SPERRY RAND

DATA PROCESSING

IN THE NEW YORK COMMON IFR ROOM

APPLICATION OF COMPUTERS IN THE CENTRALIZED AIR TRAFFIC CONTROL FACILITY FOR METROPOLITAN NEW YORK AIRPORTS

BY ROBERT H. ANDERSON

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UNIVAC
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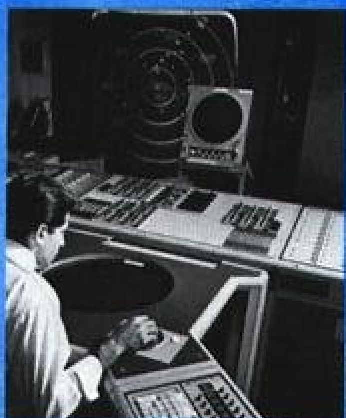

The rapid growth of aviation activity has created a need for improved air traffic control capabilities. Recent improvements in air traffic control systems have been directed toward achieving increased efficiency in the utilization of airspace, and increased traffic-handling capability with no compromise to safety. A significant development is the introduction of automatic data processing techniques to provide direct assistance to the air traffic radar controller. ■ Through radar observation, pilot reports, and flight plans, the controller follows those aircraft on instrument flight rules (IFR) in his area of jurisdiction. He keeps the aircraft safely separated by voice radio instructions to the pilots. As a flight progresses through various sectors of the airspace, control responsibility for the aircraft is transferred (handed off) from one controller to another. ■ The airspace surveillance required by an air traffic control ground facility is provided by radar and beacon sensor systems. The radar and beacon equipment both derive aircraft position (azimuth and slant range) information from the antenna orientation and the time delay between transmitted and received pulses of r-f energy. Whereas the radar receives reflected energy, the beacon equipment triggers and receives signals from a transponder aboard the aircraft. The transponder reply signals can be coded to convey aircraft identity and altitude. However, the sensor data must be presented to the controller in such a manner that he can readily assimilate it. The conventional radar plan-position indicator (PPI) has several shortcomings:

1 The controller has to determine which video returns (blips) on the radar scope correspond to aircraft of interest to him.

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2 He must then keep the identity of each aircraft properly associated even in congested traffic or clutter areas where many video returns appear in proximity.
3 With the radar PPI he has a two-dimensional representation. Altitude, the vital third dimension of the air traffic situation, is missing.

■ To alleviate these shortcomings, the FAA has developed a computer-assisted display technique that provides a dynamic display of flight data, in alphanumeric (letters and numbers) form, directly on the radar scope. This technique provides the controller with aircraft identity and altitude information continuously associated with the proper video returns. A prototype system, the advanced radar traffic control system (ARTS), has been in operation for several years at the terminal facility in Atlanta, Georgia.

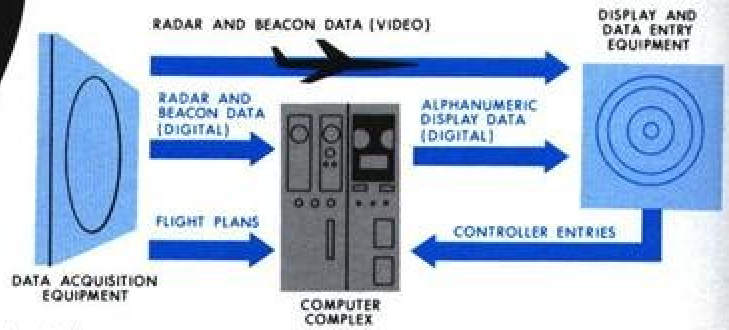
The photos on these pages show a central air traffic control facility for New York's airports. The photos were shot while the facility — called a Common IFR Room — was being installed. The room features a system that provides alphanumeric flight data directly on the controller's radar display. This system's performance and flexibility are enhanced by use of digital computers and real time data processing techniques.

A second installation, the New York Center beacon alphanumeric (NYCBAN) system, located at the FAA air route traffic control center (ARTCC) on Long Island, was put into operation early in 1967. A new control facility, serving the New York terminal area, will soon become operational. It is the data processing capability of this facility, the Common IFR Room, that is the subject of this paper.

