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The Influence of Generic Airspace on Air Traffic Controller Performance

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16. Abstract

The generic sector evaluated in this study was based on a four-corner post operation typically used in many terminal areas in the United States. Arrival aircraft originated from one of four arrival fixes just outside the sector boundaries. These arrival routes can be thought of as spokes of a wheel with the main airport site as the hub. In addition to the main airport, there were three satellite airports that were under radar control. Departure aircraft from the main and satellite airports were sent directly to one of four departure fixes located outside the sector boundaries.

Eleven air traffic controllers from the Atlantic City TRACON participated in the study. The experiment was conducted at the Federal Aviation Administration Technical Center's Human Factors Laboratory at the Atlantic City International Airport, New Jersey. The experimental apparatus consisted of a high fidelity air traffic control simulator with voice communication equipment to allow controllers to issue commands to remote simulation pilots.

The results showed significantly lower Air Traffic Workload Input Technique (ATWIT) ratings by the last generic run compared to the first generic run on the first-day training runs. Time under control and the distance flown by the aircraft significantly decreased by the last training run. Controller ratings of workload and stress were also significantly lower by the last generic run. In addition, post-scenario questionnaire ratings for ability to plan, exchange information, and prioritize were significantly higher by the last run. Correlations between scores on the generic sector and the Atlantic City sector were significant for the over-the-shoulder ratings, ATWIT ratings, and post-scenario questionnaire ratings. Final questionnaire comments indicated that the participants thought the generic sector was representative of a typical terminal environment.

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EXECUTIVE SUMMARY

The Separation and Control Hiring Assessment (SACHA) program has the goal of developing a valid selection process (i.e., test battery) for selecting air traffic controllers. Component tasks of this program include job analysis, predictor development, criteria development, and validation of these predictors and criteria. Ideally, these performance criteria would be based on measures taken from the controller's own sector. However, a controller's performance may vary depending on the amount of time he or she has spent working the sector. In addition, sectors vary in complexity, and therefore, in difficulty for the controller. A standard generic sector could be a solution in that the conditions under which performance is measured would be the same for all participants. This would be a significant advantage over using performance measured on each controller's home sector where many factors such as familiarity and sector complexity vary unsystematically. The question remains concerning the validity of measurement based on generic airspace. Specifically, will a controller's performance in a generic airspace be representative of, and related to, performance achieved at his or her home sector.

The generic sector evaluated in this study was based on a four-corner post operation typically used in many terminal areas in the United States. Arrival aircraft originated from one of four arrival fixes just outside the sector boundaries. These arrival routes can be thought of as spokes of a wheel with the main airport site as the hub. In addition to the main airport, there were three satellite airports that were under radar control. Departure aircraft from the main and satellite airports were sent directly to one of four departure fixes located outside the sector boundaries.

Eleven air traffic controllers from the Atlantic City International Airport (ACY) Terminal Radar Approach Control (TRACON) participated in the study. The experiment was conducted at the Federal Aviation Administration Technical Center's Human Factors Laboratory at Atlantic City International Airport, New Jersey. The experimental apparatus consisted of a high fidelity air traffic control (ATC) simulator with voice communication equipment to allow controllers to issue commands to remote simulation pilots. Each controller performed nine different scenarios over 2 days of testing. The first day of testing was considered a training day where controllers performed one low traffic volume run on the ACY sector and then four runs on the generic sector. These generic runs were of moderate traffic volume. The second day was considered a test day where controllers performed four, 1-hour runs. Two (one low volume, one high volume) of these were on the home sector and two (one low volume, one high volume) were on the generic sector. Low volume runs consisted of 7 aircraft appearing every 15 minutes, moderate traffic runs used for training consisted of 10 aircraft appearing every 15 minutes, and high traffic runs consisted of 11 aircraft appearing every 15 minutes.

Data reflecting ATC performance, workload, system effectiveness, and self-assessment of performance were collected during the simulation. Some additional controller performance measures were collected using a new over-the-shoulder rating form in development for the SACHA program. Dimensions on this form included communication and informing, managing multiple tasks, maintaining attention and vigilance, and maintaining a safe and effective traffic flow. System effectiveness measures included number of controller transmissions, aircraft density, and number of clearances issued. Controller workload was assessed using the Air Traffic

Workload Input Technique (ATWIT). The ATWIT consisted of collecting participants' ratings of workload as they controlled traffic.

In addition to the previously described measures, several questionnaires were used to collect subjective ratings from participants. First, a demographic questionnaire was completed that requested background information from each participant. In addition, after each scenario was finished, controllers made self assessment ratings of their own performance in a post-scenario questionnaire. A final questionnaire was administered at the end of the simulation to obtain subjective impressions of the realism of the simulation and the representativeness of the generic sector.

The results showed significantly lower ATWIT ratings by the last generic run compared to the first generic run on the first-day training runs. Time under control and the distance flown by the aircraft significantly decreased by the last training run. Controller ratings of workload and stress were also significantly lower by the last generic run. In addition, post-scenario questionnaire ratings for ability to plan, exchange information, and prioritize were significantly higher by the last run.

Correlation co-efficients between scores on the generic sector and scores on the ACY sector were significant for the over-the-shoulder ratings, ATWIT ratings, and post-scenario questionnaire ratings. The correlation co-efficients were higher and most consistent for the high-volume traffic runs. The correlation co-efficients for the system effectiveness variables were moderate and not consistent across variables. However, when scores from the high and low traffic runs were averaged and then correlated between sectors, most of the correlation co-efficients increased. These runs were averaged because the combination of runs provided a larger sample of the controller's performance than either run separately. In addition, the combination of high and low runs provided a data point which reflected performance over a range of traffic volume. The results suggest that more runs are needed to obtain significant correlation co-efficients for the system effectiveness variables.

Final questionnaire comments indicated that the participants thought the simulation was very realistic. In addition, all participants thought the hands-on training for the generic sector was very adequate. The majority of the controllers thought the generic sector was representative of a typical terminal environment. Most controllers expressed that they had a positive experience working on the project.

The fact that performance indicators did not change appreciably over the four training runs is considered a positive finding. Genera was designed for ease of implementation. Controllers were able to learn it very quickly and work traffic with no major complications. Ideally, a generic sector should not pose hurdles, but rather facilitate performance, as was accomplished by this sector.

1. INTRODUCTION.

1.1 PROBLEM STATEMENT.

Since the beginning of human kind, people have evaluated each other's performance. Much of this evaluation was based on individual standards of which the evaluator may not have even been aware. If one asks an expert in any field what constitutes "good" performance, he or she may provide an answer that has meaning for them alone, and the response may or may not translate to the expectations of another expert.

A meeting was convened in June 1987 by the Federal Aviation Administration's (FAA's) Air Traffic Requirements (ATR) organization to discuss the nature of air traffic controller errors, and their impact on operations and training. It was noted that while automation had increased, the number of aircraft that a single controller could work had not increased appreciably, and controllers continued to make the same sort of mistakes. These were often attributed to a failure to perceive critical information.

Lauber (1993, p. 23) expressed his concern about human performance issues in Air Traffic Control (ATC). He stated that "human performance issues clearly present the major challenge to all of us. If we are to make the system significantly safer we must find ways of minimizing or eliminating all together, human error induced accidents."

In 1993, there were 764 controller operational errors in the United States (FAA, 1994), a slight increase from 738 errors the previous year. The FAA is constantly trying to reduce the probability of these errors. By developing more effective measurement tools, it may be possible to better understand the true range of acceptable performance.

1.2 ASSUMPTIONS AND GOALS.

When novices are taught a skill, they are trained in one of two ways. One is based on an absolute standard of performance that is clearly defined in advance and easily recognized by anyone in the trade or occupation. The other method is to use a relative standard that is based on how everyone else does or on the trainers' understanding of what it takes to perform the task set (Berlinger, Angell, & Shearer 1964). In this second situation, the training system is very much dependent on the trainer and/or on how all the other trainees are doing. These relative standards make performance measurement very complicated. There has also been a lack of integration between training theory and evaluation models for complex performance (Cannon-Bowers, Tannenbaum, Salas, & Converse, 1991).

In ATC, there are some absolute or minimum standards against which everyone is judged. One of the most fundamental standards is based on the minimum separation allowed between aircraft under positive radar control. Every controller must achieve this if he or she is to stay in the system. Since this is an absolute standard, everyone who lasts in ATC meets it or risks being removed. This means that this standard is not very useful for looking at the range of performance that controllers, as all human operators, produce. The system has evolved into the use of relative standards employing, as the basic metric, an over-the-shoulder rating scale that is open to considerable latitude in interpretation (FAA, 1990). Each evaluator must introduce his or her experience and biases when doing a controller check ride or evaluation.

Performance is a complex construct that has seen considerable research over the years. While there are many definitions of performance, the following is an operational definition that is currently being used in the research to be discussed in this report:

> Performance is the accomplishment of a task or interrelated set of tasks in relation to a defined and specified standard while operating within constraints of space, time, and resources.

This definition means that a human operator is involved. The operator must accomplish something in relation to a specified standard. If the behavior exceeds the standard, it is evaluated as successful, and if it fails to meet the standard, it is not successful. The distance above or below the standard determines different levels of accomplishment within the unsuccessful and successful categories respectively.

This current experiment is based on the assumption that the performance of air traffic controllers can be measured in a number of ways. It is also based on the belief that the quality of this measurement can continue to be improved, and that this improvement is a worthwhile endeavor.

This research in controller performance is being done for a number of reasons. First, it is a step to improve performance and reduce the possibility for error. Second, it evaluates the feasibility of using airspace models for testing and training that the participating controllers have not seen before and have not over-learned with practice. The use of generic airspace can simplify and reduce the cost of training and selection if personnel are able to perform as well with it as they can with an over-learned environment.

This experiment is also a stepping stone for a follow-on effort that will use video tapes collected during the experiment. The follow-on project will cross validate measures collected in the simulation, to be described in a latter section of the report. The cross validation shall examine the relationship of the simulation measures to those collected from supervisory or training controllers, who will evaluate the performances that they see on the video tape.

1.3 REVIEW OF THE RELATED LITERATURE.

Even when performance standards are absolute, clear definitions have to be agreed upon concerning the desirable behavior. When the standards are relative, they depend very heavily on the trainer's internalized model of what good performance is all about.

Rault (1979) pointed out that flight crew personnel, for example, often establish an operational standard against which they compare their own performance. They tend to judge themselves in relationship to how closely their performance resembles this standard. It is likely that most professionals operating in high reliability organizations have both minimum external standards and internalized personal standards. Warm and Dember (1986) expressed concern about the level of alertness of personnel who operate complex systems and spend much of their time monitoring data flows. Even with a great deal of motivation and a fairly high internal standard, human operators can lose their focus. In aviation, it does not take much, in terms of a loss of situation awareness (SA), to create problems.

While human beings add flexibility and adaptability to the system, they also add the potential for error. Senders and Moray (1991, p. 1) describe, "All of us have experienced human error. When we interact with machines or complex systems, we frequently do things that are contrary to our intentions. Depending on the complexity of the system and the intentions of the people interacting with it, this can be anything from inconvenience (often it is not even noticed) to a genuine catastrophe."

In an early comprehensive study of controller errors, Kinney, Spahn, and Amato (1977) analyzed FAA reports and developed eight categories of errors. These included: controlling in another's airspace, timing and completeness of flight data handling, inter-positional coordination of data, use of altitude on the display, procedures for scanning and observing flight data, phraseology and use of voice communications, use of human memory to include relying on recall in a noisy environment, and dependence on automatic capabilities.

Today, the FAA uses a different set of categories to classify operational errors. In the FAA (1988), the following categories were employed: radar display, communication, coordination, aircraft observation, data posting, and position relief. By far, the most frequent source of errors identified was in a subclass of "radar display: the misuse of data." This category implies that information was available and was either misinterpreted or inaccurately stored in working memory.

Controller performance issues are not limited to only a litany of errors made in an operational setting. Research has been conducted for over 25 years on various ways of trying to quantify performance. McKenzie, Buckley, and Sarlanis (1979) conducted a study of the potential usefulness of physiological indicators to evaluate controller workload. In this study, 10 controllers watched films of a simulated radar displa and were asked to identify potential aircraft conflicts. These conflicts occurred in two counterbalanced conditions where the aircraft volume differed considerably. The goal was to determine if controllers would respond physiologically to the differing demands of the two conditions. Both heart rate and galvanic skin resistance (GSR) were measured. The results indicated that heart rate did not discriminate across the two conditions, but GSR frequency changes, and the area under the GSR plot, were significantly different between high and low system demands.

McKenzie et al. (1979) noted that the scenarios they created were extreme, and physiological measures may or may not be sensitive under conditions where the differences in task demands are not so diverse. Further, this exploratory study did not involve the requirements that controllers actually separate traffic. They did not have the stresses of responsibility that are characteristic of the control task. So, any conclusions may not necessarily generalize to either an operational or an ATC simulation environment.

Buckley, O'Connor, Beebe, Adams, and MacDonald (1969) conducted what may have been the first simulation study of air traffic controllers that included physiological measurement. Their primary focus was on the assessment of controller performance and its relationship to chronological age. However, they also collected two physiological indicators: heart rate and GSR. They found a relationship between heart rate and heart rate variability and objective measures of task load, the average density of aircraft under control. The correlation co-efficients were small, usually less than r=.38, but significant. The authors concluded, "These results confirm the hypothesis that physiological functions may be sensitive indicators of workload" (pp 2-7). This was one of the studies that has been conducted to examine controller performance and workload issues.

Systems designers are most concerned with measures of primary task performance. This can be complicated by workload and other factors such as task load, which is the demand placed on the operator by the environment. When workload and performance are measured separately across a wide range of task load, they can be inversely related to each other as task load and workload increase (Stein, 1985). However, when examining operational errors as a performance indicator, there is a common finding that errors occur more frequently at lower to moderate levels of task load (Rodgers, 1993; Kinney et al., 1977; FAA, 1988). This finding has been demonstrated both in the United States and by Transport Canada (Stager & Hameluck, 1990). Rodgers and Duke (1993) suggest that previous taxonomies of errors have been incomplete and may have missed information processing failures that subsequently led to inappropriate actions. This occurs when task load is defined as number of aircraft or in terms of complexity that is assessed using a rating scale 1 (low) to 5 (high) complexity (standard FAA form for operational error investigations).

Seven (1989) stated that "it is in the real world that workload problems contribute to accidents and system inefficiencies, and result in over-manning or under-manning on critical tasks." She suggests that we develop unobtrusive measures specific to the operational systems, and then generate realistic data based on real-time measurement. In essence, she proposed the use of noncritical tasks as indicators of workload, assuming that performance would decline as the load from primary tasks increased. This is basically similar to the theory behind secondary task techniques without the addition of artificial secondary tasks.

There has also been considerable effort expended in a search for task or environmental models of workload in ATC. While it is generally believed that workload and performance are related, the nature of this relationship continues to be disputed. One of the oldest environmentally-oriented models of system task load, which is related to workload and, therefore, to performance, was developed by Arad (1964). He identified three basic components of load: background, routine, and airspace. Arad created a mathematical model for computing overall load based on such variables as aircraft types, and what they were doing in the airspace. This modeling activity was designed for use in answering staffing questions, rather than evaluating operator real time activities.

Jolitz (1965) decided to conduct a comprehensive test of the Arad model using simulation of 16 ATC sectors and testing the degree to which the model would predict mean subjective ratings of load by controllers. Jolitz concluded that there was no relationship, and that a better predictor of controller's concept of load was simply the number of aircraft handled per hour.

Robertson, Grossberg, and Richards (1979) developed and evaluated another computer model of controller activity which had both workload and performance implications. They referred to this model as the relative capacity estimating process (RECEP). It places a heavy emphasis on system events and functions in an off-line data processor capable of analyzing these events after they have occurred. While the primary purpose of the model was to estimate workload, it did, by necessity, examine controller activities. It divided these activities into three general categories: routine, surveillance, and conflict prevention. These were similar to those proposed by Arad (1964). By computing and summing all the sub-task performance times, Robertson et al. (1979) proposed maximum limits in terms of man- minutes-per-hour of operational time. RECEP measures correlated favorably with subject matter expert's (SME's) ratings of work pace. There was considerable variability across different airspace sectors.

One of the strengths of the work of Robertson et al. (1979) was its use of data from operational facilities. There is a more recent program that makes even more comprehensive use of operational data and has a strong performance orientation. This program is called the Situation Assessment though Recreation of Incidents (SATORI) and is being developed by personnel at the Civil Aeromedical Institute in Oklahoma City, Oklahoma (Rodgers and Duke, 1993). SATORI analyzes system analysis report (SAR) tapes that contain all the operation events for one radar position over a given time period. These tapes are routinely recorded in ATC centers. The original purpose of SATORI was to evaluate the factors that led up to an airspace incident or controller operational error. Rodgers, Manning, and Kerr (1994) have taken this project one step further. They have developed the performance and objective workload research program (POWER). This software package will allow for the output of many performance measures described by Stein (1992).

