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AIRPORT, RUNWAY, AND RAMP DESIGN

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BIBLIOGRAPHY OF REFERENCE MATERIAL PERTINENT TO AIRPORT DESIGN AND CAPACITY ANALYSIS

Contract FAA/BRD-136
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Airborne Instruments Laboratory
A DIVISION OF CUTLER-HAMMER, INC.

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Deer Park, Long Island, N. Y.

TABLE OF CONTENTS

A. REFERENCES ON AIRPORTS, THEIR DESIGN AND OPERATION

1. "The Airport and Its Neighbors," The Report of the President's Airport Commission, Washington, D. C., U. S. Government Printing Office, 16 May 1952.

> This report, prepared by a specially appointed three-man commission, reviews the relationship of the airport to the surrounding communities and to the Federal Government. It includes recommendations on changes in airport planning, zoning, design, terminal air traffic control, federal assistance, legal relationships, and flight operations near airports.

2. "National Requirements for Aviation Facilities: 1956-1975," Curtis Report, Vol I, May 1957.

> This report, prepared for Edward P. Curtis (special assistant to the president for aviation facilities planning), forecasts the demand on the nation's aviation facilities system.

3. "Modernizing the National System of Aviation Facilities," Systems Engineering Team, May 1957.

> This report, prepared by the Systems Engineering Team of the Office of Aviation Facilities Planning, The White House, is a plan concerned with the modernization of the national system of aviation facilities--including airports--over the next two decades.

4. "Accelerated Modernization of the U. S. Air Traffic Control and Navigation System," Air Coordinating Committee, March 1957.

> This report, prepared by Special Working Group 13, which included representatives from government and industry, reviews the status of the air traffic control system, including airports, and makes recommendations for improvement.

5. Airport Operators Council, Tenth Anniversary Report and Directory, May 1957.

This report contains a statement of airport operators' needs with regard to design and airport planning.

6. "Aerodromes," International Civil Aviation Organization, 12 January 1958, Annex 14.

This publication records the international standards and recommended practices for aerodromes.

7. "Airport Design," U. S. Department of Commerce, U. S. Government Printing Office, January 1945.

This report discusses the key factors involved in airport design, the key design standards relative to runway lengths and widths, separation criteria, grades, and others, that are included as guides for the airport designer, and suggested airport configurations.

8. "Airport Planning," U. S. Department of Commerce, Civil Aeronautics Administration, July 1952.

This publication is a guide for community leaders and public officials engaged in the planning of airport systems both local and national, and presents a planning method and techniques devised to encourage and advance the orderly development and growth of airports.

9. "Planning Standards for U. S. Naval and Marine Corps Air Station Facilities," Department of the Navy, Bureau of Aeronautics, 1957.

This is a manual of drawings and instructions for the planning of Naval and Marine Corps station facilities.

10. "Air Field Criteria Study--Summary of Conclusions and Recommendations," Parsons, Brinckerhoff, Hall, and McDonald, for the Office of the Assistant Secretary of Defense for Properties and Installations, June 1955.

This study reviewed current Air Force design criteria for all aspects of airfield and approach designs, and either confirmed present criteria or suggested new criteria.

11. "Air Traffic Capacity and Flow Direction Analysis of the New York Metropolitan Area," Prepared cooperatively by the Civil Aeronautics Administration First Region and the Port of New York Authority, January 1951.

A study which fixed the geographical locations of the New York airports, and analyzed other pertinent factors in airport design to determine the optimum runway layout and capacity of each airport. The factors considered were weather and wind data, aircraft cross wind operational characteristics, direction of air traffic flow, lateral separation between airports, and major obstructions in the area. As a result, the optimum instrument approach direction for all airports was selected, and airport capacity as related to terminal area capacity was developed.

