A Preliminary Operational Evaluation of Volscan Model GSN-3 (XD-1)

By
Joseph P O'Brien
Marvin H. Yost
Addison B. Johnson
Loren S. Foot
Fred S. McKnight
Navigation Aids Evaluation Division

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D M Stuart, Director, Technical Development Center

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A PRELIMINARY OPERATIONAL EVALUATION OF VOLSCAN MODEL GSN-3 (XD-1)*

SUMMARY

This report describes a preliminary operational evaluation of the GSN-3 (XD-1) VOLSCAN equipment This equipment was designed as the terminal-area scheduling and control portion of a military traffic control and landing system. The evaluation was conducted by the Civil Aeronautics Administration Technical Development Center during May 1957, at the USAF Cambridge Research Center's Navigation Laboratory on Deer Island, Boston, Massachusetts The VOLSCAN equipment was maintained jointly by Navigation Laboratory personnel and by the contractor, Crosley-AVCO, representatives The FPS-8 radar on Deer Island provided the radar input for the tests Franklin Institute personnel, under contract to the Technical Development Center, assisted in the planning and organization of the tests, data-taking, and data analysis Aircraft for this program were furnished by the U. S. Air Force and CAA Control positions were staffed by air traffic control specialists from CAA operating facilities and from the Technical Development Center during the evaluation tests

The results of this preliminary evaluation indicate that the VOLSCAN equipment tested at Deer Island is not suited for application to the common air traffic control system in the following respects

1 Maneuvering airspace requirements are greater than those available in most high-density traffic areas in the United States
2 The equipment does not recognize and instruct aircraft to avoid high terrain or airspace reservations
3 Controller workload is materially greater than that required with present-day manual radar control procedures for densities of traffic of 30 to 35 arriving aircraft per hour
4 The safety and reliability of the air traffic control service, when using VOLSCAN, does not appear as good as the present manual radar control system
5 The reliability of tracking by means of the track-while-scan gates was very poor. Only 56 per cent of the aircraft targets initially acquired in the tracking gates were tracked through a complete run to the delivery point
6 The quality of radar data for VOLSCAN operation is more critical than that required for manual radar control
7 The method of assignment of the tracking gates to the radar target, by use of the light gun, requires excessive attention
8. The constant airspeed required of aircraft under VOLSCAN control is not suitable for making normal approaches and landings for many present-day aircraft

More comprehensive evaluation tests of the VOLSCAN equipment are planned at Eglin Air Force Base during 1958

INTRODUCTION

VOLSCAN was developed to satisfy a U. S. Air Force requirement for rapid recovery of aircraft at an air base Large numbers of aircraft on tactical missions frequently return to base at about the same time, and it is desirable to land these aircraft at high rates VOLSCAN is the terminal-area scheduling and control portion of a proposed traffic control and landing system In this system, it is proposed to place returning aircraft under control of the VOLSCAN scheduling equipment when they are 40 miles or more from the air base The VOLSCAN equipment then would direct aircraft to arrive at an approach gate a few miles from the end of the runway with a spacing of 30 seconds between successive aircraft

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A breadboard model of VOLSCAN was built by the Navigation Laboratory of the Air Force Cambridge Research Center (AFCRC) and tested at Clinton County Air Force Base (AFB) in Wilmington, Ohio, during 1952 As a result of experience gained with this breadboard model, specifications for a prototype model were prepared, and a contract was later awarded to the Crosley Division of AVCO Manufacturing Company to construct three models of the AN/GSN-3 (XD-1) VOLSCAN The first of these three equipments was delivered to the Air Force in the fall of 1956 It was given engineering acceptance tests at Clinton County AFB, and then was moved to Deer Island where it is installed in one of the concrete bunkers An FPS-8 radar on Deer Island is used with this installation of the VOLSCAN equipment This first model of the VOLSCAN was used for the evaluation tests described in this report

This evaluation test of VOLSCAN was conducted by the CAA Technical Development Center (TDC) as part of an ANDB project Further evaluation tests are being planned for the second VOLSCAN unit which will be installed at Eglin AFB in 1958 The third model of the XD-1 is to be delivered to Wright-Patterson AFB at Dayton, Ohio

The Navigation Laboratory of the AFCRC has prepared specifications for a VOLSCAN model, XD-2, which will incorporate greater flexibility than is possible with the XD-1 models Although the basic philosophy remains unchanged, several new features are incorporated in the XD-2 These features are (1) automatic voice instruction, (2) a GKA-5 data-link coupler, (3) flexible height programming, (4) independent scheduling for six airports, (5) automatic velocity correlation between aircraft and computer, and (6) increased accuracy of scheduling The XD-2 contract specifications call for the production of two units

The preliminary evaluation of VOLSCAN (XD-1) was conducted at Deer Island so that ANDB, CAA, and industry could have an early indication of the possible application of VOLSCAN to the solution of terminal-area problems The test procedures, criteria, and plans were designed to apply to the evaluation of any automatic or semiautomatic approach aid Although it was not the intent of the preliminary evaluation to "demonstrate" the operation of VOLSCAN to visitors, no attempt was made to restrict visitors from the operating quarters during the conduct of the evaluation

TEST OBJECTIVES

The preliminary operational evaluation of VOLSCAN was conducted to.

1 Subject the equipment to a relatively large volume of traffic to determine if it meets specified capabilities
2 Determine if the equipment, or some of its component parts, can be integrated into the common system
3 Determine if the equipment will function under existing civil-military separation standards
4 Evaluate the controller workload necessary to operate the equipment
5 Evaluate the equipment configuration with respect to controller coordination
6 Determine the communications requirements, both interposition and air/ground
7 Evaluate the duties and responsibilities of each position of operation
8 Determine the maneuvering airspace requirements
9 Evaluate the seriousness of known equipment limitations

These objectives were not all accomplished fully in this preliminary evaluation

TEST PERSONNEL

Air traffic control (ATC) specialists from TDC and the CAA Office of Air Traffic Control, Washington, and personnel of Franklin Institute Laboratories (FIL), Philadelphia, Pennsylvania, participated in the preparation of detailed test plans Each of the four domestic regions of CAA supplied two experienced ATC controllers for the test

FIL personnel assisted in the data recording and made a statistical analysis of the data obtained during the test period The VOLSCAN equipment was maintained jointly by personnel of the Navigation Laboratory and the contractor, Crosley-AVCO

Air Force aircraft were provided for the test by the AFCRC Test Support Squadrons at Bedford, Massachusetts Also, three civil aircraft flown by CAA pilots participated for the duration of the evaluation

