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AUTHOR	Redding, Richard E.; And Others
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ABSTRACT

A cognitive task analysis was performed to analyze the key cognitive components of the en route air traffic controllers' jobs. The goals were to ascertain expert mental models and decision-making strategies and to identify important differences in controller knowledge, skills, and mental models as a function of expertise. Four groups of participants from all 20 Air Route Traffic Control Centers in the continental United States comprised a hierarchy of skill levels ranging from current developmental controllers with no formal radar training to expert controllers who were supervisors. Seven data collection procedures were used: unstructured interviews, structured interviews, critical incidents interviews, paired problem solving, cognitive style assessment, DYSIM (Dynamic Simulator) performance modeling, and DYSIM structured problem solving. This first phase resulted in the identification of 12 primary tasks, a mental model representing expert controllers' organization of domain knowledge, three categories of controller strategies, a hierarchy of goals and a set of methods used by experts to achieve those goals. The findings were used to specify the instructional content and sequencing for the Federal Aviation Administration's new en route air traffic control curriculum. (Appendixes include the following: 28 references; structured interview questions; scenarios for DYSIM performance modeling and structured problem solving; a summary of critical incident types; paired problem solving comparison diagrams and dictionary; a report of COGNET (cognitive network of tasks) analysis; problem-solving analyses of expert, intermediate, and novice groups; and statistical analyses of cognitive style assessments.) (YLB)

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COGNITIVE TASK ANALYSIS OF PRIORITIZATION IN AIR TRAFFIC CONTROL

Developed By:

Richard E. Redding
John R. Cannon
Bruce L. Lierman
Joan M. Ryder
Thomas L. Seamster
Janine A. Purcell

Human Technology, Inc.
McLean, Virginia

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Abstract

A cognitive task analysis was performed to analyze the key cognitive components of the en route air traffic controllers' job.

Our goal was to ascertain expert mental models and decision-making strategies, and to identify important differences in controller knowledge, skills, and mental models as a function of expertise. By comparing experts, intermediates, and novices, the cognitive analysis provides a much better understanding of skill progression than would traditional, behavioral methods of task analysis. This understanding can serve as a foundation for improving the training of professional air traffic controllers, and provides important insights into improved training methods for other complex, high-performance job environments that require speedy decision-making and prioritization of competing tasks (such as aircraft flight decks, nuclear power plant operation, and combat information centers).

This report presents the results from the first phase of data collection and analysis. This phase involved seven data collection and analysis techniques including structured/unstructured interviews, critical incidents interviews, paired problem-solving, cognitive style assessment, simulated performance modeling, and structured problem-solving. This first phase resulted in the identification of twelve primary tasks, a mental model representing expert controllers' organization of domain knowledge, three categories of controller strategies, and a hierarchy of goals and a set of methods used by experts to achieve those goals. The findings are being used to specify the instructional content and sequencing for the Federal Aviation Administration's new en route air traffic control curriculum.

This research represents one of the first uses of cognitive task analysis to support the development of a complete curriculum for the training of a complex, high-performance task. The results suggest exciting and innovative approaches for air traffic control training, as well as for training other tasks that must be performed in a time-constrained, multi-tasking environment.

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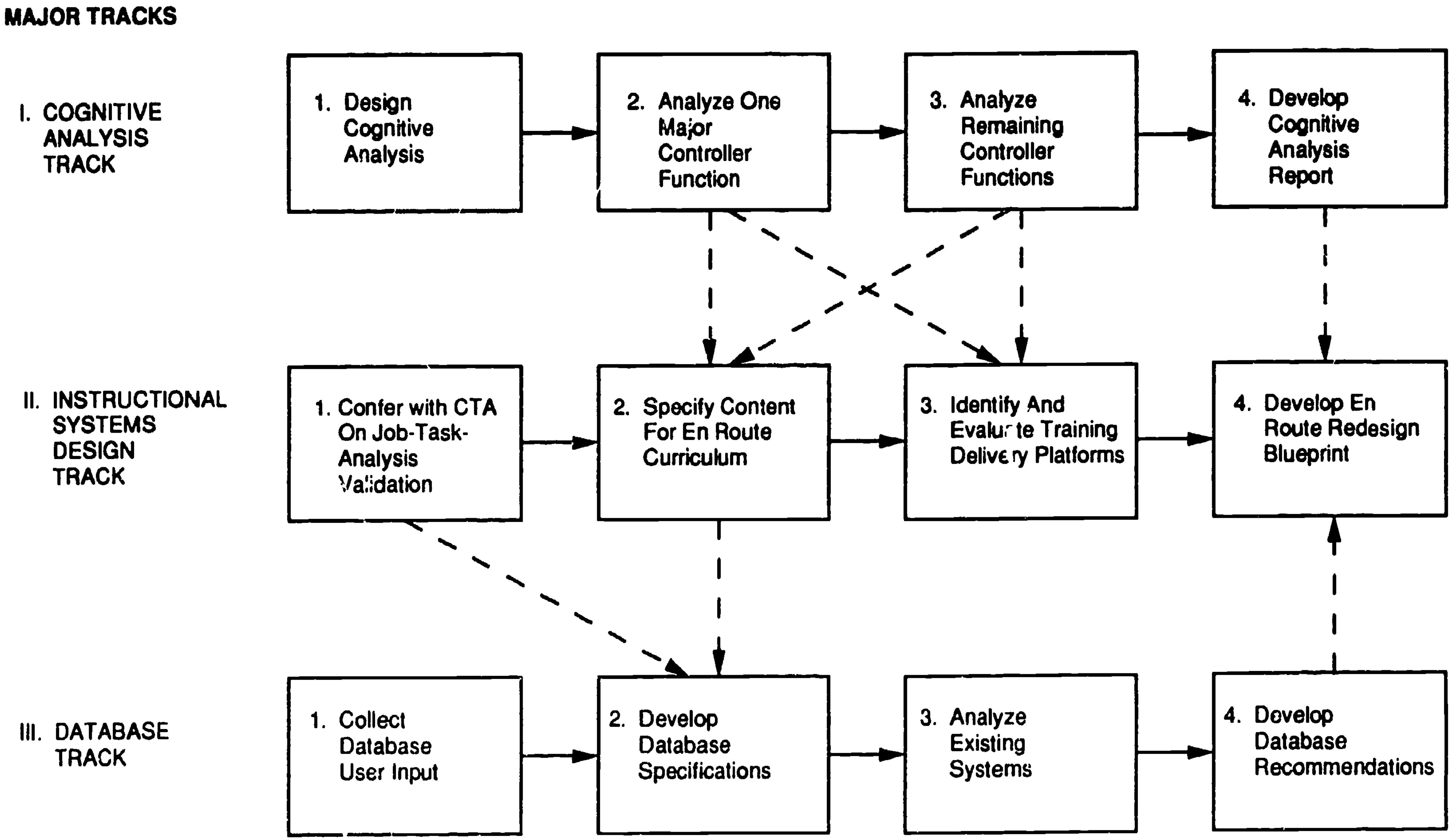
INTRODUCTION

CONTEXT

FAA is embarking on a major redesign effort to improve the training of en route air traffic controllers. The first part of this endeavor is a front-end analysis project that will result in a comprehensive blueprint for all subsequent curriculum redesign and development efforts.

Figure 1, on the following page, summarizes the major components of the front-end analysis project. As is illustrated in Figure 1, the cognitive analysis of the en route controller job is one major track of the front-end analysis effort. This cognitive analysis is important and unique because the results of the cognitive analysis are to be used to support an entire curriculum redesign, including recommendations on content, instructional sequencing, media selection, and training delivery.

FIGURE 1. PROJECT COMPONENTS



GOALS

The overall goal of the cognitive analysis is to better understand and describe the cognitive components of en route air traffic control so that training of controllers can be more effective and efficient.

The subgoals of the analysis are to ascertain and analyze expert mental models and decisionmaking strategies, and to identify and analyze important differences in controller knowledge, skills, and mental models as a function of experience and expertise.

By comparing experts, intermediates, and novices, the cognitive analysis provided a much better understanding of the progression from novice to expert controller. This understanding will serve as a foundation for improving the content and delivery methods of the en route air traffic control curriculum.

Historically, experienced controllers have passed on their cognitive expertise informally through on-the-job training and working together on the floor. The cognitive analysis enabies the "capturing" of this rich expertise so that it can be systematically transmitted to developmental controllers.

The focus of the prioritization analysis was on the development of practical information that will be directly applicable to the en route curriculum redesign process. The guiding perspective was that the cognitive analysis will be useful to the extent that it produces data that can be readily used to improve the training of controllers.

GENERAL APPROACH

The framework for the cognitive analysis was a modification of the integrated task-analysis methodology developed by Ryder and Redding (1990). The analysis was iterative, involving two progressive cycles of data collection, analysis, and interpretation, conducted in three interrelated content areas -- knowledge, skills, and mental models (see Figure 2).

Recent research in cognitive analysis suggests that the determination of decisionmaking procedures and skills is not a one-pass process (e.g., Breuker & Wielinga, 1987). Rather, it involves progressive refinement. The need for multiple analysis stages is analogous to the iterative nature of any system design process in which design begins at a gross level and becomes progressively more specific and fine-tuned.

In this two-stage analysis approach, each stage involved planning, data collection, data analysis, and interpretation. The two cycles helped prevent collection of large amounts of irrelevant data. Instead, effort was targeted on those areas requiring detailed analysis.

Using this framework, knowledge, skills, and mental models were analyzed more thoroughly in each progressive stage. Also, the information produced in the first stage was used to refine the data collection procedures and analyses that were conducted in the subsequent stage. The goal of Stage 2 was to determine how controller knowledge, skills, and mental models differ as a function of level of expertise. This entailed determining how novice and intermediate controllers approach job tasks and problem situations, and comparing these approaches to the heuristics, strategies, and skill refinements used by experts. By conducting this analysis after the Stage 1 analysis, the data collection was refined to better assess knowledge and skill areas that were likely to separate novice from expert performance.

During all phases of data collection and analysis, a variety of procedures and measures were used to capture expertise and skill differences in air traffic control in order to obtain convergent validity.

The general approach outlined above will be used throughout the cognitive analysis of all major controller functions. The focus of this analysis was on the major controller function of prioritizing. The methodology will be refined as needed, and cognitive analyses will be conducted on the remaining major controller functions.

The remainder of this document describes the cognitive analysis of the prioritization function.

FIGURE 2. GENERAL APPROACH TO COGNITIVE ANALYSIS

ANALYSIS CYCLES	CONTENT: KNOWLEDGE	CONTENT: SKILLS	CONTENT: MENTAL MODELS
Stage 1: Basic Analysis	• Identify and define expert conceptual structures	• Identify and analyze major skill areas	• Determine expert model components, format, and organizing principles
Stage 2: Refinement And Learning Analysis	• Refine expert conceptual structures • Define novice and intermediate conceptual structures/ misconceptions/ probable errors	• Refine expert skill analysis • Identify and analyze novice to expert skill progression	• Refine expert models • Determine novice and intermediate models • Analyze novice to expert model progression

METHOD

PARTICIPANTS

There were four groups of participants, resulting in a hierarchy of skill levels ranging from current developmental controllers with no formal radar training to expert controllers who are currently supervisors. It was important to represent various skill levels to permit analysis of skill progression and expertise development.

Experts included two subgroups: 5 Supervisor/Full Performance Level (FPL) controllers (Mean Age = 47.2, SD = 3.27; Mean Yrs. FPL = 18.8, SD = 3.27) and 7 FPL's with more than 5 years of FPL experience (Mean Age = 46.7, SD = 7.65; Mean Yrs. FPL = 14.6, SD = 6.58). All participants in these groups were male.

The intermediate group included 13 FPL's (11 males, 2 females) with less than 1 year of FPL experience (Mean Age = 29.7, SD = 2.50; Mean Yrs. FPL = .77, SD = .19).

The novice group included 11 developmentals (10 males, 1 female; Mean Age = 26.5, SD = 2.42).

Participants were drawn from all 20 Air Route Traffic Control Centers in the continental United States.

DATA COLLECTION PROCEDURES

Prior to data collection, the overall goals of the project were explained to the participants, and anonymity was ensured. (Participants are not identified by name in the analyses or this report.) The participants were also given a pre-briefing before each procedure, to ensure that they understood the task.

Seven data-collection procedures were used: unstructured interviews, structured interviews, critical incidents interviews, paired problem solving, cognitive style assessments, DYSIM* performance modeling, and DYSIM* structured problem solving. Each procedure is discussed in the following sections. All data collection took place at the FAA Academy in Oklahoma City.

*NOTE: Technically, the Academy simulator is a VAX-based stand-alone simulator rather than a Dynamic Simulator (DYSIM), but DYSIM is used throughout the report to emphasise that data were collected from simulated situations rather than live-traffic situations.

Unstructured Interviews

In order to orient experimenters to air traffic control and to begin to get a gross-level view of mental models and strategies for prioritization, unstructured, open-ended interviews were first conducted with five supervisor FPL's.

Structured Interviews

This procedure was developed after Stage 1 data collection. Preliminary analysis of the data obtained in Stage 1 revealed the task domains critical for prioritization as well as key decision points in ensuring separation. Based on this information, specific questions were developed designed to determine priorities for strategy/technique selection. Half of the participants in the intermediate and novice groups were asked a series of structured interview questions, listed in Appendix A. In addition, a separate group of four experienced FPL controllers responded in writing to the structured interview questions.

Critical Incidents Interviews

The critical incidents method, developed by Klein, Calderwood, and MacGregor (1988) is designed to elicit the experiential cues experts rely upon -- i.e., the "gut-level" or intuitive knowledge an expert acquires over the course of experience that he or she brings to bear in critical situations. This retrospective interview approach, focusing on nonroutine cases, offers a rich source of data about expert capabilities. Experts frequently rely on intuitive knowledge, but often are unable to verbalize it. Difficult or critical situations, however, can serve to bring such knowledge to conscious awareness because the expert may use his or her knowledge and skills in a more conscious, attention-demanding fashion when the novel situation taxes the expert beyond his or her normal range of capabilities. Moreover, such critical situations often can best distinguish expert strategies because true expertise involves the successful and efficient performance of novel, difficult, or complex tasks.

Five supervisor FPL's were individually interviewed during two interview sessions, each lasting about two hours. Participants were asked to identify and describe "critical incidents" that have occurred to them in their experience as controllers. These incidents were defined as unusual and/or difficult situations the controllers have encountered in which they felt their expertise and experience made the critical difference in outcome. Often, these were situations in which there was a near or actual "DEAL."

Participants were asked to "walk the interviewer through" what happened in a step-by-step fashion, explaining their goals and each step taken to arrive at the goals, from the time the situation first presented itself to its resolution.

Continued . . .

Critical Incidents Interviews (Continued)

During the second session, the experimenter repeated the incident(s) back to the participant, verifying the situation, goals, and each action step. Participants were also asked to think of possible alternatives to each step taken, and to explain why an alternative might be used.

For each action taken or goal/subgoal stated, participants were asked a series of questions:

- What were you seeing here? Visualizing? Hearing?
- What were you sensing about the situation at this point?
- What were your instincts telling you here?
- Was there time pressure, stress involved at this point?
- What were your goals at this time?
- What information did you bring to bear at this point?
- What experience did you find particularly useful?

After the above questions were asked about each specific problem-solving step or goal, the following questions were then asked about the situation as a whole:

- What made you remember the incident?
- How did your experience make the difference in this case?
- What did you do, because of your years of experience, that even a very good but new FPL might not have done?
- Can you think of any specific training/rules of thumb that would help a novice to deal with the situation as effectively as you did?
- When you were confronted with this situation, did it remind you of any similar situations? If so, how did those similar previous experiences help you to solve the problem?
- What key feature(s) of the situation would have made the incident not critical, i.e., not unusual or difficult?

All interviews were audiorecorded and fully transcribed for data analysis.

Paired Problem Solving

The paired problem-solving technique (see Means & Gott, 1988) involves having participants develop problems themselves and then giving them to one another, thus directly involving participants as collaborators in the research. This collaboration stimulates them to provide a richer description than would be given by one participant alone.

Continued . . .

Paired Problem Solving (Continued)

The paired problem-solving format allowed the reasoned development of a problem-and-solution sequence by various levels of controllers. Unlike the other exercises where an actual time-sensitive problem was in progress, controllers could change their minds and modify solution sequences in these exercises, and discuss their reasons for so doing.

This flexibility made the paired problem solving a good complementary exercise to the structured problem-solving and performance-modeling exercises conducted as part of this study. The format of the interviews provided good insight into the controller's conscious reasons for taking each action, and the solution sequences provided a step-by-step comparison of goals and means. The primary limitations on the methodology are that it does not allow development of the problem over time, or use of chronological cues for solution. Also, in the exercises created by the controllers, many cues are absent that would be used in the controller work environment and the exercises do not include housekeeping tasks such as data block updating, flight strip marking, and display clutter reduction.

All participant groups participated in this exercise, which consisted of two sessions. During the first session, each participant was asked to develop a difficult problem on paper (i.e., to sketch out and explain the problem on a paper sector map). Controllers were told to create a situation that would be difficult for an expert, and that had a "best" solution sequence. The problem should have some items that needed immediate attention, and some that might not be so immediate so the controller would have to prioritize actions. Each controller was given a map of Aero Center Sector 02 and a set of blank flight strips or sheet of paper to write out the flight plans for the aircraft. The aircraft positions were marked on the map to show the position of the aircraft at the time of the problem.

With the experimenter present, the participant constructed a scenario specifying the problem situation, including drawings depicting various points in the problem scenario. A solution path toward solving the problem was then generated by the participants identifying each step to be taken toward a solution (e.g., vector aircraft 1 left 30 degrees), the hypotheses or goals motivating each action step (e.g., to eliminate conflict between aircraft 1 & 2), the perceived consequences of each action, and what information is required at each action point to solve the problem. Additionally, the participant was asked to anticipate, for each step along the solution path, any alternative steps that could be taken. The experimenter asked the following series of probe questions.

To determine how the expert conceptualizes the problem-space:

- What is the problem, as you see it?
- Why do you think that?
- What does this information tell you?

Continued . . .

Paired Problem Solving (Continued)

To determine steps:

- What would you do first?
- What would you do next?

To determine information used and hypotheses generated:

- How would you know to do that?
- What would happen if you did that?

To determine the consequences of each step:

- What would the result of that step be?
- What would happen if you did that step?

To determine feedback drawn from consequences:

- What would that tell you?
- What would you think after getting that result?
- How would that change your conceptualization of the problem?

To determine alternate solution paths:

- At this point, what might someone else do?
- Why would someone do that rather than what you did?
- Would a novice controller typically do the same thing at this point?

This procedure typically resulted in several problem graphs depicting how the problem might be solved.

During the second session, the participant who generated the problem then presented it to another participant, who was asked to explain each step he or she would take toward solving the problem (as was the first participant who generated the problem). The problem originator first gave the solving controller a short briefing of the information on the flight strips and on the map, similar to the relief briefing given when one controller relieves another at a radar console in the center. After getting answers to any questions concerning the information in the problem, the solving controller developed out loud a solution sequence for the problem. Next the originator controller's solution sequence was read aloud so the solving controller could hear how the originator saw the problem.

Continued . . .

Paired Problem Solving (Continued)

The interviewers then led the controllers in a discussion of the problem, including a discussion of any alternative solutions that might have been used, any situations in the problem that either controller thought the other had not addressed, and the situations in the problem a novice controller might have had difficulty with. When interviewing the novices, the interviewers asked what parts of the problem the novice controllers thought were particularly difficult.

The paired problem solving sessions were audiorecorded and fully transcribed for data analysis.

Cognitive Style Assessments

Cognitive styles are relatively consistent individual ways of perceiving and processing information. There is evidence in the research literature that cognitive styles affect both problem-solving performance (Kemler Nelson & Smith, 1989; Long, 1974; Messer, 1976) and learning (Messick, 1984; Witkin, Moore, Goodenough, & Cox, 1977). Because of these previous research findings, even though cognitive styles were not a primary focus of the present study, it was decided to make some initial assessments of the cognitive styles of the controllers who participated in this project.

Two measures of cognitive style were administered to all of the controllers in this study: the Matching Familiar Figures Test and the Group Embedded Figures Test.

The Matching Familiar Figures Test (MFFT), developed by Jerome Kagan, is a measure of a cognitive dimension called "reflection -- impulsivity." Previous research has shown that individuals who are more reflective tend to perform better than those who are more impulsive on tasks that require attention to detail (Morris & Rouse, 1985; Zelniker & Jeffrey, 1976). On the other hand, there is some evidence that individuals who are more impulsive tend to perform better than those who are more reflective on tasks that require rapid, overall synthesis of information (Zelniker & Jeffrey, 1976). The MFFT requires test takers to look at a line-drawing figure and then find that exact figure among eight similar figures that are only slightly different from each other. The test takers are scored on both the speed with which they respond and the accuracy of their responses.

The Group Embedded Figures Test (GEFT), developed by Herman Witkin and his associates, is a measure of a cognitive dimension called "field dependence -- field independence." Previous research has shown that individuals who are more field independent are better able than those who are more field dependent to perceive and process pieces of information apart from the context or environment in which the pieces of information are presented (Witkin & Goodenough, 1981).

Continued . . .

Cognitive Style Assessments (Continued)

In addition, field independence has been found to be positively related to performance on a variety of tasks that require analysis and problem-solving skills (Goodenough, 1976; McDonald & Eliot, 1987; Thomas, 1983). The GEFT requires test takers to look at a simple geometric figure, and then find and trace that figure in a much more complex geometric design. The test takers are scored on the number of figures correctly traced out of 18 test items.

DYSIM Performance Modeling

The purpose of this procedure was to capture the actual, real-time performance of subject-matter experts (SME's) in order to develop a model of expertise in the task.

The individual DYSIM performance of five supervisor-SME's was recorded by video cameras that captured visual angles of the radar display as well as the controllers' hand motions. All controller and ghost-pilot verbalizations were also recorded. Additionally, a paper copy of all controller entries as well as ghost-pilot responses was obtained by way of a VAX computer printout. Each participant completed four problem scenarios, each lasting between 20 and 35 minutes, with a short break after the second session. Since the purpose was to capture real-time performance, participants worked the situations without interruption from experimenters.

To capture workload and situational factors, the four scenarios represented two different problem situations which included two levels of complexity (65% vs. 100%), resulting in a 2 x 2 design. A description of each scenario is included in Appendix B. The order of scenario presentation was counterbalanced across participants.

Following the first session, which involved uninterrupted performance on the four problem scenarios, a subsequent session was conducted the following week. The initial session was replayed to the participant who was asked to describe, for each action taken, his/her intentions and expectations of outcomes. Experimenters prompted when appropriate, and asked the following series of questions regarding each discrete action the controller took:

- What were you paying attention to here?
- What's going on now that's most important?
- What were you doing? Why?
- Why was it most important to do that?
- What were you thinking about in doing that?
- What was your goal?
- Why did you do it now?

Continued . . .

DYSIM Performance Modeling (Continued)

- Did you have to do it? Now?
- What activity was it part of?
- How does it relate to what you did just before it?
- How do you know what needs to be done next?
- What might you have done differently?
- What were you concerned about becoming a problem?
- What did you see as being the critical events at this point?
- How were you feeling about the situation, at this particular point?

The followup session resulted in the production of a post-experimental timeline protocol, upon which each participant's responses were related to each action taken in sequence, with the overlay of relevant task-global contextual parameters.

DYSIM Structured Problem Solving

This task was designed to capture performance strategies across participant groups in an actual, real-time environment. All of the experts and half of the intermediates and novices completed this exercise on the DYSIM equipment.

All sessions were recorded by video cameras that provided simultaneous views of both the radar display and the controllers' hand motions. In order to capture workload, situational, and display (i.e., data availability) factors, each participant was presented with four problem scenarios representing four general categories:

1) Typical problem, of low complexity (65% complexity requiring prioritizing under normal traffic conditions)

2) A problem representing a job bottleneck, but of low complexity (65% complexity requiring planning and visualization)

3) A typical problem of low complexity (65%), but with time constraints

4) A typical problem of low complexity (65%), but without complete flight data information

Categories 3 and 4 above are particularly useful in revealing expert strategies and subtle and refined aspects of expert reasoning.

Appendix C provides a detailed description of each problem scenario.

Continued . . .

DYSIM Structured Problem Solving (Continued)

Each scenario lasted about 30 minutes, with the order of presentation counterbalanced across participants. Participants were given a half-hour break after the first two problems. During the sessions, participants were asked to think aloud as they went about solving the problem. They were instructed to describe what they were thinking, rather than simply describe the overt actions they took. Participants, however, were not asked to introspect on their thought. Rather, they were encouraged to provide a "stream of consciousness" account. One limitation of other methods that rely on retrospective reports (i.e., describing thought processes after task completion) is that such reports are often less complete and/or accurate than reports based on participants' describing their thoughts while actually performing the task.

Participants were prompted to think aloud frequently by experimenters, but this was done as unobtrusively as possible in order to avoid disruption of the problem-solving process. Participants were prompted when there were long pauses or logical gaps in their verbalizations, or in order to seek clarification, fill in gaps, or elicit relevant information. At pre-specified 5-minute intervals, the scenario was frozen, to provide an opportunity for discussion between controller and experimenter about the problem evolution and actions taken.

MEASURES AND DATA ANALYSIS

Unstructured And Structured Interviews

A content analysis was performed on the interview transcripts to support development of a flowchart and listing of strategies. Additionally, results of questions explicitly asking participants about task priorities were tallied across the three participant groups.

Critical Incidents Interviews

A total of 30 critical incidents were generated across the five participants. A listing summarizing incident types is contained in Appendix D. However, because participants had considerable difficulty recalling truly critical incidents (as opposed to just difficult, but relatively normal situations) and also because many of the accounts were not very rich in terms of steps or goals (i.e., involving only one or two steps toward solution of a relatively routine problem), data analysis was done in an iterative fashion in which a first-pass, preliminary analysis was done to select incidents for further analytic effort. This resulted in a total of 11 incidents retained for the analysis (37% of all incidents), with at least one incident per participant.

Continued . . .

Critical Incidents Interviews (Continued)

A content analysis was performed on the interview transcripts of these 11 incidents. This analysis aimed at identifying and classifying cognitive optimizing strategies and experiential cues used by experts.

Several limitations were noted in the use of this method in this context. First, critical incidents were obtained only from the supervisor group of controllers who had been away from full-time controlling for some time. This situation may have limited their ability to recall incidents. There was also difficulty in eliciting specific incidents, perhaps for the same reason (i.e., "every day is an incident"). Some "incidents" elicited were not really critical incidents at all. Rather, they were generic descriptions of difficult control tasks (these were deleted altogether from the analysis). Finally, some controllers appeared uncomfortable in relating such incidents to others, perhaps feeling a sense of embarrassment. Incidents generated varied widely in quality in terms of detail and the degree to which they actually represented a true "critical incident."

Paired Problem Solving

To a large extent, resolving undesirable situations is the essence of expertise in air traffic control. Any noteworthy change in the situation (weather, winds, traffic density, special requirements, etc.) has a negative effect, which will require a corrective action from the controller. The severity of the undesirable situation may vary radically, from overlapping data blocks to imminent midair conflict.

Based on our experience in the paired problem-solving exercises, we define the controller's cognitive task as follows: to find the least costly (in terms of mental resources) means to resolve an undesirable situation. This definition provides the basis for our analysis of controller actions. Our analysis methodology was to:

1) Develop measures of the mental resource cost of various means to solve a situation.

2) Find measures of the undesirability of a given air traffic control situation.

3) Determine prioritization rules used in selecting procedures to meet task goals.

These measures provide standards to describe expert controller skills. They also provide means to measure differences between expert and novice controllers.

Sequence Comparison Diagrams

First, the interviewers developed a sequence comparison diagram that showed the degree of congruity between the two participants' solutions to each problem. This was done by listing the reasons for the first controller's actions down the center of the page, then listing the originating controller's actions in sequence down one side of the page and the second controller's actions taken for each reason down the other edge of the page. This diagram showed the degree to which the controllers addressed the same kinds of problems ("reasons") in the same order. If the solving controller listed any reasons not given by the originating controller, these were listed at the bottom of the original diagram, and the matching sequence steps were listed beside them. Appendix E contains the comparison diagrams from the paired problem-solving exercises.

Modified GOMS Analysis Methodology

GOMS models provide a format for representing knowledge of procedures as a set of means and ends. GOMS is an acronym standing for:

Goals	Desired end states or results.
Operators	Actions that can be taken, such as a keyboard entry.
Methods	Sequences of operators or actions taken to satisfy a goal or some part of a goal.
Selection Rules	Criteria for selecting methods to accomplish goals in any given situation.

This methodology for modeling and decomposing knowledge is well suited to the analysis of controller expertise. Controllers are engaged in a goal-directed activity, i.e., the elimination of undesirable situations. Operators are represented in specific controller actions, as described while "solving" the paired problem exercises. The methods are represented in larger order activity descriptions such as "coordinate" or "separate," which imply a sequence of actions. Selection rules are the heuristics and logic used by controllers in deciding what to do at any given time. These selection rules are generally synonymous with prioritization, which is the subject of this analysis.

Organization Of Collected Data

A structured dictionary was formalized with a comprehensive list of verbs, noun/objects, problem categories, goals, actions, means, and conditional statements. This set of standard terminology was developed and maintained to establish definitions for all terms used in the paired problem-solving analysis. The dictionary is provided in Appendix F.

The primary analysis tool was the solution sequences recorded during the exercises. The solution sequences provide a strong basis for the analysis because:

1) They contain information about goals (objectives of problem resolution) inferred from the reasons given for each sequence step.

2) They contain information about goals priority (sequencing of objectives) inferred from the reason sequence.

3) They contain information about means (actions available to achieve each objective) inferred from the actions taken in each step.

4) They contain information about means priority (priority of actions) inferred from the frequency of occurrence of the action.

Definition Of Problem Categories

The next step in the paired problem-solving analysis was a definition of problem categories. Problem categories are a finite set of problem types derived from the reasons given by controllers for taking a particular action. The categories were described in operational terms (e.g., "separate two conflicting aircraft"). All the categories found in the problems were listed in the structured dictionary.

The actions also were recorded in the dictionary. As with problem categories, the action list was expanded as each exercise was analyzed. Action categories required less interpretation, because they generally corresponded to the verbs used in the solution sequence notes (e.g., vector, climb, descend).

Goals And Methods Analysis

Goals were derived from comments made by controllers during the discussions of the paired problem-solving exercises. Goals were classifications of objectives based on the perceived consequences of inaction to the situation. That is, since the controller's overall goal is to deal with undesirable situations, goals are classified based on how bad the controller thought the situation would get if no action was taken. The goals and the hierarchy of goals are described in the results section of the report.

Methods descriptions were derived from classification of actions based upon the amount of effort required to complete the action. That is, actions were grouped based upon an evaluation of the "mental resources" required to complete the action. For example, a computer input is a highly automated task with a completely predictable outcome, and therefore requires a minimal amount of attention to complete. An off-frequency coordination with another facility requires the controller to plan the request, change frequencies, make the communication, and possibly negotiate with the facility for the desired action. Therefore, an off-frequency coordination requires more mental resources to complete than a computer input, and represents a different methods class. All actions were sorted into four methods classes based on judgment of mental resource requirements. The methods classes and the relative mental resource requirements of each method are described in the results section.

Once the mapping of problem categories to goals and actions to methods classes was completed, the goals and methods priorities were developed.

Goals priorities rules were determined from the sequence of goals in the problems. The assumption underlying this analysis is that the controller will attend to the highest priority goal first, and attend to lesser priorities in order from most to least important.

Methods priorities (preference for particular methods) rules were determined from the frequency of the particular methods selections. This analysis makes the assumption that in any given situation, the controller has a choice of several methods categories, and will select the one(s) viewed as most effective. This interpretation is subject to limitations based on the type of situation presented in the problem. The controller cannot choose to hand off an aircraft not planned for transition to the other facility and not physically located close to another facility, but in a summative analysis any clear preference for one method over another should still appear. Also, any differences in methods choices between controllers of different experience levels should be detectable.

Cognitive Style Assessments

Standard descriptive and inferential statistics were computed on the data derived from the administration of the Matching Familiar Figures Test (MFFT) and the Group Embedded Figures Test (GEFT) to all participants in this study.

DYSIM Performance Modeling

The COGNET (which stands for COGnitive NETwork of tasks) modeling procedure, developed by Zachery, Ryder, & Zubritsky (1989), was used. COGNET is a framework for modeling human-machine interaction and decision making in complex, real-world environments, particularly those that unfold in real-time and make multiple demands on the attention of the human decisionmaker. Air traffic control requires the operator to share attention among competing task demands and involves dealing with real-time problem data. Consequently, it is a prime example of the type of job that COGNET is ideal for modeling. A full explanation of the COGNET theoretical approach and analytical procedures is given in Appendix G. This procedure involves decomposing the task performance timelines into various levels ("panels") within an overall knowledge structure representation ("Mental Model"). Additionally, a task decomposition procedure is used which segments the task into common cognitive goals and activity chunks, and then identifies the critical subgoals within each task. Tasks were grouped into similar areas and assessed by asking the following questions:

> "Is task A a kind of task B (or vice versa)?"
>
> "Is task A a part of task B (or vice versa)?"
>
> "Are tasks A and B both instances of some more abstract task C?"

DYSIM Structured Problem Solving

Participants' verbalizations were used to infer cognitive processing, using standard protocol analysis techniques (see Ericsson & Simon, 1984). This analysis involves encoding responses into theoretically determined coding categories, as a function of types (categories) of strategies exhibited. These data were then used to derive a typology of strategies used in relation to monitoring, planning, control, and workload reduction.

Selective Notations

Notations of the critical protocol sections were encoded into productions. This selective notation approach was combined with a listing of the status of key aircraft at 5-minute segments for each of the sessions. A sample of this selective notation is shown in Table 1. Key aircraft were identified for each scenario, and then verbalizations for those aircraft were selected for analysis. Selective notations for the key aircraft were recorded both during the freeze periods and during the real-time problem solving. The notations during the freeze period summarize that participant's understanding of the status, and when the participant indicated the first action he or she would take following the freeze, that verbalization is prefaced with the label, "FIRST:"

TABLE 1. SAMPLE SELECTIVE NOTATION

Selective Notations From 5-Minute Freeze

Using arrows on strips, a better visual representation of where they are going.

Both inbound to MLC. At this point A616 is number 1, and ARMY is number 2.

5AP and 77L, have to make a choice. Make 5AP number 1 and put him under 77L.

128E departing and heading East. Stop him at lower altitude and stop 5AP on altitude above him and wait till they pass.

FIRST: Start A616 down. He is in my airspace and is number 1.

Selective Notations From 5-10-Minute Sequence

7:11 A49616: A616, start him down to 3,000.

7:57 N128E: 128E, give him 3,000, an MIO departure.

Continued . . .

Selective Notations (Continued)

The selective notations made during the real-time problem solving are time-stamped based on the times displayed on the video tapes. These notations are also prefaced with the key aircraft being discussed in the verbalization. The selected verbalizations were recorded in notation form capturing the concepts in the verbalization. These notations are not full or precise transcripts of the controller's verbalizations, but in all cases, they do accurately record the stated intentions and relationships between one or more aircraft. These notations were further decomposed into productions based on the work of John Anderson (1981), and that process is further discussed in the next section. Participants, however, were not able to verbalize all their decisions, especially at points of highest workload where they were speaking with aircraft, sectors, or the tower. Therefore, this should be considered a preliminary analysis, and participants would later have to provide more detailed protocols for further analysis.

Productions

Productions were developed for all real-time selective notations for the structured problem labeled SPS 2A. This included the expert, intermediate, and novice protocols. Problem SPS 2A was selected because it presented the lowest workload (65% complexity, requiring prioritizing under normal traffic conditions), and consequently all three participant groups were able to verbalize during the problem-solving process. When solving the more demanding problems, the intermediates and novices had greater difficulty in verbalizing their thought processes, and the resulting protocols could not be easily compared.

SPS 2A is based on a scenario of three aircraft inbound to Tulsa. All three need to be sequenced and are set up to arrive in Tulsa at about the same time. As the scenario approaches the 15-minute mark, a new inbound appears, which is followed shortly by two more inbounds. This new set of inbounds also needs to be sequenced into Tulsa. The problem is somewhat artificial in that there are no other targets on the PVD, but it presents a reduced workload, and consequently all three groups of participants were able to verbalize their plans and actions.

Table 2 presents a sample production. Each production has a set of conditions which are grouped under the leading IF statement: these are the existing conditions that have led the controller to follow a particular strategy or take a specific action. The second part of the production is the action to be taken which is grouped under the THEN statement.

Continued . . .

TABLE 2. SAMPLE PRODUCTION

7:11 A49616: A616, start him down to 3,000.

PRODUCTION

If a high performance aircraft is inbound to VFR tower airport
AND he is within 10-15 miles of the airport
AND there is no immediate traffic

THEN descend him to lowest safe altitude
AND monitor to clear to approach

RESULTS AND DISCUSSION

GENERAL LIMITATIONS OF THE DATA

Each data collection procedure used has general advantages and disadvantages as well as those specific to the context of air traffic control which place limitations upon conclusions that can be drawn from the data. Regardless of the specific procedure, however, the general limitations of the study in terms of time available for data collection, analysis, and validation as well as participant populations available require the discussion of several caveats.

Originally, we had planned to include both supervisor-FPL's and "current" FPL's in the "expert controller" group. Use of supervisor-FPL's during the first week of data collection was necessitated by availability of FPL's provided by FAA. Subsequent data analysis, however, indicated that supervisor-FPL's differed markedly from nonsupervisor-FPL's in numerous respects, including their ability to remember critical incidents, the types of control strategies used, performance on measures of cognitive style, and even general attitudes about the air traffic control job. This situation limits the data analysis and interpretation in several critical respects.

First, analysis of each subgroup separately decreases the total number of participants available for analysis within an overall "expert" group; this in turn limits the conclusions that can be drawn from some of the data because the number of participants in each group is so small. Second, data from two of the procedures -- DYSIM Performance Modeling and Critical Incidents Interviews -- were obtained only from the supervisor-FPL group. Because this group of experts differs considerably from the other group of experts, the data collected from these two procedures require extensive validation with a larger, representative sampling of FPL's.

Another limitation is the need to address team factors in the air traffic control job. In this initial analysis, we wanted first to measure the performance of the individual controller before moving on to investigate the interaction between the radar controller and D-side. Because strategies may vary depending upon whether the controller is assisted by a D-side, it is important to note that our analysis only characterizes cognitive models and strategies for the radar controller performing without a D-side.

The most serious limitation was the time constraints imposed upon the data collection, analysis, and interpretation. This report provides a comprehensive overview of the important cognitive components of prioritization, but further data collection and analysis are required to permit development of a more robust and more detailed model.

Continued . . .

GENERAL LIMITATIONS OF THE DATA (Continued)

It is important that the results obtained be extended and validated not only with a panel of representative FPL's but also by correlating objective performance measures with controllers' use of the cognitive models and strategies outlined here. All results obtained from all analyses were preliminarily validated through consultation with at least one Subject-Matter Expert (SME), but because of variability among experts, and also in order to obtain a truly reliable validation, more extensive validation is still required.

The cognitive task-decomposition analysis obtained from the DYSIM performance modeling should be viewed as very preliminary. Clearly, there are other cognitive chunks of the air traffic control task, and any decomposition of tasks may vary as a function of situational factors yet to be explored, such as team factors. This decomposition also requires extensive validation and further analysis to determine expert strategies and selection rules as related to each subgoal within each task element. Similarly, the Mental Model requires validation and refinement. Additional analysis is required to extend the model to include identification of each type of perceptual information perceived and the areas of the Mental Model where that information would be best evaluated.

In conclusion, the results, interpretations, and training recommendations presented herein are to be viewed as exploratory and tentative. Recommendations should be viewed as tentative at this point because they flow from an analysis that has not been fully validated and that is derived from limited data. The results thus far, however, do suggest exciting and innovative approaches to the training of en route air traffic controllers.

DYSIM PERFORMANCE MODELING

Cognitive Decomposition Of Tasks

Tasks were decomposed in a manner congruent with the cognitive (problem solving, decision making, and perceptual) demands placed upon the controller. This differs from traditional, behavioral task decomposition in several ways. The criteria for task segmentation differ between the behavioral and cognitive approaches; the behavioral analysis divides tasks according to observable actions, whereas our task decomposition divides tasks according to the underlying goals and cognitive operations associated with them. Behavioral task analysis segments a job into behaviorally distinct tasks -- tasks that can be isolated because of the unique, discrete behaviors associated with them. Cognitive task analysis decomposes a job into skill-based tasks that may not necessarily be behaviorally distinct.

Continued . . .

Cognitive Decomposition Of Tasks (Continued)

Our approach to task decomposition emphasizes identification of tasks based upon the cognitive skills required, and then divides the overall task into cognitively salient "chunks" -- that is, a unit of activity that involves a group of cognitively related decisions, operations, or activities, and that exists independently across a wide spectrum of situations or scenarios. In the cognitive approach to task decomposition, tasks are identified and segmented according to their cognitive underpinnings with the perceptual events triggering their execution; thus, this task segmentation permits part-task training design around tasks involving similar goals and cognitive skills.

A task is defined as a single unit of goal-directed behavior that will execute to completion if uninterrupted. Thus, each task encapsulates a logically self-contained set of subgoals that describe the steps taken to attain the overall task goal. A given task triggers attention based on the current contents of the five panels within the Mental Model (see Figure 3 on page 31). For example, the nearly simultaneous appearance of three airplanes heading for landing at a common airport should trigger reference to the Sector Management, Sector Data, and Conditions panels of the Mental Model.

The ten primary tasks involving cognitive operations are listed and briefly described immediately below.

1) **Monitor Situation** -- Obtain information about current situation and evaluate it to determine events that must be dealt with.

2) **Accept Handoff Or Pointout** -- Assess and accept or decline a handoff or pointout from a transferring controller.

3) **Sequence Aircraft For Arrival** -- Take steps to sequence a group of aircraft for arrival.

4) **Resolve Aircraft Conflict** -- Determine potential conflictions and implement means to avoid them.

5) **Route Aircraft (per requests from pilot or other controllers)** -- Respond to requests for routing, etc.

6) **Manage Departures** -- Respond to departure clearance requests.

7) **Refine Situation Understanding** -- Obtain information to resolve inconsistencies between perceived aircraft data and current situation understanding.

Continued . . .

Cognitive Decomposition Of Tasks (Continued)

8) **Issue Advisory** -- Initiate information update to pilot or other controller.

9) **Handoff/Pointout Aircraft** -- Initiate and complete handoff (or pointout) of aircraft to receiving controller.

10) **Maintain PVD Readability** -- Maintain clarity and accuracy of current situation as captured on the PVD screen in terms of data blocks displayed.

Some of these tasks will be suspended pending information or the controller will switch attention to other tasks and then later return to those tasks. This aspect of a full Mental Model (i.e., attention switching between tasks) is not captured in the following task models, and would be included with additional analysis.

Each of the 10 high-level tasks listed above describes a single goal. Each task is composed of subgoals that capture the steps needed to attain this goal. Also, a task becomes active because it is triggered by the appearance of certain patterns of information. The subgoals and triggers are listed below for each of the 10 tasks (goals):

1) **MONITOR SITUATION**

Trigger: Absence of high priority task OR awareness of x time period elapsed since last screen scan OR limited data block* OR close to sector boundary*

Subgoals:

- Observe aircraft data
- Project aircraft routes
- Compare with current sector situation understanding

2) **ACCEPT HANDOFF OR POINTOUT**

Trigger: Aircraft flashing on PVD AND NOT in middle of critical task OR pointout from other traffic controller OR call on override*

Subgoals:

- Evaluate request
- Accept or deny pointout IF pointout
- Accept or delay handoff IF handoff
- Establish radio contact IF handoff accepted

Continued . . .

Cognitive Decomposition Of Tasks (Continued)

3) **SEQUENCE AIRCRAFT FOR ARRIVAL**

Trigger: Two or more aircraft converging on one airport for landing within x span of time AND NOT all spaced and sequenced for arrival OR different aircraft types*

Subgoals:

- Evaluate aircraft routes and timing
- Determine sequence for landing
- Develop backup plans*
- Derive/revise plan for sequencing/slowing/descending aircraft
- Implement plan for sequencing/slowing/descending aircraft
- Handoff to terminal*
- Monitor plan execution

4) **RESOLVE AIRCRAFT CONFLICT**

Trigger: Two or more aircraft at same altitude OR converging on same lat/long/altitude

Subgoals:

- Evaluate routes, goals, and characteristics of aircraft
- Determine plan
- Issue clearances
- Call and coordinate*

5) **ROUTE AIRCRAFT**

Trigger: Clearance request from pilot or adjacent controller OR weather in flight path OR prohibited area in flight path OR flow control directive*

Subgoals:

- Evaluate route
- Issue or deny clearance
- Call and coordinate*
- Update flight plan and flight strip IF clearance issued

Continued . . .

Cognitive Decomposition Of Tasks (Continued)

6) **MANAGE DEPARTURES**

Trigger: Departure clearance request from tower flight controller OR departures expected within x time span AND adverse conditions within airport locale OR flow control directive*

Subgoals:

- Assess potential confliction with current and projected sector traffic
- Issue clearance IF NO confliction
- Postpone departure IF confliction
- Restrict future departures IF adverse conditions (weather, workload, level of traffic)

7) **REFINE SITUATION UNDERSTANDING**

Trigger: Possible discrepancy between displayed versus real altitude, heading, speed, PVD information, and issued altitude, heading, speed

Subgoals:

- Query pilot about data item
- Update PVD or flight strip IF data incorrect or incomplete
- Monitor PVD*

8) **ISSUE ADVISORY**

Trigger: Other aircraft traffic within x range of another aircraft OR weather system at y location OR birdflight*

Subgoals:

- Alert pilot of situation
- Update PVD or flight strip*

Continued . . .

Cognitive Decomposition Of Tasks (Continued)

9) HANDOFF/POINTOUT AIRCRAFT

Trigger: Aircraft nearing edge of sector (distance or time from boundary -- distance can be greater when no traffic in route)

Subgoals:

- Issue pointout IF aircraft will go through small amount of third sector AND no other aircraft are or will be in that portion of third sector
- Initiate handoff to receiving controller
- Coordinate with receiving controller IF coordination necessary
- Confirm handoff acceptance from receiving controller if primary handoff
- Confirm handoff visually if non-primary handoff*
- Issue new radio frequency to pilot WHEN receiving sector accepts handoff
- Drop data block WHEN outside your airspace

10) MAINTAIN PVD READABILITY

Trigger: Two overlapping data blocks OR when project flight paths, there will be overlapping data blocks in the near future

Subgoals:

- Anticipate OR see overlapping data blocks
- Move data blocks UNTIL data blocks clear

*NOTE: The above task decomposition was verified with only one SME, with her suggested additions denoted by an asterisk. Because cognitive task decomposition is based upon a modeling procedure aimed at identifying cognitively-valid knowledge "chunks" across a range of experts, these suggested additions should be viewed even more tentatively, as they were elicited through an interview procedure with only one controller.

Mental Model Of Knowledge Categories For En Route ATC

This model depicts the categories of knowledge required to support performance of the various tasks described previously, and could be used as a framework for structuring training. It serves as a framework for classifying aircraft and situation data into patterns of events. The Mental Model can be characterized as a generic expert-typical knowledge representation of the knowledge required to support performance of the 10 decomposed tasks. It serves as an organizer or "categorizer" of information: a "mental checklist" of what factors the controller should consider, the relative importance of each set of factors (panels), and the interrelationship between knowledge categories or panels. Figure 3 presents the Mental Model for en route control.

The structure of the Mental Model implies a conceptual framework used by the controller for organizing domain knowledge and implies a strategy for applying the knowledge in job conduct. The information on the Mental Model is partitioned into panels containing conceptually different categories of information. Panels represent both Control (Sector Management, Procedures) and Display (Sector Data, Conditions, Sector Airspace) functions. Each panel contains several levels. The lower levels on each panel are the more basic data. The higher levels are more cognitively "processed" or "derived" types of information. The levels are organized hierarchically, with the information at each level representing partial solutions to the problem.

The Mental Model contains five panels, as shown in Figure 3. They are as follows:

1) **Sector Management** -- contains an understanding of the events that are occurring or are anticipated to occur in the sector. The elements of this panel are events involving one or more aircraft.

2) **Sector Data** -- contains basic data about the aircraft in the sector. Information on this panel is used in reasoning about the current situation and in categorizing aircraft into events on the Sector Management panel.

3) **Conditions** -- contains subjective factors that determine the controller's general level of stress and workload.

4) **Sector Airspace** -- contains knowledge about the spatial layout of the sector and its characteristics.

5) **Procedures** -- contains knowledge about the general procedures for separating aircraft and for handling different kinds of situations.

Continued . . .

FIGURE 3. MENTAL MODEL FOR EN ROUTE CONTROL

(suggested additions denoted by an asterisk)

SECTOR MANAGEMENT

Handoff Accomplished
Background Aircraft
Future Events
Ongoing Events
Conflictions
Aircraft Under Your Control
Approaching Aircraft

SECTOR DATA

Altitude Partitions
Route Structure
Requests
Special Short-Term Conditions
Weather
*Aircraft Characteristics
Flight Strip Data
PVD Data

CONDITIONS

Overall Condition
Traffic Level
Screen Readability
*Radio Frequencies
Weather Factors
*Upper Winds
Affective Factors
*Team Factors

SECTOR AIRSPACE

Published Arrivals, Departures, Approaches
En Route Structure
Restricted Areas
Topography
Geography
Sector Boundaries
*Altitude Strata
*Approach Control Areas

PROCEDURES

ATC Procedures
Facility/Area/Sector Procedures

Mental Model Of Knowledge Categories For En Route ACT (Continued)

The top three panels contain information relating to the situation in a specific sector at a particular time, while the bottom two panels (Sector Airspace, and Procedures) contain background knowledge. The bottom two panels, containing background knowledge, are relatively stable, and the situation-specific panels are relatively dynamic. The Sector Management panel is the primary panel used for prioritization of decision making, because it represents the understanding of the events that must be dealt with. However, determining how to deal with each event involves reference to the data on the Sector Data panel and the Conditions panel, and other events on the Sector Management panel, as well as knowledge of standard procedures from the Procedures panel. The events are also interpreted with reference to the static spatial representation of the sector airspace (embodied on the Sector Airspace panel).

The remainder of this section discusses the individual panels of the Mental Model and their constituent levels in more detail.

Sector Management Panel

The Sector Management panel is divided into seven hierarchical levels, according to the general flow through the sector airspace, as follows:

1) **Approaching Aircraft** -- includes aircraft that are entering the sector and require accepting handoff from adjacent sector or approach control.

2) **Aircraft Under Your Control** -- includes aircraft that are now under sector control but have not yet been classified into any other events.

3) **Conflictions** -- includes events that if not dealt with will result in conflictions (separation violations, etc.).

4) **Ongoing Events** -- includes events that must be dealt with over a period of time, such as sequencing aircraft for arrival.

5) **Future Events** -- includes events that must be dealt with at some future time (e.g., an aircraft that has been vectored around weather and must be vectored back on course when past the weather, or an aircraft that has been kept at a lower altitude than desired to avoid traffic above and can be cleared higher after the traffic has passed).

6) **Background Aircraft** -- includes aircraft that are clear over the expected route through the sector, and will only require handoff.

Continued . . .

Mental Model Of Knowledge Categories For En Route ATC (Continued)

Sector Management Panel (Continued)

7) **Handoff Accomplished** -- includes aircraft that have been handed off but are still within radar contact and shown on the PVD.

The data elements on this panel are events with various modifying parameters, represented as:

Event [aircraft involved], [criticality of event], [time window]

where "criticality of event," which contributes to task prioritization, is a rating of the consequences of not dealing with it, as follows:

1) Separation violation

2) Procedural deviation (e.g., not following LOA for handoff)

3) Efficiency for controller workload

4) Efficiency for pilot and aircraft route of flight (e.g., delays, flight plan deviation requests)

The above criticality ranking is congruent with the goals priorities obtained from the Paired Problem Solving analysis. "Time window" refers to the time within which the event must be dealt with to avoid the consequences.

Sector Data Panel

This panel of the model contains the following levels:

1) **PVD Data** -- information about each aircraft, location of aircraft, some weather systems, limited route, approach, and departure location.

2) **Flight Strip Data** -- information about filed flight plan for each aircraft.

3) **Aircraft Characteristics** -- knowledge of aircraft performance parameters.

4) **Weather** -- any noteworthy weather information such as wind speed, temperature, zones of turbulence and/or precipitation, barometric pressure.

Continued . . .

Mental Model Of Knowledge Categories For En Route ATC (Continued)

Sector Data Panel (Continued)

5) **Special Short-Term Conditions** -- unusual, temporary local conditions; for example, a closed runway at an airport due to weather conditions.

6) **Requests** -- requests from pilots or other sector controllers f. . :arance, pointouts, handoffs, etc.

7) **Route Structure** -- individual aircraft assembled according to arrival to or departure from airports within the sector, overflights over the sector.

8) **Altitude Partitions** -- designates aircraft flying at a given stratum of altitude.

In general, the knowledge contained on this panel refers to dynamic factors occurring within the sector airspace, including the location and movement patterns of the individual aircraft, weather, and short-term special conditions.

The bottom two levels of this panel contain information about the aircraft that can be reviewed from the PVD screen or the hard-copy flight strips. Thus, controllers can access these data from some physical location without needing to remember or compute it. The remaining levels on this panel refer to information that is not necessarily available for reference in "hard" copy. Thus, this information must be remembered by the controller. The top two levels (Altitude Partitions and Route Types) are derived from the lower-level categories and seem to be a basic information management technique used by controllers; i.e., categorization of flights into route type (overflights, arrivals, and departures) and then according to altitude partitions (high overflights, low overflights, etc.).

The Request level of this panel is a critical level on the model. At this level many new requests function as triggers to activate tasks. Thus, entries made at this level will shift attention from one task to another when the resulting pattern constitutes a triggering condition with a higher priority than the current task (due to the new posted request).

Conditions Panel

The Conditions panel contains the following eight levels:

1) **Team Factors** -- includes factors unique to teamwork.

2) **Affective Factors** -- includes factors such as the individual controller's self-perception, and relations and interactions with coworkers and pilots.

Continued . . .

Mental Model Of Knowledge Categories For En Route ATC (Continued)

Conditions Panel (Continued)

3) **Upper Winds** -- a subjective assessment of the effects of upper winds.

4) **Weather Factors** -- a subjective assessment of the current weather conditions.

5) **Radio Frequencies** -- a characterization of the audibility and fidelity of the radio frequencies.

6) **Screen Readability** -- a characterization of the level of screen clutter.

7) **Traffic Level** -- a characterization of the current overall level of traffic; e.g., sparse, moderate, or heavy traffic.

8) **Overall Condition** -- a summation of the overall workload as a function of conditions posted on the other seven levels of this panel.

The Conditions panel provides a mechanism for determining when the usual strategies should be modified. In general, this panel reflects stress factors that influence controller workload. Team and affective factors are part of the Mental Model because they can influence stress and workload by influencing the decisions a controller makes about asking supervisors and other sector controllers for help or favors, perceiving a situation as out of control, etc. The remaining levels of this panel post general characterizations of weather, radio control, PVD screen appearance, and traffic level made by individual controllers about the current situation. Because these characterizations are subjective assessments, they capture individual differences.

Sector Airspace Panel

The Sector Airspace panel captures knowledge about the three-dimensional space of a particular sector in terms of manmade and ATC constructs and natural features. The levels of knowledge within this panel are:

*1) **Approach Control Areas**
*2) **Altitude Strata**
3) **Sector Boundaries**
4) **Geography**

Continued . . .

Mental Model Of Knowledge Categories For En Route ATC (Continued)

Sector Airspace Panel (Continued)

5) **Topography**
6) **Restricted Areas**
7) **En Route Structure**
8) **Published Arrivals, Departures, Approaches**

ATC constructs include the sector boundaries, altitude strata, approach control areas, published arrivals, departures, and approaches, en route structures, and restricted areas. These elements represent the principal locations for movement of aircraft in a manner similar to a highway on the ground. Thus, they are a primary component of the controller's internal model of the physical characteristics of the sector airspace.

Natural features include the geography of the region and topographic features such as mountains and towers. Manmade entities include airports, NAVAID equipment, and runways. This knowledge would be represented by a three-dimensional model of the sector airspace, reflecting its inherently spatial characteristics.

Procedures Panel

On the Procedures panel, there are two levels of procedural knowledge for en route ATC. The levels on the panel are **ATC Procedures** and **Facility/Area/Sector Procedures**.

ATC procedures are the rules that apply to radar controllers nationwide, while the other procedures levels refer to the rules that govern a given facility, area, or sector. These procedures in essence create the boundaries that constrain and define the actions of the air traffic controller. These rules form background knowledge to guide actions taken by controllers in response to the current situation captured in the Sector Management, Sector Data, and Conditions panels of the Mental Model.

ATC procedures are delineated in the FAA Handbook 7110.65F. This document includes the rules that govern radar control and give "global" guidance for the administration of all airspace within the jurisdiction of the FAA. Other procedures are embodied in procedural Letters of Agreement (LOA's). LOA's are used to document cooperative or concurrent agreements between facilities.

Continued . . .

Mental Model Of Knowledge Categories For En Route ATC (Continued)

Procedures Panel (Continued)

The information on these panels is evaluated in terms of:

- Procedure Class [rule]

where the rule is an individual procedure.

Relationship Between Mental Model And Cognitive Tasks

This empirically derived Mental Model characterizes expert knowledge used to support performance of the tasks, and has important implications for instructional organization and sequencing. The importance of these results lies in the relationship between the task decomposition (10 tasks) and the Mental Model.

Because the Mental Model contains the important and cognitively salient knowledge categories found to support task performance, and also because the Mental Model represents expert-typical mental categorizations, controllers should be taught to think about tasks with reference to this Mental Model. Specifically, controllers should use this model as a basis for recognizing when a particular task should be performed and as a type of checklist of factors to consider to support performance of each subgoal listed under the decomposition of tasks. Of course, some categories will be relevant only to certain tasks or task subgoals and/or the relevance of a category may vary according to the specific situation. However, if controllers learn to automatically (i.e., quickly and almost subconsciously) visualize this model and run through the categories as a type of checklist while performing tasks, then all relevant and important factors would be considered.

Instruction should be reorganized and resequenced to focus not on specific ATC procedures, but rather, upon each panel and its category within the Mental Model. The three upper-level panels (Sector Management, Sector Data, and Conditions) were found to be the most important knowledge domains for expert performance.

Current basic radar training, however, is organized around very specific behavioral tasks and specific ATC procedures. These tasks consist mainly of FAA ATC standard procedures, although results of the DYSIM performance modeling, DYSIM structured problem solving, structured interviews, and critical incidents interviews all show that experts place greater emphasis on higher-level cognitive activities which involve information gathering and decisions related to the Sector Management, Sector Data, and Conditions panels of the model. The following excerpt from the Instructional Program Guide (1988, EP 12-0-1E) of Phase XIB Radar Controller Training provides an example.

Continued . . .

Relationship Between Mental Model And Cognitive Tasks (Continued)

EXAMPLE OF BEHAVIORAL-TASK ORGANIZATION OF CURRENT BASIC RADAR TRAINING

OBJECTIVE: To prepare developmentals for entry into OJT in Phase XII by providing training which will permit them to demonstrate, under simulated conditions, the skills and knowledges that are required under live conditions.

A. Radar Academic Procedures.

The developmental will accomplish the following in accordance with Handbook 7110.65F:

1. Explain the differences between narrowband, DARC, and broadband radar.
2. Describe the PVD controls and their functions.
3. Describe procedures for turning on and adjusting a PVD.
4. Locate and identify each radar system serving the assigned area of specialization.
5. Prepare RDP message for entry into the computer.
6. Describe the radar coverage and any limitation pertaining to the area of specialization and adjacent areas.
7. List the components of the ATC radar beacon system and describe the function of each component.
8. Explain the conditions which may make it necessary to adjust the PVD display prior to assuming responsibility for a radar position.
9. Describe procedures for selecting and monitoring assigned beacon codes.
10. Identify the radio equipment and land lines associated with radar positions.
11. Identify the beacon codes assigned to departures, en route, arrivals, terminal coordination, VFR on Top, IFR cancellation, emergency, radio failure, and hijacking.
12. State the correct phraseology for code assignments changing transponder to low or standby, beacon termination, and inoperative or malfunctioning interrogator/transponder.
13. Explain what action to take when an aircraft's transponder fails in positive control airspace.
14. State the beacon code assignment for VFR advisory service.
15. Describe the procedure for identification of aircraft using both primary and secondary radar.