12. Civil Aeronautics Board, Bureau of Safety Investigation. A series of reports has been prepared covering the occurrence of aircraft accidents. These occurrences are reported in:

1. Résumé of U. S. Civil Air Carrier and General Aviation Accidents, Calendar Year 1955.
2. Résumé of U. S. Civil Air Carrier and General Aviation Accidents, Calendar Year 1956.
3. Résumé of U. S. Civil Air Carrier and General Aviation Accidents, Calendar Year 1957.
4. Under-shoot Accidents in U. S. Scheduled and Irregular Air Carrier Operation Transport-Type Aircraft, 1946 through 1955.
5. Over-shoot Accidents in U. S. Scheduled and Irregular Air Carrier Operation Transport-Type Aircraft, 1950 through 1955.
6. Accidents Involving Slick or Snow-Covered Runways, 1948 through 1958.
7. Air Carrier Operations Continental United States.

13. "Jet Operations Requirements Panel," International Civil Aviation Organization, Document 7828, JOR/3-1 and 2, 1957.

A comprehensive report prepared by an international panel established: "To predict the operational requirements for ground service (including aerodromes), and aids to air navigation that may be expected for the large-scale operation (including operation in areas of extremely dense traffic), of large turbine-engined aircraft of such characteristics as may be expected to enter commercial services by 1961."

14. "Jet Age Planning," Civil Aeronautics Administration, U. S. Department of Commerce, Progress Report No. 1, July 1956; Progress Report No. 2, July 1957; Progress Report No. 3, January 1958.

These reports discuss the operational and facility problems posed by the introduction of jet aircraft into civil commercial use, and methods of meeting these problems.

15. "London Airport Ground Traffic Movement," Ministry of Civil Aviation, MCAP 68, 1949.

This report discusses the investigation of routing of aircraft, ground movement control, aircraft parking, apron vehicles, and passenger handling at London Airport.

16. "Survey of Aircraft Ground Time, Washington National Airport," U. S. Department of Commerce, Civil Aeronautics Administration, June 1951.

This study is an analysis, made at Washington National Airport in December 1950, of findings resulting from a survey of aircraft ground time as affecting gate position and other ramp requirements. The survey includes time spent at each gate, an evaluation of the operations conducted in loading, unloading, and servicing an aircraft at the gate, an analysis of the gate position occupancy relative to runway movements, and an indication of methods for calculating gate position requirements.

17. "ANC Procedures for the Control of Air Traffic," prepared jointly by the United States Army, United States Navy, United States Air Force, United States Coast Guard, and Civil Aeronautics Administration. U. S. Government Printing Office. Third Edition, effective 15 September 1957 and revision dated 15 May 1958.

This is a manual of air traffic control procedures to be observed by air traffic control tower personnel of the Army, Navy, Air Force, CAA, and other civil air traffic control agencies. Standard phraseology for use in air traffic control are prescribed in the manual.

18. R. Horonjeff, "Configurations of Exit Taxiways from Runways," Institute of Transportation and Traffic Engineering Research Report No. 25, University of California, November 1957.

This reports the results of an investigation of high-speed runway exits, that used four-engine, transport-type aircraft for high-speed ground runs, and suggests criteria for exit design.

19. R. Horonjeff, D. M. Finch, D. M. Belmont, and G. Ahlborn, "Exit Taxiway Location and Design," Institute of Transportation and Traffic Engineering Report, University of California, August 1958.

This reports the results of tests to determine minimum turning radii, turn-off taxiway design, and turn-off taxiway guidance. Representative Air Force, Navy and civil aircraft were used. It was concluded that these aircraft can safely and comfortably turn off runways at speeds about 60 to 65 miles per hour. Taxiway configurations for these turn-off speeds were developed. Preliminary work on visual guidance for these turn-offs was conducted. Time savings of as much as twenty seconds might be achieved by transport category aircraft if they were able to exit from the runway at speeds of 60 miles per hour instead of turning off on conventional 90-degree taxiways.

20. D. M. Finch, R. Horonjeff, G. Ahlborn, J. Howard, and D. Dunlap, "Surface Mounted Lights for Runway Guidance," Institute of Transportation and Traffic Engineering, Interim Report, University of California, April 1959.

