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TESTS OF THE SRS-1 EQUIPMENT MODIFIED FOR AIR TRAFFIC CONTROL USE

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SUMMARY

This report describes a second series of tests to evaluate certain features and special modifications of the SRS-1 equipment for application in air traffic control systems.

A previous evaluation of the original SRS-1 equipment was conducted by the Technical Development Center during May 1957. It was concluded that if the equipment were modified to take advantage of flight plan information an improved operation and a more realistic air traffic control evaluation would be possible Accordingly, the SRS-1 was modified to provide for (1) insertion of flight plan course and speed in the tracking channels, (2) course and speed readout from the tracking channels, (3) initial positioning of tracking channels at preselected fixes, (4) pushbutton selection of tracking channels, and (5) individual lamp indicators to show tracking channel availability.

Some of the modifications to the SRS-1 proved of definite value in improving the versatility and efficiency of the equipment for air traffic control while others were of limited value. The use of certain SRS-1 features to improve radar handoff was the most promising potential application of the SRS-1 to an air traffic control system. Operator proficiency is a very important factor in the performance of this system. The SRS-1 equipment as modified, however, would offer only limited advantages in any immediate application to the existing air traffic control system.

Further evaluation tests after additional modifications to the basic SRS-1 equipment are recommended These include displays providing alpha-numeric information with tracking symbols and improvement in stability of tracking gates.

INTRODUCTION

Acceleration of the Federal Airways radar implementation program has emphasized the need for improved air traffic control (ATC) display systems incorporating radar-derived information. Although no existing system appears to meet all proposed operational requirements for systems of this nature, certain systems such as the SRS-1 perform one or more functions which may satisfy some of these requirements.[1,2]

The Technical Development Center (TDC) conducted some preliminary tests of the SRS-1 during May 1957 to determine the utility of automatic and rate-aided tracking, combined symbolic and radar situation displays, and remote tracking for application in an ATC system.[3]

During these first tests, it was noted that:

1. Unaided automatic tracking did not appear practical for ATC applications. This was due to erratic behavior of the tracking gates when radar returns from other than the desired target were received, such as in the presence of ground clutter or other aircraft returns.

2. A controller could track and control four to six aircraft simultaneously using a combination of automatic and coast modes. This limited capacity was due primarily to the workload involved in maintaining the tracking gates in association with the proper radar targets and to the workload in associating individual flight progress strips with targets and gate symbols on the cathode-ray tube (CRT). It appeared that this capability would be increased if the targets to be tracked were localized in one area of the display.

3. Certain modifications appeared possible which would warrant further evaluation.

As a result of recommendations based on these preliminary tests, the SRS-1 equipment was modified to allow the controller to use simple dials to insert flight plan data in the position and velocity storage elements of any tracking channel. Auxiliary equipment was provided also to facilitate the selection of a particular channel and to display the stored heading and speed. See Figs. 1 and 2.

A second series of tests was conducted with the SRS-1 at the Airborne Instruments Laboratory, Mineola, N. Y., during the week of September 23, 1957. The objectives of this evaluation were to determine the value of the modifications and to obtain additional experience and information regarding the desirability of incorporating any features of this

[1] "A Development Plan for an Improved Air Traffic Control System," Technical Development Report No. 300, Revised September 1956.

[2] Fred S. McKnight, "Operational Requirements for ATC Displays," Technical Development Report No. 308, September 1957.

[3] C. E. Dowling and F. H. Ottersberg, "A Preliminary Evaluation of Surveillance Radar Station (SRS-1) for Air Traffic Control," Technical Development Report No. 323, September 1957.

equipment in improved ATC data processing and display equipment. The test program included one week of preliminary trials and operator training followed by one week of tests.

Tabulations of observations, recordings, and opinions of participants were analyzed to determine:

1. The advantages and possible application of the modifications.

2. Relative performance of each tracking method with and without modifications.

3. Capacities of trackers and controllers using all SRS-1 features.

4. Comparisons of estimated tracking and control capability of radar controllers in three configurations:

   a. Controller performing all control and tracking.

   b. Controller performing all control and monitoring, an assistant accomplishing all tracking, with both controller and assistant sharing a common situation display.

   c. Controller performing all control and monitoring, with tracking accomplished at a remote display by his assistant(s).

5. The ATC functions best performed with the SRS-1.

EQUIPMENT AND MODIFICATIONS

There are four situation displays provided with the SRS-1 equipment, three of these consoles were designed to function as tracking consoles and the other as a supervisory console. Each console incorporates a 16-inch P-7 phosphor CRT with the characteristics of the usual PPI indicator for presenting radar returns, with the capability of writing certain symbols indicating the positions and mode of operation of the tracking channels.

Approximately 23 of the 24 tracking channels were available during the tests. The operation of these tracking channels could be initiated, monitored, and controlled by any one of the four consoles. Control of individual tracking channels could be transferred from console to console as desired. Each channel was capable of tracking targets in an automatic mode[4] or a manual rate-aided (coast) mode.[5]

[4]Automatic Mode. Corrections to position and velocity storage are obtained automatically by examination of video within the tracking gate.

[5]Coast Mode. Corrections to position and velocity storage are determined only as a result of track-stick manipulations.