Continued . . .

Relationship Between Mental Model And Cognitive Tasks (Continued)

EXAMPLE OF BEHAVIORAL-TASK ORGANIZATION OF CURRENT BASIC RADAR TRAINING (Continued)

16. Describe automatic acquisition and explain the action required.
17. Describe how, when, and where to effect a handoff.
18. Identify the parameters established for initiating and receiving handoffs.
19. Effect a transfer of control and communications.
20. State the procedures for confirming a handoff.
21. State the radar separation minima for narrowband, DARC, and broadband modes.
22. List the conditions under which radar separation may be applied.
23. Explain how to apply radar separation between aircraft targets in narrowband, DARC, and broadband modes.
24. State the conditions under which vectoring may be applied.
25. Formulate vector clearances.
26. Explain the application of radar separation and vectoring techniques as applied to departing aircraft.
27. Explain the application of radar separation and vectoring techniques as applied to arriving aircraft.
28. Describe speed adjustment procedures.
29. Specify minimum speeds to be used when applying speed adjustment procedures.
30. Describe how to provide radar assistance for aircraft with a communications failure.
31. Recognize target indications of emergencies, lost communications, and hijacking.
32. Describe the procedures for issuing traffic information, vectors because of traffic, weather information, chaff information, surveillance of holding patterns, and merging target procedures.
33. Explain the effects of weather on the PVD for the narrowband, DARC, and broadband modes.
34. Explain the purpose of ECM and chaff and how they affect the radar display.
35. Explain in detail applicable Letters of Agreement and any special radar procedures.

Relationship Between Mental Model And Cognitive Tasks (Continued)

The stated OBJECTIVE of the above is "To prepare developmentals . . . by providing training which will permit them to demonstrate, under simulated conditions, the **skills and knowledges** that are required . . . ." Although acquisition of skills and knowledge is the stated objective, the specific objectives are primarily organized behaviorally, not cognitively. The Mental Model, however, suggests that training be organized around the panels and categories of the model. Emphasis should be given to overall pattern recognition (i.e., identifying the relevance of each bit of information perceived and relating this to a category within the Mental Model), performance strategies related to each category, and the relationship between knowledge contained within the categories and the various cognitive tasks and their subgoals. A general example of instructional design organized in this fashion for Phase XIB Radar Controller Training might be as follows:

- -

The developmental will accomplish the following in accordance with Handbook 7110.65F:

SECTOR MANAGEMENT

Handoff Accomplished: Identify aircraft that have been handed off, but that are still within radar contact and shown on the PVD.

Background: Identify aircraft that are clear over the expected route through the sector, and will only require handoff.

Future Events: Identify events that must be dealt with at some future time [estimate criticality of event] X [estimate time-window].

Ongoing Events: Identify events that must be dealt with over a period of time (such as sequencing for arrival).

Conflictions: Identify events that if not dealt with will result in conflictions.

Aircraft Under Your Control: Identify aircraft which are now under sector control but which have not yet been classified into any other events.

Approaching Aircraft: Identify aircraft that are entering your sector and require accepting handoff from adjacent sector or approach control.

- -

Continued . . .

Relationship Between Mental Model And Cognitive Tasks (Continued)

Specific optimizing strategies and algorithms would then be taught under each of the above categories. Examples of such strategies might include increased vigilance in PVD monitoring when there are many "Ongoing Events," speed control taught in relation to estimating the time window under the "Future Events" category, etc. The flowchart for prioritization of decision making for separation (see Figure 17 on page 74) could be included when teaching Sector Management and the critical cue inventory (see Table 8 on page 78) could be taught under the "Overall Conditions" category.

The analysis of DYSIM Structured Problem Solving in the next text section provides a preliminary listing of many expert-typical strategies.

Note that under such an approach, the training objectives currently listed in EP 12-0-1E would not be discarded, but would be included within each category of the Mental Model. The current objective of "Identify the parameters established for initiating and receiving handoffs" would be included in the Sector Management panel under the category "Handoff Accomplished," while the current objective "Describe the radar coverage and any limitation pertaining to the area of specialization and adjacent areas" would be included under the Sector Airspace category of "Sector Boundaries."

Of course, many of the current objectives do not fit into the Mental Model categories at all because they are behavioral or because they are discrete bits of declarative knowledge which must be learned or memorized, but which do not relate to any larger, conceptual model of air traffic control -- i.e., the Mental Model. Learning to write presents an analogous situation. In order to write effectively, one must know how to spell words, but knowing how to spell does not relate well to performance of the larger task of writing complete sentences and organizing those sentences into effective prose, nor to clarity and conciseness in writing. Nonetheless, spelling, like knowing beacon codes for example, is important.

Similarly, many of the current objectives, although not fitting any cognitive category within the Mental Model, are necessary for air traffic control. Again, the main implication of the cognitive approach outlined here is a shift in emphasis away from ATC procedures and discrete facts toward emphasis upon attention to contextual factors and overall pattern recognition (i.e., task triggers) for the whole task, and the development of an underlying Mental Model to serve as a broad cognitive organizer in support of task performance. The Mental Model and associated task decomposition provides a framework for categorizing events, for understanding the overall sector situation, and for organizing task strategies. This framework entails a shift in organization away from discrete, behavioral tasks to the more global cognitive and perceptual activities and knowledge categories, using the latter as the primary organizer.

Continued . . .

Relationship Between Mental Model And Cognitive Tasks (Continued)

Behavioral task objectives still must be taught and mastered, but are subordinated to the cognitive objectives based upon the Mental Model, rather than themselves serving as the endpoints of training for the particular training module (e.g., XIB). Part-task training should be provided on each of the 10 cognitive tasks. This should include training in recognition of the task triggers, in identifying subgoals, and in relating task triggers and subgoals to each category within the Mental Model. Under this approach, training for this task would entail the repeated presentation of each task individually on a DYSIM to students over a compressed time period. This is necessary to achieve high skill levels, such that the task is recognized and performed rapidly and without requiring a lot of attention to be devoted to it, thus freeing mental resources for the performance of other tasks such as overall situation monitoring.

Consider the task of "Sequencing Aircraft for Arrival." Students would be taught to look for the triggering event (two or more aircraft converging on an airport for landing within a certain time span AND NOT all spaced and sequenced for arrival OR AND different aircraft types), and then to automatically associate this triggering event with each of the listed subgoals. The task triggers are particularly relevant to prioritization, because they specify what controllers should be attending to at any given moment in the task. The triggers specify when to shift attention from overall situation monitoring to the performance of individual tasks and when to switch attention between competing tasks. They specify the Mental Model contents that should set a particular task in motion. For instance, within the Mental Model, when information in the "Ongoing Events" category contains an ongoing sequencing for arrival pattern that needs to be performed within a certain time parameter as determined by the types of aircraft involved, and/or when certain "Aircraft Characteristics" are contained in that category, the Sequencing Aircraft for Arrival task needs to be performed. The student would be trained to evaluate when to perform tasks and how to best perform each of their subgoals with reference to the information categories contained in the Mental Model structure.

Thus, the cognitive-perceptual trigger for "Sequence Aircraft for Arrival" is defined algorithmically as "Two or more aircraft converging on one airport for landing within x span of time AND NOT all spaced and sequenced for arrival AND OR different aircraft types." Developmentals could be taught to automatically perform this task when this trigger is presented, as informed by the controller's review of the relevant information categories in the Mental Model. Consider also the task defined as "Route Aircraft." Within the Mental Model, when information in the "Request" category contains a clearance request from pilot or adjacent controller OR when information in the "Weather" category contains data about adverse weather in the flight path OR when information in the "Prohibited/Restricted Areas" category contains data about a prohibited area in the flight path, the Route Aircraft task needs to be performed. A complete model would identify each type of information perceived and its specific relationship to which category within the Mental Model.

Continued . . .

Relationship Between Mental Model And Cognitive Tasks (Continued)

An example of problems encountered by a controller who did not have an effective Mental Model for solving a problem is provided by the following summary of an actual controller performing a task (scenario description given in Appendix C - Problem 1) during the DYSIM Performance Modeling task:

> The controller recognizes that he has a "major sequencing problem," but rather than attacking it head on, panics and asks another sector to spin two of the aircraft to give him time to separate the others. He uses altitude and vectoring as spacing methods, but never uses speed -- he slows the first aircraft first. He puts off a call and never calls back. He doesn't anticipate well and could have eased his workload if he had cleared N123EH for approach earlier (as others did).
>
> It takes almost 3 minutes before he starts sequencing the first three aircraft.
>
> In summary, the controller:
>
> 1) Recognizes three aircraft tied and has "major sequencing problem"
>
> 2) Spins two aircraft outside sector
>
> 3) Starts vectoring aircraft for sequencing
>
> 4) Puts off call because "too busy" and never calls back

This controller would benefit from refresher-training in the Mental Model. For instance, under the Sector Management panel of the Mental Model, this controller would be instructed in considering the time frame of Future Events, identifying Ongoing Events, and so forth. This could be augmented with specific strategies for "Sequencing Aircraft for Arrival" -- when to use speed control, altitude, and vectoring to expedite the process. Also, training could cover use of workload reduction strategies such as taking an early handoff or asking another sector to slow approaching aircraft if an overload situation (i.e., reference to Traffic Level and Overall Condition) might be developing.

Given the above Mental Model and task structures, a model of ATC en route control actions can be incorporated into a computer-based decision-aiding system. Such a system can anticipate and suggest subgoals to the controller during tasks and aid the controller in keeping track of unfinished or next priority tasks when more critical tasks capture attention.

Continued . . .

Relationship Between Mental Model And Cognitive Tasks (Continued)

The Sector Airspace panel, for instance, could be represented as a spatial model on a computer-based trainer with the various types of information (represented as levels) color-coded. The airspace could be viewed as a kind of 3-D model, or projected onto a 2-D plane which could be rotated to different views. Using this spatial representation, different categories of Sector Data or Sector Management could be superimposed on the airspace model.

DYSIM STRUCTURED PROBLEM SOLVING

In general, experts were better able to think about larger groupings of data -- i.e., forming larger cognitive "chunks" of information, thus increasing their problem-solving efficiency. The experts have relatively more protocol segments that address all three incoming aircraft. Intermediates and novices, on the other hand, tend to verbalize about just one or two aircraft at a time. In general, experts are able to handle solutions with fewer, more "compiled" actions, suggesting better skill in advance planning and organization of data. Experts also exhibit fewer cases of having to implement alternative plans, suggesting better initial problem understanding (problem-space representation). The total number of expert actions is generally fewer than those of intermediates in the same situation.

The listing of key controller actions in Table 3 served as the starting point to generate the Glossary of Strategies presented in Table 4. Strategies are loosely divided into the following three categories: display strategies involving the planning and monitoring of the sector, control strategies involving the execution of control activities in the sector, and workload reduction strategies that are employed to reduce the controller's workload. Overall counts for the numbers of times a strategy was used by experts and novices are also provided in Tables 5 and 6.

The expert production rules (i.e., specific algorithms derived from the protocol analysis) through which the results are derived are contained in Appendix H. These algorithms, following validation and some refinement, could be used to form the data base for an intelligent tutoring system. Such a system could use these algorithms as the basis for providing prompts to controllers in strategy usage at key points during a problem scenario.

Continued . . .

TABLE 3 . DISPLAY, CONTROL, AND WORKLOAD REDUCTION STRATEGIES

Display Strategies

- Planning strategies:
    - High-level, primary plan
    - Lower level plan
    - Backup plan
    - Anticipating changes
    - Refine primary plan
    - Short-term contingencies
    - Estimating (speed, distance . . .)
- Monitoring Strategies:
    - Gather aircraft data
    - Observe to implement backup
    - Observe to vector
    - Observing separation
    - Observing for sequencing
    - Reading vectors
    - Sector scanning
    - Use of J-ring

Control Strategies

- Approach strategies (descend and slow)
- Departure strategies (ascend and speed up)
- Sequencing strategies (high level between 3 or more aircraft)
- Separation strategies (lower level between 2 aircraft):
    - Use speed for separation
        - Performance strategies
    - Vector for separation
    - Vertical separation
- Routing strategies
- Handoff strategies:
    - Initiating handoff
    - Accepting handoff

Workload Reduction Strategies

- Eliminating a factor
- Early control
- Early pilot notification
- Expediting handoffs
- Letting aircraft run at speed
- Letting speed take effect
- Shortcutting
- Slowing to intermediate speeds
- Speed up to expedite
- Tighten separation

TABLE 4. GLOSSARY OF STRATEGIES

Accepting handoff:	A subgroup of the handoff strategies where the controller accepts the handoff from another sector or control.
Approach strategies:	A group of high-level control strategies involving descent and slowing of aircraft.
Anticipating changes:	A subgroup of the planning strategies where the controller plans on potential changes.
Backup plan:	A subgroup of the planning strategies where the controller makes an alternative plan to his or her high-level plan.
Control strategies:	A top-level category of strategies associated with the management of sector activities.
Departure strategies:	A group of high-level control strategies involving ascent of aircraft.
Display strategies:	A top-level category of strategies associated with analyzing sector data with the objective to plan or monitor sector activity.
Dropping tracks:	A group of workload reduction strategies of dropping tracks when they are no longer under sector control.
Early control:	A group of workload reduction strategies used to initiate a plan or sequencing before the aircraft has entered the sector.
Early pilot notification:	A group of workload reduction strategies where the controller notifies an aircraft pilot of some plan before it takes place.
Eliminating a factor:	A group of workload reduction strategies where the controller eliminates an aircraft as a factor in a problem.
Estimating (speed, etc.):	A subgroup of the planning strategies where the controller estimates speed, altitude, or direction as part of the planning.

Continued . . .

TABLE 4. GLOSSARY OF STRATEGIES
(Continued)

Expeditious handoffs:	A group of workload reduction strategies used to speed up the handoff process.
Gather aircraft data:	A subgroup of the monitoring strategies where the controller either looks up or requests specific aircraft data such as heading, speed, or altitude.
Handoff strategies:	A group of control strategies including accepting handoffs, initiating handoffs, and changing frequency.
High-level, primary plan:	A subgroup of the planning strategies where the controller makes a high-level plan that will be executed over the next 5 to 20 minutes.
Initiating handoff:	A subgroup of the handoff strategies involving starting up the handoff.
Letting aircraft run at speed:	A group of workload reduction strategies where the controller lets the aircraft run at current speeds to expedite the situation.
Letting speed take effect:	A group of workload reduction strategies where the controller waits to let the aircraft speed provide separation rather than vectoring.
Low-level plan:	A subgroup of the planning strategies where the controller makes a low-level plan to be used in the short term.
Monitoring:	A group of display strategies including working with vector readouts, use of the J-ring, sector scanning, and gathering of aircraft data.
Observe/implement backup:	A subgroup of the monitoring strategies where the controller observes the situation in order to consider whether to implement the backup plan.
Observe to vector:	A subgroup of the monitoring strategies where the controller observes aircraft route and separation to determine when to vector.

Continued . . .

TABLE 4. GLOSSARY OF STRATEGIES (Continued)

Observing separation:	A subgroup of the monitoring strategies where the controller observes the separation between aircraft.
Observing for sequencing:	A subgroup of the monitoring strategies where the controller observes aircraft to make sequencing decisions.
Performance strategies:	A set of strategies associated with the change of speed to separate strategies where the controller increases an aircraft's speed based on the aircraft's performance characteristics.
Planning:	A group of display strategies including high- and low-level planning, backup planning, and estimating based on sector data.
Reading vectors:	A subgroup of the monitoring strategies where the controller runs out vector lines to see where aircraft will be at certain times in the future.
Reduction of PVD clutter:	A group of workload reduction strategies used by the controller to declutter the PVD.
Refine primary plan:	A group of planning strategies where the controller makes small changes to the primary plan.
Routing strategies:	A group of control strategies including the routing and re-routing of aircraft.
Sector scanning:	A subgroup of the monitoring strategies where the controller does a scan of the PVD to spot sector problems.
Separation strategies:	A group of low-level control strategies including vertical, speed, and vector separation.
Sequencing strategies:	A group of high-level control strategies involving the sequencing of three or more aircraft.

Continued . . .

TABLE 4. GLOSSARY OF STRATEGIES
(Continued)

Short-term contingencies:	A subgroup of the planning strategies where the controller selects an alternative contingency to some immediate problem.
Shortcutting:	A group of workload reduction strategies to expedite an aircraft's route.
Slowing to interm. speeds:	A group of workload reduction strategies where the controller slows an aircraft to an intermediate speed rather than the final speed in order to expedite the situation.
Speed up to expedite:	A group of workload reduction strategies where the controller speeds up an aircraft to expedite the situation.
Tighten separation:	A group of workload reduction strategies where the controller reduces the separation between aircraft in order to expedite the situation.
Use of J-ring:	A subgroup of the monitoring strategies where the controller places a J-ring on one or more tracks for closer monitoring.
Use speed to separate:	A subgroup of the separation strategies used by controllers to increase or decrease aircraft separation by assigning two aircraft different speeds.
Vector for separation:	A subgroup of the separation strategies that are usually invoked when speed has failed to achieve separation.
Vertical separation:	A subgroup of the separation strategies where the controller uses aircraft altitude to separate aircraft.
Workload reduction:	A top-level category of strategies associated with management of the controller's own workload and related to a number of conditions such as traffic level, weather factors, and PVD clutter.

TABLE 5. EXPERT STRATEGY USAGE

Display Strategies

Planning Strategies:	10	Lower level plan
	10	High-level, primary plan
	8	Refine primary plan
	5	Anticipating changes
	4	Backup plan
	3	Estimating (speed, distance, etc.)
	1	Short-term contingencies
Monitoring Strategies:	21	Observing separation
	11	Gather aircraft data
	10	Observing for sequencing
	9	Observe to vector
	3	Reading vectors
	2	Observe to implement backup
	1	Use of J-ring

Control Strategies

7 Approach Strategies (descend and slow)
15 Sequencing Strategies (high level between 3 or more aircraft)
Separation Strategies (lower level between 2 aircraft):

10	Use speed for separation
4	Performance strategies
3	Vector for separation
1	Vertical separation

7 Routing Strategies

Handoff Strategies:	3	Initiating handoff
	2	Accepting handoff

Workload Reduction Strategies

5	Letting speed take effect
5	Eliminating a factor
4	Speed up to expedite
3	Letting aircraft run at speed
3	Early control
2	Tighten separation
1	Slowing to intermediate speeds
1	Shortcutting
1	Early pilot notification

TABLE 6. NOVICE STRATEGY USAGE

Display Strategies

Planning Strategies:

26	Lower level plan
16	Reconsider
10	'Vait to see
6	Short-term contingencies
6	Consider multiple options
5	Switching sequencing
5	High-level, primary plan
3	Learning from errors
2	Refine primary plan
1	Backup plan

Monitoring Strategies:

49	Observing separation
24	Observing routing
15	Observe to vector
13	Gather aircraft data
10	Observing for sequencing
7	Reading vectors
3	Use of J-ring

Control Strategies

24 Approach Strategies (descend and slow)
2 Sequencing Strategies (high level between 3 or more aircraft)
Separation Strategies (lower level between 2 aircraft):

16	Use speed for separation
13	Vector for separation
6	Vertical separation

10 Routing Strategies

Handoff Strategies:

9	Accepting handoff
8	Initiating handoff

Workload Reduction Strategies

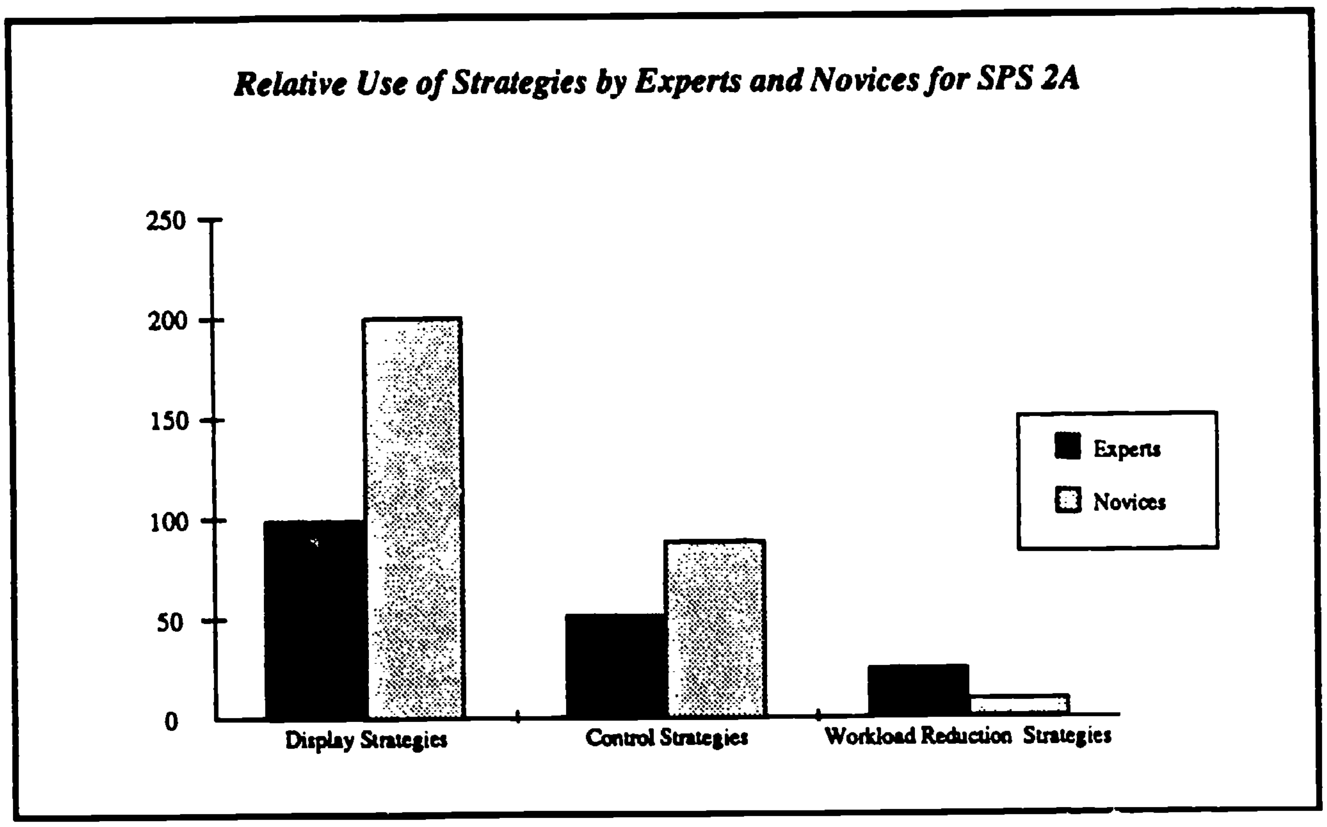
4	Early control
3	Letting aircraft run at speed
1	Eliminating a factor

DYSIM STRUCTURED PROBLEM SOLVING (Continued)

Figure 4 shows the relative use of three groups of strategies for the experts and novices. The experts used relatively more Workload Reduction Strategies. The following Workload Reduction Strategies were unique to the expert participants:

Letting speed take effect
Speed up to expedite
Tighten separation
Slow to intermediate speeds
Shortcutting
Early pilot notification

FIGURE 4. EXPERT AND NOVICE USE OF STRATEGIES



Experts may be more accurate at predicting the effects of speed on spacing, and tend to use this technique more frequently, perhaps because of its relative efficiency and minimal impact upon the user (the pilot). Due to the time required to effect a change, speed control requires a great deal of advance planning and accurate timing by the controller.

Continued . . .

DYSIM STRUCTURED PROBLEM SOLVING (Continued)

The novices, on the other hand, use more display strategies, but these are related mainly to simply watching situations develop and reconsidering previous planning rather than active monitoring to update information or long-term advance planning. The novices also use more strategies related to actually controlling aircraft. Because they are less adept at pre-planning and problem-space organization, they must initiate more actions throughout problem evolution since they are not guided by an overall long-range plan that would increase efficiency and reduce workload. See Table 6 for a breakdown of novice strategy usage. The following Planning Strategies were unique to the novice participants:

Reconsider
Wait to see
Consider multiple options
Switching sequencing

Experts are more systematic about setting up a high-level primary plan and backup, whereas novices frequently reconsider and switch sequencing. The experts spend less time reconsidering, and go to the backup if the primary plan cannot work. The novices spend much more time planning and formulating a number of lower level plans, and then reconsider those plans as the scenario evolves. Novices do formulate some high-level plans, but they generally delay that process until they are able to "wait and see" how the scenario evolves. In general, the experts are much more efficient in both the planning and control stages, and are able to execute their tasks through the use of fewer and higher-level strategies.

Additionally, the experimenters observed that expert controllers, particularly the supervisor group, had ingenious and diverse strategies, many of which represented procedural shortcuts or were designed to simplify the situation and reduce workload. This supports the findings of the Paired Problem Solving analysis, which also indicated that experts use a greater variety of strategies, use the simplifying strategy of "computer entry" (such as effecting early handoffs), and the management strategy of "monitoring." Specific strategies observed included giving early handoffs to other sectors, clearing aircraft to high sector or approach control or away from the focus of problem solving, or routing aircraft via non-standard approaches to avoid arrival sequencing, etc. Interestingly, supervisor FPL's made greater use of shortcuts, thus maximizing efficiency. Their many years of experience appear to have provided them with an enhanced repertoire of strategies and to have allowed them to perform relatively independent of routine procedures.

Continued . . .

DYSIM STRUCTURED PROBLEM SOLVING (Continued)

To summarize, experts use fewer, compiled actions and strategies to achieve goals, make greater use of speed control, develop and effect more high-level plans, spend less time reconsidering their plans and carry out initial plans rather than reverting to backup plans, take more procedural shortcuts, are less constrained by ATC-typical procedures, and make greater use of strategies aimed at reducing overall workload.

Taken together, these results suggest that experts are better equipped for advance planning activities at the early stages in the problem evolution, with greater long-range advance planning and ability to gauge event time frames. Novices tend to simply wait for the problem to develop or reconsider their initial planning and strategy selection, thus necessitating frequent reference to information contained in the Sector Management panel of the Mental Model. Experts, on the other hand, plan their strategies early and carry them out, allowing them to devote their attention to monitoring overall contextual conditions, referencing to the Conditions panel -- modifying strategies as required by overall workload conditions. They then use simplifying strategies to improve overall conditions and reduce workload.

These results suggest that two types of monitoring may distinguish novices from experts: while novices may monitor frequently insofar as passively watching events evolve, experts actively monitor so as to continually update information in the Mental Model. Similarly, two types of planning strategies may also be involved: while novices frequently reevaluate and reconsider their initial plans, experts formulate more and better high-level plans to deal with the overall evolving problem scenario, freeing mental resources to implement workload reduction strategies as required throughout the evolving situation.

PAIRED PROBLEM SOLVING

Goal Priorities

We developed a hierarchy of controller goals in order to study controller priorities. From discussions with controllers and comments on the exercises, we derived the following priorities for controller goals. The goal categories are derived from the controller's perceived consequences of the problem situation if left unresolved. That is, the controller's goals are categorized (and prioritized) by what the controller thinks is likely to happen if no action is taken. The categories appear to be related primarily to consequences to the controller, not to the aircraft involved.

Continued . . .

Goal Priorities (Continued)

In order of priority, these controller goals are to avoid:

1) **Violations** -- If the controller doesn't act, there is a probability of failure to maintain minimum separation standards (5 miles or 1,000 feet vertical spacing). There is no condition under which a controller may violate these standards without disciplinary action.

2) **Deviations (from procedures)** -- A circumstance which will result in disciplinary action if the controller takes no action to obtain prior approval for the deviation. An example would be violation of an LOA requirement.

3) **Disorder** -- Feeling of loss of control of traffic in the sector. If the controller doesn't act to correct the situation, the result is likely to be inadequate mental resources to anticipate and resolve situations as they occur. The controller will be at risk of being overcome by events. An example might be aircraft climbing and descending in the same area, with no positive altitude or lateral separation.

4) **Delays (in the air traffic flow)** -- Delays may result in informal or formal complaints about the controller's performance. This is undesirable not only because it may affect job performance ratings, but also because expert controllers know that these delays result in the aircraft being in their sector longer and therefore taking more mental resources to manage the delays in traffic and the conflicts it may cause. Delays may be particularly onerous if they involve special handling aircraft such as "lifeguard" or navigation route aircraft. This, though apparent in interviews with experts, was not a significant category in paired problem solving, due to the limitations placed on the problems and discussions.

5) **Flight plan deviation requests** -- As a goal, the controller generally wants to avoid making requests of the pilot, and wants to honor pilot requests as part of the service the controller provides. Pilots want to avoid excessive unplanned maneuvering for several reasons. This maneuvering may cost the pilot money (in loss of incentive bonuses for saving fuel), time, or in some cases the pilot may be unable to comply with the requested maneuver due to aircraft or weather characteristics. If the pilot cannot comply, the controller will have to devote more mental resources to the problem to find an alternative corrective action. Though expert controllers place other factors above pilot considerations, they still attempt to avoid excessive flight plan deviations as one of their goals.

These goals were derived from analysis and consolidation of problem categories identified in the paired problem-solving exercises.

Priorities Of Methods (General Strategies)

From discussions with controllers across various cognitive analysis activities, it appears expert controllers have a well-developed hierarchy of corrective actions, or methods, to employ to achieve their goals. The prioritization of an action is dependent on the situation; i.e., the priority of an action may be intensified or alleviated by other factors.

The selection of methods appears to be based upon the mental resources required to execute the action. On this basis, four categories of methods were defined.

1) **Situation Monitoring** -- This is the highest priority method, because it facilitates awareness of the evolving problem situation.

2) **Computer Entries** -- The second-highest priority method, computer entries are desirable because they are highly automated tasks with predictable consequences. This category includes handoffs and pointouts.

3) **On-Frequency Communications** -- Though the controller must mentally compose the communication, there is a standard vocabulary that becomes automatic over time and no physical actions are required except keying the mike. The results are generally predictable, but may be affected by pilot or aircraft characteristics.

4) **Off-Frequency Communications** -- These are less desirable as a method because they often require composition of original communications because of unique situations and local vernacular. They also require the controller to select the proper frequency, and may require the controller to negotiate for the desired result. If the controller is making a request, it may be refused, requiring development of an alternate strategy. Expert controllers seem to be very skilled at assessing the acceptability of their request to the approval authority.

The results of the analysis are presented in the following figures describing the controller's patterns of goal reporting and methods used, and in the inferred rules for selecting methods presented at the end of this section. Each of these figures is discussed in the following sections.

Continued . . .

Priorities Of Methods (General Strategies) (Continued)

FIGURE 5. AVERAGE PERCENT OF RESPONSES IN EACH GOAL CATEGORY AT EACH SEQUENCE STEP IN SOLVING THE PROBLEM, ACROSS ALL PARTICIPANT GROUPS

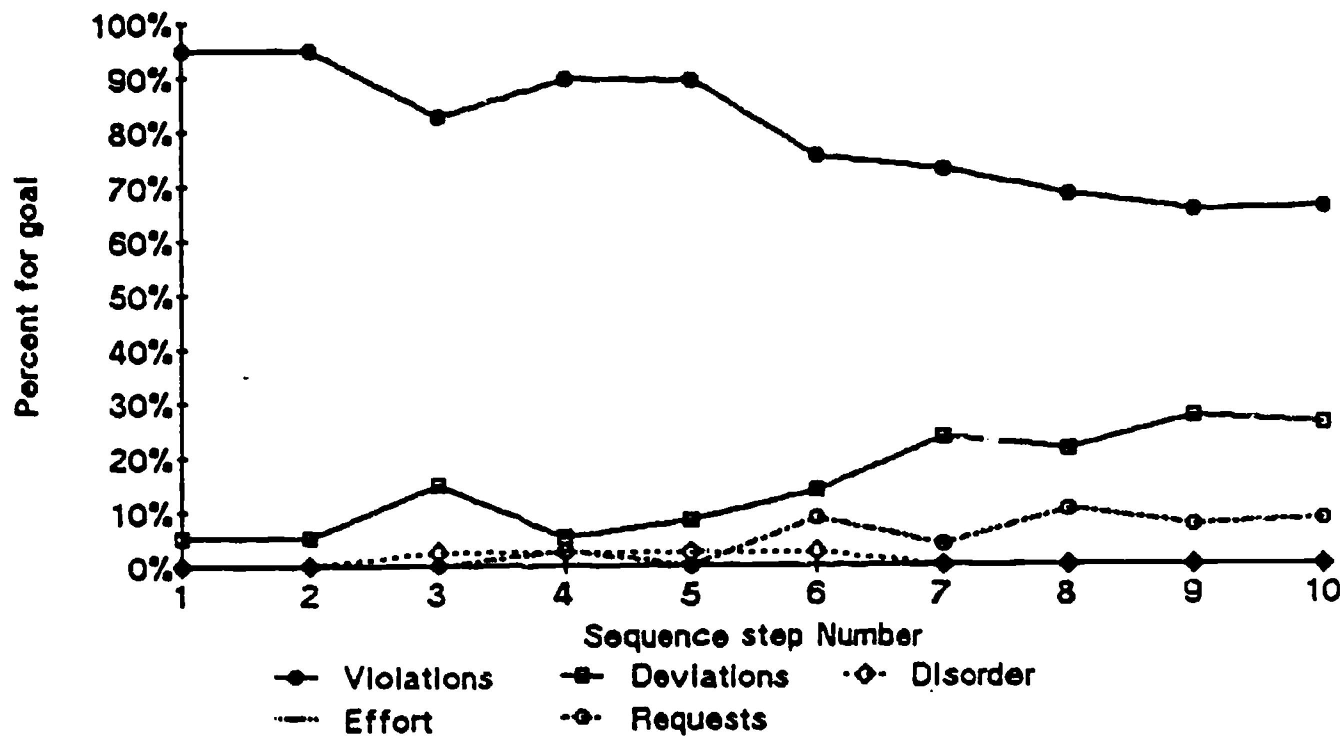


Figure 5 shows the goals reported by all controllers at each step in problem solving. The graph shows that controllers tend to concentrate first on resolution of situations which they see as potentially resulting in a violation. As these situations are resolved, they tend to turn their attention to situations that could lead to a deviation. As the solution sequence progresses, the other goals categories (situations leading to disorder, responding to pilot requests) are listed as goals with greater frequency. These data support the intuitive view, and the present FAA policy, that the controller should make his first priority safety of flight, then orderly, then expeditious.

Continued . . .

Priorities Of Methods (General Strategies) (Continued)

FIGURE 6. EXPERTS' PERCENT OF RESPONSES IN EACH GOAL CATEGORY AT EACH SEQUENCE STEP IN SOLVING THE PROBLEM

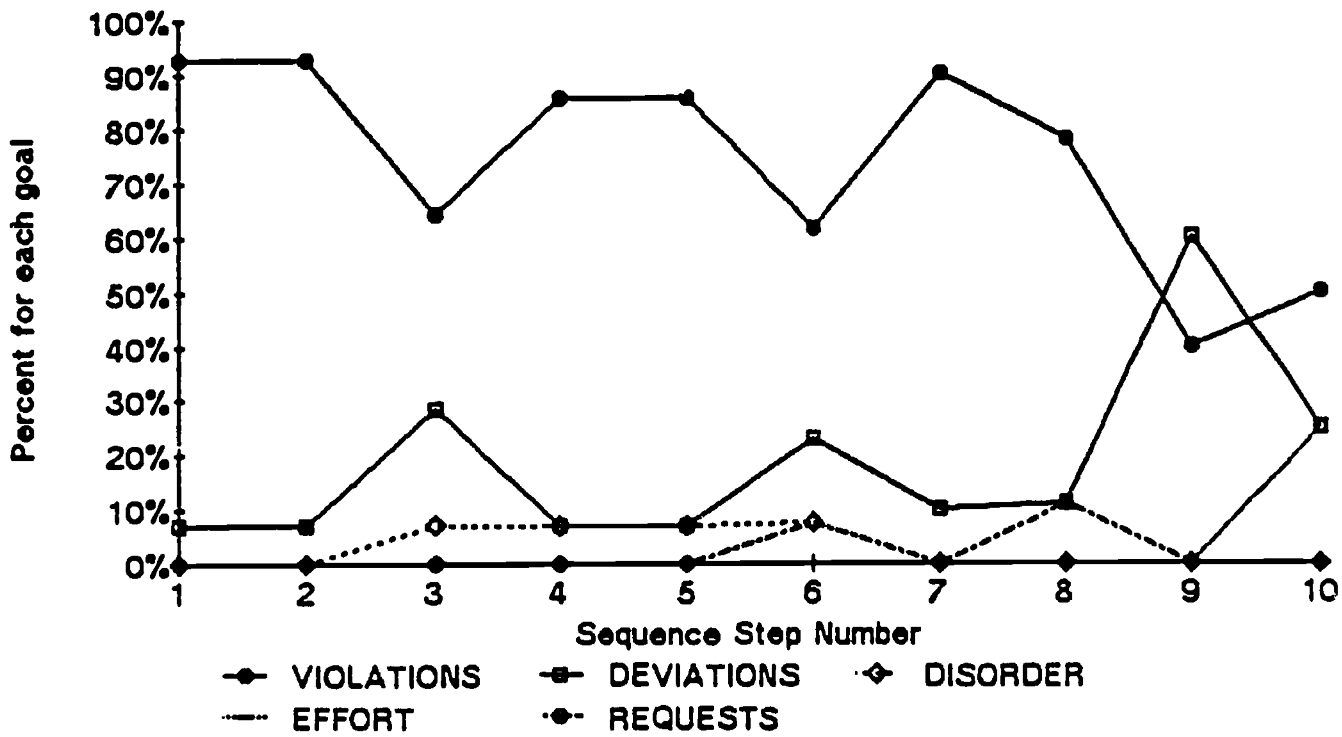


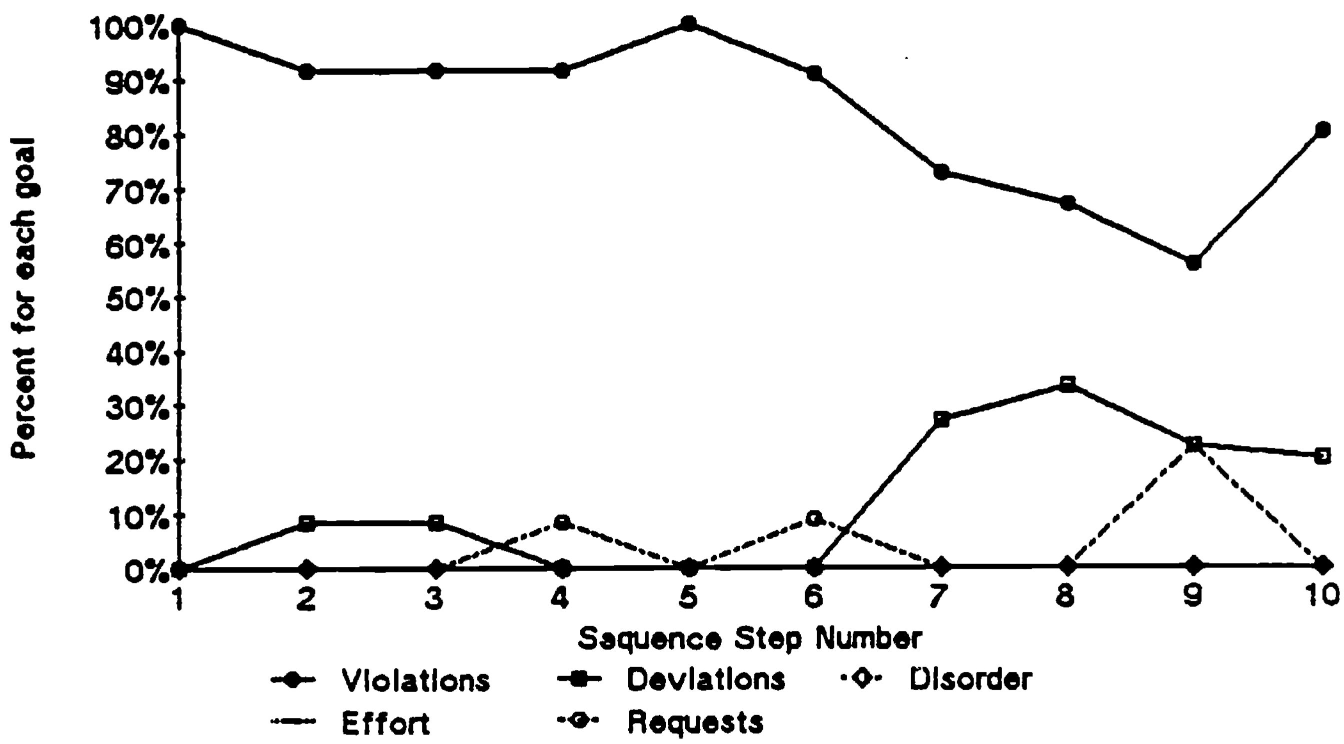
Figure 6 shows the goals reported by experts at each sequence step. The pattern of expert goal selection deviates from the overall average of all groups combined. The experts do not respond as directly to the need to deal with violations immediately until all violations are reduced. They report goals in a recursive pattern, addressing violations and deviations alternately as they progress through the solution sequence.

This pattern of expert goals leads us to the conclusion that experts are more global in their analysis of problem situations. They respond not only to situations that are threatening, but also simultaneously address goals that will improve the order in the sector or meet a regulatory requirement or pilot request. Expert controllers take a more comprehensive view of the evolving scenario.

Continued . . .

Priorities Of Methods (General Strategies) (Continued)

FIGURE 7. INTERMEDIATES' PERCENT OF RESPONSES IN EACH GOAL CATEGORY AT EACH SEQUENCE STEP IN PROBLEM SOLVING

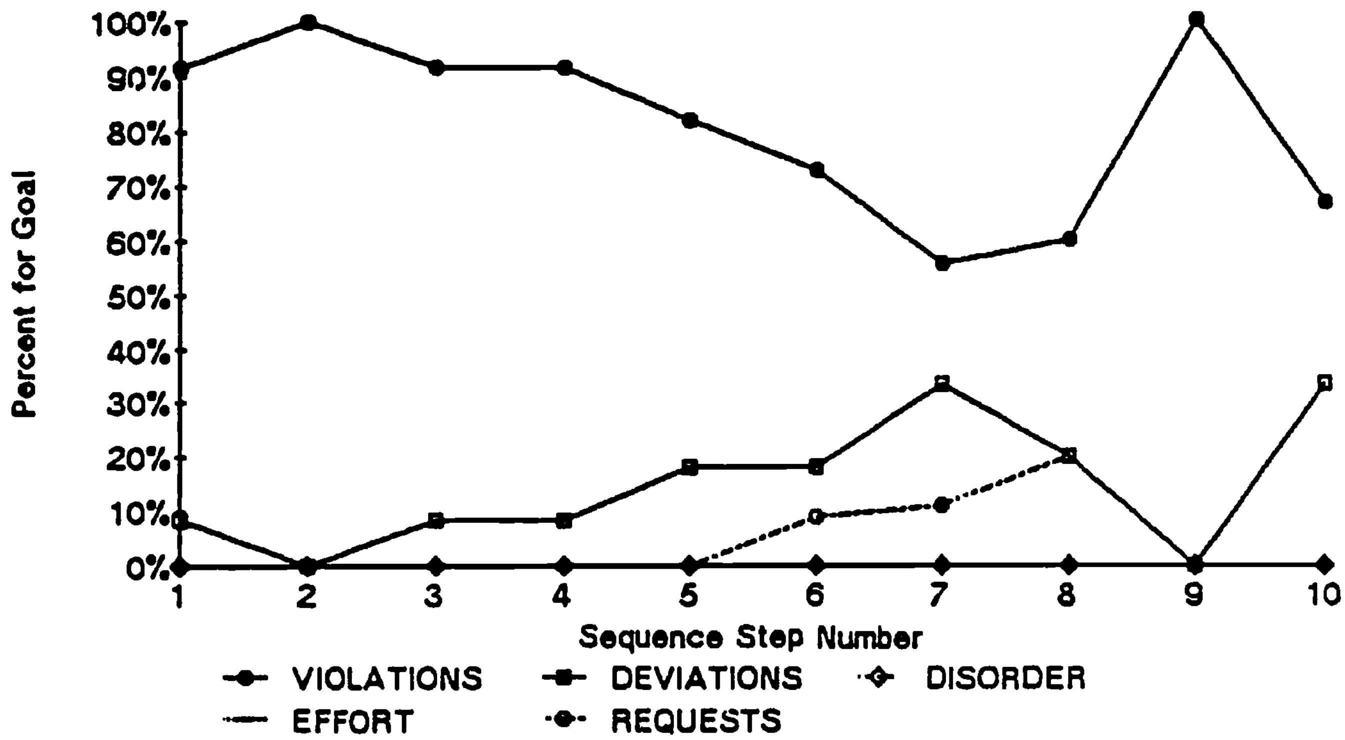


Patterns for intermediates and novices were similar, but not identical. Both groups tended to report concentrating predominantly on violations in the early stages of the solution sequence. Intermediates did this almost exclusively through the first five steps of the sequence (see Figure 7). Some consideration was given first to deviations, then to requests as the sequence progressed. This tends to reflect the ability of intermediates to attend to more goals beyond the novices' almost exclusive focus on imminent conflict situations.

Continued . . .

Priorities Of Methods (General Strategies) (Continued)

FIGURE 8. NOVICES' PERCENT OF RESPONSES IN EACH GOAL CATEGORY AT EACH SEQUENCE STEP IN PROBLEM SOLVING



Novices reported their goals as dealing exclusively with violations or deviations for the first five steps (see Figure 8). Also, the return to violations concerns in the later steps (9 and 10) indicates that they were not as successful in identifying all violation situations (i.e., perceiving task triggers and/or advance planning) when they first began their solution sequence. As they studied the problem during the exercise, they may have discovered situations they didn't see earlier that could result in a violation.

Continued . . .

Priorities Of Methods (General Strategies) (Continued)

FIGURE 9. REPORTED "VIOLATIONS" GOALS REPORTED AT EACH SEQUENCE STEP IN PROBLEM SOLVING BY EACH LEVEL OF EXPERTISE

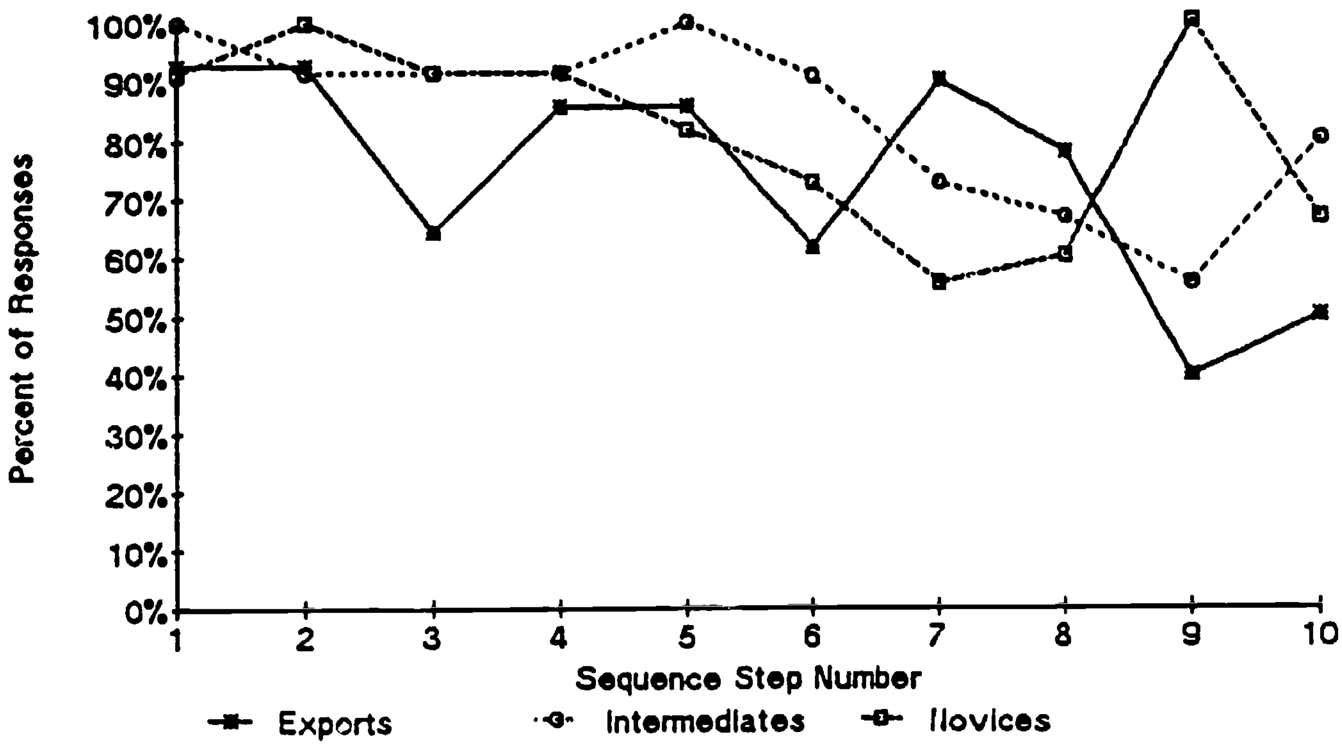


Figure 9 presents a comparison of the goal priority reported by each level of controller expertise. This graph points out the differences in response patterns as related to expertise. The experts' goals are much more variable, indicating that other factors are being considered besides just a potential violation. The intermediates show a continuing trend of reduced emphasis on violations as the situations are resolved in each successive solution step. The novice reports show a decrease in response to violations during the middle of the scenario, but their return to this goal in the last few sequences of problem solving suggests that they may not be able to quickly and consistently identify all situations that may result in a violation.

Continued . . .

Priorities Of Methods (General Strategies) (Continued)

FIGURE 10. REPORTED "DEVIATIONS" GOALS REPORTED AT EACH SEQUENCE STEP IN PROBLEM SOLVING BY EACH LEVEL OF EXPERTISE

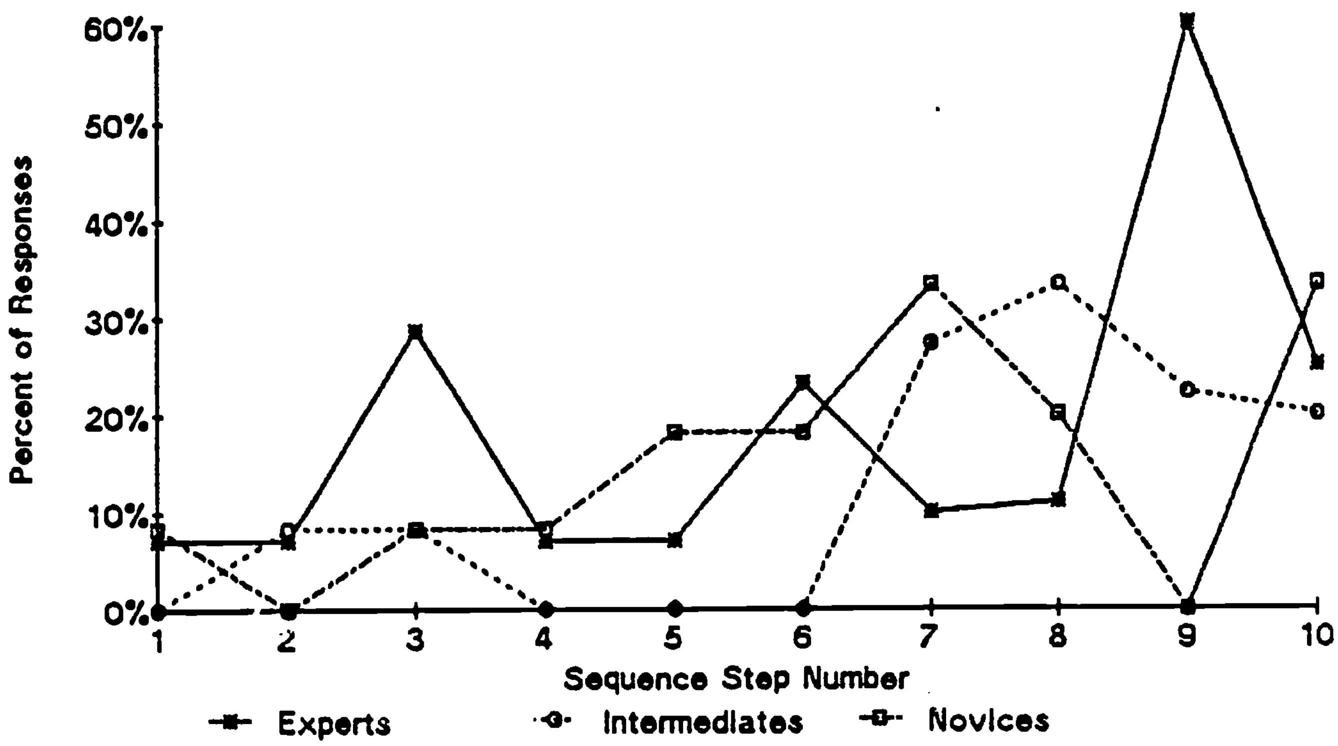
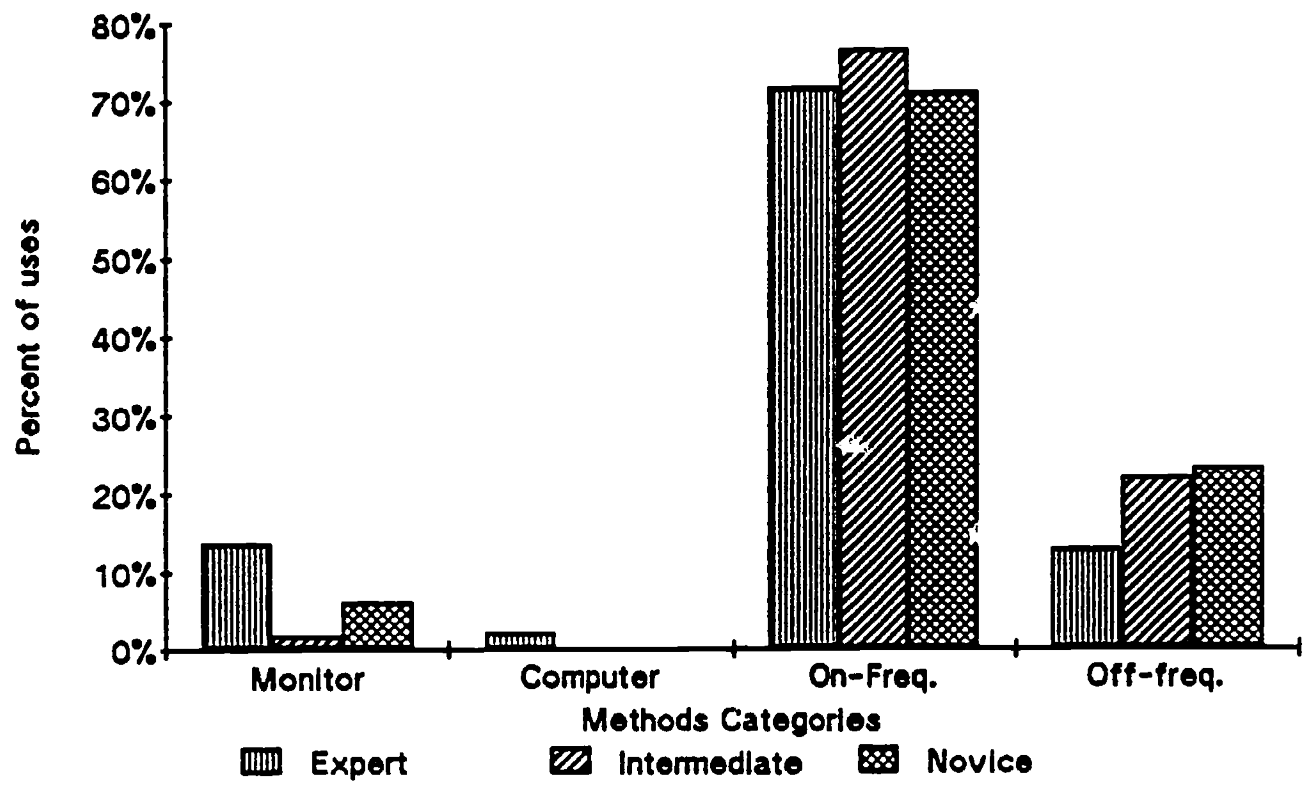


Figure 10 shows a similar phenomenon in the reports of deviations. The experts' treatment of deviations tends to increase as the solution sequence progresses, but is variable. Intermediates tended to deal more consistently with deviations in the earlier steps, showing an increasing emphasis on this goal as other goals (violations) are resolved. The later steps show that other goals take on more importance as some of the deviation situations are resolved. Novices show an erratic but increasing trend toward dealing with deviation goals.

Methods Analysis

FIGURE 11. METHODS USED BY EACH LEVEL OF EXPERTISE



We evaluated the methods used to effect the goals by controllers at the different levels of expertise. As discussed earlier, there appears to be a hierarchy of methods selection used by controllers, based on the mental resources required to use the method. Simple computer entries are preferred over off-frequency communications, for instance, because they are highly automated tasks for controllers and because they have predictable outcomes. At the other extreme, off-frequency communications require the controller to change frequencies, compose a relatively unique (as compared with the highly structured on-frequency communications) message, and possibly negotiate the outcome with the other facility.

Continued . . .

Methods Analysis (Continued)

This prioritization of controller methods is supported by the data (see Figure 11). What is important in this analysis is the comparison of the relative frequency of experts' use of each method, as compared to the other groups, rather than the comparison of frequencies between method types. While computer entry, for instance, may be seldom used, the fact that only the experts used it suggests it to be a method of choice for experts, when it can be effectively used. Computer entry, therefore, is an expert-typical strategy. This finding is consistent with the finding from the structured-problem-solving analysis that experts make greater use of general workload reduction strategies of which computer entry (e.g., giving a handoff) is one.

Monitoring is also an expert-typical strategy with experts using it about three times as frequently as intermediates and about twice as frequently as novices. If monitoring is an expert-typical strategy, it may seem illogical that novices monitor more frequently than intermediates. However, two types of monitoring may be involved: (1) overall situation monitoring to acquire new information to update/refine situation understanding, versus (2) monitoring to allow a situation to develop (e.g., observing separation, potential confliction development, etc.). This explanation would be consistent with the findings of the structured-problem-solving analysis that novices more frequently reconsider and reformulate initial plans and "wait to see," and with the findings from the structured interviews that experts assign higher priorities to overall situation monitoring activities such as scanning the PVD and reviewing flight strips.

All controllers selected on-frequency radio communications for the largest percentage of their responses. However, the expert controllers relied less than either of the other groups on the use of off-frequency radio calls, which require more actions and have less predictable results.

Observed Performance Differences Between Participant Groups

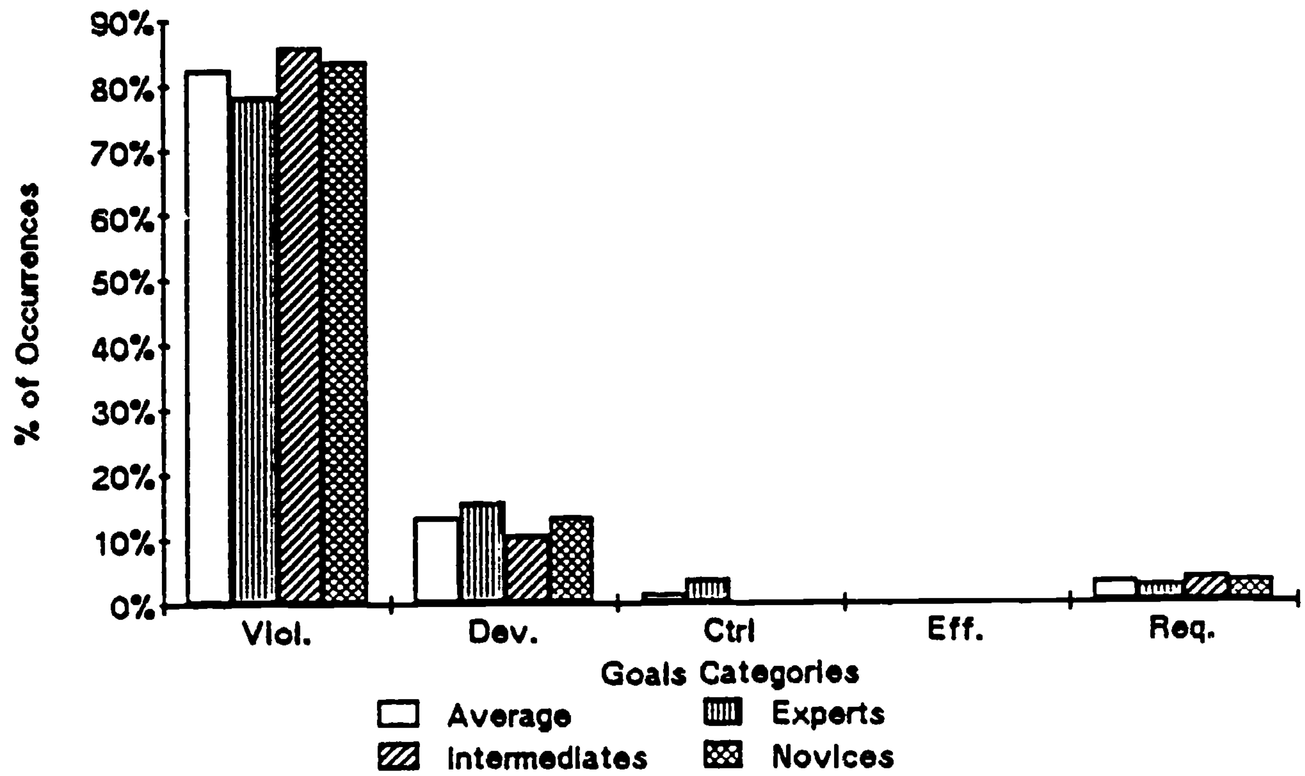
Experts are able to evaluate and attend to more goals in the undesirable situations than novices. This difference is partially because the experts devote greater resources to situation monitoring and also because they have developed a larger repertoire of control strategies. Novices tend to focus on the most critical situations as long as they are present, and are limited in their response to those actions with which they are familiar and comfortable.