This report describes a research program to develop a visual guidance system to light paved areas within runways for conditions of very poor visibility. A simulated model was constructed and promising lighting configurations were analyzed. The selected configuration was installed on a runway at San Francisco Airport. The system was evaluated using questionnaires to airline pilots and tabulating the results. The majority of the pilots felt that the center line system, in conjunction with the runway edge lights, was superior to the conventional system of edge lights only. The pilots' initial reactions to this system were favorable.

21. "Exit Taxiways and Holding Aprons," Airport Engineering Bulletin No. 6, Department of Commerce, Civil Aeronautics Administration, Office of Airports, March 1957.

A report on the analysis of aircraft performance data that are available; conclusions are drawn with regard to runway turn-off design and spacing, and holding apron design for aircraft waiting to take off.

22. "The Provision of Exit Taxiways at Washington National Airport and Their Effect on Runway Occupancy Time of Landing Aircraft," The Engineering Division, Office of Airports, U. S. Department of Commerce, April 1958.

During 1957, new exit taxiways were added to the instrument runway at Washington National Airport. This reports on a survey and study of the use and effectiveness, as measured by runway occupancy time, of the new exit taxiways. It is concluded that runway occupancy time has been reduced.

23. R. Horonjeff, J. H. Jones, "The Effect of Traffic Upon Runway Pavement Cross-section," Reprint No. 38, Institute of Transportation and Traffic Engineering, University of California.

This is a report of the investigation to determine the actual transverse distribution of traffic on runway at civil airports, and to relate this distribution to pavement thickness. Traffic distribution was observed during day and night operations under both visual and instrument flight conditions at Los Angeles, Oakland, and San Francisco Airports. After determining the transverse distribution, an attempt was made to develop a design for runway pavement of varying thickness determined by the distribution of wheel load.

24. Journal of the Air Transport Division, 1959 Jet-Age Conference Issue, Vol 85, No. AT-3, American Society of Civil Engineers Proceedings, July 1959.

This journal contains the papers presented at a conference discussing aspects of jet aircraft operation, and includes presentations on future aircraft, airport planning, jet aircraft operation, runway pavement, and visual guidance.

25. W. E. Cullinan Jr., "Airport Configuration," American Society of Civil Engineers Proceedings, Vol 83, AT-2, No. 1478, December 1957.

This reports the effects of runway configuration on airport capacity and trends in airport expansion modifications and presents the solutions to a number of unusual airport expansion problems.

26. "Terminal Area and Airport Surface Traffic--New York: Winter 1957-1958," Airborne Instruments Laboratory, Report No. 4851-1, November 1958.

A presentation of data accumulated from a study of air traffic in the New York area in early 1958. The data includes measurement of the flow of surface traffic at the three principal New York airports, and measurements and description of delays in air and surface traffic.

27. M. A. Warskow, "Use of ASDE Radar as a Tool in Airport Research Programs," Institute of Radio Engineers Convention Record, Vol 7, Part 5, Aeronautical, Military and Space Electronics. March 1959.

Airport Surface Detection Radar (ASDE) has been developed as a tool for use by the control tower operator in controlling ground traffic. Because of its outstanding resolution, this radar is useful as a means of studying airport activity. A description is given of a technique for recording the radar picture and other information to permit later analysis of the dynamics of aircraft movements on airports and other airport ground-traffic flow.

28. M. V. Cochran, T. G. Angelos, and M. D. Wiley, "Airport Capacity Study, Golden Triangle, CHI-NYC-DCA, 1956-1962," United Airlines Incorporated, Navigational Aids Division, Denver, Colorado.

This study analyzes the capacity and traffic demands of the major airports in the Chicago, New York, and Washington high-density areas, and includes information on Los Angeles and San Francisco airports. Airport capacities, determined on the basis of airport design and the effect of navigation and traffic control facilities, are used to provide a comparison between traffic demand for that airport and its capacity. Indications of the times when delays can be expected are included.