YORK COMMON IFR ROOM

ROBERT H. ANDERSON

Fig. 1 — Computer-controlled alphanumeric flight data is superimposed over normal video on the controller's radar scope. The three alphanumeric "tags" shown in this illustration are automatically following radar and beacon video returns. Relocatable data tables (upper right guadrant) display pending flights and aircraft in holding patterns. (Video map, ground clutter, interference, and noise, which complicate the real radar display, have been omitted for clarity.) Fig. 2 (below) shows the two information paths to the display equipment: a direct video path that provides sensor data in the normal manner; and a digital path, via the computer for alphanumeric data.



Common IFR Room

The New York terminal area is one of the busiest air traffic control complexes in the world. It encompasses three major airports and numerous satellite airports each of which accommodates instrument flight traffic. The control of terminal operations has been divided among three separate control facilities with a portion of the available airspace assigned for the exclusive use of each. The operating quarters (IFR Rooms) have been located at Kennedy International, Newark, and LaGuardia Airports.

These installations are being combined to provide a common centralized terminal area control facility located at Kennedy International Airport. A common IFR room will permit more efficient utilization of airspace, and will minimize delays by providing flexibility in the routing and control of flights. From this central control room, arrival and departure operations at all of the airports can be controlled on a fully integrated basis. Since controllers for the different airports work side-by-side in the same room, it becomes much simpler to coordinate their actions. It is not necessary to waste valuable airspace to provide buffer zones between operations controlled by separate facilities. Furthermore, personnel controlling aircraft in the same general proximity actually share the same displays, including large-screen displays, which provide a common reference source for all control teams.

The individual controller radar scopes and two large-screen radar displays are all augmented with alphanumeric capability. Under computer control, pertinent flight data, including aircraft identity and altitude, is electronically superimposed as tag-like data blocks adjacent to the appropriate radar video returns (see Fig. 1). The alphanumeric tags automatically follow the video while the aircraft maneuver through the terminal area.

There are significant advantages in having identity and altitude continuously associated with the radar presentation. Even a skilled controller, adept at interpreting the radar picture, presently expends considerable effort just to identify the video returns of aircraft under his control. He also relies on pilot reports for altitude information. The amount of attention and communication required increases rapidly with the number of radar targets involved. By assisting the controller in this task, the alphanumeric display system permits him to focus more of his attention on the problem of controlling aircraft. In addition, it reduces the amount of controller-pilot communication required.

A secondary benefit is the manner in which this display technique facilitates aircraft handoffs within the Common IFR Room. When responsibility for an aircraft is transferred from one man to another, the controller initiating the handoff pushes a button to cause the tag for the aircraft to appear on another controller's display. The recipient then pushes a button to signify that he has accepted control of the aircraft. Permanent transfer of control and alphanumeric data is thereby accomplished by the computer, with little or no verbal exchange of aircraft target information.

System Configuration

The hardware for the Common IFR Room system includes data acquisition equipment, display equipment, and a computer complex (Fig. 2).

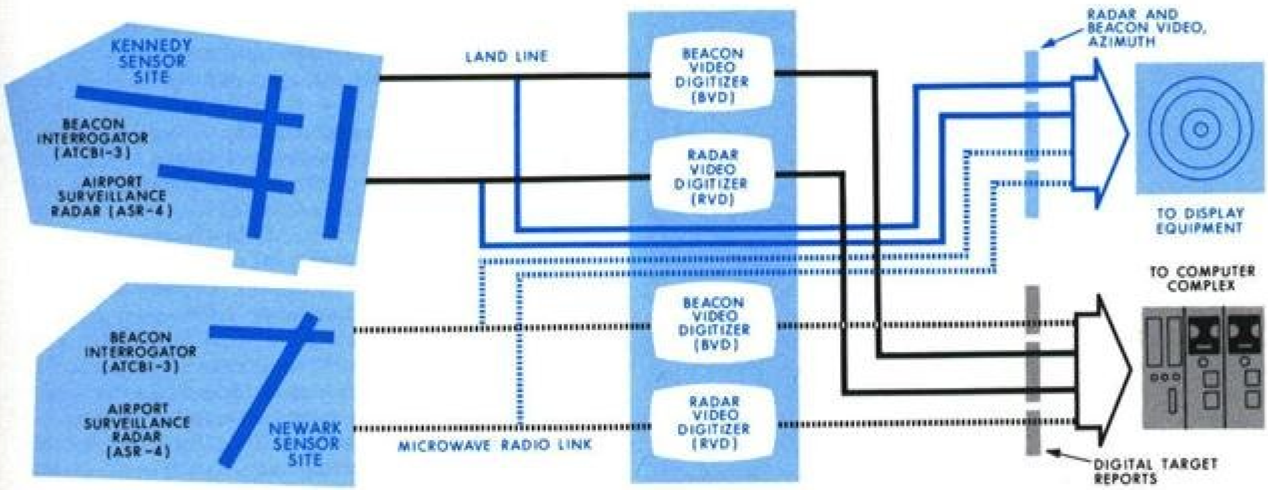
Data acquisition equipment — Surveillance of the volume of airspace comprising the New York terminal area is provided by radar and beacon sensors (Fig. 3) located at two sites: Kennedy and Newark Airports. Each site is equipped with an airport surveillance radar (ASR-4) and a beacon interrogator (ATCBI-3). The radar and beacon systems provide a 60-mile radius of coverage from each site. Wideband transmission media feed the radar and beacon video, trigger signals, and antenna azimuth from the sensor sites to the Common IFR Room facility. The Kennedy radar uses a land line, while a radio microwave link is employed for the remote Newark site.