Controller performance measurements have consistently involved tasks and variables derived from ATC and produced findings expressed in ATC terms (Hopkin, 1980). Another, possibly more beneficial, approach would be to trace the origins of the practical difficulties (e.g., memory lapses) that the controller encounters to limitations in human cognitive capabilities, and to use basic psychological knowledge to explain, measure, and resolve them. It is fundamental to consider the controller's task in human terms in order to provide perspectives, explanations, and insights into the cognitive processes that support ATC. While the use of new technologies may be essential in order to deal with the ever-increasing, information-processing demands of the ATC system, the long-term performance implications of extended use of the new technologies on human performance are largely unknown (Endsley, 1988; Harwood, Barnett, & Wickens, 1988).

As ATC automation increases, more attention to the fundamental cognitive aspects of the controller's job is necessary. It is necessary to develop cognitive performance measures so that the consequences of automation on controller performance can be effectively evaluated (Hopkin, 1991). This implies that, in the long run, we may have to expand the more traditional views of what performance is to encompass concepts that we have viewed in the past as unrelated or inconsequential.

Practice is the single most powerful factor for improving the controller's ability to perform ATC tasks. Nothing is likely to offset the frailties of working memory as will practice. The influence of practice on the attentional demands of working memory has received considerable attention within the framework of automatic and controlled processing (Schneider & Shiffrin, 1977). Controller error rates have been associated with the proportion of full performance level (FPL) controllers (those most practiced and proficient). Rodgers (1993) accomplished an analysis of the FAA's operational error database. He found that facility error rates were inversely proportional to the percentage of the work force that had achieved FPL status.

Research on performance issues has occurred in many different domains. Where we are today is due in part to what has occurred in domains other than ATC. System performance in air space is a function of both controllers and pilots.

Stein and Rosenberg (1983) studied workload and pilot performance leading to new measurement techniques that applied to both air crews and air traffic controllers. In this study, pilots flew missions at three levels of difficulty, or task load, which was induced by turbulence. Mission order was counter-balanced across pilots. Pilots were asked to respond every minute and evaluate their workload at that time. They were cued by a tone and a light-emitting diode on the response switch box mounted below the aircraft's throttles. At this time, the measurement system and the theoretical foundation behind it was called the Pilot Objective-Subjective Workload Technique (POSWAT). The subjective scaling involved the responses already discussed. The objective part was the measurement of response delays and overall pilot performance on such dimensions as flight technical error, which is the degree to which the pilot strays from his assigned flight path. Performance was evaluated against an absolute standard that assigned error points based on the magnitude of the pilots deviation from the assigned altitude. There was the growing conception that the measurement of workload is irrelevant without an evaluation of performance.

The subjective real-time scaling in this study was sensitive to the levels of taskload. Workload was related to the segments of flight, being highest in those segments that involve the greatest demands on the pilot, takeoff, final approach, and landing. Such confirmation of what has been anecdotal data would not have been possible using post-run scaling.

Stein (1984a) did a study to determine whether there were any measurable differences in workload and performance between relatively new pilots and experienced, high-time personnel. This became known as the masters-journeyman study. Professional military and civilian pilots, the masters, were compared against a unique group of instrument-rated pilots who had very low experience levels. These journeymen received their pilots' licenses through a one-time FAA experiment which evaluated the feasibility of instrument training for pilots with under 200 hours of experience. Both groups flew simulated missions under three levels of counter-balanced taskload. Taskload was influenced by turbulence and, at the highest level, by the introduction of an emergency condition toward the end of the flight. The POSWAT system for the evaluation of workload was used along with the measurement capabilities of the flight simulator in order to assess flight performance. Participants completed a post-flight measure called the Flight Workload Questionnaire. This had four scales: workload, degree of busyness, amount of thinking required, and an overall evaluation of how the pilot was feeling.

Masters performed better in all segments of flight than did the journeymen. Both inflight POSWAT and post-flight ratings of workload showed higher workload for the journeymen than for the masters. Correlation co-efficients between workload and performance produced an interesting phenomenon. When all pilots were considered, the relationship was negative; higher workload meant poorer performance. However, this finding did not appear within each of the subgroups; it required the full skill range to appear.

POSWAT was the beginning of real-time workload measurement in simulation. It would later be modified to become the Air Traffic Workload Input Technique (ATWIT), which will be described in more detail. Murphy (1987) performed what was essentially a replication of the masters-journeyman study under a contract with the FAA. His results confirmed those found at the Technical Center.

Stein (1989) completed a study which was designed to evaluate the impact of changing the minimum legal separation permitted between aircraft that are approaching independent parallel runways at a major U.S. airport. The minimum was 2 nautical miles (nmi), and the proposed change was to decrease this to 1.5 nmi. Highly-experienced controller volunteers participated in a simulation that involved controlling traffic in 1-hour sessions, using the two separation standards alternatively. Performance was measured with the automated data collection capability of the simulator and over-the-shoulder evaluations. The measurement data set was based on earlier work and will be described more completely later in this section. Workload was estimated every half-hour by the evaluators and after every hour by the participant, using a post-run questionnaire similar to that used in the workload probe study 4 years previously (Stein, 1985). ATWIT was not employed in this study, however.

In terms of performance, controllers using the reduced separation did not make any more errors than they did when using the 2 nmi minimum. In fact, they were actually able to land more planes given the reduced separation. The post-run questionnaire had five separate scales: workload, performance, busyness, stress, and workability of the separation standard. It was tailored to the specific experiment. Overall, there were no significant differences in perceived workload from either the observers or the participants.

Buckley, DeBaryshe, Hitchner, and Kohn (1983) performed two experiments to examine the use of simulation for the evaluation of air traffic controller performance. They emphasized the quality of measurement and identified the basic dimensions for measuring ATC functions in real time. They studied the issue of the interaction of sector geometry and traffic density on various performance measures. One outcome of the first experiment was that there was a statistically significant effect of sector geometry and traffic density for almost all of the 10 performance measures. There was also a significant interaction effect between geometry and density. The authors suggested that "the nature and extent of this interaction depends on the measures involved" (p. 73).

This first experiment had examined the effects on system performance measurements using two en route sector airspace layouts and three traffic density levels ranging from very light to very heavy. Data were collected from two 1-hour runs for each of 31 controllers. Sector geometry had a major impact on performance, and this led them to the design of a second experiment.

The second experiment examined the effects of collecting a great deal of data over time by repeated measures. The database was sufficient so that a factor analysis was computed to look for redundancy in the measures used to quantify system performance. Twelve 1-hour runs were conducted using the same sector with the same traffic level for each of 39 controllers.

The data resulting from Buckley's et al. (1983) first experiment were cross-validated with the factor analysis derived from the second experiment. This produced four meaningful factors or measures: confliction, occupancy, communication, and delay. The confliction factor included measures of 3-, 4-, and 5-mile conflicts. The occupancy factor included measures of the time an aircraft was under control, distance flown under control, fuel consumption under control, and time within boundary. The communication factor included path changes, number of ground-to air communications, and the duration of ground-to-air communications. The delay factor included total number of delays and total delay times. Two auxiliary measures, number of aircraft handled and fuel consumption, were also relevant. These experiments conducted by Buckley et al. have served as building blocks for most of the controller performance research that has followed.

Thackray and Touchstone (1988, 1989), working at the FAA Civil Aeromedical Institute, also were interested in performance. They examined the performance implications of varied task loads. They developed a small scale ATC simulation and examined behavior of college students required to monitor a simulated radar display for two different types of events. One was a simple task of detecting and reacting to a change in the altitude data block linked to an aircraft target. The second involved detecting the occurrence of two aircraft on the same flight path at the same altitude, a collision course. The authors saw this as a more demanding task in that the participant had to decide whether a conflict was imminent or not. Participants worked in 2-hour sessions.

Thackray and Touchstone (1988, 1989) did not attempt to scale workload; they focused entirely on performance. They were concerned with the frequency of correct detections and the missed events. Results demonstrated that the low taskload events were virtually never missed and that response times did not increase appreciably during the work sessions. For the high taskload conflict detection task, events were missed and the number and latency increased over time. This suggested fatigue and/or some sort of change in reserve capacity for information processing over time. The researchers concluded that the decline in performance with the higher taskload may have been based on the amount of information processing required and its impact on the employment of attentional resources. It was unfortunate that Thackray and Touchstone (1989) did not use a secondary task measure to more thoroughly evaluate this hypothesis.

Another unfortunate aspect of their research was the fact that they used college students. Zingale, Gromelski, Ahmed, and Stein (1993) have shown that college students are not a good model for air traffic controllers. Even with considerable training in ATC concepts and using a user friendly simulation, Zingale et al. found that college students do not behave the same way as experienced controllers, and therefore, results of studies using students can not be easily generalized to the controller work force.

In a study of how actual controllers used their information to facilitate their performance, Means et al. (1988) studied the way that en route controllers organized aircraft. They observed that controllers recalled aircraft in groups, invariably drawing one group at a time when tested. When asked to name the groups, controllers labeled them in accordance with a specific type of traffic issue (i.e., arrivals or crossing traffic at a specific fix). Geographical proximity played less of a role in grouping than did the interaction and potential conflicts between members of a group. This takes training and experience. Organization of information has been identified as the one factor which has the greatest probability of improving cognitive performance in ATC (Vortac, 1991).

Memory, SA, and performance may be related. There have been a number of definitions of SA that have been offered during its relatively short history. One definition of SA,suggested by Endsley (1989) is: ". . . the perception of or the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." Endsley (1990) described the measurement model she had created as the Situation Awareness Global Assessment Technique (SAGAT). SAGAT involves developing a question set based on potential events in a scenario. Questions are randomly selected from the set. The flight scenario is frozen at a predetermined point in time. The pilot is removed and asked to respond to the questions. The correctness of answers is determined by referring to what was actually happening at the point of scenario freeze. Scoring requires storing that information in analog or digital fashion so that comparisons can be made post hoc.

Endsley and Rodgers (1994) studied en route ATC from the viewpoint of the requirements generated for SA. These researchers attempted to identify the essential components of information that an en route controller must have in order to perform his or her tasks. Using a panel of eight SMEs, the researchers employed a replay of ATC incidents to cue participant memory. Each member of the eight-person panel was presented with one or two ATC incidents that were recreated on a video screen. Each member was subsequently interviewed about information requirements for one or more major task areas in ATC (i.e., separating aircraft, analyzing weather situations). The end product of this work was a series of information requirements linked to each aspect of the controllers duties. This may have implications for future ATC experiments to the extent that the presence or absence of these elements of information are present during the simulated ATC operations. How controllers think and use information has elicited considerable interest and research.

This interest was reflected by a family of theory and research papers that discuss the cognitive tasks as compared to the observable activities of controllers. It is unclear to what extent controller cognition can be effectively used to understand and subsequently measure performance. As part of a larger program aimed at improving controller training, a group of researchers performed a cognitive task analysis of expertise to see if experts and novices differed in how they think (Seamster, Redding, Cannon, Ryder, & Purcell, 1993). They concluded that experts took a wider view of the evolving air traffic situation. Experts appear to be more flexible in their approach to the dynamics in their airspace. The researchers identified 13 en route controller tasks that were linked to their cognitive models of the airspace: maintain situation awareness, develop and revise sector control plan, resolve aircraft conflicts, re-route aircraft, manage arrivals, manage departures, manage overflights, receive hand-off, receive pointouts, initiate handoffs, initiate pointouts, issue advisories, and issue safety alerts. Each of these is broken into numerous sub-goals which establish the matrix of the controller's mental model.

According Seamster et al. (1993), their research supports the hypothesis that experienced controllers group or organize their picture by events rather than by individual aircraft. The mental model and task accomplishment or requirement interact and influence each other. When thinking out complex ATC problems, experts (in contrast to novices) used fewer, but more varied, planning strategies and had more strategies for managing their workload. While the results of this research are important for an understanding of how controllers think, the researchers did not attempt to relate their model to actual controller performance measured objectively.

There is a diversity of opinion concerning whether SA is an indicator of performance itself or is merely a necessary, but not sufficient, condition for adequate performance. In a memory study to be described later, the authors assumed that SA is a precursor to performance and an indicator of the current level of working memory (Sollenberger and Stein, 1995-In press). However, in an extensive literature review of workload and performance measurement, Fischer (1995-In press) recommends that SA be considered as a performance measure. She suggests that it is the missing link between non-observable controller cognitive activity and resultant observable behaviors. This may be an overstatement of the measurement power of SA. However, researchers will need to continue thinking about the role of SA in the human performance equation.

This equation is a complex matter. In an effort to establish a starting point for future measurement of controller performance, personnel at the FAA Technical Center developed a compilation of measures that could be used in real-time simulation. This effort is described in the following section.

1.3.1 Performance Measurement Search For Dependent Variables.

This current work reflects a history of concern for measurement in ATC. There have been a number of expansive summaries of measurement tools for evaluating human performance and workload. For example, a guide was published (ANSI, 1992) that included measures such as POSWOT and ATWIT. However, it did not review any of the performance work and measures in ATC, and only touched other performance domains, such as piloting and even white collar clerking.

Researchers in ATC performance have been left to their own devices to establish the measures that they use. Stein (1992) assembled and consolidated the variables that had been useful over the years for researchers at the FAA Technical Center. This work was based primarily on the research of Buckley et al. (1983) and to a lesser extent on research accomplished by Stein (1984a, 1984b, 1985). What follows are excerpts from the unpublished specification which may apply to this current study.

Simulation research has been used to study ATC concepts, equipment, and procedures for 35 years or more. Over this time period, various sets of dependent variables have evolved to assist in the evaluation of system and individual controller performance. The specific subset of variables has generally been tailored to meet the research goals of each study that was run. Most of the ATC studies using simulation have been conducted at the Technical Center.

It is assumed that everything that occurs in the simulation is recordable and recoverable on a post-hoc basis. There has been no requirement for real-time data analysis. All data processing can be accomplished after the completion of the simulation. It has also been assumed that there is a data flow from target generation through controller actions and subsequent results in terms of aircraft responses that will be recoverable on a post simulation basis. This implies that all raw data, such as the relative position of aircraft, are saved so that further analyses can be accomplished.

The dependent variables, described below, are a subset of all those that are possible. This subset was selected for its generality and practicality, as well as for the potential statistical power of the measures. A researcher may wish to run a full set of analyses using all these variables or some less-inclusive group. The interface for the analysis should afford the opportunity to select those variables desired for the particular questions under study.

The majority of measures in the dependent variable set are based on frequencies of events and time, both of which should be cumulative, based on a specifiable time period. The research design may include a hypothesis of change in conflict frequencies and time duration based on the amount of time that a controller has been on position. So, the ability to compute statistics based on a specifiable time block is important.

The variables apply to Terminal Radar Approach Facilities and are presented with as much detail as necessary to facilitate their computation. Unprocessed variables are data that should require no processing, but should be available at the end of each simulation run directly from one or more storage files. They are basically self explanatory.

1.3.1.1 Unprocessed Variables.

Aircraft Identification and Flight Plans

Run Number

Run Duration(seconds)

Controller Identification Code

Airspace Sector Identification

Experimental Condition/Combination

1.3.1.2 Conflict Variables.

All conflict variables assume a technical violation of minimum separation between pairs of aircraft flying in controlled airspace. Variable names are arbitrary and may or may not have been used in previous research efforts. Variable concepts, however, have for the most part been employed in earlier work. Once a concept is explained, such as the principle of accumulating time durations of conflicts, it may or may not be repeated in similar variable descriptions.

a. SCNF(TERM) - Standard conflicts in the terminal area. The separation shall be 3 nmi or 1000 feet of vertical separation. This variable will not be useful on final approach sequences due to wake vortex considerations, and longitudinal separation violations will take over. The analysis of this variable will therefore have to take into consideration the relative location of aircraft in the airspace and rule out those aircraft on final approach. This is usually done by setting a point in space such as the outer marker or by defining the final approach heading and filtering out any conflict hits from aircraft established on final.

b. SCNFD(TERM) - The cumulative duration of SCNF(TERM) conflicts.

c. XCNF(TERM) - The user must have the option of setting a conflict criteria that is flexible. This becomes necessary when the purpose of the experiment is to evaluate the impact of changes in separation minima in the airspace. This measure applies primarily to aircraft in the Terminal Control Area (TCA) which are not on final approach.

d. LCNF - This is the primary conflict measure for aircraft that are on final approaches and are in trail of one another. This measure must take into consideration the impact of wake vortex issues as defined in 7110.65H (FAA, 1993). However, for the purposes of research, some assumptions may be made and will be made part of subsequent research designs. For example, assume that 3 miles standard separation is acceptable unless wake vortex criteria apply. Obviously, this measure will show more conflicts than, for example, SCNF and could indicate that the controller is not paying adequate attention to the aircraft types he/she is working.

e. LCNFD - The cumulative durations of LCNF.

f. PCNF - Parallel conflict frequencies. This measure is used to evaluate conflicts of aircraft that are on simultaneous parallel approaches to an airport. The criteria for violation must be user specifiable since the purpose of the research may be to examine the possible impact of changing the separation minima.

g. PCNFD - The cumulative durations of PCNF.

h. BSCNF - Between sector conflict frequencies. Here, the sector boundary must be identified. This is primarily a terminal measure, and a 3-mile criteria is acceptable. It is basically a standard conflict, but the controller generally does not have both aircraft unless he/she has taken an early inbound handoff.

i. BSCNFD - The cumulative durations of BSCNF.

j. API - Aircraft proximity index. This is a measure of conflict severity developed by Mr. Lee Paul (1990) of the FAA Technical Center. While it can be computed frequently during each conflict situation, it is most useful at the point of closest approach of two aircraft which are in violation. The computational procedures are appended to this specification. The API for each conflict situation should be recoverable at the end of the simulation, along with a mean API score for the entire simulation and sub-blocks of the total time period. For every API computed the software should provide output on the actual horizontal and vertical separation at the point of closest approach between the aircraft pair.

k. ASCNF - This is the frequency with which the controller allows aircraft to conflict with restricted airspace. The boundaries of the airspace in question shall be user specifiable. An airspace conflict occurs when an aircraft actually crosses a boundary.

l. ASCNFD - The cumulative durations of ASCNF.