One expert made the comment, and we observed during the structured problem-solving exercises that, "Novices do what they know how to do." Even when they recognize threatening situations, and are aware of the serious consequences, novice controllers will do nothing rather than risk doing the "wrong" thing.

Continued . . .

Observed Performance Differences Between Participant Groups (Continued)

FIGURE 12. GOAL TYPES SHOWN AS A PERCENT OF TOTAL GOALS FOR EACH LEVEL OF EXPERTISE

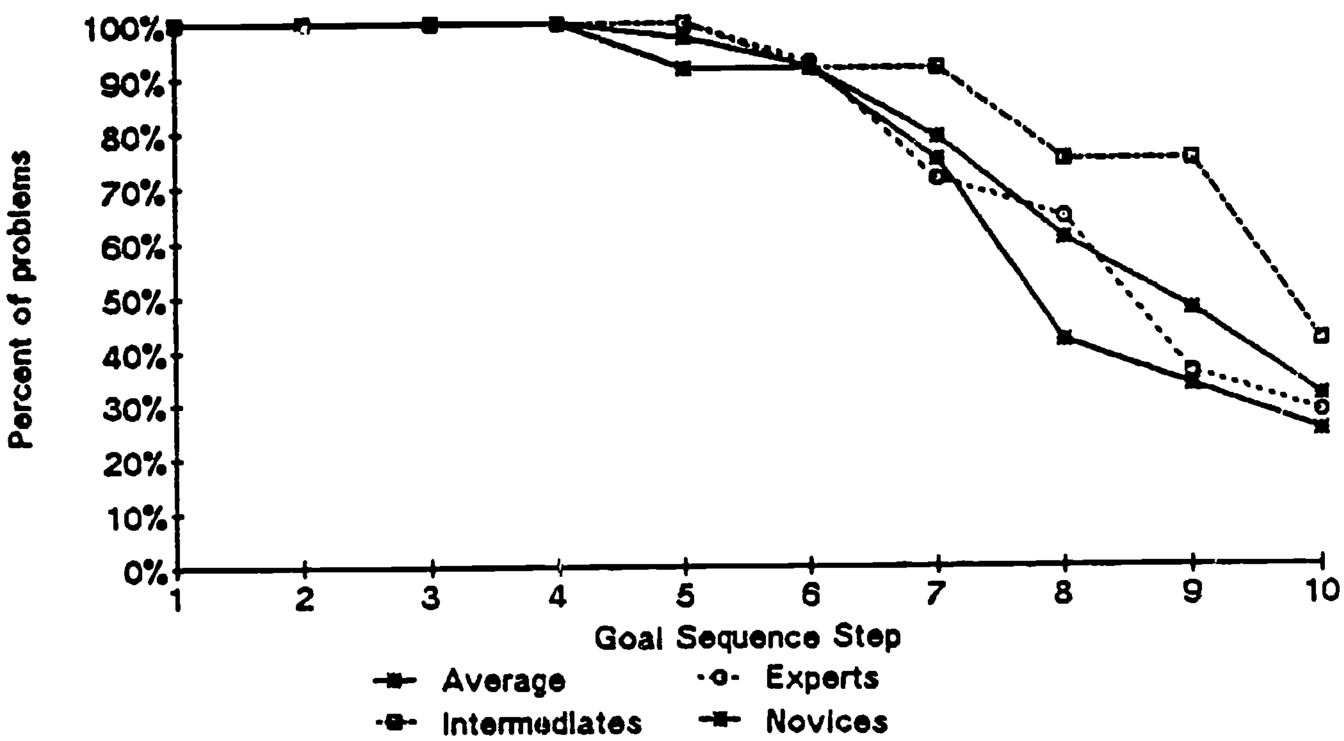


The occurrence of the goals as a percent of total reported goals is shown in Figure 12. One criticism of the analysis presented here might be that problems developed by controllers at different levels of expertise differed in the situations they presented. Experts might have developed problems that contained fewer violations than problems developed by novices, and therefore the probability of selecting a violation goal would be greater for novices. As shown in Figure 12, however, the distribution for reported goals situations is similar for all controller groups.

Continued . . .

Observed Performance Differences Between Participant Groups (Continued)

FIGURE 13. GOAL SEQUENCE LENGTH FOR EACH LEVEL OF EXPERTISE



The solution sequence length varied somewhat with the level of expertise, as illustrated in Figure 13. The experts tended to have fewer solutions with more than five steps than the intermediates and novices, while the experts and novices had somewhat fewer solutions with more than six steps than the intermediates. All of the expertise groups had some solution sequences of more than 10 steps, though for the purposes of this analysis, only the first ten steps were considered. This information indicates that the experts were more economical in resolving the problem situations than the other groups, requiring fewer solution steps on average than the intermediates. The relatively greater number of solution steps may imply that the intermediates are able to recognize situations needing resolution that are not detected by the novices, but which are more efficiently solved by the experts.

Continued . . .

Observed Performance Differences Between Participant Groups (Continued)

Taken together, these findings from the paired-problem-solving analysis are consistent with the results of other analyses; namely, that experts use the method of active monitoring to update information relatively more than do novices or intermediates. Increased frequency or enhanced skill in monitoring or scanning the PVD is perhaps likely to result in increased effectiveness in perceiving potential violations and/or anticipating such violations throughout problem evolution. This would allow the controller to take an iterative approach to dealing with violations, permitting him/her to shift attention to other tasks, such as dealing with deviations, during noncritical points.

In contrast, intermediate controllers appear to deal continually with violations until the last several problem-solving steps, at which point their attention shifts to dealing with deviations. Thus, dealing with violations is more cognitively demanding for intermediates because relatively all of their attention is allocated to dealing with violations until the end of the problem sequence; deviations are not attended to until the very end of the sequence. This might lead to ineffective Sector Management because the sector is not attended to as a whole, but rather, attention is highly focused upon dealing with potential violations. Thus, other on-going, developing, or potential problems such as deviations are not attended to in the early stages of problem evolution, limiting advance planning to deal with such problems. Many experienced controllers warn about the danger of developing what they call "tunnel vision" during difficult situations -- i.e., the narrowing of attention around the critical problem area, ignoring overall situation monitoring. This narrow focus can lead to critical situations developing elsewhere in the sector.

Experts continually monitor the evolving situation, returning to deal with violations at critical points in the problem, whereas intermediates identify violations and attend to them continuously until a solution is effected. Novices, on the other hand, appear to attend to violations at the beginning and end stages of problem solving, with deviations being attended to during the middle portions of the problem. Figure 9 shows a marked increase in responses to violations during the next-to-final step in problem solving. This suggests that the novices failed to effectively monitor violations during the middle portions of the problem and/or failed to initially perceive all the potential violations as they were initially forming a mental representation of the problem.

Novice controllers show a pattern of responses that strongly suggests poor problem space organization. That is, they fail to perceive and organize the problem boundaries and constraints and to carry out pre-planning as effectively as do experts. This finding is consistent with research showing that most errors in problem solving occur before a solution is actually attempted, and are due to faulty problem-space representations (Rumelhart & Norman, 1981). The finding is also consistent with the structured problem solving data which suggests that experts are more skilled at long-range planning.

Continued . . .

Observed Performance Differences Between Participant Groups (Continued)

Since a "problem-space representation" is merely a representation of a problem according to an underlying Mental Model of the domain area, this finding also suggests the importance of explicit instruction around the Mental Model underlying air traffic control. The experts' increased attention to monitoring fits other analysis models of expertise. As the expert develops a larger repertoire of possible strategies and actions, and more skill in detecting an undesirable situation, he or she can devote more mental resources to monitoring and planning methods that are most appropriate for the situation.

Research in other domains has shown that experts spend a significantly greater amount of time in constructing their problem-space representation and in pre-planning based upon that representation, than do novices (Chase & Simon, 1973; Chi, Feltovich, & Glaser, 1981), and improvement in problem solving has been found to be highly related to initial planning according to the problem space (Mental Model) (Reed & Johnson, 1977).

Implications For Training

These results suggest that the experts' more analytical assessment and selection of goals and attention to monitoring and long-range pre-planning should be made an explicit part of training. For example, trainees might be instructed that dealing with potential violations is of critical importance, but that focusing exclusively on potential violations may prevent making some easy actions that would reduce the workload. Some specific training on the goals categories and prioritization of goals should be made part of the training curriculum. This training might take the form of constructing situations for the trainee and stopping the problem at early intervals in the problem evolution to ask the trainee what he or she wants to do and what he or she plans to do. One goal of training should be to encourage and develop trainee skills in situation monitoring, identifying problems, and setting goals to solve them (i.e., pre-planning) separate from the specific control methods of solving the situations. The instructor would try to elicit clear goals statements ("What I'd really like to do is get this aircraft under this one so he can make the approach"), so that means can be selected to meet the goal, instead of goals being driven by the trainee's limited repertoire of means.

Continued . . .

Implications For Training (Continued)

The second recommendation for training is to include in the curriculum (under the Conditions panel of the Mental Model) explicit information on the mental resource costs of various controller actions and solution methods. Though this study has not fully elaborated the spectrum of methods and their attendant costs, it does appear that information on the relative mental resources required to perform various activities would be beneficial to trainees. This information is certainly learned implicitly over time by controllers; direct presentation of information on methods cost could help trainees learn to manage workload better and avoid potentially dangerous overloading of the controller.

Perhaps the most important implication of this analysis is the need for developmental controllers to have an opportunity to experiment with solution strategies and take risks. Novices fail to use as wide a variety of methods (strategies) as do the experts. Two strategies -- monitoring and computer entry -- were used seldom or not at all, respectively. It appears that novice controllers are inhibited in developing their repertoire of actions and fail to devote adequate time to overall situation monitoring and advance planning, perhaps because they are discouraged from taking risks or from devoting time to purely mental activities. The novice's reluctance to try new actions, even in this controlled environment, may indicate inhibition introduced by the facility environment. Several novice comments during paired-problem-solving discussions and structured-problem-solving activities indicated negative feeling toward the training environment. Trainees repeatedly mentioned that they felt the training at the centers was a continuation of the "screen" in that they were continually being evaluated for signs of weakness instead of being trained in controller skills. Clearly the opportunity to experiment with alternate actions does not exist in the operational setting. The consequences to the controller, the aircraft, and to other controllers are too great.

This need for a safe, flexible practice environment suggests strongly the need for a simulation capability as part of the controller training environment. This simulation capability should provide structured scenario development to concentrate on specific training needs or trainee weaknesses, and should provide detailed feedback on strategy usage.

The importance of a supportive environment for trainee experimentation also suggests some changes in the presentation order and affective aspects of controller training. Though training in procedures and regulations is an important part of controller training, work of Knowles (1980) and others have suggested that learning is more successful when driven by a student-perceived need for the information. Therefore, the curriculum might be improved by developing a set of parallel activities on the simulator and in the classroom. Trainee experimentation on assigned exercises on the simulator would be reinforced and supported by classroom or group activities related to the pertinent regulations and techniques of experts. That is, the student would learn requirements and strategies in the classroom that supported hands-on activities in the simulator, designed to encourage the controller to experiment with the new information in solving increasingly complex scenarios.

STRUCTURED INTERVIEWS

Figures 14, 15, and 16 present results of interview questions explicitly asking participants about priorities of activities under conditions of normal versus heavy workload.

FIGURE 14. INTERVIEWEES' SELF-REPORTED ACTION PRIORITIES (Normal Workload Conditions)

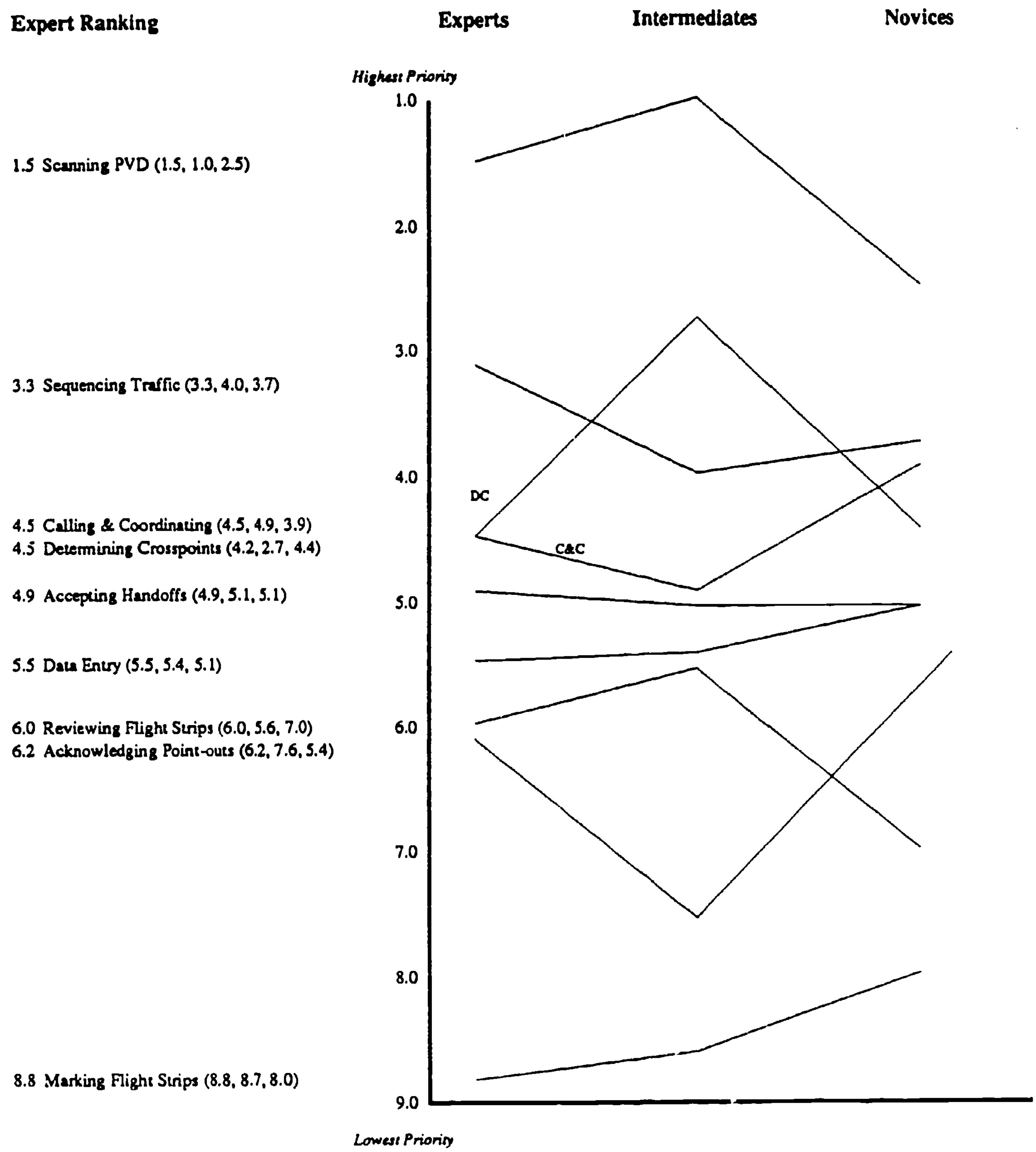


FIGURE 15. INTERVIEWEES' SELF-REPORTED ACTION PRIORITIES (Heavy Workload Conditions)

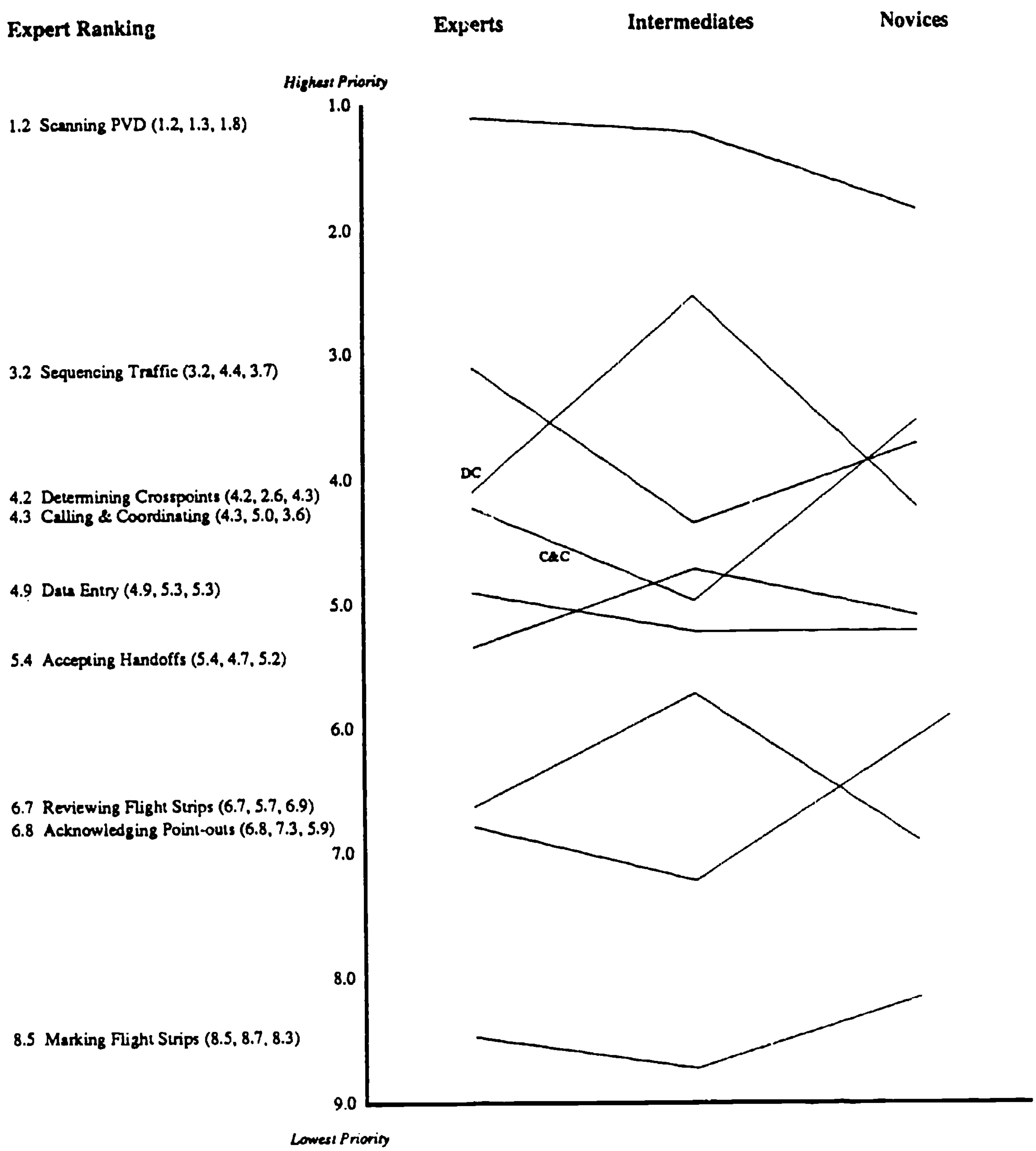
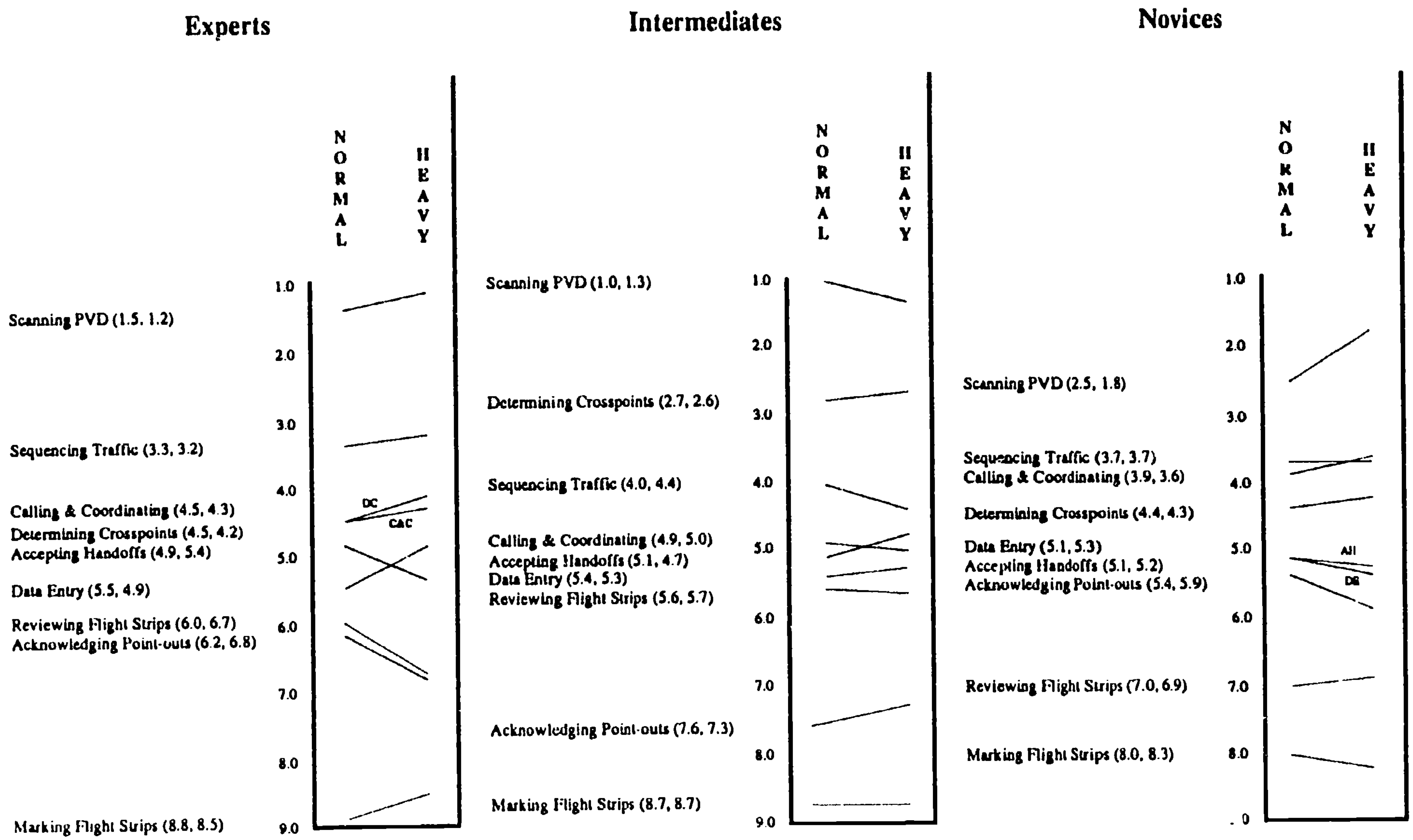


FIGURE 16. CHANGES IN PRIORITIES



STRUCTURED INTERVIEWS (Continued)

Inspection of Figure 14 reveals that novices tend to assign relatively higher priorities, as compared to experts and intermediates, to routine ATC-mandated procedures such as acknowledging pointouts and marking flight strips and communication tasks such as calling and coordinating. They place relatively less priority than do more experienced controllers on monitoring-type activities such as scanning the PVD and reviewing flight strips, and planning activities such as determining aircraft crossing points. This is consistent with results in other analyses showing increased conditions monitoring and advance planning by experts.

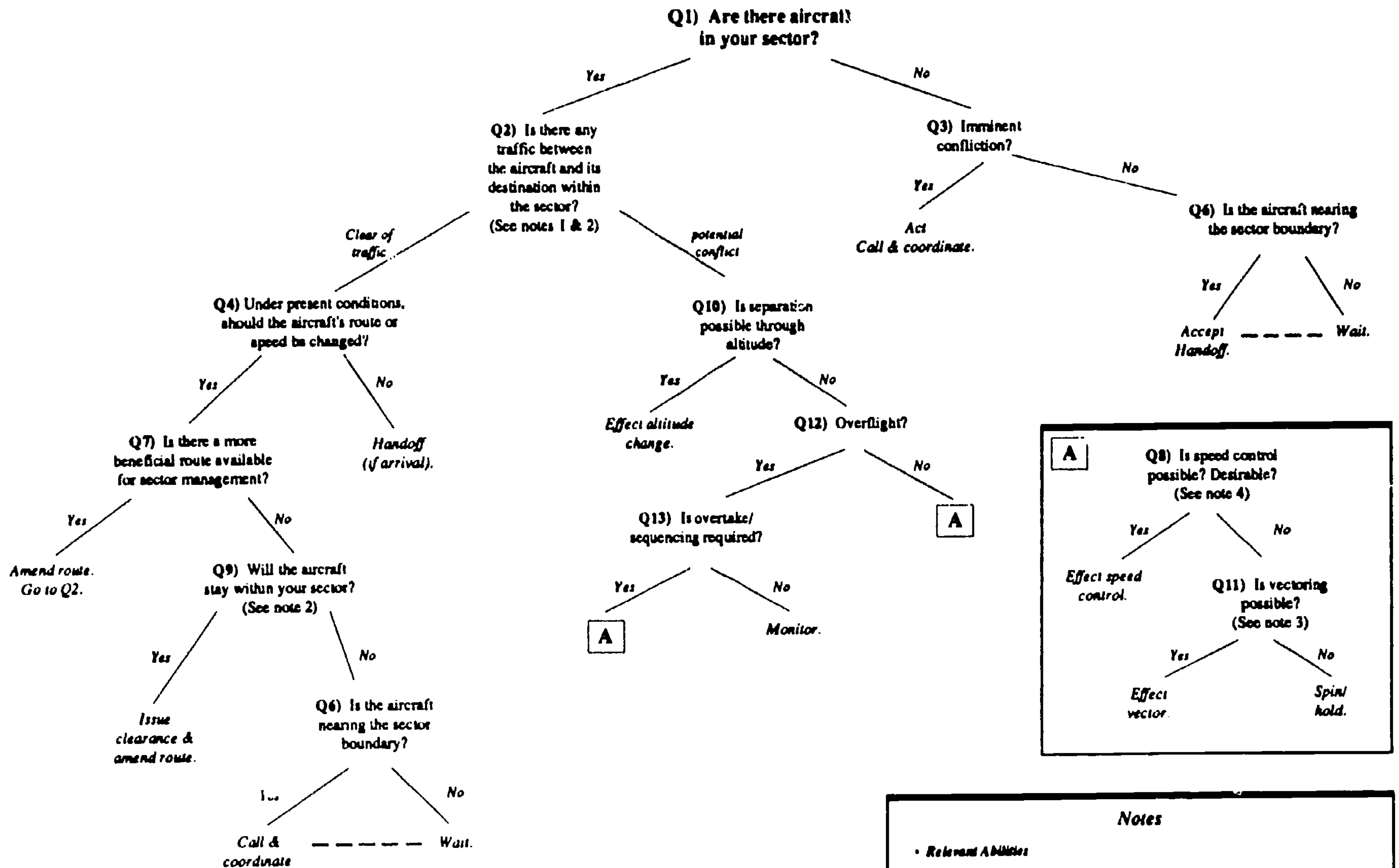
Under conditions of heavy workload, experts appear to place high priority on simplifying their task by reducing attention to only necessary activities. Under heavy workload, experts assign much lower priority to calling and coordinating than do both novice and intermediate groups.

As discussed previously, implications for training revolve around explicitly emphasizing the importance of information monitoring and advance planning and providing practice routines in these skills. Again, cognitive activities such as planning and cognitive-perceptual activities such as monitoring distinguish experts from less experienced controllers. While experts assign higher priorities to these higher-level cognitive operations, novices assign higher priorities to relatively simple, discrete, behavioral activities. This provides further support for the proposition that training should be structured around cognitive categories contained in the Mental Model, rather than discrete, behaviorally-specified learning objectives. The lesser importance assigned ATC-typical procedures by experts also lends support to the Mental Model hierarchy, where ATC Procedures are subordinated below higher-level cognitive operations such as Sector Management, Sector Data, and Conditions.

UNSTRUCTURED AND STRUCTURED INTERVIEWS

A content analysis was performed on the interview transcripts. From this analysis, a procedural flowchart (see Figure 17) was developed for decisionmaking as to separation, which includes priorities of decision points. Such a flowchart is useful as a job aid for developmentals because it provides an explicit formula as to priorities of mental decision-making points for determining separation solutions. Undoubtedly, experienced controllers either automatically (without conscious awareness) or intuitively go through such a procedure when solving separation problems. Providing such an expert-typical paradigm explicitly to novices during the early stages of training can facilitate skill acquisition and help avoid novice-typical pitfalls. Flowcharts could also be developed for many other aspects of air traffic control. Use of such charts, however, should be accompanied by training in the use of backup strategies and alternative plans so as to teach problem solving flexibility. Use of algorithms such as this is helpful if not relied upon too much. The example illustrates a generic approach which will need refinement according to the particular situation.

FIGURE 17. PROCEDURAL FLOWCHART



Notes

- ***Relevant Abilities***

1. Ability to determine aircraft crossing points, project traffic flow, project overtakes, monitor situation.

- ***Situational Factors***

2. Weather: Pilot deviations
3. Wind
4. Coordination with other controllers may be required.

CRITICAL INCIDENTS INTERVIEWS

Analysis of the 30 critical incidents originally generated resulted in the development of situation categories as a function of the primary cause of the critical incident, as shown below in Table 7. Note that there is some overlap between categories, when there was more than one related cause of the incident (e.g., weather and aircraft deviation).

TABLE 7. CAUSES OF CRITICAL INCIDENTS, WITH FREQUENCY OF OCCURRENCE

6	Misinterpretation of Data or Failure to Perceive Data
5	Weather
5	Aircraft Deviation
5	Difficulty in Coordinating with Another Controller
4	Inattention/Lack of Vigilance
3	Unclassifiable
2	Failure of Normal Procedures or Equipment
2	Lack of Familiarity with Route or Sector Area
2	Aircraft Malfunction
2	Simple Confliction -- Failure to Choose Appropriate Strategy
1	Aircraft Fails to Respond to Instructions
1	Lack of Knowledge of Aircraft Characteristics

The above table is useful for determining what controllers view as critical or unusual. In general, it appears that critical incidents are those related to adverse weather conditions/pilot deviations or are the result of a failure to properly monitor and attend to the evolving situation. Critical data were frequently not perceived, or were misinterpreted. Again, this finding is consistent with findings from all the other analyses: while novices may monitor in the sense of passively watching events evolve, true expertise requires active monitoring in order to continually update information in the Mental Model. Critical incidents often occur when this is not done, and these are the incidents that controllers remember -- i.e., they are cognitively salient. Refresher training around critical incidents might help experts to recognize such skill deficiencies.

Continued . . .

CRITICAL INCIDENTS INTERVIEWS (Continued)

Critical incidents appear to occur when sector data are misinterpreted or not properly updated or left unattended; in sum, a failure to properly monitor. This is supported by the anecdotal responses of many of the controllers who felt that critical incidents they had remembered were generally those which they felt were caused by their own inattention. One controller stated that they were "those I built for myself." Once again, the importance of monitoring is evident.

Many of the incidents recounted by the experts occurred in the very early stages of their career, soon after obtaining FPL rating. Since these experts had received their FPL rating 19 years ago on average, the fact they they have remembered the details of these incidents attests to their salient nature. Indeed, expert accounts suggest that experience with these incidents had a sobering, maturing effect upon the onetime novices. The incidents seem to have enhanced cognitive awareness of the importance of several key factors in air traffic control: importance of the ability to monitor and assess one's own workload in order to determine when to ask for assistance; the importance of intimate knowledge of the sector airspace; the importance of advance planning and projecting traffic flow; and the importance of effective situation monitoring and vigilance.

These findings, along with the literature in cognitive instructional design, suggest important implications for training. As discussed, the findings suggest that such unusual or particularly difficult incidents perhaps expedite the development of task awareness and Mental Models for task performance. Such incidents, because of their unusual and critical nature, can serve as instructional tools for allowing controllers to more explicitly and saliently recognize their own ineffective strategies or skill deficits. Development of a series of critical incident practice scenarios would allow developmentals as well as experienced controllers to fine-tune their skills in a guided self-discovery format, facilitating skill tuning and refinement. A computer-based training package could be developed to present controllers with a series of such incidents, with feedback provided as to the most effective solution(s).

The very nature of air traffic control itself suggests that training around critical, unusual, novel, and/or difficult incidents should be an integral part of training. To a large extent, expertise in air traffic control is the ability to effectively manage and resolve undesirable or difficult situations. As Kuipers and Kassirer (1987) describe, "Faced with a difficult problem, the apprentice fails to solve it at all, the journeyman solves it after long effort, and the master sees the answer." There needs to be systematic, in-depth training around such critical incidents, as they are the difficult situations that cause problems for controllers in the field environment, and because the development of expertise requires an ability to deal with the difficult and unusual situations, not just the routine. Of course, however, given the great variety of air traffic control situations that confront controllers on a daily basis, it is not possible to isolate and teach every possible critical incident that could occur.

Continued . . .

CRITICAL INCIDENTS INTERVIEWS (Continued)

However, the development of a trainer system around a representative number of such incidents should facilitate skill development by providing developmentals with an opportunity to test and refine a range of skills in a realistic environment. It would also be beneficial to experienced controllers by providing a means for them to further refine their skills, to ascertain skill areas that need to be improved, and to practice controlling many difficult situations over a compressed time period.

Critical incidents would facilitate skill refinement better than routine incidents because experts have presumably already reached high levels of proficiency in dealing with routine situations and also because routine incidents do not test the range of controller capabilities or require controllers to extend, refine, or modify their skills.

Finally, literature in cognitive instruction demonstrates the usefulness of providing training in novel conditions, once basic skills have been developed (Redding, 1990). Such training has been found to improve and expedite the process of skill refinement. An important caveat, however, is that research indicates that training on novel or unusual situations should never precede or occur simultaneously to basic skills training (Ackerman & Kanfer, 1988). Doing so appears to confuse novices and interfere with the acquisition of basic-level skills. This suggests that critical incidents training, though highly recommended, should not begin until after developmentals have mastered basic air traffic control concepts and skills.

Content analysis of the 11 selected critical incidents also permitted construction of a critical cue inventory of early warning signs of controller work overload (Table 8). Because the critical incidents method asks questions aimed at eliciting "gut-level" or intuitive cues relied on by experts, this permitted us to isolate cues which signal work overload -- i.e., when controllers should request assistance. This could be explicitly taught to developmentals and included under the Conditions panel, with reference also to the "Conflictions" category (aircraft separation cues) of the Mental Model. Some representative coping and workload reduction strategies used by experts are also listed under the table; such strategies can also be explicitly taught.

Continued . . .

CRITICAL INCIDENTS INTERVIEWS (Continued)

TABLE 8. CRITICAL CUE INVENTORY: EARLY WARNING SIGNS OF CONTROLLER WORK OVERLOAD (Overall Condition Category)

Cue Category	Description
Anxiety	Feeling uncomfortable, nervous, sweaty palms, unsteady voice
Confidence	Decreased self-confidence
Situation Assessment	Feeling of "deja vu," similarity to previous occasions of work overload
Attention	Development of "tunnel-vision," over-focusing on problem situation(s)
Communication	Failure to listen to pilot requests, controller instructions
Performance	Computer-entry errors, handoffs not executed or accepted
Aircraft Separation	Conflict alerts, aircraft overtakes

Representative Strategies For Avoiding Work Overload

- Request help when overload cues triggered (above)
- Refuse to accept handoffs when becoming too busy
- Decrease amount of communication, coordination
- Decrease or eliminate VFR traffic advisories
- Delegate more duties to radar associate
- Plan to have x-amount of time to communicate, coordinate
- Simplify and reduce control actions (increase use of workload reduction strategies)

COGNITIVE STYLE ASSESSMENTS

Initial Data Analysis

Table 9 presents the results on the MFFT (adult form) for the controllers tested in this study. The speed index is the average total number of seconds it took the controllers to make a decision on a figure for the total of 12 items in the test. The accuracy index is the average number of items the controllers got correct on the first try out of the 12 items on the test.

TABLE 9. MATCHING FAMILIAR FIGURES TEST (MFFT) RESULTS

Groups	Average Speed (in seconds)	Average Accuracy (number correct out of 12)
Experts (Supervisors, N = 5)	895.6	10.00
Experts (N = 7)	599.3	6.29
Intermediates (N = 13)	665.4	8.08
Novices (N = 11)	536.7	7.18
TOTAL GROUP	645.2	7.72

Even though the response times look quite different on the speed index, statistical tests showed that the four groups of controllers were not significantly different from each other in terms of the time it took them to make a decision about a matching figure. However, on the accuracy index, there was a significant difference among the groups. In fact, each of the four groups was significantly different from each of the other three groups.

In specific, the results indicated that:

- Supervisors were the most accurate group.
- Intermediates were the second most accurate group.

Continued . . .

Initial Data Analysis (Continued)

- Novices were less accurate than supervisors and intermediates but more accurate than nonsupervisor experts.

- Nonsupervisor experts were the least accurate group.

The detailed data from the statistical tests are provided in Appendix K to this report.

For comparison purposes, Table 10 presents MFFT scores achieved by a large sample of adult college students (159 males and 101 females ranging in age from 17 to 50 years old).

TABLE 10. COMPARISON GROUP MFFT [1] RESULTS

Groups	Average Speed (in seconds)	Average Accuracy (number correct out of 12)
Males (N = 159)	591.4	8.70
Females (N = 101)	682.0	8.80
TOTAL GROUP	626.6	8.74

[1] From "Adult Norms on the Kagan Matching Familiar Figures Test of Impulsivity/Reflection" by R.V. Heckel, J.M. Hiers, C.J. Laval, and S.S. Allen, 1981, Catalog of Selected Documents in Psychology, 11(1), 5, p.9.

Table 11 presents the results on the GEFT for the controllers tested in this study. The numbers in Table 11 indicate, for each group, the average number of simple figures correctly "disembedded" from the more complex geometric designs.

Continued . . .

Initial Data Analysis (Continued)

TABLE 11. GROUP EMBEDDED FIGURES TEST (GEFT) RESULTS

Groups	Average Number Correct (out of 18)
Experts (Supervisors, N = 5)	11.80
Experts (N = 7)	9.57
Intermediates (N = 13)	12.62
Novices (N = 11)	15.36
TOTAL GROUP	12.75

Statistical tests showed that the difference in scores between the novices and the non-supervisor experts was significant. None of the other differences among the groups was statistically significant. Again, the detailed data from the statistical tests are provided in Appendix K to this report.

For comparison purposes, Table 12 presents GEFT scores achieved by several other samples of adults.

Continued . . .

Initial Data Analysis (Continued)

TABLE 12. COMPARISON GROUP GEFT RESULTS

Groups	Number In Group	Average Number Correct (out of 18)
1970 College Men (Test Manual Norm Group) [1]	155	12.0
1983 Male Business Students [2]	115	12.1
1988 Male Business Students [3]	103	13.3

[1] From A Manual for the Embedded Figures Test (p. 28) by H.A. Witkin, P.K. Oltman, E. Raskin, and S.A. Karp, 1971, Palo Alto, CA: Consulting Psychologists Press.

[2] From "Group Embedded-Figures Test: Psychometric Data for a Sample of Business Students" by G. DeSanctis and R. Dunikoski, 1983, Perceptual and Motor Skills, 56, p.708.

[3] From "Group Embedded Figures Test: Psychometric Data for a Sample of Canadian Undergraduate Business Students" by L.S.E. McRae and J.D. Young, 1988, Perceptual and Motor Skills, 67, p.196.

Questions Raised By The Initial Data Analysis

Since there was considerable variation in cognitive style measures both within and among the groups of controllers, and since previous research has shown relationships between age and various cognitive styles, it was decided to look at these relationships for the controllers involved in this study. Table 13 shows the correlations between controller age and the cognitive style measures for each group of controllers and for the total group.

Continued . . .

Questions Raised By The Initial Data Analysis (Continued)

TABLE 13. RELATIONSHIPS BETWEEN AGE AND COGNITIVE STYLE MEASURES

Groups	Correlation Between Age And MFFT Speed	Correlation Between Age And MFFT Accuracy	Correlation Between Age And GEFT Score
Experts (Supervisors, N = 5)	.597	.917*	.517
Experts (N = 7)	-.427	-.172	-.872*
Intermediates (N = 13)	-.283	.381	.427
Novices (N = 11)	-.240	-.152	.318
TOTAL GROUP	.178	.091	-.399*

* = a statistically significant relationship (i.e., the probability is less than 5% that this correlation occurred by chance)

For the total group, age was not significantly related to either MFFT index (although within the supervisor group, the older controllers were more accurate on the MFFT). On the other hand, for the total group and within the nonsupervisor expert group, age was significantly and negatively related to scores on the GEFT (i.e., older controllers got fewer figures correct).

Because of the significant correlations that were obtained (see Table 13), further analyses were conducted to see if the controller groups differed significantly on cognitive style scores when the influence of controller age was statistically removed from the analysis.

Secondary Data Analysis

When the effect of age on cognitive style scores was removed statistically (see Appendix K for detailed data), there still was a significant difference among the groups on the MFFT accuracy index. However, there was no longer a significant difference among the groups on the GEFT (number correct).

Continued . . .

Secondary Data Analysis (Continued)

When each controller group was compared to every other controller group on the MFFT accuracy index (with the influence of age removed), the following results emerged:

- Supervisors were significantly more accurate than both the nonsupervisor experts and the novices.

- Intermediates were significantly more accurate than the nonsupervisor experts.

- Intermediates were not significantly different from either the supervisors or the novices.

- Novices were not significantly different from the nonsupervisor experts.

Simulator Performance And Cognitive Styles

To get a rough index of controller performance on simulated air traffic control problems, two of the problems that were used for the structured-problem-solving exercise were graded by two experienced instructors from the Radar Training Facility laboratory.

Table 14 presents the results of these instructor ratings.

Continued . . .

Simulator Performance And Cognitive Styles (Continued)

TABLE 14. SIMULATOR PERFORMANCE RATINGS

	Average Performance Ratings		
	Problem 2A*	Problem 5A**	Two-Problem Average Score
Experts (Supervisors, N = 5)	94.20	92.40	93.30
Experts (N = 7)	96.57	90.14	93.36
Intermediates (N = 6)	98.00	96.83	97.42
Novices (N = 6)	88.33	90.67	89.50
TOTAL GROUP	94.38	92.42	93.40

* Problem 2A is a problem of 65% complexity involving traffic bottlenecks requiring planning and visualization.
** Problem 5A is a problem of 65% complexity involving typical traffic situations and time constraints.

Statistical tests showed that there were no significant differences among the four controller groups on these performance ratings. Again, Appendix K contains the detailed data from these statistical tests.

Since there was considerable variation in controller cognitive styles both among and within the groups in this study, it was decided to look at the relationships between the cognitive style measures and the simulator performance ratings.

Table 15 shows the correlations between the MFFT and GEFT scores and the simulator performance ratings.

Continued . . .

TABLE 15. CORRELATIONS BETWEEN COGNITIVE STYLE MEASURES AND SIMULATOR PERFORMANCE RATINGS

	Performance Ratings		
	Problem 2A	Problem 5A	Two-Problem Average Score
Experts (Supervisors, N = 5)			
MFFT Speed	-.298	.037	-.304
MFFT Accuracy	.393	.052	.455
GEFT Score	-.070	.646	.278
Experts (N = 7)			
MFFT Speed	-.719	-.537	-.741
MFFT Accuracy	-.440	-.612	-.603
GEFT Score	-.148	.501	.170
Intermediates (N = 6)			
MFFT Speed	.244	.646	.578
MFFT Accuracy	.316	.141	.283
GEFT Score	-.083	-.015	-.060
Novices (N = 6)			
MFFT Speed	-.045	.571	.340
MFFT Accuracy	-.281	.044	-.101
GEFT Score	.906*	.806	.926*
TOTAL GROUP			
MFFT Speed	-.172	.078	-.066
MFFT Accuracy	-.011	.094	.046
GEFT Score	-.130	.369	.128

* = a statistically significant relationship (i.e., the probability is less than 5% that this correlation occurred by chance)

Conclusions From The Cognitive Style Assessments

The primary conclusion from the cognitive style assessments was:

> **The results of these analyses should be considered highly tentative and purely exploratory.**

The numbers of controllers in each group were so small that if one or two controllers in any group had slightly different scores, the results could have looked considerably different.

The second conclusion from the cognitive style assessments was:

> **It seems well worthwhile to pursue further research on the cognitive styles of air traffic controllers, particularly developmental controllers.**

There was considerable variation in cognitive style indexes both within and among the four groups of controllers in this study.

The following questions should be pursued because their answers may well have implications for the design and delivery of en route air traffic controller training:

- Are developmental controllers less or more accurate at visual discrimination tasks than FPL controllers?
- Are developmental controllers less accurate at visual discrimination tasks than the general public?
- Are developmental controllers more impulsive in decisionmaking than FPL controllers?
- Are developmental controllers more impulsive in decisionmaking than the general public?
- What is the distribution of field-dependent and field-independent cognitive styles among developmental controllers?
- Are developmental controllers more field-independent in cognitive style than the general public?
- Are FPL controllers more field-dependent in cognitive style than the general public?

Continued . . .

Conclusions From The Cognitive Style Assessments (Continued)

- Are the norms for field dependence and field independence changing in the controller population and in the general population?
- Among developmental controllers, is field independence positively related to performance on simulated air traffic control problems?

SUMMARY OF RESULTS

A Mental Model was developed for en route air traffic control, which depicts the cognitively salient knowledge categories required to support performance of air traffic control tasks. This model serves as an organizer or "categorizer" of information; a "mental checklist" of what factors the controller should consider. It implies a conceptual framework used by expert controllers for organizing knowledge about air traffic control. The Mental Model is partitioned into panels containing conceptually different categories of information: Sector Management, Sector Data, Conditions, Sector Airspace, and Procedures. The bottom two panels (Sector Airspace and Procedures) represent largely static knowledge which is of lesser importance to on-going air traffic control than the top three panels. Categories are contained within each panel. The Sector Management panel is the most relevant to prioritization, since it represents the understanding of events that must be dealt with. This understanding, however, also involves reference to data on the Sector Data and Conditions panels as well as other categories within the Sector Management panel, and to knowledge of standard procedures.

A cognitive task decomposition of air traffic control resulted in a delineation of 10 cognitively salient control tasks. Tasks were divided according to the underlying goals and cognitive operations associated with them. The 10 tasks are: Monitor Situation, Accept Handoff or Pointout, Sequence Aircraft for Arrival, Resolve Aircraft Conflict, Route Aircraft, Manage Departures, Refine Situation Understanding, Issue Advisory, Handoff/Pointout Aircraft, and Maintain PVD Readability. A task was defined as a single unit of goal-directed behavior. Thus, each task encapsulates a logically self-contained set of subgoals that describe the steps necessary to reach the goal for that task.

There is an important relationship between the 10 tasks and the Mental Model. A "task trigger" is defined for each task. This trigger specifies when the task should be performed and what panels or categories within the Mental Model should be referred to in order to execute the task. Thus, certain patterns of information in the Mental Model trigger performance of the tasks. Task triggers are also particularly relevant to prioritization, because they specify what controllers should be attending to at any given moment: when to shift attention from overall situation monitoring to a particular task.

A listing of expert-typical strategies was developed as related to monitoring, planning, control, and workload reduction. A flowchart was also constructed for prioritization of decisions concerning maintaining separation (Sector Management), and an inventory was developed of critical cues indicating work overload (Conditions). These strategies can be explicitly taught to developmental controllers.

Continued . . .

SUMMARY OF RESULTS
(Continued)

Experts, intermediates, and novices were compared on the types of strategies used in air traffic control. The following general findings emerged from the various data collection and analysis procedures.

As compared to novices, experts:

- use fewer, compiled actions and strategies to achieve task goals
- make greater use of speed control
- develop and effect more high-level plans
- spend less time reconsidering their plans and carry out initial plans rather than reverting to backup plans
- take more procedural shortcuts
- are less constrained by typical procedures
- make greater use of strategies aimed at reducing overall workload

Experts, as compared to novices and intermediates, take fewer steps to solve a problem, and deal continuously with violations and deviations throughout problem evolution. Intermediates, on the other hand, attend to violations first before shifting attention to deviations, whereas novices deal initially with violations, shift attention to deviations, then deal with violations again at the very end of the problem scenario. All groups prefer using on-frequency methods to off-frequency communications, but only experts make wide use of computer entry (e.g., giving a handoff) as a problem-solving method, and experts use situation monitoring about twice as often as the other groups.

Self reports obtained by way of a questionnaire given to the three groups indicate that novices, as compared to experts or intermediates, assign relatively higher priorities to routine, behavioral tasks such as acknowledging pointouts, marking flight strips, and communication tasks. Experts and intermediates, as compared to novices, assign higher priorities to monitoring activities such as scanning the PVD and reviewing flight strips and monitoring/planning activities such as determining aircraft crossing points.

Experts' recollections of "critical incidents" illustrate that such incidents most frequently involve a failure to effectively monitor so as to update information: critical data were often not perceived, or were misinterpreted.

Continued . . .

SUMMARY OF RESULTS
(Continued)

We interpret the above findings, taken together, to indicate the following factors to be the most critical in supporting expertise in air traffic control:

- Higher-level cognitive activities rather than typical procedures and behavioral tasks
- Effective underlying Mental Model to support task performance
- The Sector Management, Sector Data, and Conditions panels of the Mental Model
- Monitoring and pre-planning in Sector Management and Sector Data
- Continuous, overall situation monitoring to update information in the Mental Model
- Effective problem space organization
- Effective initial, long-term, advance planning to deal with future events
- Ability to gauge event timeframes
- Recognition of task triggers, with reference to the Mental Model
- Recognition of task triggers, vis-a-vis when to shift attention from overall situation-monitoring to performing a particular task

Finally, differences in the cognitive styles of field dependence (degree of dependence upon the context to perceive pieces of information) and impulsivity were investigated. The main findings to emerge were: supervisor-experts were less impulsive than both the nonsupervisor experts and the novices; and intermediate controllers were less impulsive than the nonsupervisor experts, but not significantly different from either the supervisor-experts or the novices. Intercorrelations were carried out between measures of impulsivity and field dependence and simulator performance ratings, but few correlations were significant. Because of the relatively small numbers of participants in each group in this study, all the results from the cognitive style assessments are to be viewed as highly tentative and purely exploratory for future research.

SUMMARY OF IMPLICATIONS FOR TRAINING

INSTRUCTIONAL CONTENT AND ORGANIZATION

The content of instruction should emphasize the underlying cognitive strategies, skills, and knowledge structures which have been found to support expert performance of en route air traffic control. Students should be explicitly taught to think about the task in terms of the Mental Model -- initially, this could be facilitated by having students describe situations in terms of the Mental Model. Emphasis should be placed upon higher-level cognitive activities related to Sector Management, Sector Data, and Conditions. Sector Management and task triggers would be emphasized when teaching rules for prioritization, as well as when training on overall goals prioritization (monitoring, computer entry, etc.). Training in expert-typical strategies should be explicit at the points in training where they become relevant. These would include, for example, use of speed control and workload reduction strategies, use of the critical cue inventory to determine work overload, use of the separation flowchart to assist in sector management, and use of specific expert-typical strategies derived from the production rules. Explicit information would be provided on the mental resource costs and relative efficiency of various strategies. This would support the development of a flexible, accessible knowledge base and efficient Mental Models for task understanding and performance.

To faciliate Mental Model development, training should be organized around "problem-types" (DeJong & Ferguson-Hessler, 1986). Training should be structured according to the tasks as defined by the cognitive decomposition of tasks. Such training should be aimed at developing automatic routines for perceiving task triggers, as a function of continual monitoring of the situation to permit information updates to the various categories contained within the Mental Model. The presence of a trigger would thus be identified by the contents of the various categories within the Mental Model at any particular point in time.

Part-task training would be particularly helpful for building automatic recognition skills of task triggers. Rapid and automatic recognition of such triggers is critical because they specify the task and accompanying cognitive operations that the controller should be accomplishing at any particular point in task evolution. Training in task subgoal recognition should be added to initial training in trigger recognition. Initially, recognition of such triggers and task subgoals would be a conscious process in which the controller explicitly references situation monitoring to categories within the Mental Model. As skill acquisition increases, however, the process would become gradually automatic (subconscious), thus freeing mental resources to explicitly reference to the Mental Model in critical, unusual, or heavy workload situations. This would substantially increase controller efficiency and might reduce stress.

Continued . . .

INSTRUCTIONAL CONTENT AND ORGANIZATION (Continued)

Continual, overall situation monitoring and pre-planning should also receive primary emphasis, as these were found to be the primary meta-strategies distinguishing expert from non-expert controllers. Perhaps the most robust and significant finding from the research is the importance of situation monitoring to update information, and long-term pre-planning. The importance of these strategies as supports of expert performance was revealed across all data collection results -- data analyses from all the procedures indicate their importance, perhaps being the most salient features to characterize expertise in air traffic control identified thus far. As discussed above, situation monitoring is critical for information updating in the Mental Model and for detecting task triggers throughout the evolution of air traffic events.

INSTRUCTIONAL MEDIA

The real-time, dynamic nature of air traffic control suggests the central importance of simulator and live-radar training as early as possible in instruction. Classroom instruction should be accompanied by simultaneous DYSIM instruction. For complex tasks such as air traffic control, a computer-based training module would also be helpful in permitting the students to acquire proficiencies in the explicit, rule-based portions of various decision domains, followed by a problem-generating practice environment in which the students can tune and refine their skills through exposure to ascending levels of situational complexity. Such scenarios could represent typical incidents, but included also should be a representative sampling of critical or unusual incidents, so as to teach problem-solving flexibility, to enhance metacognitive awareness, and to help students (as well as experts) further refine and extend their skills. An intelligent-tutoring or decision support system could be developed based upon the cognitive model presented here, in which instruction in air traffic control is organized around the Mental Model, and task triggers. Graphic representations of the panels within the Mental Models should be used if possible, to facilitate schema development. The system could prompt novices at appropriate points in the use of expert-typical strategies and provide feedback on their monitoring routines.

Such a system could include decision-aids and prompts at appropriate points in the simulation about recognizing task triggers, when to do a task, what subgoals to associate with which tasks, and which categories to reference to in the Mental Model. The system could also prompt trainees to engage in pre-planning, to formulate higher-level plans, to monitor, and to attend to other developing problems. The trainee would be provided with explicit feedback, and instruction could be tailored to the trainee's level of skill development, with prompts faded out as the trainee gains proficiency. Ultimately, a tutoring system could be developed that could determine each trainee's Mental Model, by asking certain questions. Trainees' models could be compared to the expert-typical model, with the discrepancy between the two serving as the basis for feedback to be given the trainee. Such a system could automate feedback, provide prompts and questions at critical points, provide remedial cues, and analyze novice knowledge structures (Mental Models).

INSTRUCTIONAL SEQUENCING

The sequencing of instruction should reflect cognitive principles of instructional design. The suggested sequence of instructional presentation is described below. Note that in this sequencing hierarchy, all previous instructional goals/contents are taught alongside the new goals/contents, and are used to support instruction in the new content area. For instance, automatic task trigger recognition would be taught after basic instruction in the Mental Model, but Mental Model instruction would continue -- each sequence adds a level of instruction but does not supersede the previous levels. Thus, instruction in the Mental Model is retained throughout instruction, because of its central importance in supporting acquisition of all other cognitive skills.

1) Explicit instruction in the Mental Model should be provided. Because this is the global, underlying knowledge base supporting expert performance, it should be taught initially and should form the basis of future instruction. Subsequent instruction should build on this underlying model in a progressive, hierarchical fashion. Basic-level categories and their supporting cognitive strategies should be taught first, and then interrelated with the more specific ATC Procedures as well as with the more global meta-strategy of monitoring (which is a strategy relating to updating the entire Mental Model structure).

2) Next, instruction should be provided in recognition of the task triggers, followed by training in associating the relevant subgoals upon recognition of their trigger. This would be provided in a part-task fashion, with part-task training structured around each of the 10 primary cognitive problem types. The goal would be to train toward eventual automatic recognition.

   a) Task Trigger Recognition
   b) Task Trigger Recognition + Subgoal Recognition/Association

3) Next, instruction should teach trigger and subgoal recognition in relation to the Mental Model. Students would be taught to put together # 1 and # 2 above -- i.e., relating tasks, their triggers, and subgoals, to information contained in categories within the Mental Model. This sequence should follow very soon after #2 above.

Continued . . .

INSTRUCTIONAL SEQUENCING (Continued)

4) Next, instructional routines should emphasize and provide DYSIM practice in overall situation monitoring (PVD scanning, flight strip reviewing, etc.) and planning (aircraft crossing points, etc.), and in using this meta-strategy to update information contained in the Mental Model. This meta-strategy is taught after teaching more basic strategies because research indicates that (1) basic-level strategies (i.e., ones not too specific or discrete nor too general or global) should be taught prior to lower or higher level ones, and (2) instruction in meta-strategies may interfere with skill development if taught during the acquisition of more basic strategies, due to their resource-intensive nature (continual monitoring requires a lot of attention and information updating).

5) Next, DYSIM training should be provided on typical air traffic control situations, with increasing levels of situational complexity.

6) Finally, DYSIM training should be provided on critical incidents, again with ascending levels of situational complexity.

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COGNITIVE TASK ANALYSIS OF PRIORITIZATION IN AIR TRAFFIC CONTROL

Volume II: Appendixes

Developed By:

Richard E. Redding
John R. Cannon
Bruce L. Lierman
Joan M. Ryder
Thomas L. Seamster
Janine A. Purcell

Human Technology, Inc.
McLean, Virginia

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APPENDIXES

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APPENDIX A:

STRUCTURED INTERVIEW QUESTIONS

APPENDIX A:
STRUCTURED INTERVIEW QUESTIONS

1. If you were just going on duty and relieving another controller, what steps would you take to orient yourself to what's going on in the sector? Please describe, in sequential order and as specifically as possible, the steps you would take and describe the rationale for each step.

2. How do you use the PVD and flight strips as you work? What do you pay attention to and why? Does the way you look at the PVD and flight strips change depending on the situation?

   a) How about in normal conditions?
   b) How about in heavy traffic conditions?
   c) How about in heavy weather conditions?

3. How would you assess your own workload? That is, how do you determine:

   a) When you need to ask for help?
   b) When you should decline accepting a handoff?

4. How do you mentally project traffic flow?

   a) What cues would lead you to believe that two aircraft may be in conflict? What display aids or rules of thumb do you use to project this? (Note: If the answer is very general, then prompt the controller with specific cues and ask for explanation, elaboration: time, route lines, vector lines, etc.)

   b) How do you anticipate/gauge upcoming traffic situations?

5. Generally, how would you manage a heavy traffic situation? That is, what strategies and techniques would you use to manage a heavy traffic situation that you might not use with normal or light traffic?