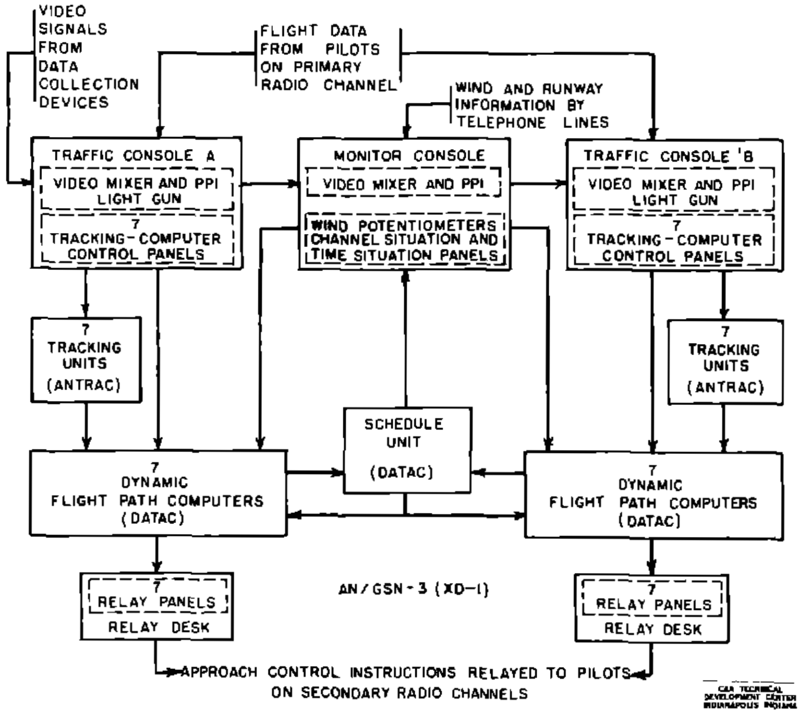

Fig 1 Block Diagram Showing Major Components of the AN/GSN-3 (XD-1) VOLSCAN

THEORY OF OPERATION

Several AFCRC reports and memoranda[1] contain detailed descriptions of VOLSCAN and its associated equipment Figure 1 is a block diagram showing the major components of the AN/GSN-3 (XD-1) The sketch does not show all of the equipments or all of the interconnections between the components

No special airborne equipment is necessary, other than a radio transmitter and receiver capable of operation on the authorized primary and secondary frequencies The aircraft can be of any type capable of cruise velocities between 70 and 550 knots, however, each aircraft is required to maintain a specific indicated airspeed corresponding to one of the cruise velocity categories of the VOLSCAN system These categories on the XD-1 model are 80, 100, 120, 160, 200, 240, and 280 miles per hour (mph), and 290, 350, 420, 500, and 550 knots Aircraft descent rates must conform to one of the following rates of descent 500 feet per minute (fpm), 1,000 fpm, 2,000 fpm, or 4,000 fpm

Prior to the use of VOLSCAN at a given installation, it is necessary to establish the X and Y coordinates of the delivery points to which the aircraft will be directed and the headings for final approach Up to six different delivery points may be used Delivery may be made to any point which is at least 4 miles from the radar and no farther away than 25 miles These delivery points usually are limited by the low-angle coverage of the radar, since an adequate radar signal must be available for each aircraft during the entire portion of the controlled flight Care must be exercised in the selection of the final approach heading to insure that the aircraft flight path does not pass within 4 miles of the radar, because the VOLSCAN cannot track or control flights within this area

The pilot of an approaching aircraft contacts the VOLSCAN unit on the primary radio frequency when within 60 statute miles of the radar A controller at one of two traffic consoles establishes communications, identifies the aircraft on a radar display, and assigns a

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[1] Phylis M Barnes, "Control Concept for Air Traffic Control AN/GSN-3 (XD-1) (VOLSCAN), " Operational Memo No 4, March 1957

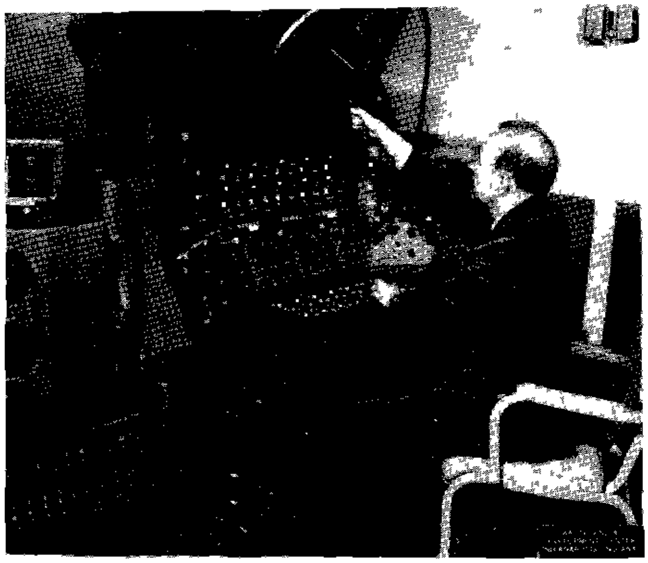


Fig 2 Traffic Operator's Console

track-while-scan gate (ANTRAC) to the radar target Each traffic console is provided with a 16-inch Plan Position Indicator (PPI) scope, a communications panel, and a tracking and computing control panel A light gun is provided for slewing the track-while-scan gate to the selected radar target Figure 2 is a photograph of a traffic console After establishing communications, flight data are requested from the pilot, and these data are entered into a flight-path computer (DATAC) through the control panels These data consist of the present altitude of the aircraft, the desired descent rate, and the cruise velocity When all pertinent information has been entered, the flight-path computer "start" button is activated

The pilot is requested to change to the secondary radio frequency and obtains vector headings from a relay operator at one of the relay desks The flight-path computer selects the earliest possible time of arrival which does not conflict with aircraft already scheduled Altitude and rate of descent are considered in the selection of the earliest possible arrival time The aircraft first is turned away from the delivery point until it reaches a position where a direct path to the "turn circle" will cause the aircraft to arrive on schedule at the delivery point As shown in Fig 3, jet aircraft are directed to fly to a tangent point on the nearest 12-mile-diameter turn circle, and propeller aircraft are directed to a tangent point on the nearest 6-mile-diameter turn circle The established final heading serves as a center line of the computer's geometry, and it also delineates the control areas for the two traffic consoles If the aircraft starting position is left of this center line, it is directed to fly to

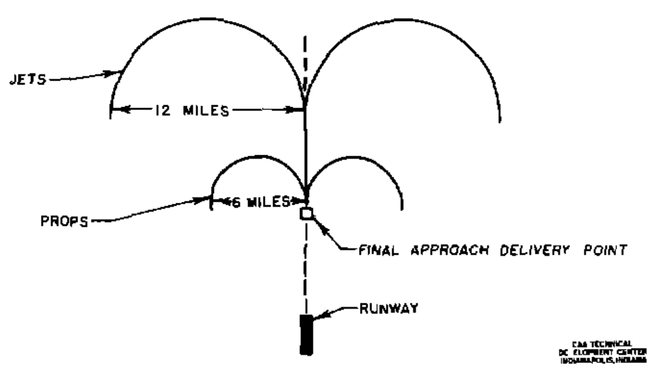


Fig 3 Final Turn Circles

Fig 4 Flight Path Computer Output - Relay Operator Panels

the appropriate right-hand turn circle The diameters of the circles are designed not to exceed standard rate turns for the different aircraft speeds