The nature and number of conflict measures does not imply that controllers are not effective or that they are unsafe. However, previous research has shown that such measures can be effective especially when trying to evaluate the effects of change on the person-machine system.

1.3.1.3 Complexity Measures.

The concept of complexity means different things to ATC personnel. There is no one generally agreed-upon definition. Most controllers comment on the aircraft frequency and/or the number of control actions they have to take with each under their control until they can hand it off.

a. CMAV - This is a very basic measure of what might better be called system activity. It is simply the average number of aircraft within X miles of each other with X being user-specifiable. A sampling rate on this of once every 10 seconds would be adequate.

b. ALT - The frequency of altitude change messages sent from the controller to the aircraft. This is cumulated over the run and/or the prespecified time block within the run.

c. HDG - The frequency of heading change messages sent from the controller to the aircraft.

d. SPEED - The frequency of speed change messages sent from the controller to the aircraft.

1.3.1.4 Non Conflict Errors.

a. MISSAPP - The frequency of missed approaches in the terminal control area. This should include both the primary airport and any satellite airports to which approaches are being controlled. This is cumulated over the run or the pre-specified time block.

b. HOFFMISS - The frequency with which the controller allows aircraft to leave his/her sector without a formal handoff to the receiving sector. This measure can be used in both the terminal and en route environments.

c. HOFFERR - The frequency with which the controller attempted to handoff an aircraft at the incorrect altitude or airspeed. These errors shall be cumulated over the entire run or based on pre-specified time blocks.

d. NDLY - The frequency of hold messages sent to aircraft and the number of turns of greater than 100 seconds duration. These two elements are summed and cumulated for the duration of the run or based on pre-specified time blocks.

e. COMDLY - An accumulated time variable based on the durations of time between the aircraft calls for service and the controller's initial response. The time, in seconds, is cumulated during the entire run or based on pre-specified time blocks.

f. COMDLYNBR - The cumulated frequency of comdlys that exceed 20 seconds. This is based on the whole run or pre-specified time blocks.

1.3.1.5 Communication Activity.

a. VOIFREQ - The frequency of voice communication from the controller to the aircraft under control if voice is used in the simulation. Each time the microphone is keyed shall be counted as one transmission. These shall be cumulated over the run or based on pre-specified time blocks.

b. VOIDUR - The cumulated time in seconds that the controller is transmitting to aircraft under control. This is based on the whole run or pre-specified time blocks.

c. CKEY - The accumulated total frequency of controller keystrokes on the keypad. This is based on the whole run or pre-specified time blocks.

d. PKEY - The accumulated frequency of simulation pilot keystrokes if simulation pilots are part of the simulation. This is based on the whole run or pre-specified time blocks.

1.3.1.6 Activity/Taskload.

a. NFLT - The number of flights handled by the controller for a given period of time based on the entire run or on pre-specified time blocks.

b. LAND- The number of landings completed by a controller working final approach in a TRACON environment. This is based on the entire run or pre-specified time blocks.

c. DEPART - The number of departures worked by a controller working departure control in a TRACON environment. This is based on the entire run or pre-specified time blocks.

d. HANDOFF - The number of successful handoffs to adjacent sectors or facilities. This applies to both en route and TRACON environments.

e. ATWIT - The Air Traffic Workload Input Technique. This measure was first used by Stein (1985). It grew out of earlier research with pilots (Rosenberg, Rehmann & Stein, 1982). The software cues the operator that a response is required. This occurs on a pre-set time frame, such as once per minute. The controller pushes a button numbered from 1 to 10 and the system records the button push and response latency. The final product of ATWIT is an average of the scaled responses for the whole run or for user-specified time blocks.

This concludes the summary of the simulation performance variables that are currently in use. It does not, however, limit researchers to only these variables. The future will determine the variety of measurement tools that researchers are able to create.

The simulation measurement described above has been recently used in the FAA Technical Center Human Factors Laboratory. Sollenberger and Stein (1995, In press) conducted a study of controller memory issues to determine whether performance could be enhanced using a memory aid.

This experiment used a training simulation called ATCoach, which was adapted for research. The performance measures were collected automatically when each of 16 controllers worked the simulation. The participating controllers worked traffic using their own airspace from Atlantic City International Airport (ACY). They worked traffic under high and low task load and under normal and memory-aided conditions. The memory aides were based on increased structure that involved pilots doing more of the navigation, using preplanned routes, and requiring controllers to do less, providing, in theory, more time for the controllers to engage in memory-enhancing activities such as maintenance rehearsal and note taking and/or strip marking.

The performance measures cited earlier were analyzed to determine if memory aiding accomplished anything. Unfortunately, the memory aides did not seem to improve controllers' SA as it was measured. They also did not improve the controllers' memory for aircraft information, such as the last commands he or she gave. On the positive side, the memory aides did have some positive influence on controllers' behavior, as recorded in the automated performance measurement data. In the aided condition, controllers made significantly fewer ground to air transmissions. Also, they gave fewer altitude and heading changes. These variables have been used as indicators of controller workload. Another positive result was that, with the memory aides, controllers made fewer handoff errors. Without the performance indicators, these positive findings would not have been discovered.

2. EXPERIMENT.

2.1 PURPOSE.

The purpose of this research was to develop and validate a generic sector that could be used to evaluate air traffic controller performance in a standard fashion. The study had two goals. The first was to evaluate controllers' ability to learn a new sector in a short amount of time. The second was to evaluate how similar or different controller and system performance would be on a generic versus a home sector, in this case the ACY sector.

2.2 LOGIC BEHIND A GENERIC SECTOR.

A new program titled the Separation and Control Hiring Assessment (SACHA) is underway to develop valid measures for selecting ATC specialists in the FAA. The SACHA program has the goal of developing a valid selection process (i.e., test battery) for selecting air traffic controllers. Component tasks of this project include job analysis, predictor development, criteria development, and validation of these predictors and criteria. Ideally, these performance criteria would be based on measures taken from the controller's own sector. However, a controller's performance may vary depending on the amount of time he or she has been working the sector. In addition, sectors vary in complexity and, therefore, in difficulty for the controller. A standard generic sector could be a potential solution in that all the conditions under which performance is measured would be the same for all participants. This would be a significant advantage over using performance measured on each controller's home sector where many factors, such as familiarity and sector complexity, vary.

In order to perform the study, a generic sector had to first be defined and developed. In the context of this research, generic refers to a sector which embodies the important elements of a terminal sector (i.e., arrival and departure routes, terminal radar range and performance, and radar procedures). In order to achieve the goals of the study, the test generic sector was specifically designed to be quite different from the home sector. The reasoning behind making the generic sector different is that this would require learning on the part of the controller, and the controller's performance on this sector would be based on his or her skill as a controller and his or her mastery of the sector. In addition, it is likely that participants in the SACHA testing would come from all parts of the country and therefore from diverse facilities and operations. Creating a sector which is different from the controller's home sector would allow us to pilot test a situation that would be very likely to occur during SACHA testing. Specific items of differentiation include the route structure, the mixture of traffic, the letters of agreement (LOAs) between the sector and adjacent facilities, the names of fixes, the direction of traffic flow, and the placement and orientation of sector boundaries.

2.3 AIRSPACE AND TRAFFIC SCENARIOS.

2.3.1 Generic Sector Airspace and Scenarios.

One of the primary concerns of this effort was that the generic airspace appears realistic to a FPL controller, yet could be learned with a minimal amount of training. To achieve this objective, an ATC specialist was heavily involved in the development of the airspace and traffic scenarios. The specialist had extensive experience working in a Level V terminal facility and had visited many other major terminal facilities across the United States as a part of previous projects.

The generic airspace evaluated in this study was based on a four-corner post operation typically used in many terminal areas in the United States. Arrival aircraft originated from one of four arrival fixes just outside the sector boundaries. The arrival aircraft traveled down corridors which converged at an arrival transition fix near the main airport. These arrival routes can be thought of as spokes of a wheel with the main airport site as the hub. In addition to the main airport, there were three satellite airports that were under radar control. Departure aircraft from the main and satellite airports were sent directly to one of four departure fixes located outside the sector boundaries.

To expedite learning of these fixes, the five-letter identifiers for these intersections corresponded to their magnetic heading location relative to the radar antenna. For example, the northwest arrival fix was named "NOWES" and the northeast arrival fix was named "NEAST." Departure fixes were also given names corresponding to their magnetic headings, but all fix names ended in a "D" to denote a departure fix. For example, the west departure fix five-letter identifier was "WESTD", the east departure fix was named "EASTD", and the southwest departure fix was named "SWEDD." Another significant feature of the generic sector was the use of structured corridors to the en route airspace for both arrival and departure aircraft. These corridors were used to hand off aircraft to the center, accept handoffs from the center, and provide path ways to and from the main airport. A map of the generic sector is presented in figure 1.

The generic sector also employed structured altitude shelves which provided safe altitude separation between aircraft when arrival and departure airspace overlapped. Arrival aircraft originating from the northeast and northwest had to maintain at or above 8,000 feet until they were within a 15-mile radius of the main airport. Departure aircraft destined for the east and west departure fixes had to maintain 7,000 feet or below until they were 15 miles east or west of the main airport. The altitude shelves were designed to add some complexity to the sector in that the controllers had to differentiate between north departures, which could ascend immediately, and the east/west departures. Figures 2 and 3 illustrate the altitude shelves and their boundaries.

LOAs were made up to provide the controllers with standardized hand-off procedures. Two en route centers were created, one for transitioning aircraft in the northern portion of the sector (North Central Center) and one for transitioning aircraft in the southern portion of the sector (South Central Center). In addition, there were four airports adjacent to the generic sector which provided arrival traffic and accepted departure traffic. LOAs were written to define operating procedures between each of these adjacent airports and the main airport. Copies of these LOAs are found in appendix A and B.

The traffic mixture for the generic sector was based on actual flights from the Official Airline Guide (OAG) 1993. This guide contains flight origination and destination information, as well as call signs and aircraft types. Flights were taken from this guide and a database was formed from flights arriving into major metropolitan terminal areas. Approximately 70 percent of the flights into and out of the generic sector were composed of transport aircraft including heavy aircraft (i.e., DC-10, L1011, and 747) and medium-performance aircraft (i.e., 727, DC-9, and MD-80). The remaining 30 percent of the mixture were general aviation aircraft, including commuter jets (i.e., Learjet, Cessna Citation) and both single- and twin- engine propeller-driven aircraft (i.e., Piper Cherokee, DeHavailland Dash 6).