6. How do you determine/anticipate a weather buildup? What are the indicators and mental cues?

7. Please explain the factors you consider in determining which separation technique you use.

   a) Altitude
   b) Speed Control
   c) Vectoring
   d) Spin/Hold

8. Please rank, with (1) being the <u>highest</u> priority, the following activities in terms of relative priority. (<u>Note</u>: Have the controller use the attached rating sheet):

   a) Calling and Coordinating
   b) Scanning the PVD
   c) Reviewing Flight Strips
   d) Data Entry
   e) Marking Flight Strips
   f) Sequencing Traffic
   g) Accepting Handoffs
   h) Acknowledging Point-Outs
   i) Determining Aircraft Crossing Points

   How do these priorities change in a high workload/heavy traffic situation and why?

9. Describe the kind of calling and coordinating (with another controller and/or another center) you do related to each of the following factors:

   a) Workload (e.g., weather, pilot requests, traffic, etc.)
   b) Non-Standard Procedures (e.g., LOA's, MOA's, etc.)
   c) Traffic Flow Management Within Your Sector
   d) Confliction

10. Looking back on your training, what do you feel were the most difficult concepts and tasks to master? Why? Please be <u>specific</u>. Relate your answers to specific mental skills required. (<u>Note</u>: You may ask, "What was the last thing you learned prior to becoming an FPL controller?")

11. When you are trying to learn something new, what strategies or techniques do you use?

12. Describe the <u>most</u> effective training you have ever had. Why was it effective?

Controller Number: ____________

Please rank, with (1) being the highest priority, the following activities in terms of relative priority:

	Normal Conditions	Heavy Workload
• Calling and Coordinating	______	______
• Scanning the PVD	______	______
• Reviewing Flight Strips	______	______
• Data Entry	______	______
• Marking Flight Strips	______	______
• Sequencing Traffic	______	______
• Accepting Handoffs	______	______
• Acknowledging Point-Outs	______	______
• Determining Aircraft Crossing Points	______	______

APPENDIX B:

SCENARIOS FOR DYSIM PERFORMANCE MODELING

APPENDIX B: SCENARIOS FOR DYSIM PERFORMANCE MODELING

This is an attempt to give an outline of the four PERF problems as they unfold during the run. Not all subjects (controllers) will do exactly the same control actions, however I will try to explain alternate ideas.

PROBLEM 1

As the scenario starts, the first actions are to accept handoffs on SWI56, an overflight, LN555 landing MLC, N123EH landing MIO and a Tulsa departure SWA16.

At approximately three minutes we depart N468TT from MLC and accept handoff on SWA16. A minute later we accept handoff on HUMBL15 landing MLC, and N14025 an overflight at eleven thousand feet.

The first control action would be to vector LN555 west towards the localizer for a straight-in approach. This solves two problems: provides a more expeditious approach for him and helps separate LN555 from N468TT climbing out from MLC.

Next we climb SWA16 to FL220 and handoff to RO1.

At six minutes we accept handoffs on AWE24 off Tulsa and DLH483, an overflight. Next we descend N123EH to ten thousand feet to start him down for approach. We then issue holding at MLC for HUMBL15 and descend him to ten thousand. AWE24 is climbed to FL200 on initial call for crossing traffic at FL210 (SWI56). We would next issue a frequency change to SWA16 to RO1.

During the eight minute period we would handoff N468TT to F10 and frequency change once it is accepted. Next we issue LN555 a heading to intercept the approach and clear for approach. If at this point the controller decided not to vector LN555 for a straight-in then the LN555 would be cleared for a VOR approach instead.

It is ten minutes into the problem and we accept a handoff on TWA13 from Tulsa. Moments later Tulsa approach calls with a point out in their airspace on a code 3301 and we would accept it. At the end of the minute we accept a handoff on N262CC, an overflight.

At eleven minutes, AWE24 is clear of the traffic and can be climbed to FL230 and handed off to R30 for higher. Frequency change to R30 should follow immediately for AWE24. TWA13 is climbed on initial call to FL220 reference N262CC at FL230.

It is now twelve minutes and N123EH should be cleared for approach to MIO. Next we accept handoff on C26262, an overflight.

At thirteen minutes, we vector DLH483 north to miss P57, the prohibited area.

At the fifteen minute mark, six new aircraft enter the picture, all of them landing at Tulsa. The sequence is going to be DAL16, AAL14, COA18, NWA22, TWA42, and last but not least UAL32. The first action would be to coordinate for control then slow COA18 and UAL32 to 250 knots.

At sixteen minutes we get a down time on LN555 from MLC and we clear HUMBL15 for approach. The next series of actions will begin the sequencing of the six Tulsa arrivals. First we descend both DAL16 and TWA42 to eleven thousand feet (either aircraft first), then descend AAL14 to FL190 and reduce to 250 knots. Next descend COA18 to eleven thousand and NWA22 to FL210. Keep in mind that these altitudes may vary slightly because all but eleven thousand are altitudes reference other arrivals. Next we slow TWA42 to 280 knots and descend UAL32 to eleven thousand feet.

It is now 20 minutes into the scenario and the three aircraft, NWA22, TWA42 and UAL32, all have to be vectored on 170 headings to join the Forts1 arrival to fall behind the aircraft already on the Forts1. All aircraft at this point will be issued altitudes to step them down reference each other until five miles or more exist between each. Finally we handoff TWA13 and frequency change him.

At twenty-three minutes into the problem we handoff SWI56 to K10 and N262CC to M10. Both get frequency changes immediately after. Handoff all six Tulsa arrivals starting from first to sixth. Clear DLH483 back on course around P57 and hand him off to KO1, then frequency change both C26262 and DLH483 to the appropriate sector.

By now all six arrivals will have been handed off and accepted by Tulsa, and frequency changes can be given.

At 28 minutes, N123EH misses approach and requests a reroute. This can be handled immediately as nothing else is a high priority.

PROBLEM 2

At one minute we have accepted a handoff on EASY28, an overflight and issued a departure clearance on N33729 to FL210.

At two minutes we accept handoffs on ACA409 and N7290A landing MLC.

EASY28 is wrong altitude for direction of flight so he is cleared to FL230. N33729 is cleared to FL220 reference EASY28.

At five minutes we accept handoff on BAW261, an overflight, and then there is approximately a two minute lag in the action.

At seven minutes we accept handoff on AWE15 off Tulsa and call Tulsa approach with a point out on N33729 off MIO. It would be prudent at this time to stop N33729 at eight thousand feet and allow AWE15 to top him since the performance of the AWE15 is much greater. Once the AWE15 is clear then N33729 can be stepped up reference him.

It is eight minutes and we clear N437WH off MIO reference N33729 using altitude. AWE15 is cleared to FL200 reference traffic overhead at FL210. It may be necessary to request control to turn AWE15 to miss N33729.

At nine minutes, AWE15 is leaving ten thousand feet and N33729 can be cleared to ten thousand. N437WH will be step climbed up reference AWE15.

At ten minutes we accept handoffs on COA26 and AAL204, both landing Tulsa and both needing routing. N33729 is clear of AWE15 and is cleared to FL200. N437WH is cleared to his requested altitude as well.

Twelve minute mark and LN27E is departed from MLC to FL210. Then we accept handoff on M51555.

At thirteen minutes we clear COA26 to eleven thousand feet and increase his speed by ten or twenty knots to stay in front. We then descend AAL204 to FL220 to get him started down. DAL62 appears and we accept a handoff on that flight.

At fourteen minutes we have five miles and increasing on COA26 and AAL204 so we descend AAL204 to eleven thousand feet. During the same minute we descend DAL62 to eleven thousand feet as well.

At fifteen minutes we climb LN27E to FL230 and handoff to R30 for higher. AWE15 is clear of BAW261 and is cleared to FL220 and handed off to K10. BAW261 is handed off to M10 and ACA409 is handed off to M10 also.

At sixteen minutes LN27E is given a frequency change to R30 and AWE15, BAW261 and ACA409 are given their appropriate frequencies as well.

N33729 is amended to FL180 for traffic then recleared to FL220. N7290A is descended to twelve thousand landing MLC and to get below M51555 at FL190.

It is nineteen minutes and we slow DAL62 to 250 knots, then AAL204, then COA26 and follow this up by handing all three off to Tulsa starting from first to last.

At twenty-one minutes we vector N729OA to heading 180 for the straight-in approach and to miss N437WH. We then handoff N33729 to R1 and switch all three Tulsa arrivals to Tulsa's frequency. We then clear N437WH to hold at MLC to allow N7290A to shoot the approach. M51555 is vectored ten degrees right to miss P57. Finally we switch N33729 to R1's frequency and that is about it.

PROBLEM 3

In the first two minutes of the scenario we have accepted handoffs on N3329T, an overflight, PRONE77 and A41469, both overflights, and issued a departure clearance on N404CC off MIO to FL200. In the next minute we issue a departure clearance on AWE13 off MLC to FL200 also.

In the fourth minute we accept handoffs on AAL41 and N381AP, both overflights. N404CC is amended to sixteen thousand feet reference NN353KJ.

At six minutes we vector A41469 to a 280 heading to miss P57. We next accept handoffs on TWA32 and AMX113 landing Tulsa and both needing proper routing.

The routing is issued for both on initial call, then we accept handoffs on M51559. In the same minute we vector A41469 to a 260 heading on course when able. COA23 appears and the handoff is accepted. As soon as this flight calls we issue proper Tulsa arrival routing.

At ten minutes TWA32 is descended to 140 reference N381AP at thirteen thousand. AMX113 is descended to eleven thousand. We then slow TWA32 to 250 knots for sequencing to Tulsa.

At the eleven minute mark we accept handoff on SWA27 and handoff and frequency N404CC to R30 for higher altitude.

At twelve minutes we descend COA23 to eleven thousand and vector him to a 120 heading (approximately) to join the SHAWN1 arrival to Tulsa.

At thirteen minutes we handoff N3329T to M10 and accept handoffs on VM4E21 landing MLC and N7611X departing Tulsa.

During the next three minutes we slow COA23 to 280 knots, handoff PRONE77 to M10, and frequency N3329T to M10.

At sixteen minutes we appreq control on SWA27, then descend SWA27 to seventeen thousand. Immediately following this we slow SWA27 to 250 knots. Next we handoff A41469 to R1 and follow this up with a frequency change as well.

At eighteen minutes we vector AAL41 due north to miss M51559 and clear AWE13 for approach. Next we give A41469 a frequency change. AAL41 should be recleared on course once he and M51559 are safely clear. What remains are timely handoffs and frequency changes for the four Tulsa arrivals and the sequence is AMX113, COA23, SWA27 and TWA32.

At twenty-two minutes we clear VME21 for approach. Tulsa approach gives us two departures, NWA41 and N7611X, a faster in back situation. They are required to provide separation but we would more than likely call Tulsa approach and have them vector NWA41 off course and climb the flight higher. Once they are separated by altitude NWA41 is recleared on course.

PROBLEM 4

At the start of the problem N111MP is on the frequency and in the sector. This flight lands at MLC.

At the one minute mark we depart N741P off MLC to thirteen thousand feet.

In the next two minutes we accept handoffs on N417DF to Tulsa, HUSKR12 and SWA67 departing Tulsa.

At four minutes N351RM is departed from MIO climbing to eleven thousand. When SWA67 calls we climb him to FL200. This is followed up by climbing N351RM to thirteen thousand.

At seven minutes we depart N287WN from MIO to eight thousand. When N287WN is radar identified we climb the flight to seventeen thousand feet north west bound. When N351RM is clear of SWA67 we climb him to FL230 and handoff to R30.

At ten minutes we handoff SWA67 to K10, then frequency N351RM to R30. Next we point out N351RM to ZKC low because he is climbing slowly, then handoff the flight to R30 for higher. As soon as R30 accepts the handoff he is given the frequency change. This is followed up by giving SWA67 a frequency change, then giving AWE21 a departure clearance off MIO to six thousand reference N287WN.

At eleven minutes we have N741P climbing to eleven for N111MP at twelve head-on. N417DF is descended to seven thousand to land at Tulsa.

We then radar identify AWE21 and climb him to FL230 on initial call.

It is approximately thirteen and a half minutes and we accept handoffs on COA24 and AAL12 landing Tulsa. Next we accept handoff on DAL312, an overflight.

At sixteen minutes, we descend COA24 to eleven thousand and AAL12 to eleven thousand, then slow him to 250 knots. AWE21 is vectored eastbound to go behind AAL12. Next we handoff AWE21 to R30 and coordinate the vector and back on course when clear of traffic.

The sequence of events in the next few minutes are vectoring N741P to a 350 heading for MIO and traffic, clearing AWE21 direct HOT and pointing them out to ZME if needed.

At eighteen minutes we handoff N417DF to Tulsa, then frequency change him. Next we clear N741DP to thirteen thousand.

At twenty-one minutes we clear N111MP for approach to MLC, slow COA24 to 250 and handoff the Tulsa arrivals, then frequency change them.

APPENDIX C:

SCENARIOS FOR STRUCTURED PROBLEM SOLVING

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SCENARIOS FOR STRUCTURED PROBLEM SOLVING

Each scenario description will include an overview of the type of traffic: arrivals, departures and overflight aircraft. Along with this will be a play-by-play chronology of each five minute segment. When there is clearly more than one option to a particular control move, other possibilities will be mentioned. For the sake of argument, most control actions will be planned using the least amount of coordination with surrounding sectors and facilities. At the end of each five minute segment, a highest priority item will be identified for the start of the next segment. If there is no clear single priority, those of greatest importance will be discussed.

** SCENARIO SPS1A **

This scenario consists of departures from all three airports: Tulsa, McAlester and Miami. Additionally, there are numerous arrival aircraft to Miami and McAlester and several overflight aircraft.

The first five minutes of this scenario were run prior to the radar controller assuming the position.

Five Minute Mark

Four aircraft have been accepted to this point and only A49616 is within the sector. At this time it would be possible to either descend A49616 landing MLC or vector him towards the straight-in ILS. It is not extremely critical to do either at this time. In addition, N88WN, a VFR aircraft has called requesting an IFR clearance. A track should have been started on N88WN and a beacon code requested for him as well.

The major priority at this time is probably to determine which type of approach A49616 will be issued. Next would be to assign the beacon code to N88WN and take care of the clearance he requested. Keep in mind that no other aircraft is in the airspace at this time, and coordination would be required on any other control action.

As the clock is started, A49616 is descended to ten thousand feet only. (This allows him to keep his speed above 250 knots.) Next, a beacon code is assigned to N88WN and his IFR clearance to MLC is issued. Now is the time to determine the arrival sequence into MLC. All arrivals except A49616 will have to be cleared to hold at MLC to await their turn. First come, first served is the rule of thumb. Three new aircraft enter the picture shortly after the clock starts; N8677L landing MIO, VM6E22 an overflight, and N292BC landing MLC. After evaluating the MIO arrivals, it is obvious that N345AP is first and as soon as he enters the airspace, he must be descended to ten thousand feet to get below N8677L. All other MIO arrivals will be cleared to hold and wait their turn for approach. MIO radio calls for clearance on N128E and he will be departed climbing to nine thousand feet reference N345AP. Towards the end of this segment, MIO radio will call for a clearance on N3688U, and he will be given a departure clearance reference the altitude N128E is vacating. A49616 should be cleared for an approach to MLC prior to reaching the MLC VORTAC or he will be delayed for no reason.

Overview

At this point in time, ten minutes into the scenario, we have A49616 on approach at MLC, two departures climbing out from MIO, an overflight and the remaining traffic cleared to hold at their respective VOR's.

Ten Minute Mark

Our priority at this point is to provide as minimal delay as possible getting the departures and arrivals up and down. N345AP can be cleared for approach as soon as N128E is clear eastbound and in return N128E can climb immediately after that. It is time to maneuver the remaining MLC arrivals into position with number two at the lowest altitude, number three above him, etc. To accomplish this, N292BC must be descended to eight thousand, R16391 at nine thousand and N88WN at ten thousand.

Two new aircraft enter the scenario at this time, TWA65 and TWA67. Both of these Tulsa departures will be issued seventeen thousand feet reference VM6E22 at FL180. Additionally, due to the minimal spacing given by Tulsa approach, concern should be given to the airspeeds of the two TWA aircraft. It quickly becomes obvious that the back aircraft is twenty knots faster and either he must be slowed or the front aircraft sped up to maintain the separation. An option would be to use altitudes to keep them separated until their routes diverge and then they can both climb unrestricted. N3688U can be climbed to his requested altitude when clear of N128E.

Fifteen Minute Mark

At this point, the highest priority is timely climb clearances to the two TWA departures when clear of VM6E22 and subsequent handoffs to the high altitude sector, R30. If speeds were used to separate them, they must be coordinated with R30 also. There is also a situation of merging traffic with N413F and VM6E22 at 170 and 180. N128E should be handed off to Memphis LOW sector and handoffs on NWA32 and AMW22 should be accepted at this time. Finally, a handoff should be given to RO1 on VM6E22 in a timely manner.

Twenty Minute Mark

This signals the end of the scenario, and at this time we are waiting to give frequency changes to VM6E22 and possibly N128E. The two aircraft on approach at MIO and MLC are not on the ground yet so we are monitoring them and finally we have just given handoffs to R30 on the two TWA aircraft and are waiting to give them frequency changes to 130.0. The two new aircraft, NWA32 and AMW22 are not in the sector yet so nothing need be done with either of them.

** SCENARIO SPS2A **

Five Minute Mark

At this point the problem has been run without a test subject. Three aircraft have been accepted, EAL121, COA15, and AAL31, all landing Tulsa. Two of the flights will need routing into Tulsa, and all three will need to be sequenced with each other. At this point, only EAL121 could be moved in any way because the others are not in the sector yet. We try to avoid calling other controllers and requesting control of aircraft unless we absolutely need it. The coordination calls cause both individuals increased workload. At present there is nothing pressing and no high priority.

At the start of the clock, the first priority is to determine the sequence. In the case where two or more aircraft are a tie, it becomes a matter of personal preference as to the order. Since EAL121 is already in the sector we would descend him to eleven thousand feet and start a speed reduction on the flight. This alone should put EAL121 well behind AAL31. Next we would descend COA15 to eleven thousand feet and reduce his speed as well. Next, proper arrival routes should be issued to EAL121 and COA15. At approximately eight minutes into the problem, a judgment should be made to determine if the speed reductions on the EAL121 and COA15 are working adequately. If more spacing is required, EAL121 should be vectored to the east and possibly rerouted to the TULSA1 arrival. COA15 can be vectored to stay behind EAL121. If the spacing is accomplished using speed control only, then all of this extra work will be avoided.

Ten Minute Mark

The scenario is frozen at the ten minute mark, and the three arrivals are spacing out nicely. The highest priority is to descend AAL31 as soon as he enters the airspace. If there is not quite five miles yet between AAL31 and EAL121, then AAL31 must be given altitudes reference the EAL121. If the previous determination was made to vector the EAL and COA, then most likely AAL31 will be able to descend to eleven thousand unrestricted.

As the clock is started, we wait then descend AAL31. At this point, every move becomes extremely time critical. All three arrival aircraft will be in relative close proximity to one another, and a minor mistake could result in a major one. If speed control is working, then all aircraft would be on course and can be handed off to Tulsa approach. Once the determination is made that adequate spacing exists, then AAL31 can be reduced to 250 knots and frequency changed to Tulsa approach. The next two arrivals can be issued frequency changes as soon as Tulsa accepts the handoff and adequate spacing exists. If vectors were used, then most likely final the second and third aircraft will need clearances to rejoin the arrival routes and then they can be given to Tulsa as well. As the scenario nears the fifteen minute mark, a new aircraft, TWA19, appears and the handoff is accepted. On initial call up proper routing to Tulsa should be issued to the flight.

Fifteen Minute Mark

There is no high priority at this point. TWA19 has been issued routing and is not yet in the sector. The previous three arrivals have been handed off to Tulsa approach and have had frequency changes already. Attention should be given to planning the next group of arrivals and reviewing the flight progress strips to gain any available information.

As the clock starts, we accept a handoff on UAL59 and issue proper routing into Tulsa on initial call. Next, TWA19 is descended to eleven thousand feet as soon as he clears the sector boundary. DAL143 appears as the next flight and the handoff is accepted. After reviewing the situation, a sequence is decided upon and TWA19 should be reduced to an interim speed of about 280 knots. Next UAL59 is descended to eleven thousand and slowed to 250 knots. The sequence is DAL143 first, TWA19 second and UAL59 third. One option to consider is reaching out and gaining control to slow and descend DAL143 and making that flight second or last. Remember we would rather not bother another controller unless absolutely needed, and in this scenario we can accomplish the sequencing without doing that.

Twenty Minute Mark

At the twenty minute mark we find the spacing shaping up nicely, but it is too early to be sure if the control actions to this point are enough or if vectors are necessary. Now would be the ideal time to make a decision to change the plan and implement a different one. The highest priority at this point is a combination of judgments. You must decide if each aircraft is spaced enough at this time and if not, determine whether the proper spacing can be achieved in the remaining mileage or whether vectors will be needed.

** SCENARIO SPS5A **

Five Minute Mark

At this point there are two aircraft engaged in refueling (SPURS12) and they have been handed off to ZME (Memphis Center). There have been two aircraft depart MLC and are climbing. We have accepted a handoff on COA35, an overflight, and N496B landing MIO. Finally, N52PB has departed MIO and we are waiting for a report from the pilot to radar identify him over the MIO vortac.

The highest priority now would be a frequency change for SPURS12 to allow for a timely transition to the next sector. Next would be a handoff to R30 for LN45T who is requesting higher altitude. Third would be to make sure that when N52PB is over the MIO vortac the frequency is not tied up so that he may make his mandatory report for identification.

As the clock is started, we change frequencies for SPURS12, and handoff LN45T to R30 and give him a frequency change as well. N52PB reports MIO vortac and we radar identify him, start a data block on the primary target and obtain a reported altitude from the pilot. At 8 minutes into the scenario AAL15 departs Tulsa and we accept a handoff. On initial call we climb AAL15 to flight level 230. Nearing the ten minute mark we ask N52PB to report reaching seven thousand feet so we can pass the information along to the next controller. Aircraft with the type of equipment N52PB has do not give us automatic altitude information.

Ten Minute Mark

We are frozen at ten minutes and there is no high priority. Actually there is literally nothing to do for about three minutes.

The only priorities would be searching the flight progress strips for traffic coming. Secondary priorities would be to handoff N52PB to ZME and N84CR to ZME. Also we would be anticipating the altitude report from N52PB that we had requested earlier. Keep in mind that all of this would be somewhat premature but certainly allowable at this point.

As the clock starts we accept two handoffs on ELDER87 and LINDA34, both on military routes and at the same altitude. A look at each route tells us that they are in direct conflict and something must be done. ELDER87 is wrong altitude for his direction of flight (WAEDOF) so he will get an altitude change. This will solve both problems. Next we would handoff AAL15 to R30 to keep his climb uninterrupted. Notice that both N84CR and N52PB are still in the sector and no big rush even though they were identified as secondary priorities earlier. Because of their speeds, new priorities can develop with higher performance aircraft making them less and less important until it becomes mandatory that they be handed off or it is too late. N496B has a transponder failure and eventually cancels his IFR so he becomes no factor. We accept a handoff on DAL15 and determine if he and AAL15 are traffic. It is decided they are not so AAL15 is changed to R30 frequency. Finally, ELDER87 enters our sector so we climb him to seventeen thousand feet to resolve the potential confliction with LINDA34. N96LR is handed off to us and we accept the handoff. He is an overflight to Kansas City.

Fifteen Minute Mark

At this point things pick up and items that we had the luxury of putting off or waiting to do become more urgent.

Priorities at this time would be in this order: obtain altitude from N52PB and call ZME with the information. Handoff N84CR to ZME. Accept handoff on COA65 and AAL52 and decide sequence to Tulsa with them and DAL15. Finally handoff COA35 to ZME.

As the clock starts, do exactly these items in any order. All are basically equal priorities and must be done within about the first minute or so. We now have the freedom to concentrate on the three arrivals to Tulsa. The order is COA65, then DAL15, and then finally AAL52. We would reduce AAL52 to 250 knots, and descend him to eleven thousand feet. Next we descend COA65 to eleven thousand feet. Next, slow DAL15 to 250 knots and descend to eleven thousand feet. Finally, slow COA65 approximately ten miles from Wagon intersection.

Twenty Minute Mark

At this point we have nothing to do except handoff the three arrivals to Tulsa approach and give them frequency changes once accepted.

The priority would be to monitor COA65 to reduce his speed at the proper time to maintain the spacing yet allow the pilot to reduce his speed in time. Next simply change the arrivals frequencies and nothing else is pressing.

** SCENARIO SPS7A **

Five Minute Mark

To this point we have accepted handoffs on eight different flights. N121EK, N368LL and LN444 all land MIO. COA23 lands Tulsa. HOMIN10, OSAGE22 and N464KK are overflights. AWE43 is a Tulsa departure.

The highest priority at this time is probably to determine the sequence into MIO and clear number two and three to hold. You must also consider AWE43 and COA23 a possible confliction at this point.

As the clock starts, we climb AWE43 to twenty-three thousand feet. Two new aircraft appear and they are DAL42 and NWA20, both landing Tulsa. We then clear LN444 for approach to MIO and the other two arrivals to hold at MIO vortac. Because N121EK will arrive second he will be number two and will hold at nine thousand. N368LL is third and will hold at ten thousand feet. The sequence for the Tulsa arrivals is DAL42 first, COA23 second and NWA20 third. (Never tell a pilot he or she is last; tell them they are third in this case. Child psychology ...) Start out by slowing NWA20 to 250 knots. Accept handoffs on YANKE79 and R12429. Slow COA23 and descend to eleven thousand feet. Descend DAL42 to eleven thousand and then NWA20 as well.

Ten Minute Mark

We are frozen at ten minutes and we have the following situations. The three Tulsa arrivals have all been descended but only the back two are slowing. We also have the three arrivals to MIO, two of which are cleared to hold and the LN444 is on approach YANKE79 and R12429 have checked on the frequency.

The highest priority is the arrivals to Tulsa. They must be monitored closely to determine if the original plan of attack will be enough. If the timely use of speed is not going to ensure the spacing, then the two aircraft coming from the north on the SPRIN arrival will need to be radar vectored to join the FORTS1 arrival. Next we would handoff AWE43 to ZME and that would be about all.

As the clock starts we accept a handoff on TWA71 from Tulsa then proceed to handoff all three arrivals to Tulsa. Next we would handoff OSAGE22 to ZKC. It would appear that our original plan on the three arrivals is not going to be enough spacing so both COA23 and NWA20 are vectored south behind DAL42 to join the FORTS1 arrival to Tulsa. We then give AWE43 a frequency change to ZME and follow that by doing the same for OSAGE22 to ZKC. It is common for a controller to give a handoff on an aircraft, then spend 30 seconds to a minute doing other things while waiting for the next controller to accept the handoff. Then he can give the frequency change to the pilot but little time is wasted in between.

Fifteen Minute Mark

We have spaced the Tulsa arrivals and are fine tuning our spacing by vectoring the last two to rejoin the FORTS1 arrival. We also know that R12429 lands MLC and we monitor that situation. Additionally, YANKE79 and HOMIN10 may be in conflict at the same altitude but we have time to analyze that. LN444 is still on approach and the other two are holding. TWA71 is climbing to 230.

Priorities include handoffs and frequency changes for the remaining Tulsa arrivals, and a handoff to ZME for TWA71. Now is the time to seriously look at YANKE79 and HOMIN10 and decide if they will fit or not.

As the clock starts, we handoff NWA20 and frequency change COA23 to Tulsa. We then handoff TWA71 to ZME and come back and frequency change NWA20 to Tulsa. We should then be able to go back and change TWA71 to ZME frequency. We have determined that OSAGE22 and HOMIN10 are in conflict so we climb HOMIN10 to 230. Either aircraft could have been moved in this case, however consideration should usually be given to the type of aircraft when the option is there. We then hand off both aircraft to ZME. MIO radio calls with a landing time on LN444 and a departure clearance for N374LJ. Because the departure is a jet, a clearance is given. The aircraft will cause minimal delay for those aircraft waiting in hold. If the departure were low performance chances are the controller would deny the clearance and clear the next arrival for approach instead.

Twenty Minute Mark

We are frozen at this point and are waiting for N374LJ to depart so we can radar identify him and climb him. He has been issued an altitude below those in hold. We are planning to climb him when clear of the holding pattern then immediately clear the next arrival for approach. Two new aircraft have appeared but little attention is given at the moment.

The highest priority is to clear R12429 for approach prior to him reaching MLC vortac, and earlier to allow the pilot a reasonable descent to the airport. We would next plan on radar identifying N374LJ and climbing him reference the aircraft in hold overhead. Next we would determine the sequence on the new set of arrivals heading towards us.

APPENDIX D:

SUMMARY OF CRITICAL INCIDENT TYPES

APPENDIX D
SUMMARY OF CRITICAL INCIDENTS GENERATED BY EXPERTS
(Highlighted incidents used in the analysis)

SUBJECT

A01:

1. Military aircraft deviation – simple controller action.
2. **Concorde Incident.**
3. Two aircraft DEAL – lack of attention; handoff problem.
4. Tower situation.
5. **Complex situation with military aircraft out of Patrick AFB.**
6. Atlanta Center – two aircraft on departure; lack of attention.
7. **DC Center Coordination with aircraft decompression incident.**

A02:

1. Separation problem – two aircraft.
2. **Complex situation – Philadelphia departures/ABE, etc.**
3. Complex situation – Cleveland to Newark with weather.
4. Confusion – solution from other team member.
5. Conflict without alert.
6. Anticipatory action to avoid future conflict.

A03:

1. Misinterpretation of aircraft call signs.
2. **Restricted airspace over LA/weather.**
3. **Palmdale – low altitude sector.**
4. Terminal Control Area.
5. **Runway change at LA.**

A04:

1. Weather – DFW situation.
2. **Continental decompression over Texas.**
3. Inattention over Texas.
4. Deviation of aircraft.
5. Wichita Falls High Sector – cleared direct.
6. Mistaken identity.
7. **Failed responses by aircraft.**
8. **Departures from DFW.**
9. Loss of primary radar/weather deviation.
10. VFR.

A05:

1. Aircraft identification problem.
2. Dead radar zone.
3. Military aircraft high jinx.
4. Handoff problem.
5. **Nose-to-nose at Seattle.**
6. **Meter Program Control situation.**

APPENDIX E:

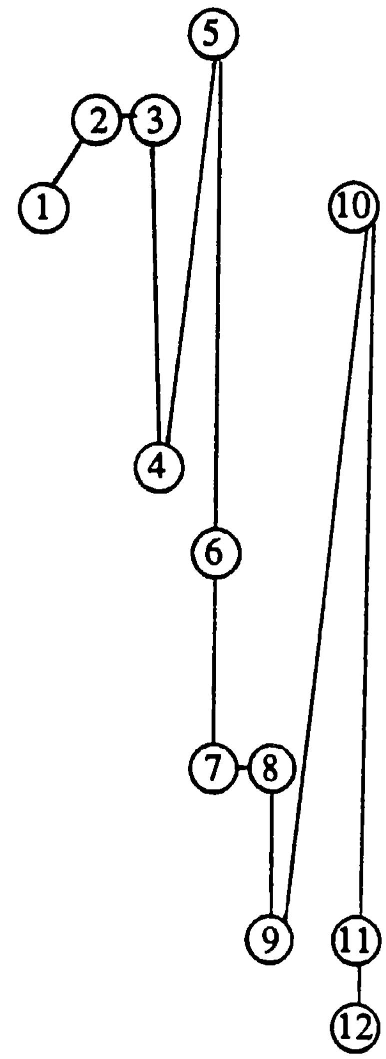
PAIRED PROBLEM SOLVING COMPARISON DIAGRAMS

Experts

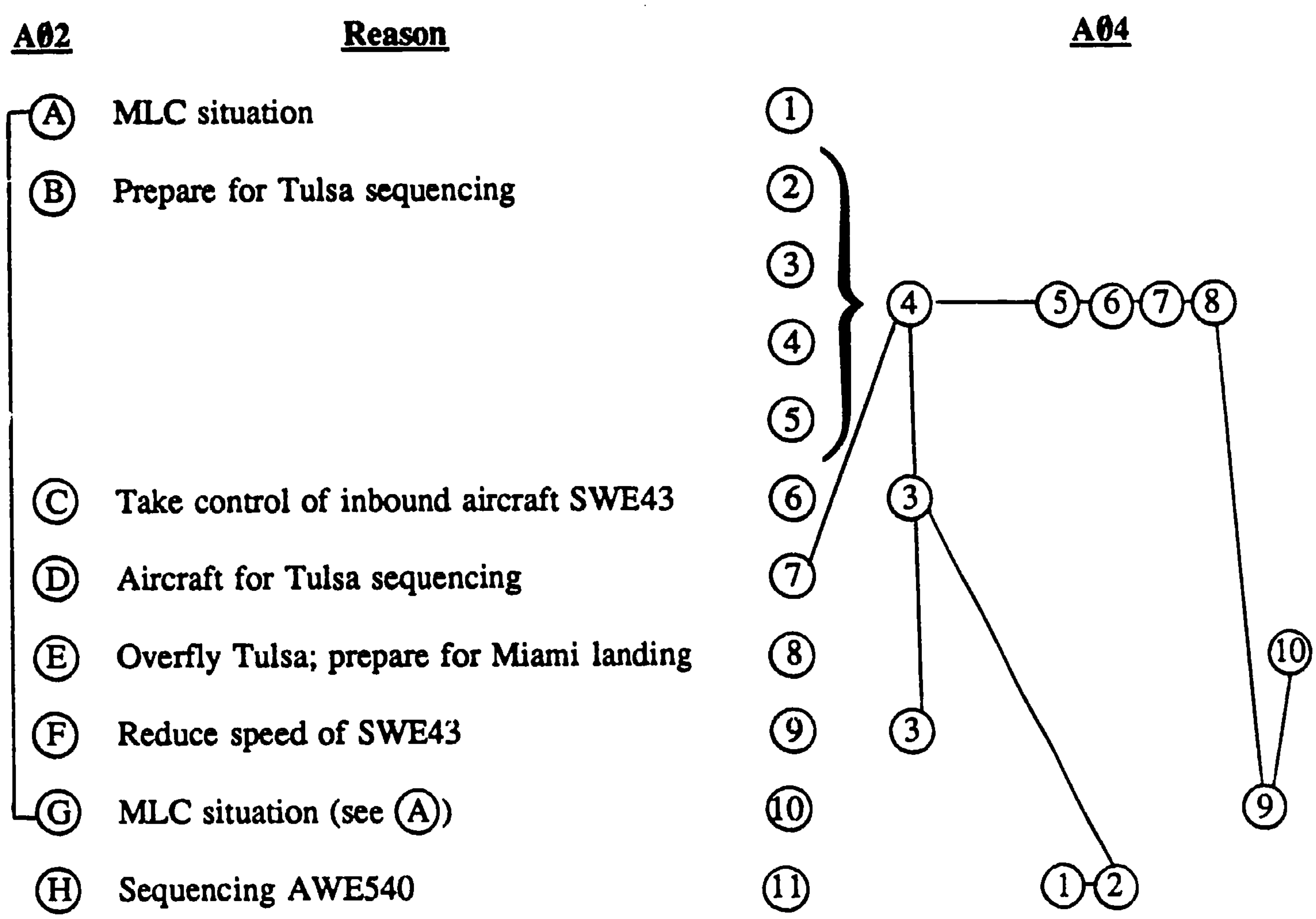
A01 COMPARISON DIAGRAM

A01	Reason
1	Get 4 away from MIO airspace
2	Separate 6 from incoming Tulsa arrivals
3	Important, most critical event. It's an error not to complete handoff before aircraft crosses Tulsa Boundary
4	Hold below 9 to avoid conflict
5	Get 1 down for approach
6	Get 5 down for approach, separate from aircraft 1, get below 4 and 9
7	Get descent started early on 12
8a	Sequence for spacing at Tulsa arrival
8b	Return to course after passing aircraft 5
	Separate 11 and 12
	Complete handoff of 11 to avoid putting 11 into holding

A04



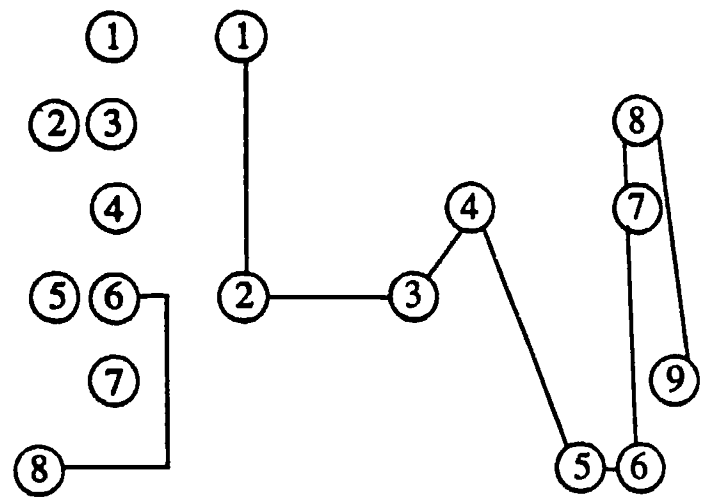
A02 COMPARISON DIAGRAM



A04 COMPARISON DIAGRAM

A04	Reason
A	Clear aircraft 1 and 2 conflict
B	MLC action
C	Sequence preparation Tulsa
D	Separation of aircraft
E	Departure Tulsa
F	Sequence preparation Tulsa See D 5 6

A02



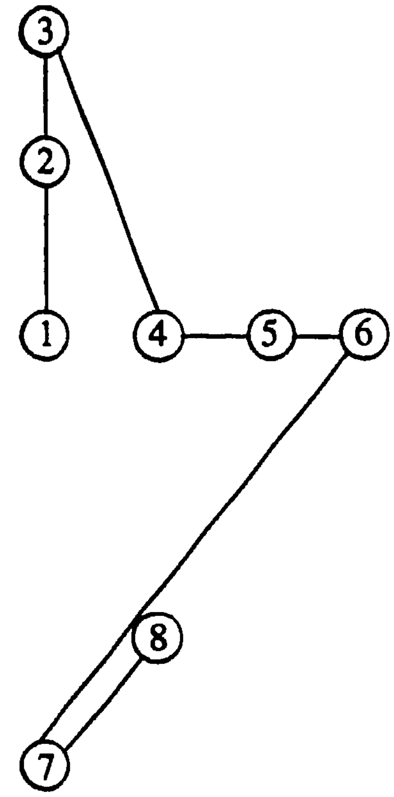
A04 COMPARISON DIAGRAM

A04	Reason	A01
1	Avoid conflict between 2 and 1 over Miami; coordinate with Memphis center to control 2	10
2	Stop 9 at 7,000 to avoid conflict between 9 and 8	
3	Meet LOA arrival restrictions at TUL	
4	Get 5 under NORDO	4-5
5	Get 4 away from NORDO (10)	3
6	Avoid head-on between 3 and 10; avoid coordination with high sector	2
7	Separate 7 from 6 and 10	1
8a-8b	Sequence 3, 4 and 8 for TUL arrival	6
	Sequence 3, 4 and 8 for TUL arrival	7-8 11-12
	Get 9 around TUL approach area	9a-9b

A06 COMPARISON DIAGRAM

A06	Reason
1	Descend aircraft 8 out of way of arriving aircraft
2	Hold aircraft 1 at 11,000 to avoid conflict with approaching aircraft 3, 4, 5, 7, 8 and aircraft 2
3	Coordinate with ZME to turn aircraft 4 to put him ahead of aircraft 8 for arrival at Tulsa
4	Slow aircraft 7 as necessary for spacing with aircraft 3
5	Climb aircraft 2 for separation with aircraft 6 and aircraft 1
6	Climb aircraft 1 on departure

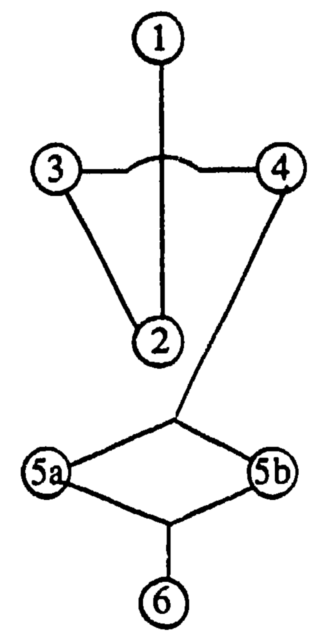
A07



A07 COMPARISON DIAGRAM

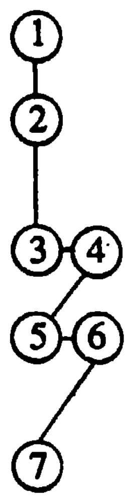
A06	Reason
1	Descend aircraft 4 to land and resolve conflict with aircraft 3
2	Vector aircraft 6 out of way of arriving aircraft 2 , 4 and 5 and sequence for arrival
3	Contact Memphis to change aircraft 1 to correct arrival
4	Protect altitude for aircraft 8 by departing aircraft 7 below aircraft 8 's altitude
5	Reroute departure of aircraft 9 to clear inbounds to Tulsa

A07



A12 COMPARISON DIAGRAM

A06



Reason

Resolve conflict with aircraft 7 and 8

Clear inbounds 4, 5, 8, 9 and 10 from aircraft 2

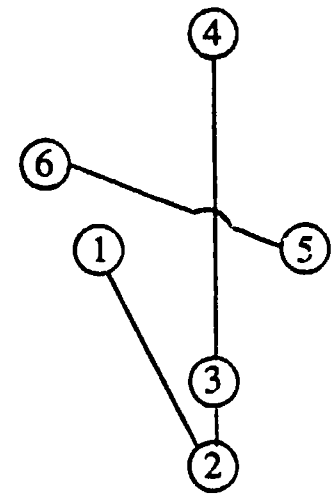
Separate aircraft 8, 9 and 10

Maintain separation between aircraft 4 and 5 for Tulsa arrival

Separate aircraft 7 and 6

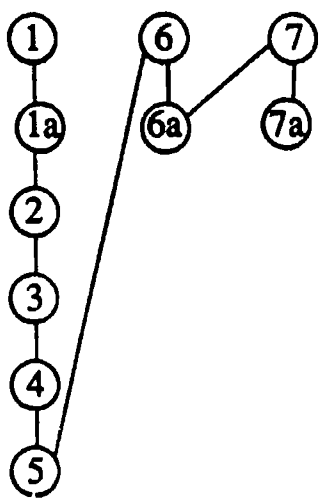
Make aircraft 9 number 1 for arrival in front of aircraft 7

A12



Intermediates

A13	Reason	A14



Separate 1 from 2

Climb 3 to FL230

Take 6 out of sequencing problem to Tulsa

Put 5 behind 7

Get 8 under 10 inbound to MIO

Get 10 in safe place to allow concentration on sequencing 4, 5, 6, 7

Make 4 number 1 for Tulsa

Put 7 behind 4

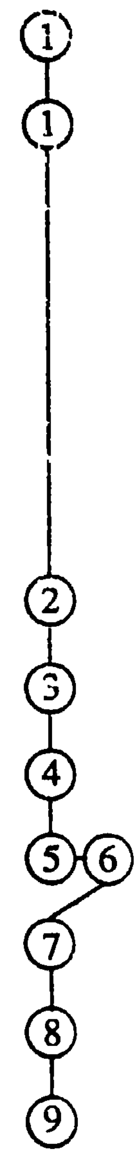
Put 5 and 6 behind 7

Get ready for 8, 10 to descend

Start 10 for approach (lowest)

Keep 8 clear of 10

Keep 9 clear of 8, 10; get his departure

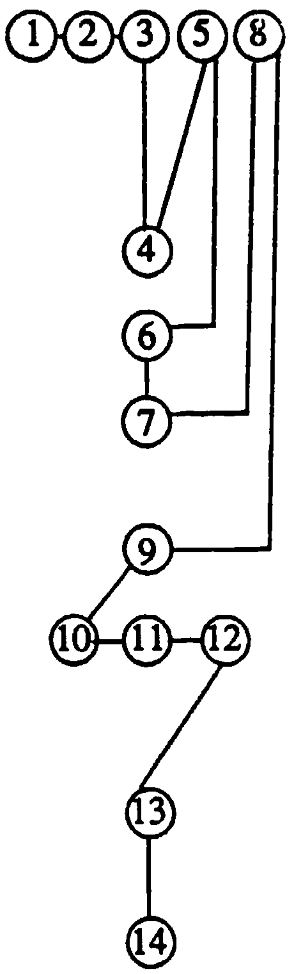


A14 COMPARISON DIAGRAM

A14	Reason	A13
1	Separate from A1, A2	1
2	Get spacing between N1, N2	6
3	Separate N3 and N5	2
4	Separate N4 from N6, N7 for descent	5
5	Separate N6, N7; get N6 off	3
6	Get R8 off; get above other traffic	4
7	Meet LOA for handoff to Tulsa	
8	Compensate for wrong altitude for direction	
9	Separate N7 from N4, N6	
9	Get N7 to desired altitude	7
	Separate N7 from N1, N2	7

A15 COMPARISON DIAGRAM

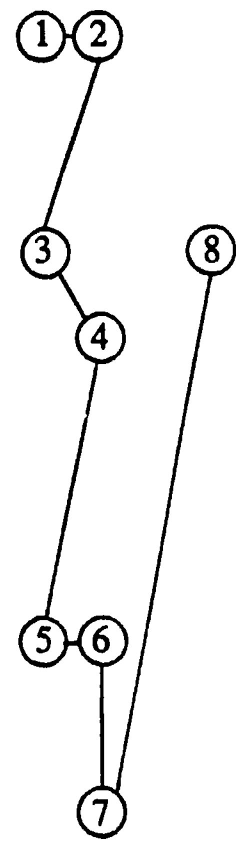
A-15



Reason

1. Conflict resolution and sequence of aircraft 2, 4, 3 and 9 for Tulsa arrival; make aircraft 4 number 1 (alternative aircraft 2 number 1)
2. Get aircraft 9 in trail of aircraft 2
3. Resolve conflict with aircraft 5, 4 and 2
4. Descend aircraft 4 for landing Tulsa when clear of refueling truck
5. Descend aircraft 9 for landing
6. Descend aircraft 7 under aircraft 8 and in trail of aircraft 6; aircraft 6 number 1 (alternative aircraft 8 number 1)
7. Expedite aircraft 7 descent to clear aircraft 5
8. Vector aircraft 6 to avoid conflict with aircraft 5

A-16



A16 COMPARISON DIAGRAM

A16	Reason	A15
1 2	Keep NW2 in front of A10; make NW2 number 1 for Tulsa	1
3	Separate N182RP from 345	
4	Put A20 behind A10	
5	Keep 823 below B45 and arrivals	3
6	Keep 456 out of Tulsa arrivals (NWAZ, A10, A20 {A40?})	6
7	Sequencing of Tulsa arrivals	
8	Avoid conflicts between 345 and Tulsa arrivals (NWAZ, A10, A20)	1 2
9	Keep A40 above 345	4
	Put A20 behind A40	5
	Separate 456 from 2RP	6
	Sequence 456 behind A20	

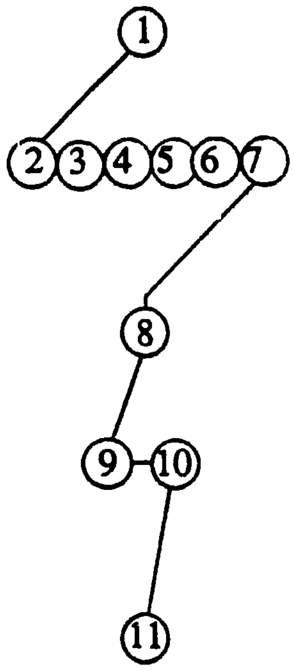
A17 COMPARISON DIAGRAM

A17	Reason	A18
1	Avoid conflict between 2 and 1	1
2	Avoid P57 restricted area for 7	
3 10	Prevent deviation when putting 8 across R1 airspace	
	Avoid conflict between 8 and 9	4
4	Avoid conflict with 4 and inbound Tulsa traffic ((5 and 6)) at WAGON	3
5	Avoid conflict between 11 and 9	
6	Make 6 first for Tulsa arrival	
7	Sequence 5 behind 6	2
8	Make 6 meet LOA	
9	Give 3 proper altitude for direction	6
	Avoid conflict of 11 and 10	5
	Avoid conflict of 10 and 4	6

Novices

A18 COMPARISON DIAGRAM

A17



Reason

Descend aircraft (4) out of way of Tulsa inbounds (or vector)

Separate and sequence aircraft (1), (2), (3) and (5) for arrival at Tulsa

Vector aircraft (9) to clear restricted area and remain clear of inbounds to Tulsa

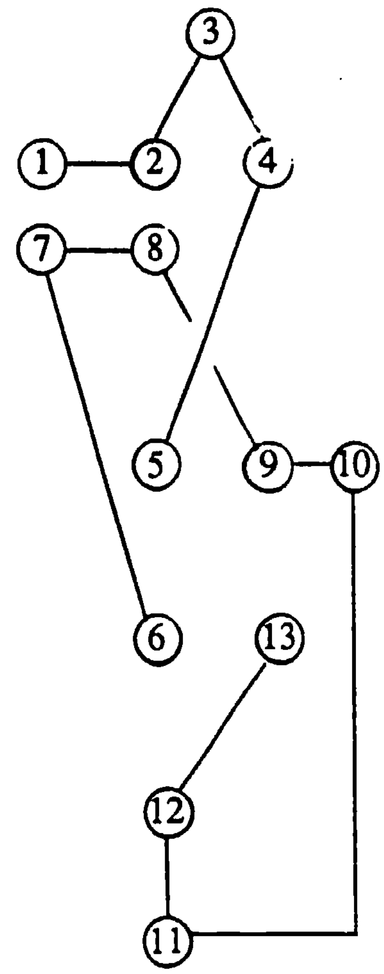
Vector aircraft (6) number (1) for arrival to MIO and separation with aircraft (7); hold aircraft (7) at MIO

Issue clearance to aircraft (8) but hold for delivery to give inbound aircraft priority at MIO (or clear (8) off prior to arriving traffic)

Clear aircraft (4) to SGF and descend to correct altitude for direction of flight

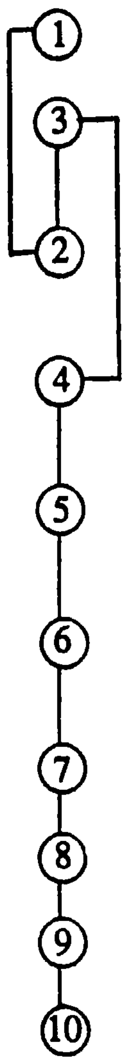
Restrict aircraft (2) to cross wagon at 11,000 feet/250 knots as per letter of agreement

A18



A25 COMPARISON DIAGRAM

A25



Reason

Resolve conflict between aircraft 8 and 9

Avoid conflict between aircraft 9 and 10 by stopping aircraft 7 at 9,000 feet

Turn aircraft 3 to avoid conflict with aircraft 8

Turn aircraft 6 to sequence behind aircraft 5; aircraft 4 will be first

Climb aircraft 2 to 17,000 feet to separate from aircraft 1 and aircraft 3

Climb aircraft 8 to desired altitude when aircraft 9 is level at FL220

Turn aircraft 3 back on desired course

Turn aircraft 2 back on course

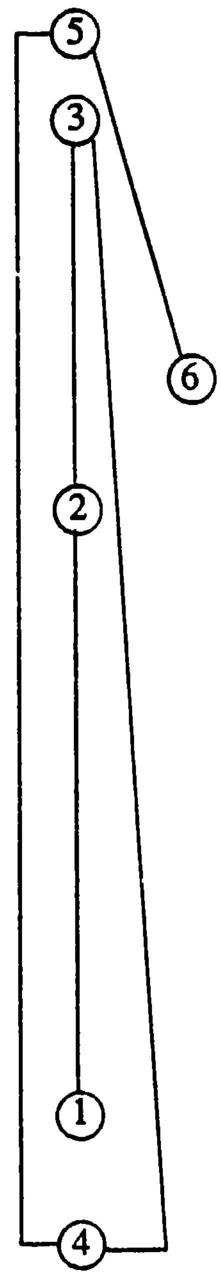
Climb aircraft 7 to desired altitude

Get aircraft 6 on approach to Tulsa

Descend aircraft 4 to 11,000 feet landing at Tulsa

Descend aircraft 5 to 11,000 feet landing at Tulsa

A26



A26 COMPARISON DIAGRAM

A26	Reason	A25
1	Climb N1 to avoid overtake from N2 and get above N3 and N7	1
2	Climb N2 and turn 090° to clear N1 and get above N3 and N7	4 7
3	Descend N7 reference N3 – N7 landing MIO	3
4	Reroute and descend N4 for spacing with N6	5
5	Descent N6 for spacing with N4	5
6 7	Adjust speed for N4 and N6 for sequencing	2
8	Appreq N5 climb to remain clear of N4 and N6	8
9	Clear N8 on departure keeping clear of N7	6

A27 COMPARISON DIAGRAM (PPS)

A27	Reason	A28
1	Separate N1 from N2, N3, N4, N5, N6	1
		2
2	Avoid conflict between N3 and N5, N4	3
		4
3	Keep N9 clear of N8, N3	
4	Keep N4 clear of N1, N2, N3, N5, N6	
	Avoid conflict with N8	
	Get right altitude for direction of flight	5
	Keep N9 clear of N4	6

A28 COMPARISON DIAGRAM (PPS)

N3 is TUX A28	Reason	A27
1	Keep N3 clear of Tulsa inbounds – N1 and N2	1, 3
2	Keep N7 clear of N6, N4, N9	5
3	Get N4 clear of N7, N6	6
	Descend N4 for Tulsa	
4	Put N1 behind N2 for Tulsa	2
5	Avoid N7 conflict with N1 and N2	
	Get N8 above N7, N4 and N6	4
	Get N5 down for arrival under N6	7
	Meet Tulsa LOA	

A29 COMPARISON DIAGRAM

A29 | **Reason** | **A30**

Stop N1 climb to avoid conflict with N6

Depart N10 avoiding N9, N3 and N8

Turn N8 and descend to get underneath N3 and N9

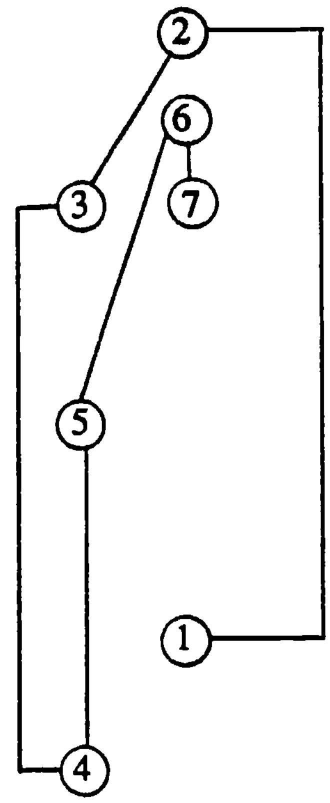
Climb N9 to clear N8 and N4

Descend N2 below N4

Monitor N7 climb – possible conflict with N5

Descend N7 to avoid conflict with N5 and get under N6

Vector N4 to clear N2



APPENDIX F:

DICTIONARY FROM PAIRED PROBLEM SOLVING

Type	Goals/means	Term	Definition
action	computer	HAND OFF	make entry to alert another controller to take aircraft
action	monitor	CHOOSE	select from a series of options
action	monitor	READ	read flight strip information
action	monitor	SCAN	check entire sector on PVD
action	monitor	SEQUENCE	separate (in trail) aircraft with identical routing
action	monitor	SORT	organize flight strips
action	off-freq	APREQ	request approval from another controller for exception
action	off-freq	POINT OUT	Advise controller and request approval for deviation
action	on-freq	CLIMB	direct pilot to increase altitude
action	on-freq	CONTACT	establish communication with another controller
action	on-freq	DESCEND	direct pilot to decrease altitude
action	on-freq	EXPEDITE	perform the required action as quickly as possible
action	on-freq	INCREASE	direct pilot to increase airspeed
action	on-freq	MAINTAIN	direct pilot to maintain altitude, airspeed or heading
action	on-freq	SLOW	direct pilot to decrease airspeed
action	on-freq	SWITCH	direct pilot to change to new frequency
action	on-freq	VECTOR	direct pilot to change to new heading
action			
category	control	DARC	radar outage
category	control	NORDO	lost radio communication (NORDO)
category	deviation	altitude/direction	establish proper altitude for direction
category	deviation	Assign STAR	action required to assign standard arrival/departure routing
category	deviation	boundary deviation	imminent boundary deviation
category	deviation	LOA compliance	action required to meet Letter of Agreement (alt./airspeed)
category	deviation	LOA deviation	impending LOA deviation
category	deviation	make handoff	make required handoff to another sector
category	deviation	restricted area	avoid restricted area
category	effort		
category	request	Meet pilot request	action to give pilot requested route/altitude
category	violation	2-ship	two aircraft in conflict at same altitude
category	violation	app fac arr dep	approach facility arrival/departure sequencing
category	violation	app fac arr seq	approach facility arrival sequencing
category	violation	app fac dep seq	approach facility departure sequencing
category	violation	arriv. cross-traffic	traffic crossing arrival route
category	violation	arriving traffic	traffic in conflict with arrival route
category	violation	boundary conflict	aircraft transiting within 5 miles of sector boundary
category	violation	climb/special	climbing traffic in conflict with a special handling aircraf
category	violation	climbing traffic	conflict with climbing traffic
category	violation	cross-traffic	traffic in conflict with a main path or flow
category	violation	dep. cross-traffic	traffic in conflict with departure route
category	violation	descending traffic	conflict with aircraft descending for landing
category	violation	non app arr conf	conflict with non approach arrival
category	violation	non app fac arr dep	non approach facility arrival/departure sequencing
category	violation	non app fac arr seq	non approach facility arrival sequencing
category	violation	non app fac dep conf	non approach departure/overflight conflict
category	violation	Refuse separation	tell another sector about problem with handoff spacing
category	violation	Special handling	conflict between special handling aircraft and other
category	violation	TUX	conflict with lost transponder aircraft
category	violation	unusual aircraft	Sequencing with unusual aircraft (C550)
condition		AND	
condition		ELSE	
condition		IF	
condition		OR	
condition		THEN	
condition			
Noun		(aircraft type)	class of aircraft denoting performance characteristics
Noun		(altitude)	specified altitude or flight level assigned to an aircraft
Noun		(call sign)	Aircraft's identifying radio identifier
Noun		(heading)	specified azimuth (0-360) assigned to an aircraft
Noun		(speed)	specified airspeed (IAS) assigned to an aircraft
Noun		(STAR)	Standard Terminal Arrival Route
Noun		arrival	aircraft planned for landing at an airfield in the sector
Noun		best possible speed	highest speed the aircraft can fly in the given conditions
Noun		conflict/confliction	an impending separation violation if not corrected
Noun		departure	aircraft departing an airfield in the sector
Noun		handoff	computer entry for another facility to an aircraft
Noun		range ring	PVD symbol showing minimum lateral separation (5 miles)
Noun		spacing	distance (lateral or vertical) between aircraft
Noun		strip	flight strip - the aircraft handling record
Noun		target	an aircraft display on the PVD
Noun			

APPENDIX G:

REPORT OF COGNET ANALYSIS

1. COGNET Approach

COGNET (COGnitive NETwork of tasks) is a framework for modeling human-computer interaction and decision-making in complex, real-world environments, particularly those which unfold in real-time and make multiple demands on the attention of the human decision-maker. The motivation for developing the COGNET methodology was to explore the extent to which models of the computer-user's problem-solving strategies in these real-time multi-tasking (RTMT) environments can lead to the design of more effective human-computer interfaces, decision aids, or training systems.

Air traffic control requires the human operator to share attention among competing task demands, such as sequencing aircraft for arrival, maintaining safe separation among aircraft in the sector, and responding to pilot requests, among other things. It also involves dealing with real-time problem data -- aircraft in flight. Consequently, air traffic control is a prime example of the type of job that COGNET is ideal for modeling.

The full COGNET framework consists of three separate but interrelated pieces. The first is a particular set of task models which the user follows to solve the problem involved. The second is an integrated problem representation that these individual tasks use in their own procedures and that, in addition, constrains their interaction into a coordinated problem-solving process. Finally, the third piece is a mechanism which describes the processes by which information (e.g., observing an aircraft symbol move on the PVD), once perceived, is introduced into the person's understanding of the problem (i.e., the global probelm representation).

Modeling the Global Problem Representation. The central component in a COGNET model is the problem representation. The technique used to formalize the problem representation in a COGNET model is the blackboard framework. The blackboard acts as a global data structure which can be independently examined by each task when it is active, and changed by that task as part of its activity. However, each time there is a change to the blackboard, each other (inactive) task is also able to examine the blackboard's (new) contents and determine whether the conditions now exist for the agent to become active. Thus, each task operates opportunistically, with no additional explicit attention mechanism needed.

