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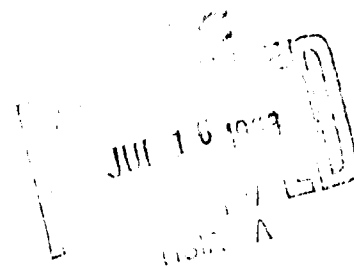
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THE INTEGRATION of AIR TRAFFIC CONTROL AND AIR DEFENSE

by D. R. Israel

THE
MITRE
CORPORATION



SEPTEMBER 1959

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**THE INTEGRATION
OF AIR TRAFFIC CONTROL
AND AIR DEFENSE**

by
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ABSTRACT

Within the past 18 months, the Federal Aviation Agency and the United States Air Force have taken definite steps toward the integration of air traffic control with air defense. Three of these steps are: 1) the successful completion of an experiment called CHARM which demonstrated that the SAGE air defense system could assist the present air traffic control system; 2) the formulation of a plan, based partly on CHARM results, to make use of nine SAGE super combat centers planned for operation in the mid-1960's to centralize integrated facilities; and 3) the beginning of an experimental program called SATIN to test integration techniques and equipment.

The SAGE direction center contains a large, high-speed, general purpose digital computer which centralizes the processing of radar data and coordinates the control of air defense weapons over an area several hundred miles square. To demonstrate that this military system could assist civilian air traffic controllers, CHARM (for CAA High Altitude Remote Monitor) used the Whirlwind computer at MIT to combine filed flight plans from the High Altitude Sector of the Boston Air Route Traffic Control Center (ARTCC) with SAGE radar data, displayed these simultaneously to track monitors for correlation, and transmitted the correlated data to a remote display for use by ARTCC controllers. CHARM concerned itself only with en route traffic above 24,000 feet.

The Federal Aviation Agency and the Air Force have initiated plans for air traffic control-air defense integration over the entire United States. The integration will be made possible by the installation during the 1960's of nine super combat centers containing improved computers. In these centers the functions of en route, high-altitude air traffic control will be collocated with air defense functions, with some separate and some common functions. Positive separation of aircraft will be maintained and direct, area, and airways flying will be permitted.

The SATIN (for SAGE Air Traffic Integration) experimental facility has been partly designed and initial operation is expected in early 1960. SATIN will use a SAGE-type computer located in Lexington, Massachusetts. It will test all traffic control functions planned for the super combat center, but with a reduced capacity of 100 aircraft.

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I.

THE SAGE SYSTEM

An improved air defense system exploiting the high speed and versatility of large, general-purpose, digital computers has been developed and placed into operation in the United States during the past nine years. The system is called SAGE, for Semi-Automatic Ground Environment. The underlying concept of SAGE is centralized data processing: the system receives surveillance data from a network of radars and controls air defense weapons over areas substantially greater than the coverage of a single long-range search radar, the traditional unit of air defense systems.

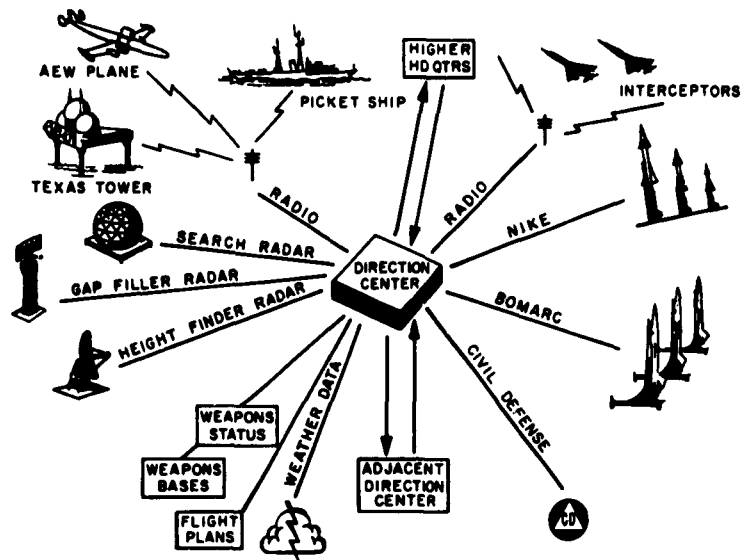
The design of the SAGE system was initiated by the Lincoln Laboratory of the Massachusetts Institute of Technology (MIT) in conjunction with the Air Defense Command of the United States Air Force. The continuing design and engineering of the system is now conducted by The MITRE Corporation, a non-profit organization formed from but independent of the Lincoln Laboratory, working with the Air Defense Systems Integration Division of the Air Force. Computer program design, implementation, and checkout is handled by the System Development Corporation of Santa Monica, California.

THE SAGE DIRECTION CENTER

The basic unit of the SAGE system is the direction center with its AN/FSQ-7 computer.¹ Each direction center, housed in a large concrete structure (Fig. 1), is responsible for the air surveillance and defense of an area roughly square in shape and several hundred miles on a side. Typical inputs and outputs of a direction center are shown in Fig. 2. Between 20 and 30 of these centers will be installed throughout the United States.