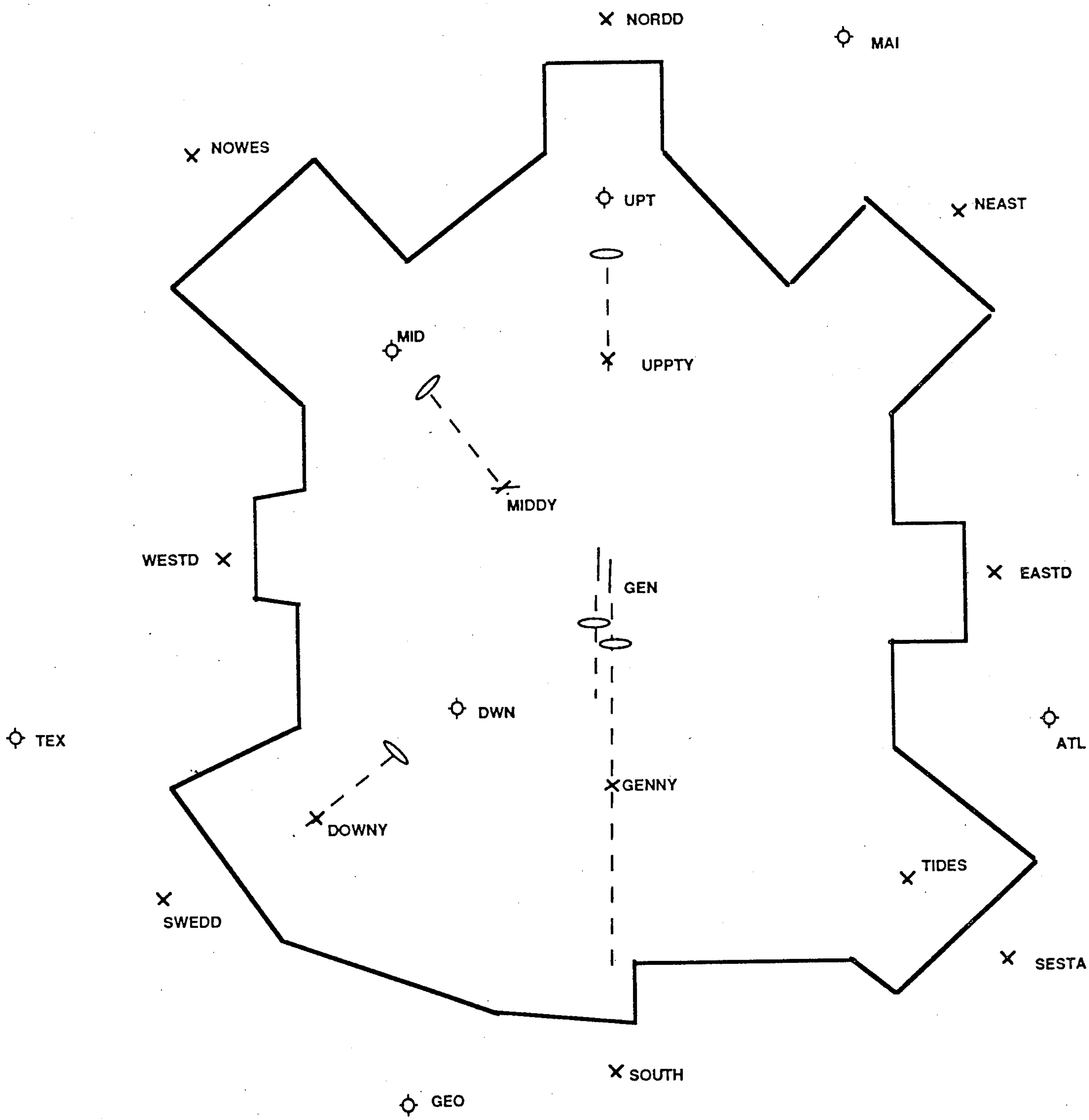

FIGURE 1. GENERIC SECTOR RADAR MAP

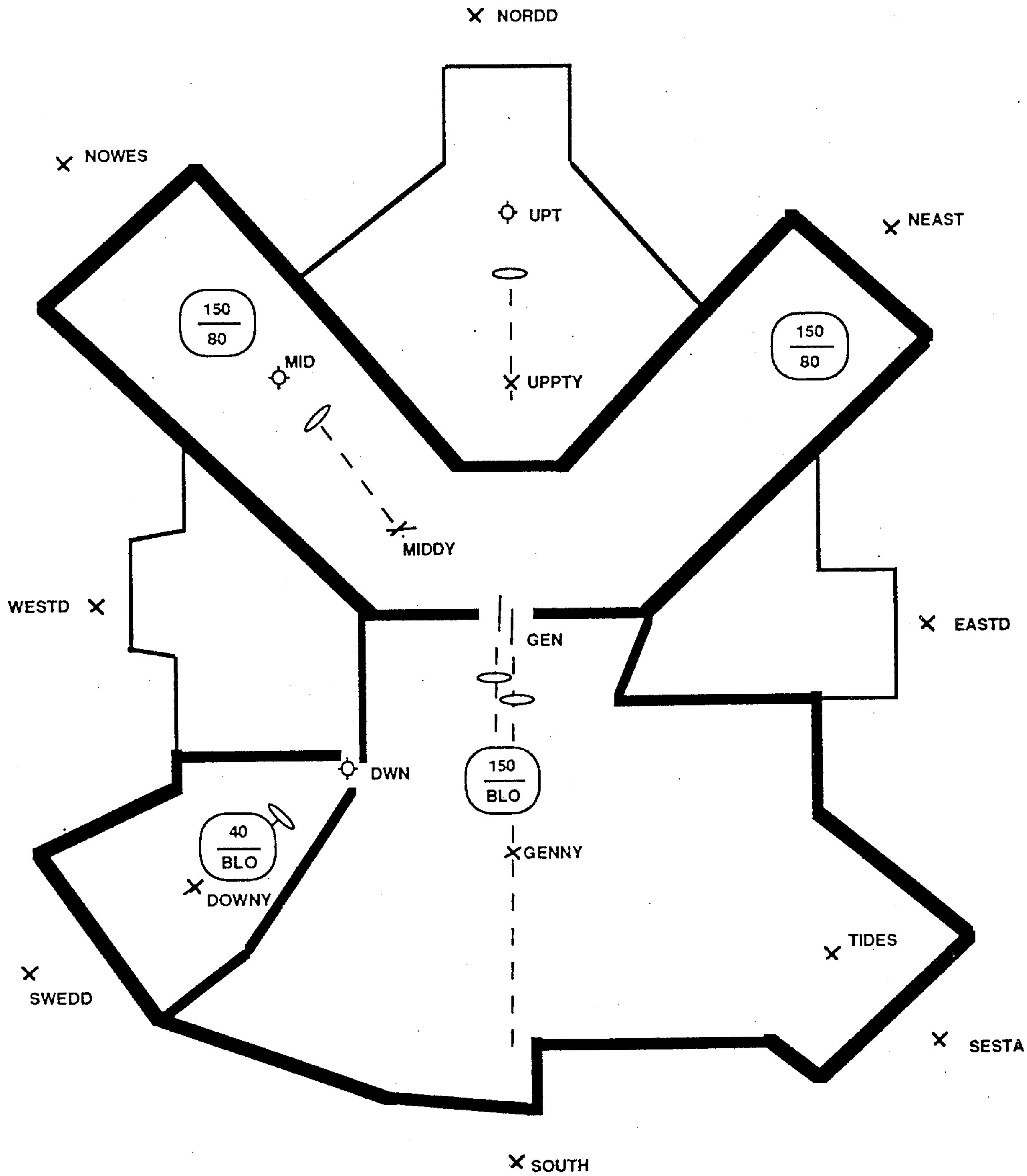

FIGURE 2. GENERIC SECTOR ARRIVAL AIRSPACE NORTH OPERATION

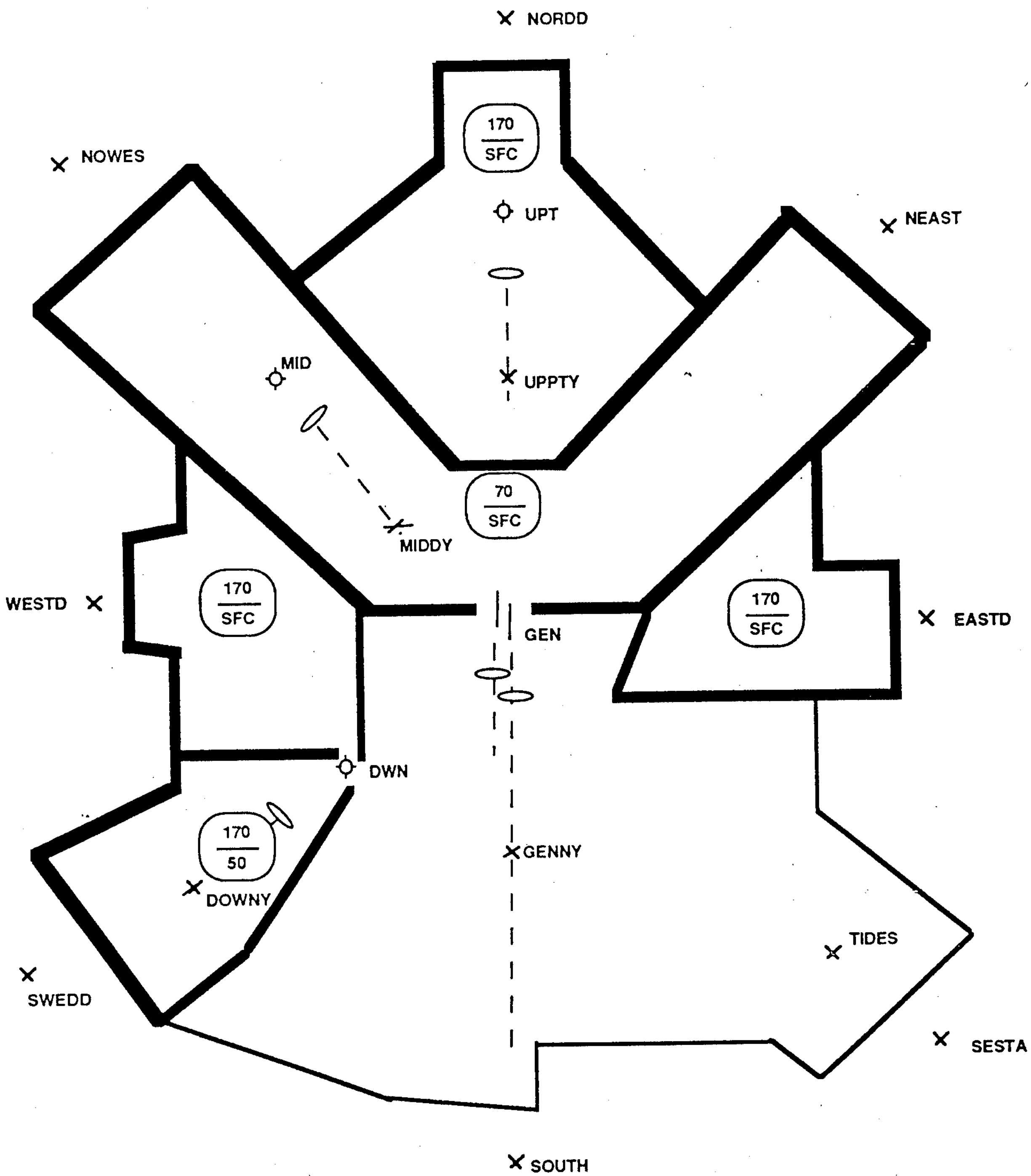

FIGURE 3. GENERIC SECTOR DEPARTURE AIRSPACE NORTH OPERATION

Scenarios were constructed that accurately simulated traffic into a major metropolitan terminal area. Most of the aircraft were arriving to and departing from the major airport (Genera International Airport) which incorporated a set of parallel runways. However, a proportion of the aircraft arrived and departed from the three satellite airports in the sector. A north operation was used for all generic sector scenarios in which all arriving aircraft used runway 36R and departing aircraft used runway 36L. The satellite airports in the sector all used a north operation as well. All scenarios started with a build-up of traffic during the first 5 minutes. An SME controlled this traffic. At 5 minutes, the SME gave the participant controller a relief briefing and then gave control over to him or her. Typically, there were at least five aircraft on the scope at this point. Aircraft steadily appeared until the conclusion of the scenario. The scheduled rate of appearance for aircraft was changed to represent either low, moderate or extremely busy traffic conditions.

2.3.2 ACY Airspace and Scenarios.

One of the primary concerns in this experiment was to create a realistic simulation of the ACY airspace for the controllers. Fortunately, during previous simulations, a large amount of data had been gathered on ACY operations, normal operating procedures, as well as airspace boundary data and LOAs between ACY sector and adjacent facilities. This data was used to create a realistic depiction of the ACY airspace and construct realistic traffic scenarios. It was believed that the efforts invested in creating a realistic simulation of the home sector would motivate participant controllers and increase the credibility of the research results. Using the information obtained from the ACY tower, the airspace was constructed with a few minor deviations from the radar map used in actual operations. Of the six airports in the simulated airspace vicinity, only four were represented because two typically have very little traffic. The ACY airspace is illustrated in figure 4.

The traffic mixture for the ACY airspace was based on information contained in actual flight strips gathered at the tower. Information on the strips contained aircraft call signs, aircraft types, and flight plan information, and databases were formed based on that information. The majority of the flights into and out of ACY sector are general aviation aircraft and the air carriers that do fly into ACY are twin engine commuter aircraft or small transports. No heavy aircraft were included in the traffic mixture since there were none represented in the flight strip database.

Scenarios were constructed that accurately simulated ACY air traffic patterns. Many of the aircraft call signs were familiar to controllers and represented common air carriers that operate in ACY airspace. Most of the aircraft were arriving to, or departing from, ACY. However, a small proportion of the aircraft used the three satellite airports in the sector. A southeast operation was used for all ACY scenarios in that all aircraft landed and departed from runway 13. Aircraft arriving and departing from the satellite airports also employed a southeast operation. All scenarios started with a build-up of traffic during the first 5 minutes controlled by an SME. At 5 minutes, the SME gave the participant controller a relief briefing and then gave control over to the participant controller. Typically, there were at least five aircraft on the scope at this point, with more steadily appearing until the conclusion of the scenario. The scheduled rate of appearance for aircraft was changed to represent either low traffic conditions or extremely busy traffic conditions.

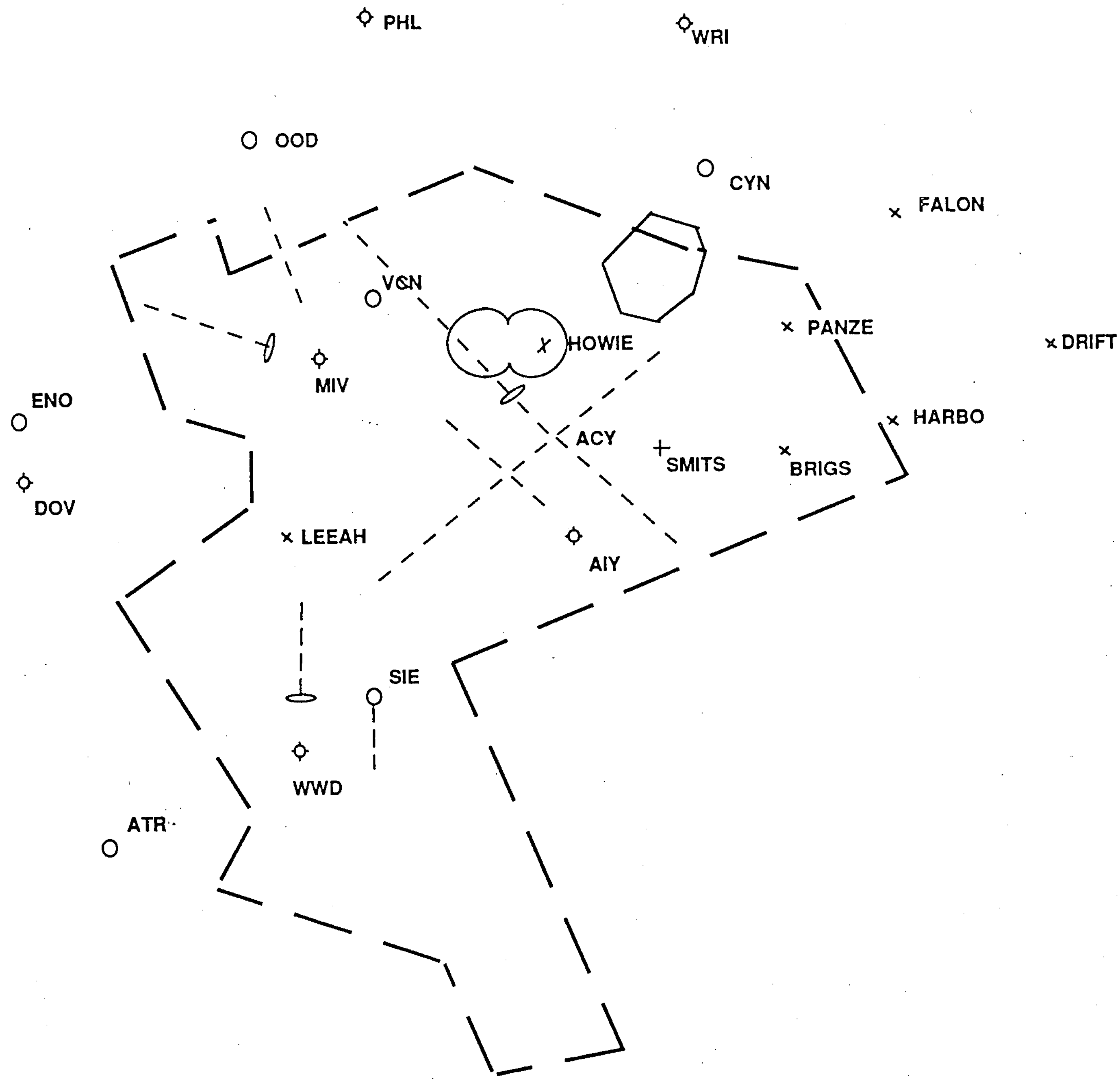

FIGURE 4. ATLANTIC CITY RADAR MAP

3. METHOD.

3.1 PARTICIPANTS.

Eleven air traffic controllers from ACY Tower volunteered for this study and were assured of their anonymity and confidentiality. All participants were FPL controllers with normal or corrected-to-normal vision and had actively controlled traffic for the 12 months prior to the study. A demographic form was completed by each controller to describe the background characteristics of the participants in this study. Controllers ranged in age from 32 to 41 years old (Mean=36.7, SD=3.13) and ranged in experience from 4 to 22 years of active service (Mean=11.3, SD=5.5). Additionally, controllers provided self ratings of four personal attributes that could affect simulation performance. Ratings were indicated on a scale ranging from 1 (low/poor) to 10 (high/good) on each question. The attributes included skill (Mean=8.2, SD=0.92), motivation (Mean=7.8, SD=1.81), and health (Mean=9, SD=0.94). The last attribute was video game experience, which was measured in terms of hours per month (Mean=2.7, SD=3.4). The purpose of the last question was based on a finding with low fidelity simulation that video game experience could have an impact on controller performance. However, such an effect was not anticipated in this high fidelity simulation study.

3.2 SIMULATION FACILITY.

The experiment was conducted in the Human Factors Laboratory (HFL) at the FAA Technical Center in Atlantic City, New Jersey. The experimental apparatus consisted of a state-of-the-art controller work station with a high resolution graphics display, voice communication equipment, networked computer resources, and ATCoach simulation software (copyright UFA INC., 1992). The simulation was conducted by a research psychologist and an ATC specialist who observed the participant in the experiment room. A voice communication link to another experiment room allowed the controller to issue commands to personnel serving as simulation pilots. Two simulation pilots provided realistic voice feedback to the controller and controlled the movement of the radar targets using simple keyboard commands. Additionally, the simulation pilots served as ghost controllers to simulate coordination with controllers in charge of the release of aircraft in Instrument Flight Rules (IFR) airspace. As part of the simulation, flight progress strips were printed and time-ordered in a strip bay prior to the start of each scenario. Figure 5 provides an example of flight strips in a time-ordered sequence. The bold face data block represents the arrival time in minutes into the scenario. During the simulation, audio-visual equipment was used to video record the participant's activities. Video tapes were made of the radar display and of the controller as he or she controlled traffic during the simulation. The audio from the simulation, which included the controller and pseudo-pilot communications, was also recorded on the video tape.

3.3 EXPERIMENTAL DESIGN.

A quasi-experimental approach was the methodology used to answer the experimental questions. Quasi-experimental designs are often used in field research or a field setting where treatments differ on a number of variables and experimental control of a single variable is not possible (Gay, 1994). Such is the case when comparing or correlating performance on sectors where many factors are different.

N217SA DH6C	5554 GEO DOWNY	A0017	IFR DWN

AAL77 B727	6665 NEAST GENNY	A0015	IFR GEN

AWE267 B737	2224 SOUTH GENNY	A0011	IFR GEN

N231XG C500	1213 SOUTH MIDDY	A0009	IFR MID

FIGURE 5. ILLUSTRATION OF FLIGHT STRIPS ARRANGED IN A TIME—ORDERED SEQUENCE

The experimental design is illustrated in table 1. It followed a time-series approach where a number of treatments are ordered chronologically and measurements are taken after each treatment. Each controller participated in 9 scenarios divided between 2 days. The first day was considered a training day where the participant controlled traffic on a low volume ACY scenario, and then controlled traffic on four medium traffic volume generic sector scenarios. The low volume scenario consisted of 30 aircraft in a 60-minute time period. This corresponded to a rate of approximately 7 aircraft entering the scenario every 15 minutes.

TABLE 1. A SUMMARY OF THE EXPERIMENTAL DESIGN.