The beacon system acquires data for transponder-equipped aircraft. Many commercial aircraft presently have transponders capable of reporting identity and altitude. It is anticipated that all commercial aircraft operating in the United States will have transponders within several years. The radar provides redundant coverage for these aircraft and also accommodates aircraft that do not have transponders. The latest beacon transponders are capable of transmitting any one of 4096 discrete identity codes as selected by the pilot. This permits the aircraft to be assigned a unique code. However, some transponders still in use are limited to 64 codes, and the same identity code is often assigned to more than one aircraft. Transponders equipped for altitude reporting transmit data that is encoded directly from a pressure-sensing altitude transducer in the aircraft. The transmitted altitude data is measured in 100-ft increments with respect to a standard pressure of 29.92 inches mercury.

Analog radar video, although suitable for PPI displays, cannot be used directly by the digital computer complex. Therefore, a radar video digitizer (RVD) is employed for each radar to convert the analog data into digital form. The RVD quantizes the video signal, correlates returns from successive radar pulses, detects radar targets, and determines target range and azimuth. It provides the computer with target reports in digital form containing the range and azimuth of each detected target.

Beacon replies are in the form of coded pulse trains. Like radar video, these signals are unsuitable for direct processing by a computer. For each beacon system, a beacon video digitizer (BVD) isolates the replies, correlates replies from successive interrogations, detects beacon targets, and determines target range and azimuth. For each detected target, the BVD provides a digital target report to the computer. In addition to range and azimuth, the target report includes transponded identity code and altitude when this information is received in ungarbled form.

Display equipment — The Common IFR Room is equipped with radar bright display equipment (RBDE-5) modified to include alphanumeric capability (Fig. 4). In addition, the standard 22-inch and 16-inch display consoles are supplemented with large screen projection displays. Eight individual consoles and two



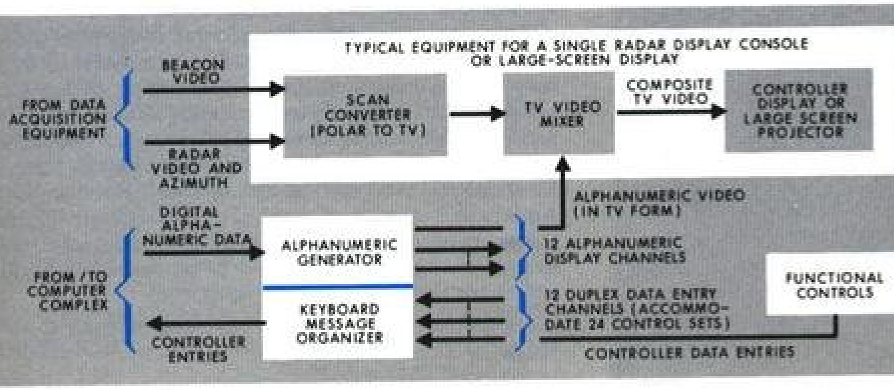


Fig. 3 — Major items of data acquisition equipment. Radar and beacon sensors at Kennedy and Newark airports transmit data to digitizing equipment at the Common IFR Room at Kennedy.

In Fig. 4, alphanumeric video and scan-converted radar and beacon video are mixed to provide a composite TV display picture. The Common IFR Room will be equipped initially with 8 RBDE-5's and two large-screen displays.

