due to pressurizing the cabin is considerable. Since the stresses run up rapidly wherever the pressure loads cannot be carried as hoop tension, reinforcements around the numerous openings are heavy. The necessary blowers, regulators, relief valves, air conditioning equipment, etc., are not only heavy and expensive, but also raise maintenance costs.

In order to operate at the higher altitudes, the engines must employ additional supercharging. The power required to drive the blowers may easily amount to several hundred horsepower for each engine, and the result is increased specific fuel consumption compared with low altitude operation at the same brake power. The use of a turbo supercharger has been proposed to alleviate this situation. The exhaust-turbine driven supercharger has been sponsored by the Army Air Corps for military use, and has yet to find commercial application. Whether it will contribute to transport economy is dubious. The added weight and drag will be considerable, maintenance will be difficult and the energy of the exhaust cannot be used for supplementary propulsion.

HIGH ALTITUDE OPERATION

These several disadvantages attendant upon altitude operation balance the advantages so that actually both the operating economy and the range turn out to be about the same whether the airplane cruises at low or high altitudes. On the other hand, the greater passenger comfort afforded is becoming of increasing importance as competition between airlines becomes more intense. Passenger discomfort due to changes in pressure and due to lack of oxygen at moderate altitudes has been of some significance in delaying the adoption of air travel. The elimination of this discomfort will make the airplane so far superior to ground methods of transportation, so far as passenger comfort is concerned, that a steady trend to air travel may be expected for this reason alone. The extreme discomfort of pressure changes, particularly when a passenger has a cold, is a far less trivial item than it would appear to be and can hardly be tolerated in a widely-used means of transportation. It may be necessary, ultimately, to supercharge cabins to sea level pressure for this reason. Perhaps the most important feature of the pressure cabin is its "over weather" operation already mentioned. When combined with highly developed blind landing systems, this feature will contribute appreciably to improved reliability.

Another important development which is proceeding steadily is the increase in size of commercial transports. Better aerodynamic efficiency automatically results; radiator scoops and auxiliary equipment can be placed inside large aircraft more efficiently; the power plant size becomes relatively smaller because its area does not increase linearly with power. The useful load tends to remain a constant percentage of the gross weight so that overall efficiency of the airplane is improved. The higher landing speeds acceptable with larger equipment permit the use of smaller wings which reduce structural weight, and the increase in physical dimension itself makes possible better structural efficiency. These effects offset the rapid increase in weight of items such as the propeller and landing gear. For these and other reasons, greater range with given payload can often be obtained only through an increase in size. As the demand for greater passenger convenience increases, range becomes more valuable since it makes possible the elimination of intermediate stops on long trips.

". . . The possibilities of air freight appear to be virtually unlimited."—Lockheed "Lodestar" in South African Airways' service.

Greater operating economy is being achieved by improved aerodynamic cleanness to which, as time goes on, there appears to be no limit. In the next few years, this will be attained through better power plant installation, improved airfoils possibly with "boundary layer control", and higher wing loadings. Power plant development has been so rapid in the past few years that it seems unreasonable to expect further increases in power output or fuel consumption, but there is little indication of diminishing returns. One of the largest improvements will come from a reduction of the drag of the accessories which now constitutes a large portion of the engine installation drag. Operation at higher altitudes and at higher powers has focused attention upon the efficiency with which the growing list of cooling accessories are installed.