29. A. A. JeSchonek, "Radar Measurements of Approach and Landing Characteristics of Transport Aircraft," The Franklin Institute Laboratories for Research and Development, Report No. I-2185-3, 31 December 1952.

This report describes and presents the results of a program involving radar measurement of present-day transport aircraft performance in the terminal area of an airport, during approach and landing. The program obtained quanitative information regarding the distances, times, velocity, and decelerations that characterize the movement of transport aircraft on the final glide path and on the runways after landing. A description of the techniques used to gather this information is included. The graphical record describes the landing operations of 137 individual aircraft (involving 13 different types of aircraft) that were then grouped for analysis into four speed classes: very slow, slow, medium, and fast.

30. "Factors Affecting Airport Capacity and Their Applicability to Simulation," in four volumes. Airborne Instruments Laboratory, Cornell Aeronautical Laboratory, Franklin Institute Laboratories, prepared for the Federal Aviation Agency, Bureau of Research and Development, Systems Analysis Division, June 1959.

> Airport capacity is analyzed from the viewpoint of air space considerations (terminal flight and final approach areas and airport surface area considerations). The factors affecting capacity are determined and the need for their reproduction and simulation is analyzed. Techniques of simulation and applicability are discussed. It is concluded that the study of airport capacity should, because of its complexity, be first simulated for a single runway and functional phases associated with feeding, final approach, landing, take-off, or taxiing, proceeding to multiple runways, with experience. Simulators are available to study the terminal flight and final approach area and economic real-time simulators can be used to study the airport surface area.

31. M. A. Garbell, "The Timing of Airport Traffic Control as Influenced by Weather and Aircraft Performance," Garbell Research Foundation, Reproduced by the U. S. Weather Bureau, Washington, D. C., September 1951.

> A study of the effect of weather on the acceptance rate of airports. The various meteorological parameters are tabulated and their effect on air traffic both in the terminal area and on the airport are assessed. The study discloses that while increases in airport acceptance rates at certain airports will be made possible with the introduction of devices and methods that are at present under development, there exist nevertheless, additional elements in the timing of airport traffic control, at numerous more complex airport locations, that are critically influenced by weather and the performance of aircraft.

32. P. T. Astholz and T. K. Vickers, "A Preliminary Report on the Simulation of Proposed ATC Procedures for Civil Jet Aircraft," Civil Aeronautics Administration Technical Development Report No. 352, May 1958.

This report reviews the data obtained in a study of system requirements and proposed procedures for handling civil jet aircraft in the air traffic control system. The report discusses operational problems of civil jet aircraft as they relate to ATC requirements and describes a number of procedures simulated in the development of practical solutions to problems.

33. K. Eldred, "Acoustical Factors in Jet Airport Design," The Journal of the Acoustical Society of America, Vol 31, No. 5, May 1959.

This paper reviews the relationship between the noise resulting from commercial jet and propeller airliner operations, including take-off, taxi, and idle, for various projected traffic densities and various airport building functional design criteria. Methods and examples are presented that expedite initial visualiation of the major acoustical factors in an airport design situation.

34. K. N. Stevens, W. A. Rosenblith, and R. H. Bolt, "A Community's Reaction to Noise: Can it be Forecast?" Noise Control, Vol I, No. 1, p 63, January 1955.

K. N. Stevens and W. A. Rosenblith, "Handbook of Acoustic Noise Control, Vol II, Noise and Man," Wright Air Development Center Technical Report 52-204, June 1953.

N. Miller and L. Beranek, "Comparison of the Take-off Noise Characteristics of the Caravelle Jet Airliner and of Conventional Propeller-Driven Airlines," Bolt Beranek and Newman, Inc., prepared for Port of New York Authority, 25 May 1957.

N. Miller, L. Beranek and M. Hoover, "Comparison of the Take-off Noise Characteristics of the Comet Jet Airliner and of Conventional Propeller-Driven Airliners," Bolt Beranek, and Newman, Inc., prepared for Port of New York Authority, March 1958.

