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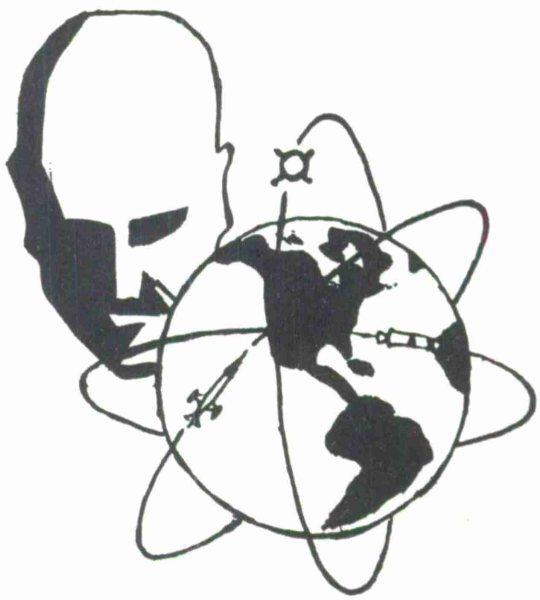
FUNCTIONAL CHARACTERISTICS OF A PROFICIENCY FACILITY FOR THE AN/TSQ-47 SYSTEM

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-179

DECEMBER 1963

Allen C. Busch
Robert B. King
Joanne F. Fitzgerald

431L/482L SYSTEMS PROGRAM OFFICE
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts



System 482L

(Prepared under Contract No. AF 19 (628)-439 by HRB-Singer, Incorporated, State College, Pennsylvania.)

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ABSTRACT

The AN/TSQ-47 specifically and the Emergency Mission Support program in general are establishing the requirements for ATC systems which will handle increasing traffic rates. The nature of mobile operations is such that there are vast separations in time and geographical locations for the use of this equipment. With these increasing demands on personnel and equipment new concepts in training are needed. This report presents the need for the functional description of, and the operational use of a sophisticated proficiency facility. This proficiency facility is essentially comprised of aircraft target generators, a flight path projection computer, simulated communications equipment, simulated tower position, and other auxiliary equipments. This facility in conjunction with an AN/TSW-5 Rapcon shelter is capable of simulating and quantitatively measuring a broad category of terminal ATC operations.

REVIEW AND APPROVAL

This technical documentary report has been reviewed and is approved.

B. F. GREEN, JR.
Chief, Technical Support Division

FOREWORD

This technical documentary report is HRB-Singer report No. 353-R-5. It constitutes the fifth in a series of reports resulting from HRB-Singer's human factors efforts on Contract No. AF 19(628)-439, in support of the AN/TSQ-47 Air Traffic Control/Communications System.

This work was performed for the 431L/482L Systems Program Office, Electronic Systems Division, United States Air Force. Actual effort was carried out at Fort Dawes, Winthrop, Massachusetts.

KEY WORD LIST

1. Communication Systems
2. Control Systems
3. Air Traffic
4. Radar
5. Design
6. Simulation
7. Training Devices
8. Models
9. Human Engineering

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

SECTION 1

INTRODUCTION

The performance of the human operator directly affects the effective, successful operation of today's complex man-machine systems. Terminal air traffic control systems such as the AN/TSQ-47 Mobile Air Traffic Control/ Communications System involve a myriad of human tasks and skills. Radar control operations include motor tasks, perceptual skills, and cognitive processes. Operators are required to retain these skills through periods of relatively low activity and apply them at peak efficiency during periods of high system load or emergencies. Control operations are further complicated by the fact that specific tasks involve several different skills. The tasks of predicting future locations of aircraft under control of the system includes all the sensory, motor, and perceptual skills of reading and interpreting the displayed radar data as well as the cognitive skills of memory, abstract and analytical reasoning, and recall of past experiences and procedures. Also, for a complex system to perform effectively, operators must understand the relationships of his tasks to the functioning of the system, and must possess the skills necessary for effective team interaction with other operators in the system.

Underlying the performance of the human element in a system is a complex of training programs and devices. The goals of individual training and of team training both produce demands for training devices. The designer of such devices must have an appreciation for systems in general and be intimately familiar with the particular system for which he is designing the training equipment. An understanding of the system mission, system performance requirements, operator procedures and the system environment as well as an intimate knowledge of the task requirements of the operator positions is necessary before decisions can be made about what skills must be trained, to what level, and by that techniques. Decisions must also be made as to what system characteristics need to be simulated and with what degree of realism; where simulated inputs should and can be introduced into the system; where performance can be observed and recorded; and what feedback of results is necessary.

As part of its Emergency Mission Support Program (EMS) the Air Force is increasing its requirements to handle higher rates of traffic in mobile air traffic control system operations. Along with this updating of the EMS traffic handling capability comes the requirement for updating operator training capability. More sophisticated training programs and simulation equipments are needed to enable the human operator of these new systems to function effectively.

This report deals with the establishment of the functional characteristics for the design of a proficiency facility to provide squadron level training for the radar and manual air traffic control portion of the AN/TSQ-47 system. This system is a mobile air traffic control system, having among its capabilities such things as airport surveillance radar (ASR), precision approach radar (PAR), long range, point-to-point communications, VFR tower control, air-ground-air communications, and TACAN navigation. The system is designed to be commensurate with the required quick-reaction capability of today's Air Force. It is intended for operation in world-wide climatic extremes under all weather conditions. It is fully air transportable, and designed for minimum set-up and take-down time.

In situations where a more complex man-machine system is replacing one already in existance, the new system must be given careful scrutiny in terms of the training requirements necessary to insure effective human performance. The new system may require new and different skills and hence new training programs and devices will be necessary. Such is the case with the system in question. The TSQ-47 is replacing a mobile air traffic control system currently in use by the air force. The current system is being outmoded for several reasons. It is too bulky and cumbersome for aerial deployment, its electronic components are becoming obsolete, and it lacks communications and traffic handling capacity.

In terms of system purpose or mission these two systems are quite similar. In terms of the means of achieving this mission and mode of operation, however, they are quite different. All aircraft handling in the basic current system is accomplished through the use of direction finders, beacon transponders, and radio coordination and reporting between the aircraft and the ground. GCA radar equipment is available, but is considered supplementary to the system and has not been used on operational deployments.

The heart of the TSQ-47 system is its radar control capability. Radar control will be conducted from a nine-operator radar approach control facility (RAPCON). Designated the AN/TSW-5, this IFR facility is fed radar data from separate ASR and PAR radar subsystems, and is supplied with UHF/VHF air-ground-air radio capability from a separate communications annex shelter. The IFR control facility contains one horizontal and three vertical 22-inch PPI displays, and two 14-inch AZ-EL displays. Controllers in this facility include one pick-up controller, two approach controllers, two departure controllers, two final controllers, one feeder, and one coordinator. Control coordination is conducted in a conference arrangement.

Operator performance in this facility is of prime concern. Control operations conducted from the AN/TSW-5 contain all the tasks and require all the operator skills of fixed radar control facilities. These general demands of air traffic control operation require not only that individual proficiency be established and maintained, but that operators work together effectively as a team. Also, much of their training must be directed toward the handling of emergency situations which do not occur under normal conditions, but which require peak performance when they do occur. The fact that the AN/TSW-5 contains certain new equipment and is a mobile facility compounds the problems of achieving and maintaining controller proficiency. Inherent in its operation are the following factors:

1. Controllers entering mobile squadron operations though experienced controllers have not had experience in mobile facility operations.
2. The AN/TSW-5 requires different modes of operation than are found in most fixed facilities and existing mobile facilities.
3. On deployment days, weeks, or even months may result with little or no traffic activity. These periods may be followed by a period of high traffic load and emergencies as in the return of a strike force.
4. Long periods of inactivity may occur between deployments. These times may vary from a few weeks to a year or more.
5. Mobile operation involves rapid changes in the operational environment. Every deployment means changes in the topography, landmarks, winds, air routes, etc.

The following section of this report presents a discussion of some operator training considerations and offers some considerations which influence the functional design of a system proficiency facility. Sections 3 and 4 present a functional description of the major equipments proposed for a proficiency facility and a detailed description of the operational use of the facility and its equipments, in that order. Section 4 also relates the operational use of the equipments with human learning principles. The last section presents conclusions and recommendations.

SECTION 2. OPERATOR CONSIDERATIONS

A. TASK DESCRIPTION

A complete description of required tasks, and the expansion of this description, tasks analysis, is the foundation for personnel subsystem development in a system. Task description and analysis provides a common reference for all the design and operating decisions and activities that are associated with the human component in the system. Operator training constitutes an integral and vital element of the personnel subsystem complex, and task descriptions are relied upon to provide the substance for the content of training, and to suggest the form and sequencing of required training.