Priority scheduling is possible for emergency situations When the emergency priority process is activated, the aircraft is automatically scheduled for delivery in the time slot which allows it to fly a direct path to the turn circle even though the time slot already may be assigned to another aircraft When this condition occurs, the non-emergency aircraft is automatically displaced to a later unoccupied time slot No other aircraft schedules are affected by this process

The output of the flight-path computers is displayed on the relay panels, with one panel serving each flight-path computer See Fig 4 The panels are located on desks which are positioned so that 4 operators can relay the instructions appearing on the 14 relay panels The instructions to be relayed to the pilot appear at the relay panel on meters, indicators, and lamps These include heading instructions, descent instructions, and an altitude display which allows the relay operator to remind the pilot of the altitude that VOLSCAN expects him to be flying at any moment There also is a "cockpit check" reminder lamp, a lamp indicator to inform the relay operator of equipment malfunctioning, and a lamp which lights when the pilot should be instructed to take the final approach heading

THE VOLSCAN EQUIPMENT DOES NOT AUTOMATICALLY PROVIDE SEPARATION BETWEEN AIRCRAFT IN THE MANEUVERING AREA. The controller at the traffic console, starting an aircraft into the system, is expected to monitor each aircraft into the delivery point If an impending confliction is noted, he may activate switches which light the traffic information lights on the relay console These consist of three red lamps at the top of each relay panel In instrument flight rule (IFR) conditions, these can be used to indicate to the relay operator that the aircraft should be turned left or right In visual flight rule (VFR) conditions they may be used to indicate traffic at 10, 12, or 2 o'clock

A monitor console, Fig 5, is provided to permit supervision and modification of the schedule assignments made by the schedule unit The monitor position has a 19-inch PPI radar indicator, a time-situation panel, a channel-situation panel, and controls for setting in the wind velocity and direction Whenever one of the two traffic consoles "starts" an aircraft into the VOLSCAN system and the schedule unit selects and reserves a time slot, this reservation is displayed by means of lights on the time-situation display panel along with the selected cruise velocity of the scheduled aircraft The monitor operator can reserve time slots for aircraft takeoffs or he can increase the time interval between successive aircraft by operating switches at the time-situation panel For example, if a fast aircraft is following a slow aircraft, the monitor operator should delay the scheduled arrival of the fast aircraft by blocking sufficient time slots to prevent overtake on the final approach course In the AFCRC concept, the monitor shares the responsibility for collision prevention with the traffic console operators

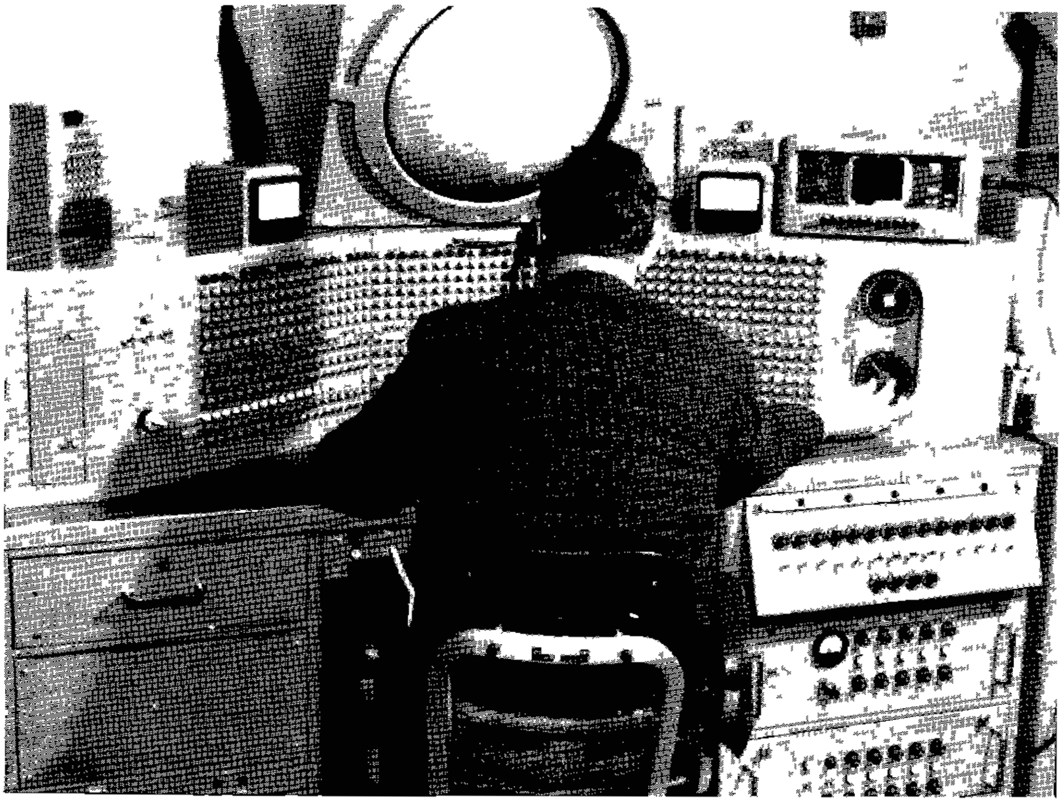


Fig 5 Monitor Console

TEST CONDITIONS

The VOLSCAN equipment at Deer Island was located in a concrete bunker formerly used for coastal defense guns The layout of operating consoles and equipment was dictated somewhat by the space available, and was not necessarily an optimum arrangement for good controller coordination between positions Only seven tracking gates (ANTRAC's) and flight-path computers (DATAC's) were available for the evaluation tests Thus, a maximum of seven aircraft could be controlled in the system at one time

Air/ground communications facilities were limited to two very high frequency (VHF) and two ultra high frequency (UHF) channels, with the military aircraft using UHF and the civil aircraft VHF One UHF channel was assigned as primary frequency for use at one of the traffic consoles The second UHF channel was used as the secondary frequency at one of the relay positions Similarly, one VHF channel was designated as primary for the civil aircraft and was used by the controller at the second traffic console The second VHF channel was used as a secondary frequency by the second relay operator

To minimize interference with other aircraft operations in the Boston area, all tests were conducted in VFR weather conditions For the same reason, an actual airport was not used except for the last test when approaches were made to Logan Airport at Boston

In this preliminary operational evaluation of VOLSCAN, a decision was made to investigate three terminal-area modes of operation (1) the single-stack operation, (2) the dual-stack operation, and (3) the multiple-fix or random-pickup operation The configuration of holding fixes used in the single- and dual-stack operations is shown in Fig 6 An outer marker was simulated at the Boston Light Ship, and the delivery point was placed at a point three-fourths mile east of the light ship on the east course of the Squantum Range The single- and dual-stack locations shown in Fig 6 met with the criteria presently observed in the placement of terminal-area aids However, these locations did not provide enough maneuvering airspace for proper VOLSCAN operation In the initial tests with these close-in stacks, a tracking gate was assigned as soon as the aircraft was observed and identified