When the "New Channel" button was depressed, a channel symbol (tag) appeared on the display as a letter C indicating coast mode. This then could be changed to the automatic mode, indicated by a change of the C to a small circle, at the discretion of the operator at the controlling console. The location of each tracking channel is shown as a bright dot on all consoles not controlling these channels. The C and small circle are approximately 1/4-inch in diameter, while the dots are about the diameter of a pencil lead. A luminous hairline (leader) begins at the center of the scope and ends near the tracking channel symbol, which then is subject to control action from this console. As the operator activates a channel sequencing button, this leader switches subsequently to each of the track channels assigned to this console. All 24 channels can be controlled from the supervisor console.

A control panel, with four dials to insert heading and one dial to insert speed, was added to each console so that assigned tracking channels could be started with known flight plan data. The supervisor console, Fig. 1, was modified to include course and speed readout indicators for a selected tracking channel, initial positioning of tracking channels at four preselected fixes, individual selection of tracking channels by pushbuttons; and a panel of lamps to indicate tracking channel availability. As shown in Fig. 2, the latter two features were mounted in a bay for holding flight progress strips, so that flight strips could be directly associated with the assigned tracking channel. Each console operator could acquire a target, subsequently reposition the symbol, and enter velocity (speed and heading) changes with a track-stick control. He also initiate or correct velocities by means of the course and speed control panel by setting the dials to the desired heading and speed and depressing a pushbutton.

The supervisory console operator could note channels available for assignment from the row of numbered lamps. A specific channel could be selected for target assignment, or immediate control, by depressing a numbered pushbutton. A new tracking channel symbol could be positioned at a preselected fix location by depressing a button in lieu of slewing the symbol manually with the track stick. The course and speed readout indicators could be used to aid in target tracking and provide current ground speeds for ATC purposes.

TEST CONDITIONS

1. The area and routes selected represented a typical route configuration in the New York control area with one-way routes and some crossing traffic. The traffic flow of radar targets observed during the test period was considered characteristic for all weather conditions, since scheduled air carriers adhere to a policy of flying IFR in the New York area regardless of weather.

2. In order to reduce the effects of variation in personnel proficiency on the final results, personnel were rotated through all positions of operation.

3. Test runs for each target covered approximately 40 to 50 miles.

4. The range scale and offcentering adjustments were identical on all display consoles.

5. Simulated aircraft targets generated by the 15 J1C radar target simulators were used for most measurements. Problems were programmed in advance and the same problems were repeated with different operators to permit comparison of test results.

6. Tags were repositioned on targets as required to maintain the estimated center of the radar target within the tracking symbol. Whenever the estimated center of the radar target lay outside the tag symbol, a miss (off target) was recorded by observers assigned to the test.

7. The number of times each tracking channel was repositioned by the tracker, and the total number of times the channel was selected by the channel sequencing button, were recorded automatically with an Esterline-Angus recorder.

8. The following tracking modes were used.

Mode 1. Automatic mode using the course and speed (C/S) dials for starting the tracking channels initially in accordance with flight plan data, and subsequent tracking accomplished automatically based on radar video, by reinsertion with the course and speed dials, on repositioning with the track stick.

Mode 2. Automatic mode with the initial positioning of tracking channel by use of the track stick followed by automatic tracking based on radar video.

Mode 3: Manual rate-aided (coast) mode with initial course and speed inserted by dials in accordance with flight plan data and subsequent corrections made by use of the track stick or by use of the C/S dials.

Mode 4: Manual rate-aided (coast) mode with initial position and velocity of tracking channel and subsequent corrections made by use of the track stick.

TESTS

Test 1: Tracking Performance - Nonmaneuvering Targets.

Purpose.

The purpose of this test was to compare tracking performance with and without the flight plan data insertion devices (course and speed dials) with nonmaneuvering targets.

Duration and Number of Targets.

Eight runs of 15 minutes each, with 5 targets each run. Total: 2 hours - 40 targets.

Equipment.

Three tracking consoles and a supervisory console; 20 tracking channels.

Procedure.

1. One controller was assigned to each of the four consoles and instructed to track targets using only the one mode authorized for use at this console. Controllers were rotated through the four positions twice.

Supervisory Console	-	Mode 1
No. 1 Tracking Console	-	Mode 2
No. 2 Tracking Console	-	Mode 3
No. 3 Tracking Console	-	Mode 4

2. Input consisted of both live and simulated targets with targets initially spaced approximately 5 miles apart on a one-way airway. Tracking was commenced on a given signal with all operators tracking the same targets.

Test Conditions.

1. Eight runs of 5 targets each (40 targets presented simultaneously at 4 consoles).

2. Each run approximately 40 to 50 miles and approximately 15 minutes' duration.

3. FPS-8 radar - 10 rpm.

4. Four controllers rotated through 4 positions twice.

5. Problem started with 1 target with 4 additional targets added at approximately 1-minute intervals. Average target load over entire 15-minute period, 3.2 targets.

Results.