"Studies of Noise Characteristics of the Boeing 707-120 Jet Airliner and of Large Conventional Propeller-Driven Airliners," Bolt Beranek, and Newman Inc., prepared for Port of New York Authority, October 1958.

"Studies of Noise Characteristics of the Comet 4 Jet Airliner and of Large Conventional Propeller-Driven Airliners," Bolt Beranek, and Newman Inc., prepared for Port of New York Authority, October 1958.

This group of papers and reports contain an extensive back-ground in aircraft noise and its effect on airport operations and the surrounding communities.

35. G. C. Miller, "Airport Design for the Jet Age and the Future," American Aviation, 22 September 1958.

A general layout for airport design is suggested where a single dominant runway direction is used with dual near-parallel runways on either side of the central terminal area. High-speed roll-out lanes are indicated to increase runway capacity. The layout is intended to provide for modern and future aircraft operations on a high-capacity, efficient operational basis.

36. "Report of International Air Transport Association Helicopter Meetings," (Three reports covering the Montreal meeting), 11 through 13 November 1954; Brussels, 23 through 25 February 1955; and San Remo, 3 and 4 May 1956.

This group of reports develops the thinking of the International Air Transport Association with regard to helicopters on the topics of economics, heliports, multi-engine helicopter performance, air traffic control, NAV/COM facilities and equipment, and technical information required from manufacturers.

37. "Steep-Gradient Aircraft Navigation, Communication and Traffic Control," prepared by Radio Technical Commission for Aeronautics Special Committee No. 63, Washington, D. C., December 1959.

This study reviews the current operational situation, the current and anticipated development of steep-gradient aircraft, the future operational situation and operational requirement and suggested criteria for navigation, communication, air traffic control, and approach and landing systems for present and future steep-gradient aircraft development. It includes discussions of the operation of steep-gradient aircraft from facilities designed solely for their use and also their operation from airports.

B. REFERENCES ON METHODS OF ANALYSIS OF AIRPORT OPERATIONS AND SIMILAR PROBLEMS

1. A. Cobham, "Priority Assignment and Waiting Line Problems," Operations Research Society of America, Vol 2, July 1954.

There are several commonly occurring situations in which the position of a unit or member of a waiting line is determined by a priority assigned to the unit rather than by its time of arrival in the line--for example, the line formed by messages awaiting transmission over a crowded communication channel in which urgent messages may take precedence over routine ones. With the passage of time a given unit may move forward in the line after the units at the front of the line have been reviewed, or may move backward in the line when units that hold higher priorities arrive. Though it does not provide a complete description of this process, the average elapsed time between the arrival in the line of a unit of a given priority and its admission to the facility for servicing is useful in evaluating the procedure by which priority assignments are made. Expressions for this quantity are derived for two cases--the single-channel system in which the unit servicing times are arbitrarily distributed, and the multiple-channel system in which the servicing times are exponentially distributed. In both cases it is assumed that arrivals occur at random.

2. H. P. Galliher and R. C. Wheeler, "Non-Stationary Queuing Probability for Landing Congestion of Aircraft," Operations Research, p 264, March through April 1958.

Illustration is made, with reference to a case study of airport landing congestion in the New York area, of how numerical solutions can be easily obtained for the transient behavior of non-stationary waiting lines, characterized by Poisson arrivals, constant holding time, and service in order of arrival. In the case study, only the mean arrival rate varies as a given function of time, but the methods used easily provide for varying servicing rates and numbers of servers. Exact numerical values are sought and obtained only at intervals of the servicing time. While these times are short in the case study, so that little information is sacrificed, the method may be adapted to yield more frequent values in the case of long servicing times. Subject to this restriction, the entire probability distribution of the queue is calculated as the main numerical routine, from which the distribution of waiting time is directly obtained. Use of a stored-program computer is simple, cheap, and especially effective under saturating arrival rates.