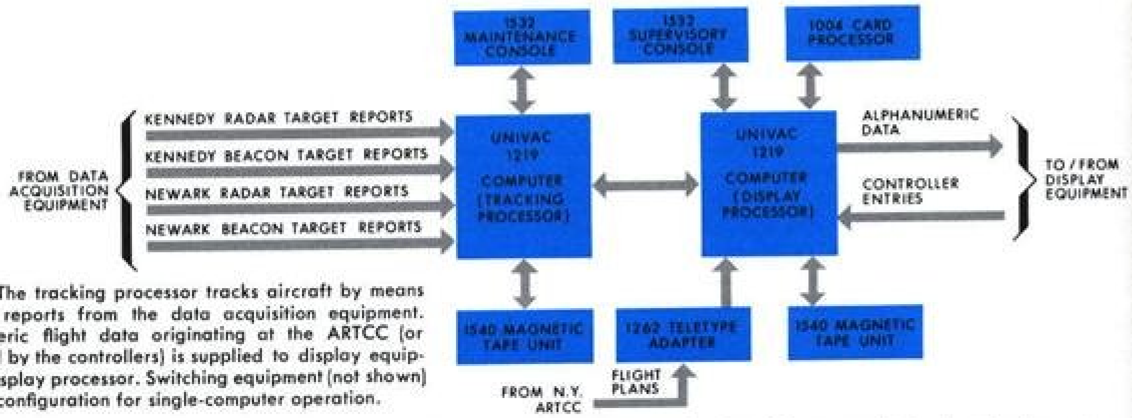


Fig. 5 — The tracking processor tracks aircraft by means of target reports from the data acquisition equipment. Alphanumeric flight data originating at the ARTCC (or introduced by the controllers) is supplied to display equipment by display processor. Switching equipment (not shown) permits reconfiguration for single-computer operation.

9-by-12-ft display screens provide a composite picture of radar and beacon video and computer-processed alphanumeric flight data.

The radar display utilizes a storage tube scan-conversion principle whereby the sensor video is converted from its original polar (range and azimuth) form into a television-type rectilinear scan before it is displayed. The resulting bright high-resolution (945 lines) presentation does not require a low ambient light environment usually necessary with radar displays. Since each display unit is essentially a TV monitor, alphanumeric data originating in the computer complex must be changed into TV form before it can be displayed. This task is performed by an alphanumeric generator, which accepts coded digital data from the computer complex and converts it into TV form signals. Alphanumeric TV signals from the generator are then mixed with radar and beacon TV signals from a scan converter, and the resulting composite is displayed. The alphanumeric generator has twelve independent alphanumeric video channels individually addressable by the computer complex. Each display console or large screen projector receives and displays flight data blocks from one or more alphanumeric channels. In addition, common data, in the form of single symbols at the position of each controlled aircraft in the system, is distributed to all display channels.

The displays are updated by the computer complex every two-and-one-half seconds to provide a dynamic picture of air traffic. Between times, the current alphanumeric video for each display channel is recorded on a magnetic drum within the alphanumeric generator. This video is then played back cyclically in synchronism with the TV raster to maintain a flicker-free display.

The manual controls that are present at each operating position enable the controller to introduce commands, alphanumeric data, and aircraft position coordinates into the computer complex. These controls include command pushbuttons, an alphanumeric keyboard, and a cursor control. Nine broad command categories are defined for use by controllers in the Common IFR Room, and each can be further qualified by up to ten specific *modifiers*, called *functions*. Supplemental data, such as aircraft identity or assigned altitude, is entered through the alphanumeric keyboard when required. The cursor control is used to position a small movable cursor symbol on the display. The position coordinates of this cursor symbol can be entered into the computer for the controller to specify the location of an aircraft or a data block.

Computer complex — The computer complex (Fig. 5) tracks the sensor inputs, associates flight plan data with tracked aircraft, and supplies alphanumeric information to the controller displays. Two UNIVAC® 1219 general-purpose digital computers provide the system with a capability for arithmetic computation, logical decision-making, data storage, and over-all system coordination.

The computer complex includes other equipment items commonly found in a data processing application. Magnetic tape units provide permanent storage for the computer programs, and are used to load the programs into computer memory. In addition, selected data obtained during system operation is recorded on magnetic tape for future processing and analysis. The input-output console, containing a low-speed printer, typewriter keyboard, and paper tape facilities is provided to permit the watch supervisor to communicate with the computers. This console, designated the supervisory console, is used to enter variable parameters (such as time or altimeter setting) required by the system. High-speed printing and punched card capability for the 1219 computers is provided by an on-line 1004 card processor.