IMPROVED AIRFOIL DESIGN

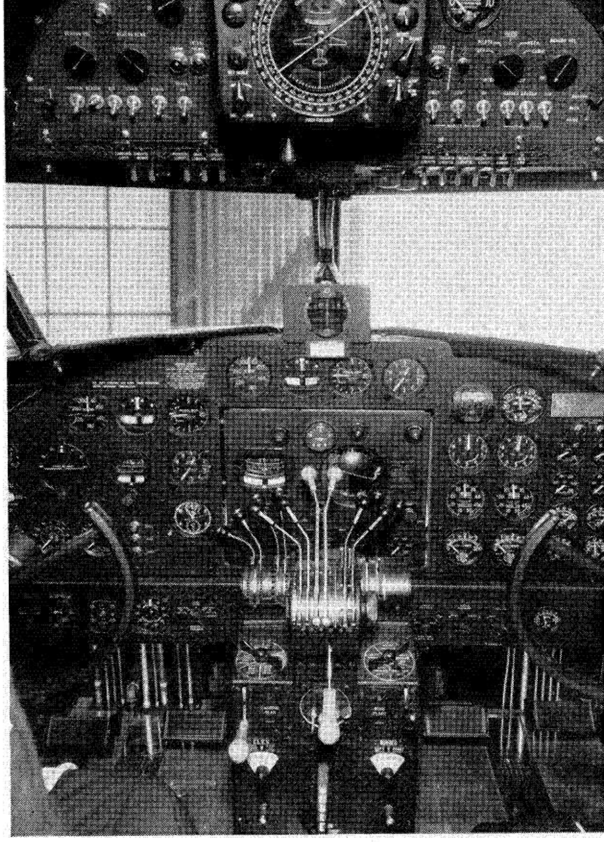
Recent improvements in airfoil design have attracted considerable attention but have not yet been extensively adopted. With information now available, there is no indication that the drag of these new airfoils is lower than conventional airfoils under actual operating conditions. Also, the criterion for airfoil efficiency includes the effect of maximum lift since in order to maintain the same landing speed, an airfoil with a low lift wing section would require a bigger wing. All of the new low drag airfoils must be considered from this standpoint. As aerodynamic efficiency improves, devices like mechanical boundary layer control become of interest. The practical complications involved have heretofore precluded their use. Flush riveting may be considered a form of boundary layer control, and has received widespread adoption. Other possibilities are a modification of contours to give a decreased pressure gradient over an extended forward portion of the airplane. Mechanical boundary layer control employing blowers offers the possibility of increased maximum lift and reduced wing drag. It also appears that the blowers employed for this purpose might be used in connection with engine cooling, cabin pressurization, or for other purposes.

Higher wing loadings which will become possible with further flap development will add to aerodynamic cleanness. Wing loadings being employed on military aircraft are beginning to approach the optimum for commercial operation under certain conditions. The new landing requirements set up by the Civil Aeronautics Board are opening the way to greater operating economy through the use of higher wing loadings. This trend has brought about the development of the "approach" flap, an intermediate setting giving an effectively lower wing loading, making possible lower speeds during the approach before landing. This gives the pilot time to work out instrument approaches and gives adequate rate of climb in the event of an emergency when the flaps cannot be retracted. Improved landing flaps giving lower landing speeds with higher wing loadings appear to be a definite possibility. The new landing requirements regulate the weight at which an airline may be operated in accordance with the airport runway length and obstacles to be encountered and the airplane's emergency climbing ability. The amount of load that can be carried legally will depend upon the airport from which the airplane is operating and the one at which it will land. There is thus a definite correlation between the capabilities of the airplane and the circumstances under which it must operate. A uniform degree of safety will therefore be achieved. Heretofore, a licensed airplane might, at times, have been operated under conditions which were questionable and at other times, restricted unduly. The new requirements also make mandatory a considerable improvement in performance with engines inoperative and in other emergency conditions. The result will undoubtedly be an improvement in both operating efficiency and safety.