TABLE I

TRACKING NONMANEUVERING TARGETS

Workload and Accuracy Factors	Mode 1 Automatic with Course and Speed Inserts	Mode 2 Automatic	Mode 3 Coast with Course and Speed Inserts	Mode 4 Coast
A. Sequentially selecting channels to observe tag alignment with radar target.				
1. Total number of sequencing operations for 8 runs	552	500	799	608
2. Average of sequencing operations per run (5 targets - 1 operator).	69	62.5	99	76
3. Average number of times each tag and target reviewed (per operator).	21.6	19.5	30.9	23.8
4. Average time for one complete cycle through targets tracked (seconds).	41.6	46.2	29.1	37.8
B. Repositioning of tracking channel tag for alignment with target.				
1. Total number of repositions for 8 runs.	518	506	765	710

TABLE I (continued)

TRACKING NONMANEUVERING TARGETS

	Mode 1 Automatic with Course and Speed Inserts	Mode 2 Automatic	Mode 3 Coast with Course and Speed Inserts	Mode 4 Coast
Workload and Accuracy Factors				
2. Average number of repositions per run of 5 targets.	65	64	96	89
3. Average number of repositions per target(average 3.2 targets on display).	20.2	20.2	29.9	27.9
4. Average time between reposition operation(seconds),	13.9	14.2	9.4	10.1
C. Accuracy of tag alignment with radar targets.				
1. Total number of times the center of the radar target was outside of tag symbol (recorded as a miss)* for all 8 runs.	186	178	103	145
2. Total number target captures.	64	81		

TABLE I (continued)

TRACKING NONMANEUVERING TARGETS

Workload and Accuracy Factors	Mode 1 Automatic with Course and Speed Inserts	Mode 2 Automatic	Mode 3 Coast with Course and Speed Inserts	Mode 4 Coast
3. Average number of misses per run of 5 targets.	23.2	29.0	12.8	18.1
4. Average number of misses per target.	7.25	9.1	4.0	5.66
5. Average time interval between misses-all 40 targets (seconds).	38.7	31.0	70.3	49.7

*Captures were recorded for target misses in the automatic mode whenever other radar returns within the tracking channel gate resulted in unreliable tracking of the desired target and reidentification of the desired target was necessary.

Test 2: Tracking Performance - Maneuvering Targets with Clutter.

Purpose.

The purpose of this test was to compare tracking performance with and without the flight plan data insertion devices (course and speed dials) while tracking maneuvering targets through areas of video clutter and traffic congestion.

Duration and Number of Targets.

Four runs of 20 minutes each, 5 targets each run. Total: 1 hour 20 minutes - 20 targets.

Equipment.

Three tracking consoles and supervisory console.

Procedure.

1. One controller was assigned to each of the four consoles and instructed to track targets using only the one mode authorized for this use at his console. Controllers were rotated through the four positions once.

Supervisory Console	- Mode 1
No. 1 Tracking Console	- Mode 2
No. 2 Tracking Console	- Mode 3
No. 3 Tracking Console	- Mode 4

2. Target input consisted of both live and simulated targets. Targets were spaced approximately 5 miles apart initially, and tracking was commenced at a given signal with all operators tracking the same targets.

Test Conditions:

1. Four runs of 5 targets each (20 targets presented simultaneously at 4 consoles).

2. Each run approximately 40 to 50 miles and 20 minutes' duration.

3. FPS-8 radar - 10 rpm.

4. Four controllers rotated through 4 positions.

5. Problem started with one target with 4 additional targets added at approximately 1-minute intervals. Average target load over entire 20-minute period, 3.8 targets.

TABLE II

TRACKING MANEUVERING TARGETS WITH CLUTTER

Workload and Accuracy Factors	Mode 1 Automatic with Course and Speed Inserts	Mode 2 Automatic	Mode 3 Coast with Course and Speed Inserts	Mode 4 Coast
A. Sequentially selecting channels to observe tag alignment with radar target.				
1. Total number of sequencing operations for 4 runs.	727	588	789	894
2. Average number of sequencing operations per run (5 targets - 1 operator).	182	147	197	227

TABLE II (continued)

TRACKING MANEUVERING TARGETS WITH CLUTTER

	Mode 1 Automatic with Course and Speed Inserts	Mode 2 Automatic	Mode 3 Coast with Course and Speed Inserts	Mode 4 Coast
Workload and Accuracy Factors				
3. Average number of times each tag and target reviewed (per operator).	47.8	38.7	51.8	59.7
4. Average time for complete cycle through targets tracked (seconds).	25.1	31.0	23.1	20.1
B. Reposition of tracking channel tag for alignment with target.				
1. Total number of repositions for 4 runs.	612	459	575	726
2. Average number of repositions per run of 5 targets.	153	115	144	181
3. Average number of repositions per target (an average of 3.8 targets on display).	40.2	30.2	37.9	47.6
4. Average time between reposition operations (seconds).	7.8	10.4	8.3	6.6

TABLE II (continued)

TRACKING MANEUVERING TARGETS WITH CLUTTER

Workload and Accuracy Factors	Mode 1 Automatic with Course and Speed Inserts	Mode 2 Automatic	Mode 3 Coast with Course and Speed Inserts	Mode 4 Coast
C. Accuracy of tag alignment with radar targets.				
1. Total number of times the center of the radar target was outside of the tag symbol (recorded as a miss).*	87	104	38	74
2. Total number of target captures.	48	62		
3. Average number of misses per run of 5 targets.	22	26	9	18
4. Average number of misses per target.	5.79	6.84	2.36	4.73
5. Average time interval between misses-all 20 targets (seconds).	54.5	46.1	133.3	66.6

*Captures were recorded for target misses in the automatic mode whenever other radar returns within the tracking channel gate resulted in unreliable tracking of the desired target and reidentification of the desired target was necessary.