Very little is known about the task criticalities, or the sensory, motor and perceptual skills involved in aircraft control operations conducted from the AN/TSW-5 IFR Facility, or, for that matter, from any air traffic control facility. Of the volumes of literature concerning the design and personnel subsystem operation of the system in point, a thorough task analysis has never been promulgated or completed. This is unfortunate indeed, because it places upon the training equipment designer the burden of establishing supposedly optimum training methods to insure proficiency on tasks known only by gross generalities.

B. CONSIDERATIONS OF HUMAN FUNCTIONS

It is possible to approach the training problem in terms of the human functions involved in a system. These functions are broad in nature, but are present in most if not all operator tasks. Taylor conceives of the role of the human operator in a system as a data transmission and processing link inserted between the displays and controls of a machine.[1] This conception is represented as follows:

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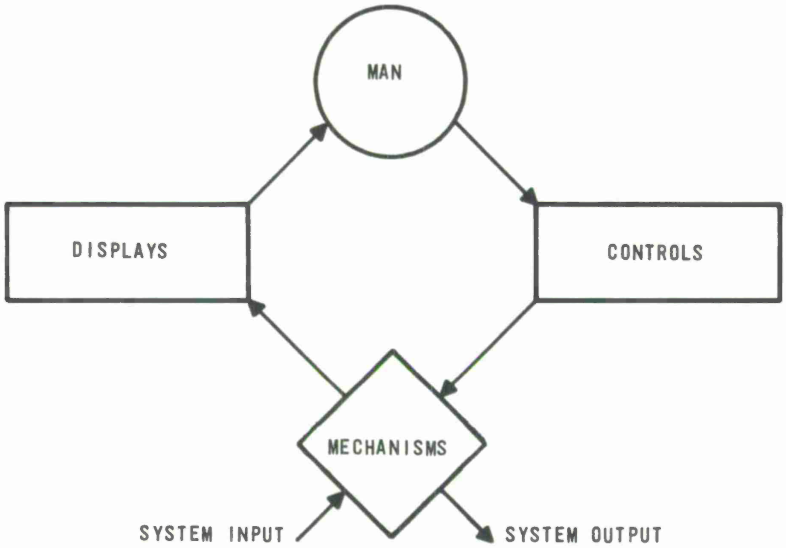
[1] Taylor, F. V., "Psychology and the design of machines:" American Psychologist, 12, 1957: 249-258.

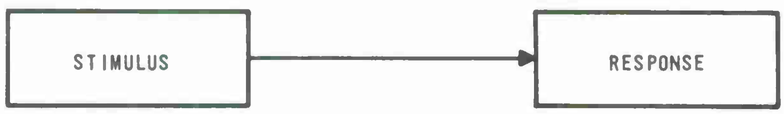


In this configuration, a system input, such as a radar signal, is transformed through certain mechanisms into a displayed signal. This signal serves as an information carrying stimulus, and it is sensed by the human operator and transformed into a response. A similar case occurs when an unidentified blip appears on a radar screen and the operator initiates action to interrogate the course of the signal and begins any necessary rerouting of aircraft in potential conflict. The response of the operator usually involves some form of control manipulation, or in our air traffic control analogy, a manipulation of the aircraft and data associated with his control situation. This manipulation passes through some system mechanisms and is transformed into system outputs which, in our case, would probably take the form of a path change of several aircraft in the control area. In a closed-loop system, such as an air traffic control system, this output becomes evidenced in the displays.

Taylor's generalization, while it indicates man's position as a system component, does not convey information which would be sufficient for a detailed analysis of the variety of human functions which take place in this transformation of a system input to a system output. There are many different types of transformations which may take place and which involve the human nervous system. In order to examine the functions of the human operator, we must look at the inputs and outputs of the operator alone, and the internal mechanisms which change an input into an appropriate output.

1. The Nature of Human Functions

All students of psychology are familiar with the learning paradigm below:

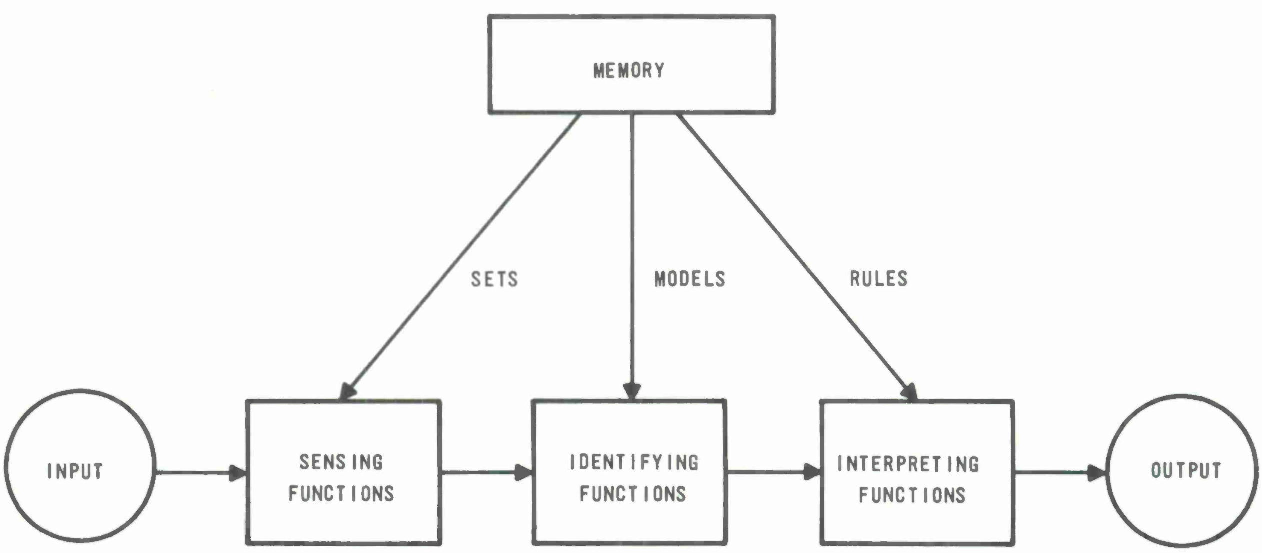


This diagram shows the concept that an organism will elicit some form of behavior in response to a perceived stimulus. The form the behavior will take depends upon the nature of the stimulus and the way the organism perceives the stimulus. The organism's perception of the stimulus is a function of the experience and training it has received in relation to the stimulus. Some behavior may be purely reflexive, such as the response of an eye blink when a puff of air is directed towards the eye. Certainly no training is involved in such a response. The eye blink response can be conditioned, however, to occur in the presence of a stimulus which would normally not produce such a response. This is trained behavior. The organism is trained to perceive such a stimulus as a bell or a light in the same way that he perceives the air puff. The behavior is still a reflex, but it is a <u>learned</u> reflex. Training has not influenced the form of the behavior (it is still instinctive or reflexive), but it has changed the organism's perception of the stimulus. The tone of the bell is perceived as a "danger signal," a threat to the eyes, and the organism behaves accordingly. Such a conceptualization of learned behavior is quite adequate to explain reflexive behavior in humans and most of the behavior of animals.

Human beings are "thinking" organisms. Their behavior capacity extends far beyond the reflex or instinctive stage. Complex "thinking" behavior requires training of a more sophisticated nature for achieving desired performance on a task. An individual has to be trained to perceive the stimulus and, because most behavior is beyond the reflexive level, he must attach meaning to the stimulus.

The appropriate response must also be learned if the behavior is to be more than a reflex. The human skills of thought and memory play a complex and vital role in learned behavior, and as a result such behavior and the learning processes involved do not readily lend themselves to analysis. It is difficult to talk about simple stimuli and the responses to these stimuli in a complex situation because these elements cannot be isolated. Even if they could be distinguished, they would be difficult to study because the process occurring between the stimulus and the response is not known. Certainly it is not a reflex. These problems are resolved to some extent by viewing behavior in terms of gross generalities. For example, an entire environmental situation may be referred to as a stimulus and any observed behavior as the response to this stimulus.