The computer complex is connected to a teletype circuit, which originates in the air route traffic control center located at Long Island-MacArthur Airport. A computer at the center transmits flight plan data for future flights to the Common IFR Room. The serial teletype signal is converted into parallel digital format by an adapter and fed into one of the 1219 computers. Automatic insertion of flight plan data is a significant advance over previous prototype alphanumeric systems, because it relieves the controller of the task of manually entering this data via a keyboard.

Data is transferred between the 1219 computers and the other devices by means of high-speed digital input or output channels. Each computer has 16 bidirectional channels to accommodate concurrent communication with all of the hardware in the computer complex as well as with the data acquisition and display equipment. The system configuration has been made flexible by a manual cable-switching arrangement that allows each external device to be connected to either computer. Normally both computers share the data processing load. One, the tracking processor, performs an aircraft tracking function, while the second, the display processor, provides alphanumeric data to the display equipment. However, if one 1219 should be unavailable, the system can be reconfigured to operate with reduced capability in a single-computer mode.

The computers perform data processing functions under the control of stored instruction sequences (programs). This is a real-time system — it keeps pace with events in the air traffic environment. The tracking processor and the display processor, although they exchange data, are completely independent asynchronous computers. They execute their programs simultaneously, thereby providing a parallel processing capability. Within each computer, however, the internal processing tasks are performed on a time-shared basis. To accomplish this, the sequence of instructions associated with each major processing task is organized into a module called a subprogram. In addition, each computer employs an executive control subprogram that performs no processing of its own, but serves to control the execution of the task subprograms. The subprograms are not executed in a fixed sequence. Rather, selection of a task depends upon an assigned priority scheme that adapts to changes in the system's processing load and permits the processor to respond to asynchronous external demands. Some tasks are executed on the basis of a fixed time interval, while others depend upon the completion of prerequisite processing or external events.

Data Inputs

The principal inputs to the computer complex are target reports, flight plans, and controller entries.

Target report messages enter the tracking processor through independent input channels from each of the four video digitizers. To facilitate efficient target report processing and tracking, each digitizer also transmits sector mark messages at 11.25-deg intervals of antenna azimuth rotation. Thus the 360-deg azimuth scan is divided into 32 sectors of convenient size for segmented, real-time processing. Approximately once per sector (125 msec), all newly received target reports are examined for format and completeness. They are ordered by sector and stored in the computer's core memory for subsequent use by the tracking function. Depending upon the density and distribution of air traffic, and the presence of noise and clutter, numerous target reports may be received in some sectors and few in other sectors. However, sufficient storage is provided in the tracking processor to accommodate 48 target reports per sector from each radar digitizer plus 24 target reports per sector from each beacon digitizer. Because of the tracking technique, the reports received in the most recent sixteen sectors must always be available.

Flight plan messages received via teletype line from the New York ARTCC are automatically fed into the display processor. A flight plan includes aircraft iden-

High-speed digital data processing equipment will play an important role in the New York Common IFR Room which is shown in the photo while equipment was being installed and tested during October. The two large-screen displays (one shown illuminated in the photograph) and eight display consoles provide a composite picture of sensor video and the computer-processed alphanumeric information.

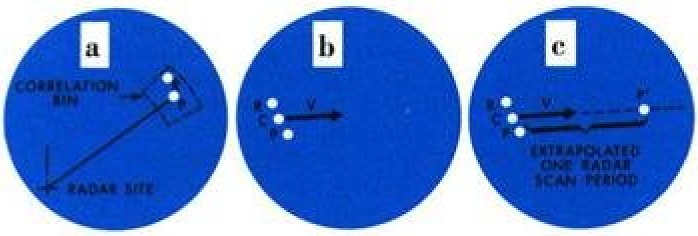


Fig. 6 — Tracking. For correlation, the track is associated with the new sensor target report by beacon identity match or by position. Positional correlation (a) finds target report *R* within bin, centered about predicted track position *P*. For correction, (b) present position C is calculated along with velocity vector *V*, using damping factors dynamically related to track-data reliability. For prediction (c) track is extrapolated along velocity vector to *P′*, a scan period in the future. *P′* becomes new position of bin when track is processed on next scan.

tity, route, estimated time of arrival (ETA) or departure (ETD), aircraft type, approach fix, departure or destination airport, and assigned beacon code. The display processor verifies the format and content of the flight plans and stores them in core memory for future use. Since this data may be received considerably in advance of the flight arrival or departure time, the display processor provides storage space for 250 flight plans.

