Real-Time Data Processing for CAA Air-Traffic Control

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FOUR years ago, the Eastern Joint Computer Conference was held in this same city. At the first session of that Conference, Vernon Weihe, representing the Air Transport Association of America, stated that "the need for automatic computation and automatic data handling (in air-traffic control) is immediate and urgent." He challenged the computer industry and the aviation industry to meet this need with sound system design incorporating human engineering and the rapidly advancing technical developments of the day. The paper took note of the fact that a start had already been made with the installation of a magnetic drum-message storage and processing system at the CAA Technical Development Center in Indianapolis, Ind. This present paper is somewhat in the nature of a status report, describing how the Civil Aeronautics Administration is beginning to use electronic computers for air-traffic control operations. In order to understand this application, it will be necessary to consider briefly the manual operations which are to be replaced.

Air-traffic control is exercised in two types of areas. The first type, called the terminal area, is that airspace in the proximity of an airport where aircraft are under the jurisdiction of an approach controller or tower controller, located at the airport itself. The second type, which is called the enroute area, is that airspace designated as Federal Airways, which are the well-traveled highways of the sky. In the enroute area, control is exercised from an air-route traffic-control center, of which there are 27 within the continental limits of the United States. A typical center has jurisdiction over an area approximately 300 miles across. Plans are well along to expand enroute control area to include all airspace above a certain designated altitude, such as 24,000 feet. This paper will concern itself mainly with the operations of the enroute area.

Fig. 1 shows an air-route traffic-control center. The individual controllers are responsible for a portion of the area called a sector. Each sector has a tabular display in the form of a board in which are inserted flight-progress strips. A close-up view of one of these boards is shown in Fig. 2. Within the geographical area of the sector, there are several key traffic-control points generally located at the intersection of airways which are called fixes. Aircraft are required to report to the ground by radio whenever they pass over one of these fixes, in order that the controller may ascertain their position and maintain proper separation from other aircraft both in altitude and in time.

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Fig. 1—Indianapolis air-route traffic-control center.

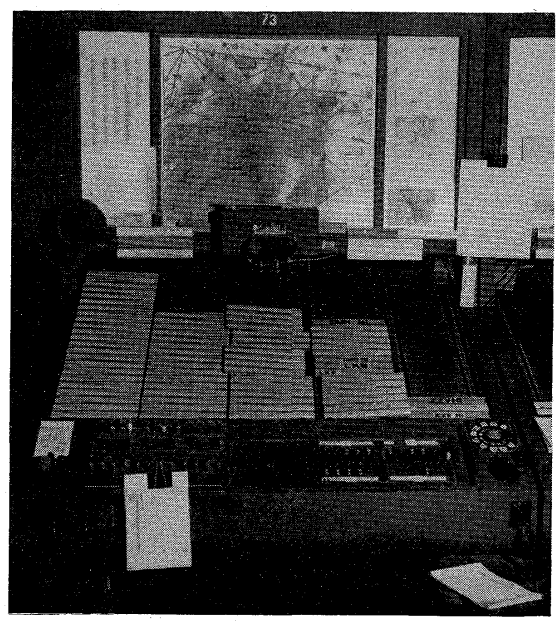

Fig. 2—Flight-progress board.

Aircraft pilots who intend to make a flight under instrument conditions or under the supervision of CAA air-traffic control must file a flight plan with the control agency. This flight plan will include the aircraft identification, aircraft type, speed, take-off point, altitude, route, and destination. From the information contained in a flight plan, individual flight-progress strips are prepared and posted at each fix over which the aircraft will pass. Fig. 3 shows a typical flight-progress strip prepared by a traffic controller for American Airlines Flight No. 34. The strip shows the following data: the aircraft is a DC-7 with a speed of 370 knots, its route of flight is from Chicago Midway (MDW) over airways designated as V 6, V 168, and R 15, to Idlewild (IDL). The flight was first estimated over Youngstown, Ohio, (Y) at 0958 which was later re-

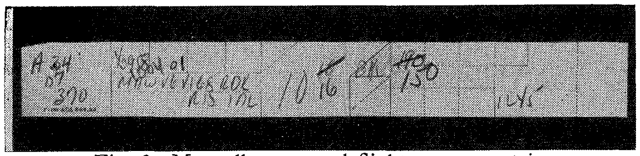

Fig. 3—Manually prepared flight-progress strip.

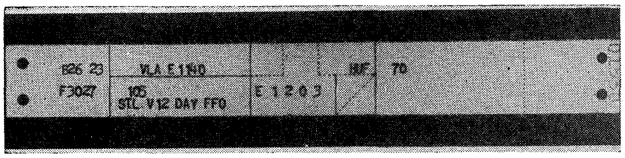

Fig. 4—Automatically prepared flight-progress strip.