When the organism to be studied is a human operator in a system, it is more meaningful to refer to a stimulus situation as an input to the human system element, and the response as an output. An input may be comprised of many different stimuli and bits of information, all interacting and all requiring consideration. It may consist of only a minute change in a display of information which, if unobserved, and unacted upon, would have disastrous effects upon the system operation. Such would be the case in a change in the course of a radar displayed aircraft and a resulting impending mid-air collision.



a. Sensing

Sensing functions primarily concern the sensory processes of vision and audition. Sensing requires a difference or change in some form of physical energy associated with the display or environment. Gagne[2] reports that experiments with trained versus untrained observers show that a trained observer does not "sense" better because of his previous training, but he does "attend" to a specific set of conditions, and thus is able to report extremely small differences in the stimulus environment with a high degree of probability. The implication is that certain observational routines may be acquired and stored in long-term memory and that these may facilitate the necessary filtering.

b. Identifying

Identifying is considered to be a much more important system function than sensing, because of dependence on training. In more traditional psychological language this is the function of perception. Long term memory or retention is a crucial aspect of identification.

A sensed stimulus is compared with stored mental "models" to establish its identity. These models are provided by long term retention and are chiefly acquired according to Gagne by a process of learning. The models serve to act as standards against which display inputs are compared, and then identified. For example, if an air traffic control operator had never seen a radar screen display of converging aircraft, he might not be able to identify such a situation when it would be presented. He would have nothing to compare it with, i. e., no model.

c. Interpretation

This is probably the most important function performed by the human operator in a system. Interpretation is the identification of the meaning of inputs. When interpreting is done in sequence, it constitutes decision-making and the appropriate action is taken, or initiated. An individual interprets an identified display situation as an "emergency." The individual classifies the perceived stimulus in terms of its effect, rather than in terms of its appearance, as in identification. According to Gagne, then, interpreting involves a choice among "courses of action." Long term memory, therefore, is vital. Memory,

[2]Gagne, R. M., Psychological Principles in System Development. Holt, Rinehart and Winston, New York, 1962.

in this case, provides the rules and the procedures that determine the course of action. These rules and procedures are established and retained through learning or training.

2. Course of Action

Certainly, the picture of the input - output function is not complete without considering the long term memory influence upon the carrying out of a course of action. Once a course of action is selected, via the interpretation process, every step in this course of action is also a function of long term memory. In Air Traffic control operations, the course of action must be carried out with the utmost precision and efficiency. The various steps involved in carrying out such a course of action are subject to reinterpretation and new stimuli may constantly emerge which will involve new identification, new interpretation and new discussions.

3. Implication

Obviously, the human functions in a system have immediate implications for training and the establishment of proficiency. In sensing, training must establish the "sets" for the sensory filtering processes. The goal here is to produce the "trained observer." In identification, training must provide the models required for this function. In interpretation, training must provide the procedural rules needed for the decision-making process. Finally, training must provide the procedural steps used in the course of action.

In proficiency training for air traffic control operations, procedural rules, and the steps used in the various courses of action are of prime concern. Because of their very nature, their establishment requires that the training situation be as realistic, or as similar to the actual operating situation as possible. This is necessary to maximize positive transfer from the learning situation to the operational situation, and it cannot be emphasized enough. Another advantage to realistic simulation would be the minimization of interference possibly produced by the training situation.

In a system such as the AN/TSQ-47, the most realistic training would be the use of live aircraft and to actually train in an operational situation. Unfortunately, this is not practical due to the high cost and logistics problems involved. Simulation can be used to best advantage in this situation since it will considerably reduce the cost and logistics problems. Care must be taken, however, to maintain a high degree of realism. The problems involved in this consideration will be examined in the next subsection.

C. SIMULATION CONSIDERATIONS

Simulation can serve to integrate the various operational concepts and skills into a complex job situation. Through its use the operator can develop and maintain proficiency both in his individual job situation and team performance. It was suggested in the previous subsection, that it is highly desirable to have the training situation be as identical to the operation situation as possible. Some of the considerations relative to this approach are discussed, then, in this section.

1. Transfer of Training

Transfer of training refers to learning being transferred from one task, referred to as the original learning task, to a second task, termed the transfer learning task. In our case, it would mean the transfer of skills and abilities learned in the simulated air traffic control situation to the live operational situation. Many transfer theories have been formulated in learning psychology. Three of the most applicable to the tasks in question in this study, deserve discussion here.

For the most part, transfer of training is determined by the differences between the stimuli or responses (or both) of the two tasks. Wylie[3] formulated one of the earliest theories of transfer. Simply stated his laws are as follows:

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[3] Woodworth, R.S., Experimental Psychology: Henry Holt, New York 1938, 201-204.

Law I: Transfer effect will be positive when an old response (acquired during original learning) is transferred to a new stimulus.

Law II: Transfer effect will be negative when a new response is learned to an old stimulus.

The implications of these laws for the design of training equipment is that there should be as much similarity as possible between the training device and the operational equipment, in terms of response elements, but that some variation in the stimulus elements may be permitted.

Osgood's[4] theory of transfer is more recent and although it is essentially similar to Wylie's, it adds one important consideration. Osgood viewed the transfer effect as continuously varying with similarity, i.e., as similarity of the two tasks would vary from high to low, the amount of transfer would vary, correspondingly. He felt that maximum positive transfer would occur when the stimuli and responses are both identical and that maximum negative transfer would occur when the stimuli are identical, but the responses are antagonistic. Osgood also specified the hypothetical situation, where zero transfer would be expected to occur: when the stimuli are neutral to each other, regardless of the response relationship.

The implication of Osgood's theory to the design of a training device is this: It would be very desirable to have the closest possible similarity between the simulation tasks and the operational tasks.

Although they used a slightly different approach, Gagne, Baker, and Foster's[5] conclusions were much the same as Osgood's. These investigators

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[4] Osgood, C. E. "The similarity paradox in human learning: a resolution," Psychological Review, Vol. 56, 1956, 132-143.

[5] Gagne, R. M., Baker, Katherine E., and Foster, Harriet. "On the relation between similarity and transfer of training in the learning of discrimination motor tasks." USN, Office of Naval Research, Special Devices Central Technical Report SDC, 316-1-5, 1949.

formulated a theory of transfer involving not only the relationships of stimuli and responses between training tasks, but also within training tasks. A stimulus in a particular task may elicit several responses, all bearing a certain relationship to each other. According to Gagne, Baker and Foster, these intertasks relationships should be similar in both the training tasks and the operational tasks for maximum positive transfer to occur. As a result of their theory, the authors have formulated a very important implication for design of training devices:"The more similar are the essential stimulus and response aspects of a training device to those of an actual task, the higher will be the transfer which results from training with the use of this device."

These authors also go on to state that "greater positive transfer will result if the training task is more difficult than the operational task." Recent experiments have shown that the relative difference in difficulty between the two tasks is indeed a dimension requiring consideration. It is controversial as to its effects, however, and further work will have to be done in this area.

2. Retention and Retroactive Inhibition

Retention and forgetting are two terms referring to the persistence of learned modifications of behavior. Retention and forgetting have long been of interest in psychology and the variables involved are still somewhat controversial. Sometimes even well-learned and established material is forgotten, and seemingly insignificant items are retained for long periods of time. For some years now psychologists have viewed the problem from the standpoint of positive retention, i. e., under what conditions is material remembered, and under what conditions is it less well remembered. There is reason to believe, however, that the study of why learned material is forgotten is a more fruitful mode of attack and one which leads to more meaningful explanations.

Current thinking stresses that forgetting does not occur passively with time, but is a function of what happens in time. McGeoch[6] states that getting "a little rusty" in a learned skill involves an active process of some kind.

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[6] McGeoch, J.A. 1942. The Psychology of Human Learning. New York: Longmans, Green.

He draws an analogy from the chemical world in that even a little rust will not accumulate by itself, but is an active oxidizing process.

In learning, this "active process" which occurs in time and is said to be responsible for forgetting is called retroactive inhibition. It is inhibition in the sense that learned responses are being inhibited, and it is retroactive in the sense that the response or behavior was learned prior to the time of the inhibition. Retroactive inhibition is itself a learning process in the sense that new responses and new learned behavior inhibits previously learned responses in similar situations. Why then is some learned behavior forgotten and some remembered? Chiefly, this is due to the nature of the material learned, the extent of the learning, and the nature of the intervening learning activities occurring between the time the original learning takes place and the person is tested for retention of the material. The effect of retroactive inhibition can be demonstrated by the following experimental design:

Original learning task	Measured proficiency on original learning task	Intervening learning task	Measured proficiency on original learning task
Group 1(Task A)	High proficiency	Task A	High proficiency
Group 2(Task A)	High proficiency	Task B	Low proficiency
Group 3(Task A)	High proficiency	Task C	Medium proficiency

Assuming equal abilities between the groups and equal proficiency on the original task the difference in proficiency as measured at the end can be assumed to be a function of the different intervening tasks, all other variables being equal. Why then did loss of proficiency or forgetting occur for the group learning intervening task B?