Test 3. Tracking Performance - High Loading.

Purpose.

The purpose of this test was to obtain data on workload and accuracy of tracking, with operator tracking 10 targets maximum and 17 targets maximum utilizing all operational features and modifications of the SRS-1.

Duration and Number of Targets.

Three runs of 21 minutes each. Total· 1 hour 3 minutes - 37 targets.

Equipment.

Supervisory console and one tracking console.

Procedure.

1. On the first two runs, two trackers were used simultaneously, one at the supervisory console and one at the tracking console. Each was instructed to perform the most reliable tracking possible for 10 targets during two runs. On the third test, one tracker was instructed to perform the most reliable tracking possible for 17 targets during one run.

2. The target input consisted of both actual and simulated aircraft targets.

3. Aircraft targets were spaced approximately 5 miles apart initially, and tracking was commenced on a given signal.

Test Conditions.

1. Four runs of 10 targets each, 10 targets presented simultaneously at 2 consoles, 1 run with 17 targets.

2. Each run approximately 40 to 50 miles' and 21 minutes' duration

3. FPS-8 radar - 10 rpm.

4. Two controllers for the 10 target runs and 1 controller for the 17 target runs.

5. Problem started with one target, with additional targets added at approximately 1/2-minute intervals. Average target load over entire 21-minute period was 7.6 targets for 10 target runs and 12.9 for 17 target runs.

Results.

TABLE III

TRACKING PERFORMANCE - HIGH LOADING

Workload and Accuracy Factors	4 Runs of 10 Targets Each 40 Targets Total	1 Run - 17 Targets
A. Sequentially selected channels to observe tag alignment with radar target.		
1. Total number of sequencing operations.	1438	394
2. Average number of sequencing operations per run.	384	394
3. Average number of times each tag and target reviewed (per operator).	50.5	30.5
4. Average time for one complete cycle through targets tracked (seconds).	24.9	41.3
B. Reposition of tracking channel tag for alignment with target.		
1. Total number of repositions.	564	156
2. Average number of repositions per run.	141	156
3. Average number of repositions per target (an average of 7.6 targets for 10 target runs and an average of 12.9 targets for 17 target runs on display.)	18.5	12.1
4. Average time between reposition operations (seconds).	8.9	8.0

TABLE III (continued)

TRACKING PERFORMANCE - HIGH LOADING

Workload and Accuracy Factors	4 Runs of 10 Targets Each 40 Targets Total	1 Run - 17 Targets
C. Accuracy of tag alignment with radar targets.		
1. Total number of times the center of the radar target was outside of the tag symbol (recorded as a miss).*	190	77
2. Total number of target captures.*	45	19
3. Average number of misses per run.	47.5	77
4. Average number of misses per target.	6.2	6.0
5. Average time interval between misses (seconds).	26.5	16.3

D. Trackers felt that they could track reliably up to ten aircraft simultaneously if these aircraft were within a localized area such as a normal size sector.

*Captures were recorded for target misses in the automatic mode whenever other radar returns within the tracking channel gate resulted in unreliable tracking of the desired target and reidentification of the desired target was necessary.

Test 4: - Handoffs.

Purpose.

The purpose of this test was to compare present radar handoff techniques with those possible with the SRS-1.

Duration and Number of Targets.

Three runs of 30 minutes each, 15 targets each run. Total: 1 hour 30 minutes - 45 targets.

Equipment.

Supervisory console and two tracking consoles.

Procedure.

A controller at the No. 1 tracking console acted as the radar departure position in an airport tower, and established tracking tags on simulated and actual targets. When tracking was established, using Mode 4 (coast), jurisdiction of the tracking channel was transferred to the supervisor's console which represented a departure control sector in the Center. This caused the remote dot at the supervisor's console to change to the C symbol. (Prior to this action, the tower controller would ask the Center controller for ARTC clearances on the flights and it was understood aircraft would depart from the airport in the sequence used for the clearance requests. Tracking channels were used in sequence). The "Center" controller then would check the new flight by depressing the channel number button associated with that flight strip to see if the leader terminated at the handoff target. Simultaneously, the tower controller described the aircraft position to the No. 2 tracking console also simulating a Center departure controller using standard verbal radar handoff phraseology When properly identified, the controller at the No. 2 tracking console acknowledged, and assumed control of the flight by establishing a new tracking channel on the proper target. Each "Center" controller was required to continue tracking a total of five other aircraft while receiving the designated radar handoffs to provide additional workload and realistic operational simulation of the handoff operation.

Measurements of elapsed time for verbal and nonverbal transfers began simultaneously. Timing ended for the verbal transfer when the receiving controller had positioned a tracking channel symbol on the correct target. In the case of automatic or nonverbal transfer, timing ended when the receiving controller observed the handoff and confirmed identity of the target by selecting the correct symbol on his display.

Results.

The average time for target transfers was 14.75 seconds using standard verbal coordination compared to 6.6 seconds using the SRS-1 special features without verbal coordination. The time required for handoffs without verbal coordination should be substantially less than that indicated when the operator is well acquainted with the procedure. During the last 20 minutes of the tests, the average time required never exceeded 4 seconds, the majority of which was used for confirmation action. No targets were lost or misidentified by either operator during the tests.