3. W. A. Rambo and R. C. Wheeler, "An Evaluation of the Traffic Capacity of a Fixed Block Traffic Control System in the Approach Zone," Airborne Instruments Laboratory, July 1947.

This report covers the simulation study of a projected fixed block traffic control system to control traffic proceeding to and from the New York airports. Delays are determined theoretically and by simulation. Conclusions are drawn regarding the relation between the build-up of delay and the capacity of the limiting factor, which was shown for the airports this study included.

4. G. E. Bell, "Operational Research Into Air Traffic Control," Journal of the Royal Aeronautical Society, 1949.

This paper records the main results of researches undertaken by the Operational Research Section of the Ministry of Civil Aviation, and covers two areas--experimental investigation including "Time and Motion" studies of takeoff and landing, studies of air/ground communications, an analysis of the traffic and air traffic pattern in southeast England, and theoretical investigations into the problems of traffic congestion. The theoretical studies include a brief analysis of the distribution of air traffic arrivals, determining an expression for mean delays, the effect of derandomizing traffic movements, and indicates some areas that show promise for reducing or controlling the arrival delays.

5. E. G. Bowen and T. Pearcy, "Delays in the Flow of Air Traffic," Journal of the Royal Aeronautical Society, April 1948.

This is a study of the arrival delays at an airport. Random arrivals are assumed and are analyzed, including the derandomizing effects of control procedures. An expression for the average delay per aircraft is developed. It is concluded that any attempt to operate an airport near its maximum capacity results in long delays and an accumulation of aircraft waiting to land. It appears that the only practical method of operating without serious delays is to provide a large reserve capacity, or else to work with a safe minimum separation that is small compared with the average interval between aircraft.

6. T. Pearcy, "Delays in Landing of Air Traffic," published by the Royal Aeronautical Society, Vol 52, December 1948.

This paper rigorously treats the problem of delays in the maximum handling capacity of an airport. The paper assumes that aircraft arrive randomly, with a mean arrival rate remaining constant. Aircraft that follow their predecessors too closely are seen to be delayed for a minimum period so that none lands with an interval less than a safe minimum. As a simplification, it is assumed that no aircraft takes off from the airport. Expressions are developed for the probability of successive delays, the fraction of aircraft delayed, and the main delay of all aircraft, along with an analysis of the delay distribution. The paper concludes with the thought, "It appears that a true estimate of the necessary handling capacity of an airport can be obtained only from a criterion based on a knowledge of the distribution of delays. It is not sufficient to base the size estimate only on the allowable fraction of aircraft delayed and the average delay. The more important criterion would be that only a certain small fraction of aircraft should suffer delays greater than a specified figure."

7. T. Rallis, "The Capacity of Airports," Ingenioren, Copenhagen, Denmark, Vol 2, p 89, August 1958.

The handling of traffic in en route areas, terminal areas, air traffic control units, runway systems, and on aprons as well as inside and outside the terminal building, is studied block by block for the purpose of ascertaining the number of service channels, the service time, arrival intervals, and waiting times both present and future. The queuing theory is used for the computation of the waiting time at a given load density, since it is hardly possible to make observations in practice. So-called gaming technique (Monte Carlo technique) is used here to include such factors in the calculation not included in the queuing theory, such as spread in aircraft performance caused by technical defects as well as special weather conditions, and finally, human reactions.

On the completion of these examinations, the utilization factor of the Copenhagen Airport has been calculated for each traffic block in 1956 and 1970, on the basis of a number of assumptions, including the introduction of jet traffic. The capacity, unfortunately, varies from block to block. An operational research has been completed, and the capacity problem set out in a table, that readily can be filled in for all terminal traffic.

8. T. E. Armour, A. B. Johnson, and T. K. Vickers, "Simulation Tests of the Factors Affecting IFR Traffic Capacity at Chicago O'Hare Airport," CAA Technical Division, Report No. 341, February 1958.