Fig. 1. SAGE direction center. The buildings contain power generation computing equipment, operational areas for directing sector operation, and office and maintenance facilities. Data is transmitted to this center both automatically and by voice phone. The center communicates with adjacent SAGE centers and transmits guidance data to weapons under its control.



SECTOR SCHEMATIC

Fig. 2. SAGE inputs and outputs. A direction center receives digitally coded data automatically and continuously from search radars and height finders over voice-band width communications circuits. Data on flight plans, weapons status, weather, and aircraft tracks is received, respectively, from the Air Movements Identification Service (AMIS), weapons bases, USAF Weather Service, the airborne early warning and picket ships over teletype and voice telephone circuits. Similarly, data from the direction center is transmitted in digitally coded form over voice-band width communications circuits to ground-air data link systems, to weapons bases, to adjacent direction centers and to command levels; data to other users is transmitted over automatic teletype circuits.

The AN/FSQ-7 is a large and relatively fast computer designed by the Lincoln Laboratory and the International Business Machines Corporation (IBM). The central machine is a stored-program general-purpose computer, based on the earlier design of the Whirlwind computer at MIT. The principal characteristics of the computer are:

- binary, parallel, single address
- 32-bit word (in two 16-bit halves)
- 250,000 word core memory (6 μ second access)
- 150,000 word drum memory
- 4 index registers
- 75,000 instruction/second operating speed
- 4000 bit manual keyboard input capacity
- in-out buffers for up to 1300 cps data
- 60,000 vacuum tubes

The AN/FSQ-7 actually consists of two computers, each with its own control, arithmetic element, storage, and in-out buffers. Only one machine of the duplex is used to perform the air defense data processing at a time, while the other is on standby status or undergoing maintenance.

Within the internal memory of the AN/FSQ-7 is stored an air defense program, of approximately 100,000 instructions, comprised of a set of routines: radar input, tracking, intercept calculations, etc. The routines are performed periodically one or more times each minute to carry out the automatic air defense functions. Independently of the central computer, input-output buffers store the large volumes of incoming and outgoing data used by the program; other storage drums hold information prepared for display purposes.

The automatic data processing of the computer is monitored, assisted, and when necessary modified by about 100 Air Force operators. These men communicate to the machine primarily by push-button switches on their operating consoles; in turn, the computer presents pictorial displays, showing aircraft plan positions, and tabular or digital information displays which provide other useful data. (See Fig. 3 and Fig. 4.)

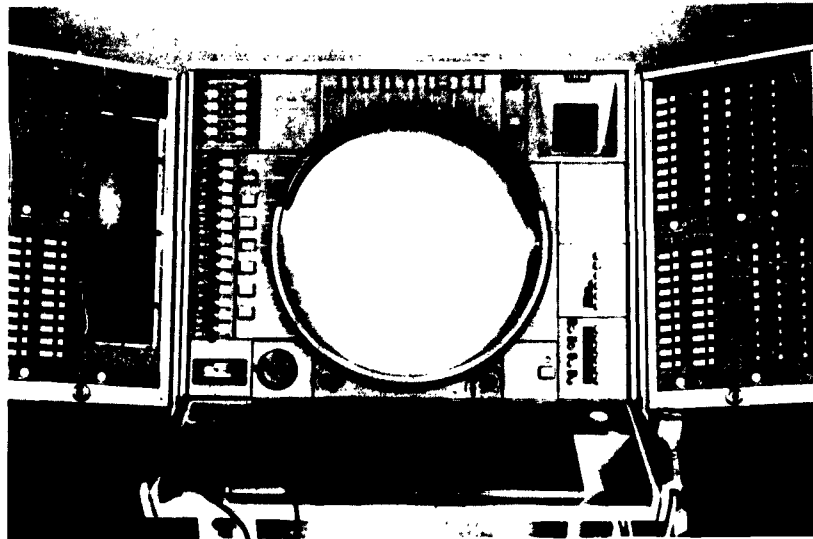


Fig. 3. SAGE operator's console.

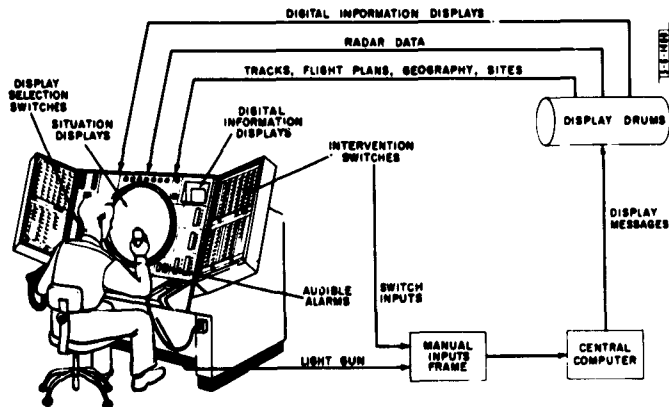


Fig. 4. SAGE console facilities. Pictorial geographic information -- tracks, coast lines, airbases, radar data -- is shown to the operator on the situation display. The tabular or digital information display presents such detailed information as weapons status, weather, and flight plan characteristics. Intervention switches and light gun permit the operator to supply the computer with additional information or affect the course of computation; display selection switches permit the operator to compose his display as required for his tasks.