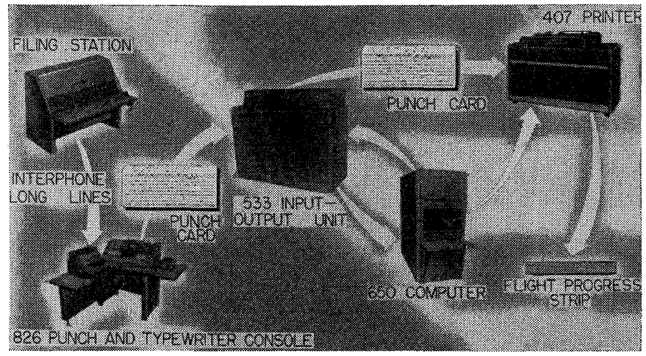

Fig. 5—IBM 650 air-traffic control operation.

vised to 1004 and actually reported at 1001. It was originally estimated to pass over Brookville, Pa., (BKL) at 1010 and this estimate was revised at 1016 on the basis of the Youngstown revision. The altitude was originally 19,000 feet and this was later changed to 15,000 feet.

During a busy hour in the New York center, as many as 1200 to 1500 flight strips will be prepared. The system has a deadline to meet in that the strips must be prepared and distributed to the proper controller approximately 30 minutes in advance of the actual arrival of the aircraft over the fix, in order that he may compare the time and altitude with that of other flights in the area and make sure that no conflicts exist. On peak days and at peak hours of traffic, the time involved in getting flight plans to the center, processing strips, and in getting clearances back to the pilot sometimes causes the delays in take-off that all of us have experienced. A great deal of manual effort is involved in gathering the data, preparing and distributing the flight-progress strips. It is in this area that the first application of computers is being made.

In 1955, under an Air Navigation Development Board project, system experimentation at the Technical Development Center began to determine the data-processing requirements for automatic printing of flight-progress strips. Although the magnetic drum-storage equipment lacked computing capabilities, a group of specially trained operators were used to simulate the computing functions. These operators would receive a flight plan and process it by breaking down into the various fixes over which the aircraft would report. They would then prepare messages in the form of fix postings and send these messages over a teletypewriter circuit to the magnetic drum equipment. The magnetic drum equipment would subsequently read out each message to one of several printers when it came time for the flight strip to be displayed in front of the air-traffic controller.

Fig. 4 shows a flight-progress strip printed during the evaluation of this system.

During the past year, an IBM 650 computer has been installed in the Indianapolis Air Route Traffic Control Center in order to carry out an operational test of printed flight-progress strips. See Fig. 5. Traffic controllers, receiving flight plans by interphone, have been preparing a punched card for each flight. These cards are fed into the computer, which determines the route of flight, calculates estimates, and prints all the strips required automatically. A complete report of this operation has been prepared and will soon be published by the CAA as a Technical Development Report. In addition, this subject was also presented in a paper given by G. B. Harwell of the Technical Development Center during an IBM 650 Scientific Symposium in Endicott, N.Y., the first week of October, 1957. Plans are now being made to expand the capability of this installation by adding RAMAC and on-line input-output facilities.

Plans are also being made to install the Model I Univac File Computer in the traffic-control centers of New York and Washington, D.C., by next summer for automatic preparation of flight-progress strips. A prototype of this system is now being assembled at the Technical Development Center in Indianapolis for testing and evaluation. Fig. 6 is a block diagram of the prototype system. In the Washington and New York installations, space limitations will require that the computer be located in a distant room or even on another floor of the building which houses the center-operation area. Provisions must be made, however, for input and output at several locations in the center itself. In the initial phases of the operation, the principal input to the system will be in the form of flight plans. Flight-plan data will be fed to the computer in two ways. Those which are received by interphone or off-line teleprinter will be encoded by operators in the center itself and transmitted to the computer. Those received from another computer-equipped center or remote station in the local area properly equipped for on-line communication will be fed directly into the computer.

One feature of the system will be the adaptation of a scanner and speed-conversion device which Remington Rand is producing for their airline reservations systems. By means of this equipment, a number of communication channels, operating at teletypewriter speeds, can work into a single high-speed input to the computer.