DAY	SCENARIOS (traffic volume)	
First	1 ACY (low)	4 Generic (medium)
Second	2 ACY (low, high)	2 Generic (low, high)

Each of the 4 generic-sector runs lasted 45 minutes. Each scenario consisted of 15 arrival and 15 departure aircraft. This corresponded approximately to a rate of 10 aircraft entering the scenario every 15 minutes. In addition, the four generic scenarios were matched in terms of the entry times for aircraft into the scenario. This was done to attempt to balance the flow of traffic. However, for a given time slot, the aircraft could be a departure or an arrival. In addition, there was no attempt to systematically order the flight plans in these scenarios, so the traffic pattern in one scenario was not predictable from the traffic patterns in preceding scenarios. These four generic-sector runs were counter-balanced to evenly distribute any differences in difficulty that might exist between the four moderate level scenarios.

The four remaining runs were completed on a second-day session. This was considered a test day since, by this point, the participant had received a full day of hands-on training on the generic sector. Each controller worked two ACY scenarios in the morning, first a 60- minute, low-traffic volume scenario and then a 60-minute high-traffic volume scenario. Each high volume scenario consisted of 22 departure and 22 arrival aircraft. This corresponded to a rate of 11 aircraft entering the scenario every 15 minutes.

Each controller worked two generic sector scenarios in the afternoon, first a 60-minute, low-volume scenario, and then a 60-minute high-volume scenario. These scenarios were matched with the ACY scenarios in terms of the number of arrivals and departures, as well as entry times of aircraft into the scenario. However, the aircraft destinations and flight plans were not systematically ordered, so the traffic patterns were not predictable from working the previous scenario.

The main dependent variables of the experiment can be categorized into four distinct categories of interest. The first category was system effectiveness. The present experiment used a long list of ATC performance measures that have been examined in previous research (Buckley, et al. 1983; Stein & Buckley, 1990). The present study focused on 10 of these system effectiveness variables. They included the number of conflicts, clustering of aircraft, number of communications, number of clearances, and total distance the aircraft flew in the scenario. The second category was controller workload which was assessed using ATWIT and through items on a post-scenario questionnaire. A third category was controller performance as measured by an over-the-shoulder observer using an over-the-shoulder rating form as a measurement tool. This form is depicted as appendix C. It incorporated behavioral-anchored rating scales which provided behavioral examples of poor, medium, and outstanding performance on a number of air traffic controller performance dimensions. These examples correspond, or are anchored, to scales points on a

Likert-type scale. Eight dimensions of the form were used for the over-the-shoulder rating and included the following areas: communication, adaptability and flexibility, managing multiple tasks, and maintaining a safe and efficient traffic flow. The last area of interest was the controller's self-assessment of his or her own performance. This was measured by a post-scenario questionnaire administered immediately after the controller finished the scenario. The self report ratings reflected categories used currently in the terminal and en route centers for performance rating. Dimensions included communication, prioritization, pre-planning, stress, and safety. In addition, an item regarding the degree to which the controller thought he or she could improve with practice was added to examine the controller's self-assessment of mastery on the generic sector. The entire list of dependent measures is presented in table 2.

3.4 PROCEDURE.

A training program was developed to assist controllers in learning the generic sector and the procedures associated with controlling arrival and departure traffic. A manual detailing the operating procedures and LOAs associated with the generic sector was developed. This manual contained detailed maps of the sector layout, as well as altitude restrictions for the arrival and departure airspace, and was provided to the participants before they arrived for their first day session. A copy of the manual is in appendix D.

When controllers arrived at the HFL, they were briefed as to how the experiment was going to be conducted, what was expected from them, and their rights as volunteers. At this point, each controller was asked for their verbal informed consent to participate in the study. Next, controllers completed a demographic form which asked them about their age and experience as an air traffic controller, as well as other variables that might affect their performance in the simulation.

On the first-day session, each controller first worked a one-hour ACY, low traffic volume scenario. After this scenario was completed, an ATC specialist briefed each controller on the generic sector. This briefing included text presentations and visual aids, including a static presentation of the generic sector on the radar screen. The specialist reviewed the LOAs, the fix names, locations, and gate altitudes for the instrument landing system. Each controller was given a chance to ask any questions and then worked the first generic scenario. As controllers worked each scenario, an ATC specialist made over-the-shoulder observations and completed the rating form. After each scenario was finished, controllers completed a self-assessment of their own performance in a Post-Scenario Questionnaire. At the conclusion of the final day of testing, participants were asked to fill out a final questionnaire and were given an opportunity to comment on their experiences.

The presentation order of scenarios and counterbalancing features of the experimental design are illustrated in table 3. All participants completed an ACY low scenario and four generic medium scenarios on their first day of testing. The ordering for the four generic medium scenarios was counterbalanced. On the second day of testing, all participants completed 2 ACY scenarios (low, high) and a 20-minute warm-up on the generic sector. In the afternoon, all participants completed 2 generic sector scenarios (low, high). Each controller completed each scenario only once.

TABLE 2. THE LIST OF DEPENDENT VARIABLES.

System Effectiveness Variables

Cumulative Average of System Activity or Aircraft Density
(Number of aircraft with 10 miles of another aircraft)
Number of Altitude Assignments
Number of Heading Assignments
Number of Speed Assignments
Number of Communications
Duration of Communications
Pseudo-Pilot Keystrokes
Total Time Under Control
Total Distance Flown
Average Arrival Interval

Controller Workload Variables

Air Traffic Workload Input Technique Rating

Over-the-Shoulder Ratings

Communicating and Informing
Managing Multiple Tasks
Technical Knowledge
Reacting to Stress
Maintaining Attention and Vigilance
Prioritizing
Maintaining a Safe and Efficient Traffic Flow
Adaptability and Flexibility

Self-Assessment Rating Categories (Post-Scenario Questionnaire)

Workload
Information Exchange
Attention
Prioritization
Technical Knowledge
Phraseology
Pre-planning
Traffic Flow
Stress
Safety

TABLE 3. THE PRESENTATION ORDER OF SCENARIOS AND COUNTERBALANCING FEATURES OF THE EXPERIMENTAL DESIGN.

Participant	Day 1	Day 2
1	AL1 GM1 GM2 GM3 GM4	AL2 AH1 GL1 GH1
2	AL1 GM2 GM3 GM4 GM1	AL2 AH1 GL1 GH1
3	AL1 GM3 GM4 GM1 GM2	AL2 AH1 GL1 GH1
4	AL1 GM4 GM1 GM2 GM3	AL2 AH1 GL1 GH1
5	AL1 GM1 GM2 GM3 GM4	AL2 AH1 GL1 GH1
6	AL1 GM2 GM3 GM4 GM1	AL2 AH1 GL1 GH1
7	AL1 GM3 GM4 GM1 GM2	AL2 AH1 GL1 GH1
8	AL1 GM4 GM1 GM2 GM3	AL2 AH1 GL1 GH1
9	AL1 GM1 GM2 GM3 GM4	AL2 AH1 GL1 GH1
10	AL1 GM2 GM3 GM4 GM1	AL2 AH1 GL1 GH1
11	AL1 GM3 GM4 GM1 GM2	AL2 AH1 GL1 GH1

AL1 and AL2 are similar low traffic volume ACY scenarios
AH1 is a high traffic volume ACY scenario
GM1 - GM4 are similar medium traffic volume generic sector scenarios
GL1 is a low traffic volume generic sector scenario
GH1 is a high traffic volume generic sector scenario

The method selected to assess controller workload was ATWIT (Stein, 1985). ATWIT provides an unobtrusive and reliable means for collecting participants' ratings of workload as they control traffic. In the present study, a touch screen was used to present the workload rating scale and record the controllers' responses. Controllers were instructed to indicate their current workload by pressing one of the touch screen buttons labeled from 1 (very low) to 10 (very high). The device was configured to query the controller every 5 minutes. The controller had 20 seconds to respond by pressing one of the buttons. If they were too busy to respond within 20 seconds, the maximum workload rating of 10 was recorded by default. In almost every instance, controllers were able to respond within the allotted time.

4. RESULTS.

4.1 OVERVIEW.

The results of this experiment will be reported in sections 4.2 and 4.3. Section 4.2 will discuss analyses conducted on the measures collected on the first-day training sessions. This approach will rely heavily on a one-way Analysis of Variance (ANOVA) on successive trials on the generic sector. This will examine the extent to which system effectiveness variables, workload ratings, and expert assessments of performance changed as the controllers became more familiar with the generic sector.

Section 4.3 results will rely heavily on correlational relationships between the two sectors with respect to system effectiveness variables, workload ratings, and expert assessments of performance. Dependent measures will be analyzed to determine the correlation between performance scores on the generic and home sectors. In addition, these correlations will be broken down by high and low traffic volume. This is done because it has been well established that ATC performance and task load change depends on the volume of traffic (Davis, Danahar, & Fischl, 1963; Buckley, et al., 1976; Buckley, et al., 1983; Stein, 1985; Bisseret, 1971; Coeterier, 1971). In addition, some performance variables may only manifest themselves under certain traffic conditions. For example, the over-the-shoulder rating attribute of managing multiple tasks may not be present in low volume scenarios where the task load is light. However, in high volume scenarios where task load is increased, there may be more of an opportunity for an evaluator to observe the controller performing multiple tasks.

Section 4.4 will summarize the feedback that controllers provided about the experiment, and the results of the final questionnaire will be presented and discussed. The final questionnaire provided another means for evaluating the generic sector since many of the comments centered on how representative the generic sector was of a terminal environment, the effectiveness of the training booklet, the effectiveness of the hands-on training, and the realism of the simulation.

4.2 PRACTICE AND LEARNING EFFECTS ASSOCIATED WITH THE GENERIC SECTOR.

The results of a series of one-way ANOVAs examining system effectiveness variables, ATC performance, and workload is reported in this section. A one-way ANOVA is a formal statistical technique for detecting differences between multiple levels of a single variable. In this portion of the experiment, the independent variable examined is practice as measured by multiple trials. The multiple trials are the four generic sector runs each controller worked. If there are significant differences between the earlier and later trials, with respect to the dependent measures, then the results would strongly suggest that learning occurred. However, lack of a significant result may have multiple interpretations, as the dependent measure may lack sensitivity to learning and more trials may be needed before a learning effect can be detected statistically. The one-way ANOVAs were based on 44 observations (11 participants times 4 scenarios per participant).

The means and results of the one way ANOVAs conducted on the performance measures are reported in table 4. Only a subset of those measures collected were submitted for formal analysis. Many of the measures collected were nearly all zero values, such as number of delays or number of conflicts, or they displayed extremely low variance between controllers. An example of this type of situation is the number of aircraft handled. Nearly every controller handled all the aircraft presented in the traffic sample. Since this was an exploratory study, a probability value of $p < .10$ was used as an indicator for what might appear in a larger sample.

As shown, most of the performance measures showed a high degree of stability and did not significantly change from trial to trial, with the exception of the total distance flown and time under control. These measures were significantly lower in magnitude by the fourth trial. Average ATWIT ratings are also included in this table. These numbers were calculated by averaging the 12 ATWIT ratings for each run to form a summary score for each trial. Planned comparisons of trial one versus trial four showed that average ATWIT ratings were significantly lower in magnitude by the fourth trial ($p < .01$).

TABLE 4. MEANS AND SIGNIFICANCE VALUES FOR SYSTEM EFFECTIVENESS VARIABLES AND ATWIT FOR FOUR MEDIUM GENERIC SECTOR RUNS (N = 11)

VARIABLE	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4.	SIG
CLUSTERING	3.90	3.7	4.05	3.58	N.S.
ALTITUDE CHANGES	60	62	65	61	N.S.
HEADING CHANGES	58	54	58	56	N.S.
SPEED CHANGES	6	6	5	4	N.S.
NO. COMMUNICATIONS	156	151	151	146	N.S.
DUR. COMMUNICATIONS	703	687	706	664	N.S.
PILOT KEYSTROKES	896	874	919	882	N.S.
TIME UNDER CONTROL	17109	17032	17519	16762	$p < .10$
DISTANCE FLOWN (miles)	1047	1041	1078	1025	$p < .05$
ARRIVAL INTERVAL (sec)	153	152	152	155	N.S.
AVERAGE ATWIT RATING	4.90	4.40	4.40	3.80	$p < .01$

N.S. - Not Significant

The means and results of ANOVAs conducted on the over-the-shoulder ratings are presented in table 5. These ratings are based on a 10-point scale where a rating of 1-3 indicates generally poor performance, a rating of 4-7 indicates satisfactory performance, and a rating of 8-10 indicates superior performance. These results also indicate an average satisfactory performance for every performance dimension as measured by the rating form on the generic sector. These ratings did increase slightly over trials for every performance dimension, but not significantly.

The cell means and results of ANOVAs conducted on the post-scenario questionnaire ratings are presented in table 6. These ratings are on a 10-point scale, with the exception of the workload scale which was based on a 12-point scale. Most of the items were phrased in terms of how well the controller performed on a particular dimension with a 1 indicating not very well and a 10 indicating extremely well. Exceptions to the not very well/extremely well dimension include thepractice item which asked the controllers how much they felt they could improve with practice, with a higher score indicating a greater amount of improvement potential. These rating dimensions were adapted from the current FAA over-the-shoulder rating form.

4.3 CORRELATION CO-EFFICIENTS BETWEEN THE GENERIC SECTOR AND ACY SECTOR WITH RESPECT TO PERFORMANCE MEASURES.

The relationship between performance on the generic sector and the ACY sector was assessed through correlational analysis. Scores collected from the ACY sector high- and low-volume traffic runs were correlated with scores from the generic sector high- and low-volume runs, respectively. A correlational analysis is a formal statistical technique for calculating the degree to which two variables relate or covary. The results of the analysis produce a correlation coefficient which ranges form -1.0 to +1.0 and indicates the strength and direction of the relationship between two variables. A coefficient of 0.0 means that no relationship exists, while -1.0 and +1.0 indicates a perfect relationship. A positive coefficient means that as the value of one variable

TABLE 5. MEANS AND SIGNIFICANCE VALUES FOR THE OVER-THE-SHOULDER RATINGS FOR FOUR GENERIC SECTOR RUNS (N=11)

VARIABLE	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	SIGNIFICANCE
COMMUNICATION	5.91	6.18	6.55	6.73	N.S.
MANAGING TASKS	6.27	6.27	6.73	6.82	N.S.
TECH. KNOWLEDGE	6.27	5.82	6.18	6.27	N.S.
STRESS	6.27	6.55	6.55	6.73	N.S.
ATTENTION	6.09	6.18	6.36	6.55	N.S.
PRIORITIZATION	5.64	6.27	6.64	6.55	N.S.
TRAFFIC FLOW	6.00	5.64	6.45	6.36	N.S.
ADAPTABILITY	5.91	6.27	6.45	6.64	N.S.

TABLE 6. MEANS AND SIGNIFICANCE VALUES FOR THE POST-SCENARIO QUESTIONNAIRE RATINGS FOR FOUR GENERIC SECTOR RUNS (N = 11)

VARIABLE	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 1 VS 4
WORKLOAD	6.91	6.64	6.55	5.45	$p < .01$
INFO EXCHANGE	6.45	7.55	7.18	8.27	$p < .01$
ATTENTION	7.09	7.27	7.27	8.09	N.S.
PRIORITIZATION	6.55	7.64	7.64	8.27	$p < .05$
TECH. KNOW.	7.36	7.91	8.00	8.18	N.S.
PHRASEOLOGY	7.27	7.91	7.45	8.36	$p < .01$
PRE-PLANNING	6.55	7.27	7.45	8.18	$p < .01$
TRAFFIC FLOW	7.00	7.64	7.18	8.09	$p < .05$
STRESS	5.55	5.55	6.09	4.18	N.S.
SAFETY	7.55	7.55	7.55	8.45	N.S.
PRACTICE	7.36	6.73	6.27	5.27	$p < .05$

increases the value of the second variable increases as well. A negative coefficient means that as the value of one variable increases the value of the other variable decreases. Strong significant correlation co-efficients suggest that performance on the generic sector is related to performance on the "home" sector. Specifically, a high positive correlation indicates that if a controller performed well on a performance dimension on the generic sector, he or she also performed well on this dimension for the ACY sector. This same correlation would also indicate that if a controller did not perform well on a performance dimension on the generic sector, he or she also did not perform well on this dimension for the ACY sector.