SAGE INPUTS AND OUTPUTS

Radar and beacon data are transmitted to the direction centers in digital form over voice-band-width data circuits. The computer processes this data, converts it to a common coordinate system, and then forms radar tracks, either automatically or as the result of operator actions. Once established, radar tracks are automatically maintained by the computer, with manual intervention as requested by the computer.

Flight plan information enters the AN/FSQ-7 by punched cards and is used for identifying newly-established radar tracks. Weapon status, weather, and winds aloft data are also made available to the computer by manual insertion of punched cards. Height information is obtained from nodding-beam height finder sites upon request by the computer.

The computer assists Air Force operators in the selection and commitment of appropriate air defense weapons. Once committed, weapon orders are automatically calculated for selected types of attacks and are transmitted automatically by radio data link to these weapons or are routed through control personnel for relay by voice radio. Adjacent direction centers exchange surveillance and weapons information automatically by digital data circuits, and all direction centers forward-tell selected information to the next higher SAGE command unit, the combat center.

SAGE AND AIR TRAFFIC CONTROL

During the development of the SAGE System, it was obvious that many of the data processing techniques being employed in air defense could help solve the air traffic control problem, particularly en route traffic. It was frequently suggested that an integrated air defense-air traffic control system using the same data processing facility be considered. But the urgency of air defense development precluded any serious consideration of such integration, and it has been only in the last 18 months that tangible steps have been taken. The developments during this time period are the subject of this paper.

It should be pointed out that the current interest in integration has fortunately been shared by the Air Force as well as the Federal Aviation Agency (FAA). The Air Force realizes that improved air traffic control will yield better air defense, especially in the process of identifying "unknown" aircraft; to the FAA, integration means a better, more flexible system at less cost and at an earlier date.

II.

THE CHARM SYSTEM

In January 1958, an experimental program was undertaken at the MIT Lincoln Laboratory to demonstrate how the SAGE System might assist the existing manual air traffic control system. This program, transferred to The MITRE Corporation at the end of 1958, was called CHARM, for CAA High Altitude Remote Monitor, and concentrated on the problem of the high-altitude traffic; i.e., above 24,000 feet.

High-altitude traffic in the United States consists primarily of Strategic Air Command (SAC) flights together with other military aircraft and an increasing number of civil jet flights. This traffic most often desires to fly off-airways and in the case of SAC flights requires the freedom to operate in an unrestricted fashion over large areas. In the absence of radar coverage and tracking, such freedom of maneuver can be presently accommodated only by relying on the "see and be seen" principle, which in effect is no control at all, or by "blocking off" or reserving large volumes of airspace. In either case the results are unsatisfactory, with conflicts among the users of the airspace and a severe control problem for the FAA.

CHARM SYSTEM DESCRIPTION

The elements of the CHARM System² are shown in Fig. 5. The Whirlwind computer, located at the Barta Building in Cambridge, Massachusetts, was used because of its availability and general experimental convenience. Flight plan data on high altitude flights was made available from the Boston Air Route Traffic Control Center (ARTCC), located at the Logan Airport, Boston, Massachusetts, and covering the northeastern part of the United States (New England plus most of New York State).

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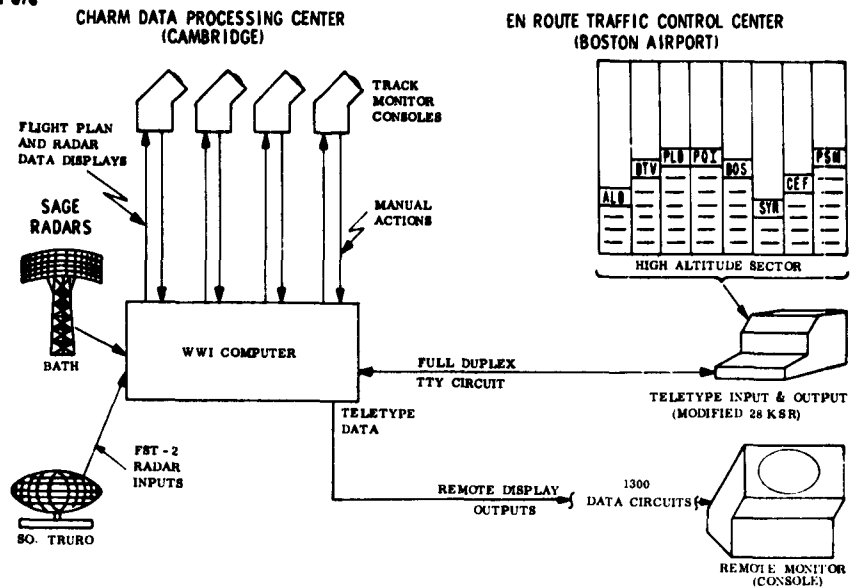


Fig. 5. Information flow for CHARM System.