It is possible for the blackboard to be separated into several independent pieces or panels. These panels can reflect different aspects or viewpoints on the problem domain. Each panel, then , is divided into levels of information. The levels, to the extent appropriate, represent a hierarchy of information converging on a problem solution. The lower levels on each panel are the more basic data. The higher levels are more "processed" or "derived" types of information. The hierarchical view of the levels fits some domains better than others, and is not a necessary feature of the blackboard structure.

Modeling Individual Task Performance. Each task is a unit of local, goal-directed, procedural knowledge about some problem-solving activity that contributes to the problem solution. The task is local in that even when successfully completed, it can not by itself solve the overall problem. The task is goal directed in that it is defined by a specific goal that indicates the local function of the task in the overall process. The task embodies procedural knowledge in that it exists as a set of (goal-directed) operations that, when executed, may achieve the (local) goal that defines the task. Each task, when active, processes information on the common representation using cognitive operations. The latter are actions that the person can take through the human-computer interface to affect change in the real-world or to manipulate information in it. Each task can and does change the contents of the common representation according to the operations performed during the task. These changes can affect other tasks indirectly through the common problem representation, but tasks never interact directly.

Each task model has a trigger that is a set of conditions under which the task should be initiated. Within the COGNET model, the triggers are expressed as patterns of information on the blackboard For example, a trigger to initiate a handoff could be an aircraft 30 miles or less from the sector boundary and no critical events occurring. The task, which is effectively a goal, is partitioned into a set of subgoals, and if appropriate, sub-subgoals. Each goal is then decomposed into a set of cognitive and motor operators that are needed to accomplish the goal. The motor operators are specific human-computer interactions (or human-human communications). The cognitive operators post information on the blackboard, take information off the blackboard, or transform information on the blackboard. For example, cognitive operators could include mentally projecting two aircraft routes, determining that a potential conflict exists, and posting a message to that effect on the blackboard. Operators can be collected into a set of Methods and Selection Rules fro deciding which Method is appropriate under the specific task conditions.

Each subgoal or operator in the COGNET task description may have a condition associated with it. Conditions must be expressed in terms that express context-free control constraints (such as if, when, until, etc.) or are completely evaluatable in terms of the blackboard contents. Thus, a condition could constrain an operator to be "applied 10 times", but not to be "repeated until a = b," unless "a=b" were a condition that could be evaluated strictly from the blackboard contents.

<u>Modeling perceptual processes</u>. The COGNET task description language links the global problem representation -- the blackboard -- strictly to cognitive operations performed within the individual tasks in the COGNET network.

The COGNET task descriptions deal only with cognitive and motor operations. What is obviously missing is the operation of the perceptual subsystem, and any perceptual operators. In a human-computer interaction situation this is a critical failing, because much elementary information on the blackboard must be posted as the result of essentially perceptual events (e.g; observing a symbol appear or change on the display screen). In the most general case, it would be desirable to include perceptual operators in the COGNET task description language that allow posting/unposting of information on the blackboard as the result of screen/workstation events. There is a problem in doing this, however, that arises from the very nature of the RTMT problem class. In RTMT domains, screen events appear as the result of unplanned, random, and/or hostile-agent actions. These unforeseen events are in fact the basis for the data-driven aspects of RTMT problem solving. The perceptual operator that perceives these events and posts them on the blackboard must therefore also be data driven. Unfortunately, such data-driven operators have no clear position in the goal-driven organization of the COGNET task language. A data-driven perceptual operator is equally applicable at all times and to all tasks in the network.

To allow for this type of data-driven perceptually-based blackboard access, a special type of construct was developed called the 'perceptual demon'. It consists of only a trigger and a POST operator, and is assumed to capture control and execute immediately whenever the triggering pattern or condition is observed. Unlike other task models, the conditions/triggers in a perceptual demon are not based on patterns on the blackboard, but instead are based on physical or workstation-based information, such as the registering of a datum on the display screen. The perceptual demons operate outside the flow of attention in the COGNET network -- which deals with the control of the cognitive processor -- because the control and sequencing of perceptual events is presumed to be separate and parallel in the human information processing architecture. Thus, the perceptual demons form the link between physical events at the workstation and the registering of the information they contain in the workstation user's mental model of the problem.

2. Focus of This Analysis

The scope and time constraints of this analysis effort were such that it would not be possible to construct a complete COGNET model of en route air traffic control dealing with prioritization. Thus, we decided to focus on the aspects of the COGNET model that have the most potential benefit for cognitive training development. One area of concentration was the blackboard structure, since the blackboard can be thought of as the controller's mental model of the domain. With regard to the individual task models, we have concentrated on identifying the tasks as units of goal-directed activity (the task decomposition), and for each task, determining the task triggers and high-level subgoal structure. We felt that decomposing the subgoals into methods and operators would be less useful for two reasons. First,it would require a larger effort than we had resources for. Second, it would overlap to a large extent with previous behavioral task analyses. The task triggers are particularly relevant to the prioritization issue, as they indicate how the an individual controller using the blackboard shifts attention from task to task.

This COGNET model is derived from the data collected in the four scenarios described below. There are undoubtedly aspects of en route air traffic control and prioritization which are not dealt with in these scenarios, and consequently are not captured in the model. The structure of the current model could accommodate these additional aspects by the addition of tasks and their component triggers and subgoals.

Prioritization in enroute air traffic control is accommodated in this COGNET model via the interaction between the blackboard contents and the task models. The task triggers capture prioritzation by specifying the blackboard contents that set a particular task in motion. Thus, when a critical event or condition is posted on the blackboard, it will cause the trigger for a particular task to fire and seize attention. When the pattern of information on the blackboard has been transformed by partial or complete execution of that task, other tasks would be triggered in response to the new blackboard configuration. Task priority is context dependent and implicit in that information posted within the various levels of the blackboard panels will be interpreted in relation to the content of the task triggers.

3. Results

This section describes the components of a COGNET model of en route air traffic control involving prioritzation. The model is based on data collected from five expert controllers each solving four simulated problems. Two problems were designed to be 100% complexity and two were 65% complexity, to allow the model to capture workload factors.

3.1 Problem Representation

As described above, the global problem representation in a COGNET model is a blackboard structure. The blackboard is an organization of knowledge and data that is used in accomplishing each ATC task. The structure of the blackboard implies a conceptual framework used by the controller for organizing domain knowledge and implies a strategy for applying the knowledge in job conduct. Information is added to the blackboard as a result of perceptual processes (represented in COGNET as perceptual demons) and as part of the procedures that make up the individual tasks. Tasks are triggered by patterns of information on the blackboard (because the configuration of information on the blackboard at any point in time represents the controller's understanding of the situation).

The information on the blackboard is partitioned into panels containing conceptually different categories of information. Each panel contains several levels. The levels are organized hierarchically, with the information at each level representing partial solutions to the problem. Cognitive operations within the task models can transform information on one level of a blackboard panel (often using information from other parts of the blackboard) to information on another level.

3.1.1 Blackboard Structure

The ATC blackboard contains five panels, as shown in Figure 1. They are as follows:

1. Sector Management -- contains an understanding of the events that are occurring or are anticipated to occur in the sector. The elements of this panel are events involving one or more aircraft.

2. Sector Data -- contains basic data about the aircraft in the sector. Information on this panel is used in reasoning about the current situation and in categorizing aircraft into events on the Sector Management panel.

3. Conditions -- contains subjective factors that determine the controller's general level of stress and workload.

4. Sector Airspace -- contains knowledge about the spatial layout of the sector and its characteristics.

5. Procedures -- contains knowledge about the general procedures for separating aircraft and for handling different kinds of situations.

The first three panels contain information relating to the situation in a specific sector at a particular time, while the last two contain background knowledge. The background knowledge is relatively stable, and the situation-specific panels are relatively dynamic. The Sector Management panel is the primary panel used for prioritization decision-making, since it represents the understanding of the events that must be dealt with. However, determining how to deal with each event involves reference to the data on the Sector Data panel and the Conditions panel, and other events on the Sector Management panel, as well as knowledge of standard procedures from the Procedures panel. The events are also interpreted with reference to the static spatial representation of the sector airspace (embodied on the Sector Airspace panel).

In the remainder of this section we discuss the individual panels of the blackboard and their constituent levels in more detail.

3.1.2 Sector Management Panel

The Sector Management panel is divided into seven hierarchical levels, as follows:

1. Approaching aircraft -- includes aircraft that are entering the sector and require accepting handoff from adjacent sector or approach control.

2. Accepted aircraft -- includes aircraft that are now under sector control but have not yet been classified into any other events.

3. Conflictions -- includes events that if not dealt with will result in conflictions (separation violations, etc.).

4. On-going Events -- includes events that must be dealt with over a period of time, such as sequencing aircraft for arrival.

5. Future Events -- includes events that must be dealt with at some future time (e.g., an aircraft has been vectored around weather and must be vectored back on course when past the weather, or an aircraft that has been kept at a lower altitude than desired to avoid traffic above and can be cleared higher after the traffic has passed).

6. Background -- includes aircraft that are clear over the expected route through the sector, and will only require handoff.

7. Hand-Off Accomplished -- includes aircraft that have been handed off but are still within radar contact and shown on the PVD.

The data elements on this panel are events with various modifying parameters, represented as:

Event Name [aircraft involved], [criticality of event], [time window]

where 'criticality of event' is a rating of the consequences of not dealing with it, as follows:

1. separation violation
2. procedural violation (e.g., not following LOA for hand-off)
3. efficiency for pilot and aircraft route of flight
4. efficiency for controller workload

and 'time window' refers to the time within which the event must be dealt with to avoid the consequences.

The criticality field depicts information that contributes to the prioritization of tasks.

3.1.3 Sector Data Panel

This panel of the blackboard contains the following levels:

1. PVD Data -- information about each aircraft, location of aircraft, some weather systems, limited route, approach, and departure location

2. Flight Strip Data -- information about filed flight plan about each aircraft.

3. Weather -- any noteworthy weather information such as wind speed, temperature, zones of turbulence and/or precipitation, barometric pressure.

4. Special Short-term Conditions -- Unusual, temporary local conditions, for example, a closed runway at an airport due to weather conditions.

5. Requests -- requests from pilots or other sector controllers for clearance, pointouts, handoffs, etc.

6. Route Type -- individual aircraft assembled according to arrival to or departure from airports within the sector, overflights over the sector.

7. Altitude Partitions -- designates aircraft flying at a given stratum of altitude.

In general, the knowledge contained on this panel refers to dynamic factors of situations occurring within the sector airspace, including the location and movement patterns of the individual aircraft, weather, and short-term special conditions.

The first two levels of this panel contain information about the aircraft that can be reviewed from the PVD screen or the hard copy flight strips. Thus, controllers can access this data from some physical location without needing to remember or compute it. The remaining levels on this panel refer to information that is not necessarily available for reference in "hard" copy. Thus, this information must be remembered by the controller.

The data elements on this panel are data types (corresponding to the level in the hierarchy) with various modifying parameters, represented as:

> Data Type, [specific altitude range, aircraft ID/characteristics, weather system, request type, route type and specificiations, special local condition, etc.] [time window].

The Request level of this panel is a critical level on the blackboard. At this level many new requests function as triggers to activate tasks. Thus, entries made at this level will shift attention from one task to another when the resulting blackboard pattern constitutes a triggering condition with a higher priority than the current task (due to the new posted request).

3.1.4 Conditions Panel

The Condition panel contains the following five levels:

1. Affective Factors -- includes factors such as the individual controller's perception of his or her self, and relations and interactions with coworkers and pilots.

2. Weather Factors -- a subjective assessment of the current weather conditions

3. Screen Readability -- a characterization of the level of screen clutter such as .

4. Traffic Level -- a characterization of the current overall level of traffic, eg., sparse, moderate, or heavy traffic.

5. Overall Condition -- a summation of the overall workload as a function of conditions posted on other four levels of this panel.

In general, this panel reflects stress factors that influence controller workload. Affective factors are posted on the blackboard because they can influence stress and workload by influencing the decisions a controller makes in terms of asking supervisors and other sector controllers for help of favors, perceiving the situation as out of control, etc. The remaining three levels of this panel post general characterizations of weather, PVD screen appearance, and traffic level made by individual controllers about the current situation.

Because these characterizations are subjective assessments, they capture individual differences in the way a particular controller might react to these aspects of the current situation.

The entries posted on this panel of the blackboard are the condition type followed by modifying parameters:

Condition Type [specific element of condition], [characterization]

Specfic element of condition is an optional parameter. Characterizations in themselves depict the criticality of a condition and thus contribute to the priority of the events in the current situation.

3.1.5 Sector Airspace Panel

The Sector Airspace Panel captures knowledge about the three dimensional space of a particular sector in terms of man-made and ATC constructs and natural features. The levels of knowledge within this panel are:

1. Geography

2. Topography

3. Restricted Areas

4. Enroute Structure

5. Published Arrivals, Departures, Approaches

ATC constructs refer to published arrivals, departures, and approaches, enroute structures, and restricted areas. These elements represent the principal locations for movement of aircraft in a manner similar to a highway on the ground. Thus, they are a primary component of the controller's internal model of the physical characteristics of the sector airspace.

Natural features include the geography of the region and topographic features such as mountains and towers. Man-made entities include airports, NAVAID equipment, and runways.

In reality, this knowledge would be represented by a three-dimensional model of the sector airspace, reflecting its inherently spatial characteristics. An alphanumeric version of this information would post a data type corresponding to the blackboard level, followed by a descriptive string for each feature of interest to be represented on the blackboard. Thus, each entry would be of the form:

Data Type [descriptive string].

3.1.6 Procedures Panel

On the Procedure Panel reside two classes of procedural knowledge for Enroute ATC. The two levels on the panel are ATC Procedures and Sector-specific Procedures.

Specifically, ATC procedures are the rules that apply radar controllers nationwide, while Sector-specific procedures refer to the rules that govern a given sector. These procedures in essence create the boundaries which constrain and define the actions of the air traffic controller. These rules form background knowledge to guide actions taken by controllers in response to the current situation captured in the Sector Management, Sector Data and Conditions panels of the blackboard.

ATC Procedures are delineated in the FAA Handbook 7110.65F. This document includes the rules that govern radar control and give "global" guidance for the adminstration of all airspaces within the jurisdiction of the FAA.

Sector-specific procedures are embodied in procedural Letters of Agreement (LOAs). These are used to document cooperative or concurrent agreeements between facilities.

The information on these panels is posted in the form:

Procedure Class [rule]

where the rule is an individual procedure.

3.2 Task Decomposition

The COGNET model of enroute air traffic control contains ten high level tasks. A task is defined as a single unit of goal-directed behavior that will execute to completion if uninterrupted. Thus, each task encapsulates a logically self-contained set of subgoals that describe the steps taken to attain the overall task goal. A given task captures attention based on the current contents of the five blackboard panels described above. For example, the nearly simultaneous appearance of three airplanes heading for landing at a common airport will post messages to the sector management, sector data, and conditions panel of the board. This configuration of aircraft and their route requirements will involve a sequencing for landing task. This task will most likely dominate information processing resources until its resolution since it is of a high priority and time critical.

The ten tasks are listed and briefly described immediately below.

1. Monitor Situation -- obtain information about current situation and evaluate it to determine events that must be dealt with

2. Accept Handoff or Pointout -- assess and accept or decline a handoff or pointout from a transferring controller.

3. Sequence Aircraft for Arrival -- steps taken to sequence a group of aircraft for arrival.

4. Resolve Aircraft Conflict -- determining potential conflictions and implementing means to avoid them.

5. Route Aircraft (per clearances from pilot or other controllers) -- responding to requests for routing, etc.

6. Manage Departures -- responding to departure clearance requests.

7. Refine Situation Understanding -- obtaining information to resolve inconsistencies between perceived aircraft data and current situation understanding.

8. Issue Advisory -- initiate information update to pilot or other controller.

9. Handoff Aircraft -- initiate and complete handoff (or pointout) of aircraft to receiving controller.

10. Maintain PVD Readability -- maintaining clarity and accuracy of current situation as captured on the PVD screen in terms of data blocks displayed.

Some of these tasks will be suspecded pending information of will call other tasks and then return control to the calling tasks. This aspect of a full COGNET model is not captured in the following task models, and could be included with additional effort.

3.3 Task Models

Each of the ten high-level tasks listed above describe a single goal. Each task is composed of subgoals that capture the steps needed to a attain this goal. Also, a task becomes active because it is triggered by the appearance of certain patterns of information on the blackboard panels. Below the subgoals and triggers are listed for each of the ten goals.

1. MONITOR SITUATION

Trigger: absence of high priority task OR awareness of x time period elapsed since last screen scan

Subgoals:

Observe aircraft data

Project aircraft routes

Compare with current sector situation understanding

2. ACCEPT HANDOFF OR POINTOUT

Trigger: aircraft flashing on PVD AND NOT in middle of critical task OR pointout from other traffic controller

Subgoals:

Evaluate request

Accept or deny pointout IF pointout

Accept or delay handoff IF handoff

Establish radio contact IF handoff accepted

3. SEQUENCE AIRCRAFT FOR ARRIVAL

Trigger: Two or more aircraft converging on one airport for landing within x span of time AND NOT all spaced and sequenced for arrival

Subgoals:

Evaluate aircraft routes and timing

Determine sequence for landing

Derive/revise plan for sequencing/slowing/descending aircraft

Implement plan for sequencing/slowing/descending aircraft

Monitor plan execution

4. RESOLVE AIRCRAFT CONFLICT

Trigger: Two or more aircraft at same altitude OR converging on same lat/long/altitude

Subgoals:

Evaluate route, goals and characteristics of aircraft

Determine plan

Issue clearances

5. ROUTE AIRCRAFT

Trigger: clearance request from pilot or adjacent controller OR weather in flight path OR prohibited area in flight path

Subgoals:

Evaluate route

Issue or deny clearance

Update data block and flight strip IF clearance issued

6. MANAGE DEPARTURES

Trigger: departure clearance request from tower flight controller OR departures expected within x time span AND adverse conditions within airport locale

Subgoals:

Assess potential confliction with current and projected sector traffic

Issue clearance IF NO confliction

Postpone departure IF confliction

Restrict future departures IF adverse conditions(weather, workload, level of traffic)

7. REFINE SITUATION UNDERSTANDING

Trigger: possible discrepancy between displayed versus real altitude, heading, speed, PVD information, and issued altitude, heading, speed

Subgoals:

Query pilot about data item

Update PVD or flight strip IF data incorrect or incomplete

8. ISSUE ADVISORY

Trigger: other aircraft traffic within x range of another aircraft OR weather system at y location

Subgoals:

Alert Pilot of situation

9. HANDOFF/POINTOUT AIRCRAFT

Trigger: Aircraft nearing edge of sector (distance or time from boundary--distance can be greater when no traffic in route)

Subgoals:

Issue pointout IF aircraft will go through small amount of third sector AND no other aircraft are or will be in that portion of third sector

Initiate H/O to receiving controller

Coordinate with receiving controller IF coordination necessary

Confirm H/O acceptance from receiving controller

Issue new radio frequency to pilot WHEN receiving sector accepts handoff

Drop data block

10. MAINTAIN PVD READABILITY

Trigger: 2 overlapping data blocks OR when project flight paths, there will be overlapping data blocks in the near future

Subgoals:

Anticipate OR see overlapping data blocks

Move data blocks UNTIL data blocks clear

3.4 Perceptual Demons

Perception of visual and auditory events constitute the perceptual demons that cause information to be posted to the blackboard. A full COGNET model would identify each type of information perceived and what message would be written to what panel and level of the blackboard. In this limited analysis, we are describing the types of perceptual information that would be included and the general areas of the blackboard where the information would be posted.

Perceptual demons would include visual events, such as seeing changes in the PVD and reading the flight strips; and auditory events, such as conversations with pilots, adjacent controllers, and other airspace and facility oweners. Perceptual demons would write to the Approaching Aircraft level of the Sector Management blackboard panel when a data block was flashing. Also perceptual demons would write to the PVD Data, Flight Strip Data, Weather, Special Conditions, and Requests levels of the Sector Data blackboard panel, as appropriate. Also, perceptual demon would post a message regarding overlapping data blocks on the Screen Readibility level of the Conditions panel of the blackboard.

An example of how perceptual information enters the global problem representation and triggers tasks follows. When a controller sees a flashing data block on the perimeter of the sector, a message is posted to the Approaching Aircraft level of the Sector Management panel of the blackboard about an approaching aircraft. If no other tasks were active, this information would initiate the Accept Handoff task. The completion of the task would result in information about that aircraft being posted to appropriate locations regarding, for example, its route and altitude. As messages are posted to the various levels in the blackboard panels the contents of the blackboard will trigger tasks sensitive to these message configurations. As tasks proceed, cognitive operations transform information on one level of the panel to another level of the same panel or to a different panel.

4. Implications for Training

The COGNET blackboard can be thought of as a controller's mental model for air traffic control. As such, it could be used as a framework for structuring training. The mental model does not explicitly contain any strategies for handling events; rather, it provides the framework for classifying aircraft and situation data into patterns of events, and for learning strategies to deal with those events.

The Sector Manageament panel characterizes categories of events that the controller must handle. Strategies for dealing with events can be grouped into those that deal with the whole category and those that are specific to the actual event. The Sector Data panel included five levels of basic data derived from various sources, and the top two levels are derived from the basic data. The categorization of flights into route type (overflights, arrivals, and departures) seems to be a basic information management technique controllers use. Also, since altitude is a major method of separating aircraft, teaching controllers to view the aircraft in the sector in their altitude partitions seems useful. The Conditions panel provides a mechanism for determining when the usual strategies should be modified. Sector-specific information is partitioned into one blackboard panel (Sector Airspace) and one level of another (the Procedures panel: Sector-specific Procedures level). This effectively segregates the part of the mental model that changes with re-assignment to a new sector. Also, the Sector Airspace panel could be represented as a spatial model on a computer-based trainer and the various types of information (represented as levels) color-coded. The airspace could be viewed as some kind of 3-D model, or projected onto a 2-D plane which could be rotated to different views. Using this spatial representation, different categories of sector data or sector events could be superimposed on the airspace model. The use of animation and/or simulation could incorporate events over time in the representation.

Given the above blackboard and task structures, a model of ATC enroute control actions can be incorporated into a computer-based decision aiding system. Such a system can anticipate and suggest subgoals to the controller during tasks and aid the controller in keeping track of unfinished or next priority tasks when more critical tasks capture attention. CHI Systems has built such a decision-aiding system using COGNET components for a Navy application. Based on that work, an architecture was developed for building future decision aiding systems from a COGNET analysis.

Also, COGNET models can support individual differences between controllers. Thus, the model of controllers can be used tc support controllers of graduated levels of experience, e.g., novice versus expert controllers, and along the lines of intelligent tutoring, support the acquisition of more expert strategies in novice controller through suggestions for actions based on the current situation context.

Within the GOMS framework, methods describe the operators that are used to meet subgoals. Expansion of the current COGNET analysis of the enroute ATC would describe strategies for dealing with events via methods.

Sector Management

- Hand Off Accomplished
- Background
- Future Events
- On-going Events
- Conflictions
- Accepted Aircraft
- Approaching Aircraft

Sector Data

- Altitude Partitions
- Route Type
- Requests
- Special Conditions
- Weather
- Flight Strip Data
- PVD Data

Conditions

- Overall Condition
- Traffic Level
- Screen Readability
- Weather Factors
- Affective Factors

Sector Airspace

- Published Arrivals, Departures, Approaches
- Enroute Structure
- Restricted Areas
- Topography
- Geography

Procedures

- ATC Procedures
- Sector-specific Procedures

Figure 1. En Route ATC Blackboard Structure

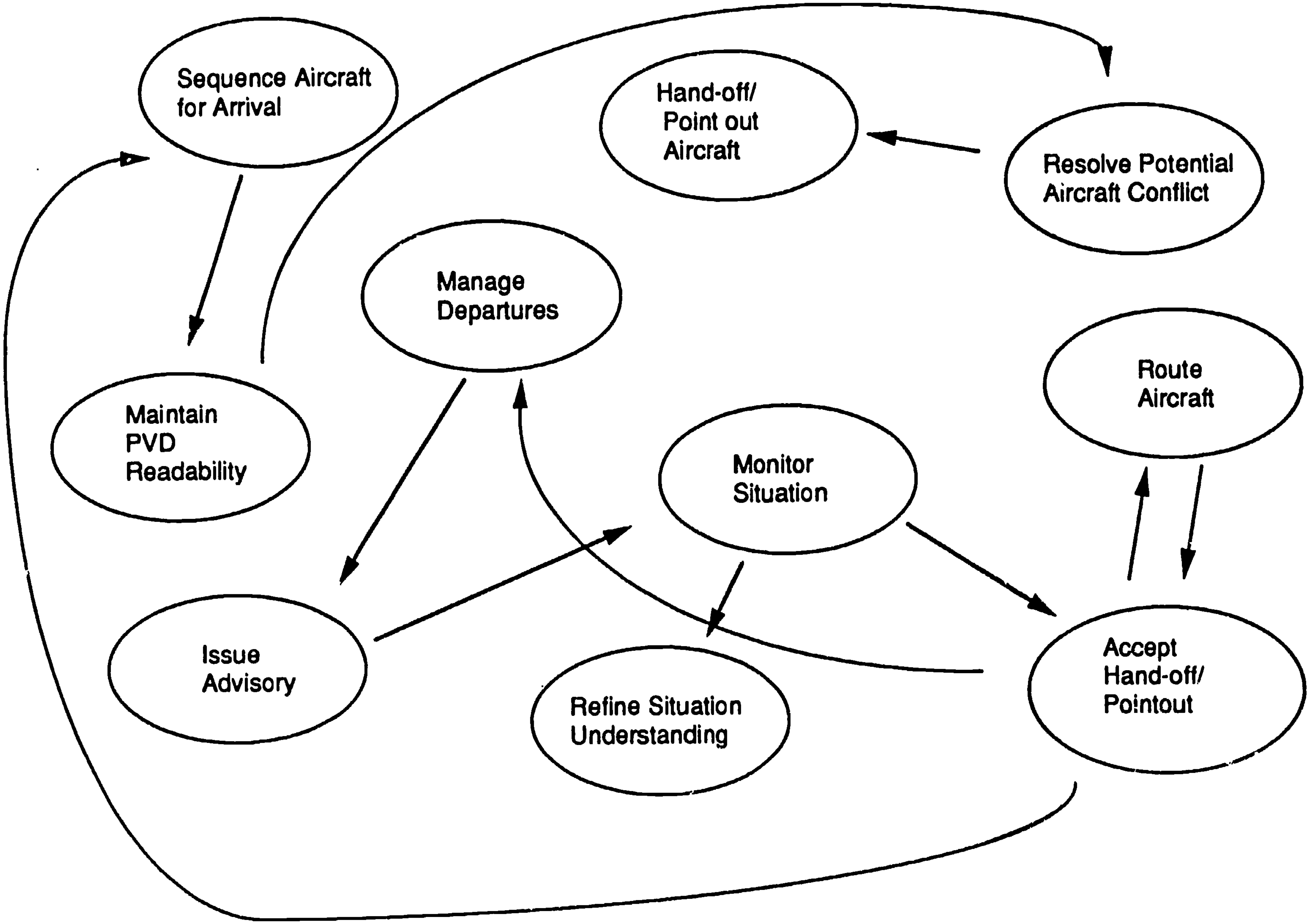


Figure 2. Nodes in the Task network with example flow of attention between nodes.

APPENDIX H:

PRODUCTIONS FROM ANALYSIS OF DYSIM STRUCTURED PROBLEM SOLVING: EXPERT GROUP

Acronyms:

AAL	American Airlines
AWE	America West Airlines
COA	Continental Airlines
DAL	Delta Airlines
IAF	Initial Approach Fix
IFR	Instrument Fight Rules
ILS	Instrument Landing System
KS	Kansas City
MIO	Miami
MIO-A	Ascending from Miami
MIO-D	Descending to Miami
MLC	McAlister
MLC-A	Ascending from McAlister
MLC-D	Descending to McAlister
NL	Life Guard
NWA	Northwest Airlines
PVD	Plan View Display
SPS	Structured Problem Solving
TUL	Tulsa
TUL-A	Ascending from Tulsa
TUL-D	Descending to Tulsa
TWA	Trans World Airlines
UAL	United Airlines
VFR	Visual Flight Rules
VOR	Very High Frequency Omnidirectional Range Station
VORTAC	VHF Omnidirectional Range/ Tactical Air Navigation

Selective Protocol Analysis for A04, SPS 1A

Table 4.1A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N8677L	MO22	140	180	110	D-MIO
N345AP	PAZT	252	190	120	D-MIO
A49616	LR35	039	420	150	D-MLC
R16391	C12	085	210	110	D-MLC
N292BC	G2	?	?	?	D-MLC

Selective Notations from 5 Minute Freeze

Lots of inbouds to MLC. One at 11,000...

Selective Notations from 5-10 Minute Sequence

8:06 A49616: Starting A616 down for approach. He is close in and need to get him down below 15,000.

PRODUCTION

IF a high performance aircraft is inbound to VFR tower airport
AND and he is within 50 miles of the airport
AND there is no immediate traffic

THEN descend him to lowest safe altitude
AND monitor to clear to approach

9:09 N128E, N345AP, & N8677L: 128E depart MIO and climbing. Have two inbouds, and will get 128E out of the way shortly.

PRODUCTION

IF ascending twin AC from uncontrolled airport
AND there are several inbounds
AND ascending will be clear of inbounds shortly

THEN monitor ascending aircraft for separation

9:34 N128E and N345AP: Going to stop 128E at 8,000 so I can descend 5AP to 9,000.

PRODUCTION

IF ascending twin AC is not clear of traffic from uncontrolled airport
AND there are several inbounds
AND inbounds need to be descended

THEN assign ascending AC and intermediate altitude
AND assign first inbound intermediate altitude above ascending AC altitude

9.45 N345AP and N8677L: Got to get 5AP underneath 77L because he should be first.

PRODUCTION

IF there are several inbounds to uncontrolled airport
AND the twin inbound who is number 1 is above the single inbound

THEN clear twin inbound to descend below the single inbound

10:08 TWA65: Got one out of Tulsa climbing to 10,000. No traffic, no problem.

PRODUCTION

IF air carrier departs from approach controlled airport
AND there are no current outbounds
AND altitude is within handoff limits
AND no coordination required from airport controller

THEN accept handoff
AND climb on initial contact to available altitude

Table 4.1B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N345AP	PAZT	253	190	115	D-MIO
R16391	C12	085	210	110	D-MLC
N292BC	G?	272	420	220	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	210	24	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	292	259	30	A-TUL
TWA67	DC10	000	0	0	A-TUL

Selective Notations from 10 Minute Freeze

N345AP and N3688U: 5AP started into MIO. Going to let 5AP shoot approach before letting 88U out of MIO.

N292BC and R16391: 2BC inbound to MLC. Got to get him started down. ARMY also inbound. Probably have him go into a hold. 2BC, start him down underneath ARMY.

Selective Notations from 10-15 Minute Sequence

11:05 TWA65 and TWA67: Another Tulsa departure. TWA67 is a DC10, going to be a problem behind A300. Use speed to separate until they split off.

PRODUCTION

IF air carrier departs from approach controlled airport
AND there is a potentially slower air carrier recently departed on same route
AND there is a possibility of an overtake

THEN monitor spacing
AND consider using speed until they split off

12:03 TWA65 and TWA67: Started TWA67 to 11,000 because they are a little close.

PRODUCTION

IF air carrier departs from approach controlled airport
AND there is a potentially slower air carrier recently departed on same route
AND there is a possibility of an overtake

THEN assign intermediate altitude to last departure below first departure
AND monitor spacing

13:16 N8677L and N345AP: Cleared 77L to hold because there are 2 inbounds into MIO.

PRODUCTION

IF there are several inbounds to uncontrolled airport
AND the number 2 inbound is within 10-15 miles of the VOR
AND the number 1 inbound has not landed

THEN clear number 2 inbound to hold
AND monitor landing of number 1 inbound

Table 4.1C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
R16391	C12	085	210	110	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	210	80	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	067	419	170	A-TUL
TWA67	DC10	068	439	110	A-TUL

Selective Notations from 15 Minute Freeze

TWA65: TWA65 started up. If I don't get him handed off to my high, I will have to do coordination which takes more time.

TWA67: Get him climbing

N128E: Climbing

Selective Notations from 15-20 Minute Sequence

15:32 TWA65 and TWA67: Got TWA65 started up. Hand him off. TWA67 can now go up.

PRODUCTION

IF there are two ascending air carriers in trail
AND the lead air carrier is clear to the high side
AND the trailing air carries was held at intermediate altitude

THEN initiate handoff on lead air carrier
AND clear trailing air carrier to ascend

18:47 VM6E22 and N413F: E22 at 18,000 and 13F at 17,000, traffic. They are 1,000 feet apart. Any time they have 1,000 or less, must issue traffic.

PRODUCTION

IF there are two aircraft within 1,000 feet vertical separation
AND the two aircraft are in the same proximity
AND there are no other higher priority considerations

THEN issue traffic advisory

Selective Protocol Analysis for A06, SPS 1A

Table 6.1A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N8677L	MO22	140	180	110	D-MIO
N345AP	PAZT	252	190	120	D-MIO
A49616	LR35	039	420	150	D-MLC
A49616	C12	085	210	110	D-MLC
N292BC	G2	?	?	?	D-MLC

Selective Notations from 5 Minute Freeze

Using arrows on strips, a better visual representation of where they are going.

A49616 and A49616: Both inbound to MLC. At this point A616 is number 1, and ARMY is number 2.

N345AP and N8677L: 5AP and 77L, have to make a choice. Make 5AP number 1 and put him under 77L.

N128E and N345AP: 128E departing and heading East. Stop him at lower altitude and stop 5AP on altitude above him and wait till they pass.

FIRST: Start A616 down. He is in my airspace and is number 1.

Selective Notations from 5-10 Minute Sequence

7:11 A49616: A616, start him down to 3,000.

PRODUCTION

IF a high performance aircraft is inbound to VFR tower airport
AND and he is within 10-15 miles of the airport
AND there is no immediate traffic

THEN descend him to lowest safe altitude
AND monitor to clear to approach

7:57 N128E: 128E, give him 3,000, a MIO departure.

PRODUCTION

IF twin AC requests departure from an uncontrolled airport
AND there are several inbounds not ready to land
AND there are no previous departures to consider

THEN issue clearance for departure
AND assign altitude below that of inbounds

8:20 N128E and N345AP: Starting a sequence on 5AP to get him down. Got to get him down through 128E.

PRODUCTION

IF ascending twin AC is not clear of traffic from uncontrolled airport
AND there is an inbound
AND inbound needs to be descended

THEN assign descending AC and intermediate altitude
AND monitor separation

8:45 A49616: A616 cancelled IFR. I can get rid of him.

PRODUCTION

IF a high performance aircraft is inbound to VFR tower airport
AND he has cancelled IFR
AND there is no immediate traffic

THEN drop track

9:35 N128E and N345AP: 128E and 5AP should not be any problem. I could readjust, but I am not going to worry about it. 128E is a little guy, not high performance.

PRODUCTION

IF ascending twin AC is not clear of traffic from uncontrolled airport
AND there is an inbound
AND inbound needs to be descended

THEN monitor separation

Table 6.1B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N345AP	PAZT	253	190	97	D MIO
R16391	C12	085	210	110	D-MLC
N292BC	G2	272	420	220	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	210	24	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	293	259	30	A-TUL
TWA67	DC10	000	[illegible]	0	A-TUL

Selective Notations from 10 Minute Freeze

I see TWA65, a BOLD1 departure coming up.

N128E and N345AP: I 128E wanted to go higher, I could stop 5AP at 5,000 or 6,000, because I don't have to get 5AP down right away.

N345AP and N8677L: 77L is not much of a factor because I will have to hold him. Main thing is to get 5AP under 77L into MIO.

TWA65 and VM6E22: No problem with E22 at 18,000 yet. Will climb TWA65 to 17,000 and watch. May clear him off BOLD1 and vector him direct.

N292BC: 2BC is faster, will probably descend to 3,000.

FIRST: Handoff on TWA65, then start 2BC down.

Selective Notations from 10-15 Minute Sequence

10:45 N3688U and N128E: Leave 88U on the ground since 128E is at 3,000.

PRODUCTION

IF there is a request for take-off from uncontrolled airport
AND there is an ascending twin AC from same airport
AND there are several inbounds

THEN deny request

11:36 N128E and N345AP: Vector 128E to the right to get him around 5AP.

PRODUCTION

IF ascending twin AC is not clear of traffic from uncontrolled airport
AND there are several inbounds
AND ascending AC is headed for one of the inbounds

THEN vector ascending AC for traffic
AND monitor to vector for re-routing

12:00 TWA65 and TWA67: TWA67 is also on BOLD1. May be a little faster. I'll watch that.

PRODUCTION

IF air carrier departs from approach controlled airport
AND there is a potentially slower air carrier recently departed on same route
AND tnere is a possibility of an overtake

THEN monitor spacing

13:00 TWA65 and TWA67: In case TWA67 is faster than TWA65, I will leave TWA67 on routing and vector TWA65 to Fort Smith.

PRODUCTION

IF air carrier departs from approach controlled airport
AND there is a potentially slower air carrier recently departed on same route
AND there is a possibility of an overtake

THEN vector one of the air carriers for spacing and re-routing

14:49 N345AP and N8677L: Can only get one guy into MIO at a time. I will hold 77L.

PRODUCTION

IF there are several inbounds to uncontrolled airport
AND the number 2 inbound is within 10-15 miles of the VOR
AND the number 1 inbound has not landed

THEN clear number 2 inbound to hold
AND monitor landing of number 1 inbound

Table 6.1C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
R16391	C12	085	210	110	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	107	210	30	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	090	419	165	A-TUL
TWA67	DC10	067	440	135	A-TUL

Selective Notations from 15 Minute Freeze

N8677L: Give him descent and holding at the same time. Saves time.

N3688U: 88U is still on the ground. Probably could have gotten him off.

TWA65 and VM6E22: Turned TWA65 direct to Fort Smith. He is clear of E22 in another minute. Will then climb him to 23,000.

FIRST: Turn 128E to get him back on airway.

Selective Notations from 15-20 Minute Sequence

15:45 TWA65 and VM6E22: TWA65 clear of E22, climb him to 23,000.

PRODUCTION

IF there are two ascending air carriers in trail
AND there is a high performance craft at an intermediate altitude
AND the lead ascending air carrier is clear of the high performance craft

THEN clear lead ascending air carrier to ascend

18:06 N413F and VM6E22: 13F asking for higher altitude. Could not do, has traffic in his face.

PRODUCTION

IF there are two aircraft within 1,000 feet vertical separation
AND the two aircraft are in potential conflict
AND the lower aircraft requests to ascend

THEN deny request
AND monitor for separation

Selective Protocol Analysis for A10, SPS 1A

Table 10.1A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N8677L	MO22	140	180	110	D-MIO
N345AP	PAZT	252	190	120	D-MIO
A49616	LR35	039	420	150	D-MLC
R16391	C12	085	210	110	D-MLC
N292BC	G2	?	?	?	D-MLC

Selective Notations from 5 Minute Freeze

A49616 and R16391: Handoff of A616 making the VOR approach, and handoff on ARMY. He is quite a bit away. A616 is a jet so he is out in front of ARMY.

Handoff on 5AP going into MIO.

FIRST: Call MLC on A616 approval

Selective Notations from 5-10 Minute Sequence

6:12 N8677L and N345AP: Who is number 1 on the MIO approach. I will make 5AP number 1.

PRODUCTION

IF there are two inbounds to uncontrolled airport
AND one is a single and the other is a twin aircraft
AND they are approximately the same distance from the airport

THEN make the twin aircraft number 1

7:34 N345AP: 5AP descend to 7,000

PRODUCTION

IF there are two inbounds to uncontrolled airport
AND you have decided who will be number 1 to descent
AND there is no other immediate traffic

THEN clear number 1 to descend to an intermediate altitude

8:08 N345AP and N128E: Have to vector 128E when I get him East to clear 5AP so I can keep 5AP down and keep 128E going up.

PRODUCTION

IF ascending twin AC is not clear of traffic from uncontrolled airport
AND there are several inbounds
AND there is a potential conflict
AND inbounds need to be descended

THEN vector ascending aircraft
AND monitor for separation

Table 10.1B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N345AP	PAZT	253	190	90	D-MIO
R16391	C12	085	210	110	D-MLC
N292BC	G2	272	420	216	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	210	38	A-MIO
N3688U	BE33	171	21	2	A-MIO
TWA65	A300	281	259	28	A-TUL
TWA67	DC10	303	25	7	A-TUL

Selective Notations from 10 Minute Freeze

N345AP and N128E: Turn 128E South to get him going, and get 5AP going down.

N292BC and A49616: 2BC clear to 5,000 going in after A616. Get 2BC below ARMY. Everyone is separated by altitude.

N8677L and N3688U: Start 77L sown to 8,000 and 88U up to 6,000 going Westbound.

FIRST: Put the J-all on 128E.

Selective Notations from 10-15 Minute Sequence

10:59 N345AP and N128E: 5AP vector North and descend to 4,000. 128E climb to 15,000.

PRODUCTION

IF ascending twin AC is not clear of traffic from uncontrolled airport
AND there are several inbounds
AND there is a potential conflict
AND inbounds need to be descended

THEN vector descending AC for traffic
AND clear vectored AC to descend
AND clear ascending AC to ascend

11:42 TWA65 and VM6E22: TWA going to 17,000 toward E22 at 18,000.

PRODUCTION

IF there are two ascending air carriers in trail
AND there is a high performance craft at an intermediate altitude
AND the lead ascending air carrier is in potential conflict with high performance craft

THEN monitor for separation

14:30 TWA65: Put J-Ball on 65 to see when I can go up with him.

PRODUCTION

IF there are two ascending air carriers in trail
AND there is a high performance craft at an intermediate altitude
AND the lead ascending air carrier is in potential conflict with high performance craft

THEN monitor ascending aircraft for separation
AND monitor to clear to ascend

Table 10.1C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
R16391	C12	085	210	110	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	085	210	106	A-MIO
N3688U	BE33	273	144	50	A-MIO
TWA65	A300	091	420	170	A-TUL
TWA67	DC10	043	440	131	A-TUL

Selective Notations from 15 Minute Freeze

N8677L and N3688U: Got to get 77L down to 7,000, clear to hold. Keep 88U going up.

N292BC and R16391: 2BC clear to hold at MLC and ARMY.

TWA65, TWA67, and N128E: Climb TWA67 and TWA67 and make sure that TWA67 tops 128E. So climb him first.

Selective Notations from 15-20 Minute Sequence

15:12 TWA67, VM6E22, and N128E: TWA67 was not clear of E22. I was concentrating too much on 128E, but caught myself. Gave TWA67 17,000 instead of 20,000.

PRODUCTION

IF there are two ascending air carriers in trail
AND there is a high performance craft at an intermediate altitude
AND the trailing ascending air carrier is in potential conflict with high performance craft
AND it is time to ascend that trailing air carrier

THEN assign the trailing air carrier an intermediate altitude below the high performance plane
AND monitor to clear to ascend

15:50 TWA67 and TWA65: Handing both to high side.

PRODUCTION

IF there are two ascending air carriers in trail
AND they have good spacing
AND there is no immediate traffic

THEN initiate handoff

19:18 N413F and VM6E22: 13F clear of his traffic (E22) and get him up to 19,000.

PRODUCTION

IF there are two aircraft within 1,000 feet vertical separation
AND the two aircraft are no longer in potential conflict
AND the lower aircraft requests to ascend

THEN clear to ascend

Selective Protocol Analysis for A11, SPS 1A

Table 11.1A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N8677L	MO22	140	180	110	D-MIO
N345AP	PAZT	252	190	120	D-MIO
A49616	LR35	039	420	150	D-MLC
R16391	C12	085	210	110	D-MLC
N292BC	G2	?	?	?	D-MLC

Selective Notations from 5 Minute Freeze

A49616 and R16391: A616 and ARMY landing at MLC. If the ARMY is that slow, should take him some time.

FIRST: Lower A616 into MLC and 5AP into MIO.

Selective Notations from 5-10 Minute Sequence

7:52 N128E: Gave clearance to 128E.

PRODUCTION

IF twin AC requests departure from an uncontrolled airport
AND there are several inbounds not ready to land
AND there are no previous departures to consider

THEN issue clearance for departure
AND assign altitude below that of inbounds

9:07 N128E: Coming off his climb to 15,000, keep him heading South. No problem.

PRODUCTION

IF ascending twin AC is clear of traffic
AND there are several inbounds
AND ascending AC can be vectored away from inbounds
AND vector can expedite situation

THEN assign requested altitude
AND vector for traffic (away from inbounds)
AND monitor to vector back on course

Table 11.1B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N345AP	PAZT	253	190	94	D-MIO
R16391	C12	085	210	110	D-MLC
N292BC	G2	272	420	167	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	226	38	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	282	248	26	A-TUL
TWA67	DC10	302	26	7	A-TUL

Selective Notations from 10 Minute Freeze

A49616 and N292BC: A616 going VFR changes picture because he is out of the way. We can go down to 2200 with 2BC.

N128E and N345AP: 128E is not maintaining the South heading I gave him. Have to watch. If he were to hold South 180, I could get 5AP in under him and then put 28E back on course. We can work that out.

N3688U and N345AP: If 88U gets out now, he will be in the way of 4AP. So let him sit on the ground.

N292BC and R16391: 2BC has speed. He will be there a long time before ARMY.

N8677L: Give 77L holding instructions. He is 10 miles out, so it will be a couple of minutes.

N8677L and N345AP: 5AP first, and 77L second.

FIRST: Vector both 128E and 5AP.

Selective Notations from 10-15 Minute Sequence

10:37 TWA65: TWA65 departure. Only going to 11,000. No problem.

PRODUCTION

IF air carrier departs from approach controlled airport
AND there are no current outbounds
AND altitude is within handoff limits
AND no coordination required from airport controller

THEN accept handoff
AND climb on initial contact to available altitude

11:41 N128E, N345AP, and N8677L: Have 128E and 5AP separation. Can descend 5AP and take 77L down to 6,000.

PRODUCTION

IF two single-engine aircraft are holding
AND there is separation with outbound aircraft
AND single # 1 is first and single #2 is second
AND no other traffic

THEN clear single #1 for approach
AND assign descending altitude to single #2 above #1

12:38 TWA67 and TWA65: Another departure, TWA67, off of Tulsa. Looks like no problem.

PRODUCTION

IF air carrier departs from approach controlled airport
AND there is another air carrier recently departed on same route
AND altitude is within handoff limits

THEN accept handoff
AND monitor spacing

13:12 TWA67: TWA67 requesting vector to Springfield. No problem, you get him out of 11,000 and he is in your airspace. You can do anything you want.

PRODUCTION

IF air carrier departs from approach controlled airport
AND air carrier has requested vector to his destination
AND your have control of that carrier
AND the requested vector is clear

THEN vector for re-routing

14:30 TWA65, TWA67 and VM6E22: Watching TWA65 and 67 getting clear of VM6E22.

PRODUCTION

IF there are two ascending air carriers in trail
AND there is a high performance craft at an intermediate altitude
AND you want to ascend the air carriers above the high performance craft

THEN monitor separation
AND formulate backup plan

Table 11.1C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
R16391	C12	085	210	99	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	084	255	106	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	067	419	170	A-TUL
TWA67	DC10	049	455	137	A-TUL

Selective Notations from 15 Minute Freeze

TWA65, TWA67 and VM6E22: TWA65 clear of E22 and can go to 23,000. TWA67 route him direct to Springfield.

R16391: Army on the way to 4,000. Get ready to make approach.

FIRST: Get TWA65 climbing and get the route on TWA67.

Selective Notations from 15-20 Minute Sequence

16:11 TWA65 and TWA67: Got route separation on these 2. High altitude should be no problem.

PRODUCTION

IF there are two ascending air carriers in trail
AND they have good route separation
AND there is no immediate traffic

THEN initiate handoff

16:50 TWA65 and TWA67: Make sure they don't enter another low altitude sector's airspace. If they are not at 24,000 when they hit boundary, they will have to be pointed out.

PRODUCTION

IF there are two ascending air carriers in trail
AND you have not issued frequency change
AND they are nearing the sector boundary

THEN monitor for altitude
AND assign altitude-ascending
AND monitor to issue pointout

17:23 R16391: ARMY descending to 4,000. Should be no delay, so he should be able to head on in.

PRODUCTION

IF a single-engine is inbound
AND and he is within 10 to 15 miles of the VFR tower airport
AND there is no other traffic

THEN descend him to lowest safe altitude
AND clear to approach

18:15 TWA65 and TWA67: Both TWAs gone.

PRODUCTION

IF there are two ascending air carriers in trail
AND they have been handed off to the high side
AND you have issued frequency change
AND they are at 24,000 or above

THEN drop track

Selective Protocol Analysis for A12, SPS 1A

Table 12.1A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N8677L	MO22	140	180	110	D-MIO
N345AP	PAZT	252	190	120	D-MIO
A49616	LR35	039	420	150	D-MLC
R16391	C12	085	210	110	D-MLC
N292BC	G2	?	?	?	D-MLC

Full Transcript of 5 Minute Mark Preamble

Looking at this one ...A616... already on the scope and already close to where he needs to be for McAlister. Probably the first thing I will do is turn him right to 90 heading and start him down to 2200 get him down below glide slope and so on.

Also the turn to get him so the he is set up to be turned on the localizer.

R1, let's see, this Gulf Stream has not shown up as of yet.

The Army is also inbound for McAlister. As soon as he enters the air-space about 110-120 heading...R391... 120 heading on him and start him down 2200 also getting him set up for the localizer.

345AP, an Aztec landing into Miami, and he is going to descend rather slowly, so as soon as he gets below... into my air space, set him down, probably choose an altitude, something like 4000 or 5000...

I do see that I got some potential departures off Miami therefore I can leave myself an out so if that a departure wants to come off of Miami, that there is airspace available to get him out without any delay.

413F is an overflight at 17, he is not a factor in the problem at all at this time...

And 8677L is another inbound for Miami, he will be slow in descending, so once he gets over into my airspace I'll shoot some plan of action probably to take him down to some altitude like 7 or 8,000 with the expectation of running this aircraft into Miami first and then run 77L in.

Looking at those strips, ahead, there is...a couple of overflights, one at 22 and one at 18. In neither case do I see any real traffic forming at this time. However, I expect these departures to end up coming into play with them also.

That is basically everything I see on the problem right now.

<u>How about on the display, anything else?</u>

There is some VFR traffic out there that might become a factor for someone, but other than that, nothing at all...

There is a VFR cutting westbound there, should not be a factor because, unless it turns South, neither one of these two planes should be influenced by it.

There is a handoff to be taken on 77L.

That is everything I see at the moment.

<u>What do you plan to do first?</u>

85 heading, down to 2200 on him, on A616 and probably buy the handoff on 77L...
and then it's just a...wait for the other aircraft to enter my sector before I descend them.

END OF 5:00 Preamble

Selective Notation from 5-10 Minute Sequence

6:04 VM6E22: Take the handoff on the MARINE an overflight at 18,000. No traffic at this time.

PRODUCTION

IF aircraft is about to enter airspace
AND there is no immediate traffic

THEN accept handoff
AND monitor for future traffic at that altitude

7:34 N128E: I see 128E tagging up, and since I am not familiar with the map, I need to check his routing.

PRODUCTION

IF twin AC requests departure from an uncontrolled airport
AND there are several inbounds not ready to land
AND controller is unfamiliar with routing
AND there are no previous departures to consider

THEN issue clearance for departure
AND review routing

8:04 A49616: A616, looks like a little too far South. I need to correct that.

PRODUCTION

IF a high performance aircraft is inbound to VFR tower airport
AND and he is within 50 miles of the airport
AND his route is incorrect
AND there is no immediate traffic

THEN vector for re-routing

9:21 TWA65 and VM6E22: Take the handoff on TWA65 and find out his route. He will be traffic with 6E22, other than that, no problem.

PRODUCTION

IF there is an ascending air carrier from an approach controlled airport
AND there is a high performance craft at an intermediate altitude
AND they will be traffic with each other

THEN monitor for separation

Table 12.1B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N345AP	PAZT	253	190	86	D-MIO
R16391	C12	120	210	70	D-MLC
N292BC	G2	240	420	170	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	210	40	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	300	359	32	A-TUL
TWA67	DC10	286	84	7	A-TUL

Full Transcript of 10 Minute Freeze

What is going on now?

Right now we got 616, he's about 2 miles from where I will make the turnoff to the localizer.

2BC is considerably faster than R16391, so I am going to change the sequence there. Once again planning to keep him out, probably 8 miles to 10 miles between these two...I have to wait for the landing to lock him before I can clear him for the approach for the landing...

I will wait for the A616 to land prior to clearing 2BC for the ILS approach.

The ARMY is a much slower aircraft. Looks like he is going to fit right in with the 2BC. If need be, I can widen R391 out there...

128E is climbing only to 4000. He is separated from 5AP. I will be able to start him down here shortly...

And other than that, really not much going on...

There is a new departure that just popped off at about ....Tulsa...that is going to be going out on the same routing as the TWA...

What am I going to do next?...I am going to enter an interim altitude with this aircraft (128E) enter an interim altitude of 4,000...

In real life what happens is that datablocks will start to flash, conflict glare would go off and it's aggravating, so you make sure that you get the interim altitude in there and it's no longer a factor.

And other than that, I am just waiting on Air Force to get down to..or get a little closer to the localizer, so I can turn him on.

Selective Notation from 10-15 Minute Sequence

11:17 A49616: A616 cancelled IFR. No longer a factor.

PRODUCTION

IF a high performance aircraft is inbound to VFR tower airport
AND he has cancelled IFR
AND there is no immediate traffic

THEN drop track

12:27 N3688U, N128E, and N345AP: Vectored 88U 270. Wanted him out of the way to descend 5AP as soon as he is clear of 128E. Don't want 88U to be a problem with him.

PRODUCTION

IF there are two ascending aircraft from uncontrolled airport
AND there are several inbounds
AND second ascending aircraft is possible traffic for one of the inbounds

THEN vector second ascending AC for traffic
AND monitor for spacing

12:46 TWA65 and TWA67: Approach let TWA67 go with less than 5 miles separation. Stopped him at 9,000 to make sure it was safe for TWA65. Slowed TWA67 to 250. That will establish separation.

PRODUCTION

IF air carrier departs from approach controlled airport
AND there is a potentially slower air carrier recently departed on same route
AND there is a possibility of an overtake

THEN assign intermediate altitude to second departure
AND assign a slow speed
AND monitor for spacing

13:35 TWA65 and TWA67: TWA67 requested vector to Springfield. Problem with spacing. TWA65 Springfield. Reexamining. Vector TWA67 to Springfield.

PRODUCTION

IF air carrier departs from approach controlled airport
AND there is a potentially slower air carrier recently departed on same route
AND there is a possibility of an overtake
AND faster air carrier requests vector for re-routing
AND there is no other immediate traffic

THEN vector faster air carrier for re-routing

Table 12.1C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
R16391	C12	120	210	40	
N413F	BE55	094	220	170	
VM6E22	F18	259	460	180	
N128E	BE65	087	210	40	
N3688U	BE33	270	144	30	
TWA65	A300	067	419	170	
TWA67	DC10	044	295	127	

Selective Notation from 15 Minute Freeze

TWA65 and VM6E22: TWA65 almost clear of E22, so climb him to 23,000 as soon as clear.

N8677L and N345AP: Vectored 77L across airport for downward entry after 5AP.

N128E: 128E can be climbed at any time.

FIRST: Vector 5AP to 180 and then climb 88U to 5,000, and 128E to his requested altitude of 15,000.

Selective Notation from 15-20 Minute Sequence

16:05 N345AP: 5AP needs to be turned down

PRODUCTION

IF ascending twin AC is clear of traffic from uncontrolled airport
AND inbound need to be descended

THEN clear AC to ascend

18:47 N128E: Late on the 128E handoff to Memphis Center

ERROR

19:26 N292BC: 2BC, turned him prematurely.

Selective Protocol Analysis for A04, SPS 2A

Table 4.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

Three landing in Tulsa. No problems. This will be easy.

Selective Notations from 5-10 Minute Sequence

5:18 EAL121, COA15, and AAL31: EAL in lead, number 1, AAL number 2, and COA number 3. This is based on 8 mile vector lines.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND vectors show one air carrier in the lead

THEN establish arrival sequence based on vectors
AND monitor spacing
AND formulate backup plan

6:56 AAL31: AAL in another airspace, so I must call to get control of him and drop him to 11,000 and slow to 280 knots.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND the number 2 inbound needs to be slowed and descended
AND the number 2 inbound is in another airspace

THEN get control from other airspace
AND clear number 2 to descend
AND assign number 2 a speed reduction

7:37 EAL121, COA15, and AAL31: Making sure that speeds are taking effect. Right now, they are tied. Things have changed. May have to go to plan B and use altitude separation when they are closer.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND they are tied
AND speeds have not taken effect

THEN monitor to implement backup plan
AND monitor to descend for altitude separation

9:30 EAL121 and AAL31: Going to vector EAL to intercept the arrival route. Will provide more separation.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 1 and 2 do not have good separation
AND speeds have not taken effect

THEN vector number 1 for efficiency and spacing
AND monitor spacing

Table 4.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	038	415	116	D-TUL
COA15	DC9	336	323	134	D-TUL
AAL31	MD80	067	338	110	D-TUL

Selective Notations from 10 Minute Freeze

Speeds are taking effect. With the EAL vector, will gain on AAL. COA will have to be descended and slowed to get him behind AAL. May have to vector COA for spacing.

Selective Notations from 10-15 Minute Sequence

12:17 EAL121, COA15, and AAL31: Got my spacing now. Going to speed AAL up same as EAL until they get up to Tulsa boundary, so I will close that hole and get more spacing between AAL and COA.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND spacing has been established between number 1 and 2
AND number 2 has been slowed down
AND spacing between number 2 and 3 has not been established

THEN assign speed to number 2 equal to that of number 1
AND monitor for spacing

14:38 EAL121: Giving the EAL handoff to Tulsa approach.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one aircraft has reached appropriate speed and altitude
AND is approaching the gate
AND there is no immediate traffic

THEN initiate handoff
AND monitor for frequency change

Table 4.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	038	330	110	D-TUL
COA15	DC9	336	295	110	D-TUL
AAL31	MD80	067	330	110	D-TUL
TWA19	B727	023	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

Looks like AAL and COA are to be closer than I anticipated. So I want to make sure (by using the J-Ball on COA) that I don't loose separation.

Selective Notations from 15-20 Minute Sequence

16:51 COA15, and AAL31: COA and AAL looked too close for comfort. So I vectored COA directly at AAL that way they can never loose separation. As soon as I am sure I have 5 miles, turn COA back in.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing between two inbounds has not been established
AND inbounds are approaching the gate

THEN vector one inbound directly toward the other for spacing
AND monitor spacing
AND monitor to vector to join arrival

18:09 COA15, and AAL31: I am sure I have got separation, so I can turn COA back in. AAL is slower.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one air carrier had been vectored for spacing
AND carrier in front is slower than the one in back
AND spacing has now been established

THEN vector air carrier to join arrival
AND monitor spacing

19:40 Let TWA, UAL and DAL run a little further, then put some speeds on them.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND they are a good distance from the gate
AND there is no immediate traffic

THEN monitor to assign speeds for spacing

Selective Protocol Analysis for A06, SPS 2A

Table 6.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

Lots of arrivals requiring vectoring techniques.

Set everything up in MLC area before getting to Tulsa.

The game plan is EAL in front, AAL number 2. So vector EAL, reach out and get control of AAL, and also vector COA.