At the manual input position, flight plans which are received by interphone will be encoded by operators and transmitted to the computer. The computer will analyze

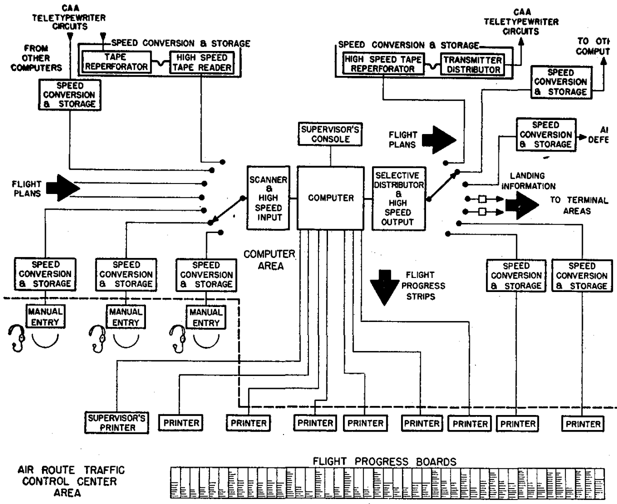

Fig. 6—Block diagram of prototype data-processing system.

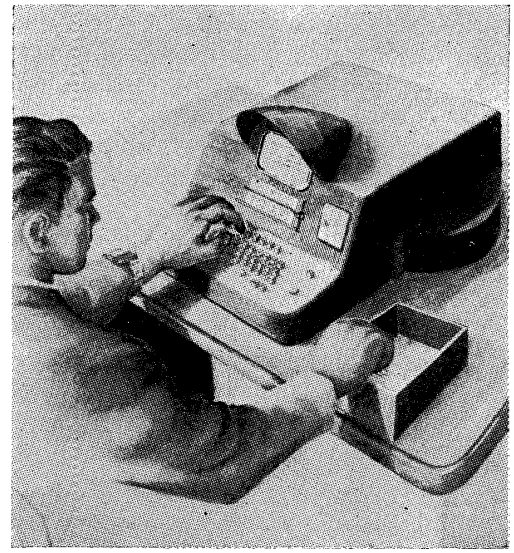

Fig. 7—Flight data-entry equipment.

the route of flight, determine over which fixes the aircraft will pass, estimate the times of arrival over each fix, assemble data in the proper form for printing flight-progress strips, and transmit the data to one or more of the flight-progress strip printers in the center area. At the same time it will keep a record of the flight plan itself and all fix data within its memory. Flight plans which enter the system from distant points over the communications lines will go directly into the computer for processing.

If a flight is to continue into an area served by another air-traffic-control center, flight-plan data must be forwarded to that center in order that strips may be prepared. At the appropriate time, the computer will locate the flight-plan information in its memory and transmit automatically over the communications circuit to the proper destination. A configuration of selective distributor and speed-conversion units will permit one high-speed output from the computer to serve a number of low-speed communications channels. During the evaluation of the prototype system, the procedures of transmitting flight plans to Air Defense and messages to terminal areas regarding landing aircraft will be investigated.

A supervisory console will be provided in the computer area for maintenance operations, and an additional printer will be located in the center area near the manual input position for flight plans which the computer may reject as erroneous.

A problem area in the preparation of data for automatic handling by computers is the rigid format required to insure that the computer treats each part of the data received in its proper category. This is particularly true in the case of a relatively long and involved series of data such as flight plans which will have an average length of 110 alpha-numeric characters. Two major types of errors may occur in the preparation of such messages. Operator errors may range from the addition or deletion of one or more characters, to failure to follow the proper ground rules. Communication errors may also occur, and with the five-unit code of standard teletypewriter systems, these may pass through the system undetected.

In order to permit rapid and accurate composition of flight-plan messages for transmission to the computer over communications circuits, the Technical Development Center has contracted with Aeronutronic Systems, Inc., of Glendale, Calif., for the development of FLIDEN (Flight Data Entry) equipment. Fig. 7 is their artist's conception of the device whereby an operator may compose a message which is displayed on a cathode-ray tube and stored electronically on a magnetic drum during composition. If the operator makes an error, he may backspace rapidly or a character at a time to the position where the error occurred. Having corrected the error, he may shift rapidly back to where the message composition was interrupted and continue. A form on the face of the display designates categories of information which should be entered. All fixed characters and functional characters are entered automatically for ease of composition and accuracy of format. The completed message is checked for accuracy by the equipment before transmission.

For detection of errors during transmission, an error check character is automatically inserted at the end of each line of data. This is accomplished by making a longitudinal count of marks at each code level and adding a check bit to make the total count odd. The check bits are combined to produce "nonsense" or check characters which are transmitted with the message. This basic technique is described by Vincent.[1] At the receiving end, a similar count will be made and the resulting check character at the end of each line of text will be compared with the check character transmitted by the FLIDEN equipment. Messages which contain

[1] G. O. Vincent, "Self-checking codes for data transmission," *Automatic Control,* vol. 5, pp. 46-49; December, 1956.