Learning theorists say the degree of inhibitory effect or forgetting is a function of the degree of similarity between the intervening learning and the original learning. Robinson[7], using experimental results obtained

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[7] Robinson, E.S. The "similarity" factor in retroaction. American Journal of Psychology 1927, 39, 297-312.

by himself and by Skaggs[8], states this relationship in the Skaggs-Robinson hypothesis. Essentially this hypothesis states that maximum retention of the original learning occurs when the intervening task is nearly identical to the original task. Retention decreases as the intervening task becomes less similar to the original task, but rises again when the intervening task becomes very dissimilar. This relationship is illustrated in Figure 1 below:

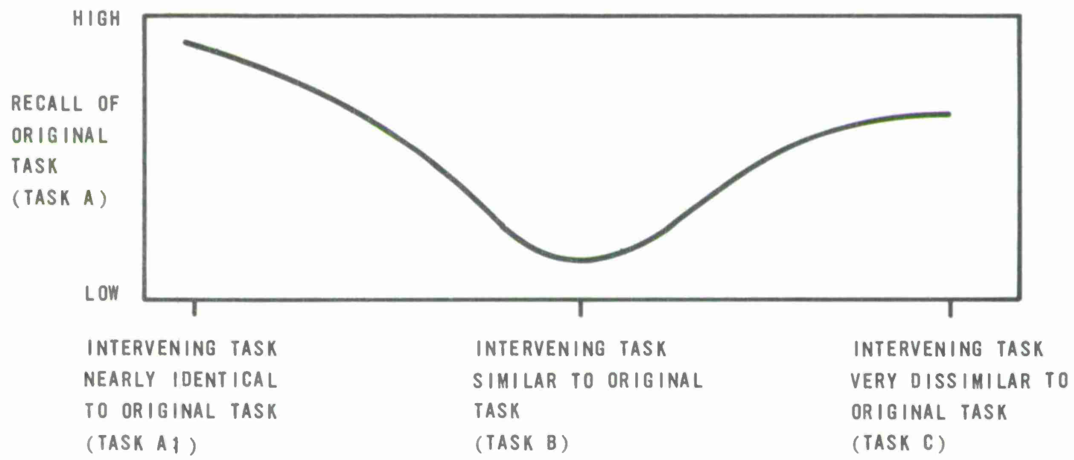

FIG. 1 - THE DEGREE OF SIMILARITY BETWEEN INTERVENING TASK AND ORIGINAL LEARNING TASK

Note that the final rise of recall (when the two tasks are very dissimilar) never attains the height of the peak when the tasks are nearly identical.

Osgood[9] has formulated an hypothesis which is generally similar to that of Robinson. Osgood, however, expands the relationship into similarity of stimulus and response elements between the two tasks. In this interpretation retention is maximum when both the stimuli and responses are nearly identical between the tasks, and is minimum when the stimuli are the same and the responses are dissimilar. Retention increases again when both the stimuli and the responses are very dissimilar between the tasks.

[8] Skaggs, E. B. Further studies in retroactive inhibition. Psychol. Monogr. 1925, 34, No. 161.

[9] Osgood, C. E. The similarity paradox in human learning: a resolution. Psychological Review, 1949, 56, 132-143.

The implications of retroactive inhibition in mobile air traffic control operator training concerns the degree of similarity between previously learned principal air traffic tasks and the training tasks learned through simulation in the proficiency facility. It is highly desirable to maximize operator performance in an operational deployment situation. Optimal performance primarily requires high proficiency in the principal tasks of air traffic control, and secondarily in those aspects of air traffic control characteristic of a particular deployment situation. The principal tasks of air traffic control are common to all air traffic control situations and include such things as the general problems of maintaining separation, prediction future aircraft positions, giving landing clearances, etc. This being the case, training for proficiency in these principal tasks should insure tasks having identical stimulus-response properties with those of previous training. Individuals receiving training and proficiency in the AN/TSQ-47 proficiency facility will have had previous training in the principal air traffic control tasks from Air Training Command and from previous operational deployments. Training in the system proficiency facility then represents an intervening activity, with the next operational deployment being the final test of retention. It is essential, therefore, that principal air traffic control training tasks in the proficiency facility be identical or nearly identical in stimulus/response elements with the tasks in all previous training situations and on operational deployments.

The secondary aspects of operator proficiency in an operational deployment situation change from deployment to deployment. These include such things as topographical knowledge, knowledge of air traffic routes, prevailing winds, etc. It is desirable that such knowledge is not carried from one deployment to another; hence, retroactive inhibition is actually desirable in this case. Operators coming from a deployment carry with them a certain learning "set" comprised of these secondary aspects. Part of the role of the proficiency facility would be to extinguish or inhibit this set prior to the next deployment. This can probably be accomplished by learning the new responses applicable to the new deployment situation.

SECTION 3. DESIGN CONSIDERATIONS OF THE PROFICIENCY FACILITY (PF)

The Proficiency Facility (PF) is envisioned as an integral unit that will "plug-into" an AN/TSW-5 IFR shelter. A previous report - "Human Factors Considerations in the Design of a Training and Proficiency Facility for the AN/TSQ-47 System," ESD-TDR-63-328, suggested that a modified Rapcon be designed specifically for certain training functions. This report assumes that the Proficiency Facility and associated connecting cables will require no major modifications to a Rapcon shelter. It is felt that it would be more economical to use a regular Rapcon than to have a modified facility built. In this way, a maximum amount of equipment is kept available for operational use by not tying up equipment for just training purposes. Also, by using a regular Rapcon, the training environment for the controllers would be completely realistic. Therefore, it is envisioned that the equipment discussed will be part of the PF, per se, with maximum compatibility with the AN/TSW-5.

The following paragraphs are intended to present functional descriptions of the major equipments proposed for a PF. Later in the report, a detailed description of the operational use of these equipments will be presented. These descriptions are not intended to be all inclusive; that is, there is no intention of describing all quantity and quality of ancillary equipments, such as cables, power supplies, chairs, console or shelter dimensions, etc. It is intended to give configuration descriptions and functional requirements for equipments basic or essential to an effective proficiency-type facility.

A. RADAR TARGET SIMULATOR

Radar target simulators should be provided in the PF so as to simulate for the Rapcon controllers, realistic aircraft flight parameters. The target simulator should be flexible in the operational conditions that it can simulate, and yet require few operator functions to be performed while "flying" the simulator. Some of the simulator characteristics should be:

range	1 to 100 nautical miles
bearing	0 to 360 degrees
heading	$\pm$ 1800 degrees

altitude	0 to 50,000 feet
cruise speed (IAS)	0 to 350 knots
descent/ascent speed (IAS)	0 to 350 knots
final speed (IAS)	0 to 300 knots
take-off speed (IAS)	0 to 300 knots
rate of descent/ascent	0 to 10,000 feet/minute
turn rate	0, 1.5 and 3.0 degrees/second
wind velocity	0 to 100 knots
wind direction	0 to 360 degrees
wind layers	3 to 5
reset time	less than 30 seconds
preset starting fixes	5
preset aircraft types	5

In order to simulate an aircraft approach, the operator will:

1. Turn the simulator on and put it in the reset mode.
2. Select any one of the preset starting fixes.
3. Select any of the preset aircraft. This provides for preset flight parameters of cruise speed, descent/ascent speed, final speed, rate of descent/ascent, turn rate, etc.
4. Select initial heading.
5. Select initial altitude.

These programmed conditions would hold their initial condition until the operator initiates flight by the "Run" and "Video On" switches. During a flight, when a heading change is desired, the operator sets the new heading on the heading control and the simulator will turn to that heading and at a turn rate appropriate to the type aircraft (Jet or Prop) being simulated. When a change in altitude is desired, the operator sets the altitude control to the new altitude and the simulator will automatically ascend or descend at the programmed rate.