Inputs

Flight plans, progress reports, and other information were transmitted by teletype from the Boston ARTCC directly into the Whirlwind computer, without intermediate tape perforation at either end. The computer automatically acknowledged every incoming message with a reply message over a return circuit. Upon request by the operator the computer also provided detailed page print information on selected flights over the return teletype circuit.

Incoming flight plan messages were broken down by the computer into the series of fixes defining the route of flight. Using the departure time and filed ground speed, estimated times of arrival were then calculated and stored for each fix. When available, incoming progress reports, including actual or predicted times over fixes, were used to correct these estimated times.

Range and azimuth information from two long-range search radars was continuously made available to the computer. Both search and beacon data was included. This data was converted to a common coordinate system, stored, and displayed.

Display and Correlation

Periodically the computer would interpolate the stored fix and time data to determine the present flight plan position. An extrapolation status characterizing the nature of the flight at that time was also determined; possible statuses included: inactive (not yet airborne), holding, direct (proceed directly between fixes), radius flight (in the general vicinity of a fix but not on a fixed path), etc. Present flight plan position, extrapolation status, and computer assigned track number were then displayed on four track monitor consoles connected to the computer.

Radar information, periodically redisplayed to form trails, was superimposed on the flight plan position displays. The track monitors matched (correlated) flight plan positions with radar data and, where necessary, updated or corrected the flight plan position with light gun or switch actions (Figs. 6, 7). The resulting correlated flight plan positions were then prepared by the computer for transmission to the ARTCC.

It should be noted that CHARM did not include an automatic radar tracking feature, such as in SAGE. Rather the flight plan extrapolation process and the radar data processing and display were independent processes. The only interaction of these processes was that forced by the track monitors.

Conflict Detection

As an additional feature, the computer program automatically checked for possible "conflicts" of flight plans over fixes, defined to exist when:

- a. the estimated times over a fix differed by less than ten minutes, and



Fig. 6. CHARM track monitor positions. Present aircraft positions and radar data are displayed on a 19-inch cathode ray tube. Switches alongside each console permit operator selection of displays and insertion of track monitor information -- track number, speed change, etc. Light gun incorporating optical system and photocell can be used to designate selected pieces of radar information for correlation purposes.

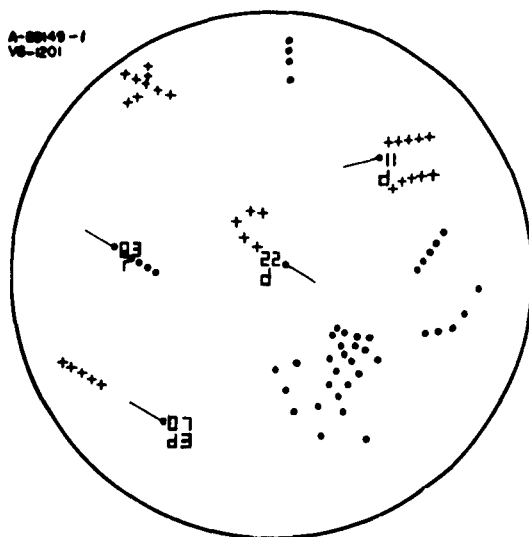


Fig. 7. Typical track monitor display. Past and present radar and beacon data is shown by dot or cross, respectively. Flight plan positions are indicated by point and vector. Vector indicates speed (equivalent to minutes of flight) and heading. Top line of symbology is track number; second line indicates extrapolation status and number of aircraft (if greater than one).

- b. the altitudes of the two aircraft differed by less than 2000 feet, or
- c. either aircraft had not filed a specific altitude, but was "on-top."

When such a conflict was created -- as the result of filing a flight plan, progress report, or flight plan revision -- the computer printed out the pertinent information as part of the teletype reply to the filed message.

Remote Monitor Display

The flight plan data, as modified by track monitor actions, was transmitted over a 1300 cps data circuit to the remote display console. This information permitted a "clean" (that is, with no radar data) plan position display of the corrected present and expected flight plan positions (Fig. 8). The remote display console, a prototype model, had a direct view storage tube with a Charactron matrix, a bright image and a controlled persistence of several minutes. The resulting display was intended to supplement the controllers' flight progress strips in the control of the traffic at the ARTCC.



Fig. 8. Remote monitor display. Geographical data is shown by an X with a three-character location identifier. Aircraft are designated by a three-line group of characters: aircraft call sign (e.g., AF1234) is shown in first two lines; aircraft altitude and flight size is shown on last line. Dot or square to left or right of first line indicates present position: dots for uncorrelated flights, squares for correlated flights. Expected aircraft positions in 2.5-minute intervals are shown as dots extending from symbology.

System Capacity

CHARM was designed during the period January to November 1958, when system operation began. The design, preparation, and checkout of the computer program, which contained 22,820 instructions, required 50 man-months of effort and 340 hours of computer time.³ The experimental area over the New England states was roughly 400 miles square. The computer program was built to handle only 24 flight plans, enough for purposes of the experiment. System capacity was set at a limit of 15 fixes per flight plan, and the computer was programmed with sufficient data to recognize 225 geographical fixes and 96 different airways.