The action and time required to establish a tracking symbol on a radar target with verbal coordination was estimated to be approximately equal to that required for handoffs using plastic chips on a VG scope

Test 5: Tracking and Control Tests - Controller Only.

Purpose.

The purpose of this test was to evaluate the modified SRS-1 with a controller performing the tracking task as well as the traffic control functions.

Duration and Number of Targets.

Five runs, averaging 28 minutes in length. Average of 14 targets per run. Total: 2 hours 20 minutes - 70 targets.

Equipment.

Supervisor console and one tracking console.

Test Procedure.

Simulated targets following a programmed ATC problem were used for all runs with normal radar targets also displayed on the indicator. A controller at the No. 1 tracking console simulated a radar departure controller and initially, established a tracking channel on the simulated targets. The tracking channel then was transferred to a "Center" controller at the supervisor console without verbal coordination when the target reached the handoff area. Other simulated targets were introduced as crossing flights and were identified to the "Center" controller at the supervisor console by verbal handoff procedures. The "Center" controller then continued to track all aircraft in the sector, the departures climbing to cruising altitude and the crossing traffic using any tracking mode desired. He also was required to issue all necessary control instructions and maintain flight progress strips current alongside the radar display. The four test controllers were rotated through the "Center" control position, each run lasting approximately 28 minutes, with an average of 14 targets each run.

Results.

Runs 1 and 2 were conducted with a heavy traffic sample in an effort to determine the maximum capacity of a controller performing all functions of control and tracking. However, this was not possible with the number of target simulators available. Consequently, a limited sample control problem was used, starting with run 3 and continuing through the remainder of all the test 5 runs.

Based on the consensus of the controllers participating as subjects in the test and the observers, it is estimated that a controller normally should be able to simultaneously track and control up to eight aircraft by himself. In this arrangement, the controller is not dependent upon the tracking ability of another operator and therefore is fully aware of the quality of tracking upon which his control will be predicated. However, his attention must be divided between tracking and control, to the detriment of both. Controllers indicated a preference for the present system using VG radar indicators and transparent identification markers rather than the SRS-1 system tested, principally because the VG offered identification on the display surface.

Test 6. Tracking and Control with Local Tracking Assistance.

Purpose.

The purpose of this test was to evaluate the use of a tracker performing tracking, and a controller performing typical control functions, with the two-man team using the same display.

Duration and Number of Targets.

One run of 28 minutes - 14 targets. (Only one run performed due to the shortage of time and equipment maintenance problems.)

Equipment.

Supervisor console and one tracking console.

Procedures.

This test was similar to Test 5 except that a tracker performed all of the tracking functions with the controller performing all control, both men working from the same display.

Results.

The sample taken is extremely limited. Further evaluations of this type should be made before final opinions are reached; however, the consensus of subjects and observers was that when both the controller and tracker share a common display (tracking performed by assistant), a control capacity of 10 aircraft should be realized. This system relieves the controller of the confining tracking functions, but does congest the display area.

Test 7: Tracking and Control with Remote Tracker Assistance.

Purpose.

The purpose of this test was to evaluate the modified SRS-1 in a simulated air traffic control operation, with two or more trackers operating at consoles separate from the controller and performing all tracking functions, and the controller performing all control functions.

Duration and Number of Targets.

Three runs, averaging 14 targets per run. Average length - 25 minutes. Total: 1 hour 16 minutes - 43 targets.

Equipment.

Supervisor console and two tracker consoles.

Test Procedure.

The same control problem used in Tests 5 and 6 was used. The simulated tower departure controller transferred the tracking channel first to the "Center" controller at the supervisor console; he, in turn, after checking the new tracked target against his flight strip board for proper identity, transferred the target to the second tracker console where a tracking operator continued tracking this and all other "flights" under control through the sector. The controller issued all control instructions required in the problem. The controller's display had both the radar targets and the tag symbols visible so that he could observe the coincidence between radar target and tracking gate.

Results.

The sample taken was very small. Further evaluations should be made before final opinions are reached. The consensus of subjects (controllers and trackers) and observers indicated that a controller should be able to control 12 to 15 aircraft at a time when the tracking is performed at separate consoles. It was believed that the arrangement used, with the controller assuming control of all new targets initially and then transferring tracking responsibility to remote trackers, aided the controller in keeping current with the traffic situation. The controller's display console area was less congested than in Test 6, and he was relieved of the major part of target tracking. This allowed him more time to study the flight data board and to preplan control. The controller was able to identify any target being tracked by depressing the appropriate pushbutton channel selector alongside the flight progress strip and noting the display leader. The controller also could adjust his display of raw radar and filtered data to best advantage. The major question to be resolved in using a separate tracker is the reliability of tracking. In the short period of this test, fatigue problems were not observed. Situations undoubtedly could develop where the tracker doing a routine job might fail to remain alert and, in turn, track the wrong target. The controller under this condition might base control actions on improperly identified targets. This test was not long enough, or broad enough in scope, to arrive at definite conclusions to this question.

DISCUSSION OF OPERATIONAL TESTS AND RESULTS

A definite operational requirement exists for an improved method of maintaining the identity of radar targets, since reidentification requires additional time and is a distracting effort for the controller. An efficient system to accomplish this would facilitate all aspects of radar control, particularly handoffs between facilities.