The ETA or ETD of each stored flight plan is periodically checked by the display processor. Ten minutes before the aircraft is due to arrive or depart, the flight plan data is examined and the computer determines which controller will be initially responsible for the aircraft. Although active tracking does not begin at this time, the computer assigns a track number, and causes the aircraft identity to be displayed in a tabular STORE list on the appropriate controller's radar display. This informs the controller of the pending arrival or departure and allows him to plan for it.

Controller entries transmitted as digital messages originating at the controller data entry devices (keyboard, cursor, etc.), are channeled into the display processor. These messages contain category and function elements that describe the action desired by the controller as well as amplifying data in the form of alphanumeric and cursor coordinates. After the parity and format of a message is validated, the message is interpreted and executed by the display processor program. A controller entry affecting the tracking function is relayed by the display processor to the tracking processor.

Tracking

Each aircraft of interest to the Common IFR Room is automatically tracked by the tracking processor so that the alphanumeric data tags will follow the sensor video on the controllers' displays. Through scan-to-scan correlation of radar and beacon target reports, the tracking function computes dynamic position and velocity for each aircraft and associates flight data with the proper aircraft. As many as 250 aircraft can be tracked simultaneously. Tracking of each aircraft (target) is accomplished with the target reports from a single radar-beacon site. Aircraft under the jurisdiction of Kennedy and LaGuardia controllers are tracked utilizing only the Kennedy radar and beacon reports. Those under the jurisdiction of Newark controllers are tracked via Newark radar and beacon reports. This approach avoids inter-radar correlation difficulties resulting from antenna misalignment, propagation anomalies, and slant-range corrections.

Tracking (Fig. 6) is accomplished by associating new radar and beacon target reports with previous track information, determining the present position and velocity of the aircraft, and predicting where the radar should see it next. Three basic processes (correlation, correction, and prediction) are performed for every track once each radar scan.

The correlation process (Fig. 6a) determines which new target report is associated with a tracked aircraft. Correlation is accomplished primarily on the basis of positional proximity. A two-dimensional (range, azimuth) bin, or gate, is formed around the predicted position of the track. The new target reports are searched to find if any of them fall within the bin. In the ideal case, one, and only one, report is found, and unique correlation is achieved. Due to sensor and digitizer noise, aircraft maneuvers, and tracking compromises this does not always occur. Ambiguous situations are logically resolved by the tracking subprogram by comparison of the assigned and reported beacon codes, when necessary. During correlation, beacon reports are normally used in preference to radar reports. Radar reports are used, however, when no valid beacon report is received or when the controller specifies that a particular aircraft is to be tracked by radar only.

The bin-size parameters depend upon the history of the track. An *initial* track, less than three scans old, requires a large bin to ensure correlation because its position and velocity are still unreliable. For a *normal* track, with a history of successful correlation, the bin becomes progressively smaller as the ability to predict future positions increases. However, if an aircraft with a normal track should perform a sudden maneuver, the next target report may fall outside the primary correlation bin. To enable the tracker to detect the maneuver and follow the aircraft, a secondary correlation procedure, utilizing a much larger bin, is attempted. Successful secondary correlation results in a *trial* track, which branches away from the original track. If the trial track then correlates on the succeeding scans, it becomes the main track, and the original is discontinued. Otherwise, the trial track is eliminated. The primary and secondary correlation bin sizes are optimized for aircraft having speeds less than 600 knots and turning accelerations up to 1 g.

As a result of correlation, either a track is associated with a unique target report or else unsuccessful correlation is indicated. In the former case, the target report is used to update the track data through a process called correction (Fig. 6b). The corrected position (X_C, Y_C) in Cartesian coordinates is calculated by combining the predicted position (X_P, Y_P), which was obtained during the previous scan, and the reported position (X_R, Y_R) from the correlated target report, as follows:

$$X_C = X_P + \alpha(X_R - X_P)$$
$$Y_C = Y_P + \alpha(Y_R - Y_P)$$

The factor α is a smoothing parameter whose value $(0 < \alpha \leq 1)$ is a function of the previous history of a track. It determines how much the track position will be influenced by a new target report. Initially, a unity value of α is used to make a track responsive to the reported data. However, as a track accumulates a history of successful correlation, the value of α progressively decreases, and the smoothing effect becomes more pronounced. That is, more emphasis is placed upon predicted position, and noise components in the input data are filtered out.