TELETYPE INPUT-OUTPUT

The teletype input and output facility had several features worthy of detailed mention. Emphasis was placed on simplifying the task of the teletype operator: the format was flexible and roughly in accordance with present FAA procedures; the operator was not required to convert to a special coordinate system or to "pad out" or add non-essential items in the message; the message was typed as a series of alpha-numerical groups, each group separated from the next by at least one space; an identifying character signified the start of a message and its types and a final character (#) signified message termination. The message sequence following the initial character was aircraft designation, type, speed, route (including altitudes), and time (Fig. 9). Route could be specified by fixes, airways, latitude-longitude, points related to fixes, or any combination of these (Fig. 10).

Errors could be corrected by the teletypist at any time before completion of his message. As shown in Fig. 11, the combination (space) X (space) erased the immediately preceding group from the computer storage, and this facility could be used repetitively to erase several groups. The sequence XXX erased the entire message.

(INPUT) F AF1234 T33 440 BOS 330 A7 HFD 105/ALB 4230N/7230W ALB P1345 # (OUTPUT) 🔔 F AF1234 03 1340 #

A - 89157 - /
VG - 1061

Fig. 9. Flight plan input message and response. Input messages start with letter designator for type of message: F for flight plan, P for progress report, R for revision, etc. Message sequence consists of identification (2-7 characters), number (if available) and type of aircraft (2-5 characters), speed (3 digits), route with altitudes (in hundreds of feet), time (four digits prefixed with P for proposed, E for estimated, D for departure, A for airborne), and termination character (#). Output response consists of single bell (printed and sounded), a repeat of the first two input message groups, assigned track number, and present time.

<u>TYPE OF SPECIFICATION</u>	<u>EXAMPLE</u>
FIXES	BOS
DISTANCE AND DIRECTION FROM FIX	10W/BOS
LATITUDE - LONGITUDE	4310N/6703W
RESTRICTED OR WARNING AREA (PLUS TIME)	W/518/1.30
RADIUS OF FIX (PLUS TIME)	200R/BOS/1.15
AIRWAYS	
LOW FREQUENCY (LF-MF)	A7
VICTOR (VOR)	V13E
JET	J21T
CONTROL AREA	C1205

A - 88521 - /
VG - 871

Fig. 10. Fix and route specification. Format for designation of fixes and routes is very flexible. Any combination of the above can be used as long as fixes preceding or following an airway are actually on the airway; e.g., BOS A7 HFD. Two or more airways may be used in succession if they intersect; e.g., BOS A7 G5 IDL.

(a) F UAL24 DC5 X DC7 370 BOS 330 POK SYR X X POU SYR D1210 #
(b) F BOB21 B52 74-1? XXX
F V2110 F4D NHZ VFR NCO 0930Z #
(c) 00F4D
300 NHZ VFR NCO 0930Z #

A-89158
VG-1209

Fig. 11. Examples of error detection and correction. In example (a) the operator typed DC5 in place of DC7 but immediately detected this mistake and corrected it by providing an X followed by DC7. A later error, POK for Poughkeepsie, was not immediately detected by the operator and was corrected by two X's after SYR, following which POU was correctly typed and the message completed. In (b) the entire message was cancelled by the XXX combination. In example (c) the operator completed his message without detecting the omission of the aircraft speed. The computer detected the error and alerted the operator by two bells (printed and sounded) followed by a repeat of the last correct item. The operator now finishes the message correctly from that point.

The computer itself examined all incoming messages for completeness and errors. If an error were detected, the computer's printed reply message to the operator indicated the last correct group, and the operator was to proceed again from that point.

The computer provided two types of teletype response messages at the request of the operator. An input message of the format J AF43671 # would provide a reply giving the present position of AF43671 in terms of the fix which it had most recently passed, together with the name of the next fix and the estimated time over that fix. A request message with the prefix Q would initiate a reply indicating the entire route of flight for the aircraft, together with the times and altitudes over fixes. (See Fig. 12.)

AF43671	C	400	N7
1800	BOS	290	
E1818	GDM		
E1823	30N/CEF	320	
E1830	7400N/3200W		
E1836	ALB	#	

IA-8915-3
VG-1203

Fig. 12. Response to a Q request. In response to a request for information on the flight plan for AF43671, the output teletype message from the computer lists certain status information and then information for each fix of the processed route. Fixes are typed one per line, with actual time (1800) or estimated times (E 1818) and changes of altitude (100's of feet).

RESULTS OF THE CHARM EXPERIMENT

With the cooperation of the Boston ARTCC, tests of the CHARM System using live aircraft (primarily otherwise scheduled SAC flights) and radar data were conducted for two-to-three hour periods twice a week from November 1958 through May 1959. The tests were conducted so as to avoid any interference with normal operation of the ARTCC. A large number of these periods of operation were devoted to personnel training or to demonstrations, and a planned series of detailed tests was not conducted due to the premature shutdown of the Whirlwind computer. Nevertheless, a large amount of experimental data was obtained.⁴

Correlation

It was found that radar and beacon data could be readily correlated with flight plan data if the latter was accurate and current. Roughly 70% of the attempted correlations were deemed successful. Of the failures, half were traced to faulty or tardy flight plan data, while the remainder were unexplained. In general, correlation was excellent when Instrument Flight Rule (IFR) conditions prevailed and was less successful under Visual Flight Rule (VFR) conditions when there is small incentive for the aircraft to adhere closely to the flight plan. Most of the flights used area or radius clearances.