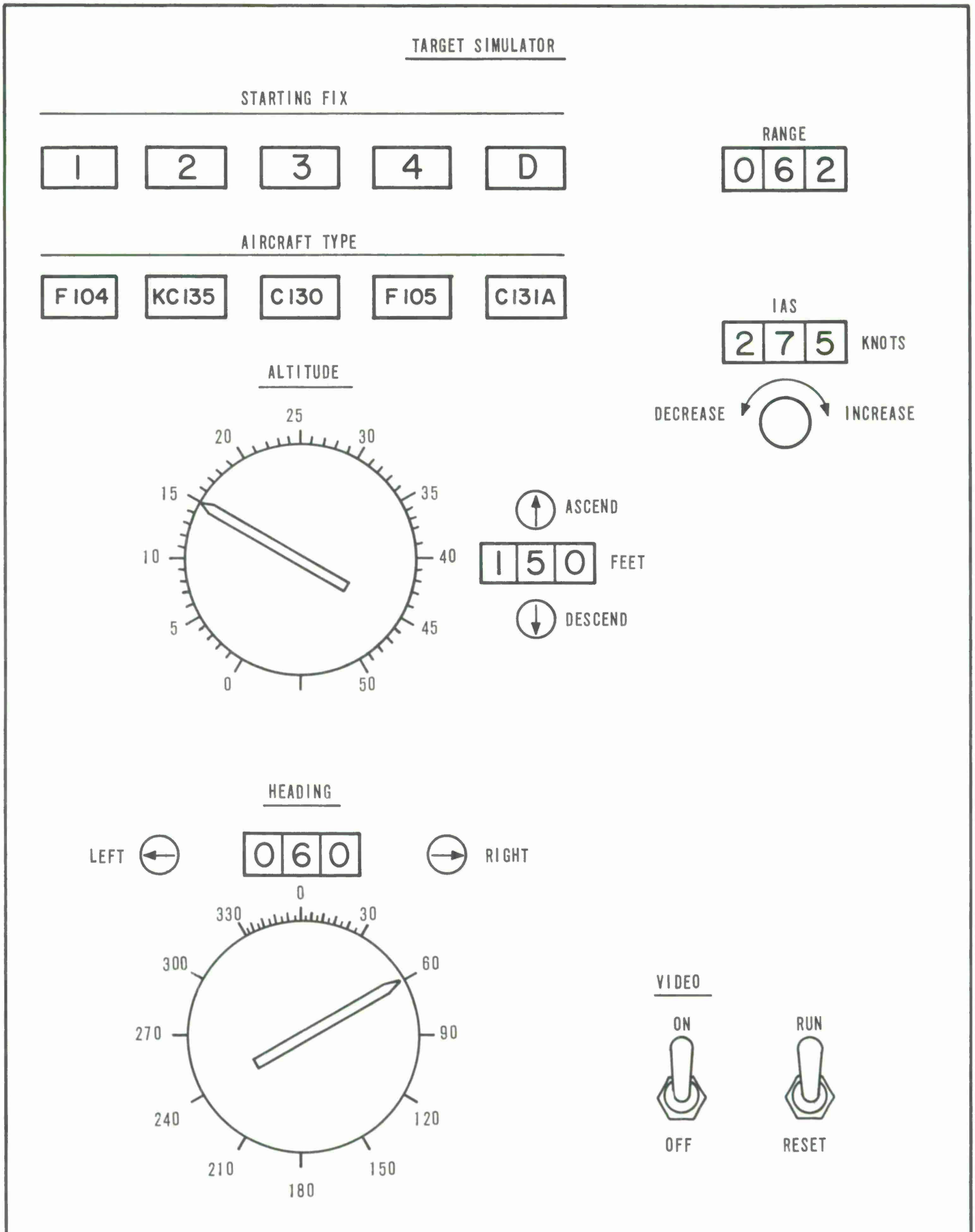

FIG. 2 - CONTROL PANEL TARGET SIMULATOR

Besides the previously mentioned controls, the following associated indicators should be provided on each radar tracking panel (See Figure 2):

1. Range in nautical miles from the runway (nixie tube-type display).
2. Altitude read-out in 100 ft. increments and linked to the servo, so that during any altitude change the indicator will indicate the change (nixie tube-type display).
3. Two small indicator lights associated with the altitude control, one indicating an ascent in progress, the second indicating a descent in progress when illuminated.
4. Heading read-out in degrees, indicating the heading of the aircraft at all times (nixie tube-type display).
5. Two small lights associated with the heading read-out, indicating whether a right or a left turn is in progress.
6. Small indicator associated with the heading control to indicate if the heading control is at one end or the other of the turn pot.
7. IAS (indicated air speed) indicator displaying the speed at which the aircraft is "flying" (nixie tube-type display).
8. Velocity control so that the simulated aircraft can be slowed down or accelerated within a nominal range around the programmed velocity for that particular aircraft type. This will allow for use of "velocity control" by the Rapcon controller especially when the aircraft is approaching or "on final."

Having these controls more automatic, that is, more preprogrammed and servo-driven functions than has generally been the case in most present-day aircraft simulators, should allow one operator to operate more than two simulators at a time. It is proposed that four (4) radar target simulators, a twenty-four hour clock, and a communications panel to connect the simulator operator with the Rapcon and the PF operator, be incorporated in one radar simulator console. It is expected that with properly sequenced targets, one operator could operate as many as three aircraft simulators at one time with the fourth being reading to operate when any of the others would terminate their flight. Having five (5) simulator consoles should allow for a reasonable loading of the Rapcon.

B. COMMUNICATIONS

To make maximum utilization of the PF and to optimize the transfer of learning from the PF to the real operational situation, it is desirable to have the communications network, as it appears to the AN/TSW-5 Rapcon controllers, look as "real" as possible. Since the general communications media for Rapcon controllers will be via their communications control panels at each of the consoles, each of the communications controls should be directly linked to appropriate simulator-operator positions in the PF. Instead of the communications panels being linked to the transmitters and receivers in the A/G/A shelter, they would be linked to the simulated position in the PF, via appropriate audio amplifiers. Thus, the operators in the Rapcon would use their "normal" communications media (VHF, UHF, HF, and intercom controls) and would have these circuits terminate at the aircraft simulator positions or simulated tower positions with a command override/monitor function at an instructor's console.

Since the "communications measurements are significant indices of controller work load,[10]" the following communications factors should be recorded and/or measured.

1. All audio transmissions and receptions by the controllers.
2. Total number of separate messages on each channel or independent keyings.
3. Total time communications channels are congested (when two or more pilots desire to use a channel simultaneously).
4. Total intercontroller coordination time.

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[10] Baker, Grant, Vickers, "Development of a Dynamic Air Traffic Control Simulator;" Civil Aeronautics Adm. Technical Development Report No. 191, Oct. 1963.

C. AIRCRAFT FLIGHT PATH PROJECTION

An aircraft flight path predictor is a high speed iterative computer that takes the two-dimensional position (x. y) of an aircraft from radar return information (or simulated input) and programmed aircraft parameter data, and both computes this information in fast time and displays the most optimum flight path from present position to touchdown on a standard resolved-sweep or other suitable display device.

This equipment could have two operational configurations, that is a flight data preprogrammed mode activated by a single switch and a manual mode. The type of variable data that could be preprogrammed, are aircraft characteristics. It would then be necessary to have only an individual switch labeled for each aircraft type. This mode would be advantageous when there would be only a limited number of aircraft types expected to fly the system (4 to 6 would be a convenient limitation for the number of preset aircraft types). If a nonstandard or non-preprogrammed type were to fly the system, it would be necessary for the operator to use a manual mode and thus insert, via an appropriate control panel, the necessary data: cruise velocity, descent velocity, final velocity, and rate of descent, suitable for the particular aircraft and approach conditions.

The operator in the PF must go through some type of an acquisition function in order to coordinate the programmed computer with the appropriate radar data. This could be implemented in two manners.

1. The controller in the Rapcon will, as part of his normal operational tasks, acquire a new target with the symbol-tracking equipment. This action will superimpose an alpha-numeric symbol/track over the desired target. This data could be fed from the Rapcon shelter to the PPI in the PF. The operator in the PF could then depress a single control labeled with the desired alpha-numeric symbol and feed this track information into the flight path projection computer. A disadvantage to this is that modifications and special wiring would be necessary within the Rapcon shelter.

2. A second technique would be for the PF to have its own symbol-tracking equipment with the simulated radar target data being fed directly into this equipment as it is being fed into the Rapcon. After the acquisition function is

performed in the Rapcon, the PF operator would then perform his own acquisition simultaneous with his flight path computer coordination. This technique will require some type of positive identification to assure that the Rapcon controller and PF operator are assigning the same track data to the same radar target return.

After the target is acquired, the Flight Path computer derives an optimum path solution which accounts for altitude, air density, variable indicated approach speeds, turn rate, acceleration/deceleration, descent/ascent rate, wind profile and fuel consumption. This path is then displayed on the PPI at the operator console within the PF. This operator would then have the option of displaying or not displaying this projected path on the PPI's in the Rapcon shelter.