Technical development directed towards improvement in safety is one of the most urgent concerns of the research staffs. Strangely enough, the greatest improvement which appears imminent is likely to come not from the airplane designer, but from the instrument designer. It is significant that none of the last five major airline accidents in this country and Canada have offered any evidence of structural or mechanical failure. It must be assumed either that the instruments and navigation aids failed or were inadequate, or that the pilot simply made an error due to fatigue. The sharp upsurge in accidents during winter months clearly indicates whence improvement must come. Fundamentally, airline accidents are caused by one factor — the weather. Navigation aids are then most important; pilot fatigue is next; and mechanical failures last. Navigation aids are developing as rapidly as any phase of the transport picture. An important step will be taken when blind landing systems, now in the advanced development stage, are perfected and receive widespread adoption. It is apparent that the time is not far off when completely blind flight will be a practical reality, when pilots will consider a complete trip, takeoff, flight and landing a routine operation in "zero-zero" weather. The number of airline accidents which have been caused by the pilot's not knowing exactly where he was, both with regard to location and altitude, indicates that navigation is far from automatic. The procedure for "letting down" through an overcast in approaching an airport is a complex navigational problem which must be performed with precision and in an unbelievably short space of time. The use of blind landing systems will add rather than subtract from the responsibility on the pilot and the complexity of the tasks he must perform.

SIMPLIFICATION OF PILOT'S JOB

The switch from two- to four-engined equipment has brought designers to the realization that the pilot's job must be simplified and that more attention must be paid to lessening fatigue and discomfort. The trend is to make the pilot's only concern the actual handling of the airplane. A third and sometimes a fourth crew member will relieve the pilots of the functions of



". . . . The pilot's job must be simplified."—Instrument panel in Lockheed "Lodestar" transport plane.

engineer, navigator, and radio operator. On long trips, relief pilots will be provided.

Although operating safety and operating reliability appear at times to be diametrically opposed, the same developments that improve safety will mean greater reliability. Perfection of blind landing systems alone would eliminate the cause of most trip cancellations.

The current cost of air transportation is roughly the same as the premium fares using rail transportation, but the possibilities for increased economy in air travel appear very great. In fact, the indications are that it would be possible, starting today, to design a transport airplane which could compete on a dollar-per-passenger-mile basis with the least expensive rail transportation. The greater speed of the airplane would then be available to the passenger absolutely without cost. To visualize the volume of passenger traffic which such equipment would attract to the airlines would strain the imagination.

AIR FREIGHT

A new field of expansion, the freight-carrying airline, can be shown to be economically sound using present equipment, on the basis of surveys of the volume of freight that would be available at a given cost and speed. As the cost of air transportation steadily comes down, the volume of freight available increases very rapidly. The possibilities again appear to be virtually unlimited.

It is recognized in the industry that no single thing will do as much to make air travel universal as greater safety. The curve of passenger-miles flown is very similar to the curve of passenger-miles per fatality. Fortunately, the latter curve is moving steadily upwards, and there is every indication that its slope will increase sharply in the immediate post-war years.

Everyone who has been two or three days late for an appointment because of an airline cancellation realizes that air transportation will never be the primary means of travel until

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AQUEDUCT RESEARCH

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effects a straight subtraction, i.e., it actually reduces the mineral content of the water. This is a desirable procedure; also, lime is cheaper than the other softening agents. However, certain hardness-forming compounds cannot be removed by lime but require the use of zeolite or soda ash. These agencies soften by base-exchange, i.e., they remove the hardness compound but leave another in its place.

Theoretically, barium acts on other hardness compounds in much the same way that lime acts on calcium bicarbonate, and effects a straight subtraction. Because of its cost, its suitability for large-scale water softening never has been developed. Large deposits of this mineral are available within reasonable distance of Los Angeles and it was thought possible that its use might be justified. However, a series of tests indicated that much development work will be required before large-scale use of barium for water softening is practical, if indeed it ever is.

All of the investigations described were carried out under the direction of F. E. Weymouth, General Manager and Chief Engineer of the Metropolitan Water District of Southern California.

L. H. Tuthill, Testing Engineer, was in charge of cement, concrete, and curing compounds studies, working with Professor Raymond E. Davis, of the University of California, as a consultant.

The pump tests were carried out by J. M. Gaylord, Chief Electrical Engineer, and R. M. Peabody, Mechanical Engineer, in collaboration with Professors Theodor von Karman and Robert L. Daugherty of the California Institute of Technology. Dr. W. F. Durand was consultant.