Table 7 shows the results for 10 of the system effectiveness variables measured in the simulation. This table also includes average ATWIT ratings. The results show significant correlations for the number of altitude changes and for the duration of communications for the high-volume runs and the number of altitude changes and the number of simulation pilot keystrokes for the low-volume runs. In addition, when high and low traffic volume runs are averaged, the average scores are

TABLE 7. CORRELATION CO-EFFICIENTS AND SIGNIFICANCE VALUES FOR SYSTEM EFFECTIVENESS VARIABLES FOR ACY AND GENERIC SECTORS

VARIABLE	HIGH VOLUME (N = 10)	LOW VOLUME (N = 9)	AVERAGED (N = 9)
CLUSTERING	- 0.12	0.39	0.52
ALTITUDE CHANGES	0.63**	0.80*	0.84*
HEADING CHANGES	0.11	-0.19	0.07
SPEED CHANGES	0.46	0.47	0.63***
NO. COMMUNICATIONS	0.50	0.57	0.74**
DUR. COMMUNICATIONS	0.58***	0.27	0.74**
NO. PILOT KEYSTROKES	0.20	0.76**	0.49
TIME UNDER CONTROL (sec)	0.08	0.61***	0.33
DISTANCE FLOWN (miles)	0.09	0.58***	0.37
AVERAGE ATWIT	0.80*	0.90*	0.90*

* $p < .01$
** $p < .05$
*** $p < .10$

correlated for each system effectiveness variable. These correlation co-efficients are much higher and more consistent across the variables then for the high or low volume data, respectively. Correlation co-efficients which could be significantly different from zero with a $p < .10$ were included, since this was an exploratory study.

Table 8 shows the results from the correlational analyses from the over-the-shoulder rating form (appendix C). For the high-volume runs, five of the eight rating categories are significantly correlated, indicating a positive relationship between performance on the ACY sector and the generic sector. The significant correlation co-efficients range from r=.64 to r=.80, indicating a moderate to high relationship between performance on these sectors. For the low volume runs, only the communication category was significantly related.

TABLE 8. CORRELATION CO-EFFICIENTS AND SIGNIFICANCE VALUES FOR OVER-THE-SHOULDER RATINGS FOR ACY AND GENERIC SECTORS

VARIABLE	HIGH VOLUME (N = 10)	LOW VOLUME (N = 10)
COMMUNICATION	0.71**	0.68**
MANAGING TASKS	0.80*	0.00
TECHNICAL KNOWLEDGE	0.59	0.25
STRESS	0.64**	0.40
ATTENTION & VIGILANCE	0.64**	0.16
PRIORITIZATION	0.39	-0.38
TRAFFIC FLOW	0.38	-0.19
ADAPTABILITY	0.71**	0.71

* $p < .01$
** $p < .05$

Table 9 shows the results from the correlational analyses from the post-scenario questionnaire ratings that the controllers completed at the end of each scenario run. These rating categories were derived from the current FAA over-the-shoulder rating form. The results indicate high positive correlation co-efficients for every rating category with the exception of prioritization for the high-volume runs. Five of the categories were significantly correlated for the low-volume runs.

TABLE 9. CORRELATION CO-EFFICIENTS AND SIGNIFICANCE VALUES FOR THE POST-SCENARIO QUESTIONNAIRE RATINGS FOR ACY AND GENERIC SECTORS

VARIABLE	HIGH VOLUME (N = 10)	LOW VOLUME (N = 10)
WORKLOAD	0.77*	0.72**
INFO EXCHANGE	0.91*	0.50
ATTENTION	0.66*	0.30
PRIORITIZATION	0.44	0.38
TECH. KNOWLEDGE	0.75*	0.54
PHRASEOLOGY	0.85*	0.72*
PRE-PLANNING	0.86*	0.85*
TRAFFIC FLOW	0.91*	0.80*
STRESS	0.71**	0.51
SAFETY	0.72**	0.74**
PRACTICE	0.66**	0.54

* p < .
** p < .05

4.4 FINAL QUESTIONNAIRE COMMENTS ON THE ENTIRE EXPERIMENT.

A final questionnaire was administered to each controller at the end of their second day session. The questions requested information concerning the realism of the simulation and the effectiveness of the training aids developed for this experiment. These comments are summarized in table 10. As far as the realism of the simulation, the majority (8 of 10 responses) thought the simulation was very realistic. The remaining two controllers thought that, for the most part, the simulation was realistic. The majority of the controllers thought the generic sector was representative of a typical terminal environment (6 of 10 responses). The training booklet received a somewhat mediocre review. A number of controllers thought that there was more information than needed, although it was helpful for learning the frequencies and general airspace layout. All controllers responded positively to the hands-on training session they received during the first day session. The questions and a complete summary of the responses are listed in appendix E.

TABLE 10. FINAL QUESTIONNAIRE COMMENTS ON THE GENERIC SECTOR SIMULATION

Realism of the simulation	Number of Controllers Commenting
Very realistic	7
For the most part realistic	2
About 90% realistic	1
Representative of a typical sector	Number of Controllers Commenting
Very representative	5
O.k. somewhat typical	3
Not too typical	1
No comment	1
Helpfulness of the training booklet	Number of Controllers Commenting
Very helpful	1
Somewhat helpful	4
Not very helpful	3
Didn't look at it	2
Adequacy of the hands-on-training	Number of Controllers Commenting
Yes, it was adequate	10
No, it wasn't adequate	0
Responsiveness of the pseudo-pilots	Number of Controllers Commenting
Excellent job	3
Very good job	4
Good job	2
Fair job	1
Intrusiveness of the ATWIT device	Number of Controllers Commenting
Yes, it did interfere with operations	0
No, it did not interfere with operations	10

5. SUMMARY AND CONCLUSIONS.

5.1 DISCUSSION OF LEARNING RATE FOR THE GENERIC SECTOR.

Learning rate for the generic sector can be inferred from differences in the performance scores over trials on the first day for the four performance measurement categories. Air Traffic Workload Input Technique (ATWIT) data provided the strongest support for learning with significantly lower ATWIT scores by the last trial. One explanation for this finding is that many features of the sector became more familiar as controllers went though the multiple runs. Specifically, controllers learned the fix locations, the routes, the typical flight plans, and landing altitudes. As this information was learned, it became more automatic, and therefore, the controller did not have to expend as much energy thinking about these sector features as they did during the initial runs.

Two system effectiveness variables, total time under control and total distance flown, were significantly lower by the last generic run. One possible explanation for these results is that arrival aircraft were being handled more efficiently on the last run. This efficiency was accomplished by closer turn-ons to final and better control techniques in spacing arrivals on the localizer.

Post-scenario questionnaire ratings for information exchange, prioritization, and pre-planning were also significantly higher by the last generic run. Questionnaire ratings of workload and stress were significantly lower by the last generic run. These results also support the idea that controllers became more familiar with the features of the generic sector in the later runs. By the last run, when controllers had learned the fixes, flight plans, and routes, they were better able to perform strategic functions such as prioritization and pre-planning. Lower workload and stress were a result of familiarity, better planning, and prioritization in the later runs.

The fact that performance indicators did not change appreciably over the four runs is considered a positive finding since Genera was designed for ease of implementation. Controllers were able to learn it very quickly and work traffic with no major complications. Ideally, a generic sector should not pose hurdles, but rather it should facilitate performance. This sector did just that.

5.2 DISCUSSION OF CORRELATIONS BETWEEN PERFORMANCE SCORES ON THE HOME SECTOR AND THE GENERIC SECTOR.

Three of the four performance categories showed high and consistent correlations between the home and Atlantic City International Airport (ACY) sectors. These categories were ATWIT ratings, over-the-shoulder ratings, and post-scenario questionnaire ratings. These relationships suggest that controller timing, communication, and task management were basically the same regardless of the sector configuration. Workload, as measured by ATWIT, was also highly correlated between the two sectors for both high and low traffic runs. This result suggests that once the sector was learned, the task load was basically the same regardless of the sector configuration. The results indicated that controller performance, as measured by ratings and self-report measures of workload, was very similar in both sector configurations.

The automated System Effectiveness Measure (SEM) variables showed low to moderate correlations between the home and generic sectors. This could mean that there are low relationships between SEMs for the two sectors, given the small sample sizes and limited number of runs. Given the fact that the majority of other data does correlate, a more likely hypothesis is that more data is needed before the SEMs will provide significant correlations. Support for this idea is provided by the correlational analyses which used data which was averaged over the high and low traffic trials. These correlation co-efficients are larger in magnitude than correlation co-efficients using the segregated high and low traffic volume data.

There is another more logical explanation as to why the correlations were not higher than they were. The researchers on this project may have tried too hard to make the generic sector all it could be. They were concerned with its generalizability to other contexts and felt that it would be enough if it was similar to the home sector and could evoke relatively comparable performance patterns. The traffic scenarios were developed using the Official Airline Guide as compared to those for the home sector that were based on the actual traffic seen at ACY. In an effort to create the ultimate terminal generic sector, they may have inadvertently created differences between the home sector and generic runs that lowered the performance relationships. This was a classic design artifact, and it was fortunate that the correlations were as high as they were. In a follow up study, subject matter experts and supervisory controllers rated 20 hours of video-taped performance from this study. They used a new evaluation form developed for reliability and validity. The experts were able to transcend the artificial air traffic scenario differences, and they identified much higher relationships across home and generic sectors. This follow-on study will be reported at a later date.

In general, these findings support the idea that a generic sector, once learned, can be used as a performance measurement tool even though it may have different physical features from the controller's home sector.

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APPENDIX A

LETTERS OF AGREEMENT BETWEEN GENERIC SECTOR AND ADJACENT AIRPORTS

Effective: 1 November 1994

SUBJECT: Tower En Route Control (TEC)

TO: Genera International Airport
Texas Regional Airport

1. PURPOSE. This agreement defines Genera International Airport and Texas Regional Airport procedures for Instrument Flight Rule (IFR) TEC.

2. SCOPE. The TEC procedures contained herein shall apply unless prior coordination is affected. These procedures are effective only with operational radar. TEC will be on an approval request basis if either facility's radar is out of service.

3. PROCEDURES.

a. TEC is limited to flights landing and taking off within both approach control's airspace.

b. Radar handoffs are mandatory prior to entering the receiving facility's area, either by automated procedures or manually via interphone. Transfer of control releases control for turns of up to 30 degrees from assigned heading.

c. Transfer Control Points (TCPs):

1) The TCPs, with associated routes, altitudes, and frequencies for TEC, are listed below and depicted on attachment 1

d. Flow Control.

1) Initiate, update ,and relay essential information between facilities to establish and ensure an acceptable TEC traffic flow.

2) When flow control restrictions have been imposed within the TEC structures, concerned facilities shall inform adjacent locations.

3) Verbal approval requests shall be required prior to releasing aircraft on the ground when delays are in effect.

4. COORDINATION. All advance flight coordination shall be via automated flight progress strips. In the event of NAS computer failure, the aircraft identification, type aircraft, discrete transponder code, route destination airport, and altitude shall have been relayed to the receiving facility prior to initiating a handoff.

TEXAS TO GENERA (TERMINAL EN ROUTE CONTROL)

TCP	ROUTE	ALTITUDES	FREQUENCY
TGNXA	TEX GENNY GEN	3000/5000	127.5
TGNXA	TEX MIDDY MID	3000/5000	127.5
TGNXA	TEX UPPTY UPT	3000/5000	127.5
TGNXA	TEX DOWNY DWN	3000/5000	127.5

GENERA TO TEXAS (TERMINAL EN ROUTE CONTROL)

TCP	ROUTE	ALTITUDES	FREQUENCY
WESTD	GEN WESTD TEX	4000/6000	128.0
WESTD	UPT WESTD TEX	4000/6000	128.0
WESTD	MID WESTD TEX	4000/6000	128.0
WESTD	DWN WESTD TEX	4000/6000	128.0

5. ATTACHMENT

Attachment 1.---Transfer of Control Points, Arrival/Departure Routes and Frequencies.

EDWARD BUCKLEY
Manager, Genera International Airport

EARL STEIN
Manager, Texas Regional Airport

LETTER OF AGREEMENT

Effective: 1 November 1994

SUBJECT: Tower En Route Control (TEC)

TO: Genera International Airport
Georgia Regional Airport

1. PURPOSE. This agreement defines Genera International Airport and Georgia Regional Airport procedures for Instrument Flight Rule (IFR) TEC.

2. SCOPE. The TEC procedures contained herein shall apply unless prior coordination is effected. These procedures are effective only with operational radar. TEC will be on an approval request basis if either facility's radar is out of service.

3. PROCEDURES.

a. TEC is limited to flights landing and taking off within both approach control's airspace.

b. Radar handoffs are mandatory prior to entering the receiving facility's area, either by automated procedures or manually, via interphone. Transfer of control releases control for turns of up to thirty (30) degrees from assigned heading.

c. Transfer Control Points (TCPs):

1) The TCPs, with associated routes, altitudes and frequencies for TEC are listed below and depicted on attachment 1.

GEORGIA TO GENERA (TERMINAL EN ROUTE CONTROL)

TCP	ROUTE	ALTITUDES	FREQUENCY
GGNXA	GEO GENNY GEN	3000/5000	128.5
GGNXA	GEO DOWNY DWN	3000/5000	128.5
GGNXA	GEO MIDDY MID	3000/5000	128.5
GGNXA	GEO GEN UPPTY UPT	3000/5000	128.5

GENERA TO GEORGIA (TERMINAL EN ROUTE CONTROL)

TCP	ROUTE	ALTITUDES	FREQUENCY
SWEDD	GEN SWEDD GEO	4000/6000	129.0
SWEDD	DWN SWEDD GEO	4000/6000	129.0
SWEDD	MID SWEDD GEO	4000/6000	129.0
SWEDD	UPT SWEDD GEO	4000/6000	129.0

5. <u>ATTACHMENT</u>

Attachment 1.---Transfer of Control Points, Arrival/Departure Routes, and Frequencies.

EDWARD BUCKLEY
Manager, Genera International Airport

PAUL STRINGER
Manager, Georgia Regional Airport

GEO/GEN TWR LOA EFFECTIVE: NOVEMBER 1, 1994

LETTER OF AGREEMENT

Effective: 1 November 1994

SUBJECT: Tower En Route Control (TEC)

TO: Genera International Airport
Maine Regional Airport

1. PURPOSE. This agreement defines Genera International Airport and Maine Regional Airport procedures for Instrument Flight Rule (IFR) TEC.

2. SCOPE. The TEC procedures contained herein shall apply unless prior coordination is effected. These procedures are effective only with operational radar. TEC will be on an approval request basis if either facility's radar is out of service.

3. PROCEDURES.

a. TEC is limited to flights landing and taking off within both approach controls' airspace.

b. Radar handoffs are mandatory prior to entering the receiving facility's area, either by automated procedures or manually, via interphone. Transfer of control releases control for turns of up to thirty (30) degrees from assigned heading.

c. Transfer Control Points (TCPs):

1) The TCPs, with associated routes, altitudes, and frequencies for TEC are listed below and depicted on ATTACHMENT 1.

MAINE TO GENERA (TERMINAL EN ROUTE CONTROL)

TCP	ROUTE	ALTITUDES	FREQUENCIES
MGNXA	MAI GENNY GEN	3000/5000	129.5
MGNXA	MAI GEN DOWNY DWN	3000/5000	129.5
MGNXA	MAI MIDDY MID	3000/5000	129.5
MGNXA	MAI UPPTY UPT	3000/5000	129.5

GENERA TO MAINE (TERMINAL EN ROUTE CONTROL)

TCP	ROUTE	ALTITUDES	FREQUENCIES
NEAST	GEN NEAST MAI	4000/6000	130.0
NEAST	DWN GEN NEAST MAI	4000/6000	130.0
NEAST	MID NEAST MAI	4000/6000	130.0
NEAST	UPT NEAST MAI	4000/6000	130.0

d. Flow Control.

1) Initiate, update, and relay essential information between facilities to establish and ensure an acceptable TEC traffic flow.

2) When flow control restrictions have been imposed within the TEC structures, concerned facilities shall inform adjacent locations.

3) Verbal approval requests shall be required prior to releasing aircraft on the ground when delays are in effect.

4. COORDINATION. All advanced flight coordination shall be via automated flight progress strips. In the event of National Airspace System (NAS) computer failure, the aircraft identification, type of aircraft, discrete transponder code, route destination airport, and altitude shall have been relayed to the receiving facility prior to initiating a handoff.

5. ATTACHMENT

Attachment 1.---Transfer of Control Points, Arrival/Departure Routes, and Frequencies.

EDWARD BUCKLEY
Manager, Genera International Airport

JERRY GUTTMAN
Manager, Maine Regional Airport

LETTER OF AGREEMENT

Effective: 1 November 1994

SUBJECT: Tower En Route Control (TEC)

TO: Genera International Airport
Atlantic Regional Airport

1. PURPOSE. This agreement defines Genera International Airport and Atlantic Regional Airport procedures for Instrument Flight Rule (IFR) TEC.

2. SCOPE. The TEC procedures contained herein shall apply unless prior coordination is effected. These procedures are effective only with operational radar. TEC will be on an approval request basis if either facility's radar is out of service.

3. PROCEDURES.

a. TEC is limited to flights landing and taking off within both approach control's airspace.

b. Radar handoffs are mandatory prior to entering the receiving facility's area, either by automated procedures or manually, via interphone. Transfer of control releases control for turns of up to thirty (30) degrees from assigned heading.

c. Transfer Control Points (TCPs):

1) The TCPs, with associated routes, altitudes, and frequencies for TEC are listed below and depicted on ATTACHMENT 1.