Simultaneous to the display of the projected paths, two indications appear on a time situation display. The indication at the top of the display indicates the computed time at which the aircraft should start "on final" or a "no passing zone" and the second indication at the bottom of the display would indicate the time at which the aircraft is computed to be touching down. When a line is drawn between these two indications, a permanent record is made of when and how long in time, this aircraft will be on final. Inspection of this display will indicate the expected separation of aircraft on final. If a fast jet were to start on final, say only two minutes after a slow prop-type aircraft, the lines indicating the times on final for these aircraft would probably cross, indicating a serious problem unless the jet were given a delay prior to starting on final.

The computation time of a single flight path course should be in the order of milliseconds and the paths should be replotted with each sweep of the antenna or display of radar data. The PF operator would be able to have a path projection for each of the aircraft that the controllers in the Rapcon would have under active control. Since the present limitation of the Rapcon is 16 symbol-tracking channels, it is assumed that if traffic density were to exceed this at any one point in time, a "holding pattern" technique would be employed. Thus tracking symbols would not be assigned, nor would flight path projection be necessary.

The PF operator should be able to vary the length of the aircraft flight path projection from zero (0) to thirty (30) minutes in time for all paths simultaneously. This way, he can keep his scope clutter to a minimum and yet, as the occasion demands, look into future times as needed.

Also displayed with the flight path projection would be indications as to when would be the most optimal time for an aircraft to begin descent and to level off for final. The auxiliary time situation display will indicate when the aircraft should be beginning its final descent down the glide slope.

All of the flight path projection controls and displays (PPI and auxiliary time situation display) would be mounted in a central instructor console. This console would be the main programming and control position for the whole PF.

D. SIMULATED TOWER POSITION

It will be necessary to provide a console with primarily communications equipment connecting with the Rapcon, the radar target simulators and the PF controller. This position will perform the necessary functions of a tower operator, that is:

1. Give runway clearance to Rapcon controllers for arriving aircraft.
2. Receive the transfer of the aircraft simulators from the GCA operator to tower and terminate the flights.
3. Establish departure times with the aircraft simulators and coordinate actual departure with departure operators in the Rapcon.

E. CENTRAL DISPLAY

A central display visually presenting the simulated aircraft positions should be located within the PF so that the simulator operators can see the path of their aircraft in relation to ground fixes and other location information. This could be a remoted TV display of the PPI information; it could be an actual 22-inch PPI in parallel with the PF operator scope; or, it could be a scan conversion display of the PPI information.

F. RADAR SIMULATOR

It would be advantageous to have two modes of operation in respect to presenting radar information:

1. A radar simulator providing the necessary inputs to the Rapcon, so that the displays (PPI and Az-El) appear to be receiving live data; and

2. Have the real radar information fed into the PF from the radar shelters in the AN/TSQ-47. This way real and simulated targets could be fed into the Rapcon shelter.

One technique of presenting acceptable radar information, such as weather, radar echoes, etc., would be to use a video mapper within the PF and relay the data to the Rapcon. A whole series of pictures could be taken of various degrees of radar degradation and used with the video mapper to vary the situations in the Rapcon. Another device that could be employed would be a random noise generation.

SECTION 4. OPERATIONAL USE OF THE PROFICIENCY FACILITY (PF)

This section proceeds on the assumption that training in the very broad sense of instructing or providing the facilities for a person to become proficient or qualified in a specific set of skills is both a necessary and desirable function. The PF, as previously described when used in conjunction with an AN/TSW-5 Rapcon Facility can be an expedient addition to the overall EMS system. Flying aircraft for the purpose of training controllers is very expensive and having controllers trained with only classroom instructions and on-the-job training is slow due to the necessity of using a graduated loading or slow increase in the aircraft traffic load and responsibilities that can be given to new controllers. Training a controller to handle the complex operations of the approach and feeder positions with a high traffic rate takes years. The proportion of training time to useable time as a 7 or 9 level controller, before his enlistment time is completed, is high. A proficiency facility, as presently envisioned, and effectively utilized as a part of the regular well-supported and well-administered training program (probably at squadron level) should give the Air Force qualified air traffic controllers in a shorter period of time.

The following is a description of some of the various uses to which the PF could be put. It is not expected that these categories mentioned will be all-inclusive.

A. PREDEPLOYMENT PROBLEM SOLVING

When a decision has been reached to deploy an AN/TSQ-47 System to a location, a certain sequence of decisions needs to be determined. If deployment is to be to some remote site, where the arrival and departure patterns have not been established, then this needs to be done. Or frequently, certain modifications to established approach and departure patterns, such as fixes, turn-on points, angle of glide slope, etc., need to be made. In many instances the terminal flight patterns being used at a facility where there had been only a minimum number of aircraft would not necessarily be the most expeditious for high density traffic. When a complete AN/TSQ-47 is deployed, it is expected that high density traffic will occur. For these reasons then, considerable attention should be given to establishing the most expedient approach and departure flight patterns, with a minimum of conflicts or crossing, prior to deployment.

The flight path projection computer, in conjunction with a target simulator can, by means of its fast time computation, solve these problems. Other items of use would be: topographical maps, indicating ground contours and natural obstacles; weather maps, indicating predominate winds, direction and velocity, barometric pressure, and other weather information; updated survey maps, indicating access roads, man-made obstacles, and general airport runway layout. This information can assist in determining the major approach and departure directions and the final approach lane or glide slope. This data (winds, barometer pressure, length and angle of glide slope, etc.) can then be programmed into the flight path projection computer. Simulated aircraft can be positioned randomly around the periphery, acquired by the flight path projection computer and in fast time (in the order of milliseconds) an optimum flight path is visually presented. From this presentation the arrival time and pattern can be determined.

With "real time" simulation it takes, on the average, 15 minutes for an aircraft to fly from 50 miles out to touchdown.. With this fast-time computer, the time limiting factor is changing the aircraft position (in azimuth, range and altitude) and aircraft type. It could be expected to have data on at least 15 flights in fast-time computation during the same time interval that it would produce data for only one flight in "real time."

After flying numerous aircraft types from numerous positions, the optimum approach and departure patterns can be determined. In short, the PF provides a very effective means of quickly pointing out potential bottlenecks in specific ATC locations and thus facilitates the deployment of better combinations or integration of the AN/TSQ-47 facilities and procedures into a specific geographical location.

B. PREDEPLOYMENT TRAINING

After the various geographical positioning problems and terminal flight patterns have been arrived at for the area to which the AN/TSQ-47 is going to be deployed, it would be advantageous to provide some simulation exercises for the Rapcon crew which is going on the mission. There is frequently a necessity to handle high density traffic, shortly (within a day or two) after the TSQ-47 is deployed and controllers have very little opportunity to become familiar with the peculiarities of a new location. Because of this, not to provide some type of predeployment training to controllers, a slower acceptance rate of the aircraft is likely to occur. Being in a new situation, the controllers are apt to be cautiously reserved in their sequencing of aircraft, by providing more separation than they would after they become experienced in this new location.

With this degree of sophistication in the PF and with the previously mentioned predeployment problems solved, it would be very easy to rapidly set up some very realistic training exercises based upon the parameters of the new location. The aircraft simulators could be set up for the general type of aircraft to be expected for the mission in question. Their arrival or starting fixes could be programmed for the expected location at which they would be likely to enter the system. Data regarding the general characteristics of the location could be programmed for the overhead projectors (optical mapping) within the Rapcon.

With both the PF and a Rapcon in running condition, Rapcon crews could get in at least several hours of realistic training exercises prior to deployment. After a brief indoctrination period, the controllers could sit down at their assigned operating positions within the Rapcon and start controlling simulated aircraft just as if they were already on location. Initially, the PF operator might display the projected path of the acquired aircraft for the controllers. This would show the controller immediately the most expeditious pattern for that aircraft. After controlling a few aircraft under these conditions, the projected path might be removed from the controller's scope. The controller would then control the aircraft on his own. The PF operator would monitor the controller's performance and watch for any variance between the aircraft's computed course and the course being provided by the controller. During initial sessions, as variance occurred, the PF operator could provide feedback immediately to the controllers concerning the adequacy of the commands to the aircraft.