The design philosophy represented by the SRS-1 is one approach that may satisfy this requirement. Visual tracking symbols assigned to specific targets are displayed on the radar indicator. This eliminates the need for a horizontal plotting radar display required for static identification markers or chips, which must be repositioned manually on appropriate targets. Although the present SRS-1 indicators display only a tracking symbol which requires correlation with a flight data board, they could be modified to display alpha-numeric flight plan data with a radar target. The SRS-1 system also converts tracked radar position and velocity into electrical form which will be necessary for data processing computers in future automation.

All concerned believed that reliable but limited radar control could be accomplished with the present SRS-1, however, most felt that in any immediate application, the equipment in its present status would offer no over-all operational advantage over the present system using VG indicators.

Most of the personnel did not feel that the SRS-1 tag was any improvement over the use of "shrimp boat" markers or plastic chips. They objected to the extensive cross-checking required to correlate channel symbols with flight progress board data. They also objected to the lack of target trail compared to that available on VG indicators and they preferred the brighter VG displays.

The test participants were asked to list any additional modifications they would desire if the SRS-1 or similar tracking devices were to be applied to air traffic control. Their recommendations are as follows:

1. Rearrange or modify channel selectors, flight strip board, and channel availability indicators to aid data correlation.

2. Remove two of the course read-in dials from each console.

3. Terminate the leader closer to the tracking symbols.

4. Modify sequencing controls to provide forward and reverse sequencing order.

5. Present the tracking gate boundaries on the display when in automatic mode.

6. Add a lighted dial to the rotary channel selector.

7. Incorporate an acknowledgement system for radar handoffs or similar operations.

8. Provide a trigger switch on the track stick to be used in lieu of the present selector button for new channels. Additional switches might also be located on the track stick similar to the electric trim tab controls on fighter aircraft.

9. Utilize scan-conversion to provide a bright control display with target trail in lieu of standard P-7 phosphor PPI's.

10. Modify the SRS-1 to present alpha-numeric flight plan information on the same scope with the radar targets and selectivity controls to reduce the alpha-numeric data to the minimum required for the operation. Retain mode symbol to indicate automatic or coast mode if both are available in the ultimate system.

During these tests it was noted that the operators exerted considerable effort when tracking five or more targets simultaneously. It appeared possible that the operators actually were working against the machine by constantly making fine position and velocity corrections to the tracking symbol, instead of allowing the tracking channel to stabilize and make some consistent computations. Operators especially were prone to reposition tags as soon as there was any indication that the tag was leaving the target. On the other hand, it was felt that position and velocity drift errors, coupled with other system inaccuracies, may have necessitated the excessive number of operator corrections.

Following the operational tests, a study was conducted to determine the SRS-1 velocity drift characteristics and how machine error might effect the manual rate-aided tracking mode. The study was based on the allowable specified drift per channel and on actual measurements of tracking channel memory. Whereas relatively long-term position prediction accuracy is an important operational requirement in an ATC display system, in the military application for which the SRS-1 was designed this was not an important requirement. Figure 3 indicates the possible SRS-1 symbol displacement due to storage drift when targets are tracked in the coast mode without operator intervention. The error due to drift in velocity and position storage obviously is not acceptable in an ATC application. After discussing this drift problem with SRS-1 design engineers, it was indicated that the drift could be reduced to approximately 5 per cent of its present value by certain modifications. Even smaller dirft is considered possible by using basically different design concepts. Figure 4 indicates the anticipated effect of modifying the SRS-1 to reduce velocity drift only.

CONCLUSIONS

The following conclusions are based on recordings, observations, and subjective opinions of the personnel who participated in the tests. Soon after the test program began, it become obvious that insufficient time had been allotted to personnel familiarization and thorough testing. The lack of thorough training undoubtedly influences the following conclusions, which therefore should be accepted with reservations.

1. Automatic tracking faces definite limitations in congested traffic areas or in the presence of precipitation, ground clutter, or radar interference. In Tests 1, 2, and 3, it can be seen that target captures and tracking failures in automatic modes were so prevalent that constant tracker attention was required to prevent loss of target identity. As long as manual attention is required continuously, it is concluded that expensive automatic circuits operating on present-day radar data are not justified.

2. In the SRS-1 system, channel velocity drift was so excessive that the task of manual tracking was unnecessarily difficult. An engineering analysis indicates this drift can be reduced 95 per cent. Most of the benefits of course and speed inserts were masked by this drift. From Tests 1 and 2 and the engineering analysis, it is concluded that, manual tracking designed specifically for ATC applications, with course and speed inserts, appears to be the best ATC tracking mode.

3. From Test 3, it is concluded that an average tracker could track reliably up to ten aircraft simultaneously.if these aircraft were within a localized area such as a normal-size sector. With improved channel reliability (see item 2), this number probably can be increased.

4. From the data and subjective opinions of Test 4, it is concluded that electronic circuits, such as in the SRS-1, which provide a visual display of the location of an aircraft being handed off, is far superior to verbal techniques now being used. This method also lessens the danger of misidentification.

5. From the subjective opinions of Test 5, it is concluded that one operator, doing his own tracking and controlling, could handle eight aircraft simultaneously. The safety in handling eight, or even more, aircraft could be improved by more convenient association of tracking channels and flight progress strips. An improvement in safety, and perhaps in volume, also can be expected from better operator training (see item 1) and more stable tracking channels (see item 3).