ATLANTIC TO GENERA (TERMINAL EN ROUTE CONTROL)

TCP	ROUTE	ALTITUDES	FREQUENCY
AGNXA	ALT GENNY GEN	3000/5000	130.5
AGNXA	ALT DOWNY DWN	3000/5000	130.5
AGNXA	ALT GEN MIDDY MID	3000/5000	130.5
AGNXA	ALT UPPTY UPT	3000/5000	130.5

GENERA TO ATLANTIC (TERMINAL EN ROUTE CONTROL)

TCP	ROUTE	ALTITUDES	FREQUENCY
EASTD	GEN EASTD ALT	4000/6000	131.0
EASTD	DWN EASTD ALT	4000/6000	131.0
EASTD	MID GEN EASTD ALT	4000/6000	131.0
EASTD	UPT EASTD ALT	4000/6000	131.0

d. Flow Control.

1) Initiate, update, and relay essential information between facilities to establish and ensure an acceptable TEC traffic flow.

2) When flow control restrictions have been imposed within the TEC structures, concerned facilities shall inform adjacent locations.

3) Verbal approval requests shall be required prior to releasing aircraft on the ground when delays are in effect.

4. COORDINATION. All advanced flight coordination shall be via automated flight progress strips. In the event of NAS computer failure, the aircraft identification, type aircraft, discrete transponder code, route destination airport, and altitude shall have been relayed to the receiving facility prior to initiating a handoff.

5. ATTACHMENT

Attachment 1.---Transfer of Control Points, Arrival/Departure Routes, and Frequencies.

EDWARD BUCKLEY
Manager, Genera International Airport

DENNIS FILLER
Manager, Atlantic Regional Airport

APPENDIX B

LETTERS OF AGREEMENT BETWEEN GENERIC SECTOR AND EN ROUTE CENTERS

NORTH CENTRAL CENTER AND GENERA INTERNATIONAL AIRPORT LETTER OF AGREEMENT

Effective: November 1, 1994

SUBJECT: APPROACH CONTROL SERVICE

1. PURPOSE: To establish Genera Approach Control boundaries and define the coordination necessary to exercise approach control service.

2. DELEGATION OF AUTHORITY: North Central Center (ZNC) delegates to Genera Tower (GEN) authority and responsibility for control of Instrument Flight Rule (IFR) arrival, departure, and tower en route aircraft in controlled airspace within the Approach Control Area, as described herein.

3. SCOPE: The procedures contained herein shall apply unless prior coordination has been effected.

4. GENERAL: Minimum separation between aircraft when transfer of control is accomplished shall be at least 5 miles constant or increasing.

5. RADAR HANDOFFS: Radar handoffs are mandatory prior to the aircraft entering the receiving facilities' airspace.

6. COORDINATION: Verbal coordination is not required for any aircraft having an Automated Terminal Radar System (ARTS)- or Flight Data Entry Printout (FDEP)- generated flight plan. In the event of ZNC computer or GEN FDEP failure, the receiving facility shall be informed of the incoming or outgoing flights flight plan well in advance of the flights arrival or departure.

7. PROCEDURES:

   a. DEPARTURE CONTROL

      1) GEN Approach Control shall initiate departure clearances to all aircraft without calling the center.

      2) GEN shall clear departure aircraft to altitudes within the Approach Control Airspace (17000 and below).

      3) Departure aircraft shall be established on assigned routes by GEN prior to penetrating ZNC airspace, as shown on Attachment 1.

      4) Aircraft requesting altitude/flight level above the initial clearance altitude (17000) shall be told to expect further clearance to requested altitude/flight level ten (10) minutes after departure.

b. ARRIVAL CONTROL

1) All arrivals shall be assigned airport clearances via routings depicted in Attachment 2.

EXCEPTIONS:

a) When GEN radar is inoperative.
b) When arrival delays are anticipated.

2) All arrivals shall be cleared to descend to 8000 providing radar handoff and communications transfer is made prior to the arrival aircraft entering GEN airspace.

3) The tower shall have control for descent and 30 degree turns right or left of course after transfer of control has been accomplished.

4) All arrival aircraft shall have a speed restriction of 250 kt when the hourly arrival rate exceeds 25 aircraft.

8. ATTACHMENTS:

a. Attachment 1--- Departure routes, Frequencies, and Transfer of Control Points.
b. Attachment 2--- Arrival routes, Frequencies, and Transfer of Control Points.

ED BUCKLEY
Air Traffic Manager
Genera International Tower

KATHY MANN
Air Traffic Manager
North Central Center

SOUTH CENTRAL CENTER AND GENERA INTERNATIONAL AIRPORT
LETTER OF AGREEMENT

Effective: November 1, 1994

SUBJECT: APPROACH CONTROL SERVICE

1. PURPOSE: To establish Genera Approach Control boundaries and define the coordination necessary to exercise approach control service.

2. DELEGATION OF AUTHORITY: South Central Center (ZSC) delegates to Genera Tower (GEN), authority and responsibility for control of IFR arrival, departure and tower en route aircraft in controlled airspace within the Approach Control Area as described herein.

3. SCOPE: The procedures contained herein shall apply unless prior coordination has been effected.

4. GENERAL: Minimum separation between aircraft when transfer of control is accomplished shall be at least five (5) miles constant or increasing.

5. RADAR HANDOFFS: Radar handoffs are mandatory prior to the aircraft entering the receiving facilities' airspace.

6. COORDINATION: Verbal coordination is not required for any aircraft having an ARTS or FDEP generated flight plan. In the event of ZSC computer or GEN FDEP failure, the receiving facility shall be informed of the incoming or outgoing flights flight plan well in advance of the flights arrival or departure.

7. PROCEDURES:

a. DEPARTURE CONTROL

1) GEN Approach Control shall initiate departure clearances to all aircraft without calling the center.

2) GEN shall clear departure aircraft to altitudes within the Approach Control Airspace (17000 and below).

3) Departure aircraft shall be established on assigned routes by GEN prior to penetrating ZSC airspace as shown on Attachment 1.

4) Aircraft requesting altitude/flight level above the initial clearance altitude (17000) shall be told to expect further clearance to requested altitude/ flight level ten (10) minutes after departure.

b. <u>ARRIVAL CONTROL</u>

1) All arrivals shall be assigned airport clearances via routings depicted in attachment 2.

<u>EXCEPTIONS:</u>

a) When GEN radar is inoperative.

b) When arrival delays are anticipated.

2) All arrivals shall be cleared to descend to (8000) providing radar handoff and communications transfer is made prior to the arrival aircraft entering GEN airspace.

3) The tower shall have control for descent and 30 degree turns right or left of course after transfer of control has been accomplished.

4) All arrival aircraft shall have a speed restriction of 250 kt when the hourly arrival rate exceeds 25 aircraft.

8. <u>ATTACHMENTS:</u>

a. Attachment 1 --- Departure Routes, Frequencies and Transfer of Control Points.

b. Attachment 2 --- Arrival routes, Frequencies and Transfer of Control Points.

ED BUCKLEY
Air Traffic Manager
Genera International Tower

RANDY SOLLENBERGER
Air Traffic Manager
South Central Center

APPENDIX C

SACHA OVER-THE-SHOULDER RATING FORM

ID# ____________

SCENARIO # ____________

COMMUNICATING AND INFORMING

USES CLEAR CONCISE ACCURATE LANGUAGE TO GET MESSAGE ACROSS UNAMBIGUUOUSLY, TALKING ONLY WHEN NECESSARY AND APPROPRIATE; EMPLOYING PROPER PHRASEOLOGY TO ENSURE ACCURATE COMMUNICATION ; NOTIFYING PILOTS/CONTROLLERS/OTHER PERSONNEL OF INFORMATION THAT MIGHT AFFECT THEM AS APPROPRIATE; ISSUING ADVISORIES AND ALERTS TO APPROPRIATE PARTIES; LISTENING CAREFULLY TO REQUESTS AND INSTRUCTIONS AND ENSURING THAT THEY ARE UNDERSTOOD; ATTENDING TO READBACKS AND ENSURING THAT THEY ARE ACCURATE.

Is consistently too wordy, imprecise in phraseology, or uses slang inappropriately during transmissions to pilots and other controllers	Radio and interphone communications are usually easy to understand; at times, may be somewhat wordy or use ambiguous phraseology on the air	Always uses clear, consise phraseology when talking to pilots or other controllers; is very easy to understand
Is careless about informing pilots concerning circumstances that affect them such as weather, nearby traffic etc.	Is normally good at informing pilots about situations and conditions that affect them (e.g. safety related items)	Consistently provides pilots with the information they need such as timely safety alerts, weather advisories, warnings about unpublished obstructions
Often fails to ensure that own instructions are understood; is not very good at picking up on errors in pilot readbacks of clearances, course changes, etc.	For the most part checks to be certain that own instructions are understood; only occasionally fails to pick up on inaccurate readbacks from pilots	Always ensures that own instructions are clearly understood; pays careful attention to pilot readbacks of clearances

1 2 3	4 5 6 7	8 9 10

MANAGING MULTIPLE TASKS

KEEPING TRACK OF A LARGE NUMBER OF AIRCRAFT/EVENTS AT ONE TIME; CONDUCTING TWO OR MORE TASKS SIMULTANEOUSLY ; REMEMBERING AND KEEPING TRACK OF AIRCRAFT AND THEIR POSITIONS; REMEMBERING WHAT YOU WERE DOING AFTER AN INTERRUPTION; RETURNING TO WHAT YOU WERE DOING AFTER AN INTERRUPTION AND FOLLOWING THROUGH; PROVIDING PILOTS WITH ADDITIONAL SERVICES AS TIME ALLOWS

Has difficulty keeping track of several aircraft at the same time may focus too narrowly on some aircraft while ignoring others	Keeps on top of movement of several aircraft simultaneously while also dealing with routine communication. When very busy may have to simplify the situation to reduce the number of things attended to.	Is extremely adept at keeping track of many aircraft while at the same time handling pilot communications, strip work, etc.
Is ineffective at performing multiple tasks simultaneously prefers to take one thing at a time	Is good at performing two or sometimes more routine tasks at the same time (e.g. monitoring the screen, talking with pilots and handling strips)	Is fully capable of performing two or more complex tasks simultaneously.
Interruptions and distractions often cause him/her to forget about some of the immediate air traffic problems; may be slow in recalling what he/she intended to before the interrupt	After an interruption, can usually handle the air traffic problems remaining from prior to the interruption successfully.	After an interruption, always quickly remembers where aircraft are or should be, what he or she was doing with the traffic before the interruption, and the intended control strategy

1 2 3	4 5 6 7	8 9 10

TECHNICAL KNOWLEDGE

KNOWING THE EQUIPMENT AND ITS CAPABILITIES AND USING IT EFFECTIVELY; KNOWING AIRCRAFT CAPABILITIES LIMITATIONS (SPEED, WAKE REQUIREMENTS) AND USING THAT KNOWLEDGE; KEEPING UP-TO-DATE ON LETTERS OF AGREEMENT, CHANGES IN PROCEDURES, REGULATIONS, ETC. KEEPING UP-TO-DATE ON SELDOM USED PROCEDURES OR SKILLS

At times, may not remain current on new letters of agreement, revised air traffic procedures, etc.	Is usually knowledgeable about and up-to-date on all information relevant to controlling traffic (e.g. letters of agreement, air traffic procedures, etc.)	Always keeps up-to-date on letters of agreement, all pertinent procedures and policies, any sector-specific changes (e.g. revised boundaries)
Has basic knowledge of most aircrafts' capabilities, but may make errors related to not knowing aircraft limitations	Has good knowlege of different aircraft capabilities and applies that knowledge to avoid most errors associated with not knowing aircraft limitations.	Has thorough knowledge of different aircraft capabilities and as a result never makes errors such as climbing an aircraft beyond its limits, making an inappropriate speed assignment, or requiring an impossibly tight turn.
May be unfamiliar with some of his/her equipment and how it works	Is reasonably familiar with his/her eqipment and how it works	Is extremely knowledgeable about and familiar with his/her equipment and how it functions

1 2 3	4 5 6 7	8 9 10

REACTING TO STRESS

REMAINING CALM AND COOL UNDER STRESSFUL SITUATIONS; HANDLING STRESSFUL AIR TRAFFIC CONDITIONS IN A PROFESSIONAL MANNER

Becomes shaken and ineffective in emergency situations.	Remains calm and cool to most emergency situations	Remains very calm and cool and reacts effectively even in very serious emergency situations such as aircraft in-flight emergencies, lost pilots etc.
Reacts poorly and performance suffers under stressful air traffic conditions	Stays, calm , focused and functional under busy conditions; may be somewhat less effective in very stressful air traffic situations	Stays calm, focused and very functional in busy and very stressful conditions
Does not function effectively when equipment/system problems arise	Shows professional cool in handling routine equipment/ system problems	Handles even serious equipment/system degradation probelms with professional cool

1	2	3	4	5	6	7	8	9	10

MAINTAINING ATTENTION AND VIGILANCE

SCANNING PROPERLY FOR AIR TRAFFIC EVENTS, SITUATIONS, POTENTIAL PROBLEMS ETC. KEEPING TRACK OF EQUIPMENT WEATHER STATUS ; IDENTIFYING UNUSUAL EVENTS, IMPROPER POSITIONING OF AIRCRAFT. RECOGNIZING WHEN AIRCRAFT HAVE POTENTIAL FOR LOSS OF SEPARATION; VERIFYING VISUALLY THAT CONTROL INSTRUCTIONS ARE FOLLOWED, REMAINING VIGILANT DURING SLOW PERIODS

Has a tendency to focus too narrowly on one air traffic problem and sometimes fails to recognize other potential problems with conflictions, traffic flow etc.	For the most part, properly scans the scope and monitors aircraft to maintain awareness of air traffic events, potential problems etc.	Consistently recognizes potentially dangerous conditions such as errors made by pilots (i.e. wrong turns, descending through assigned altitude)
Often does not recognize that an action is required; is often lax in watching the radar scope and tends to signficantly reduce vigilance during slow periods	Is attentive to the radar scope and maintains vigilance, especially during rush periods; may sometimes be inattentive when traffic is light	Always checks and verifies that clearances and other instructions to pilots are followed; remains highly vigilant even during slow periods.
Has problems remembering that an action was taken or that an action is required	Seldom forgets own actions taken or that an action is required	Is very good at remembering own actions taken or that an action is required (i.e. change of course to avoid restricted area)

1	2	3	4	5	6	7	8	9	10

PRIORITIZING

TAKING EARLY OR PROMPT ACTION ON AIR TRAFFIC PROBLEMS RATHER THAN WAITING OR GETTING BEHIND KNOWING WHAT TO DO FIRST AND IDENTIFYING THE MOST IMPORTANT SITUATIONS; RECOGNIZING THAT SOME PROBLEMS OR SITUATIONS ARE LESS IMPORTANT AND CAN WAIT; PREPLANNING BEFORE BUSY PERIODS; ORGANIZING THE BOARD AND USING FLIGHT STRIPS EFFECTIVELY TO KEEP PRIORITIES STRAIGHT FOR HANDLING AIR TRAFFIC SITUATIONS QUICKLY AND DECISIVELY DETERMINING APPROPRIATE PRIORITIES.