It became evident that SAGE-like automatic tracking is required to ease the load on the monitors and increase their capacity. Without such tracking, a monitor could only handle three to five flight plans at a time. Further, the closest possible coordination between controller and track monitor is desirable; ideally they would not be separated, as in CHARM, but would be located beside each other in the same building using the same computer. In general, SAGE radar coverage was satisfactory and high blip-scans were observed; radar coverage was not a cause of lack of correlation.

Teletype Facility

The provisions for entry of teletype messages in a flexible format with operator correction, computer error detection, and automatic message acknowledgement, were eminently satisfactory. Only minor shortcomings in the design, primarily in error detection and correction, were uncovered. In general, messages were introduced rapidly and accurately after a minimum of operator training. Computer programming costs of this input were relatively inexpensive and as a result such a message input scheme is now planned for SAGE.

Display

The remote display console, the first of its kind, proved to be better in principle than in execution. It required careful adjustment, and the control of intensity and persistence proved to be extremely complicated. As a result,

the console itself was never moved to the Boston ARTCC but was kept at the computer site. According to design, however, its only connection to the computer was by means of a telephone line. Based on this experience, an improved model is being designed which will incorporate a magnetic core storage in place of the storage surface.

In general, the major problems in CHARM were related to the execution of our tests in a manner which did not interfere with the normal operation of the Boston Center. Since the controllers in the ARTCC could not be used to transmit the flight plan data to the computer, extra personnel monitored the flight progress boards to gather this data. This additional step introduced delays and resulted in incomplete data collection. In some later CHARM tests, flight plan data was collected at the Barta Building, directly by monitoring the radio channels.

III.

THE PLAN FOR INTEGRATION

GENERAL REQUIREMENTS

In late 1958, the successful experience with CHARM coincided with the initial installations of the SAGE System and a general realization that centralized data processing by high-speed digital computers offered the most promising solution to en route traffic control problems. Accordingly, increased attention was given to air traffic-air defense integration. Simultaneously, the development of faster and an improved solid-state version of the AN/FSQ-7 was announced, and the Air Force expressed its intention to use this new computer -- the AN/FSQ-7A -- to increase the data processing capacity and capability of the SAGE System. This increase will take the form of nine new air defense centers equipped with the AN/FSQ-7A. The new centers -- termed super combat centers (SCC) -- will provide coverage over the continental United States.

Collocation

Based on these developments, early in 1959 the Federal Aviation Agency and the United States Air Force undertook the joint planning for the integration and collocation of air traffic-air defense functions at the super combat centers. Collocation at these centers would permit common use of the radar and beacon inputs from FAA and Air Force radars as well as the joint use of the SAGE data processing capabilities. The Air Force and the FAA would each maintain their organizational integrity within the SCC, with FAA control teams and supervisory personnel using separate display consoles and operating areas.

Although the planning for this integrated system is not yet complete, and many administrative, technical, and financial problems are still unresolved, the general characteristics of the system can be outlined.⁵

Coincident Control Areas

The control aspects of the integrated system will be limited to en route traffic, particularly at the altitudes above 24,000 feet. In the less dense areas traffic control will go to lower altitudes, possibly all the way to the ground. The boundaries of the nine en route traffic control areas will coincide with the corresponding air defense boundaries (Fig. 13), thereby permitting the efficient integrated use of air defense and air traffic control radars, communications, and computer programs, as well as reducing coordination problems between the two systems.

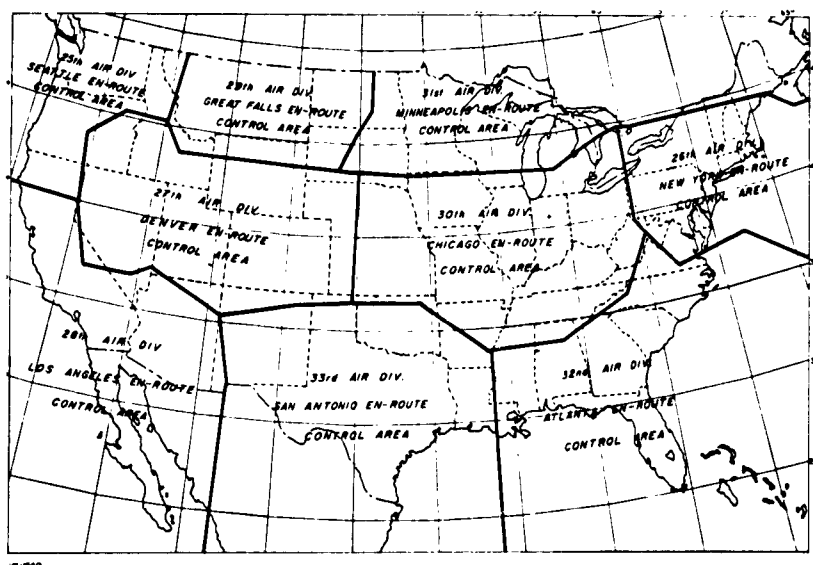


Fig. 13. Proposed ATC/AD coincident boundaries.