6. A significant conclusion of Test 5 is the operator preference for the VG-type display now in use at radar centers. This preference is due to the increased target trail, display brightness, and the direct association of alpha-numeric and radar data on the VG It therefore is concluded that these three features are required in future display systems whether they do or do not have the other SRS-1 features.

7. Tests 6 and 7 were the last tests performed, and sufficient time was not available to obtain conclusive data. The consensus of operators and observers is that a controller and a tracker using the same display could handle ten aircraft simultaneously, and a controller with two or more remote trackers using separate consoles could handle 12 or 15 aircraft simultaneously. The conclusions based on these tests, however, should not be considered firm.

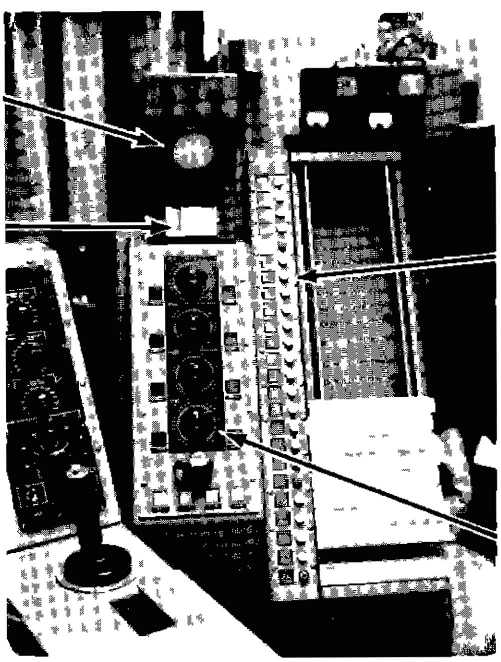
RECOMMENDATIONS

It is recommended that a much more elaborate evaluation program be planned for a further SRS-1 test. The basic equipment should be modified to provide much better track channel stability. The displays should be scan-converted to provide trail and higher brightness. Alpha-numeric data should be added to the display itself, and more convenient association of track channel and flight progress strips also should be provided. The next tests should be preceded by several weeks of personnel familiarization so that the learning factor does not influence the result. The test program itself should last five weeks or more to provide samples from which positive conclusions and recommendations can be made. Consulting services of qualified persons should be employed to assist in test planning and data collection to insure that the results obtained are statistically valid.