This report is a simulation study of high-density air traffic operations at Chicago O'Hare Airport under IFR conditions, using the dynamic ATC simulator. Test results, which showed that use of contemplated additional runways would be restricted by operations of neighboring airports, illustrate the value of overall systems simulation.

9. T. K. Vickers, "Simulation Tests for Army Air Traffic Control," Civil Aeronautics Administration, Technical Development Report, No. 298, December 1956.

This report is a study of airway, airport, and navigation systems for rotary and conventional-wing aircraft. The study was made on the dynamic ATC simulator.

10. C. M. Anderson and T. K. Vickers, "Application of Simulation Techniques in the Study of Terminal-Area Air Traffic Control Problems," Civil Aeronautics Administration, Technical Development Report No. 192, November 1953.

This report discusses the application of graphic and dynamic techniques of simulation to the evaluation of developments in control procedures and equipment. Both methods have their advantages and limitations, and--as shown in this study--are complementary.

11. S. M. Berkowitz and E. L. Fritz, "Analytical and Simulation Studies of Terminal-Area Air Traffic Control," Franklin Institute Laboratories for Research and Development, Technical Development Report No. 251, Civil Aeronautics Administration Technical Development and Evaluations Center.

This report summarizes the program of terminal-area simulation work, jointly at the Franklin Institute and at the Technical Development and Evaluation Center of the CAA during a nine-month period. The specific tasks involved the setup, description, and analysis of the mathematical and physical system analogs, and the determination of the interaction of the many variables involved. Washington National Airport was used in establishing certain generalized problems with many specific applications and solutions. Tests showed that stacks can be useful reservoirs and coarse filters for derandomizing the inbound traffic, and for maintaining a steady supply to the final approach. Information was obtained on the actual performance in dynamic simulation as compared with theoretical performance. The steady-state traffic-delay theory now in use was found to be inadequate for the study of air traffic control. The communications load involved for various traffic levels was studied.

12. S. M. Berkowitz and R. S. Grubmeyer, "Requirements for New Universal Air Traffic Control Simulator," Transactions of the Institute of Radio Engineers, 1957.

This paper summarizes the uses of dynamic simulation in helping to solve current and future air traffic control and navigation problems, and in helping to evaluate proposed system concepts, control philosophies, procedures, and equipments. A brief description of the CAA Technical Development Center's electromechanical-optical simulator is presented, and some of its present limitations are outlined. Some of the more important requirements for a new universal simulator are presented and discussed in terms of their necessity and their technical feasibility in view of the present state of the art.

13. S. M. Berkowitz and R. R. Doering, "Analytical and Simulation Studies of Several Radar-Vectoring Procedures in the Washington, D. C. Terminal Area," The Franklin Institute Laboratories for Research and Development, Civil Aeronautics Administration Technical Development Report No. 222, April 1954.

This report summarizes the comparative evaluations of three promising traffic control configurations for the Washington National Airport terminal area. The three phases were analyzed comparatively by the use of three simulative screening techniques: ideal, graphical-time, and dynamic simulation using the TDEC dynamic simulator. An analysis was made of the optimum combination of outer marker separation and runway-exit modifications that would be consistent with the maximum acceptance rate and traffic.

14. S. M. Berkowitz, "Simulation as a Means for Analyzing Airport Capacities and Methods of Airport Surface Control," The Franklin Institute Laboratories for Research and Development, Report No. F-2164-4, August 1950.

This report discusses many situations involved in moving aircraft on the surface of an airport, the proposed methods of controlling aircraft on the ground, and the various simulated means for analyzing and evaluating all of these factors. Two devices are recommended as simple, easily used, inexpensive, and flexible tools for determining quantitatively the relationships among the important variables involved in airport surface control, present and future. An illustrative example of an actual airport situation is included.