The correction process also calculates a new velocity for the track. The corrected velocity $(\dot{X}_C, \dot{Y}_C)$ is derived from the previous velocity $(\dot{X}'_C, \dot{Y}'_C)$, as follows:

$$\dot{X}_C = \dot{X}'_C + \frac{\beta}{\Delta t}(X_R - X_P)$$
$$\dot{Y}_C = \dot{Y}'_C + \frac{\beta}{\Delta t}(Y_R - Y_P)$$

The smoothing parameter β performs the same function in the velocity correction that α performs in the position correction. Its value $(0 < \beta \leq 1)$ is, likewise, a function of the track history. The term Δt is the elapsed time since the track was last corrected.

After a track has been correlated and corrected, the new corrected position and velocity are used to predict its probable position for the next radar scan (Fig. 6c). The predicted position is required because it (1) serves as the position of the correlation bin on the succeeding scan and (2) is used to update the position of the alphanumeric tag on the controller's display. The prediction process is a linear extrapolation:

$$X_P = X_C + (\dot{X}_C)T$$
$$Y_P = Y_C + (\dot{Y}_C)T$$

where T is the period of the last radar scan. (If the aircraft velocity has a significant tangential component, a minor adjustment to T is required.) If a track fails to correlate during the current scan, no corrected data is calculated, and the track is extrapolated on the basis of the previous position and velocity information. This process is called *coasting* the track.

Track initiation can be either automatic or manual. Automatic initiation (acquisition) takes place if, after correlation is completed, there are any remaining uncorrelated target reports within a sector. If, on two successive scans, an uncorrelated target report is found, which has a discrete beacon code that is identical to the assigned code of a pending track in the tabular STORE area on a controller display, the flight data is removed from the STORE area and displayed at the reported position. Active tracking will then be automatically initiated. Automatic acquisition of arriving aircraft occurs at a range of 45 to 60 miles. Departing aircraft are acquired several miles after takeoff.

Tracks are automatically terminated by the computer when they are no longer required. After prediction, the position of each track is checked to see if it satisfies the geographic criteria for automatic termination.

Display Data

The display processor transmits updated alphanumeric data to the display equipment every two-and-one-half seconds to provide the controller with a dynamic current picture of the air traffic situation. Flight data is presented to the controller in one of several formats depending on whether the aircraft is being actively tracked or is displayed in a tabular list. Each tag, tabular item, or single symbol to be displayed requires a digital message from the computer specifying the location, format, and content of the display data.

The location information in a digital display message can be specified in either of two x, y coordinate systems: *display* coordinates or *system* coordinates. Tabular data, positioned in display coordinates, appears at an absolute location on the display screen. The fixed 512 by 512 display coordinate grid is independent of the radar range-scale and off-center controls on the display. The radar-related alphanumeric tags and symbols, however, are keyed to a system coordinate grid. This grid, 2048 miles square, is centered at the Kennedy radar site. System coordinates, specified to the nearest ⅛ n.m., are referred to the southwest corner of the grid. Alphanumeric data in system coordinates, like the sensor video display, is sensitive to radar range-scale and off-center controls. Therefore, it remains in registration with the radar picture.

The alphanumeric tag, which accompanies an active track (Fig. 7a), is positioned according to coordinates predicted by the tracking processor. A leader connects the tag to a single symbol, which represents the tracked position of the aircraft. This symbol is an alpha character that uniquely denotes the cognizant controller. A velocity vector with length proportional to the calculated track speed may also be displayed by controller selection. The tag can contain as many as 21 alphanumeric characters arranged in three rows, each holding a maximum of 7 characters.

The top row displays assigned altitude and reported beacon altitude expressed in hundreds of feet. Also displayed in the top row, when necessary, is a controller-entered arrow which indicates that the aircraft has been cleared to climb or descend. When an arrow is not present, the display processor automatically monitors the beacon altitude reported by the aircraft. If it differs from the assigned altitude by 200 ft or more, a

a

K——030↓063
EA123
18 0401

030	Assigned altitude — 3000 ft
↓	Cleared to descend
063	Reported beacon altitude — 6300 ft
EA123	Eastern Air Lines Flight 123
18	Aircraft speed — 180 knots
0401	Reported beacon code
K	Responsible controller (JFK final approach controller). Also indicates tracked position of aircraft.