FIG 1 SUPERVISORY CONSOLE

COURSE READOUT

SPEED READOUT



CHANNEL SELECTION

COURSE AND SPEED INSERT

FIG 2 SUPERVISORY CONSOLE ADDITIONS

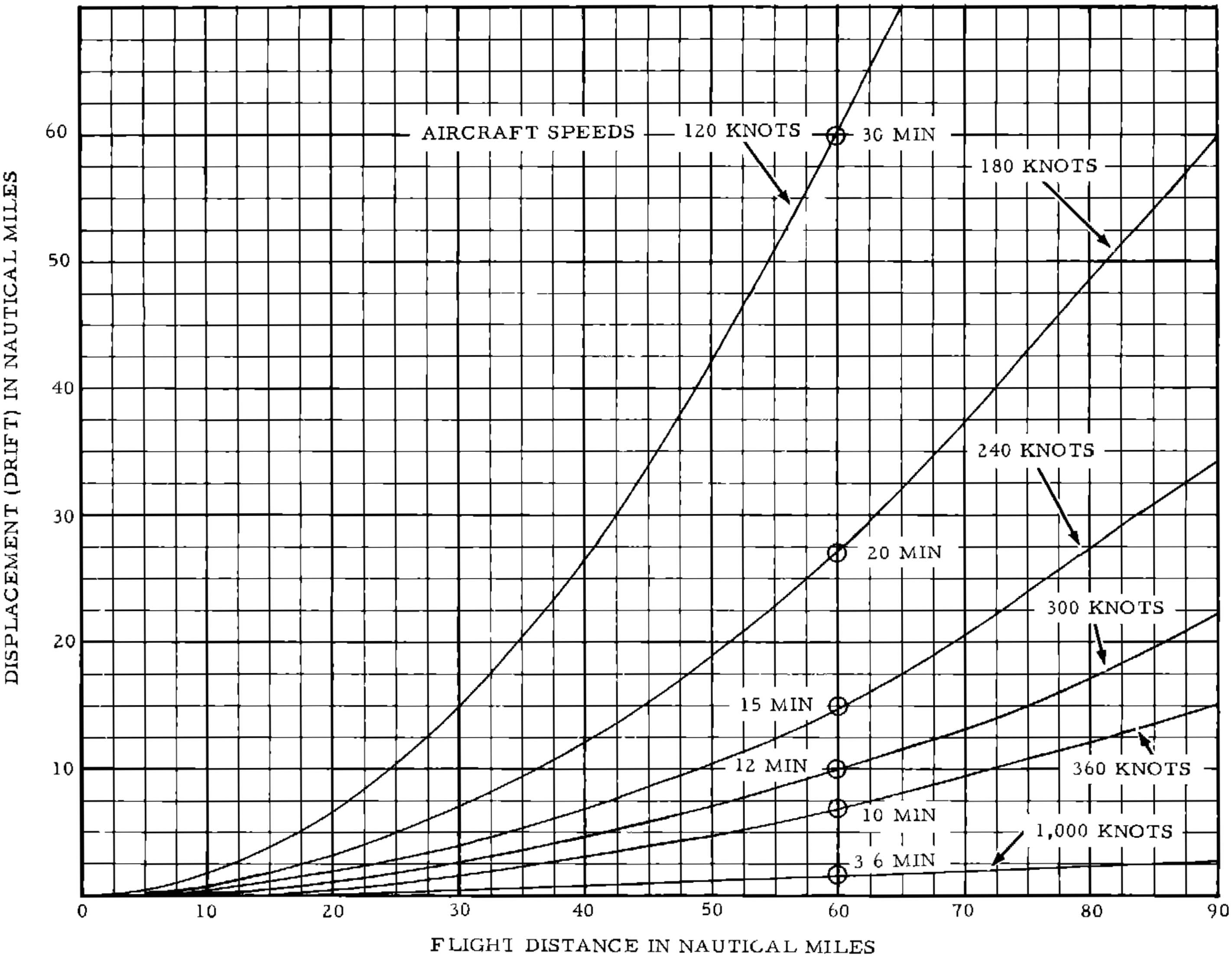


FIG 3 POSSIBLE TAG DISPLACEMENT DUE TO STORAGE DRIFT

WITHOUT OPERATOR INTERVENTION

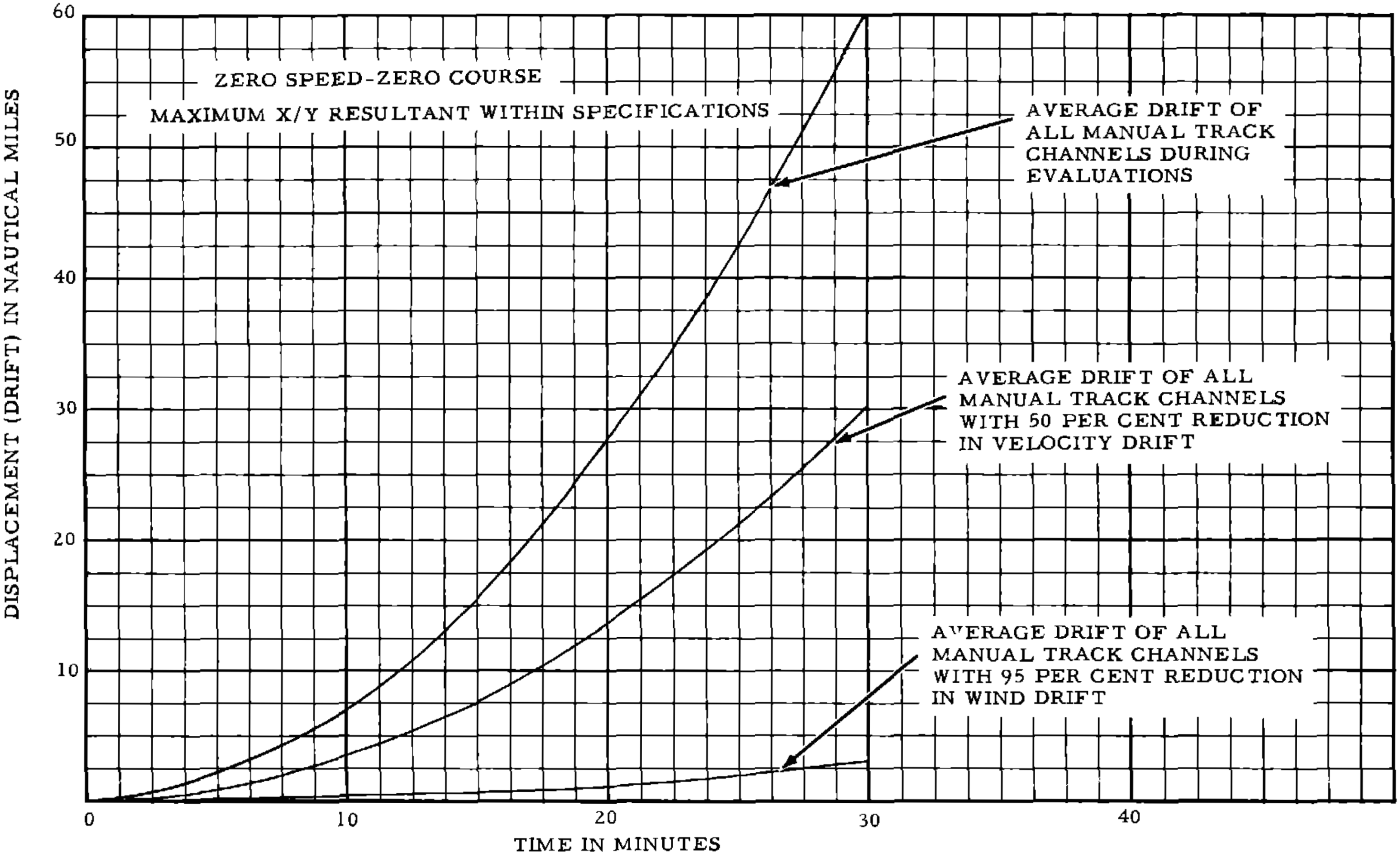


FIG 4 PRESENT TAG DISPLACEMENT AND PREDICTED DISPLACEMENT WITH REDUCED VELOCITY DRIFT WITHOUT OPERATOR INTERVENTION