The water softening experiments were carried out by W. W. Aultman, '27, Engineer, with the assistance of Messrs. Charles P. Hoover and James M. Montgomery, consultants.

AIR TRANSPORT PROSPECTS

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such occurrences are eliminated. It is encouraging that the means of achieving almost 100 per cent schedule completion are at hand. It will probably take a number of years of peace time development to realize this goal, but the post-war decade will certainly see the airlines moving at any time when ground transportation is moving, and at times when trains and busses are stalled.

The year 1940 saw passenger air traffic up 64 per cent over 1939. Nearly a million more revenue passengers were carried, one-third more miles were flown, and a third more express was carried. Likewise, 1939 had seen similar gains over 1938. This phenomenal growth took place in a period when the attention of research and development groups was diverted to military needs, and therefore gives only a hint of what may be expected from the post-war era.

The air transport industry is hardly out of the adolescent stage. It will attain maturity when it realizes economy, safety and reliability that are the equal of any other means of transportation. These assets are now coming within reach. Speed, air travel's basic inherent advantage, is an ace in an off suit. Only when the trumps have been led will its real value become apparent.

ALUMNI SEMINAR

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Naval Base on Terminal Island" by Professor F. J. Converse, and on "Earthquake Forces in Terms of Design Factors" by Professor R. R. Martel.

Electrical Engineering — meeting presided over by Professor Royal W. Sorensen; discussions by Wendel Morgan '33 on the stability limits of a transmission line, and on "Dynamic Mechanical and Electrical Measurements by Means of a Recording Oscillograph" by George W. Downs.

Geology — discussion led by Professor Ian Campbell with reviews of current research projects; talks by Professor Horace J. Fraser on "The Effect of the National Defense Program on the Mining Industry," by Professor J. P. Buwalda on "Engineering Geology," by Clay T. Smith '38 on "The Chromite Deposits of the Western States, and by Professor Robert M. Kleinpell and Willis Popenoe, Ph.D. '36, on the progress of petroleum exploration in the Philippine Islands.

Humanities — Inspection of the art treasures of the Huntington Library as a sequel to the earlier lecture by Professor Macarthur.

Industrial Relations — meeting led by Professor Robert D. Gray; talks by representative personnel directors in California industries, including Cassius Belden of the Union Oil Company and Robert C. Storment of Lockheed Aircraft Corporation, on the subject of "Validity of Testing Techniques in Personnel Work."

Mechanical Engineering — meeting presided over by Professor Robert I. Daugherty; talks on "Vibration Damping in Metals" by Donald Hudson '38, "Methods and Results of Refrigeration of Quick-Frozen Foods" by Regis Gubser '27, and "Problems in Mounting of the 200-Inch Telescope" by Mark Serrurier '26.

Physics — seminar led by Professor Earnest C. Watson; lectures by Dr. Maurice F. Hasler '29, Ph.D. '33, on "Spectographic Analysis of Materials," and by Professor William V. Houston on "The Electron Microscope."

SUNDAY PROGRAM

Address, "Propoganda Three Centuries Ago and Today," by Kermit Roosevelt, Jr., dealing with the techniques and comparative effectiveness of propaganda today and in the time of Cromwell.

Address, "Some Problems in Modern Astronomy," by Dr. John A. Anderson, covering some of the major problems in astronomy and astrophysics which are currently being pursued by local and other scientists.

Address, "The Economic Consequences to America of a Totalitarian Victory," by Dr. Edwin F. Gay, Institute Associate in Economic History and former Dean of the Harvard Graduate School of Business Administration — a description of the government-controlled barter system employed by Germany in international trade, and an analysis of the problems that may be in store for us.

Address, "Synthetic Gasoline, Rubbers, Resins, and Plastics," by Professor Howard J. Lucas — discussion of polymerization reactions and their relation to modern industrial development and the national defense program.