Typically, under existing simulation facilities, the simulator operators can tell the controllers only after a flight has been completed, that a delay resulted because the real flight time was greater than the minimum computer flight time. Under the conditions described, it is possible to indicate to the controller, almost immediately, that his last command resulted in a time delay. Also, it is possible to immediately show the controller, visually, by means of the projected path, what the optimum flight pattern would be and thus, what the optimum command would have been. This rapid feedback of information should result in learning which is much more accelerated than is the present method. Bugelski states that "knowledge of results must be supplied quickly if it is to be effective. The subject or learner must be able to know if he is 'right' or 'wrong' as soon as he has performed some response. Delaying this feedback is about as bad as not supplying it at all."[11] Since there is not much training or exercising time available prior to deployment, we should be interested in accelerating the learning of the new air traffic control situation.

Field personnel participation in these simulation exercises can gain a better understanding of the reasons why certain procédures are more efficient than certain other procedures. They can see how and why procedures for any one specific location need alteration for a different location. The PF can be used to maximize this flexibility of controllers to adapt to new situations and loose the "set" or unique behavior characteristics required at a specific location.

C. AN/TSQ-47 FAMILIARIZATION TRAINING

Job knowledge training in the Air Force follows a careful stage-by-stage progression, which takes the trainee from a knowledge of general principles to more specific applications of what knowledge. Air traffic controllers get their basic training in the Air Training Command. After receiving "on-the-job" training at a fixed site they become available for assignment to one of the Mobile Squadrons. Even though he is at the 5 skill level, the new controller arriving at the mobile squadron must perfect his overall controller skills, he must learn the unique characteristics of mobile operations, and he must acquire the specific knowledge and skills required by the special features of the AN/TSQ-47. All these types of skills can be developed and trained with the PF and Rapcon shelter. TSQ-47 familiarization training for new controllers would consist of: the location of equipments that the operator already has knowledge about concerning their use; the location and operation of unique equipments such as the optical projectors, the symbol tracking group, etc.; overall system deployment and operational procedures; and predeployment duties associated with teardown and setup.

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[11] Bugelski, B.R., <u>The Psychology of Learning</u>; Henry Holt and Company; New York, 1956.

Besides training the newcomer to the mobile squadron, there will be a need to provide AN/TSQ-47 familiarization training or retraining to personnel presently using "4-wheels" equipment. Familiarization training of this type does not necessarily require a special training device. It is usually acquired on the job. However, by using this facility, better familiarization training than is normally the case can be provided. It will do this by enabling such training to be better controlled; to actually precede operations rather than be simultaneous with operations; to be accomplished more rapidly; to be better programmed and administered; and to provide a more enriched or sophisticated training environment.

Presently, after a controller finishes his basic Air Training Command training, he achieves the rest of his knowledge and skills by "on-the-job" training (OJT). This means that he starts at elementary control positions such as an assistant or data man. While performing these functions, he becomes aware, through observations and discussion, of the general requirements of the next "higher" jobs. When traffic density is at a minimum, he starts to fill-in in the performance of these other jobs until he slowly becomes "proficient" at that job. As his skills, seniority and training increase, he moves into positions of more responsibility. This process is slow, because he is being trained in the real operational world. He is controlling real aircraft, which by its very nature, necessitates a cautious acceptance. Thus, the training of controllers under operational conditions necessitates that their training be by a graduated loading method. That is, they control only a few aircraft at any one time during their early training phases and then as experience is acquired, the controller handles a higher traffic load. Research literature from the Ohio State University's Laboratory of Aviation Psychology, indicates that by programming higher input loads early rather than a graduated input load results in superior performance at the program termination.[12]

Therefore, the PF could be used to give accelerated training in mobile operations and AN/TSQ-47 familiarization. As in the discussion in the pre-deployment previous section, where the PF would be used to give accelerated

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[12] Kidd, J.S., "A Comparison of Two Methods of Controller Training in Simulated Air Traffic Control Task," WADC Technical Report 58-449, Jan. 1959.

training to controllers for predeployment problems, the PF could, in this case, provide accelerated training and familiarization to controllers for mobile operations if personnel had just been transferred from a fixed installation and in specific AN/TSQ-47 equipment and procedural familiarization. Again, since traffic density tends to be high during the first few days after the TSQ-47 is set up at a new location, this is no time to be training.

D. MAINTAINING CONTROLLER PROFICIENCY

Mobile squadron operations are characterized by their intermittency. When a mobile unit is needed it must be ready to go into operation at peak efficiency. The time period between deployments is an interval when controller skills and knowledge is apt to deteriorate. The PF can be used to assist in maintaining a high level of proficiency during this interval.

If steps are not taken to prevent the natural process of forgetting by some type of positive reinforcement, then the loss of controller proficiency will be a direct function of how much time is spent between deployments. Informed estimates of the length of this interval vary from a few weeks to as much as a year or more. Even allowing for the subjectiveness of these estimates, it would appear that very real performance losses could result.

Training and training devices, to be effective, must be flexible enough so that they can be adapted to the performance level of the learner. For complex learning, the higher the proficiency level that is to be maintained, the more sophisticated the training situation must be. This usually demands as refined, complex and realistic task duplication as possible. In acquiring rudimentary job knowledges and skills, simple training techniques and devices can be used. Frequently, lectures and simple graphic-type training aids are adequate for this type of training. As skill levels and task complexity increase, more and more refined training methods and devices are required to exercise and shape performance.

It is advantageous for positive transfer of learning and motivation to have the training situation place demands on the trainee. The trainee should not be allowed to repeatedly perform a "pat" memorized set of responses but should consciously be required to vary his response to fit a different set of circumstances.

The PF should provide an opportunity for performance to improve or be exercised in situations that are new to the learner.

The PF can be used to do cross-training for the AFSC 272x0A & B job descriptions. Nonradar types can receive radar training and radar types can receive manual ATC training. Also, tower controllers could receive cross-training in radar operations, thus hastening the up-grading process. Cross-training would also improve the overall AN/TSQ-47 System performance by increasing the understanding and appreciation on the part of radar personnel of the problems, information and needs of the radar controller. In operations, the two types of controllers work together for the safe and orderly flow of aircraft. Such cross-training would improve the integration of their respective tasks and responsibilities.

Due to the flexibility and sophistication of the equipments in the PF, a vast variety of ATC problems and situations can be simulated. With proper planning and foresight the PF operator can program situations, so that a Rapcon team can be kept at peak performance. They can receive a great deal of training in high density traffic and new or unusual circumstances. This way the controllers will be much more "prepared" to handle the "unusual" circumstances when they occur in the real situation.

Baker, et al., states, "It (simulation) has proved to be a valuable aid for training ATC personnel in the finer points of radar traffic control."[13] The PF, having such dynamic programming flexibility, will allow for exercising situations very realistically which may occur in real ATC operations. Also, due to the capability of the PF operator to provide immediate feedback to the Rapcon controllers concerning the adequacy of their commands, learning should be maximized.

E. MEASURING CONTROLLER/SYSTEM PERFORMANCE

Several different criteria have been used to evaluate various operating characteristics of an ATC system. These measurements have been so commonly

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[13] Baker, et al., Op. cit.

used that they are considered basic to practically all ATC tests. The most universally used is aircraft delay. This factor is indicative of the efficiency of the system in handling a specific traffic demand rate, since the function of any system is to provide a smooth, orderly flow of traffic with minimum delay to any one aircraft and with an equitable distribution of any necessary delays.

Under actual or real traffic conditions, the only delays measurable with present techniques are those which are accrued by aircraft in holding patterns. In simulation, it is possible to measure the total delays due to holding, path stretching and velocity control. This is done by comparing the actual arrival time with the theoretical arrival time computed for that flight. Other criteria frequently used and related to the above method, are fuel consumption and separation at touchdown.

The biggest deficiency of these types of measurements is that all we are really aware of is the input information (e. g., starting time, position, aircraft characteristics, traffic rate) and the final outcome or system measurement (e. g., landing rate, average delays per aircraft, separation, etc.). We do not know how, why, what, or when these delays started to occur; nor can we say how much delay is attributed to velocity control; path stretching; or to their interactions, if different control techniques are used.

With the PF as presently envisioned, the PF operator(s) can tell when an aircraft first begins to accrue any delay from its optimum or minimum time schedule. By monitoring or playing back the associated voice communications with an aircraft flight, he can tell what was wrong with any particular command. Also, the PF operator(s) can assess the reasons for any further delay or improper control operations as they occur. A positive differential assessment can be made.

Since the PF operator(s) will have a flight path projection for each acquired aircraft, he will see immediately when an aircraft varies from the optimum course. As it varies, he can measure at fixed time intervals, the variance of the actual course from the programmed optimum course. The PF operator(s) can take actual measurements with a rule or any linear device for measuring from the face of the PPI of the true position of the simulated aircraft relative to the programmed position. This way we can tell if the variance is a constant occurring error due to one wrong operation; or whether it is a variable; or a nonconstant variance, indicative of over-compensation, under-compensation, or other attempts on the part of the controller to correct what he interprets as an inadequate flight pattern.