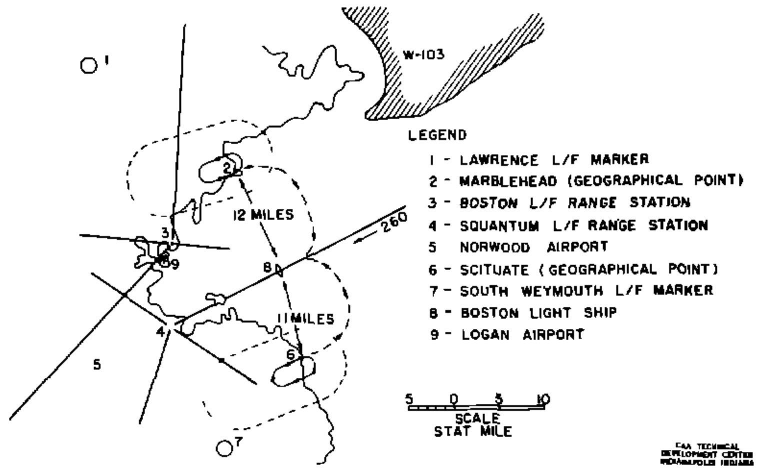


Fig 6 Twin Geographical Holding Fix Arrangement Used First for VOLSCAN Tests

leaving a holding fix By the time the aircraft had been advised to change to the secondary frequency, and by the time the monitor had observed the scheduled reservation for the aircraft and modified it as necessary, the aircraft was very close to the turn circle and an extensive delay pattern was necessary to establish the desired interval between aircraft at the delivery point On subsequent days, the holding fixes were moved to points farther away from the delivery point (Lawrence and South Weymouth in Fig 7) and the operation was improved The configuration planned for the multiple-fix or random-pickup operation is shown in Fig 8 In addition to Lawrence and South Weymouth, the Bedford outer compass locator, the Franklin fan marker, and the Boston LF range station were used as feeder fixes For this configuration, the Logan outer marker was to be used as the delivery point for approaches to Runway 4 at Logan Airport

Since the equipment was being tested for possible application to the common civil-military system, all tests were based on the use of ANC radar separation standards These standards, which have been agreed to by the responsible Government regulatory agencies and by the users of the airspace (aircraft operators), require a basic minimum of 3 miles lateral

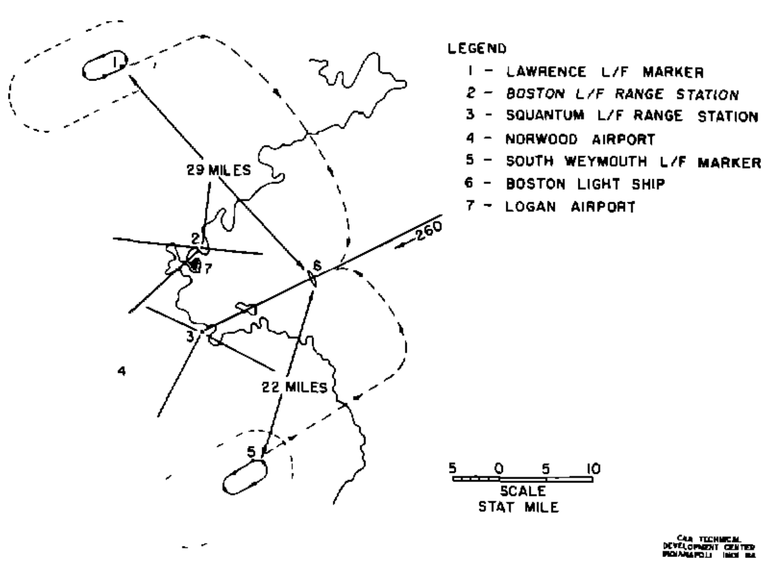


Fig 7 Twin Geographical Holding Fix Arrangement Used Subsequently for VOLSCAN Tests

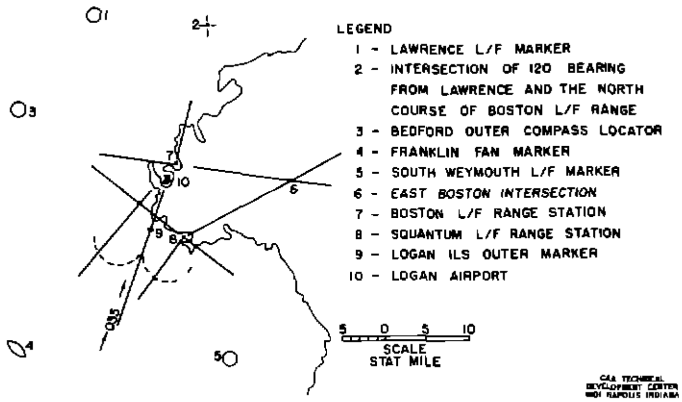


Fig 8 Example of Perimeter Fix Layout for VOLSCAN Tests

separation between aircraft as observed by radar, or 1,000 feet vertical separation The VOLSCAN equipment is, primarily, a scheduling device for placing aircraft over a delivery point at intervals, and it does not compare the positions and paths of aircraft, or detect potential collisions and automatically warn the controller of these situations The two controllers operating the traffic consoles were required to follow closely all aircraft on the PPI radar displays to determine if the VOLSCAN-generated flight paths would cause unsafe or less-than-standard separation minimums In IFR operations, if an unsafe situation developed, or if it appeared that a confliction might occur, the traffic console controller would be required to switch on the traffic lights to indicate merging traffic at 10, 12, or 2 o'clock The relay operator observing these lights would be required to advise the aircraft of this traffic information and to instruct the aircraft in question to switch back to primary frequency so that the traffic console controller could manually vector the aircraft out of danger This process is considered to be very cumbersome, and the time lag involved could result in critical situations In TDC tests, conducted under VFR conditions, the lights were used to indicate traffic to the left, straight ahead, or to the right

Since, with ANC separation standards, the basic 3-mile minimum separation is required all the way to touchdown, it is necessary to use much more than 30-second spacing at the delivery point on the final approach course for normal aircraft approach speeds

Tables I and II were prepared to assist the monitor in establishing the minimum separations at the delivery point for the various sequences of Slow (S), Medium (M), Fast (F), and Jet (J) aircraft These separations were computed for the conditions of (1) zero headwind, (2) a seven-mile delivery point to runway distance, (3) a minimum radar separation of three miles, (4) no speed control on the glide slope, and (5) on the basis of average approach speeds and rates

It was the responsibility of the monitor operator to compare the speed of each new flight being scheduled with the speed of the preceding aircraft He then would block sufficient 15-second time increments and reschedule the new flight, if necessary, by operation of the switches on the time-situation panel to provide the required interval between aircraft at the delivery point for maintaining a minimum 3-mile separation to the runway