15. A. Blumstein, "The Monte Carlo Method as a Decision Aid in Airways Modernization," Cornell Aeronautical Laboratory.

Decisions pertaining to future airways design--as with any operating system--must be made in the context of the entire system. Techniques to investigate a broad spectrum of possible decisions are required. The decisions must be made before the system is operational, and often before major portions even exist, so that abstractive, rather than experimental, techniques are called for. This paper introduces one such technique--the Monte Carlo method--to illustrate its application, and to evaluate its role in airways modernization. The steps in using the Monte Carlo method of simulation are presented, and a typical Monte Carlo model is recorded to illustrate the technique. The paper draws conclusions as to the application of Monte Carlo techniques in comparison with other system analysis techniques.

16. N. Jennings, "Computer Simulation of Peak Hour Bus Operation," Port of New York Authority, October 1957.

The simulation of a complex dual-waiting-line problem in the form of a Monte Carlo model on an IBM 650. This is illustrative of the type of problem that is particularly suited to digital computer simulation.

17. J. J. Foody and R. J. A. Paul, "Simulation Techniques in Aeronautics," Journal of the Royal Aeronautical Society, p 878, December 1958.

Electronic Computers, used as models of dynamic systems, are considered. Analog and digital techniques are applied for simulation of externally and internally controlled systems.

18. P. F. Dunn, C. D. Flagle, and P. A Hicks, "Queuiac: An Electromechanical Analog for Simulation of Waiting-Line Problems," Operations Research, p 648, December 1956.

Describes electromechanical simulation equipment that displays network of handling operations and provides estimates of congestion at any or all points of a system. Particularly adaptable to simulation of human handling operations.

19. R B. Coulson and V. B. Burgmann, "An Investigation Into Air Traffic Control by a Simulation Method," Commonwealth Scientific and Industrial Research Organization, Radio Physics Laboratory, Commonwealth of Australia, March 1950.

This paper describes a series of investigations of air traffic control problems by simulation methods, made with laboratory equipment especially developed for the purpose and the results obtained from a detailed study of a number of possible control systems. It was found that the specified minimum separation between landings cannot be rigidly adhered to. The capacity of an airport is affected by the type and performance of the navigational aids installed.

20. L. R. Philpott, "The External Rate of an Airport, an Analysis," Air Navigation Development Board, Washington, D. C., 22 June 1951.

This study isolated some of the factors affecting airport capacity and evaluated their effects quantitatively. A comparison is made of the airport acceptance rate under several sets of rules and conditions. The resulting air delays caused by stacking during periods of excess demand are developed and applied as an average delay accruing to each aircraft. The method of analysis used included a division of the landing period into seven phases, beginning with the turn-on to the common final approach path and ending with the issuance of a clearance to land to the next succeeding aircraft. The time required to execute each phase was then calculated. The total time required to land was then derived by the simple addition of the various phase times involved.

21. E. A. Whiteley, "The Spacing of Aircraft Under High-Density Approach Conditions," published by the Royal Aeronautical Society, August 1952.

The purpose of this paper is to examine some of the techniques and methods that may be used to ensure safety separation between aircraft during the approach to an air terminal, under high-density traffic conditions, in the period 1955 to 1965. The flow of aircraft is assumed to comprise many types, with differing approach speeds, arriving from a variety of directions, and with initial altitudes up to 35,000 feet. No mention is made of departing aircraft. The general philosophy includes discussion of two features of many existing air-traffic systems that should be eliminated. The first is the stacking of aircraft in the vicinity of terminals. The second is the practice of having large numbers of aircraft under close control--that is, subject to continuous flow of verbal directions from the ground. The paper examines a number of assumptions and provides an outline of the essential elements of any system and the various phases of any approach.

22. "Solution Methods for Waiting Line Problems," The Port of New York Authority, September 1958.

The Port of New York Authority has found much use for scientific analysis of waiting line problems developing as a part of their extensive transportation facilities operation. In their work involving waiting line problems analysis, much useful material has been collected from widely scattered descriptions published in a variety of technical and management literature. This paper is an attempt to summarize under one cover general principles of waiting system analysis and the application of appropriate solution methods. A collection of formulas and curves is included, covering a broad range of the more common problem types.