Has difficulty recognizing which air traffic problems are the most pressing; may deal with problems in chronological order, or take the easy ones first.	Usually recognizes the most important air traffic problems and handles them before the less pressing ones	Always recognizes which air traffic problems need immediate attention and handles them before less pressing ones; recognizes appropriate priorities for control actions
Often acts on air traffic problems without evaluating the possible consequences of these actions	Normally looks ahead to assess potential air traffic problems that might result from own actions or from changing conditions.	Is very good at looking ahead to assess potential problems that might result from revised clearances, aircraft counts or altitude changes
Often puts off decisions or actions that should be taken right away	Is usually good about taking early or prompt action on air traffic problems; may sometimes put off a decision or an aciton that should be attended to immediately	Consistently takes early or prompt action on air traffic problems

1 2 3	4 5 6 7	8 9 10

MAINTAINING SAFE AND EFFICIENT TRAFFIC FLOW

REACTING TO AND RESOLVING POTENTIAL CONFLICTIONS EFFECTIVELY AND EFFICIENTLY; USING PROPER AIR TRAFFIC SEPARATION TECHNIQUES EFFECTIVELY TO ENSURE SAFETY; SEQUENCING AIRCRAFT EFFECTIVELY FOR ARRIVAL OR DEPARTURE; SEQUENCING AIRCRAFT TO ENSURE EFFICIENT/TIMELY TRAFFIC FLOW; CONTROLLING TRAFFIC IN A MANNER THAT ENSURES EFFICIENT TRAFFIC FLOW; CONTROLLING TRAFFIC IN A MANNER THAT MINIMIZES TRAFFIC PROBLEMS (E.G. CONFLICTIONS, TRAFFIC FLOW PROBLEMS) FOR OTHER CONTROLLERS AND PILOTS

Sometimes fails to maintain minimum separation or to recognize and resolve potential conflictions	Typically uses appropriate control actions to maintain proper separation or to resolve potential conflictions	Consistently maintains safe, efficient, and orderly traffic flow, even under difficult or unusual circumstances (e.g. extremely heavy traffic)
Uses control actions that fail to resolve potential conflictions or that result in excessive workload (e.g. waits until potential conflictions are critical before taking action	Resolves simple conflictions and traffic flow problems quickly; without causing unnecessary delays.	Recognizes potential problems or conditions early and takes appropriate actions to maintain spearation and minimize inconvenience
Does not always sequence aircraft adequately or ensure proper spacing between aircraft; may cause excessive and unnecessary delays by choosing poor control actions waiting too long to provided needed commands, etc.	Generally uses correct procedures to sequence and space aircraft safely; maintains smooth traffic flow, but may not use the most efficient control actions (e.g. may not always take aircraft types into account	Sequences and spaces traffic effectively and efficiently; even when extremely busy; always maintains proper separation while minimizing delays (e.g. avoides delaying vectors as appropriate, use flow control procedures when necessary

1 2 3	4 5 6 7	8 9 10

ADAPTABILITY AND FLEXIBILITY

REACTING EFFECTIVELY TO DIFFICULT EQUIPMENT PROBLEMS, CHANGES IN WEATHER, TRAFFIC SITUATIONS, ETC, OR TO UNEXPECTED ACTIONS ON THE PART OF OTHER CONTROLLERS OR PILOTS; USING CONTINGENCY OR FALL-BACK STRATEGIES EFFECTIVELY WHEN UNFORSEEN/ UNANTICIPATED AIR TRAFFIC PROBLEMS EMERGE OR IF FIRST PLAN DOESN'T WORK; ASKING FOR HELP WHEN IT'S NEEDED; DEVELOPING/EXECUTING INNOVATIVE SOLUTIONS TO AIR TRAFFIC PROBLEMS; DEALING EFFECTIVELY WITH SITUATIONS FOR WHICH THERE MAY NOT BE CLEARLY PRESCRIBED PROCEDURES, SITUATIONS WHICH REQUIRE NOVEL THINKING; ADAPTING TO EQUIPMENT UPDATES, NEW PROCEDURES ETC.

Does not adjust well to unusual and difficult air traffic situations	Is usally able to adapt effectively to difficult situations such as rapidly worsening weather, equipment problems etc.	Reacts very effectively to complicating events and difficult equipment problems.
Rarely displays good "fall-back" strategies for dealing with unanticpated air traffic problems	Frequently, but not always, has effective contingency strategies for unforseen or unanticipated air traffic problems when they arise	Is very adept at using effective contingency or "fall-back" strategies when unforseen or unanticipated air traffic problems arise
Is ineffective at handling air traffic situations with no clearly prescribed procedures	For the most part, is good at handling air traffic situations that have no "textbook answers", but does better with the more routine problems	Deals very effectively with air traffic situations where there are no clearly prescribed procedures

1 2 3	4 5 6 7	8 9 10

APPENDIX D

GENERIC SECTOR TRAINING MANUAL

FORWARD

The purpose of this Training Guide is to develop Standard Operating Procedures and define radar position responsibilities for GENERA APPROACH CONTROL (FAA's Generic Sector) along with presenting operating guidelines to be followed while controlling traffic in both the ACY and Genera scenarios.

Controllers are expected to be familiar with the provisions contained in this guide as they pertain to the operational requirements of the Genera Arrival and Departure positions and to exercise their best judgment if they encounter situations not covered by it.

Since this is a two part experiment and one half of the study deals specifically with ACY traffic, it is envisioned that controllers will adhere to current procedures contained in the Standard Operating Procedures (SOPs) Manual (ACY 7110.4) while controlling ACY traffic. With the exception of certain automation restrictions as noted in this guide, most traffic should closely follow SOP patterns.

BACKGROUND

Earlier PERI/FAA experimental studies, in memory related areas, have confirmed that inexpensive ATC simulation systems can provide a vehicle for testing controller performance on a limited basis.

Using PC-based, off the shelf, hardware and TRACON II, an ATC software program that graphically depicts a radar approach control scope display, experimenters were able to investigate the effects of two memory strategies (planning and flight strip management) on ATC performance.

Since completion of the initial experiments in May, 1993, the FAA Technical Center Human Factors Laboratory has purchased several high fidelity, state of the art, console based simulation and training systems from UFA Inc. of Lexington, MA., the makers of ATCoach. These systems came equipped with a 22 inch, high resolution, color radar display monitor, with three button trackball, ARTS IIIA keyboard, pseudo-pilot position and offer, as an option, a speaker independent, voice recognition, pilot response communications system.

ATCoach's simulation system is configured to closely replicate both terminal and en route environments including control panels and keyboards. Approach Control airspace and En Route sector boundaries can be constructed to align with map overlays in use at FAA facilities. Scenarios that closely resemble the daily traffic flow, including STARs and SIDs, can be developed using air traffic data collected from actual flight progress strips of past days traffic. Currently in use at several Universities, the ATCoach system has been primarily programmed to satisfy basic radar training requirements with the emphasis on developing a college level curriculum that meets FAA criteria. ATCoach provides staff personnel with adequate information to enable instructors to closely monitor new developmentals for adherence to ATC rules and procedures as well as analyzing the future controllers decision making skills.

This record keeping process is exceptional in that everything that transpires during a given traffic scenario is collected and stored in memory. So far, its use has been mostly in an academic setting and many of its outstanding features have not been explored. This state of the art system was successfully programmed to allow experimentors to evaluate specific memory variables in a recently completed memory enhancement experiment (May 1994).

GENERAL METHOD

PERI/FAA memory experiments which began in January 1994, included modifying and intensifying the record keeping capabilities of the ATCoach data processor. Specific variables were created to measure controller on-the-job performance in memory and performance related tasks. Scenarios were designed to test memory limitations under a variety of circumstances. Memory techniques /strategies and aids were tested from two standpoints; first, to check for usability under heavy workloads, and second, to assess the aids ability to effectively increase productivity without draining mental resources.

Results gathered from past experiments coupled with data derived from this performance study should prove to be invaluable in evaluating additional memory aids, developing new and enhanced aids, assessing individual controller techniques/strategies as they relate to reducing memory requirements, improving memory recall, increasing memory capacity, and hopefully, in measuring controller performance.

Additionally, information, collected from past experiments, is being used as the basis for a database that should enable future researchers to detect specific variables that increase/decrease reliance on working memory and increase/decrease a controllers traffic handling capacities while improving performance. This data will be indispensable in defining individual controller memory limitations and recording performance as it relates to productivity.

ATCOACH SPECIFICS and SCENARIO RESTRICTIONS

ATCoach is pretty particular about certain separation standards.

YOU MUST STAY AT LEAST THREE MILES FROM THE FINAL APPROACH COURSE WHEN VECTORING AN AIRCRAFT ON DOWNWIND LEG. IN MOST CASES IT IS BEST TO USE A WIDER DOWNWIND LEG OR ALTITUDE SEPARATION TO PRECLUDE A "CA" ALERT.

YOU MUST USE THE TWENTY/THIRTY DEGREE INTERCEPT RULES WHEN TURNING AN AIRCRAFT ON THE FINAL INTERCEPT HEADING PRIOR TO ISSUING APPROACH CLEARANCE. ALLOW AN EXTRA MILE OR TWO. BETTER YET, MAKE ALL YOUR TURN ONS AT TEN MILES.

TRY TO PREPLAN ALL OF YOUR ACTIONS. SINCE THIS IS A COMPUTER BASED SIMULATION, IT WILL BE IMPOSSIBLE TO:

A) MAKE TIGHT TURNS

B) EXPEDITE CLIMBS/DESCENTS

C) MAKE VISUAL APPROACHES

If you make a poor turn on and your aircraft executes a missed approach, you will still be responsible for safely vectoring the aircraft back around for another approach. If the turn to final is the fault of the pseudo pilot or computer, the aircraft will be allowed to land and you won't be penalized. This decision will be made by a PERI staff controller who has a background in terminals and will be monitoring your control techniques.

Flight progress strips will closely resemble those currently used at your facility. Controllers are urged to use them as a back-up system. The ARTS 111A keypack should enable controllers to perform computer functions that closely replicate their facilities environment. Phraseology should be in accordance with the ATP 7110.65 manual.

Although no provisions were made for separate landline communications, coordination should be handled in a manner similar to facility SOPs simulating the use of an intercom for voice communications. The pseudo-pilots will initiate most coordination requests.

The ATCoach simulator has been preset at a range that will offer optimum radar coverage for the scenarios. You may want some adjustments made prior to testing. We can alter the following:

a) range mark intensity
b) A/N character size
c) compass rose--on\off
d) radar range

Efforts have been made to keep simulation scenarios realistic and challenging, including using actual aircraft call signs gathered from past traffic statistics. Control instructions will be issued to pseudo-pilots who will make the necessary computer entries and try to respond in a professional manner. Since it is virtually impossible to cover all phraseology associated with controlling traffic in a terminal environment, you may have to repeat some instructions. Your patience will be appreciated.

Pay close attention to readbacks. Hopefully, the pseudos have enough experience to correctly read back clearances but there still may be an occasional inverted number. If a mistake is made it will be purely unintentional as there aren't any built-in glitches.

NOTE: Standard responsibilities for the separation and control of Air Traffic are not reiterated in this guide, since they are explained in other handbooks and manuals and controllers should be familiar with their application.

<u>EXCEPTIONS:</u>

Due to the experimental design, a few exceptions were made:

a) Controllers have to accept and give radar hand-offs. Departures will not automatically hand-off.

b) All radar positions are combined. Although the combining of positions is a routine occurrence, it only happens under light to moderate traffic conditions. Most of the heavy traffic scenarios would require de-combining the positions. Keeping positions combined was a intentional manipulation designed to increase complexity by forcing controllers to scan the entire scope, thereby, increasing their workload.

** NOTE: The heavy scenarios are deliberately designed to replicate an overloaded terminal sector. We are trying to determine when a sector is saturated using a combination of heavy volume and traffic complexity. Do not feel intimidated. You are expected to stop the traffic flow and initiate holding whenever you see the need.

c) Controllers will be required to make final approach turn ons to all satellite airports. In order to equalize workload, no provisions were made for using the Rainbow Transition or other automated approach route segments.

Scenario Design ACY

Scenarios were designed to take into account most of the tasks associated with controlling the Atlantic City South Arrival and Departure radar positions, in a South landing configuration at the Atlantic City Approach Control under Instrument Flight Rules (IFR). For all of the test scenarios, we have programmed the following weathers.

ACY : W4X1F 56/49 1508 30.00 ILS Runway 13 approaches in use

AIY : W7X2F 54/50 1408 30.00 VOR Runway 11 approaches in use

MIV : W6X1F 55/48 1205 30.00 ILS Runway 10 approaches in use

WWD : W8X2F 57/51 1606 30.00 ILS Runway 19 approaches in us

Information "A" is the current ATIS.

The weather dictates that all scenario aircraft have to be treated as instrument flights. This precludes using any Visual Approach techniques. Scenarios consist of light and heavy traffic volumes and will be assigned at the discretion of the experimenters. Holding patterns have been established which correlate with airspace boundaries.

Scenario Design Genera Approach

Scenarios were designed to take into account most of the tasks associated with controlling the Genera North Arrival and Departure radar positions, in a North landing configuration at Genera Approach Control under Instrument Flight Rules (IFR). For all of the test scenarios, we have programmed the following weathers.

GEN : W5X2F 56/49 3608 30.00 ILS Runway 36R approaches in use

DWN : W6X1F 55/48 0205 30.00 ILS Runway 04 approaches in use

MID : W7X2F 54/50 3408 30.00 ILS Runway 33 approaches in use

UPT : W8X2F 57/51 3606 30.00 ILS Runway 01 approaches in use

Information "G" is the current ATIS.

The weather dictates that all scenario aircraft have to be treated as instrument flights. This precludes using any Visual Approach techniques. Scenarios consist of light, moderate and heavy traffic volumes and will be assigned at the discretion of the experimenters. Holding patterns have been established which correlate with airspace boundaries.

ARRIVAL AND DEPARTURE CONTROL

Controllers are expected to comply with facility established routings as depicted in the Letters of Agreement (LOAs).

1. Arrival Control--- Arrivals should be vectored and descended within the confines of the Arrival Airspace Jurisdiction Charts as depicted herein.

   a) Hand-offs should be accepted as soon as the aircraft are flashing in a hand-off mode.

   b) Although positions are combined, all efforts should be made to conform to altitude restrictions as depicted in the Airspace Jurisdiction charts.

2.) Departure Control--- Departures should be vectored and climbed within the confines of the Departure Airspace Jurisdiction Chart as depicted herein.

   a) Hand-offs should not be made until the departing aircraft is clear of all traffic, climbing to prescribed altitude, and navigating to first assigned fix outside of Genera Airspace.

   b) Although positions are combined, all efforts should be made to conform to altitude

APPENDIX E

FINAL QUESTIONNAIRE RESPONSES

1. How realistic was the simulation?

   01. Very good, other than the DH8 descent.

   02. The simulation was very realistic.

   03. No response.

   04. Very.

   05. For the most part very realistic.

   06. This simulation was very realistic. It standardized the arrival and departure sequence allowing me to accept more traffic without losing sight of my objective.

   07. Very realistic, better than what we use in our TTG simulator.

   08. Pretty realistic.

   09. Very real.

   10. About 90% realistic, work still needs to be done on descent rates and turn rates.

   11. The simulation seemed very realistic.

2. How representative was the generic sector of a typical terminal environment?

   01. OK, maybe too basic.

   02. Very representative, except that ACY normally works overflight traffic.

   03. No response.

   04. Very.

   05. N/A (only worked ACY).

   06. Very representative of a level V type approach control.

   07. Fairly well representative, satellite airports and altitude restrictions seem realistic.

   08. Set up well.

   09. Very typical

   10. Not to typical, it works to well.

   11. It differs much from ACY operation, but I suppose it is typical of a level 5 operation.

3. How helpful was the training booklet in learning the generic sector?

   01. Didn't look at it before the problems.

   02. Not much for myself.

03. No response.

04. Didn't really see it.

05. Not very, too much information.

06. The booklet gave me enough information to allow me to begin each scenario with minimal required information.

07. Somewhat, there is more information than is needed, however the airspace, sector boundaries, etc., are very helpful to know in advance.

08. Very helpful.

09. Not very.

10. More information in the booklet than was needed. It could have been simplified.

11. Good to learn frequencies and airspace layout, but I didn't really understand much of the operation till I saw it in operation.

4. Was the hands-on training adequate on the day 1 session?

01. Yes, very good.

02. Yes.

03. No response.

04. Yes! Very.

05. Yes.

06. The hands-on training provided the other half of the necessary information to allow me to operate with confidence and ease.

07. Yes.

08. Yes.

09. Yes.

10. Yes.

11. Yes.

5. How could the generic sector be improved?

01. For people to learn it, it's pretty good.

02

a) Make it easier to move leader lines.

b) Create a little more space for strips.

c) Have a foot pedal.

d) The airspace is fine.

03. No response.

04. Freq's N/E-odd (ncc) 135.0/(ncc) 137.0S/W-even (scc) 136.0/(scc) 138.0

05. Blank.

06. I do not think it would need any further improvement at this time.

07. Add in some overflights.

08. Transfer of departures could be sooner.

09. Need a foot pedal.

10. No improvements needed.

11. I don't know how you could take a unfamiliar sector and make it any easier than it is. The standard climbs and descents made it very easy along with names (intersections, arps, etc.) and the north, south setup.

6. Did the ATWIT device interfere with controlling traffic on either sector?

01. No.

02. No. I would disregard it for a second or two if I had a priority to work on.

03. No response.

04. No.

05. No.

06. No.

07. No, we used the same equipment in the previous project and it's fairly automatic now, I didn't really even notice that I was responding.

08. No.

09. No.

10. No.

11. No.

7. How well did the pseudo-pilots respond to your clearances in terms of traffic movement and call-backs?

01. Fair, they we're new.

02. They were good except for 1 problem.

03. No response.

04. Very well, excellent.

05. Pseudo-pilots did a very good job.

06. Excellent

07. Very well, they did an excellent job.

08. Response was very good.

09. Good job.

10. 95% correct.

11. Very good job.

8. Do you have any other comments about your experiences during the simulation?

01. I enjoyed this one.

02. No.

03. No response.

04. I enjoyed it a great deal!

05. Blank.

06. No.

07. Just that I'm anxious to see the results!

08. Blank.

09. No. Nice system.

10. Having intersections 10 miles from the O/M on all ILS apch's helped greatly. You do need a foot pedal with all the writing and strip management that is necessary!

11. No.

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