DATA RECORDING

Air/ground communications on the two VHF channels and two UHF channels were recorded on tape during the test, and an analysis was made of the number and length of messages Also, a record of total live time on each channel was made The various control functions were timed with stop watches Photographs were made of the indicator on a frame-per-antenna scan basis during the test period The flight path of each VOLSCAN-controlled aircraft was recorded on a VG plot Data also were compiled on the following

TABLE I

AIRCRAFT PERFORMANCE CATEGORIES

Speed Class		Approx Hold and Approach Speeds (mph)	(knots)	Intermediate Speeds (mph)	(knots)	Average Descent Rate (fpm)	Average Rate of Turn (deg /sec)
Slow	(S)	120	104	150	130	500	3
Medium	(M)	140	122	190	165	1000	3
Fast	(F)	150	130	220	191	1000	3
Commercial Jet	(CJ)	200	174	280	243	2000	3
Military Jet	(MJ)	240	209	333	290	4000	1 1/2

1 The time and altitude each aircraft left its feeder fix to be vectored to the delivery point (If holding stacks were used, the time of entering the holding stack also was recorded)
2 The time each aircraft was originally, and also finally, scheduled by VOLSCAN to arrive at the delivery point
3 The actual time each aircraft arrived at the delivery point
4 How closely the aircraft was aligned on the final approach course at the delivery point
5 The number of times, and the circumstances under which, aircraft had less than the prescribed 3-mile or 1,000-foot altitude separation
6 Wind and air density
7 Controller comments and workload
8 Pilots' comments
9 Number of times, and circumstances under which, an ANTRAC was not available
10 Number of times, and circumstances under which, aircraft could not be assigned a track because of the 14 1/4-minute limit of the scheduler
11 Intercontroller coordination

The control personnel were rotated through each of the positions of operation An assistant and an observer were assigned to each position for data gathering and for coordination between positions Since transmitter facilities were limited, each aircraft was returned to the primary frequency as soon as a run had been completed, and the aircraft was directed to the starting point for the next run by the traffic console operator

Data on the operation of the B-47 aircraft were not tabulated because the pilot was reluctant to reduce speed to 240 mph unless committed to a landing

TEST RESULTS

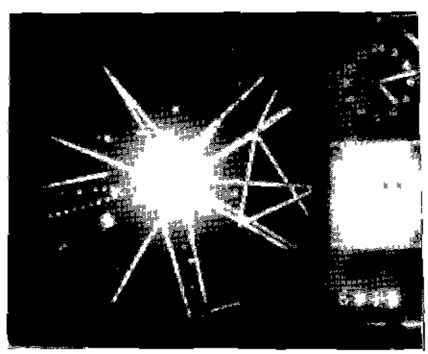
Table III is a summary of the tests for each day showing the aircraft participating

Although detailed traffic samples had been prepared for the test program, it was impossible to follow the schedule because of the lack of knowledge as to the exact number and types of aircraft that would be available on a given day, and because of the many difficulties experienced with the tracking gates in locking-on and continuously tracking the aircraft radar targets Equipment maintenance problems and adverse weather reduced the total time available for operational tests At various times during the tests, it was possible to rally three or four aircraft near one of the entry fixes where they were scheduled in rapid succession to create a traffic problem The following results were recorded during the test period

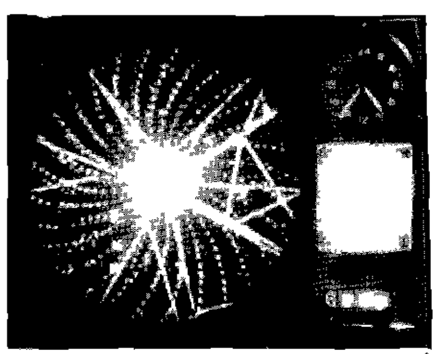
Total number of runs attempted	216
Total number of runs on which tracking was initiated	207
Total number of runs delivered to the delivery points	116
Per cent of targets entered which were delivered	56
Number of runs by beacon-equipped aircraft	132
Number of runs delivered	81
Per cent delivered	61
Number of runs by non-beacon-equipped aircraft	75
Number of runs delivered	35
Per cent delivered	47

Reason for Incomplete Run	No of Runs
Gate stolen by radar interference	66
Gate stolen by permanent echo	6
Gate stolen by ship echo	5
Gate stolen by another aircraft return	3
Various malfunction of radar equipment	4
Loss of communications	4
Avoidance of confliction (controller initiated)	1
Aircraft too far off schedule	1
Monitor operator flipped wrong switch	1
	91

Approximately 70 per cent of the 91 runs which were started, but not completed, were not completed because the tracking gate left the target due to interference from other radars Figure 9 shows photographs of the radar indicators with typical conditions encountered The Piper Apache presented a marginal radar target which frequently was not sufficiently strong to provide an adequate input for operation of the tracking gates



Indicator Without Interference



Indicator With Interference

Fig 9 Photographs of Radar Indicators With and Without Interference

TABLE II

MINIMUM SEPARATIONS AT 7-MILE DELIVERY POINT
(5-MILE DIST.)
(Zero Wind, 3-Mile Minimum, No Speed Control)

Sequence No 1	Sequence No 2	Dist Sep, (stat miles)	Time Sep (minutes)	Time Sep (1/4-min increments)
	S	4 5	2 25	9
S	M	5 9	2 55	10
	F	6 6	2 70	11
	CJ	8 7	2 90	12
	MJ	11 0	2 75	11
	S	3 3	1 67	7
	M	4 5	1 93	8
M	F	5 1	2 04	8
	CJ	7 7	2 63	11
	MJ	10 0	2 50	10
	S	3 0	1 50	6
	M	4 0	1 75	7
F	F	4 5	1 80	7
	CJ	6 9	2 30	9
	MJ	9 0	2 25	9
	S	3 0	1 50	6
	M	3 0	1 29	5
CJ	F	3 0	1 20	5
	CJ	4 5	1 50	6
	MJ	7 0	1 75	7
	S	3 0	1 50	6
	M	3 0	1 29	5
MJ	F	3 0	1 20	5
	CJ	3 0	1 00	4
	MJ	4 5	1 12	5

NOTES

1 Theoretical maximum sustained acceptance rate for the above separations averages 32 per hour, or an average interval of 113 seconds For a delivery point-to-runway distance of 5 miles and corresponding conditions, the sustained acceptance rate would be 38 per hour, an average interval of about 95 seconds

2 Headwinds will decrease the acceptance rates cited in 1, above, by a factor of $V_W/172$, where V_W is the final approach headwind component in mph

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The interval between the scheduled arrival time and the actual arrival time at the delivery point was measured with a stop watch for each completed run The distribution of these intervals is shown in Fig 10 During the test program, when large but consistent errors between scheduled and actual times were experienced, the monitor operator attempted to, and usually was successful in, reducing these errors on subsequent aircraft by adjusting the single average wind setting in the computer Some large errors were due to temporary loss of the tracking gate on the final turn near the delivery point Although these measurements give some indication of the spread of timing errors which may be experienced, it is believed that the tests were not of sufficient length to determine a statistically valid timing-error distribution