Selective Notations from 5-10 Minute Sequence

6:11 EAL121 and AAL31: EAL is much quicker, L101 vs the MD80. EAL is a faster aircraft, so I can tell him to speed up.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one air carrier has faster speed than the other
AND the faster air carrier has higher performance characteristics

THEN plan to assign speed to the faster carrier for separation
AND monitor spacing

7:47 EAL121 and AAL31: Since EAL is no factor, I will put the J-Ball on him. I started him on down and got his airspeed up. The faster EAL, the sooner AAL can be turned on in.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one air carrier has faster speed than the other
AND the faster air carrier has higher performance characteristics
AND speed is being used for separation

THEN assign speed to the faster carrier for separation
AND descend faster carrier
AND monitor to vector second air carrier to join arrival

8:43 COA15 and AAL31: Started AAL down, when I feel good about it, I can start COA down. I could start them all down, but I don't like that.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND the lead aircraft has been started down
AND speed is being used for separation

THEN monitor to clear trailing air carrier for descent

9:53 COA15 and AAL31: Slowed COA down, to sequence him behind AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND the lead aircraft has been started down
AND speed is being used for separation
AND speeds have not taken effect

THEN assign speed reduction to air carrier in trail

Table 6.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	043	435	150	D-TUL
COA15	DC9	306	407	234	D-TUL
AAL31	MD80	090	405	200	D-TUL

Selective Notations from 10 Minute Freeze

FIRST: Start AAL down to 16,000, using altitude separation and waiting a minute to vector him back. Will let COA ride a little more. As soon as they pass. I will swing him back in.

This is a radar environment. I am not worried about strips.

Selective Notations from 10-15 Minute Sequence

10:33 AAL31: I turned AAL in and put him on the TULSA1 radial. Should not have to talk to him again. The only thing I need to do is give him altitude and speed (250).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND the lead aircraft has been started down
AND speeds have taken effect

THEN vector the lead air carrier to join arrival
AND monitor to assign altitude and speed reduction

12:12 COA15 and AAL31: Turned COA. Should have plenty of room between COA and AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND the lead aircraft has been vector to join arrival
AND spacing has now been established

THEN vector the trail air carrier to join arrival
AND monitor for spacing

13:33 AAL31, EAL121, COA15, and TWA19: It will work okay. Could vector AAL, but don't need to. TWA is no problem relative to COA, AAL, and EAL.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND there is a new inbound approaching my sector
AND spacing has now been established

THEN the new inbound is no problem in reflation to first set of inbounds
AND monitor to vector the inbounds

14:37 AAL31: Vector AAL just to clean him up.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds is not on the arrival
AND spacing has now been established

THEN vector that air carrier to join arrival

Table 6.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	358	409	110	D-TUL
COA15	DC9	355	295	110	D-TUL
AAL31	MD80	064	405	110	D-TUL
TWA19	B727	023	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

Reduced COA airspeed so I did not have to vector him. Looks like TWA will be number 1. Got the handoff on him, so I can control him. I cannot control the others without reaching for them.

Selective Notations from 15-20 Minute Sequence

16:56 EAL121 and AAL31: EAL is off and gone, and has taken care of AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND the lead has been handed off
AND have issued frequency change on lead
AND trail air carrier is nearing the gate

THEN drop track of lead air carrier
AND handoff the trailing air carrier

18:13 UAL59, DAL143 and TWA19: TWA is a 7272, DAL is a 767. I am going to take DAL back. TWA first, DAL, and then UAL. I am reevaluating.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND one air carrier appears to be in the lead

THEN establish arrival sequence based on relative positions
AND make lead aircraft number 1
AND monitor for spacing
AND formulate backup plan

18:38 DAL143: I would normally take DAL first, because he is a faster aircraft, but in this case, I don't have to worry.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND one air carrier is a higher performance air carrier
AND one air carrier appears to be in the lead

THEN establish arrival sequence based on relative positions
AND monitor for spacing

18:50 UAL59: May change, because UAL is out in front based on vector lines.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has been established
AND based on vector lines number 3 is out in front of number 2

THEN review backup plan
AND monitor for spacing

Selective Protocol Analysis for A10, SPS 2A

Table 10.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

Take handoff on AAL and COA. Vector EAL on TULSA1 arrival. EAL is an L101 ano should stay out in front.

Reach out to control AAL for lower.

Selective Notations from 5-10 Minute Sequence

6:16 COA15, and AAL31: Trying to see who will be number 2, AAL or COA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 air carrier has been determined
AND numbers 2 and 3 have not

THEN review routing
AND monitor to establish arrival sequence

6:40 EAL121: The vector on EAL took him too far to the right. I want to vector him closer.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 air carrier has been determined
AND number 1 was misvectored

THEN vector number 1 to join arrival

7:48 EAL121, COA15, and AAL31: EAL is number 1, AAL is number 2, and COA is number 3

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 1 air carrier has been determined
AND the other two are tied
AND one of the these two has been handed off

THEN make the one handed off number 3
AND monitor for spacing

8:23 EAL121, COA15, and AAL31: May have to vector COA. It is starting to work with EAL in front of AAL. May have to vector COA, but he may slow down here.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has been determined
AND separation is good between 1 and 2
AND separation has not been established between 2 and 3

THEN monitor number 3 to vector for spacing

Table 10.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	039	435	143	D-TUL
COA15	DC9	320	336	190	D-TUL
AAL31	MD80	067	405	151	D-TUL

Selective Notations from 10 Minute Freeze

EAL in front. When I am sure it works with AAL, then I will slow EAL to 250. When COA is working, I will swing COA back up to he approach and drop 250 at 11,000.

FIRST: Hand off EAL to approach.

Selective Notations from 10-15 Minute Sequence

10:38 EAL121: Eventually, I will have to pull EAL back to 250. Make sure he is out in front.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one aircraft has not reached appropriate speed and altitude
AND is approaching the gate
AND separation has not been firmly established

THEN delay assigning speed reduction
AND monitor to initiate handoff

12:30 COA15: Let COA get 10 miles closer, then I will turn him in. Will let the pilot know the plan.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one air carrier has to be routed
AND separation has not been firmly established

THEN delay vectoring air carrier to join arrival
AND notify pilot of plan

13:39 TWA19: Took handoff on TWA.

PRODUCTION

IF new air carrier is about to enter airspace
AND there are inbound air carriers to an approach controlled airport
AND there is not heavy workload

THEN accept handoff
AND monitor to establish new arrival sequence

14:33 UAL59 and DAL143: Looking at UAL. My next concern is UAL and DAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND have accepted the handoff on one
AND two more are entering the airspace

THEN monitor new arrivals to establish arrival sequence

Table 10.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	039	259	110	D-TUL
COA15	DC9	320	295	110	D-TUL
AAL31	MD80	067	295	110	D-TUL
TWA19	B727	022	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

Will let COA go another 5 to 10 miles and then vector him for approach. Will handoff AAL to approach. Looks good.

Got DAL. May be out in front, then TWA and UAL. I will see how he is going to fit in.

FIRST: Keep an eye on AAL and COA, and get COA up to turn.

Selective Notations from 15-20 Minute Sequence

16:50 DAL143: DAL is slightly out in front. He will be number 1.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one air carrier is out in front
AND have not determined arrival sequence

THEN establish arrival sequence by making carrier in front number 1

17:31 EAL121, COA15, and AAL31: AAL and EAL are working. Not sure if I turned COA back too soon.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND the spacing for number 1 and 2 has been established
AND the spacing for number 3 has not been fully established

THEN monitor number 3 for spacing

18:21 TWA19, UAL59: Has to give TWA clearance on the SHAWN1 arrival. Have to do the same with UAL, and may have to do some vectoring.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND two air carrier have to be routed
AND separation has not been firmly established

THEN monitor to vector to join arrival
AND monitor for spacing

19:19 TWA19, DAL143, and UAL59: Descending DAL through TWA's altitude. Check to see that it is working. My plan is to make DAL number 1, TWA number 2, and UAL number 3.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has been established
AND number 1 is above number 2

THEN clear number 1 to descend to an available altitude below number 2
AND monitor for spacing

Selective Protocol Analysis for A11, SPS 2A

Table 11.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

There is a problem with AAL and EAL. They are separated but about the same distance from the arrival gate. COA will enter into it, since he will be at the arrival gate about the same time. AAL, if you want lower on him, you will have to work with other sector.

FIRST: Take handoff on AAL.

Selective Notations from 5-10 Minute Sequence

5:43 EAL121 and AAL31: EAL and AAL are a tie, your first problem.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND two carriers are tied

THEN review routing
AND monitor to establish arrival sequence

6:54 AAL31: AAL is outside our area, so have to take control to reduce his speed.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND the arrival sequence has been established
AND you need to reduce speed on one of the air carriers

THEN get control from other airspace
AND assign speed reduction

7:15 COA15, EAL121 and AAL31: Judging by speed, looks like EAL is first, AAL second, and COA third.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND one aircraft has greater speed than the rest

THEN establish arrival sequence based on speed
AND monitor spacing
AND formulate backup plan

7:58 COA15, EAL121 and AAL31: Have control of AAL, so when EAL starts down, I can start AAL down also. Watch the speed when AAL come back, give him 11,000 and he falls in the hole...Watch COA, his speed is back also, may need vector.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND have control of number 1 and 2
AND getting ready to descend number 1

THEN monitor to clear number 1 to descend
AND monitor to clear number 2 to descend
AND monitor number 3 to vector for spacing

9:12 COA15 and AAL31: Turning COA will bring him behind AAL.

PRODUCTION

IF there inbound air carriers to an approach controlled airport
AND arrival sequence has been established
AND number 3 has not been routed
AND spacing between number 2 and 3 has nct been established

THEN vector number 3 for re-routing and for spacing
AND monitor spacing

Table 11.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	125	D-TUL
COA15	DC9	280	327	152	D-TUL
AAL31	MD80	067	366	240	D-TUL

Selective Notations from 10 Minute Freeze

EAL is still full speed ahead and number 1. AAL at 250 has fallen back 5 miles and is number 2. And COA with turn, has fallen behind AAL.

FIRST: Interim altitude on AAL.

Selective Notations from 10-15 Minute Sequence

11:04 EAL121 and AAL31: Biggest concern is watching distance between AAL and EAL. Their speed is working: 430 on EAL and 370 on AAL.

PRODUCTION

IF there inbound air carriers to an approach controlled airport
AND arrival sequence has been established
AND number 1 and 2 spacing is not fully established

THEN monitor 1 and 2 for spacing

11:25 EAL121 and AAL31: You got your 5 miles built in. Working good. Also, got altitude separation. EAL at 11,000, AAL at 12,000. You have altitude until you get vertical separation.

PRODUCTION

IF there inbound air carriers to an approach controlled airport
AND arrival sequence has been established
AND number 1 and 2 spacing is just established

THEN monitor 1 and 2 for spacing
AND maintain vertical separation

12:00 COA15: Got ahead of myself. Could have left COA at normal speed until closer. I don't like to waste space.

PRODUCTION

IF there inbound air carriers to an approach controlled airport
AND spacing between number 2 and 3 is established

THEN maintain present speed on number 3
AND monitor 3 for speed reduction

13:29 TWA19: Take handoff on TWA.

PRODUCTION

IF new air carrier is about to enter airspace
AND there are inbound air carriers to an approach controlled airport
AND there is not heavy workload

THEN accept handoff
AND monitor to establish new arrival sequence

14:19 DAL143: I will sequence by time. There is a 767, and may have a 727 behind. This may pose a problem.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has not been established
AND there is a higher performance air carrier behind a lower performance one

THEN monitor for spacing
AND monitor to establish new arrival sequence

Table 11.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	067	435	110	D-TUL
COA15	DC9	351	295	110	D-TUL
AAL31	MD80	067	295	110	D-TUL
TWA19	B727	022	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

Forgot to give EAL 250 knots. See DAL coming up. That is about it.

FIRST: Watch TWA as soon as he gets in my airspace, will start him down.

Selective Notations from 15-20 Minute Sequence

17:08 TWA19, DAL143, and UAL59: Got a 727 (TWA), and a 767, and UAL (727). So you are dealing with same type of aircraft. Should be no problem.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has not been established
AND the performance level of the three is about the same

THEN monitor to establish new arrival sequence
AND establish sequence on other than aircraft type

17:40 TWA19, DAL143: DAL or TWA could be first. TWA will be first because he is at lower altitude.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has not been established
AND the performance level of the three is about the same
AND two of the air carriers are tied
AND one of the air carriers is at a lower altitude

THEN establish arrival sequence with lower AC as number 1

18:06 COA15: Give COA his Tulsa approach.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one air carrier has been vectored for spacing
AND spacing has been established

THEN vector air carrier to join arrival
AND monitor for spacing

18:40 TWA19 and UAL59: In real life, I would take TWA direct to the fix. I can put him ahead of UAL without slowing either down.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 can be short cut to the arrival

THEN vector number 1 for efficiency
AND maintain present speed on both air carriers

Selective Protocol Analysis for A12, SPS 2A

Table 12.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

EAL121 and AAL31: Move EAL out in front of AAL. They are tied, now, but L101 is capable of better speed, so I will call adjoining sector and descend AAL.

COA15: COA will need the TULSA1 routing.

Looks like a minor sequencing problem between the three.

Display makes EAL and AA look closer than expected, so it will take more effort to get EAL out in front. AAL, slow him down to 280, and COA should fall right in line.

FIRST: Call sector to request control to take AAL down.

Selective Notations from 5-10 Minute Sequence

6:24 EAL121, AAL31, and COA15: Take a look at the vector lines. Speeds are working, give me about 7 miles there (between EAL121 and AAL31). COA drop him to 11,000 and 280 knots. He will be no factor after that.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND speeds are working to establish number 1 and 2 arrival sequence
AND number 3 needs additional spacing

THEN clear number 3 to descend
AND assign number 3 a speed reduction

7:04 EAL121, AAL31, and COA15: Assessing EAL speed increase, and would have expected a greater decrease of AAL speed. Watching to see if I have enough miles, and in that case, I can then put more speed on AAL to pull him out in front of COA.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND speeds are working to establish number 1 and 2 arrival sequence

THEN monitor to assign speed increase to number 2

8:29 COA15: COA is not slowing down as much as I expected. Don't know the wind setup, so I have slowed him down some more.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND speeds are working to establish number 1 and 2 arrival sequence
AND number 3 needs additional spacing

THEN assign speed reduction to number 3
AND monitor for spacing

9:05 AAL31 and COA15: Looking at how the speeds are starting to work between COA and AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND speeds are starting to work between number 2 and number 3

THEN monitor for spacing

9:13 EAL121: Also trying to decide how far from the gate I want to slow EAL to 250 to make that restriction.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND is approaching the gate

THEN monitor to assign speed reduction

Table 12.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	038	415	116	D-TUL
COA15	DC9	336	323	134	D-TUL
AAL31	MD80	067	338	110	D-TUL

Selective Notations from 10 Minute Freeze

Picked AAL's speed up become I am trying to build the gap for COA a little sooner.

FIRST: Run the vector line out to check separation.

Selective Notations from 10-15 Minute Sequence

10:13 EAL121 and AAL31: I will slow AAL to 250 before I slow EAL because it looks like I will have 7 miles there.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 and 2 are in trail
AND there is separation
AND the number 1 craft needs to be slowed

THEN assign speed reduction to number 2 first
AND monitor to assign speed reduction to number 1

11:26 EAL121, AAL31, and COA15: At the very most, I am thinking of where I will be slowing AAL and EAL, and watching to make sure that COA stays where he is supposed to be.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 1 and 2 are in trail
AND there is separation
AND both air carriers need to be slowed

THEN monitor to assign speed reduction to number 1 and 2

12:23 Since AAL is going fast, I have slowed him now to 280 and will slow him down to 250 at a later time.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 and 2 are in trail
AND there is separation
AND the number 2 craft needs to be slowed

THEN assign intermediate speed reduction to number 2
AND monitor to assign additional speed reduction

12:50 EAL121, AAL31, and COA15: Main thing is make sure that I keep AAL in front of COA. EAL is no factor at all. He already has the 7 miles I was looking for.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 1 and 2 have good separation
AND number 1 in no longer a factor
AND number 2 and 3 have separation

THEN monitor spacing between 2 and 3

Table 12.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	038	330	110	D-TUL
COA15	DC9	336	295	110	D-TUL
AAL31	MD80	067	330	110	D-TUL
TWA19	B727	023	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

Will slow EAL to 250 and ship him. AAL I will let him catch up more with EAL, to pull him out in front of COA.

TWA needs the SHAWN1 arrival, and I see another one coming up here...Their speeds are comparable. The MD80 and DC9 are a little slower aircraft than the 727.

FIRST: EAL slow to 250 and contact TULSA approach.

Selective Notations from 15-20 Minute Sequence

16:16 AAL31 and COA15: Checking spacing on COA and AAL. Looks like it is an adequate 7 miles. (Slow AAL).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established
AND the lead air carrier is approaching the gate

THEN assign speed reduction to lead air carrier
AND monitor spacing

17:08 AAL31 and COA15: Once again, AAL and COA. Since I am not that familiar with the map, just checking to see that the separation is alright.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established
AND the lead air carrier has been slowed for the gate

THEN monitor spacing

17:38 DAL143, TWA19, and UAL59: UAL is obviously number 3 in the sequence. Planning on starting him down, let him reduce, and should show a considerable reduction in speed. He is number 3 in the sequence behind DAL and TWA. The sooner I start him down, the more effect the speed control has on him.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND one air carrier is clearly further from the gate
AND arrival sequence has not been established

THEN establish furthest air carrier as number 3 in the sequence
AND monitor to assign number 3 a speed reduction

18:38 DAL143: DAL was high. Will call next sector and get control for lower (pointout).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one inbound needs to be descended
AND that inbound is in another sector

THEN get control from other sector
AND monitor to clear to descend

Selective Protocol Analysis for A04, SPS 5A

Table 4.5A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
SPURS12	KC10	087	300	170	REFUEL
SWIFT66	B52	087	300	170	REFUEL
N84CR	C182	086	149	31	A-MLC
LN45T	LR35	345	400	130	A-MLC
COA35	B737	087	420	150	OVER
N496B	PASE	084	170	90	D-MIO
N52PB	C177	000	0	0	A-MIO

Selective Notations from 5 Minute Freeze

No PVD comments

Selective Notations from 5-10 Minute Sequence

6:15 N52PB: Cleared him off, gave him 6,000 because I have traffic coming and I just want to get him off the ground.

7:01 SPURS12 and SWIFT66: Just switched them...they are getting ready to cross the boundary.

7:11 LN45T: He is wanting a high altitude. I am going to hand him off to the high side.

8:20 N52PB: He just got off of Miami and is climbing and has not transponder. Have him report VOR to me and I'll start a track.

8:41 AAL15: Got a handoff on AAL15 from Tulsa.

9:13 N52PB: He just reported to me over the MIO VOR, so I now want to start a track on him.

9:41 N52PB: I assigned him 7,000, got radar on him, and asked him to report since he has no transponder.

Table 4.5B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN45T	LR35	347	400	290	A-MLC
N496B	PASE	084	170	90	D-MIO
N52PB	C177	067	150	24	A-MIO
AAL15	B727	069	307	102	A-TUL
LINDA34	F4	170	430	160	OVER
ELDER87	B52	249	410	160	OVER

Selective Notations from 10 Minute Freeze

When I started off, one of the highest priorities was getting N84CR handed off. N52PB with no transponder was not critical, and \AL15 was no problem.

Selective Notations from 10-15 Minute Sequence

10:09 LINDA34 and ELDER87: Took the handoff on ELDER87 and LINDA34. Get a route readout on them.

10:51 AAL15: Gave the handoff on AAL to my high sector because he has requested high. Get him up and out of the way.

12:04 LINDA34: There is no one at 18,000, so I will assign it to him as soon as it crosses the line.

12:52 N496B: This aircraft is inbound to MIO and I want to start him down (5,000).

13:38 LINDA34: That takes care of my conflict (climb to 18,000).

14:11 DAL15: Just got an inbound to Tulsa.

14:36 AAL52: Trying to take the handoff on AAL52.

Table 4.5C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
DAL15	B727	192	410	240	D-TUL
AAL52	B727	194	420	220	D-TUL
COA65	MD80	255	410	240	D-TUL
LN45T	LR35	028	400	290	A-MLC

Selective Notations from 15 Minute Freeze

Two inbounds to Tulsa about 7 miles apart that need to get down. Need to check the speeds on them. DAL15 is 440, and AAL52 is 450. Not that much difference in speed. Got to get them down to 11,000 and check were COA65 is going to fit in. Make sure you have 5 miles.

Conflict between LINDA and ELDER has been taken care of.

Selective Notations from 15-20 Minute Sequence

15:11 COA35: Handoff COA35 to Memphis so if I get involved in Tulsa inbounds, that will be taken care of it.

15:45 DAL15 and AAL52: Put a J-Ball around DAL15 so I can make sure that AAL52 is 5 miles behind him.

16:28 DAL15 and AAL52: I am going to spread them out for approach. DAL15 to 11,000, 280 or greater, and AAL52 has 250, so I will be increasing my spacing.

17:36 DAL15, AAL52, and COA65: These aircraft are going to come together near Tulsa, so I am going to maintain altitude separation until I have longitudinal separation.

18:41 COA65 and LINDA34: My biggest priority is to get COA under LINDA34 , and I can get that done right now.

19:03 DAL15, AAL52, and COA65: I have good spacing so I could fit COA between AAL and DAL, or in front...looks like he can go in front.

20:00 DAL15, AAL52, and COA65: Have reduced AAL and DAL to 250, and COA is doing 310.

Selective Protocol Analysis for A06, SPS 5A

Table 6.5A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
SPURS12	KC10	087	300	170	REFUEL
SWIFT66	B52	087	300	170	REFUEL
N84CR	C182	086	149	26	A-MLC
LN45T	LR35	002	243	38	A-MLC
COA35	B737	087	420	150	OVER
N496B	PASE	084	170	90	D-MIO
N52PB	C177	173	118	7	A-MIO

Selective Notations from 5 Minute Freeze

SPURS and S.VIFT are gone.

FIRST: Stop LN45T at 23,000

Selective Notations from 5-10 Minute Sequence

5:38 LN45T: I will have the Tulsa incoming, so I will coordinate LN with the high altitude.

5:48 COA35: He is an overflight and is no problem...right not don't have anything to worry about.

7:38 LN45T: No problem with him here, so I will hand him off...there is no traffic in his way.

8:33 Just waiting to see what will happen...

9:10 AAL15: He is already on the transition. No traffic, just let him go.

9:40 LINDA34 and ELDER87: There is my conflict. I see where the two airline are, and I just watch them.

Table 6.5B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN45T	LR35	004	400	290	A-MLC
N496B	PASE	084	170	90	D-MIO
N52PB	C177	067	150	47	A-MIO
AAL15	B727	068	290	100	A-TUL
LINDA34	F4	170	430	160	OVER
ELDER87	B52	249	410	160	OVER

Selective Notations from 10 Minute Freeze

I will be looking for LINDA34 and ELDER87. I could reach out and changed altitude, but look how much separation I have. Just something to keep in the back of your mind. I may put a J-Ball as a reminder.

The only other factor is AAL15. May cross with ELDER87. I will do a route readout (20 minutes out) and then make the appropriate action.

FIRST: Put a J-Ball on

Selective Notations from 10-15 Minute Sequence

10:27 Got to take a handoff first, I should have just done that.

11:42 LINDA34 and ELDER87: I am just going to watch these two. Their routes are strange, but ELDER is supposed to land. So I won't worry about it.

12:22 AAL15: The AAL15 is no problem. He is already above So what I will do is hand him off to the high altitude sector.

13:12 AAL15: He is handed off. I will let the high altitude worry about separate him and DAL. Or I can send AAL direct to Fort Smith.

Table 6.5C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
DAL15	B727	192	410	240	D-TUL
AAL52	B727	194	420	220	D-TUL
COA65	MD80	255	410	240	D-TUL
LN45T	LR35	004	400	290	A-MLC

Selective Notations from 15 Minute Freeze

I am going to make COA65 number 1. Turn DAL15 and AAL52 down to the South. Let them fall right in behind COA.

LINDA34 and ELDER87 still a factor to think about. In the real world you would ask for their destination.

I am going to let the COA right in. I will vector the other two South, so they are away from the Tulsa departures.

FIRST: More clerical actions: Taking and giving handoffs.

Selective Notations from 15-20 Minute Sequence

15:54 ELDER87: I know what is going on with him (destination KS), so I will solve it right now. "East is least" take him to 17,000.

16:33 AAL15: AAL is gone. He is above everyone so I let him go.

16:47 DAL15 and AAL52: Start DAL15 on down and see how he fits in with the other guy...I will put the J-Ball on DAL15.

17:27 COA35: Get rid of him. He is just a distractor.

17:42 COA65 and DAL15: I have COA65 on his way heading South. I want to see how he fits in with DAL15.

18:18 DAL15 and AAL52: I am going to step them on down (AAL and DAL). Looks like the weather is going to be a factor.

19:00 LINDA34: One more time, check the LINDA, no problem.

19:18 DAL15 and COA65: DAL15,000 and COA at 14,000 deviating, no problem.

19:42 DAL15 and COA65: Since DAL is inside to the North, I will make DAL first, and COA second.

Selective Protocol Analysis for A10, SPS 5A

Table 10.5A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
SPURS12	KC10	087	300	170	REFUEL
SWIFT66	B52	087	300	170	REFUEL
N84CR	C182	000	0	0	A-MLC
LN45T	LR35	000	0	0	A-MLC
COA35	B737	087	420	150	OVER
N496B	PASE	084	170	90	D-MIO
N52PB	C177	000	0	0	A-MIO

Selective Notations from 5 Minute Freeze

LINDA34 is coming Southbound, and ELDER87 is coming Southwest bound. May be a conflict. May have to change altitude.

SPURS12 and SWIFT66 are ready to handoff to Memphis Center

We have taken the handoff on COA35 and 496B.

FIRST: Handoff SPURS to Memphis Center.

Selective Notations from 5-10 Minute Sequence

5:31 SPURS12 and SWIFT66: I switched SPURS12 and SWIFT66 over.

6:42 N84CR and LN45T: I am waiting to get N84CR on the frequency and work him up so I can release LN45T.

8:57 Next move to go back to MLC.

Table 10.5B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN45T	LR35	006	108	2	A-MLC
N496B	PASE	084	170	90	D-MIO
N52PB	C177	174	150	13	A-MIO
AAL15	B727	068	258	71	A-TUL
LINDA34	F4	170	430	160	OVER
ELDER87	B52	249	410	160	OVER

Selective Notations from 11+ Minute Freeze

I am clear by LN45T, so I can climb him up to 23,000. First give him 14,000 to make sure he clears COA35, and then get him up to the high side.

Keep and eye on LINDA34 and ELDER87.

Get AAL15 to higher altitude.

FIRST: Climb LN45T.

Selective Notations from 10-15 Minute Sequence

13:38 AAL15: He is cleared direct to Fort Smith.

14:22 DAL15 and AAL15: Turning DAL15 to get him under AAL15.

Table 10.5C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
DAL15	B727	192	410	240	D-TUL
AAL52	B727	194	420	220	D-TUL
COA65	MD80	255	410	240	D-TUL
LN45T	LR35	360	400	217	A-MLC

Selective Notations from 15 Minute Freeze

496B has lost his transponder.

May have to turn DAL15, AAL52 will be last.

45T to the high side.

I have a spacing problem. My initial thing is pull AAL52 back...I don't know, may take a little further look at that. The minute he gets into my airspace, COA, I will descend him to get him away from AAL15, and I can vector him.

N496B lost his transponder, I will have to work on that.

FIRST: Sent LN45T to the high side.

Selective Notations from 15-20 Minute Sequence

18:08 Checking vector lines to see how my spacing is doing.

19:11 LN45T: Don't understand why they are not taking this guy up.

19:23 Spacing is not working out. (DAL first , COA second and AAL third)

Selective Protocol Analysis for A11, SPS 5A

Table 11.5A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
SPURS12	KC10	087	300	170	REFUEL
SWIFT66	B52	087	300	170	REFUEL
N84CR	C182	086	149	26	A-MLC
LN45T	LR35	345	400	133	A-MLC
COA35	B737	087	420	150	OVER
N496B	PASE	084	170	90	D-MIO
N52PB	C177	000	0	0	A-MIO

Selective Notations from 5 Minute Freeze

SPURS12 and SWIFT66 the refuel track.

COA35, overflight at 35 going to Hot Springs.

FIRST: Get 45T handed off to high altitude.

Selective Notations from 5-10 Minute Sequence

5:41 LN45T: We got 45T handed off to high altitude.

6:04 SPURS12 and SWIFT66: The SPURS12, they are going through, so I will hand them off to Memphis Center.

7:12 N52PB: PB has no transponder, so there is no altitude readout. So just have to get the reports on him.

7:24 AAL15: Just flashed up out of Tulsa at 10,000 going to 23,000.

9:00 AAL15: Flash him to the high altitude sector.

9:34 N52PB: He does not have a transponder, but we can use radar if we get him within the appropriate distance by having him report over the VOR.

Table 11.5B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN45T	LR35	347	400	290	A-MLC
N496B	PASE	084	170	90	D-MIO
N52PB	C177	067	150	31	A-MIO
AAL15	B727	068	260	89	A-TUL
LINDA34	F4	170	430	160	OVER
ELDER87	B52	249	410	160	OVER

Selective Notations from 10 Minute Freeze

AAL15 take him to 23,000. No problem there.

The refuelers are gone, and 52PB over the VOR to be radar identified.

LINDA and ELDER will bear watching when they get closer.

FIRST: Get the 5?PB radar identified.

Selective Notations from 10-15 Minute Sequence

10:30 LINDA34 and ELDER87: We take the handoff on LINDA34 and ELDER87.

10:45 AAL15: We can make the handoff on him to the high altitude sector.

11:31 You can handoff an AC any time you have track control. The sooner you can hand him off, if there is not traffic, the better.

12:09 LINDA34 and ELDER87: They could get together. The same speed, LINDA34 is a little faster. Shoot the route on them. They will cross. Just watch them. You may have change altitude on one of them.

13:16 DAL15 and AAL52: DAL15 arriving from the Northeast. AAL15 is still climbing and DAL is at high altitude, and AAL is clear of traffic, so AAL15 to the high side.

13:48 DAL15, AAL52, and COA65: Got the DAL, and AAL and the COA65. Think of doing some spacing. Right now, looking okay. COA65 and AAL52 flashing a handoff.

14:30 ELDER87: Because of LR at 15,000, ELDER is going to 18,000.

Table 11.5C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
DAL15	B727	192	410	240	D-TUL
AAL52	B727	194	420	220	D-TUL
COA65	MD80	255	410	240	D-TUL
LN45T	LR35	028	400	290	A-MLC

Selective Notations from 15 Minute Freeze

ELDER is on the way to 18,000, so that eliminates any conflict with LINDA.

COA65 and MD80, let sequence COA, DAL, and AAL.

The weather does not appear to be a factor.

AAL15 is not my problem anymore.

FIRST: Report N52PB at level 7,000 and 496B just lost his transponder. Check on that.

Selective Notations from 15-20 Minute Sequence

16:26 Take the COA down first (11,000).

16:39 DAL15, the AAL is gone, no more problem (descend him to 11,000)...we got five miles and AAL52 and DAL are the same type of aircraft, should work.

18:25 DAL15, AAL52, and COA65: Watching the COA and the DAL, the COA has a little speed so...take AAL52 down to 11,000 and slow, and we can slow the DAL down as soon as the speed starts to work on AAL52.

19:13 DAL15, AAL52, and COA65: We got the speed back on the AAL, so we can take the speed back on DAL. We are watching the DAL and the COA, should be no problem as soon as the speeds start to work. COA we will turn in, and the DAL we may have to bring him on down. Just watching the speed now.

19:48 DAL15, AAL52, and COA65: Watching the COA and the DAL. AAL52 speed is coming down, so it is working good.

Selective Protocol Analysis for A12, SPS 5A

Table 12.5A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
SPURS12	KC10	087	300	170	REFUEL
SWIFT66	B52	087	300	170	REFUEL
N84CR	C182	086	147	30	A-MLC
LN45T	LR35	345	400	145	A-MLC
COA35	B737	087	420	150	OVER
N496B	PASE	084	170	90	D-MIO
N52PB	C177	167	70	4	A-MIO

Selective Notations from 5 Minute Freeze

There is a little weather out there, but we will wait to see how the pilots react to it. It is on the Tulsa primary arrival route.

COA35 has a VFR that needs to be issues.

45T is climbing nicely to 23,000.

SPURS12 and 66 are already handed off.

FIRST: VFR to COA35.

Selective Notations from 5-10 Minute Sequence

6:44 LN45T: 45T got level at 23,000 without the handoff being completed...wait for the handoff and ship him immediately. Everything else looks normal.

7:25 Just checking for anything new. Nothing at all.

8:20 AAL15: AAL15 going out BOLD1, then turning to Fort Smith. I was thinking of short cutting him, but with the weather there is nc reason to.

9:14 Watching the whole scope. There are no conflicts, and nothing to worry about.

9:53 ELDER87 and LINDA34: Looking at the routing for ELDER87 and LINDA34, trying to see where there will be any sort of problem.

Table 12.5B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN45T	LR35	347	400	290	A-MLC
N496B	PASE	084	170	90	D-MIO
N52PB	C177	067	150	44	A-MIO
AAL15	B727	068	287	97	A-TUL
LINDA34	F4	170	430	160	OVER
ELDER87	B52	249	410	160	OVER

Selective Notations from 10 Minute Freeze

Relatively quiet. 84CR is climbing out of 7,100

COA35 is still Eastbound. No factor.

ELDER and LINDA have been handed off, and we can decide where there will be a problem if at all. Possibly climb the ELDER to 18,000 when he gets in my airspace.

Selective Notations from 10-15 Minute Sequence

10:10 ELDER87 and LINDA34: Watching ELDER87 and LINDA34 to decide who is going to end up in the airspace first.

11:23 AAL15: He is already handed off, and I will be shipped as soon as he leaves 18,000.

12:07 AAL15: Checking his altitude. So at 18,000, he will be shipped.

12:37 N84CR: Making sure he is close enough to the border so his data block will not time out.

13:41 LINDA34: (Sent to 18,000) That problem is resolved. No longer a factor.

13:56 DAL15, AAL52, and COA65: Starting to formulate a plan (on Tulsa arrivals)...

14:47 DAL15: He might be a slight problem.

Table 12.5C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
DAL15	B727	192	410	240	D-TUL
AAL52	B727	194	420	220	D-TUL
COA65	MD80	255	410	240	D-TUL
LN45T	LR35	028	400	290	A-MLC

Selective Notations from 15 Minute Freeze

96B need to change him to an non-transponder AC so that computer will continue to track accurately.

LINDA and ELDER, the problem has been resolved.

AAL52 will not be a factor with AAL15, I don't believe.

Start formulating a plan. DAL15 and AAL52 can be shortcutted in front of the weather, and COA65 may want to go South around the weather, in which case he would be third.

FIRST: Enter the proper code for 96B.

Selective Notations from 15-20 Minute Sequence

16:37 AAL52 and DAL15: Making sure it did not blow the separation between AAL52 and DAL15. Looks fine.

17:20 DAL15, AAL52, and COA65: Running out the vectors to see the spacing between the COA65 and AAL52. Looks like COA65 should be out in front about 5 miles. DAL15 snould be out in front 8 to 10 miles.

18:57 COA65, LINDA34, and AAL52: the COA65 and the LINDA34 problem has been solved. Not a factor...and AAL52 is falling right into the sequence as is COA65.

19:35 Looks like handoffs to Tulsa, and more handoffs...and separate some data blocks.

Selective Protocol Analysis for A04, SPS 7A

Table 4.7A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	142	380	100	D-MIO
AWE43	DC9	068	258	65	A-TUL
N368LL	PASE	252	200	100	D-MIO
COA23	B727	197	410	240	D-TUL
DAL42	B747	289	430	240	D-TUL
NWA20	DC10	197	440	247	D-TUL

Selective Notations from 5 Minute Freeze

More Tulsa inbounds. Don't see any conflicts yet.

Selective Notations from 5-10 Minute Sequence

5:31 LN444 inbound for MIO. Clear him

6:29 DAL42, NWA20, and COA23: Trying to decide who is going to be first into Tulsa. Looks like COA, NWA, and then DAL. Based on the distance to the airport.

7:24 EK cancelled IFR. He is no longer a problem.

8:21 TWA71: He is off.

9:09 NWA20: Slow him down to get some more spacing.

9:18 COA23 and NWA20: COA is out of 19,000. So I can start NWA20 to 19,000. I don't quite have my five miles of separation.

Table 4.7B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	179	139	21	D-MIO
AWE43	DC9	068	420	145	A-TUL
N368LL	PASE	253	200	100	D-MIO
COA23	B727	196	410	160	D-TUL
DAL42	B747	292	430	179	D-TUL
NWA20	DC10	195	353	221	D-TUL
TWA71	DC10	068	391	115	A-TUL

Selective Notations from 10 Minute Freeze

Sequencing the three aircraft into Tulsa. Making sure that TWA71 and AWE43 clears them.

DAL would be number 1, with the speed he has. The other two are basically tied.....

Selective Notations from 10-15 Minute Sequence

10:18 AWE43: He is at 23,000, so I will hand him off.

10:50 N368LL: He is landing MIO, so I am starting him down.

11:03 DAL42, NWA20, and COA23: Might be a little tight, so I am going to stop DAL42 at 13,000, above the other two.

11:18 DAL42, NWA20, and COA23: NWA is behind COA and is slowed to 250, so their spacing will increase. So NWA cannot catch COA, and DAL is in front of them.

11:44 HOMIN10: He wants to hold at Tulsa.

12:13 Concentrating on the three Tulsa inbounds.

12:27 NWA20 and COA23: I am checking on the spacing. I need to get NWA20 turned so that he will fall in behind COA.

14:04 DAL42, NWA20, and COA23: Will set all three of them flashing.

Table 4.7C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
HOMIN10	A7	307	348	210	OVER
YANKE79	F14	087	480	210	
COA23	B727	280	295	110	D-TUL
DAL42	B747	288	295	110	D-TUL
NWA20	DC10	225	300	120	D-TUL
TWA71	DC10	027	430	230	A-TUL
R12429	U21	331	250	58	D-MLC

Selective Notations from 15 Minute Freeze

I am all caught up. The spacing into Tulsa is working fine.

The ARMY is descending, I will clear him for an approach in a while.

N368LL I will clear him for approach, and OSAGE is gone.

Selective Notations from 15-20 Minute Sequence

17:06 N464KK: He would be a concern if I did not know that they were going to descend the inbounds.

17:53 R12429: I cancelled radar service on ARMY at MLC tower.

18:17 YANKE79 to Memphis Center.

Selective Protocol Analysis for A06, SPS 7A

Table 6.7A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	142	380	100	D-MIO
AWE43	DC9	068	258	65	A-TUL
N368LL	PASE	252	200	100	D-MIO
COA23	B727	197	410	240	D-TUL
DAL42	B747	289	430	240	D-TUL
NWA20	DC10	197	440	247	D-TUL

Selective Notations from 5 Minute Freeze

COA23 is probably number one, he should be out in front. By turning AWE to the North, I can turn COA to the West.

HOMIN10 is no problem at 21,00 right now.

FIRST: Get LN444 down to 4,000

Selective Notations from 5-10 Minute Sequence

6:23 NWA20, DAL42 and COA23: DAL42 us way out in front based on the vector lines. So I will make DAL first, and vector COA and NWA to the South.

8:14 DAL42 and COA23: I am still going to make the DAL one, and put the COA over here.

8:34 NWA20 and COA23: I am going to vector NWA to the outside and behind COA.

9:08 N368LL: He is on his way down to 5,000. I will not give him holding until I see how it works out.

9:20 NWA20: I turned the NWA way to the South to get him out of the way.

Table 6.7B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	272	212	40	D-MIO
AWE43	DC9	058	420	189	A-TUL
N368LL	PASE	253	200	89	D-MIO
COA23	B727	180	410	200	D-TUL
DAL42	B747	293	354	196	D-TUL
NWA20	DC10	160	440	240	D-TUL
TWA71	DC10	068	384	100	A-TUL

Selective Notations from 10 Minute Freeze

LN444 is holding at 4,000 and N374LJ is climbing to 3,000. I cannot go any higher because I do not have radar separation with LN444. I will vector him 160, so he can get away from traffic. Once I have separation, I will let him go.

This situation is working pretty good. I will turn the COA back in a bit, and he will fall right in behind the DAL. The NWA is at 160, so I can bring him back to 180. All the time I am gaining room.

No factor on TWA71 going to 23,000. May have to coordinate lower altitude under N374LJ who has also requested 23,000. I will probably stop the TWA at 21,000.

Need to find out where OSAGE22 is going.

Selective Notations from 10-15 Minute Sequence

10:12 DAL42 and COA23: COA and DAL, vector COA to tighten that up a bit.

10:50 AWE43: Hand off AWE43 to the high side. That takes care of him.

11:22 Tulsa inbounds look pretty good. Just let them go.

12:36 TWA71: The coordination has been made with TWA71

13:21 R12429: I know ARMY is landing. No problem with that.

13:44 HOMIN10: He is holding, so no problem with that.

13:47 NWA20, DAL42 and COA23: I am doing the handoffs on DAL and COA...I started with the tail end (NWA) to reduce the airspeed so he won't catch DAL and COA. I will wait a few minutes and then reduce COA, and then DAL, in reverse fashion.

Table 6.7C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
HOMIN10	A7	317	348	210	OVER
YANKE79	F14	087	480	210	
COA23	B727	286	410	110	D-TUL
DAL42	B747	287	295	110	D-TUL
NWA20	DC10	286	352	138	D-TUL
TWA71	DC10	027	429	210	A-TUL
R12429	U21	331	250	100	D-MLC

Selective Notations from 15 Minute Freeze

Because I was explaining to you, I got carried away. I can climb TWA to 23,000.

ARMY is no problem.

HOMIN10 is holding at 21,000.

END OF PROBLEM

Selective Protocol Analysis for A10, SPS 7A

Table 10.7A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	142	380	100	D-MIO
AWE43	DC9	068	258	65	A-TUL
N368LL	PASE	252	200	100	D-MIO
COA23	B727	197	410	240	D-TUL
DAL42	B747	289	430	240	D-TUL
NWA20	DC10	197	440	247	D-TUL

Selective Notations from 5 Minute Freeze

Have the handoff on AWE43 going to St. Louise. Will have to climb him to 23,000.

Will have to pass the inbound to MIO on LN444.

Take the handoff on COA23...and the handoff shortly on NWA20.

N368LL, I will have to give MIO radio all three of these inbounds at the same time.

FIRST: Talk to Memphis and get control of COA23 and NWA20 to get something going with spacing. We will have to see what their airspeeds are.

Selective Notations from 5-10 Minute Sequence

5:14 NWA20 and DAL42: I just took the handoff on NWA20 and DAL42. Also this is going to be my spacing problem into Tulsa.

Table 10.7B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	333	209	30	D-MIO
AWE43	DC9	068	419	150	A-TUL
N368LL	PASE	253	200	100	D-MIO
COA23	B727	205	410	160	D-TUL
DAL42	B747	292	432	230	D-TUL
NWA20	DC10	195	432	230	D-TUL
TWA71	DC10	068	430	100	A-TUL

Selective Notations from 10 Minute Freeze

When you are busy, you don't need a VFR, so let him stay VFR.

DAL42 is number one, followed by COA23, and then NWA20 as number 3.

Going into MIO, I am going to start 121EK to 5,000 and 368LL number 3.

OSAGE22, I can hand him off.

May be a problem with HOMIN10 and YANKE79. They are both at 21,000. May have to change altitude on them.

The spacing on Tulsa inbounds may work out. HOMIN10 is coming down this way, and I have all of them underneath him.

I am concerned about the inbounds to MIO. I have to hand AWE43 to Memphis Center.

TWA71, here is a trap. He is headed for Springfield, not being familiar with the area, he may have to be descended.

FIRST: I will stop TWA71 at 17,000. And start 121EK down to 5,000.

Selective Notations from 10-15 Minute Sequence

10:55 COA23 and DAL42: Vectored COA and reduced to 270, to improve his separation with DAL42.

12:05 DAL42: Reduced DAL42 to 250 for approach.

13:15 NWA20: Stopped NWA at 12,000 for insurance. The separation was a little close.

14:20 NWA20: Turned NWA20 too soon, will have to vector him South and bring him back.

Table 10.7C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
HOMIN10	A7	346	348	210	OVER
YANKE79	F14	087	480	210	
COA23	B727	287	410	110	D-TUL
DAL42	B747	076	302	119	D-TUL
NWA20	DC10	286	360	120	D-TUL
TWA71	DC10	027	430	185	A-TUL
R12429	U21	331	250	89	D-MLC

Selective Notations from 15 Minute Freeze

Need to clear R12429 for VOR approach, and switch him over to the tower.

In a little, I need to turn NWA20 and have him intercept the 105 radial.

HOMIN10 is holding so I don't have to worry about that.

Get rid of TWA71.

FIRST: Pull COA23 to 250, and clear ARMY for the approach. 121EK cannot be cleared for approach until I get a cancellation on LN444.

Selective Notations from 15-20 Minute Sequence

17:09 Seeing how it is all working.

17:38 N368LL: 121EK has been cleared for approach, and N368LL is cleared to hold at 4,000.

18:09 NWA20: NWA20 need to switch him over and call out his VFR traffic.

19:06 Looks like it is almost over...Are we still going now.

Selective Protocol Analysis for A11, SPS 7A

Table 11.7A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	142	380	100	D-MIO
AWE43	DC9	068	258	65	A-TUL
N368LL	PASE	252	200	100	D-MIO
COA23	B727	197	410	240	D-TUL
DAL42	B747	289	430	240	D-TUL
NWA20	DC10	197	440	247	D-TUL

Selective Notations from 5 Minute Freeze

Biggest concern is getting the airlines into Tulsa. Get AWE climbing. Then get the COA down using radar separation.

FIRST: AWE43 is already climbing to 23,000, so LN444 into MIO, starting him down.

Selective Notations from 5-10 Minute Sequence

5:12 Just got a handoff NWA20 landing Tulsa...COA already, then we have the DAL from the Southeast. So your biggest concern is getting your landing sequence, with AWE coming out.

6:00 Right now the sequence will be COA, NWA, and then DAL. That could change, no big thing.

6:30 Get the LN down, and then the 121EK is landing MIO. The 368LL landing MIO also. Looks like 121EK will be number 2.

6:51 That takes that out of the problem (121EK cancelling IFR). So no problem there...So the only thing you have to worry about MIO now is the 68LL coming in.

7:02 Looks like our AWE is not climbing very fast, so... we will get the COA23 started down.

7:33 We will get the AWE handed off to the high altitude sector, no problem...if it looks like a problem between COA23 and AWE43, we can work with high sector and get them going. Should be no problem.

7:58 NWA20 reduced to 250 because it is a DC10 filed 30 knots faster than the COA. Normally NWA would reduce their speed when descending, because that is how they descend their planes.

8:45 Take the 68LL down to 4,000 landing MIO. Just to get him lined up when the LN444 cancels.

8:53 Another Tulsa departure, TWA71.

9:15 Soon as the LN gets down, we will have no problem there.

9:54 The reason for "leaving 11,000: is to get him out of the Tulsa Control airspace before you doing any turning.

Table 11.7B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	333	209	30	D-MIO
AWE43	DC9	068	419	150	A-TUL
N368LL	PASE	253	200	100	D-MIO
COA23	B727	205	410	160	D-TUL
DAL42	B747	292	432	230	D-TUL
NWA20	DC10	195	432	230	D-TUL
TWA71	DC10	068	430	100	A-TUL

Selective Notations from 10 Minute Freeze

AWE43 is on top of everyone, so he is no problem. The TWA vectored for Springfield. He is no problem.

The COA23, is ahead of the DAL. He has about 5 miles on him. I should have looked before slowing him, but keeping his speed up now will reduce the DAL. Right now the sequence will be COA, DAL, and NWA.

YANKE79 is an overflight, he is no problem. HOMIN10 is no problem. It could be a problem if you are not paying attention. It should be watched. Any time you have 2 AC at the same altitude, there is always a chance...

FIRST: Get the altitude down for the DAL, and going to 12,000 for the COA.

Selective Notations from 10-15 Minute Sequence (Times are off in this segment)

10:05 Put the altitude of 12,000 on the DAL. He is back to 250. The sequence will be COA, DAL, and NWA.

10:20 AWE is out of the way...Take the route on TWA, direct Springfield...He is going to stay at 23,000 so no problems. AWE out of 24,000. He is gone.

11:20 HOMIN10 is going to hold, so he will not be a problem with YANKE79.

11:28 COA is going to be number 1. He has his speed up. Looks like we should have about a 10 mile hole between COA and NWA to put the DAL jet into.

11:44 LN is still messing around at 2200 at MIO. Will have to put 68LL to hold.

12:11 COA still has the 250 at 11,000, The DAL is going to 12,000. If he does not hurry with descent, we will have to have rapid descent with Tulsa approach...

12:40 The OSAGE22, just confirm where he is going. A little early handoff on him. No problem.

12:55 HOMIN10 is about to enter the hold at Tulsa.

13:16 R12429: Cleared for approach. No one in his way, so he can just go on in there, no problem.

13:29 Putting the altitude limit on ARMY.

13:46 Still trying to get the DAL slowed down.

14:02 Talked to Tulsa approach. DAL is going to be a little high at the gate. Is is just out of 14,00. Speed is working, should be no problem. As soon as we get ready, we will dump him on to 11,000 and on over to approach control.

Table 11.7C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
HOMIN10	A7	346	348	210	OVER
YANKE79	F14	087	480	210	
COA23	B727	287	410	110	D-TUL
DAL42	B747	076	302	119	D-TUL
NWA20	DC10	286	360	120	D-TUL
TWA71	DC10	027	430	185	A-TUL
R12429	U21	331	250	89	D-MLC

Selective Notations from 15 Minute Freeze

The DAL is the biggest concern.

The LN looks like he might have missed his approach because he is past the VOR. The ARMY is on the way to his approach. No problem. HOMIN10 has entered a hold.

FIRST: Give the DAL 11,000 into the Tulsa approach.

Selective Notations from 15-20 Minute Sequence

15:55 We can give the MIO approach to the 368LL, now that LN has canceled. As soon as he is down. The LR, if he had been out a little further, we could have gotten the Falcon jet out with no problem. Since he is so close, we won't worry about it.

16:31 Got all the Tulsa inbounds taken care of. YANKE79 is still going along, no problem. TWA71 we will handoff to Memphis Center.

16:42 230, he is not hurting anyone. OSAGE22, is already handed off, we can ship him.

17:09 TWA71 is gone. OSAGE22 is gone. HOMIN10 is holding at 21,000.

17:16 464KK is not hurting anyone at 11,000. If any arrivals, you would have to watch. You may have to send lower reference that traffic.

18:10 ARMY is cleared for the approach at 2200, no problem there.

18:39 See some limited datablocks coming in from the East and Northeast. So you have a couple of inbounds coming. They may be tied at the gate.

Selective Protocol Analysis for A12, SPS 7A

Table 12.7A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	142	380	100	D-MIO
AWE43	DC9	068	258	65	A-TUL
N368LL	PASE	252	200	100	D-MIO
COA23	B727	197	410	240	D-TUL
DAL42	B747	289	430	240	D-TUL
NWA20	DC10	197	440	247	D-TUL

Selective Notations from 5 Minute Freeze

HOMIN10 may be in conflict with YANKE79.

LN444 is in the airspace at 10,000. He will require priority handling into MIO. I will vector him to the VOR, down to 3,000.

AWE43 is a departure FL 23,000.

COA23 is not a problem, but there is an arrival right behind him.

N368LL and EK are both landing at MIO. Because of traffic, it is easist to put them in a hold and spin them down from there.

FIRST: Vector LN and down to 2,200.

Selective Notations from 5-10 Minute Sequence

5:30 Two handoffs, NWA and DAL. There is an overtake situation (NWA and COA), but it is the sector's responsibility to make sure that there is 5 miles separation (assigns speeds as follows NWA 250, COA 310).

7:37 Take the handoff on TWA, see which way he is going. Going to Springfield, should not be a factor.

7:44 LN is coming down fine.

8:11 Looking at how the speeds are working with NWA and COA (descends NWA to 15,000).

8:26 Take the handoff on YANKE79. He may be a problem with HOMIN10. Watch that one.

8:51 Vector AWE43 to keep him West of the departures.

9:31 Short cutting the COA and putting him ahead of DAL (a vector to the arrival).

9:54 DAL is not looking good with COA. I will have to slow him down (250).

Table 12.7B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	333	209	30	D-MIO
AWE43	DC9	068	419	150	A-TUL
N368LL	PASE	253	200	100	D-MIO
COA23	B727	205	410	160	D-TUL
DAL42	B747	292	432	230	D-TUL
NWA20	DC10	195	432	230	D-TUL
TWA71	DC10	068	430	100	A-TUL

Selective Notations from 10 Minute Freeze

It's hectic, but no problems. Next thing we are going to do is give 250 to DAL. The 20 degree turn on COA should provide about 3 additional miles. Right now I am a couple of mile short. I have altitude separation on these three to get an extra margin of safety for separation.

YANKE79 and HOMIN10 do not look like they will be a problem.

AWE and TWA are looking fine.

LN can go Eastbound.

There are a lot of things that are going to take place in a short period of time, but it does not look that bad.

FIRST: Slow the DAL to 250.

Selective Notations from 10-15 Minute Sequence

10:05 AWE43 is close to the next airspace. I ca[illegible] hand him off.

10:39 The LN is fine, no problems.

10:58 Looking at LN444 to see how he is in relation to the final approach: how close he is and how soon I need to make the turn.

11:09 Looking at the COA. I will have to be reducing him very shortly. The DAL and how that vector is working and how NWA is coming down. I can give 14,000 to him now.

12:18 COA is slowed down (250).

13:45 I see I did not make the handoff on COA in a timely manner.

14:32 Make a handoff on the OSAGE22.

Table 12.7C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
HOMIN10	A7	346	348	210	OVER
YANKE79	F14	087	480	210	
COA23	B727	287	410	110	D-TUL
DAL42	B747	076	302	119	D-TUL
NWA20	DC10	286	360	120	D-TUL
TWA71	DC10	027	430	185	A-TUL
R12429	U21	331	250	89	D-MLC

Selective Notations from 15 Minute Freeze

COA has been shipped. DAL is down to 11,000, at good speed going direct Tulsa. I can ship him at this time. NWA can go to 11,000. Has not been done yet.

LN, I am waiting on a cancellation. 8LL is on a Southbound heading. A little change on the original plan. I am going to run 8LL right on in.

HOMIN10, I made a mistake and put 4,000 in his data block. Other than that, all normal.

FIRST: Flash OSAGE22 to KS Center.

Selective Notations from 15-20 Minute Sequence

15:28 Making an overall assessment of the sector. Watching 4KK, to make sure that approach gets DAL and NWA out of their altitudes in a timely manner.

15:53 Make the handoff on NWA.

17:03 It was not anticipated that LN would turn. Would expect him to go straight in. NWA is not a factor.

19:32 See how the ARMY is coming down. See if I need to turn him.

Systematic Grammar Network for A04, SPS 2A

Display Strategies

Planning strategies:

- 2 High-level, primary plan
- 1 Lower-level plan
- 1 Backup plan
- 1 Refine primary plan
- 1 Short-term contingencies

Monitoring Strategies:

- 4 Observing separation
- 3 Observe to vector
- 1 Observing for sequencing
- 1 Observe to implement backup
- 1 Gather aircraft data

Control Strategies

4 Sequencing strategies (high-level between 3 or more aircraft)

Separation strategies (lower-level between 2 aircraft):

- 2 Use speed for separation
- 2 Vector for separation

1 Approach strategies (descend and slow)

1 Routing strategies

Handoff strategies:

- 1 Initiating handoff

Workload Reduction Strategies

- 2 [illegible] speed take affect
- 1 Tighten separation
- 1 Speed up to expedite
- 1 Letting aircraft run at speed
- 1 Early control

Systematic Grammar Network for A06, SPS 2A

Display Strategies

Planning strategies:

- 2 Lower-level plan
- 2 High-level, primary plan
- 2 Anticipating changes
- 1 Refine primary plan
- 1 Estimating (speed, distance...)
- 1 Backup plan

Monitoring Strategies:

- 4 Observe to vector
- 3 Observing separation
- 2 Observing for sequencing
- 2 Gather aircraft data
- 1 Use of J-Ball

Control Strategies

- 1 Approach strategies (descend and slow)
- 2 Sequencing strategies (high-level between 3 or more aircraft)
- Separation strategies (lower-level between 2 aircraft):
  - 2 Use speed for separation
  - 2 Performance strategies
- 3 Routing strategies
- Handoff strategies:
  - 1 Initiating handoff

Workload Reduction Strategies

- 3 Eliminating a factor
- 2 Speed up to expedite

Systematic Grammar Network for A10, SPS 2A

Display Strategies

Planning strategies:

4 Lower-level plan
2 High-level, primary plan
1 Refine primary plan
1 Backup plan
1 Anticipating changes

Monitoring Strategies:

4 Observing separation
2 Observing for sequencing
2 Observe to vector
2 Gather aircraft data
1 Reading vectors
1 Observe to implement backup

Control Strategies

3 Sequencing strategies (high-level between 3 or more aircraft)
2 Routing strategies
1 Approach strategies (descend and slow)

Handoff strategies:

1 Accepting handoff

Workload Reduction Strategies

1 Early pilot notification
1 Letting aircraft run at speed
1 Letting speed take effect

Systematic Grammar Network for A11, SPS 2A

Display Strategies

Planning strategies:

- 2 Lower-level plan
- 1 Refine primary plan
- 1 High-level, primary plan
- 1 Backup plan
- 1 Anticipating changes

Monitoring Strategies:

- 5 Observing separation
- 4 Gather aircraft data
- 2 Observing for sequencing
- 1 Reading vectors

Control Strategies

1 Approach strategies (descend and slow)
3 Sequencing strategies (high-level between 3 or more aircraft)
Separation strategies (lower-level between 2 aircraft):

- 2 Performance strategies
- 1 Vertical separation
- 1 Vector for separation
- 1 Use speed for separation

1 Routing strategies

Handoff strategies:

- 1 Initiating handoff
- 1 Accepting handoff

Workload Reduction Strategies

- 1 Early control
- 1 Letting aircraft run at speed
- 1 Letting speed take effect
- 1 Shortcutting
- 1 Tighten separation

Systematic Grammar Network for A12, SPS 2A

Display Strategies

Planning strategies:

- 4 Refine primary plan
- 3 High-level, primary plan
- 2 Estimating (speed, distance...)
- 1 Lower-level plan
- 1 Anticipating changes

Monitoring Strategies:

- 5 Observing separation
- 3 Observing for sequencing
- 2 Gather aircraft data
- 1 Reading vectors

Control Strategies

- 3 Approach strategies (descend and slow)
- 5 Sequencing strategies (high-level between 3 or more aircraft)

Separation strategies (lower-level between 2 aircraft):

- 5 Use speed for separation

Workload Reduction Strategies

- 2 Eliminating a factor
- 1 Early control
- 1 Letting speed take effect
- 1 Slowing to intermediate speeds
- 1 Speed up to expedite

Combined Systematic Grammar Network for Experts on SPS 2A

Display Strategies

Planning strategies:

- 10 Lower-level plan
- 10 High-level, primary plan
- 8 Refine primary plan
- 5 Anticipating changes
- 4 Backup plan
- 3 Estimating (speed, distance...)
- 1 Short-term contingencies

Monitoring Strategies:

- 21 Observing separation
- 11 Gather aircraft data
- 10 Observing for sequencing
- 9 Observe to vector
- 3 Reading vectors
- 2 Observe to implement backup
- 1 Use of J-Ball

Control Strategies

7 Approach strategies (descend and slow)

15 Sequencing strategies (high-level between 3 or more aircraft)

Separation strategies (lower-level between 2 aircraft):

- 10 Use speed for separation
- 4 Performance strategies
- 3 Vector for separation
- 1 Vertical separation

7 Routing strategies

Handoff strategies:

- 3 Initiating handoff
- 2 Accepting handoff

Workload Reduction Strategies

- 5 Letting speed take affect
- 5 Eliminating a factor
- 4 Speed up to expedite
- 3 Letting aircraft run at speed
- 3 Early control
- 2 Tighten separation
- 1 Slowing to intermediate speeds
- 1 Shortcutting
- 1 Early pilot notification

APPENDIX I:

PRODUCTIONS FROM ANALYSIS OF DYSIM STRUCTURED PROBLEM SOLVING: INTERMEDIATE GROUP

Selective Protocol Analysis for A13, SPS 1A

Table 13.1A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N8677L	MO22	140	180	110	D-MIO
N345AP	PAZT	252	190	120	D-MIO
A49616	LR35	039	420	150	D-MLC
R16391	C12	085	210	110	D-MLC
N292BC	G2	?	?	?	D-MLC

Selective Transcript of 5 Minute Freeze

What I have, I see first off that I have two aircraft inbound to McAlister...
So already I am formulating some type of game-plan that I am going to utilize to get these aircraft into the airport with the least amount of delay to the second aircraft....