b

EA123

EA123	Eastern Air Lines Flight 123

c

060↓068B
EA123

060	Assigned altitude — 6000 ft
↓	Cleared to descend
068	Reported beacon altitude — 6800 ft
B	Holding fix (Bohemia holding pattern)
EA123	Eastern Air Lines Flight 123

Fig. 7 — Alphanumeric display formats. A tag for an active track (a) contains up to 21 characters. The tag is attached to track position symbol by a leader. A velocity vector indicates heading of the aircraft. Indicator bars (not shown in illustration) can be displayed above tag to denote a special kind of status such as emergency, attention, hand-off, or coast. Each item in tabular *Store* list (b) consists of identity of a pending flight. List is ordered according to time of arrival or departure. Each item in the tabular *Hold* list (c) refers to an aircraft assigned to a holding pattern. Removing tags from these tracks reduces alphanumeric congestion around a holding fix. This list is arranged by chronological order of entry.

blinking square symbol is displayed to alert the controller to the altitude discrepancy. The altitude reported by the beacon transponder must be corrected by the display processor before it is displayed. For aircraft flying below 18,000 ft, it is necessary to compensate for the difference between local barometric pressure and the reference pressure (29.92 inches Hg) used by the aircraft altitude sensor.

The middle row of characters contains the aircraft identification. For a commercial airliner, this normally consists of the airline initials and flight number. The bottom row of alphanumerics is used to display information that is somewhat less significant to the controller. This row is time-shared to permit accommodation of four data items. Tracker-derived aircraft speed and controller-entered *scratch pad* data are displayed alternately for short periods of time (8-16 sec). The display of reported beacon code and computer-assigned track number is similarly alternated.

Directly above the alphanumeric tag there is space for the display of two horizontal bars. A solid upper bar is used to mark a track that requires special attention or handling. It is automatically displayed as an alert when the associated aircraft is transmitting an emergency beacon code. A dashed lower bar indicates that the track is involved in a hand-off action between controllers. A solid lower bar indicates that the track is being coasted on the basis of historical velocity information. The alphanumeric tag and leader can be offset in different directions from the track position symbol. To minimize the overlap of tags in congested areas of the display, the computer periodically checks the relative positions of all tags and adjusts the offset to reduce superposition of alphanumerics.

Each item displayed in the tabular STORE list (Fig. 7b) of pending flights consists solely of the aircraft identification. The list is automatically ordered according to the ETA or ETD of the flights. A second tabular display list is available when it becomes necessary for the controller to discontinue active tracking of flights assigned to a holding pattern. Each item in this HOLD list has a format consisting of two rows of alphanumerics (Fig. 7c). The data content is identical to the first two rows of the active track tag, except that an additional letter is included to denote the holding fix. HOLD items are listed according to their chronological order of entry. At the option of the controller, the STORE and HOLD lists can be located at any convenient place on the display screen.

Conclusion

The Common IFR Room and previous installations (ARTS, NYCBAN) demonstrate the applicability of electronic data processing techniques to air traffic control alphanumeric display systems. The digital computer data handling and processing capabilities are sufficient to meet the real-time requirements of the most complex air traffic environment, as exemplified by the New York terminal area. Furthermore, a general-purpose computer with a stored program provides significant benefits in the form of system flexibility, which cannot be matched by special-purpose, fixed-logic hardware. The system can be improved by altering program instructions rather than redesigning equipment.

Robert H. Anderson, author of "Data Processing in the New York Common IFR Room," is a senior system design engineer in the Air Traffic Control and International Systems Department, UNIVAC Federal Systems Division, St. Paul, Minnesota.

MR. ANDERSON joined the company in 1959 as an electrical engineer assigned to the preparation of equipment and computer program specifications for the naval tactical data system (NTDS). He advanced to system design engineer in 1961 and took part in the development of computer-aided equipment-checkout techniques for the NTDS, the Mark-11 shipboard weapons direction equipment, and the data processing module of a tactical intelligence information system. In 1964, he was assigned to the system design effort for the Army Operations Center System (TARMOCS) and was later responsible for the design and preparation of programed performance tests for the system hardware. Mr. Anderson advanced to his present position in 1966 and has participated in system design activities for air traffic control applications, including the New York Common IFR Room. From 1954 to 1956 he served in the Army Security Agency. He received the B.E.E. degree from the University of Minnesota in 1959.

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UNIVAC PARK, ST. PAUL, MINNESOTA 55116 • TEL. (612) 456-2222

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