TABLE III

SUMMARY OF TESTS

Date May 1957	Configuration	Wind	Aircraft	No Runs Attempted	No Runs Completed
21	Twin Stack	NE at 25k	AF 796, AF 085 X 70p, X 182	25	13
22	Twin Stack	NE at 23k	AF 443, X 70p	12	7
22	Twin Stack	NE at 25k	AF 796, AF 085 AF 443, AF 514 X 70p, X 182	56	27
24	Twin Stack	W at 40k	AF 085, AF 443 AF 514, AF 828 AF 812, X 70p X 182	30	17
24	Twin Stack	WNW at 35k	AF 085, AF 443 AF 514, AF 828 AF 812, AF 796 AF 327, X 70p X 182	44	23
28	Twin Stack	W at 17k	AF 796, AF 085 X 70p, X 182 X 7	32	21
28	Perimeter Fix	WSW at 24k	AF 812, AF 514 AF 085, X 182	17	8
			Total	216	116

Aircraft Participating in Test Program and Cruise Speeds Used in Tests

AF 796	C-131	--------	200 mph
AF 085	C-47	--------	160 mph
AF 443	C-54	--------	160 mph
AF 828	BCFT	--------	120 mph
AF 514	B-47	--------	290 knots
AF 812	C-131	--------	200 mph
AF 327	B-25	--------	200 mph
X 182	DC-3	--------	160 mph
X 70p	Piper Apache	--------	120 mph
X 7	Twin BCFT	--------	120 mph

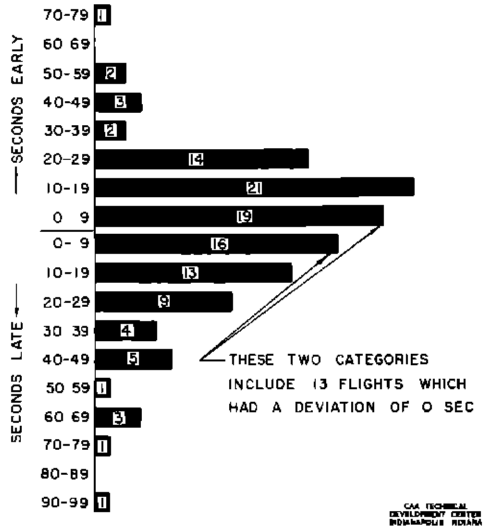

Fig 10 Data on 116 VOLSCAN Flights Showing Deviations in Seconds from Scheduled Time Over Delivery Gate

Of the 116 completed runs, 45 were observed to be 1,000 feet or more to the right or left of the delivery point Figure 11 shows the error distribution These data were obtained from the VG plots made during the run These data also are based on a relatively small sample and may not be indicative of results which might be obtained from more comprehensive tests

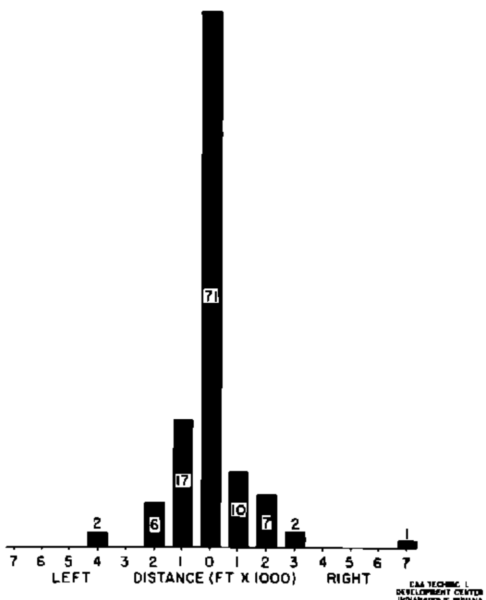

Fig 11 Data on 116 VOLSCAN Flights Showing Distance to Right or Left of Delivery Point

A few hours of the ground/air communications recordings were analyzed with the following results

Primary Frequency (used by traffic operator)

Average number of messages per aircraft
- Controller 3
- Pilot 3

Average communication time per aircraft
- Controller 20 seconds
- Pilot 6 seconds

Communications involving initial run assignments were not included in the above data

Secondary Frequency (used by relay operator, almost all ground-to-air)

Average number of messages per aircraft	29
Average communications time per aircraft (minutes)	2
Average number of heading changes per aircraft	25

Figures 12, 13, 14, and 15 are VG plots of some typical runs In Fig 12, Run 42 started with a ratio of time scheduled to time direct, $R = \frac{t_s}{t_d} = 1\ 65$, and thus required a considerable delay Its stretched path is apparent in the plot Figure 13 shows a normal run (No 51), a run which was started but stopped due to the loss of the tracking gate (No 52), a run which was completed but had to be reslewed twice (No 53), and a completed run with an irregularly shaped path (reslewed once) (No 54)