Positive Separation

The air traffic control function planned at the SCC will stress the maintenance of positive separation of all air traffic under control, at the same time making the most of the available airspace. Positive separation, under IFR and VFR conditions, will be provided for direct, area, and airways flights. The control will not depend on the presence of an airways route structure, but will use such a structure when it defines a route of flight.

Inputs

The basis for maintenance of positive separation will be input data in the form of flight plans, progress reports, search radar and radar beacon data, or other data sources as they become available. In general, radar and beacon data will be used, as in CHARM, to provide confirmation and "fine-grain" correction to the flight plan data.

Flight plans and pilot-reported progress reports will be entered directly into the computer by controllers -- directly on-line from remote points, locally by flight data entry personnel. This input will use teletype or similar equipment, with procedures and format similar to those used in CHARM.

Search radar and radar beacon data will enter the computer for both air defense and air traffic control purposes from the AN/FST-2 equipment at the radar sites and the associated communications and computer input equipment.

Communications

Control information will be transmitted to aircraft primarily by means of direct controller-to-pilot, ground/air radio. As devices for more automatic relay of information become available and prove desirable, these may be incorporated. Coordination information required at adjacent facilities of the air traffic control system will be communicated automatically, where possible, via teletype and ground/ground data circuits. In some cases, voice communication will be required for coordination purposes.

Computer Programs

Certain programs within the SCC computer will be used jointly by air traffic control and air defense, whereas others will be unique to each function. The air surveillance (e.g., radar input, tracking, track display) programs, which are large users of computer times, will be common to both functions. Manual input programs involving flight plan processing, winds aloft and terminal weather will also serve the purpose of both air defense and air traffic con-

trol. Of necessity, programs such as those involved in missile guidance and air traffic conflict detection will be unique to the air defense or air traffic control function. A rough breakdown of the separate and common functions is shown below:

<u>Air Traffic Control</u>	<u>Air Defense</u>
Flight Plan Aid to Tracking	Height Finding
Conflict Prediction	Identification
Conflict Resolution	Weapons Assignment and Control
Crosstell to Other Traffic Control Facilities	Raid Forming
Traffic Flow Control	Command Post
	Crosstell to Other Air Defense Facilities
<u>Common to Both</u>	
Flight Plan Input	
Radar Inputs	
Radar Tracking	
Beacon Tracking	
Track Display	
Crosstell to Adjacent SCC	

PROGRAM FUNCTIONS FOR AIR TRAFFIC CONTROL

The basic computer program functions within the en route air traffic control will be those of: flight data entry, flight progress maintenance, control for separation, and flow control (traffic level management).

Flight data entry will include the processing of flight plans, progress reports, and weather data into system tables required for the control process. Input messages will be decoded and subjected to error detection processes. Notification of acceptance or rejection of input data will be transmitted to the source automatically through computer output.

Flight progress maintenance will involve the computation of aircraft position and velocity based on flight plan as well as radar and beacon data available in the joint air surveillance program. Computed flight plan position and velocity will be adjusted by pilot-reported progress and the progress of the associated radar or beacon track. The automatic radar tracking function, in turn, will be assisted by the knowledge of intent contained within the flight plan.

Control for separation will sense to predict conflict situations, making use of the previously-determined aircraft position and velocity. In addition, aircraft position, velocity and intention will be displayed to the responsible control personnel.

Flow control processing will utilize information available on terminal acceptance rates to direct traffic so that the rates are not exceeded. Traffic within the en route center will be analyzed by destination and compared with terminal acceptance rates. The results of the computation will be made available to flow control personnel for use in adjusting traffic flow.

CONTROL TEAMS

FAA control personnel will be seated at SAGE-type consoles with plan position and tabular displays. The pictorial displays, similar to those on the CHARM remote monitor, will be selectable, permitting, for example, the presentation of aircraft only in a certain area or at a specified altitude. Information that is today presented to a controller on flight progress strips will be available in several different formats on the tabular display. The controller will enter information into the computer via a keyboard, again based on techniques derived in CHARM.

The control of traffic over a given en route area will be the responsibility of a control team composed of two or more controllers and assistants. One operator in the control team will monitor the processing and matching of radar, beacon, and flight plan data; although the computer will perform automatic tracking, it may be desirable to have this operator make the initial match or correlation. A second controller of a team will be responsible for monitoring the control process. As far as possible, standard data processing functions

and decisions will be made by the computer. The operating personnel would take over in unusual circumstances, for example, to resolve a computer-detected conflict.