Typically, we could only measure the time or distance separation of the aircraft as they landed. Now, with the use of the flight projection equipment and the time situation display for aircraft on final, we can measure the adequacy of the separation at any point on final. However, since these equipments are predicated upon the concept that all aircraft will be on final for a constant or equal amount of time, the only measurements we would need to be concerned with would be the separation at the beginning and end of the final course. For if the separation was adequate at the start and end of the final course, then it would have to have been adequate in the middle.

Now for the first time, each functional task of the operators in the Rapcon can be quanitatively measured. (For a description of the functional operational tasks of a Rapcon, see "The Data Flow Analysis of a Mobil ATC Aid," Busch, McNair and Kirby, ESD-TDR-62-190, August, 1962 and "Information Flow Analysis of a Transportable Air Traffic Control System," Pogust, et al., February 1962, ESD-TDR-62-111). Since errors and variance from preferred course can be identified as they occur, they can be correlated with the functional task being performed within the Rapcon. With this data, tasks can be defined as to their difficulty or probability of error occurrence.

If studies were to be done in this area, significant improvements should occur in being able to describe the man-machine or system operations. More concise and descriptive system measurements can be made. The criticality of tasks as they relate to system performance can be better defined. The skills associated with the tasks can be delineated and weighting factors applied.

Other measures of system performance that should be made when running simulation problems are safety and workload. Since the PF operator(s) can see as much as 30 minutes in advance of present flight position, he can see if there will be any probability of a violation of safety criteria. That is, adequate separation, both laterally and horizontally (altitude). The flight path projections would indicate if two or more courses would converge or nearly converge at the same time in space. The PF operator can tell if there is adequate time or space separation. He can see if the controllers give delays or path corrections to prevent an impending safety violation. Also, he can tell if flight path changes are made because the controllers were anticipating a problem which would not in fact have been a problem.

Communications measurements have been the conventional indices of controller workload. The PF is instrumented so that the following measurements can be made:

1. Total live or on-line time per simulated air/ground channel.
2. Total number of separate messages per channel.
3. Total time communications channels are congested.
4. Total intercontroller coordination time.

Another measure of controller work load can be obtained by an "operational activity" analysis. This type of study is comprised of:

1. Evaluation of the visual tasks of an operator, e.g., the portion of time spent on radar surveillance, meter and lamp fixations, etc.
2. Analysis of all motor activities, i.e., control manipulation, writing, idleness, etc.
3. Analysis of all communications media:
4. An analysis of various combinations of visual, motor and communicational activity. This is in a sense, a "time-sequence" analysis. This type of analysis was used as a part of the acceptance test program conducted on the AN/GSN-11.[14] An operational activity analysis can be a good indication of the load of a system.

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[14] "Category 1 Acceptance Test of Air Traffic Control Central AN/GSN-11" prepared for 482L/431L System Program Office, Electronic Systems Division, Air Force Systems Command, United States Air Force, L. G. Hanscom Field, Bedford, Massachusetts.

F. EMERGENCY SITUATION TRAINING

This category probably should be part of several previously discussed subsections; however, the authors felt that since the PF can be employed to such an added advantage in emergency situations training over what has ever previously been available, it should be mentioned separately.

A PF operator, with the use of the fast time computer of the flight path projection equipment, can rapidly set up situations where he knows that the aircraft are on programmed collision courses, near-collision courses, conflicts on final, or other such safety violations. The problems can be planned so that the apparent conflict will occur at almost any point in the future time that is desired. This way the PF operator(s) can observe just when the controller is aware of any problem and what action can be taken to compensate for it.

The PF can simulate equipment malfunctions such as complete or partial loss of communications; loss of video or radar failure; aircraft emergency such as low on fuel, flame out, etc.; bad weather and minimum ATC conditions; or a whole host of other conditions.

True emergencies occur so seldom that the average controller is probably not prepared to handle them optimally. At present the best training for emergencies is many years experience. At times when emergencies occur it is essential that controllers be able to change their operating mode suddenly and efficiently. The PF can provide training in making the judgments required to shift rapidly from normal procedures to optimal emergency operations.

G. STANDARDIZED TEST PERFORMANCE MEASUREMENT

The PF provides an instrument which supplies several of the prerequisites for a good training device.

1. Objective measurements - measurements in which performance is recorded in quantitative terms are strongly preferred to subjective opinions, comments and ratings. Opinions are influenced by ones own preferences, experiences, training and habits. People tend to prefer the familiar rather than new things. This type of conservatism frequently biases the evaluation of new procedures and systems. Ratings are colored by what people think they

ought to say - either what their own "command" would expect of them or what the designers hope they will say. The very atmosphere of the situation will tend to provide a bias, depending on how the observer perceives the situation. It is not at all unusual for operator preference or criticism to be inconsistent or opposed to that which objective measures of system performance indicates to be a satisfactory or preferred equipment or mode of operation.

2. Reliable measurements - measurements of human or system performance referring to the consistency or repeatability of stimuli and measurements. To be useful, measurements should be able to be duplicated and equivalent results obtained. The PF can be programmed so that a particular problem such as a fixed number of aircraft, being fed into the system at fixed intervals, from the same position, can be run as frequently as possible. Various system parameters can be varied at the discretion of the PF operator(s) and equivalent system measures can be made. In this way, any number of controllers or control terms can be given identical problems. With the measuring techniques described in previous subsections, the same criteria can be applied to each measurement. Thus, consistent types of measurements of operator(s) and system performance can be made.

A standardized testing and measurement device which covers the specific skills in question, is an ideal device for certification testing and upgrading of personnel. The whole process of controller performance evaluation can be less personal, less clouded with instructor bias, and more objective.

Adams states:

> Central use of them, (simulators) where aircrews might be placed on temporary duty for evaluation, has the advantage that all aircrew personnel could be evaluated under standardized conditions by a highly trained evaluation team. The concept of a trained evaluation team is an important one for good proficiency measurement and has not always been given the recognition it deserves. Such a team must be trained in:
>
> (1) standardized use of the simulator, so that all aircrews are rated on the same mission problems,

(2) observations and scoring methods so that judgments of aircrew performance will be the same from aircrew to aircrew, since all measures will not be obtained with automatic scoring devices,

(3) data reduction and analysis methods, so that the measures can be put into meaningful form,

(4) knowledge of the functional simulator and its capabilities, so that it will be used intelligently,

(5) knowledge of the calibration requirements of the simulator so that its quality can be maintained on each mission.[15]

H. EMS SYSTEM EXPERIMENTATION

The PF, besides being an extremely useful operational and training device is a very useful laboratory device for determining the basic laws which affect traffic flow. Much of this knowledge can be utilized to put the planning of air navigation and traffic-control aids on a more scientific basis than has been possible heretofore. In addition, such knowledge can be used to develop more efficient control methods. The PF furnishes a method of testing proposed ATC equipment while such equipment is still in a developmental stage.

The PF will allow the accumulation of normative data concerning operator and system performance. This data can form a base line against which data from new equipment and/or procedures can be compared. We will be able to judge more quantitatively what operational changes might effect overall system capacity. Since the same equipment, personnel and traffic samples can be utilized in all phases of a comparative test, the results can be considered indicative of the true relative performance of each system. Thus, the results can safely be regarded as a valid and reliable predictor of the preferred system.

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[15] Adams, J.A., "Some Considerations in the Design and Use of Dynamic Flight Simulators;" Selected Papers on Human Factors in the Design and Use of Control Systems; H. W. Sinaiko, Ed., Dover Publishing Inc.; New York, 1961.

SECTION 5. CONCLUSIONS AND RECOMMENDATIONS

A. General principles of learning indicate that a proficiency facility as described in this report should result in a high rate of learning and positive transfer in air traffic control operations.

B. The nature of present mobile squadron operations indicates the need for a proficiency facility in a squadron level training program. This is necessary to meet the overall need imposed by the increasing demands of the Emergency Mission Support program.

C. The dynamic simulation capabilities of the PF should adequately meet the growing training demands of the overall Emergency Mission Support program.

D. To properly integrate a PF into an overall training program, considerable effort is needed to organize and implement such a program. A whole training curriculum would need to be developed. Along with this, training crews or trained evaluation teams would need to be developed in the use of the PF.

E. Before development work could be done on a PF, further details concerning circuitry and packaging need to be worked out.

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