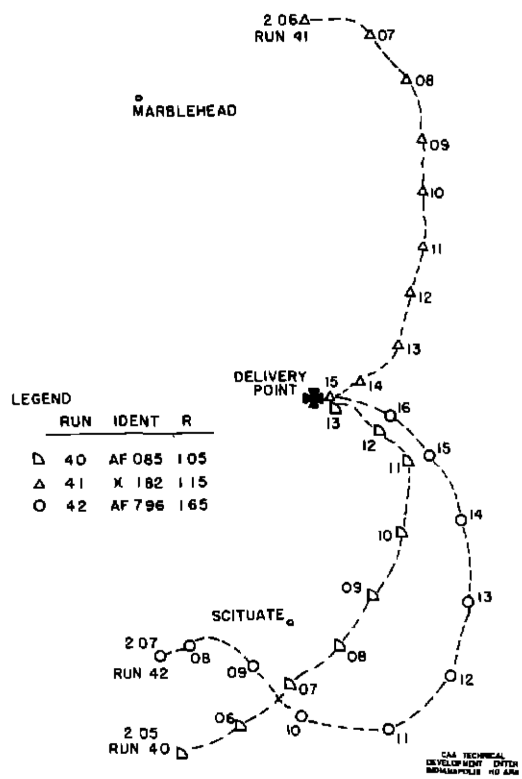

Fig 12 Plots of Aircraft Tracks from VG Radar Indicator

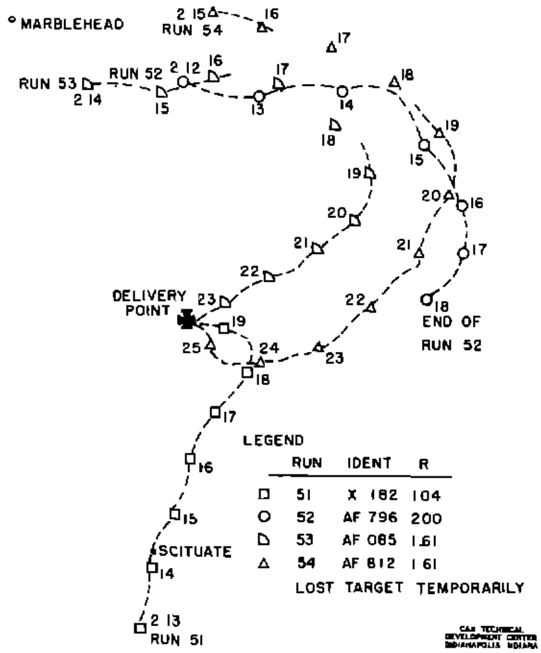

Fig 13 Plots of Aircraft Tracks from VG Radar Indicator

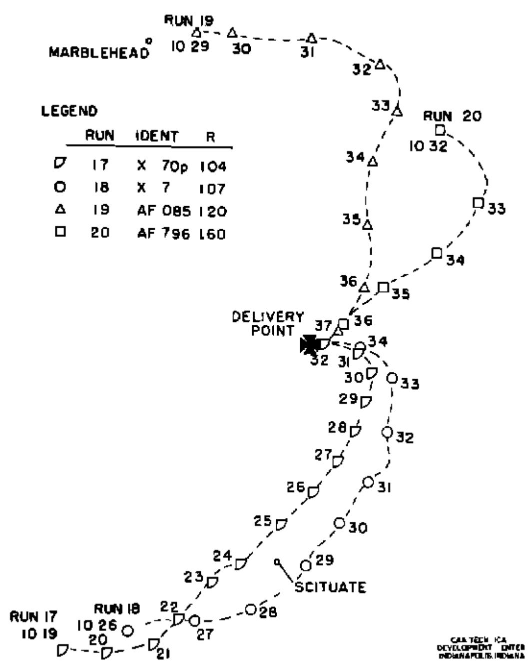

Fig 14 Plots of Aircraft Tracks from VG Radar Indicator

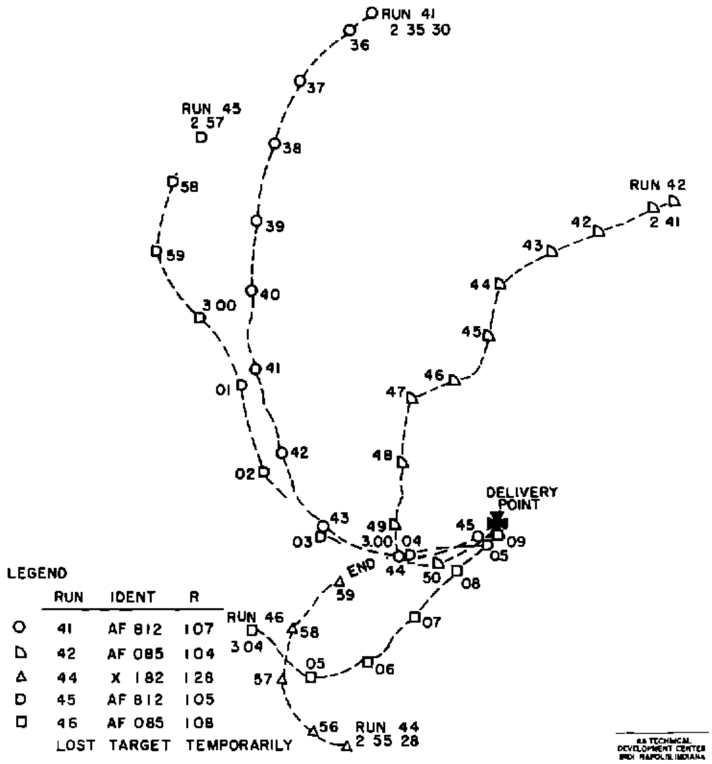

Fig 15 Plots of Aircraft Tracks from VG Radar Indicator

The workload of the controllers at the traffic consoles was very high After establishing radio communications and identifying the aircraft on the radar indicator, the controller selected the desired video (normal radar, MTI, or beacon) on a vacant tracking gate (ANTRAC) panel, depressed a "slew" switch with one hand, and with the other hand aimed the light gun at the radar target To acquire a target, it is necessary to accomplish the above while the radar antenna scans through the target If radar returns are poor, or other targets are within the gate area, it may be necessary to repeat this operation more than once to initiate tracking A "gate widener" button may be depressed to expand the size of the tracking gate to assist in acquiring the target Knowledge of a successful or unsuccessful acquisition of the target by the tracking gate is not known until the next scan of the antenna

After obtaining cruising speed and rate of descent desired by the pilot, the controller inserted this information into the tracking channel by turning a switch to set in airspeed and by pushing a button for rate of descent

After accomplishing the first two steps and observing that the aircraft was in a suitable position for starting a run, the "start" button on the tracking channel was activated This caused the information to be inserted into the flight-track computing unit and the aircraft scheduling unit, and simultaneously, caused an alert lamp to light on the associated tracking channel panel on the relay desk The traffic console controller then would ask the pilot to change to the relay operator on the secondary frequency

Throughout the balance of the run, the traffic console controller was responsible for monitoring the movement of each aircraft and insuring that the assigned tracking gate stayed on the proper radar target If the desired target approached a clutter area or other targets, the controller would select other video for the gate to work on, or switch the gate onto the "coast" mode from the "automatic tracking mode until the target had passed through the clutter area If the tracking gate failed to follow the target, the "gate widener" button could be used to assist in re-acquiring the target In many cases it was necessary to "reslew" the gate onto the target

In addition to the above, the controllers at the two traffic consoles were responsible for providing separation between all aircraft under control If it appeared a confliction was about to occur in the vector area, the controller activated the traffic conflict switches which lighted lamps on the associated panel at the relay operator position If it appeared necessary, the controller then would ask the relay operator to change the aircraft back to the primary frequency for additional manual vectoring

Accomplishing all of the above duties for several aircraft, under conditions of clutter or radar interference, presented a very high workload For traffic densities of 30 to 35 arrivals per hour, it appeared this workload would be much higher than that required in normal manual radar-vectoring procedures from close-in stacks The quality of radar data also must be much better than is required for manual vectoring

It was felt that lack of immediate A/G communications between the traffic console controller and the pilot of the aircraft, while the latter is on the secondary frequency receiving heading instructions from the relay operator, could result in seriously unsafe traffic situations This problem was compounded by poor communications facilities for coordination between the VOLSCAN positions of operation To talk on the intercommunication circuit, it was necessary to actuate a spring-loaded toggle switch on the lower part of the console about 12 inches above the floor This switch had to be held down manually to signal another position and throughout the conversation for both talking and listening

Under the test conditions using ANC separation standards, the VOLSCAN scheduling unit and the time-situation display on the monitor console could not accommodate more than 5 to 7 aircraft at a time Aircraft can be scheduled for only 14 1/4 minutes ahead Normally, during the test period a steady flow of aircraft could not be produced Various factors contributed to this including unreliable operation of the tracking gates, the limited number of aircraft available, a limited number of tracking channels, limited and, in some cases, unreliable A/G communications, inadequate pilot briefing, and the use of geographical points for feeder fixes rather than radio navigational facilities