The exact number of control teams per super combat center is as yet undecided. It will depend upon the number of aircraft to be controlled and the capacity of the control system. Traffic estimates are now being made on the basis of current traffic, growth trends, changes in aircraft characteristics, etc.; first estimates indicate peak traffic loads of 200-500 aircraft under control by each SCC at a peak hour of a busy day. The capacity of each control team is estimated as 10-20 aircraft at a time; final figures for design purposes are expected to be obtained from the experimental work described below.

IV.

TEST FACILITY: SATIN

At the earliest stages of the planning for the integration of functions at the super combat centers, the Federal Aviation Agency recognized the need for an experimental facility where the concepts, techniques, and design of an integrated system could be thoroughly tested. Such a facility would also provide experimental data on such items as capacity of a control team, length of computer programs, and adequacy of displays.

The design and implementation of this facility -- termed SATIN, for SAGE Air Traffic Integration -- has been started by The MITRE Corporation, working under contract to the Federal Aviation Agency and the United States Air Force. SATIN will use the AN/FSQ-7 (XD-1) computer located in Lexington, Massachusetts, and presently engaged in air defense experimental activities. The SATIN test area will be roughly 600 miles square. It will cover a large part of the northeastern United States, including the National Aviation Facilities Experimental Center of the Federal Aviation Agency at Atlantic City. This area is comparable to those planned for operational super combat centers.

Since the AN/FSQ-7 (XD-1) has less capability than the improved AN/FSQ-7A, SATIN will be limited in two respects: capacity and number of functions. A capacity of 100 aircraft is planned, with four control teams and additional supervisory positions. All air traffic control and common functions planned for the super combat center will be included; air defense functions independent of air traffic control considerations will be omitted.

Certain modifications to XD-1 will be required, primarily for teletype input and output. Initially, SAGE consoles, supplemented by teletype keyboards for data entry, will be used. However, as the design of new consoles for control personnel is completed, experimental consoles will be added. A Stromberg-Carlson display console incorporating a Xerographic display process will be the first to be tested.

The design of SATIN started early this year. Computer programming and equipment modification and installation are in progress, and limited operation of flight plan input and beacon tracking programs may be expected early next year. Full system testing should be underway in the fall of 1960. In general, the progress seems quite satisfactory, and no major technical problems relating to system design are evident. However, considerable attention is now being given to the unsolved problem of how to test the system adequately without compromising the existing manual air traffic control system.

CONCLUSION

Significant steps have been taken over the past 18 months to apply the high-speed data processing techniques developed for air defense to the en route air traffic control problem. High-speed digital computers can relieve control personnel of the routine, time-consuming tasks of flight plan and progress report processing, calculation of times over fixes, determination of potential conflicts, etc. However, of equal if not greater importance is the application of such computers to the combining and processing of radar, beacon, and flight plan data to yield the timely and accurate aircraft position information upon which an improved air traffic control system must be predicated. It seems clear that high-speed sensing and data acquisition devices -- radars, beacons, and data links -- will only become effective when they have been coupled to high-speed data processing devices.

The fact that the first steps have been taken must not draw attention from the magnitude and complexity of the task ahead. Hand-in-hand with these data processing techniques, improved communications must be provided, not only between pilots and controllers, but between controllers and computers. If not, a future system may only provide the controller with an "electronic strait-jacket." High speed data processing techniques and equipments should be applied concurrently to all parts of the air traffic control system; otherwise, the full benefits of the mechanization of the high altitude en route problem will not be realized, particularly in the coordination and "handover" of control. Non-technical problems must also be faced, not the least of which is the acceptance of a semi-automatic control system by the pilots and controllers "brought up" on the present manual system.

Compared to the cost of a separate traffic control system of similar capability, the integrated system at the super combat centers will represent substantial savings, possibly up to one billion dollars and several years of time. Benefits of integration to the air defense system will be equally important, although not so directly describable in quantitative terms: the knowledge of the position of all air traffic will permit substantial improvements in the identification of non-friendly or hostile aircraft as well as in the safe conduct of friendly retaliatory forces in times of emergency. These benefits of integration will far outweigh the added efforts required to coordinate the needs of the two using agencies in making an integrated system a reality.

REFERENCES

1. SAGE, A DATA PROCESSING SYSTEM FOR AIR DEFENSE (SR-1), Everett, R. R., Zraket, C. A., Benington, H. D., The MITRE Corporation, Lexington, Mass.
2. CHARM SYSTEM DESIGN (SR-4), Israel, D. R., Stylos, P., Nicol, W. S., The MITRE Corporation, Lexington, Mass. (May 4, 1959)
3. CHARM DESIGN AND IMPLEMENTATION EFFORT (6M-5989), Israel, D. R., Quigley, J. W., MIT Lincoln Laboratory, Lexington, Mass. (December 22, 1958)
4. CHARM OPERATION AND RESULTS (SR-5), Stylos, P., Nicol, W. S., Israel, D. R., The MITRE Corporation, Lexington, Mass. (June 9, 1959)
5. PRESENT STATUS OF AIR TRAFFIC CONTROL INTEGRATION AT THE SUPER COMBAT CENTER (TM-304), Israel, D. R., Kirshner, H. J., The MITRE Corporation, Lexington, Mass. (June 23, 1959)