Initially as as I see that A49616 is approaching McAlister from the Southwest, I am going to vector him to the localizer for an ILS approach. Which will benefit the pilot, it will get him in sooner. It will help me so I can get him on the ground so that it will be that much easier to clear the second aircraft for approach.

As I look at the next aircraft and Aztec. N345AP, inbound to Miami, no real problem. I just know that I am going to have to issue him an approach clearance. Right now their is no traffic for him, I am not really concerned with him..........

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I've got proposals off all the airports, but you never know when they are going to take off, so I don't concern myself with them until they are active traffic...

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N8677L also inbound to Miami. Looks like he is basically tied with N345AP into Miami, so it looks like someone is probably going to have to hold until the first aircraft is able to land.

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First thing I am going to do is A49616 give him an initial vector toward the localizer.

Selective Transcript of 5-10 Minute Sequence

5:45 Right now my priority is to get the A616 altitude down for his approach, A49616. That is why I ignored the VFR pilot, issued the control instruction to A616. VFR, low priority, I will get back to the VFR aircraft as soon as I am able...

7:40 Okay, situation has developed, N292BC just check on frequency, also landing at McAlister...My plan it to also vector him for the ILS approach in order to facilitate his being able to get in without having to hold or wait any undue length of time...

8:22 The first aircraft, N345AP...

9:30 Okay, departure off of Tulsa...going to Atlanta. As I take the handoff, I see one potential traffic, VM6E22, opposite direction flight level 180, my initial plan are to climb TWA65 17000 until I have established lateral separation and then continue to climb...

Table 13.1B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N345AP	PAZT	253	190	120	D-MIO
R16391	C12	085	210	110	D-MLC
N292BC	G2	240	420	220	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	178	209	17	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	282	250	26	A-TUL
TWA67	DC10	000	0	0	A-TUL

Selective Transcript of 10 Minute Freeze

What I am thinking initially here is once I get TWA65 in one of my own altitudes of sending him directly to Fort Smith which will separate him from VM6E22 a little bit sooner...

I am looking at N345AP, my first inbound to Miami. I think I am going to start that aircraft down for his approach to Miami...

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My planned next move for TWA65, once he gets out of 1100, I am going to send him direct to Fort Smith. That way it won't be a direct opposite direction with MV6E22 and since the pilot is on course a little sooner it will help insure separation a little sooner between those two.

Selective Transcript of 10-15 Minute Sequence

10:18 TWA65, I am putting a J-Ball on his target so as soon as he is separated from MV6E22, I will climb him to altitude...

11:53 Stopping the aircraft at 17,000, TWA67 stopped at 17,000 due to opposite direction traffic, MV6E22...

Table 13.1C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
R16391	C12	085	210	110	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	209	70	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	089	420	170	A-TUL
TWA67	DC10	068	390	115	A-TUL

Selective Transcript of 15 Minute Freeze

TWA67 requested vectors for Springfield, I told TWA67 to stand by, !n my mind, the priority now was N128E who had been held at a lower altitude...was now clear with N345AP, the inbound to Miami, so I cleared N128E to climb to requested altitude..and I issued the approach clearance to N345AP I just wanted him to start his descent sooner so that he would not have any difficulty for his approach into Miami.

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TWA67, I will work on giving him his heading towards Springfield.

Selective Transcript of 15-20 Minute Sequence

15:35 TWA65 is clear of the MV6E22 I climbed him to flight level 230 which is the top of my altitude, flashed to the high side. The high-side will continue his climb.

16:12 TWA67 is now clear of MV6E22 so I am climbing him to flight level 230 to the top of my altitude, and flashing the aircraft to the high-side....

17:45 TWA67, I am going to give to the high-side...

18:19 N413F requested higher altitude opposite traffic VM6E22, 1000 feet above, Obviously I am not going to climb him until he is clear....

Selective Protocol Analysis for A14, SPS 1A

Table 14.1A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N8677L	MO22	140	180	110	D-MIO
N345AP	PAZT	252	190	120	D-MIO
A49616	LR35	039	420	150	D-MLC
R16391	C12	085	210	110	D-MLC
N292BC	G2	?	?	?	D-MLC

Selective Notations from 5 Minute Freeze

A49616 and R16391: Speed things up by vectoring A49616 for ILS. Possibly avoid some holding.

FIRST: Descend A49616 and vector for ILS

Selective Notations from 5-10 Minute Sequence

5:44 N345AP and N8677L: Looking at vector lines, AP will get to MIO before 77L. Need to get 5AP below 77L and get his approach started.

6:43 N292BC and A49616: N292BC is another MLC arrival. Get him down and then trail with A616

6:56 A49616: Heading not good, so turn him 20 degrees to right.

9:47 N292BC and R16391: 2BC is faster than 391. Take 2BC in first, and vector him to ILS to expedite landing.

Table 14.1B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N345AP	PAZT	253	190	95	D-MIO
R16391	C12	085	210	110	D-MLC
N292BC	G2	272	420	220	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	209	25	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	291	259	30	A-TUL
TWA67	DC10	000	0	0	A-TUL

Selective Notation from 10 Minute Freeze

N345AP and N128E: Descend 5AP to 7,000 relative to 128E, ascending to 6,000 out of MIO.

N292BC: Needs to be vectored left and down to get him strait on to ILS.

Selective Notation from 10-15 Minute Sequence

10:50 TWA65 and VM6E22: Check TWA65 to determine if there is a conflict with E22.

11:09 N345AP and N128E: 5AP and 28E are tail to tail. Clear 5AP for approach.

11:45 N3688U and N128E: Stopped 88U at 5,000 and 28E at 6,000.

12:31 N345AP and N3688U: Use J-Ball to see when can drop 5AP for approach. Get 88U to the West before dropping 5AP.

13:46 TWA65 and TWA67: TWA65 and 67 stuck below 6E22. 128E passed traffic, and clear to 15,000.

14:20 TWA67: Don't have time for TWA67. Vector him to Springfield.

14:51 TWA65: TWA65 by VM6E22, can climb him now.

Table 14.1C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
R16391	C12	085	210	110	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	209	70	A-MIO
N3688U	BE33	273	163	29	A-MIO
TWA65	A300	068	419	136	A-TUL
TWA67	DC10	068	457	126	A-TUL

Selective Notation from 15 Minute Freeze

N292BC: N292BC is 20 minutes to localizer. I will vector him in.

N345AP and N3688U: Descend 5AP as soon as he can stay behind 88U.

Got everything stopped vertically.

Selective Notation from 15-20 Minute Sequence

15:29 R16391: Vector ARMY for ILS to keep him from having to go to VORTAC and holding.

15:45 TWA67 and TWA65: Can climb TWA67, but he is overtaking TWA65. They should diverge: potential problem.

16:05 TWA67: TWA67 vector right, direct for Springfield.

16:28 TWA67 and TWA65: TWA67 and TWA65 healthy overtake with 1,000 feet.

Selective Protocol Analysis for A15, SPS 1A

Table 15.1A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N8677L	MO22	140	180	110	D-MIO
N345AP	PAZT	252	190	120	D-MIO
A49616	LR35	039	420	150	D-MLC
R16391	C12	085	210	110	D-MLC
N292BC	G2	?	?	?	D-MLC

Selective Notations from 5 Minute Freeze

R16391: Army will have to be issued a hold.

N345AP: 5AP needs to be descended down since there is an aircraft right behind him.

First Thing: Clear A49616

Selective Notations from 5-10 Minute Sequence

8:00 N345AP: Just putting him in.

Not much time to verbalize

Table 15.1B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N8677L	MO22	141	180	110	D-MIO
N345AP	PAZT	253	190	90	D-MIO
R16391	C12	085	210	110	D-MLC
N292BC	G2	272	420	165	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	209	24	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	283	259	29	A-TUL
TWA67	DC10	000	0	0	A-TUL

Selective Notation from 10 Minute Freeze

N292BC and R16391: Both into MLC, descend 2BC to 10,000 to get him under 391.

N128E and N345AP: Ascend 128E up to 3,000 and descend 5AP to 4,000...Change AP back to 7,000 and 128E to 6,000.

Selective Notation from 10-15 Minute Sequence

11:53 N8677L, N345AP, & N128E: 77L another into MIO. 5AP first, then 77L and can't clear 5AP until cleared 128E.

12:07 TWA65 and TWA67: TWA67 going out on BOLD1. Problem with speed DC10 vs. Airbus. Approach should have started something... just to make sure...Pick up 65's speed.

12:48 N292BC: Descent 2BC to 4,000

13:48 TWA65 and TWA67: Speeds should work

14:15 A49616 and N292BC: When AF is on the ground, I can clear 2BC for approach.

Table 15.1C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
R16391	C12	085	210	110	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	209	60	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	067	429	170	A-TUL
TWA67	DC10	067	322	132	A-TUL

Selective Notation from 15 Minute Freeze

TWA67: TWA67 heading too extreme. Should have gone more to a 40 heading. 020 heading taking him to KS, Need to correct to 050.

R16391: Issue traffic on ARMY, these two are so slow, I can wait a few minutes.

Selective Notation from 15-20 Minute Sequence

16:36 TWA67: I won't need to re-coordinate heading on TWA67, because I told him "when able, direct to Springfield".

Selective Protocol Analysis for A16, SPS 1A

Table 16.1A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N8677L	MO22	140	180	110	D-MIO
N345AP	PAZT	252	190	120	D-MIO
A49616	LR35	039	420	150	D-MLC
R16391	C12	085	210	110	D-MLC
N292BC	G2	?	?	?	D-MLC

Selective Notations from 5 Minute Freeze

STRIPS: Tulsa departures: DC10 behind the Airbus. DC10 will probably be faster.

A49616 and R16391: A616 and ARMY into MLC. No MLC departures, no concern there at all.

N345AP: 5AP into MIO, set him up for approach.

FIRST: Descend A616 into McAlister.

Selective Notations from 5-10 Minute Sequence

6:53 A49616 and N292BC: 2BC also into MLC. No problem, vector him behind A616.

9:18 N128E and N345AP: 128E coming out of MIO is going to be on top of 5AP. Start 5AP down to 7,000. Wait till he clears, then climb them both.

Table 16.1B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N345AP	PAZT	253	190	120	D-MIO
R16391	C12	085	210	110	D-MLC
N292BC	G2	253	420	218	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	210	24	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	283	175	15	A-TUL
TWA67	DC10	000	0	0	A-TUL

Selective Notation from 10 Minute Freeze

N292BC: Turn him straight down into MLC.

N128E, N8677L, & N345AP: Call traffic (VFR) on 128E and start him up to 9,000. To get 5AP bellow 77L, dump him to 10,000.

Concentrating more on MIO, not working much on MLC.

TWA65: Departure from Tulsa, potential traffic, not much concern.

FIRST: Descend 5AP to 10,000.
Climb 128E to 9,000.
77L hold out of MIO.

Selective Notation from 10-15 Minute Sequence

10:22 N128E and N345AP: As soon as 128E is clear, I will give 5AP the approach clearance.

11:12 N345AP and N3688U: Change of plan. 88U off MIO, so put 5AP on hold.

11:26 TWA65 and VM6E22: TWA65 climb reference NAVY to 16,000.

14:30 TWA65 and VM6E22: TWA65 traffic with E22.

Table 16.1C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
R16391	C12	085	210	110	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	085	210	93	A-MIO
N3688U	BE33	273	187	34	A-MIO
TWA65	A300	069	419	162	A-TUL
TWA67	DC10	068	290	107	A-TUL

Selective Notation from 15 Minute Freeze

N345AP and N3688U: 5AP no longer a factor with 88U. Clear him for approach.

TWA67: Can't exceed 250 at 10,000. Got a lot of room, let them go.

ARMY: Not number 1 priority, may let him do full ILS.

N3688U: Stay at 9,000 because of 77L at 11,000.

FIRST: Assign speeds to TWA65 and 67 and hand off to high altitude.

Selective Notation from 15-20 Minute Sequence

17:17 N8677L and N3688U: Call VFR 77L, and 88U climb to 12,00.

18:17 Soon as they clear, I will go to 19,000.

18:30 N8677L: did not issue holding instructions. I will do it now.

Selective Protocol Analysis for A18, SPS 1A

Table 18.1A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N8677L	MO22	140	180	110	D-MIO
N345AP	PAZT	252	190	120	D-MIO
A49616	LR35	039	420	150	D-MLC
R16391	C12	085	210	110	D-MLC
N292BC	G2	?	?	?	D-MLC

Selective Notations from 5 Minute Freeze

The order into MLC will be: A49616 first, N292BC second, and R16391 third.

There is a concern with the primary traffic to the EAST of MLC

FIRST: Request the type of approach from A616 and head him down to airport or ILS.

Selective Notations from 5-10 Minute Sequence

5:26 A49616: Starting him down and vector to ILS.

6:35 Taking handoff before answering line, because it is more important.

8:09 N128E, N8677L, and N345AP: Cleared 128E to 5,000 to allow other two down (77L and 5AP).

8:28 A49616: I gave A616 a 20 right. He turned 20 left, need to vector.

9:36 N3688U, N8677L, and N345AP: Cleared 88U off from MIO rather than have 2 inbouds come in first (77L & 5AP). Gave them holding instructions. Once I have separation, I will deliver clearance on 88U.

Table 18.1B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
N345AP	PAZT	253	190	105	D-MIO
R16391	C12	085	210	110	D-MLC
N292BC	G2	272	420	220	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	209	35	A-MIO
N3688U	BE33	000	0	0	A-MIO
TWA65	A300	303	259	33	A-TUL
TWA67	DC10	000	0	0	A-TUL

Selective Notation from 10 Minute Freeze

The biggest problem is 2 departing from MIO and 2 inbounds to MIO. Have not issued my holding instructions.

N128E, N345AP, and N3688U: 128E to 5,000. Descend 5AP to 6,000 that will be changed. 5AP will he held because 88U coming out cleared to 5,000.

TWA65 and VM6E22: Climb TWA to 17,000 because E22 at 18,000.

FIRST: Issue holding instructions to 5AP and 77L. They are getting within 4 or 6 minutes of the VOR.

Selective Notation from 10-15 Minute Sequence

11:31 TWA65 and VM6E22: Handoff on TWA65. Clear him to 17,000 because of traffic with E22.

11:42 A49616: A616, got to let him get a little closer.

12:08 TWA65 and TWA67: Have TWA67 handoff. Diverging path with TWA65, should be no problem.

12:29 N8677L and N345AP: Start 77L down to 8,000 relative to AP out of 7,000.

13:38 N292BC and A49616: Vector 2BC behind A616. 10 minute separation.

14:27 N128E and N345AP: 128E is now clear to 5AP. Climb 128E to 15,000.

Table 18.1C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
R16391	C12	085	210	110	D-MLC
VM6E22	F18	259	460	180	OVER
N128E	BE65	087	209	55	A-MIO
N3688U	BE33	178	144	18	A-MIO
TWA65	A300	067	419	170	A-TUL
TWA67	DC10	067	440	101	A-TUL

Selective Notation from 15 Minute Freeze

N8677L and N345AP: 77L and 5AP, holding instructions for main VOR.

N128E: 128E is clear.

TWA65 and VM6E22: TWA65 about clear of E22, in another mile, will climb him.

TWA65 and TWA67: TWA67 is faster in back of TWA65. Because of altitude separation, should not be a problem.

R16391 and N292BC: ARMY should be able to come in behind 2BC and not have to hold.

FIRST: No real priority. Vector ARMY to intercept ILS.

Selective Notation from 15-20 Minute Sequence

16:26 TWA65 and TWA67: I am climbing TWA67, because TWA65 is ahead and 5,000 feet above him.

17:03 N8677L and N345AP: Start 77L down 1000, above 5AP.

17:11 N292BC and A49616: Because A616 wants further vectors, run 2BC through and loop the A616 behind. ARMY is so slow, should not be a factor.

18:04 TWA67 and TWA67: TWA67 is higher, even though there is just 4-5 miles separation, and TWA65 will be turning.

Selective Protocol Analysis for A13, SPS 2A

Table 13.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Transcript of 5 Minute Freeze

Locking just at the strips on the board, time-wise. EAL121 looks like he should be the first aircraft...AAL31 and COA15 are basically tied...coming in from two different directions, so I am thinking I have got to do something here...

Look up ahead, TWA19, UAL59. and DAL143 all 3 time-wise look within 4 minutes....that is so far ahead that I don't really concern myself with is at this point.

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As I look at the display, EAL121 and AAL31 look like they are dead tied. Whereas when I v s initially looking at strips only, EAL121 was 5 minutes out in front, bu as I look at the real situation, that is not true...and I also see I have COA15 looks like he may be fairly close with EAL121 and AAL31. Don't know yet, I will have to wait till I can run out out my vector lines...

Selective Transcript of 5-10 Minute Sequence

5:24 EAL121, COA15, and AAL31: As I run out my vector lines, I see that EAL121 and AAL31 are at dead tie and it appears that COA15 should fall behind....

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND vectors show two air carriers are tied
AND vectors show one air carrier in trail

THEN monitor to establish arrival sequence based on vectors
AND formulate backup plan

5:45 EAL121 and AAL31:So my game-plan between EAL121 and AAL31... EAL121 is already lower, ne is within my own airspace so that I could descend him first and my game-plan is to make him number 1. AAL31, my initial plan to keep the spacing, is to reduce his speed.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has not been established
AND two of the air carriers are tied
AND one of the air carriers is at a lower altitude

THEN establish arrival sequence with lower AC as number 1
AND assign speed reduction to number 2

6:15 EAL121, COA15, and AAL31: EAL121 first, AAL31 second, and COA15 third. That is how I see it at this time.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND if number 3 has not been established
AND number 1 and 2 have been established

THEN establish arrival sequence
AND monitor for spacing

6:46 AAL31 and COA15: My concern about reducing AAL31 speed too soon is... that COA15 will probably catch up that much quicker. So I don't want to reduce the speed too soon.....

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 2 needs a speed reduction
AND speeds have not taken effect

THEN maintain present speed for number 2
AND monitor to assign number 2 a speed reduction

8:58 EAL121, COA15, and AAL31: I am still going to make COA15 number 3 by reducing his airspeed back now. That will allow EAL121 and AAL31 to run out in front of him that much more...

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has been established
AND separation between number 2 and 3 has not been established

THEN assign speed reduction to number 2
AND monitor for spacing

Table 13.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	336	389	210	D-TUL
AAL31	MD80	067	405	240	D-TUL

Selective Transcript of 10 Minute Freeze

... I am not planning on having to vector anyone off course. I am planning on using speed alone to get the spacing that I need. If it does not appear to be working... my plan then would be to vector AAL31 to the right....

I am going to pull COA15 back to 250 knots just so I don't have to worry about it.

Selective Transcript of 10-15 Minute Sequence

10:33 COA15, and AAL31: I am trying to get an idea of where COA15 is going to fall with reference to AAL31...

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has been established
AND number 3 needs to be routed

THEN monitor for spacing
AND monitor to vector for re-routing

10:46 COA15, and AAL31: AAL31 I am going to have to pull the speed back in a moment so that will reduce the spacing I had between AAL31 and COA15...

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing between number 2 and 3 has been established
AND number 2 needs to be slowed

THEN assign number 2 a speed reduction
AND monitor for spacing

11:54 EAL121, COA15, and AAL31: My plan, EAL121, I am going to initially get him to 11,000, AAL31 12, and COA15 13. That will always give me vertical separation. If I have to start vectoring these three aircraft with spacing I will always have the vertical separation...

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has been established
AND spacing is not firmly established

THEN clear the air carriers for descent with number 1 lowest
AND maintain vertical separation

13:46 EAL121 and AAL31: Looking pretty good here, EAL121 he is now about 3.5 miles out in front of AAL31. Should not have any difficulty getting 5 miles.....

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing spacing has not been established between 1 and 2
AND speeds are taking effect

THEN monitor for spacing
AND formulate backup plan

14:40 EAL121: The last thing I will do before I hand off EAL121 to Tulsa is to pull his speed back to 250 knots also which is required. Right now I have exactly 5 miles.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 is approaching the gate
AND speed is in excess of gate speed
AND separation between number 1 and 2 is not fully established

THEN monitor assigning number 1 a speed reduction
AND monitor for spacing

Table 13.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	067	435	110	D-TUL
COA15	DC9	336	304	130	D-TUL
AAL31	MD80	067	311	132	D-TUL
TWA19	B727	023	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Transcript of 15 Minute Freeze

Worst case if it looks tighter than I thought, I will take COA15 and give him a vector out to the West...

Selective Transcript of 15-20 Minute Sequence

16:48 COA15: I don't think I have the 5 miles between ....COA15 has finally made the turn...I don't think I have it, so I am going to give COA15 a vector.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 3 has vectored to join the arrival
AND separation has not been fully established

THEN vector number 3 for spacing
AND monitor for spacing
AND monitor to vector number 3 to join arrival

17:59 COA15: Now I have got COA15 on a heading I have got lateral separation established, I will start him down to 11000....

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 3 has vectored to join the arrival
AND altitude is in excess of gate altitude
AND separation has been established

THEN clear number 3 to descend
AND monitor for spacing

Selective Protocol Anal .s for A14, SPS 2A

Table 14.2A. Key Alrc..ft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

The plan is to slow down AAL and vector COA to the West and bring back to TULSA 1 when he is behind AAL. CAO and AAL are the same altitude, but not a problem. I will use vertical separation until I have lateral separation.

FIRST: Start EAL down to 11,000 and contact R3 to get permission to slow and start him down.

Selective Notations from 5-10 Minute Sequence

6:05 EAL121 and AAL31: See how AAL and EAL work out. I know I have to fix routes.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has not been established
AND two of the air carriers are tied

THEN review routing
AND monitor to establish arrival sequence

6:30 AAL31 and COA15: AAL has arrival routing, COA does not. May vector him West and then join.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one air carrier has routing
AND one carries needs to be re-routed

THEN consider vectoring air carrier for re-routing
AND monitor to establish arrival sequence

6:51 EAL121: Get EAL out in front by having him turn and join SHAWN1 arrival.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one carries needs to be re-routed
AND arrival sequence has not been established

THEN vector air carrier for efficiency
AND establish his number 1 in the arrival sequence

7:22 AAL31 and COA15: Start slowing COA because he will start overrunning AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing for number 2 and 3 has not been established
AND number 3 is faster than number 2

THEN assign number 3 a speed reduction
AND monitor for spacing

7:49 COA15: Get COA below 24,000 before slowing him down. Otherwise must coordinate with other sector. Just one more thing to do.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing for number 2 and 3 has not been established
AND number 3 has to be slowed
AND number 3 is in the high sector

THEN reach out for control
AND clear number 3 to descend

8:18 AAL31 and COA15: Looks like I tied AAL and COA. So I will vector COA West and then rejoin TULSA1 arrival.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing for number 2 and 3 has not been established
AND number 3 is faster than number 2

THEN assign number 3 a speed reduction
AND monitor for spacing

9:11 AAL31 and COA15: Could have vectored AAL to TULSA1, behind COA, but AAL is further North.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing for number 2 and 3 has not been fully established

THEN monitor to formulate backup plan
AND monitor for spacing

9:45 AAL31 and COA15: Got lots of mileage, could resume AAL's speed, and keep reduced speed on COA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established
AND there is substantial distance to the gate

THEN assign number 2 speed increase
AND maintain present speed on number 3
AND monitor for spacing

Table 14.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	033	435	110	D-TUL
COA15	DC9	336	345	160	D-TUL
AAL31	MD80	067	295	110	D-TUL

Selective Notations from 10 Minute Freeze

By increasing AAL, he won't catch EAL, and I may be able to get COA in tail without having to turn COA.

FIRST: See if AAL speed starts picking up.

Selective Notations from 10-15 Minute Sequence

10:13 COA15: Took COA to 12,000. 250 knots at 12,000 is slower than 250 at 15,000.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 3 needs to be slowed
AND there is substantial distance to the gate

THEN clear number 3 to descend
AND monitor for spacing

11:11 COA15: Got 3 miles to work with. Leave COA on course because I think speed will work.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established
AND there is substantial distance to the gate

THEN maintain present speed
AND monitor for spacing

12:15 COA15 and AAL31: Can see AAL and COA separation. I have established it with speed.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established

THEN maintain present speed
AND monitor for spacing

13:17 EAL121: Start EAL handoff, and remind myself to slow him to 250.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one aircraft has reached appropriate altitude
AND is approaching the gate
AND there is no immediate traffic

THEN initiate handoff
AND monitor to assign speed reduction

13:32 COA15 and AAL31: COA will stay behind AAL so descend him to 11,000.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established
AND they are approaching the gate

THEN clear air carrier in tail for descent
AND monitor for spacing

14:27 Now that everything is working, I will see who is first in the next group of arrivals.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound approaching my sector
AND spacing has now been established

THEN monitor to establish new arrival sequence

Table 14.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	067	435	110	D-TUL
COA15	DC9	336	295	110	D-TUL
AAL31	MD80	067	404	110	D-TUL
TWA19	B727	023	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

FIRST: Slow EAL down and ship to approach.

Selective Notations from 15-20 Minute Sequence

15:23 UAL59: UAL, take handoff on him. Scan real fast, because he is not at level altitude. Make sure there is no traffic.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound approaching my sector
AND spacing has now been established

THEN accept handoff
AND scan for conflicts

15:47 TWA19 and UAL59: Check to see TWA and UAL. TWA looks in front but he has longer distance to gate. With just 2 aircraft, can start by slapping speed on UAL.

PRODUCTION

IF there are just two inbound air carriers to an approach controlled airport
AND one air carrier looks in front
AND arrival sequence is to have him number 1

THEN assign speed reduction to number 2 aircraft
AND monitor for spacing

16:10 DAL143 and TWA19: Here comes DAL which confuses the picture. Check DAL with TWA. Looks like DAL is ahead. Slow TWA down or vector to get my 5 miles. Will use just speed.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 2 is ahead of number 1

THEN switch sequencing
AND assign speed reduction to the new number 2
AND monitor for spacing

16:59 COA15: Start handoff on COA. He has already slowed down: don't have to worry about him.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one aircraft has reached appropriate gate speed and altitude
AND is approaching the gate
AND there is no immediate traffic

THEN initiate handoff
AND monitor for frequency change

17:17 DAL143 and TWA19: Plan A is to make DAL first and TWA second.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 is still ahead of number 2
AND there is spacing

THEN maintain arrival sequence
AND monitor for spacing

18:02 DAL143, TWA19 and UAL59: I have 3 miles, DAL over TWA, since I have slowed TWA. UAL starting to catch him.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing between number 1 and 2 has not been fully established
AND number 2 has been assigned a speed reduction
AND number 3 is catching up to number 2

THEN monitor for spacing
AND formulate a backup plan

18:28 DAL143, TWA19 and UAL59: Leave UAL and DAL full speed. DAL will stay in front of UAL, and UAL will be in front of TWA. Will descend TWA to make speed take effect.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND spacing has not been fully established
AND number 2 has been assigned a speed reduction

THEN switch sequencing making number 2 number 3
AND clear the new number 3 to descend
AND monitor for spacing

19:16 DAL143, TWA19 and UAL59: Punish TWA and leave other 2 at full speed.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND spacing has not been fully established
AND number 3 has been assigned a speed reduction

THEN maintain present speed on 1 and 2
AND monitor for spacing

Selective Protocol Analysis for A15, SPS 2A

Table 15.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

It is a matter of putting them in trail for approach.

FIRST: AAL is 10 miles in front of COA. EAL is a tie with AAL. EAL first, have him pick up speed. AAL 280, not 250 because of COA. Ensure separation via altitude.

Selective Notations from 5-10 Minute Sequence

6:40 Use leader lengths to get an idea.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has not been established

THEN review routing
AND monitor to establish arrival sequence

7:03 EAL121, COA15, and AAL31: EAL is ahead, and COA is a little tighter with AAL that I thought. So I will keep COA going down (11,000) and back to 250.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND air carrier that is ahead in number 1
AND spacing has not been established between 2 and 3

THEN clear number 3 to descend and to assign speed reduction
AND monitor spacing

8:01 EAL121, COA15, and AAL31: Looks okay. AAL and COA may still be a problem. AAL and EAL should work out. May have to vector AAL a little.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND spacing has been established between 1 and 2
AND spacing has not been established between 2 and 3

THEN monitor to vector number 2 for spacing
AND monitor spacing

8:26 EAL121: Would have been better to keep EAL up at altitude.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 2 is gaining on number 1

THEN should have kept number 1 at altitude
AND formulated backup plan
AND monitor spacing

9:30 Should work without vectoring.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established

THEN monitor spacing

Table 15.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	043	378	110	D-TUL
COA15	DC9	329	322	152	D-TUL
AAL31	MD80	067	347	133	D-TUL

Selective Notations from 10 Minute Freeze

EAL 320 or greater to put out in front of AAL. AAL at 280, slow to 250 shortly. COA at 250, should fall behind AAL nicely.

Considering putting AAL on heading. Hold on to EAL as long as possible before slowing him down to 250.

Selective Notations from 10-15 Minute Sequence

10:07 EAL121, COA15, and AAL3: Leave AAL at 12,000. Play it safe with EAL and COA at 11,000. Let AAL fall in and make turn before letting AAL down.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND spacing has just been established
AND number 2 has not been vectored to join arrival

THEN maintain vertical separation
AND monitor to vector number 2 to join arrival
AND monitor spacing

11:45 Leader lengths look good. Don't like the fact that SHAWN1 arrival makes such a drastic turn. You have to watch out.

12:41 EAL121: EAL is close enough to slow to 250 and ship him.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one air carrier has reached appropriate altitude
AND is approaching the gate
AND there is no immediate traffic

THEN assign speed reduction to air carrier
AND initiate handoff

13:15 EAL121 and AAL31: Did not descend AAL because I want to see how he makes the turn.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established
AND number 2 has not been vectored to join arrival

THEN maintain vertical separation
AND monitor to vector and descend number 2
AND monitor spacing

13:44 DAL143 and TWA19: DAL put in trail with TWA . Pick TWA speed up.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has not been established
AND it appears that number 2 will be in trail with number 1

THEN assign number 1 speed increase
AND monitor spacing

Table 15.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	043	295	110	D-TUL
COA15	DC9	329	295	110	D-TUL
AAL31	MD80	067	300	120	D-TUL
TWA19	B727	023	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

EAL has reduced speed with AAL. May vector AAL so he fall in line better. Have lots of room between AAL and COA.

FIRST: Have AAL vector 10 degrees to follow EAL a little better. TWA19 may have to join TULSA1 instead of SHAWN1.

DAL at 38,000, may be going fast. TWA at 23,000. Speeds may not be effective at this point.

Selective Notations from 15-20 Minute Sequence

15:18 TWA19, DAL143, and UAL59: Have another situation. UAL is lower than DAL. I plan TWA number 1, DAL number 2, and UAL number 3. Put 250 on UAL.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has been established
AND number 3 is lower than number 2

THEN assign number 3 speed reduction
AND monitor to clear number 2 to descend
AND monitor spacing

16:07 EAL121 and AAL31: Have a 12.5 miles between EAL and AAL. Since I put AAL on further Eastbound heading, should be not problem with separation. So I will descend AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 2 has been vectored to join arrival
AND spacing has been established

THEN clear number 2 to descend
AND monitor spacing

16:50 TWA19, DAL143, and UAL59: DAL doing 410, TWA 460. TWA first, DAL, and then UAL.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has been established
AND number one is faster than number 2

THEN maintain arrival sequence
AND monitor spacing

17:09 AAL31 and COA15: AAL cutting it kind of short to the TULSA1, and COA starting to catch him. Have a lot of room to play with.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established
AND number 2 has been vectored to join arrival
AND number 3 is gaining on number 2

THEN monitor spacing

17:31 TWA19: Change of plan. TWA to TULSA1 rather than SHAWN1. Easier to bring him into TULSA1 because of extreme angle of SHAWN1.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND air carrier has been routed to arrival with extreme angle
AND spacing has been established

THEN vector air carrier for re-routing
AND monitor spacing

17:48 TWA19 and DAL143: Not going to start TWA down right away. Leave him up to altitude. When I get DAL in my airspace, I will descend TWA and get DAL on top of him.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 has been re-routed to new arrival
AND number 2 is not yet in airspace

THEN monitor accept handoff on number 2
AND monitor to descend number 1
AND monitor to descend number 2
AND maintain vertical separation

18:43 UAL59: UAL is number 3, pulled him back to 250. Slow him down first so speed will work better.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 3 is in the airspace

THEN assign speed reduction to number 3
AND monitor for spacing

19:33 TWA19 and DAL143: May be a problem because of the TWA heading. Lost time making him number 1, so DAL will be closer. May have to vector DAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 was vectored to new arrival
AND number 2 is gaining on number 1

THEN monitor to vector number 2 for spacing
AND monitor for spacing

Selective Protocol Analysis for A16, SPS 2A

Table 16.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

AAL31 in front of EAL121 with COA15 behind even though EAL121 is faster. Don't want a big gap.

FIRST: Slow EAL down to 280 and reach out on AAL and speed him up.

Vector EAL to TULSA1. That buys me 10 miles. COA should fall behind. If that does not work, Vector EAL to SHAWN1.

Selective Notations from 5-10 Minute Sequence

5:45 AAL31: Reach out and grab AAL31. 310 or grater for spacing.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 is in another sector
AND number 1 needs a speed increase

THEN reach out for control
AND assign number 1 speed increase

6:18 EAL121 and COA15: I want to cut EAL speed because possible conflict with COA. If there is too much room, I will vector EAL and cut off some of the dog leg.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has not been established for number 2 and 3

THEN assign number 2 speed decrease
AND monitor to vector number 2 for spacing
AND monitor spacing

6:40 COA15: As soon as COA crosses boundary, he is going down.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 3 is in another sector
AND number 3 needs to be descended

THEN monitor accept handoff on number 3
AND monitor to clear number 3 to descend

7:12 COA15 and EAL121: Biggest conflict is COA with EAL. COA is going down and slowing to 280.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 3 is in another sector
AND number 3 needs to be descended

THEN monitor accept handoff on number 3
AND monitor to clear number 3 to descend

8:10 COA15: Only went to 280 on COA. Don't want to pull everyone back too soon.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 3 needs a speed reduction
AND there may be excessive spacing

THEN assign number 3 an interim speed reduction
AND monitor for spacing

8:44 EAL121, COA15, and AAL31: I am going to stay vertical with everybody.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has not been firmly established
AND air carries need to be re-routed for arrival

THEN maintain vertical separation
AND monitor for spacing

8:55 EAL121 and AAL31: Vector lines tell me that AAL is together with EAL. So I'll come back to the right (EAL 040).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 and number 2 are tied
AND number 1 is approaching the gate

THEN vector number 1 for spacing
AND monitor for spacing

9:36 COA15: COA15: Want to make sure that the speeds are working. COA is falling in fine. Just pull him back to 250 when need be.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing on air carrier in trail has been established

THEN monitor to assign speed reduction for number 3
AND monitor for spacing

Table 16.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	039	364	130	D-TUL
COA15	DC9	336	364	170	D-TUL
AAL31	MD80	067	454	240	D-TUL

Selective Notations from 10 Minute Freeze

Speeds are starting to work.

NEXT: Wait for AAL to cross then descend him to 11,000. Put COA to 14,000, he should fall in behind EAL. If it gets tight, pull COA back to 250 knots. Then I will have to pull them all back to 250.

Selective Notations from 10-15 Minute Sequence

10:35 AAL31 and EAL121: Now AAL ahead of EAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 is ahead of number 2
AND number 1 is approaching the gate

THEN monitor for spacing

11:44 Right now looks good.

12:05 COA15 and AAL31: COA is falling in perfect. Need to slow AAL to 250 at last possible second.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing on air carrier in trail has been established

THEN maintain present speed on number 1
AND monitor to assign speed reduction for number 1
AND monitor for spacing

12:23 EAL121, COA15, and AAL31: Slowed EAL to 250, COA have to pull back now too. But AAL in a second. Don't want any compression.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 1 is approaching the gate
AND number 1 needs to be assigned speed reduction
AND there is a possibility of compression

THEN assign speed reduction to number 2 and 3
AND monitor assign speed reduction to number 1
AND monitor for spacing

13:00 AAL31: AAL can go 300 till sector, then 250. A little tight.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 is approaching the gate
AND number 2 and 3 have been assigned speed reductions
AND spacing between number 1 and 2 is not fully established

THEN monitor to assign speed reduction to number 1
AND monitor for spacing

13:54 COA15: Will stay vertical here. Problem with COA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing between number 2 and 3 is not fully established

AND maintain vertical separation
AND formulate backup plan
AND monitor for spacing

14:47 COA15 and AAL31: COA got sharp vector. Now should work out. AAL heading threw me off.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing between number 2 and 3 is not fully established

THEN vector number 3 for spacing
AND monitor for spacing

Table 16.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	069	295	110	D-TUL
COA15	DC9	279	300	120	D-TUL
AAL31	MD80	067	295	110	D-TUL
TWA19	B727	023	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

We will stay vertical until I have the spacing. Start looking at next arrivals.

FIRST: The same situation, DAL first, TWA second, and UAL third, reduce speed.

Selective Notations from 15-20 Minute Sequence

15:30 EAL121 and AAL31: Looking at EAL and COA, not concerned with DAL and TWA because there is so much time to deal with them.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing between number 2 and 3 is not fully established
AND new inbounds are approaching your airspace

THEN monitor for spacing on current inbounds

16:20 DAL143: DAL is coming in high. Should be faster, but he is not.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one air carrier is coming in high

THEN consider establishing high air carrier as number 1 in the arrival sequence
AND monitor for spacing

16:50 Don't have full strategy yet.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is conflicting data

THEN monitor to establish arrival sequence
AND monitor for spacing

17:30 DAL143 and COA15: DAL may run right over COA, if COA sits there too long.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND the trailing air carrier is still at the gate
AND new inbounds are in your airspace

THEN monitor for spacing between new inbouds and inbounds at gate

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17:52 Do it with speed. Don't turn anyone.

19:14 TWA19, UAL59, and DAL143: Get TWA and UAL down (15,000). There goes DAL's speed.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND have established arrival sequence
AND number 2 and 3 need speed decrease
AND using speed for spacing

THEN clear number 2 and 3 to descend
AND monitor spacing

19:43 DAL143: Now expecting speed to do it all. DAL speed to go up.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND have established arrival sequence
AND number 2 and 3 have been assigned speed reduction
AND using speed for spacing

THEN monitor spacing

Selective Protocol Analysis for A18, SPS 2A

Table 18.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

Put AAL31 behind EAL121 because MD80 is a slower aircraft.

Call the high side to get control of AAL31 for vector and speed reduction and give EAL121 preferential routing.

Speed reduction on COA and he should ball behind AAL31.

Selective Notations from 5-10 Minute Sequence

6:28 EAL121, AAL31, and COA15: EAL turned 10 degrees right to intercept arrival. That should help with spacing with AAL. At this point, I have 5 miles built in. Then turn AAL behind EAL and COA. I will descend and slow COA and put him behind AAL.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND have established arrival sequence
AND spacing between number 1 and 2 has not been fully established

THEN vector number 1 for efficiency and spacing
AND monitor to vector number 2 to join arrival
AND monitor to assign speed reduction to number 3
AND monitor spacing

7:02 AAL31: I won't descend AAL until he gets in my airspace.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND have established arrival sequence
AND number 2 is not in airspace

THEN monitor to accept handoff on number 2
AND monitor to clear number 2 to descend
AND monitor spacing

7:36 COA15 and AAL31: By the time COA descends and slows, should be behind AAL. Possibly turn him a little to the right.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number spacing between number 2 and 3 has not been established
AND number 3 has been descended and assigned a speed reduction

THEN monitor vector number 3 for spacing
AND monitor spacing

9:20 EAL121, AAL31, and COA15: Another 3 minutes can vector AAL to intercept the SHAWN1 arrival. At that point he will fall behind EAL. I can then give COA the TULSA1 arrival and he will fall behind AAL.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND have established arrival sequence
AND spacing has not been fully established

THEN monitor to vector number 2 to join arrival
AND monitor to vector number 3 to join arrival
AND monitor spacing

Table 18.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	034	435	116	D-TUL
COA15	DC9	321	366	141	D-TUL
AAL31	MD80	083	345	174	D-TUL

Selective Notations from 10 Minute Freeze

AAL31 at 13,000 and EAL121 at 12,000. Could take AAL down to 11,000. Already have 5 miles separation, so take him to 13,000. COA is so far away, set him to 11,000.

FIRST: Flash EAL131 to Tulsa, then in one more minute, tell AAL31 to join SHAWN1, then COA...

Selective Notations from 10-15 Minute Sequence

10:10 Nothing critical to be done.

10:22 AAL31 and COA15: Speeds are comparable, may pull COA back a little more.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 2 and 3 spacing has just been established
AND number 2 and 3 speeds are the same

THEN assign speed reduction to number 3
AND monitor spacing

10:48 If you can do it with speeds, no need to turn.

12:24 For now no need to slow them any sooner that you have to. Better to let them go faster. They get out of your sector faster.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established
AND air carries need a speed reduction before the gate

THEN maintain present speed
AND monitor to assign speed reductions
AND monitor spacing

13:15 EAL121, AAL31, and COA15: First pull COA speed back. EAL is still faster than AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established
AND air carries need a speed reduction before the gate
AND number 1 is approaching the gate

THEN assign speed reduction to number 3
AND monitor other air carriers to assign speed reductions
AND monitor spacing

13:40 TWA19: Just took handoff on TWA also needs routing into Tulsa.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has been established
AND there is a new inbound

THEN accept handoff
AND monitor spacing

14:14 AAL31 and COA15: Looking at AAL and COA, may have to give COA a small vector. Right now speeds are gone, that is why you hate to reduce to 250, it removes an option.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there may be a spacing problem between number 2 and 3
AND air carries have been assigned maximum speed reduction

THEN monitor number 3 to vector for spacing
AND monitor spacing

Table 18.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	034	295	110	D-TUL
COA15	DC9	359	295	110	D-TUL
AAL31	MD80	039	295	110	D-TUL
TWA19	B727	023	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

COA15 may need an additional short turn for spacing. We will see what AL looks like when he makes his turn.

TWA19 is a 727 as is UAL59. Looks like TWA19 will be fast.

FIRST: Watch and see how AAL31 makes his turn.

Selective Notations from 15-20 Minute Sequence

15:33 AAL31 and COA15: Looks tight. So I will vector COA for spacing.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there may be a spacing problem between number 2 and 3
AND air carries have been assigned maximum speed reduction

THEN monitor number 3 to vector for spacing
AND monitor spacing

16:05 Turn COA 2 or 3 miles then turn him back...

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there may be a spacing problem between number 2 and 3
AND air carries have been assigned maximum speed reduction

THEN vector number 3 for spacing
AND monitor number 3 to join arrival
AND monitor spacing

16:14 DAL143 and TWA19: DAL143 is flashing. He is a bit in front of TWA19. I will make him first.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND another sector has issued the handoff on two inbounds
AND number 1 is in front of number 2

THEN accept handoff on number 1
AND monitor to accept handoff on number 2

17:20 UAL59 and TWA19: Will put UAL behind TWA19. Turn him right and reduce him to 250 knots.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has been established
AND number 2 and 3 are at similar speeds

THEN vector number 3 for spacing
AND assign number 3 a speed reduction
AND monitor spacing

18:24 Have 10 miles with DAL143. 300 looks excessive, I will turn him back sooner.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing between number 1 and 2 is excessive
AND number 1 needs to be vectored to join arrival

THEN monitor to vector number 1 to join arrival
AND monitor spacing

19:14 DAL143 and TWA19: Descending DAL to 15,000 because TWA is leaving 14,000 just in case I have to turn someone.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has just been established
AND number 1 needs to be descended

THEN maintain vertical separation
AND clear number 1 to descend to available altitude
AND monitor spacing

19:30 AAL31 and COA15: COA worked out. Looks like I will have about 8 miles.

Selective Protocol Analysis for A13, SPS 5A

Table 13.5A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
SPURS12	KC10	087	300	170	REFUEL
SWIFT66	B52	087	300	170	REFUEL
N84CR	C182	086	149	30	A-MLC
LN45T	LR35	345	400	145	A-MLC
COA35	B737	087	420	150	OVER
N496B	PASE	084	170	90	D-MIO
N52PB	C177	167	70	4	A-MIO

Selective Transcript of 5 Minute Freeze

As I look at the display, I see that I have a large area of weather West...East of Tulsa...First of all when you have weather, precipitation...it can always make your workload more difficult...

Selective Transcript of 5-10 Minute Sequence

6:05 As I thought of that, I have an aircraft requesting clearance off (LN45T), I look, I have an aircraft sort of in the vicinity of McAlister, he is at 4,000 ...and the aircraft is northbound, I know that I have 5 miles established. N84CR, 5 miles East of McAlister I know that... he will be separated laterally.

8:29 Got a departure, AAL15 going eastbound, so...first thing I am thinking...is that aircraft may have a problem with the weather... don't know yet. Wait till the aircraft checks on frequency.

8:38 Got 45T wanted radar vectors to Kansas City... so I will do that...

9:14 Had radar established on N52PB. I gave him a 30 degree left turn for one minute for radar identification...That is what I need plus his position.... One thing I could not do...I was hoping that he was going to check on before he reached the Miami VORTAC...that way I could just have him report Miami VORTAC...and then I would have the radar. Since he was already past Miami, I have to use another means to get the radar identification.

Table 13.5B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN45T	LR35	347	400	290	A-MLC
N496B	PASE	084	170	90	D-MIO
N52PB	C177	067	150	44	A-MIO
AAL15	B727	068	287	97	A-TUL
LINDA34	F4	170	430	160	OVER
ELDER87	B52	249	410	160	OVER

Selective Transcript of 10 Minute Freeze

One potential thing that I was concerned with is AAL15...departure off of Tulsa proceeding Eastbound and LN45T North of McAlister proceeding Northbound. There is a potential those two aircraft could cross, of if AAL15 wanted to vector South around the weather, that would put him even more in the path of 45T, however, I have got 7500 feet vertical climbing. LN45T is a faster climbing aircraft. I am not concerned that it will ever have the loss of separation there, so I am not concerned with that....

One thing I want to get N52PB I want to have him report 7000....He does not have mode C...I want to pin him down when he is level at 7....

My last concern that I mentioned, I have 2 16 random routes...I think that they are going to cross...My plan to establish separation is the one aircraft, ELDER87, when he leaves my airspace he is going to be the wrong direction for LC flight so I was going to climb him or descend him to 15 or 17 and that will establish the separation there.

Selective Transcript of 10-15 Minute Sequence

10:23 (Running out the vector line) I want to see where if and when these two are going to cross (ELDER87 and LINDA34).....

10:39 Looks like they are going to cross just Northwest of McAlister...so that is a situation that has to be rectified...The way that I am going to take care of it is to climb ELDER87 to 1700....

12:21 The situation again with ELDER87 and LINDA34...now I know that they are going to cross...if they were going to cross relatively quickly...I would probably reach out to Memphis center and get control to climb ELDER87 to 17000....being that I have got 15 minutes before the planes are a factor, I will just wait until he is in my airspace, and I will climb ELDER87...

13:31 Got a situation, I have ...AAL15 climbing Eastbound and and DAL15 inbound to Tulsa will have to descend....Gave AAL15 direct to Fort Smith, which will give a little bit direct routing and keep him from conflicting with DAL15.

14:45 Situation...I see three Tulsa inbounds....

Table 13.5C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
DAL15	B727	192	410	240	D-TUL
AAL52	B727	194	420	220	D-TUL
COA65	MD80	255	410	240	D-TUL
LN45T	LR35	028	400	290	A-MLC

Selective Transcript of 15 Minute Freeze

I notice 3 inbound to Tulsa, DAL15, AAL52, and COA65, all appear pretty close to being tied going into Tulsa. My plan is for DAL15 to be number 1...and I was not sure quite yet, I was going to run out the vector lines to determine if COA65 or AAL52 was going to be number 2...

Selective Transcript of 5-10 Minute Sequence

15:53 My plan is DAL15, COA65 2, and AAL52 number 3...So what I will do when AAL52 enters my airspace, I will reduce his speed.

17:05 That kind of messes up my plan. He was supposed to be number 2, now he wants vectors North, I am going to make him number 3...So speed AAL52 back up.

19:09 COA65 I am watching the most, I have two things to do with him...I have got to keep him vectored around the weather which he requested, and keep my spacing behind AAL52...

Selective Protocol Analysis for A14, SPS 5A

Table 14.5A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
SPURS12	KC10	087	300	170	REFUEL
SWIFT66	B52	087	300	170	REFUEL
N84CR	C182	008	74	4	A-MLC
LN45T	LR35	009	69	2	A-MLC
COA35	B737	087	420	150	OVER
N496B	PASE	084	170	90	D-MIO
N52PB	C177	143	21	2	A-MIO

Selective Notations from 5 Minute Freeze

I have three VFR targets, and the one by COA35 is the only one that I am concerned about.

SWIFT66 and SPURS12, I want to make sure that they turn left and don't keep going into Memphis center airspace, or they will need a pointout.

Selective Notations from 5-10 Minute Sequence

5:18 N84CR and LN45T: Put a J-Ball around 84CR so that I can see when the two are separated.

5:53 COA35: COA is already by the VFR traffic.

7:15 N84CR and LN45T: LN45T, the only reason I climbed him, he is already above 4CR, and there is not way the Queen Air is going to outclimb LN45T. He is a Life Guard so I have no problem clearing him direct for KS. I gave him a heading I thought would get him close. Soon as I see if the heading is working, I will reassess.

8:06 SWIFT66 and SPURS12: Need to hand them off right away. They are my first priority, and will ignore N52PB call.

8:52 N52PB: 2PB off of MIO, not radar identified. He is not going to hit anyone, but as a priority, I have got to get him identified.

9:15 SWIFT66 and SPURS12: I have shipped my refuelers, and I don't have to worry about them anymore.

9:20 LN45T: I am going to check LN45T altitude. I need to get him handed off. I need to fix his heading...Pass him to high sector.

Table 14.5B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN45T	LR35	016	400	230	A-MLC
N496B	PASE	084	170	90	D-MIO
N52PB	C177	067	150	39	A-MIO
AAL15	B727	068	287	92	A-TUL
LINDA34	F4	170	430	160	OVER
ELDER87	B52	249	410	160	OVER

Selective Notations from 10 Minute Freeze

LN45T: I have got his heading taken care of, I just need to ship him.

AAL15: Have a handoff flashing at Tulsa, need to take the handoff.

N52PB: Need to establish radar contact. I told him to report leaving 3,000, so I can get above the MIA and turn him for radar identification. That is my number one priority. He is at 7,000 but I have not seen him. I want to use radar separation instead on non-radar separation.

I then check the others that I don't have at level altitude.

FIRST: Ask 52PB for his altitude, and if he has cleared 3,000, I will turn him 30 degrees to identify him. I am not that worried about him, he is the only primary I have.

Selective Notations from 10-15 Minute Sequence

10:34 N52PB: (Turned 2PB) We will start to track him.

11:42 N52PB: I am going to turn him back to the right and see if I can see him.

12:00 LINDA34 and ELDER87: Just took the handoff on two aircraft. I want to see their routes are, and they are the same altitude, and I think there are close, and will cross sooner or later. Keep an eye on.

13:16 N52PB: Just tagged my target at 6,600. Put than in data block.

13:28 DAL15 and LINDA34. Have a DAL flashing at me, a Tulsa arrival. Have to watch with LINDA34. Have to get DAL down to 11,000.

13:56 N52PB and N496B: Just noticed 2PB reported 7,000 on his data block, and 96B, lost radar, so I am going to tell him reset his transponder.

14:22 Got two more Tulsa arrivals. There is going to be a situation.

Table 14.5C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
DAL15	B727	192	410	240	D-TUL
AAL52	B727	194	420	220	D-TUL
COA65	MD80	255	410	240	D-TUL
AAL15	B727	068	287	92	A-TUL
LN45T	LR35	016	400	290	A-MLC

Selective Notations from 15 Minute Freeze

Put a J-Ball around AAL52 to see how close he really is to DAL. Can't descend either one because I have AAL15 climbing to 23,000. AAL52 is coming into 22,000. So I will stop AAL15 at 21,000. Take the handoff back to stall AAL15 at 21,000.

Starting getting behind coming up with a plan. My priority is to make sure that AAL15 does stop at 21,000.

N496B: If I don't get into radar soon, will tell him radar contact lost and just have him report MIO, and work him non-radar.

Get something working with speeds here. Can't work with altitude until AAL15 crosses with DAL15 or AAL52.

FIRST: Call R3 to have AAL15 stop at 21,000. Won't ship him until he is clear of my traffic.

Selective Notations from 5-10 Minute Sequence

15:26 COA65, AAL52, and DAL15: Looking at the vector lines to see about the arrivals. I think I will turn these two to the South, and let COA stay fast because you cannot take COA behind the other 2. I will slow AAL52 down (250) to give me some speed so I won't have to keep them on that heading so long.

16:58 COA65, AAL52, and DAL15: COA has requested a vector around the weather. Because of that, I will start him down below everyone so he will not hit the other two. Solve with altitude.

17:25 AAL52, and DAL15: Put a J-Ball around DAL to see when he gets behind AAL15.

18:36 N496B: Don't have time for VFR advisory. Cancel his data block and take him off.

19:17 COA15 and LINDA34: Got to make sure that COA is below LINDA34.

19:23 DAL15 and LINDA34: DAL, I need to start down. Stopped DAL 17,000 to make sure he stays on top on LINDA34. The option is to bring DAL to the FORTS1 arrival or put him back on the SPRING1 arrival. I will get more separation if I keep him heading South.

Selective Protocol Analysis for A15, SPS 5A

Table 155.5A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
SPURS12	KC10	087	300	170	REFUEL
SWIFT66	B52	087	300	170	REFUEL
N84CR	C182	082	149	22	A-MCL
LN45T	LR35	000	0	0	A-MCL
COA35	B737	087	420	150	OVER
N496B	PASE	084	170	90	D-MIO
N52PB	C177	000	0	0	A-MIO

Selective Notations from 5 Minute Freeze

There is weather out here. Probably just rain showers, and most AC can go through that. May have them vectored around the weather when I have them inbound to Tulsa.

SPURS12 and SWIFT66: This military block has been pre-coordinated with the next center. I am waiting for them to take both AC.

FIRST: Call the center and have them take the handoff on SPURS12.

Selective Notations from 5-10 Minute Sequence

6:33 Nothing to think about just yet.

8:00 Trying to start a track on this one little guy.

8:27 AAL15: AAL they just launched. He will be going to Fort Smith via the BOLD1 departure. He may want to deviate around the weather. I will continue him climbing when he comes on to my frequency.

9:51 LINDA34 and ELDER87: I am thinking that these two may be in conflict. To verify, I am going to do a route read-out.

Table 15.5B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN45T	LR35	002	261	30	A-MCL
N496B	PASE	084	170	90	D-MIO
N52PB	C177	067	150	30	A-MIO
AAL15	B727	068	258	85	A-TUL
LINDA34	F4	170	430	160	OVER
ELDER87	B52	249	410	160	OVER

Selective Notations from 10 Minute Freeze

LINDA34 and ELDER87: You can do a route read-out for however many minutes you want and see where they are going to be a conflict. So it looks like they may be and I wanted to verify that. I will change one of their altitudes if necessary.

Should be calling up KS center and N52PB and tell them that we do have a primary only climbing to 7,000.

Will put 96B in for approach as soon as PB is cleared out of the way.

FIRST: Take the handoff on LINDA34 and do the route-readout between LINDA34 and ELDER87 to see if they are going to be a problem for each other. Probably change ELDER87 altitude since he is going North, and 16,000 is the wrong altitude for that direction.

Selective Notations from 10-15 Minute Sequence

10:39 Looks like their will be a problem. As soon I get ELDER87 into my airspace, I will climb him to 17,000. Even though he will be proceeding wrong altitude for direction, when he will be leaving my airspace he will be the right altitude.

12:01 Waiting for ELDER to get in my airspace and climb him to 17,000.

12:08 When I had Memphis Center, I should have pointed out AAL15. He may be level by the time he gets to the boundary...I will do that, so I can ship him to Memphis Center.

13:02 I see there is a primary South of the COA. He should not be a problem.

13:10 There is a limited. DAL15 here he is.

13:26 Since DAL is out there, I can keep him going down to 22,000 by stopping AAL15 at 21,000.

13:52 DAL15, AAL15, and COA65: DAL is going to get stuck on top of AAL15, and then call Memphis Center and get control for lower on COA (11,000).

14:48 Just decided to make COA number 1.

Table 15.5C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
DAL15	B727	192	410	240	D-TUL
AAL52	B727	194	420	220	D-TUL
COA65	MD80	255	459	225	D-TUL
LN45T	LR35	346	261	30	A-MCL

Selective Notations from 15 Minute Freeze

Next thing I was going to do is find out DAL's speed. I would not slow him back until I was talking to AAL52. I have to reduce his speed before pulling back on DAL15.

Right now I have COA going fast, DAL15, when I get him, I will adjust his speed and possibly put him on a heading to go behind COA. And slow AAL52 and keep him descending.

N496B: Has gone gone into a post track, so I would want to verify his DME from MIO.

FIRST: Call Memphis Center for lower, and dump as soon as I get him.

Selective Notations from 5-10 Minute Sequence

16:19 N496B: I am going to issue the traffic for the VFR in a second.

17:35 I can ship COA35, and just working on my scan. I see that ELDER is coming back to the East at 17,000. Should never be a problem with DAL15.

17:48 As soon as I am clear of AAL15, I can keep DAL15 descending. AAL52 is just about level at 11,000 an back to 250 knots. Should help to spread out DAL15 better.

18:26 AAL15, and DAL15: Making sure that I have my five miles before I keep AAL15 climbing.

18:49 Get DAL15 down as soon as possible and keep AAL15 going up. I am pretty close to have my 5 miles. I do have it.

19:29 The spacing if going to work fine. As soon as I get COA a little more in front of DAL, I am going to start easing DAL back on the FORT1 arrival. Will vector him closer, rather than have him go all the way down.

Selective Protocol Analysis for A16, SPS 5A

Table 16.5A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
SPURS12	KC10	087	300	170	REFUEL
SWIFT66	B52	087	300	170	REFUEL
N84CR	C182	086	150	29	A-MLC
LN45T	LR35	345	400	128	A-MLC
COA35	B737	087	420	150	OVER
N496B	PASE	084	170	90	D-MIO
N52PB	C177	169	91	5	A-MIO

Selective Notations from 5 Minute Freeze

COA35 has some VFR traffic.

N496B will be entering the airspace. I will keep that in mind. Get him setup for the approach.

There some weather out there, but it is light. So should not make a difference.

The primary may call us. That is it

FIRST: Put my altimeters in and then call Memphis about the military. First call the VFR traffic for COA35. That is the most immanent thing.

Selective Notations from 5-10 Minute Sequence

5:51 LN45T: Put 23,000 in and set him up for a flash to the high altitude so he does not have to stop climbing. No potential traffic.

6:07 AAL15 is coming off of ...

7:33 LN45T: The LR35 is gone, no longer a factor.

7:38 AAL15: AAL is flashing at us. We will advise him of the weather. 23,000 on him, because no traffic on him.

8:43 N52PB: Got to remember to coordinate him as a primary only.

9:29 N52PB: He is just radar to KS. Keep getting altitude checks on him. (Report at 7,000)

9:52 Got LINDA34 coming in and ELDER87. Make sure that these two don't conflict.

Table 16.5B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN45T	LR35	347	400	290	A-MLC
N496B	PASE	084	170	90	D-MIO
N52PB	C177	067	150	45	A-MIO
AAL15	B727	069	309	102	A-TUL
LINDA34	F4	170	430	160	OVER
ELDER87	B52	249	410	160	OVER

Selective Notations from 10 Minute Freeze

LINDA34 and ELDER87: Take the handoffs on those two and get read-outs on them. Make sure that they are not in conflict. ELDER87 would be wrong altitude for direction, so I would move it to 15 or 17,000 if they are a conflict.

N52BP: As soon as he leaves...will make the handoff to KS.

Two VFRs coming into Tulsa airspace. Could call them to warn them.

FIRST: Take the handoffs on LINDA34 and ELDER87 and read them out.

Selective Notations from 10-15 Minute Sequence

10:58 LINDA34 and ELDER87: It is pretty close, nothing to make a move now. I know were they are going. He will have to go 15,000 (ELDER87). As soon as he gets into my airspace I will make my move.

12:01 Don't have anything for COA35, so we will get rid of him.

12:33 ELDER87, keep on eye on him. No factor for COA.

12:44 N496B: His transponder has failed. We will find out what is going on with him.