CONTROLLER COMMENTS

In the briefings which preceded the flight test, the controllers were requested to keep a daily record of the positions they had worked, the amount of time they had worked each position, and any comments pertaining to a particular position of operation It was suggested that they make notes of specific traffic situations wherein the equipment handled the job well, or was limited in ability to handle them At the end of the test program, each controller filled out a lengthy questionnaire, and was asked to recommend equipment changes or improvements and note any features of VOLSCAN which might have application to present or future air traffic control systems The following statements summarize the comments made by the controller personnel

1 The controller personnel commented upon the need for reliable track-while-scan equipment They stated that the workload required for continuous monitoring of the tracking gates, to insure reliable tracking of the proper target, and in reslewing and coasting the gates through clutter and past other targets represented a major workload at the control positions Suggestions for improved reliability of tracking-gate operation included use of coded beacon replies, data links, or possible addition of altitude data derived by radar to discriminate between targets that overlap The initial assignment of tracking gates to radar targets was considered too difficult and demanded too much attention Suggested improvements included a pinpoint of light on the scope to indicate to the controller where the light gun was pointing, or some means of making the gate visible during the slewing process

2 Several of the controllers commented on the lack of provision for adequate communications with the aircraft, and the lack of intercommunications between operating positions All felt much could have been done to improve the VOLSCAN evaluation by some work on communications

3 All of the controllers indicated that they felt that the maneuvering airspace requirement for a VOLSCAN operation was excessive and too large for most civil airports

4 Several suggestions were made for rearrangement of the operating controls and repositioning of the indicators These included the lowering of the indicator to an easier viewing angle, a change in the wind setting controls such as having the "0" setting indicating north rather than the final approach heading, and a relocation of the important or critical controls to avoid accidental or unintentional operation

5 All controllers indicated that they felt it was imperative that one of the positions have information on the complete traffic picture with the capability and necessary communications to take over manually and override the computer immediately when unsafe traffic situations develop or to take over manually in the event of an equipment failure No one man had all of the pertinent information for controlling the traffic or the capability of immediate access to the pilot by radio

6 Most of the controllers indicated that they felt that the idea of automatic voice relay had merit Several controllers indicated an immediate application of automatic voice for routine runway information and wind and weather information

PILOT COMMENTS

The pilots of the aircraft participating in the tests were asked to comment on the VOLSCAN runs Their comments indicated the following

1 The heading changes issued were too small This caused an excessive number of contacts with each aircraft and required that the pilots listen very carefully in order to pick out the instructions intended for their particular flight This was found to be especially difficult when one relay operator was providing instructions to more than two aircraft The pilots indicated that at times they were somewhat confused by instructions requiring them to make a turn of a certain magnitude in one direction, and before they had reached the desired heading, receiving instructions to execute turns in the opposite direction

2 Some of the pilots stated that they were too high at the delivery point to have effected a landing at their stated rate of descent

3 Several of the participating pilots and several of the observer pilots commented on the unrealistic requirement for constant speed from the time they first start to receive VOLSCAN instructions until they arrive at the delivery point A single indicated airspeed was programmed for each approach This meant that a C-131, for example, arrived at the delivery point cruising 200 mph Since approaches were not being made to an airport, no check was possible to determine whether or not a reduction in speed could have been made to complete a landing

An airline pilot observer stated that it would be impossible to slow down a DC-6 or DC-7 aircraft sufficiently in the space from the delivery point to the touchdown point to effect a landing Several pilots commented that an intermediate speed between the cruise speed and the approach speed was needed in order to prepare the aircraft for the landing

4 None of the pilots expressed an objection to the idea of using automatic voice instructions Two of the pilots stated that they thought the automatic voice should be monitored on the ground by a controller so that the pilot could ask for a repeat in the event he missed an instruction or did not understand it

CONCLUSIONS

Although the preliminary operational evaluation tests of the VOLSCAN GSN-3 (XD-1) equipment at Deer Island were limited and were not conducted under optimum environmental test conditions, it is concluded that this equipment is not suited for application to the common civil/military air traffic control system in the following respects

1 Maneuvering airspace requirements are greater than those available in most high-density traffic areas in the United States

2 The equipment does not recognize or instruct aircraft to avoid high terrain or airspace reservations

3 Controller workload is materially greater than that required with present-day manual radar control procedures for densities of traffic of 30 to 35 arriving aircraft per hour

4 The safety and reliability of the air traffic control service, when using VOLSCAN, does not appear as good as the present manual radar control system

5 The reliability of tracking by means of the track-while-scan gates was very poor Only 56 per cent of the aircraft targets initially acquired in the tracking gates were tracked through a complete run to the delivery point

6 The quality of radar data for VOLSCAN operation is more critical than that required for manual radar control

7 The method of assignment of the tracking gates to the radar target, by use of the light gun, requires excessive attention

8 The constant airspeed required of aircraft under VOLSCAN control is not suitable for making normal approaches and landings for many present-day aircraft

In considering VOLSCAN or any other device aimed at the solution of terminal area problems, it should be remembered that the civil need is not for assistance in saturating the final approach delivery gate with aircraft spaced 30 seconds apart, but rather for assistance in providing safe and orderly positioning of aircraft throughout the maneuvering area to touchdown Due consideration must be given to aircraft of various speed and performance characteristics, runway and field conditions, runway reservation demands for departing aircraft, aircraft in emergency, and, to some extent, varying weather conditions Safety is a prime consideration in any traffic control system, whether manual, semiautomatic, or fully automatic The ability to adhere to safety regulations, recognize confliction and danger situations, and quickly initiate corrective or preventative action must be inherent in any system receiving consideration for civil use

RECOMMENDATIONS

It is recommended that additional operational evaluation of VOLSCAN be conducted as planned at Eglin AFB The following environmental conditions should be met if possible

1 All 14 tracking channels should be available on the VOLSCAN equipment
2 Sufficient aircraft should be available for sustained high-density traffic tests
3 Sufficient air/ground communications channels should be provided to simulate present-day and proposed communications capabilities
4 Improved controller coordination interphone circuits should be provided
5 Tests should be made using actual airports with typical navigation aids for feeder fixes and for final approach and landing
6 At least part of the tests should be made with successive aircraft completing landings on the airport runway, and taxiing back for handling as departures from the airport

In addition to the above, it would be desirable to modify the VOLSCAN equipment to provide for

1 Automatic detection of possible traffic conflictions in the maneuvering area
2 Automatic vectoring or control to resolve any potential traffic conflictions
3 Automatic computation of the proper timing interval at the delivery point for successive aircraft of different types and approach speeds to insure minimum separation on the final approach to the runway
4 An aircraft speed program to permit normal slowdown from cruising, to intermediate, to final approach
5 Use with close-in feeder stacks or fixes spaced 8 to 15 miles from the final approach course

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