13:40 Got a couple of Tulsa's now.

14:48 COA65: Got another flyer at 15,000.

Table 16.5C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
DAL15	B727	192	410	240	D-TUL
AAL52	B727	194	420	220	D-TUL
COA65	MD80	255	410	240	D-TUL
LN45T	LR35	028	400	290	A-MLC

Selective Notations from 15 Minute Freeze

56LR is traffic for ELDER87. LINDA34 is not a factor.

Start working on the inbounds...

N496B: Has lost his transponder...

Won't do anything to DAL15 until he is clear of AAL15...

FIRST: Put a J-Ball in ELDER87 and do a read-out. I don't want to turn them. If need be, I will go to 17,000 with the ELDER87.

Selective Notations from 5-10 Minute Sequence

16:02 N496B: VFR in his vicinity.

16:09 ELDER87 and LINDA34: Not concerned about them. If anything I will give them a little turn to keep them away from each other. I will go wrong altitude for direction of flight to KS Center. There is no sense in moving them...We will just keep an eye on them for now.

16:46 Will start working on the Tulsa inbounds in a second. We will go COA65, DAL15 and AAL52. Right now we will work speeds and vector as I have to.

18:23 Changed my mind. Going to change the altitudes (ELDER87 to 17,000) and work the arrivals and forget about these two.

19:08 N496B: His transponder came back so we can give him his VFR advisory.

19:14 Moved a little too late so we will have to do some vectoring and pull DAL15 to 250.

19:27 COA65 and DAL15 are getting pretty close. Hopefully the speed will work. If not we will vector.

19:38 Already have the AAL52 at 250 so he is okay.

Selective Protocol Analysis for A18, SPS 5A

Table 18.5A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
SPURS12	KC10	087	300	170	REFUEL
SWIFT66	B52	087	300	170	REFUEL
N84CR	C182	086	149	24	A-MLC
LN45T	LR35	345	399	135	A-MLC
COA35	B737	087	420	150	OVER
N496B	PASE	084	170	90	D-MIO
N52PB	C177	000	0	0	A-MIO

Selective Notations from 5 Minute Freeze

The SWIFT66 with the SPURS, I will switch the SPURS to Memphis. I don't need him.

COA35 has traffic at 12 o'clock. Will issue the traffic to him.

LN45T: Life Guard, I will issue the direct to KS, there is no need for him to run over Tulsa. Being a Life Guard, he will want priority.

FIRST: Issue traffic to COA35 because the traffic in front of him did climb 1,000 feet. Then give the Life Guard direct to KS.

Selective Notations from 5-10 Minute Sequence

7:15 N52PB: Got to start a track with 52PB. I am going to have to get him turned to identify him.

7:35 AAL15: Just took the handoff on AAL15. He is on the BOLD1 departure...

8:05 LN45T: I have dropped the Life Guard off my scope because he is out of my airspace and I don't need to watch him.

8:24 N52PB: Starting a track on 52PB, and make sure I don't miss him climbing out there.

8:44 N496B: 496B checked on 9,000. He is inbound to MIO. Since I have a break, I may as well call him on MIO radio.

9:32 N52PB: I am turning him 30 degrees left, and running my histories out so that can identify the turn when he makes it.

9:47 ELDER87 and LINDA34: Taking the handoff on ELDER87 and LINDA34.

9:58 SPURS12: Dripping my tracks on the SPURS12 because he is not in my airspace.

Table 18.5B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN45T	LR35	018	399	290	A-MLC
N496B	PASE	084	170	90	D-MIO
N52PB	C177	037	149	30	A-MIO
AAL15	B727	069	304	101	A-TUL
LINDA34	F4	170	430	160	OVER
ELDER87	B52	249	410	160	OVER

Selective Notations from 10 Minute Freeze

COA35 is passed traffic, and no longer a factor.

N52PB, I will wait till he makes his turn, then I will radar identify him.

Will run the route lines out on ELDER87 and LINDA34 because they are flying random routes out throughout the area. May be a conflict.

AAL15 climbing to 23,000. Make sure that ELDER does not make a turn into him.

FIRST: Nothing pressing, but I will run out the lines on the ELDER and the LINDA and wait on 52PB's turn before I radar identify him.

Selective Notations from 10-15 Minute Sequence

10:34 ELDER87 and LINDA34 : As you can see by the routes, their speeds are comparable, and they are going to be in conflict about 15 NW of MIO. Probably change altitude on ELDER87.

11:54 N52PB: I had to coordinate that with Memphis Center. Since I took him off his route, he can now go direct to Springfield.

12:16 AAL12: AAL is looking for a higher altitude. Normally 15 or 16,000 is a good time to start flashing to the high side...I will give them a call and see if they will flash him on through to Memphis Center, and I won't need to make a comm change then.

13:19 DAL15 and AAL15: Just got a handoff flashing on DAL15 inbound to Tulsa in conflict with AAL15.

14:15 DAL15 and AAL15: Turning AAL15 direct to Fort Smith. That will get him out of my way. So I can start my inbound traffic down.

14:45 COA65: Taking the handoff on COA65.

Table 18.5C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
DAL15	B727	192	410	240	D-TUL
AAL52	B727	194	420	220	D-TUL
COA65	MD80	255	410	240	D-TUL
LN45T	LR35	018	399	209	A-MLC

Selective Notations from 15 Minute Freeze

496B, lost his transponder, may have to turn him to identify him.

ELDER and LINDA34, LINDA34 is going South cross the inbound corridor. Got to make sure got my departures down.

I have a faster in back, only 10 knots on AAL52, but there is altitude separation so no problem. I do have a tie with COA65 and the DAL15. Will have to do some spacing.

AAL15 will have to coordinate direct with the next center. At the rate he is climbing. Will have the separation.

ELDER87, will probably give lower with reference to COA35 because he will eventually be a factor with LINDA34. Start him now, and I won't have to worry about it later.

FIRST: Climb AAL15 to 25,000 and make sure to miss DAL15. Once clear of DAL15, switch him to Memphis and get him off my frequency...then get back to my spacing to figure out who is going to be first into Tulsa.

Selective Notations from 5-10 Minute Sequence

15:33 AAL52: Just took the handoff on AAL52 and 96LR.

15:39 COA35: I am going to flash the handoff on COA35.

15:54 AAL15 and DAL15: AAL15 is not clear of DAL15. That is no problem.

17:37 AAL54, COA65, and DAL15: Reduced AAL52 (280) for spacing. COA wants to vector (around weather). I have gotten him down below DAL and COA.

18:30 COA65 and DAL15: Now that I have COA on heading, I can descend DAL15 to 11,000 per letter of agreement.

19:27 AAL54, COA65, and DAL15: I am going to run COA a little North, and then back down. DAL15 I turned right to make sure he stays in front. AAL15 I turned to the left so that my order will be DAL15, COA65, and then AAL52.

Selective Protocol Analysis for A13, SPS 7A

Table 13.7A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	142	280	100	D-MIO
AWE43	DC9	068	258	71	A-TUL
N368LL	PASE	252	200	100	D-MIO
OSAGE22	A6	048	450	190	OVER
HOMIN10	A7	130	450	210	OVER
COA23	B727	197	410	240	D-TUL
DAL42	B747	289	430	240	D-TUL
NWA20	DC10	197	440	247	D-TUL

Selective Transcript of 5 Minute Freeze

Now as I look at the scope, COA23, Tulsa inbound flashed at me. I can see the limited data block of the other two inbounds to Tulsa, DAL42 and NWA20. So as I see all three of them coming in, I am thinking about what kind of game plan I am going to use get them in. Obvious, right now, COA23 would be number 1...who is going to be number 2 and number 3, I will probably look at it as they get a little closer, draw their vector lines out and see who is number 2 and who is number 3.

And I also see with my AWE43 departure flies the published ....the BOLD1, the BOLD1 departure for Springfield transition. That could be a problem with the COA23 inbound and the NW.'20 inbound. So my plan is to vector him a little North of course or run him direct to Springfield to keep him away COA23 and NWA20...

Selective Transcript of 5-10 Minute Sequence

5:56 My plan is to let DAL42 go in first, COA23 and NWA20, numbers 2 and 3 respectively. I will accomplish it two ways. Either by simply reducing speeds, or by vectoring them to the...

6:26 COA23 and NWA20 are lined up one right behind the other and...all three appear to be tied. I think it is easier...these two are going to obviously follow each other, COA23 ....So I think it is easier in this case to let the Delta run in and with a minimum amount of effort either speed reduction of just leaving COA23 and NWA20 on the present heading they will fall right into place behind the DAL42. For me, I find that the easiest way to go...

7:53 They wanted higher for another reason. They have got another departure coming right behind, TWA71, so they want to keep AWE43 climbing...

8:34 AWE43 checked on, and I issued him a direct to Springfield and a climb which will keep him clear of my inbounds to Tulsa.

Table 13.7B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	170	188	22	D-MIO
AWE43	DC9	037	420	183	A-TUL
N368LL	PASE	252	200	74	D-MIO
OSAGE22	A6	045	450	190	OVER
HOMIN10	A7	127	450	210	OVER
COA23	B727	216	397	148	D-TUL
DAL42	B747	292	430	180	D-TUL
NWA20	DC10	195	366	198	D-TUL
TWA71	DC10	045	410	118	A-TUL

Selective Transcript of 10 Minute Freeze

A couple of situations going. I have two departures out of Tulsa, AWE43 and the TWA71 both filed bold one departures for Springfield transition, which was a problem because I had two inbounds from the SPRIN1 arrival, COA23/NWA20. I vectored them both direct to Springfield so that I could keep them clean laterally from COA23 and NWA20. I would have automatic separation...

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Now I am working on my sequencing for Tulsa. I have got NWA20 pulled back to 250 knots. He was faster than COA23, who was right in front of him at the same altitude, so I pulled him back and started him down to ensure the separation between those two. Now that I have got NWA20 slowed down... I am all set with that. My next move would be to take COA23 reduce his speed and so DAL42 with the speed alone I am hoping will be able to stay out ahead of COA23. If the speed does not work my move would be to take COA23 vector him South, until I have my five miles behind DAL42...If I have to vector COA23 South, I therefore will have to vector NWA20 South so he does not catch up with COA23...

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My first priority was separating the Tulsa departures...and spacing in the Tulsa inbounds.

Selective Transcript of 10-15 Minute Sequence

10:27 Still watching the spacing with COA15 and DAL42. That is what I am watching the most now. I might have waited a little too soon to start the speed reductions. So that is what I am watching now.

13:08 So it did not work out as I planned. I waited a little too long to reduce the speed on COA23, so he was getting too close to DAL42...COA23 was level at 11, since I started vectoring him I was worried about NWA20 catching him. So I stopped NWA20 at 12000 so I would maintain vertical separation.

13:37 Now that I have got 5 miles, I will send them back at course.

Table 13.7C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C505	227	160	21	D-MIO
N368LL	PASE	180	200	40	D-MIO
OSAGE22	A6	045	450	190	OVER
HOMIN10	A7	104	450	210	OVER
COA23	B727	288	295	108	D-TUL
DAL42	B747	272	295	110	D-TUL
NWA20	DC10	313	304	1308	D-TUL
TWA71	DC10	045	429	230	A-TUL
N374LJ	DA10	000	0	0	A-MIO
R12429	U21	331	250	100	D-MLC

Selective Transcript of 15 Minute Freeze

Two things I am thinking of doing right now...is issuing holding instructions for 368LL in Miami...and R12429 landing in McAlister, I was going to issue vectors for the ILS approach. They are not busy down there, you got time to do it.

Selective Transcript of 15-20 Minute Sequence

16:00 All done, now I will issue the Army's vector for the ILS at McAlister.

16:16 He is not too fast moving, so there is no real hurry to issue the vector for localizer....368LL was coming up, he is about 5...7 miles from the Miami VORTAC. He is probably going to be expecting lower for his approach clearance, so I wanted to give him his holding instructions and let him know what was going on first.

17:19 Okay, first come, first serve, 368LL is waiting to land, I will issue his approach clearance, when he is on the ground I will give the departure clearance for 74LJ

18:04 When you vector for a localizer, you have to keep a close eye on it so you can issue the proper heading to join the localizer... so I am keeping an eye on that...

Selective Protocol Analysis for A14, SPS 7A

Table 14.7A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	142	380	100	D-MIO
AWE43	DC9	283	173	14	A-TUL
N368LL	PASE	252	200	100	D-MIO
COA23	B727	197	410	240	D-TUL
DAL42	B747	289	430	240	D-TUL
NWA20	DC10	197	440	247	D-TUL

Selective Notations from 5 Minute Freeze

LN444 is getting close to MIO, so I am going to start him down.

I am going to get 1EK down below 8LL so that I can set up my holding pattern with EK holding first.

I have a departure out of MIO, and I may have him wait on the ground since LN is a priority mission, so I may have to land LN444 first.

FIRST: Descend LN444 to 6,000 and clear him for approach since he is within 10 minutes of the airport. He is only 4 minutes from MIO, so I need to clear his approach.

Selective Notations from 5-10 Minute Sequence

6:11 LN444 and N368LL: LN is not starting down yet, so I will have to make sure that he gets down before 68LL gets over by MIO.

6:27 DAL42 and NWA20: Got to take some handoffs, DAL42 and NWA20.

6:46 COA23, DAL42, and NWA43: Right now COA23 and DAL42 are tied. I will do what I did before, let DAL42 run fast, and take COA and NWA down South since I know where my limitations are.

7:46 AWE43: Take the handoff on AWE43.

7:50 COA23: Going to get COA23 started South...I have to get him below 24,000 before I can get him to turn South.

8:43 AWE43, COA23, and NWA20: AWE43 will stop below these two ACs (COA and NWA) right now.

9:23 COA23: COA did not take the turn, so I had to go back and do that.

Table 14.7B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	179	151	41	D-MIO
AWE43	DC9	069	420	129	A-TUL
N368LL	PASE	253	200	100	D-MIO
COA23	B727	180	410	200	D-TUL
DAL42	B747	292	430	184	D-TUL
NWA20	DC10	190	366	240	D-TUL
TWA71	DC10	068	407	105	A-TUL

Selective Notations from 10 Minute Freeze

I am trying to get the Tulsa sequence set up. By turning COA and NWA, I opened up the departure routing for AWE43 and TWA71. AWE43 and TWA71 still need to get to their requested altitude. If it looks like TWA71 will catch AWE, I will leave him at a lower altitude so there will not be an overtake.

TWA71 is requesting direct Springfield. That is low priority now. I can leave him on the departure fix.

LN444, I am going to wait for him to report his procedure turn.

FIRST: Give 68LL holding instructions, and then descent COA and NWA.

Selective Notations from 10-15 Minute Sequence

11:26 COA23 and DAL42: COA23 is way behind DAL42, so I am going to give COA his airport clearance.

11:33 TWA71 and COA23: First I am going to get TWA up to altitude. TWA is overtaking COA, so I will shortcut TWA to Springfield and leave him at a lower altitude. That will take care of the overtake situation.

13:05 LN444 and N368LL: I have LN444 inbound and 68LL set up and hold

13:23 COA23: I need to get down to 11,000. He is joining up on his arrival route.

13:32 DAL42: I need to ship to approach.

13:37 TWA71 and AWE43: TWA71 and AWE43 and going direct Springfield at 23,000. I don't need to worry about either of those. Just need to start my handoff to Memphis.

Table 14.7C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
HOMIN10	A7	317	348	210	OVER
YANKE79	F14	087	480	210	
COA23	B727	286	408	119	D-TUL
DAL42	B747	288	295	110	D-TUL
NWA20	DC10	287	304	130	D-TUL
TWA71	DC10	039	506	210	[illegible]
R12429	U21	331	250	100	D-MLC

Selective Notations from 15 Minute Freeze

COA23 I can ship at any time, and NWA20, I still have to start a handoff on.

I don't really have a priority, but I would like to get rid of the three incoming aircraft. That will be less for me to worry about, and then assign the requesting IFR a code. He has only requested an IFR clearance.

Still not sure where YANKE79 is going. May have to run a route out on him. May be heading NE, and have to watch him with P57.

FIRST: Ship COA23, TWA71, and AWE43. Start a handoff on OSAGE22.

Selective Notations from 15-20 Minute Sequence

15:30 YANKE79: Going to check YANKE79 route. I think he is staying Eastbound. Should not be a problem.

16:29 N7447B: Lets get a code going on 74B. Cannot do it...I am assuming that MIO is VFR...

18:04 R12429: Need to clear ARMY for approach, but he has 10 minutes to vortex, so I don't have to worry about him any time too soon.

18:17 LN444 and N368LL: I am waiting for a down time on LN444, so I can clear 8LL for approach.

18:44 N7447B: I would have liked to help that guy out there, but he is a /x. Not worth it for 5 miles.

19:34 YANKE79: Start my handoff on YANKE79.

Selective Protocol Analysis for A15, SPS 7A

Table 15.7A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	142	380	100	D-MIO
AWE43	DC9	068	258	79	A-TUL
N368LL	PASE	252	200	100	D-MIO
COA23	B727	197	410	240	D-TUL
DAL42	B747	289	430	240	D-TUL
NWA20	DC10	197	440	247	D-TUL

Selective Notations from 5 Minute Freeze

I am going to make COA23 first, since he looks ahead, and I will be talking to him first.

DAL42 and NWA20 are going to be tied, but as soon as they get into my airspace, it will be descending them.

FIRST: Clear LN444 for approach to MIO, and then work on COA.

Selective Notations from 5-10 Minute Sequence

8:56 COA23 and TWA71: My primary concern is that I don't think it is going to work with COA. Should go with the second plane. Also have TWA71 climbing out, which may hold things up (for the arrivals).

Table 15.7B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	179	171	28	D-MIO
AWE43	DC9	067	419	170	A-TUL
N368LL	PASE	253	200	100	D-MIO
COA23	B727	202	423	180	D-TUL
DAL42	B747	293	341	195	D-TUL
NWA20	DC10	180	354	220	D-TUL
TWA71	DC10	068	383	105	A-TUL

Selective Notations from 10 Minute Freeze

As soon as DAL gets underneath TWA (who is stopped at 15,000), I may vector DAL to go behind COA. Otherwise, I will vector COA to intercept to pull him ahead. NWA20 is doing fine. AWE is almost clear.

Still wondering about the LN.

YANKE79 and HOMIN10, I still need to look at. I just took the handoff on YANKE and I am not sure what he is doing. Could be a conflict.

FIRST: Working out this in-trail problem with COA and DAL.

Selective Notations from 10-15 Minute Sequence

No verbalizations during this period - Heavy workload

Table 15.7C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
HOMIN10	A7	104	450	210	OVER
YANKE79	F14	087	480	220	
COA23	B727	288	367	105	D-TUL
DAL42	B747	287	295	110	D-TUL
NWA20	DC10	257	332	167	D-TUL
TWA71	DC10	027	470	228	A-TUL
R12429	U21	331	250	100	D-MLC

Selective Notations from 15 Minute Freeze

I just handed off the OSAGE22. I should have started flashing him sooner. He was about to violate their airspace.

I should issue LL VFR traffic over MIO.

Still waiting for LN to cancel his IFR, because I cannot clear anyone else for approach.

I have to start the ARMY down, landing MLC.

This situation with HOMIN and YANKE, the approved 22,000, no problem. Normally before I issue wrong altitude for direction, I check with the next sector.

The Tulsa arrivals are taken care of as are the arrivals.

FIRST: Issue ARMY approach to MLC, and traffic for 8LL, and ship OSAGE22.

Selective Notations from 15-20 Minute Sequence

16:00 NWA20: I am going to ship NWA20, and then turn call Tulsa approach to verify that they are watching KK and that they are going to get underneath him. I should call approach first.

17:13 HOMIN10: Going to ship HOMIN10...

17:23 NWA20 and N464KK: After I saw that NWA20 was below KK, I would put him on course. Approach knows that he is on a 50 heading, they are going to be getting below him. I release control for lower on NWA20. That should help them out a bit, otherwise they would have to wait until they got into their airspace.

18:01 AWE43 and TWA71: There is an overtake. AWE43 and TWA71, looks like AWE43 is turning back into me. I would call Memphis Center and bring it to their attention. It is going to be a head-on outside my airspace.

18:39 NWA20: We have another arrival...could have issued the NWA20 a safety alert for the VFR, but since I shipped him early enough, that should not be a factor.

19:09 We are working again? I though we were frozen.

Selective Protocol Analysis for A16, SPS 7A

Table 16.7A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	142	380	100	D-MIO
AWE43	DC9	315	258	30	A-TUL
N368LL	PASE	252	200	100	D-MIO
COA23	B727	197	410	240	D-TUL
DAL42	B747	289	430	240	D-TUL
NWA20	DC10	197	440	247	D-TUL

Selective Notations from 5 Minute Freeze

Arrivals to MIO. LN444 is my first priority, set him up and get him in.

Put N121EK in a hold, and N368LL set him up for a hold also.

COA23 I take the handoff.

I will route display these two military craft to see where they are going (OSAGE22 and HOMIN10).

I see the possible conflicts with the Tulsa arrivals.

FIRST: Take the handoff on COA23.

Selective Notations from 5-10 Minute Sequence

8:04 DAL42, NWA20, COA23, and AWE43: Going to start COA down...the AWE43 is coming up. NWA20, I am going to reduce and start down(20,000) , and the DAL15 I am going start down.

9:52 OSAGE22: I am doing a route readout on the OSAGE22 to see where he is going.

Table 16.7B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	179	143	29	D-MIO
AWE43	DC9	068	420	152	A-TUL
N368LL	PASE	253	200	100	D-MIO
COA23	B727	196	389	160	D-TUL
DAL42	B747	292	430	202	D-TUL
NWA20	DC10	195	342	204	D-TUL
TWA71	DC10	068	429	120	A-TUL

Selective Notations from 10 Minute Freeze

Got watch this overtake between NWA20 and COA23. I will be vectoring in a second if it...

DAL42, will assign him speed as soon as I get him, 300 or greater. COA23 is reduced to 280, and NWA20 is reduced to 250.

AWE43 is on his way to 23,000.

TWA71, I started him up to 18,000 because I did not know where OSAGE22 was heading. Did not want a potential.

HOMIN10 and YANKE79, got to do a route readout to make sure that they are not in conflict. Don't know who I am going move.

I will get to the VFR when I get a chance.

LN444, waiting for him to report procedure turns so I can ship him to him over to MIO.

ARMY, got to look where he is going and take the handoff.

FIRST: See where HOMIN10 is going.

Selective Notations from 10-15 Minute Sequence

10:16 HOMIN10 and YANKE79: I just displayed both routes, they are going to merge at Hot Springs. This is something I will tell the next center. If I don't like it I will change the altitude.

10:50 TWA71 and AWE43: TWA71 is going to 23,000. Now I have just got to watch because I have a DC9 with a DC10, look at their airspeed. Nothing big.

12:45 Right now I am waiting for TWA to acknowledge the speed restriction.

12:53 DAL42, NWA20, and COA23: DAL42, I am going to reduce his speed, COA23 should join pretty good. NWA20 I am going to bring in on a heading and start him down.

13:03 AWE43 and TWA71: Pass the speeds on AWE43 and TWA71 and get rid of them.

Table 16.7C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
HOMIN10	A7	104	450	210	OVER
YANKE79	F14	087	480	210	
COA23	B727	287	295	110	D-TUL
DAL42	B747	288	269	94	D-TUL
NWA20	DC10	189	325	168	D-TUL
TWA71	DC10	027	432	230	A-TUL
R12429	U21	331	250	100	D-MLC

Selective Notations from 15 Minute Freeze

OSAGE22 I am going to ship him to KS Center. TWA71, I am going to ship him to KS.

I have got to ship this LN to the MIO radio.

NWA20, it is not looking as good as I thought. Went to 12,000 because of COA at 11,000. Depends on how he joins, if not 5 miles, I will vector him. Going to be close.

HOMIN10 and YANKE79, I will probably move one. Move one to whatever the pilot wants to do.

ARMY, I am going to start him down into MLC, vector for visual approach.

FIRST: Start HOMIN10 down, because he is going to land in Hot Springs. Make sure he does not hit P57. First thing, do a route readout.

Selective Notations from 15-20 Minute Sequence

15:47 **NWA20:** The NWA20, I vectored him down, now I will vector him back (for separation).

16:47 HOMIN10 and YANKE79: HOMIN10 says he wants to hold. He is already past the VOR, and there is nothing out there at 21,000, so he can do what he wants. Now he is no longer a factor for YANKE79.

17:15 Handing off YANKE79 and getting the ARMY set up for his approach.

17:20 NWA20: I am going to ship NWA20 to Tulsa approach. I have my spacing.

17:24 N368LL: 8LL, I will start him down in a second. No real big hurry.

18:17 NWA20: This NWA20, all these guys are supposed to be descended by approach, I am going to cross my traffic at 11,000. Now they are starting him down.

18:54 R12429: Now I am just call MLC on the ARMY inbound.

19:20 HOMIN10: Now my HOMIN10 is a factor. (changed him to left turns) I gave him poor holding instructions. If he makes a right turn he goes into P57.

/

Selective Protocol Analysis for A18, SPS 7A

Table 18.7A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	142	380	100	D-MIO
AWE43	DC9	068	258	65	A-TUL
N368LL	PASE	252	200	100	D-MIO
COA23	B727	197	410	240	D-TUL
DAL42	B747	289	430	240	D-TUL
NWA20	DC10	197	440	247	D-TUL

Selective Notations from 5 Minute Freeze

LN444 is about 12 to 15 miles from MIO. Short left turn and take him down to 4,000.

8LL and EK,

AWE43, I have the handoff on, I will climb him to 15 or 16,000.

COA23, when he enters my airspace, I will descend him to 1,000 feet above AWE43, and give him a restriction of 250.

OSAGE22 and HOMIN10, I will look at their routes.

FIRST: LN444 because of speed and proximity to MIO. I will start him down to 3,000. Priority handling. Visual approach would be the fastest way for him to go in.

Selective Notations from 5-10 Minute Sequence

7:58 Looking at my inbounds. I will make COA23 first, DAL42 second, and NWA20 third. I have to take them down reference AWE43.

8:14 I have a TWA71 flashing.

9:07 NWA20 and DAL42: I need to get the incomings down to 23,000 so I can do something. Once they get into my airspace, I can turn them. I can reduce them now.

9:30 TWA71 just checked on.

9:32 LN444: LN, I am just waiting to hear when he cancels IFR.

9:45 Once at 23,000, NWA20 will turn to the left, and fall behind DAL42. COA23 has been turned ahead of DAL42.

Table 18.7B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
LN444	C501	333	209	30	D-MIO
AWE43	DC9	068	419	150	A-TUL
N368LL	PASE	253	200	100	D-MIO
COA23	B727	205	410	160	D-TUL
DAL42	B747	292	432	230	D-TUL
NWA20	DC10	195	432	230	D-TUL
TWA71	DC10	068	430	100	A-TUL

Selective Notations from 10 Minute Freeze

I have 2 departures out of Tulsa. The back one (TWA71) should not be a factor with the inbounds.

COA23 I started down to 16,000 for AWE43. NWA20 and DAL42, reduced and descended for control. Vector NWA20 and slow DAL to 250 to make sure I have my spacing. Right now it is not working so hot.

LN444 I was waiting for a cancellation.

68LL I will hold at MIO for departures.

FIRST: Vector NWA20 for spacing, DAL42, slow and down. COA let him go on course. Will do a route readout on OSAGE22.

Selective Notations from 10-15 Minute Sequence

11:06 Since OSAGE22 is going directly out of my airspace, I will hand him off to KS Center.

11:41 My spacing is no good, so I have to turn the COA in more. Turn the DAL in and back down, and NWA20 I will keep him like he is.

12:45 Looking at the poor spacing.

13:11 I will recover by vectoring DAL42 straight North for 3 miles and back for 3 miles. That will give me my 6 miles. I will have my spacing.

13:30 LN444 still has not cancelled, so I cannot get the departures off of MIO.

Table 18.7C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
HOMIN10	A7	346	348	210	OVER
YANKE79	F14	087	480	210	
COA23	B727	287	410	110	D-TUL
DAL42	B747	076	302	119	D-TUL
NWA20	DC10	286	360	120	D-TUL
TWA71	DC10	027	430	185	A-TUL
R12429	U21	331	250	89	D-MLC

Selective Notations from 15 Minute Freeze

I fell behind on my spacing, and that messed me up. COA23, I need to reduce speed. DAL42 instead of second, he is going to be third. NWA20 is just going to go on in.

LN444, I am going to call MIO radio and see what happened to him. He should be on the ground by now.

ARMY is starting down to 5,000. When he gets closer, I will give him his approach clearance.

TWA71, I will flash to the high side. He is at 18,000 looking for higher.

FIRST: Call Tulsa and tell them that COA is at 250 and will switch him. He is now at the fix.

Selective Notations from 15-20 Minute Sequence

15:48 I need to watch to make sure that Tulsa approach takes down COA23 before KK

17:24 I have to call MIO radio and see what happened to LN444.

17:57 Start 68LL down and entering him in a hold. Should not have had to do that.

18:20 Osage is out of my airspace, don't need to watch him. DAL42 is handed off, I will hold on to him to make sure he does intercept the FORTS1.

18:46 Waiting to hear from the LN, should have heard from him by now.

19:45 Taking handoffs on two more inbounds.

APPENDIX J:

PRODUCTIONS FROM ANALYSIS OF DYSIM STRUCTURED PROBLEM SOLVING: NOVICE GROUP

Selective Protocol Analysis for A26, SPS 2A

Table 26.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	033	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

EAL has the best airspeed, vector him to the SHAWN1 arrival. AAL is already on the SHAWN1 coming in behind EAL. COA, get control from the other sector, and vector him behind AAL.

FIRST: Start AAL down. (error: A26 meant to say EAL)

Selective Notations from 5-10 Minute Sequence

6:08 COA15: Looking at COA in relationship to the sector boundary. I will wait a few minutes and let him get in my sector before I give him a vector instead of pointing him out.

PRODUCTION

IF there inbound air carriers to an approach controlled airport
AND one of the inbounds is not in the sector

THEN monitor to accept handoff
AND wait to see
AND monitor spacing

6:26 EAL121 and AAL31: Could turn EAL more. O23, maybe should be 030. The vector lines indicate that they will meet.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND two of the inbouds will intersect
AND have vectored one of the aircraft
AND vector was not sufficient

THEN reconsider vector
AND monitor spacing

7:58 COA does not look good. Will turn him as soon as he gets into my airspace.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds is not in the sector
AND the spacing on that inbound is not adequate

THEN monitor that inbound for handoff
AND monitor to vector for spacing

8:28 EAL121 and AAL31: Looking at how it is coming together with EAL and AAL. (looking at vector lines and slowing down AAL to 250).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND two inbounds were tied
AND one of the inbounds was slowed for spacing

THEN review vector lines
AND monitor spacing

9:08 No change of plans. I will have five miles with EAL and AAL. COA will be well behind to join.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND first and second inbound have spacing
AND third inbound appears to have spacing

THEN do not change plans
AND monitor spacing

9:32 As long as EAL keeps his airspeed up, until I get him in front, and then I will give him 250...

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND there is separation

THEN monitor to assign speed reduction
AND monitor spacing

Table 26.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	034	435	110	D-TUL
COA15	DC9	306	425	230	D-TUL
AAL31	MD80	067	300	120	D-TUL

Selective Notations from 10 Minute Freeze

EAL, AAL, and COA, all coming into Tulsa on SHAWN1. When EAL gets in front of AAL, make sure he has adequate distance. Reduce EAL to 250 and ship him. Then drop AAL to 11,000. Descend COA to 13,000 so I can further reduce speed.

FIRST: Descend COA to 13,000.

Selective Notations from 10-15 Minute Sequence

10:29 Looking at COA airspeed, seeing if I should reduce him. (Reduces him to 250).

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND third inbound is in airspace

THEN assign speed reduction to third inbound
AND monitor spacing

10:49 I am thinking that EAL will need the 250 restriction and will be out in front of AAL. COA will fall in nice behind AAL. I will give one more vector as soon as he gets in closer.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND first inbound is nearing the approach
AND third inbound's spacing is not fully established

THEN monitor first aircraft to assign speed reduction
AND monitor third aircraft to vector for spacing
AND monitor spacing

11:18 Start EAL flashing to Tulsa.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND first inbound is nearing the approach
AND there is good spacing

THEN initiate handoff
AND monitor spacing

11:54 As soon as EAL reports joining the SHAWN1, I will give him a the 250 restriction and ship him to Tulsa.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND first inbound is nearing the approach
AND there is good spacing
AND that inbound's speed is in excess of airport approach restriction

THEN monitor inbound to assign speed reduction
AND monitor to issue frequency change
AND monitor spacing

13:09 EAL was not exactly on the SHAWN1 when he reported...Don't need to do anything about it.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND first inbound is nearing the approach
AND reports being on the arrival route

THEN monitor to drop track

13:35 Got the TWA handoff. He will intercept SHAWN1 up there.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound approaching the sector
AND new inbound will intercept approach

THEN accept handoff
AND monitor for spacing

14:07 Thinking of putting COA on a 350 to join the SHAWN1 behind AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND third inbound's spacing is fully established
AND third inbound needs to be vectored to join arrival

THEN vector to join arrival
AND monitor spacing

14:58 Probably too much of a turn with COA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND inbound has been vectored to join arrival
AND vectoring does not look on route

THEN reconsider vectoring to join arrival
AND learn from errors
AND monitor routing

Table 26.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	067	295	110	D-TUL
COA15	DC9	349	304	130	D-TUL
AAL31	MD80	067	295	110	D-TUL
TWA19	B727	023	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

Looks pretty good. COA, looks like I can bring him in nice and tight behind AAL.

TWA, wait and see his airspeed. When he gets over my boundary, I will vector him to join and give him airspeed since there is plenty of room behind COA.

DAL is slower coming in behind TWA, and then there is UAL.

FIRST: Descend COA to 12,000 and wait until TWA crosses the boundary, and I will take him.

15:18 UAL59: COA was flashing. Take him...I mean UAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound approaching the sector
AND new inbound is flashing

THEN accept handoff
AND monitor for spacing

15:49 UAL59: UAL, when he gets into my airspace, I will vector him to bring him into the SHAWN1.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds is not in the sector
AND the spacing on that inbound is not adequate

THEN monitor that inbound for handoff
AND monitor to vector for routing

16:03 AAL31: Can start AAL flashing at Tulsa.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one inbound is nearing the approach
AND there is good spacing

THEN initiate handoff
AND monitor spacing

16:13 DAL143: DAL is descending out of high. I can take him (request control).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one inbound is descending from the high-side

THEN reach out for control
AND monitor to sequence for arrival

16:47 DAL143: DAL is mine, I can do with him what I want.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND you have control of one of them

THEN consider multiple options for that inbound
AND monitor to sequence for arrival

17:03 TWA19: The plan is the same as the last time. TWA has the best forward airspeed...Give him a heading to turn into Tulsa.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one has the best forward airspeed

THEN sequence him number 1 for arrival
AND monitor to vector for re-routing

19:00 COA15: COA, I was thinking about giving him 10 degrees more. Not necessary.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one is a small amount off route

THEN reconsider vectoring for re-routing
AND monitor to vector for re-routing

19:07 TWA19: TWA, what is he is doing. Did a 360 to get from 023 to 030. Will make him fourth (last).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one took the wrong vector

THEN sequence that aircraft last for arrival

Selective Protocol Analysis for A27, SPS 2A

Table 28.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

Looks like the plan will work. EAL first, AAL second, and COA third. Take COA on a vector if we need the extra space.

FIRST: Get control of AAL to descend.

Selective Notations from 5-10 Minute Sequence

5:33 AAL31: Want to get control of AAL since it will be hard to get him down in such a short space. He has a short distance to go.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one is outside the sector
AND that inbound needs to be descended

THEN reach out for control

6:03 EAL121: Since EAL is the first one in, get him down (to 11,000) because he will be free and clear of everyone.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one has been sequenced as number 1
AND number 1 is clear of the other inbounds

THEN clear to descend

6:21 EAL121: Looking at the routing on EAL. Will give him the SHAWN1 arrival.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one has been sequenced as number 1
AND number 1 needs to be routed

THEN vector to join arrival

7:01 AAL31: See if AAL is on frequency to start him down and reduce speed.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds is ready to be descended

THEN monitor to see if inbound is on frequency

7:26 COA15: Vector COA for additional spacing.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 3 inbounds has not established spacing

THEN vector for spacing

7:52 AAL31: Start AAL down (19,000).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds is ready to be descended
AND inbound is on frequency

THEN clear to descend to intermediate altitude

8:02 EAL121 and AAL31: Looks good so far. The vectors, AAL is going in slow and EAL is faster, and EAL is showing into the arrival first.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 is going faster.
AND number 2 is going slower
AND separation is just established

THEN review vector lines
AND monitor for spacing

8:33 EAL121, COA15 and AAL31: COA, will vector him to the North as soon as EAL and AAL are in further.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 1 and 2 are still a distance from the gate

THEN monitor to vector number 3 for re-routing
AND monitor for spacing

9: 12 COA15 and AAL31: I am laddering down (AAL and COA) so when I get closer, I can turn them without being at the same altitude.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 2 and 3 are not fully separated
AND number 2 and 3 need to be descended
AND one of them needs to be vectored for routing

THEN assign altitude for separation
AND monitor for spacing
AND monitor to vector for re-routing

9:34 COA15 and AAL31: Slowing COA to 250 should ensure the needed spacing. The COA was catching up to AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 2 and 3 are not fully separated
AND number 3 is catching up with number 2

THEN assign number 3 a speed reduction
AND monitor for spacing

9:58 EAL121 and AAL31: I am looking at EAL turning on to the arrival route. Right now he is ahead of AAL with a 100 knots speed difference.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 is turning on the the arrival route

THEN monitor for spacing

Table 28.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	118	D-TUL
COA15	DC9	270	350	209	D-TUL
AAL31	MD80	067	327	160	D-TUL

Selective Notations from 10 Minute Freeze

EAL is almost at 11,000 ahead of COA and AAL. He will be going in free and clear. AAL has 100 knots less then EAL and behind. Looks good, descend him to 12,000, and when we have the five miles, descend on down to 11,000.

Turn COA to the NORTH. His speed is starting to decrease. We have plenty of mileage. That is all right now.

Selective Notations from 10-15 Minute Sequence

10:24 COA15: Making sure the speeds are good. An waiting a few minutes to turn COA to the North.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds needs to be vectored for re-routing
AND and spacing is not fully established

THEN monitor to vector for re-routing
AND wait to see
AND monitor for spacing

11:07 EAL121 and AAL31: Still looks good with EAL and AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND two are approaching the gate

THEN monitor for spacing

11:26 AAL31: Put the J-Ball on AAL so I will be able to tell when I have my spacing. Looks good.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing is not fully established

THEN monitor for spacing

11:52 AAL31 and COA15: At those speeds, we will have not problem getting AAL in there. And I look at the vector lines, and AAL is still clear of COA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has just been established

THEN monitor for spacing

12:27 EAL121: Let EAL run at his speed, and reduce him to 250 when I ship him...Flash him to Tulsa. Then when I send him, I will give him his speed restriction.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND lead air carrier is approaching gate
AND lead air carrier still needs speed reduction

THEN issue handoff
AND monitor to assign speed reduction

13:05 COA15 and TWA19: TWA also landing in Tulsa. He is behind the COA, and is clear there. I will have to give him the arrival routing into Tulsa.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND that new inbound needs routing

THEN accept handoff
AND monitor to vector for routing

14:02 EAL121: Will give EAL the speed restriction and hand him over to Tulsa...That takes care of him.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND lead inbound is at the gate

THEN assign speed reduction
AND drop track

14:32 COA15 and AAL31: Take COA to 11,000 because he is clear of AAL, and handoff AAL to Tulsa approach and we still have to reduce him to 250.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND lead inbound is approaching the gate
AND lead inbound needs to be descended
AND separation has been established

THEN clear lead to descend
AND initiate handoff
AND monitor to assign speed reduction

Table 27.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	067	351	110	D-TUL
COA15	DC9	360	295	110	D-TUL
AAL31	MD80	067	302	110	D-TUL
TWA19	B727	022	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

TWA and the DAL, a 727 and a 767. Looking at the speeds of the two aircraft. They are going about the same. Reducing the one in the back will provide spacing.

The plan for the first three worked just fine.

Looking what we might do with TWA, DAL, and UAL. TWA looks ahead of UAL. And DAL looks ahead of UAL. So we will do the same thing with UAL that we did with COA. We will give him a turn, then turn him North after we get our spacing. TWA and DAL, I will wait to get the handoff and see how the vectors look to see which one is in front, and reduce the one behind.

Selective Notations from 15-20 Minute Sequence

15:20 UAL59: Take the handoff on UAL.

PRODUCTION

IF there are inbound air carriers to an appro' h controlled airport
AND there is a new inbound
AND that new inbound is in sector

THEN accept handoff

15:56 COA15: Looking at the spacing, COA is clear and going to 11,000. He will make it through the arriva gate just fine.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND trailing inbound is approaching the gate
AND trailing inbound needs to be descended
AND separation has been established

THEN clear trailing inbound to descend
AND monitor to initiate handoff

16:09 DAL143: Take the handoff on DAL...Looks like DAL is ahead.

Table 28.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	067	351	110	D-TUL
COA15	DC9	360	295	110	D-TUL
AAL31	MD80	067	302	110	D-TUL
TWA19	B727	022	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

TWA and the DAL, a 727 and a 767. Looking at the speeds of the two aircraft. They are going about the same. Reducing the one in the back will provide spacing.

The plan for the first three worked just fine.

Looking what we might do with TWA, DAL, and UAL. TWA looks ahead of UAL. And DAL looks ahead of UAL. So we will do the same thing with UAL that we did with COA. We will give him a turn, then turn him North after we get our spacing. TWA and DAL, I will wait to get the handoff and see how the vectors look to see which one is in front, and reduce the one behind.

Selective Notations from 15-20 Minute Sequence

15:20 UAL59: Take the handoff on UAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND that new inbound is in sector

THEN accept handoff
AND wait to see

15:56 COA15: Looking at the spacing, COA is clear and going to 11,000. He will make it through the arrival gate just fine.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND trailing inbound is approaching the gate
AND trailing inbound needs to be descended
AND separation has been established

THEN clear trailing inbound to descend
AND monitor to initiate handoff

16:09 DAL143: Take the handoff on DAL...Looks like DAL is ahead.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND that new inbound is in sector

THEN accept handoff
AND monitor to sequence for arrival

17:01 TWA19 and UAL59: Reduced speed on TWA and UAL. That takes care of the things I have to do now.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND tentative sequencing has been established

THEN assign speed reduction to numbers 2 and 3

17:13 TWA19, DAL143, and UAL59: Spacing wise, DAL is in first, but I will change my plan and take UAL...Because TWA has to go straight and then make the jog, and by making the jog UAL can go straight on. So we will turn the TWA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND tentative sequencing has been established
AND tentative number 2 must be vectored
AND number 1 is till in first

THEN switch sequencing
AND make number 3, number 2
AND monitor to vector new number 3

17:45 DA:143: Before I do that, get control of DAL and descend him.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND sequencing has been determined
AND number 1 is not in the sector

THEN reach out for control of number 1
AND monitor to clear number 1 to descend

18:08 DA:143: Take DAL all the way down because he is clear of everyone (11,000).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND you have just gotten control of inbound
AND inbound needs to be descended
AND inbound is clear

THEN clear inbound to descend

18:20 TWA19, DAL143, and UAL59: DAL first, UAL second, and TWA third. I think we will turn TWA...That will get him going to the East until we can see that UAL is passing him and we have our spacing.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND sequencing has been determined
AND spacing is not fully established

THEN monitor to vector trailing aircraft
AND monitor separation

19:02 DAL143 and COA15: Speed looks good on DAL, and got to watch DAL with COA to make sure that he doesn't catch up with COA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND new inbound is approaching the gate

THEN monitor spacing between new inbound and other inbounds

Selective Protocol Analysis for A28, SPS 2A

Table 28.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

EAL is going to be number 1. I am going to re-route him and start him down to 11,000. COA will be number 2. AAL31, I have control, so I will reduce him to 250. He will be 3rd in. I will leave him up for a while.

FIRST: Recued AAL...I don't have him on frequency yet, so I will re-route EAL.

Selective Notations from 5-10 Minute Sequence

5:26 AAL31: Waiting for AAL to come over. That is the next thing I want to do.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND the trailing inbound is approaching the sector
AND trailing inbound needs to be assigned a speed reduction

THEN monitor to accept handoff
AND monitor to assign speed reduction

5:36 EAL121: Going to give EAL present heading until intercept the SHAWN1 arrival.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one inbound needs to be vectored for re-routing

THEN vector for re-routing

7:16 COA15: Want to give COA an arrival route on TULSA1.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds needs routing

THEN establish routing

7:52 EAL121 and AAL31: I am thinking AAL is still going too fast and he is going to catch EAL...My plan is to reduce AAL as much as possible and make him third. If I cannot make him third speed wise, I am going to vector him.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND the arrival sequence has been established
AND number 3 may catch number 1

THEN assign number 3 a speed reduction
AND monitor to vector for spacing

8:27 COA15 and EAL121: Taking COA to 12,000 in case I have a confliction with him and EAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there may be a confliction between inbouds
AND the inbounds need to be descended

THEN assign altitude for separation
AND monitor spacing

8:45 COA15 and EAL121: Going to leave EAL and COA at their speeds as long as I can.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has been determined
AND number 1 and 2 are still a distance from the gate

THEN monitor to assign speed reduction
AND monitor spacing

9:21 EAL121 and AAL31: Looking at EAL and AAL. They are getting pretty close...I am going to start vectoring AAL...Giving myself a little more space.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND two of the inbounds do not have separation

THEN vector trailing inbound for separation
AND monitor spacing

Table 28.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	019	435	110	D-TUL
COA15	DC9	325	425	183	D-TUL
AAL31	MD80	126	366	240	D-TUL

Selective Notations from 10 Minute Freeze

EAL is level, and I will have to start reducing his speed eventually.

AAL, I will turn him back in another 30 seconds, and that will give me plenty of spacing.

COA...I was thinking that my major problem was between AAL and COA. I am still not sure that there will be enough separation when they reach they join near Tulsa. So I may still leave AAL on his heading for 45 seconds. That should give me plenty of time. I am going to start COA to 11,000 since their should be no problem with EAL. I am going to start AAL down too to 12,000.

FIRST: Start COA down.

Selective Notations from 10-15 Minute Sequence

10:27 AAL31 and COA15: AAL and COA, I am estimating their distances for them.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND have vectored trailing inbound for spacing

THEN review vector lines
AND monitor to vector back on course

11:43 AAL31: Turned AAL back.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND have vectored trailing inbound for spacing
AND spacing has been established

THEN vector back on course

12:00 AAL31 and COA15: Descend AAL to 12,000 as a safety precaution. There should be no confliction with COA because COA's speed is well ahead of AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND separation has just been established
AND trailing inbound needs to be descended

THEN clear trailing inbound to descend
AND assign altitude for separation

12:46 EAL121: Start the EAL handoff. And when they take the handoff, I will reduce him to 250.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND lead air carrier is approaching gate
AND lead air carrier still needs speed reduction

THEN issue handoff
AND monitor to assign speed reduction

13:05 AAL31 and COA15: Judging the distances between COA and AAL. There is no confliction at all.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND separation has been established

THEN review vectors
AND monitor separation

13:27 EAL121: Watching, thinking about reducing EAL down to 250.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND lead inbound is at the gate
AND handoff has been accepted
AND inbound needs speed reduction

THEN monitor to assign speed reduction

14:58 AAL31 and COA15: Don't perceive any conflict between COA and AAL any more.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND separation has recently been established

THEN scan for conflict
AND monitor for separation

Table 28.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	067	366	110	D-TUL
COA15	DC9	359	425	110	D-TUL
AAL31	MD80	029	303	124	D-TUL
TWA19	B727	029	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

AAL, no problem with him and COA. Descend AAL to 11,000, and when he is low, start his handoff.

TWA, once he gets into my airspace, I am going to start stepping him down. Don't perceive any problem with him and UAL.

DAL, his times look fine, but visually it looks like insufficient separation...DAL in the SHAWN1, and TWA, will be routing him to the SHAWN1. There is a confliction, because DAL's distance is longer. I am going to reduce DAL, and see if that solves it. May have to vector DAL and let TWA go ahead of him.

If I put TWA on the SHAWN1, I am thinking if that will put him into confliction with UAL.

FIRST: Wait for Tulsa to take COA handoff and reduce him to 250...Get control of DAL for vectors and speed.

Selective Notations from 15-20 Minute Sequence

15:52 UAL59: When UAL comes on frequency, I will have to re-route him and get him on the TULSA1 arrival.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND new inbound needs re-routing

THEN monitor for inbound to get on frequency
AND monitor to vector for re-routing

16:20 UAL59: I know I want to do something with him right away.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND new inbound needs re-routing

THEN consider multiple options

16:50 UAL59: UAL, as soon is he is in my sector, I will clear him direct to McAlister, TULSA1 arrival.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND new inbound needs re-routing

THEN monitor to accept handoff
AND monitor to vector for re-routing

18:11 AAL31, DAL143 and TWA19: I am looking at DAL and TWA. Thinking about turning DAL South, like I did with AAL, to get some spacing. Maybe not such a drastic turn as I did with AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND two inbounds look tied
AND one of the inbounds needs routing

THEN learn from errors
AND monitor to vector for spacing

18:50 DAL143: I want to turn DAL back in a little while as soon as he is clear of TWA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds has been vectored for spacing

THEN monitor to vector back on course
AND monitor spacing

19:04 TWA19 and UAL59: Looking at TWA and UAL and estimating their distances to get up to arrow.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND separation has not been fully established

THEN review vectors
AND monitor spacing

19:17 AAL31: Looking at AAL. Have to hand him off.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there are new inbounds
AND last of first inbounds is at the gate

THEN initiate handoff
AND monitor spacing

19:48 UAL59 and TWA19: Reducing UAL because I thing he will be in confliction with TWA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND separation has not been fully established

THEN assign speed reduction to trailing aircraft
AND monitor spacing

Selective Protocol Analysis for A29, SPS 2A

Table 29.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	230	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

Right now, I can get a general idea of the planes and who is going to be first, second, or third. I may have to slow one of them up or turn one of them. Looks like it will run smoothly.

Selective Notations from 5-10 Minute Sequence

5:20 EAL121, COA15, and AAL31: AAL, I am just getting him down now. I want to get him down. If for some reason he does not get ahead of EAL, I may want to crank out EAL quicker and leave AAL on top. I may give COA some preferential routing, but he looks okay.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has not been established
AND there is a candidate for number 1

THEN clear potential number 1 to descend
AND formulate backup plan

6:08 EAL121, COA15, and AAL31: Right now keeping an eye on EAL and AAL. COA, right now he is kind of looks like he will be dragging. Looks like we will need to slow EAL.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND arrival sequence has not been established
AND there is a potential tie

THEN monitor to assign speed reduction
AND monitor separation

6:39 EAL121: Going smooth right now. May have to turn EAL, but right now just scanning the entire scope.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a potential conflict
AND trailing inbound has been slowed

THEN monitor to vector for spacing
AND monitor separation

7:15 EAL121 and AAL31: EAL, I gave him the descent clearance first, so he is getting down to 12,000. Could be a problem with AAL, but should have time for AAL. EAL has slowed back to 340.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a potential conflict
AND trailing inbound has been slowed and descended

THEN monitor to vector for spacing
AND monitor separation

7:35 EAL121 and COA15: Might have to slow COA back just a little, but I will let him maintain normal speed for right now. Can give him a turn if necessary, or I can put COA in front of EAL. Right now it is a just waiting game.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a potential conflict

THEN monitor to assign speed reduction
AND consider multiple options
AND wait to see

8:07 EAL121, COA15, and AAL31: I will put the J-Ball on EAL, because he will be a factor with both AAL and COA. That way one ball takes care of two other planes.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND separation has not been established

THEN monitor separation

9:07 EAL121, COA15, and AAL31: Still looking good (looking at vectors). Looks like AAL is going to crank out there. I am going slow EAL to 250. I will put COA ahead of ...

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 1 is out in front
AND number 2 and 3 have not established separation

THEN assign a speed reduction to number 2
AND reconsider arrival sequence

9:27 COA15, and AAL31: Looks like AAL will crank in there first. I am going to change my mind and put COA in.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 is out in front
AND number 2 and 3 have not established separation
AND speed has not taken effect

THEN reconsider arrival sequence
AND switch sequencing

9:51 AAL31: I am going to flash AAL first. So I don't get hung up latter handing people off.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 1 is approaching the gate
AND number 2 and 3 have not established separation

THEN initiate handoff
AND monitor spacing

Table 29.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	300	120	D-TUL
COA15	DC9	336	425	199	D-TUL
AAL31	MD80	067	405	110	D-TUL

Selective Notations from 10 Minute Freeze

I had planned on putting AAL in first, and EAL and then COA. I have decided to put COA second and EAL third. The problem is that EAL is at 12,000 and COA is at 13,000 and I am going to have to get COA below EAL. AAL is going to be out of COA's way. One of my first moves is to take COA down to 11,000. That way I am sure that he will be below EAL.

FIRST: Take COA down to 11,000.

Selective Notations from 10-15 Minute Sequence

10:26 EAL121, COA15, and AAL31: Slowed down COA, now I am assured of keeping him behind AAL. Should keep him ahead of EAL. AAL I still have him at speed. Won't give him his speed restriction until I switch him. That way I am sure he will keep his speed up.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 1 is out in front
AND number 1 needs a speed reduction
AND number 2 has not fully established separation with number 1

THEN assign a speed reduction to number 2
AND monitor to assign number 1 a speed reduction
AND monitor spacing

10:54 EAL121, COA15, and AAL31: Right now it looks like AAL is first, COA is second, EAL is third. AAL, I will hold on a little longer even though Tulsa has taken the handoff on him. I still have to give him the speed restriction, but I don't want to do that until I know that he is clear of COA.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 1 has been handed off
AND number 1 needs a speed reduction
AND number 2 has not fully established separation with number 1

THEN monitor to assign number 1 a speed reduction
AND monitor spacing

11:28 EAL121, COA15, and AAL31: The speeds are looking good right now...Now that I have slowed down COA, AAL has gotten well ahead of him. COA looking good. EAL is at 250, should keep him. When he makes his turn, it might be a little tight. Not sure...Still wait and see.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND number 1 has been handed off
AND separations have been just established
AND trailing inbound needs to be vectored for routing

THEN monitor to vector for routing
AND wait and see

12:24 EAL121 and COA15: I am fluctuating between COA and EAL. I just cannot decide. If I have to, I will turn EAL to the East in case I have to slow him down. Or I can turn COA and slow him down.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 has been handed off
AND arrival sequence may be switched
AND separation has not been established between number 2 and 3

THEN reconsider
AND consider multiple options
AND monitor to vector training inbound to vector for spacing

12:44 TWA19: Limited data block, TWA. I know I will have to put him on another arrival routing.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND new inbound needs routing

THEN monitor to vector for routing
AND monitor spacing

13:20 AAL31: AAL is well enough ahead that he can slow his speed down.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 has been handed off
AND number 1 needs a speed reduction
AND spacing has been established with number 1

THEN assign number 1 a speed reduction
AND monitor spacing

13:28 TWA19: TWA is flashing at us. Go ahead and take it...This time looks like the first two...maybe the third one getting tight.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND new inbound is flashing

THEN accept handoff
AND monitor spacing

14:04 EAL121 and COA15: I am changing my mind once again. EAL is going to beat COA...Not good to change mind 3 or 4 times.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 2 is ahead of number 3
AND have already switched sequence

THEN reconsider
AND monitor to switch sequencing
AND monitor spacing

14:28 EAL121 and COA15: Got to watch it. Taking EAL to 11,000 and COA is down to 11,000. It is kind of dangerous if Tulsa did not take the handoff. I do have the option of giving COA a turn and turning him back in.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 2 is ahead of number 3
AND have already switched sequence

THEN reconsider
AND consider multiple options
AND monitor spacing

Table 29.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	067	295	110	D-TUL
COA15	DC9	336	295	110	D-TUL
AAL31	MD80	067	295	110	D-TUL
TWA19	B727	023	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

My plan is to take EAL in ahead of COA. See another limited data block. The same as the last situation. The plane from the Southwest will be the spacing problem again. The way it look now, there will be a tie. Based on what happened the last time, I might slow one of them sooner or turn them. Or short cut routings so that I won't have to change my mind.

FIRST: Flash EAL to Tulsa, and give COA a turn.

Selective Notations from 15-20 Minute Sequence

15:12 COA15: I don't like the looks of that...Turning COA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 3 does not have spacing
AND have already switched sequence

THEN vector number 3 for spacing
AND monitor spacing

15:35 TWA19: Take care of the TWA handoff while I have a second.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND new inbound is flashing
AND there is no immediate concern

THEN accept handoff

16:12 COA15: Got COA on a heading. Will leave him on that heading...I am not sure what it looks like. May have to vector him more. Should have done that a long time ago. If I had turned him earlier, it would have been no problem.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND heading for trailing inbound is not good

THEN monitor to vector for routing
AND reconsider
AND monitor routing
AND learn from errors

16:55 COA15: Will still have to turn COA another 15 degrees...should have turned him a long time ago.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND heading for trailing inbound is not good

THEN vector for routing
AND monitor routing
AND learn from errors

17:26 DAL143: Getting control of DAL so that he does not get hung up high

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND new inbound is flashing

THEN accept handoff
AND monitor to clear to descend

17:32 COA15: Looks like I have my spacing with COA. I am going to tell COA to keep that heading until he joins the SHAWN1 arrival.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there has been a problem with his heading
AND he has been vectored
AND new heading is taking effect

THEN monitor routing
AND issue routing

17:57 COA15: Still looking too tight. Should not have to crank him that hard (COA).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there has been a problem with his heading
AND he has been vectored
AND spacing has not been fully established

THEN monitor for spacing
AND monitor to vector for routing

18:09 TWA19 and DAL143: Going to check who is going to be first, TWA or DAL. They are locked. This time I will take DAL down and put him in first and keep his speed up. Reduce TWA and have him go behind.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND two inbounds are tied

THEN sequence for arrival
AND monitor to assign speed reduction to number 2

18:50 COA15: Got to get back to COA. I have neglected him, which is not good. (vector him to the SHAWN1).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND he has been vectored
AND he needs to be vectored to the arrival

THEN vector for routing
AND monitor routing

19:37 TWA19, DAL143, and UAL59: As I am looking now (at vectors) UAL and DAL are going to be tied. I think I will slow TWA to 250 right now and see what happens.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND two are tied
AND arrival sequence has been determined

THEN assign speed reduction to number 2
AND review vector lines
AND wait to see

Selective Protocol Analysis for A30, SPS 2A

Table 30.2A. Key Aircraft Status at 5 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	023	435	204	D-TUL
COA15	DC9	334	425	240	D-TUL
AAL31	MD80	068	405	240	D-TUL

Selective Notations from 5 Minute Freeze

Start EAL descending once he is inside my sector. COA and AAL are outside, so I cannot do anything with them yet.

I am going to see how this sequence with AAL and EAL, both on the same arrival, so I will have to see which one is first.

FIRST: Get control for lower on AAL with R1.

Selective Notations from 5-10 Minute Sequence

5:32 EAL121 and AAL31: Use the vector lengths to see how AAL and EAL are going to work. So I will turn EAL to go behind AAL. (reduces EAL speed).

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND two are tied

THEN review vector lines
AND establish arrival sequence
AND assign speed reduction to number 2
AND vector for spacing

6:14 EAL121: Pointed EAL to R1

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has been determined
AND one of the inbounds has been descended into adjoining sector

THEN issue pointout

6:32 EAL121 and AAL31: Looking at the heading on EAL, may have been too much, but should bring him behind AAL.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has been determined
AND one has been vectored for spacing

THEN monitor routing
AND reconsider

6:44 EAL121 and AAL31: Thinking when I should issue AAL's speed restriction to Tulsa. I want to keep him going fast, that is why I have reduced EAL to 250.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has been determined
AND number 1 is approaching the gate
AND number 1 needs a speed reduction

THEN monitor to assign speed reduction
AND monitor spacing

7:25 EAL121 and COA15: Thinking about COA and EAL, whether they will be a factor at the intersection.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has been determined
AND trailing inbound has not been vectored to the arrival route
AND separation has not been fully established

THEN monitor to vector trailing inbound for routing
AND monitor spacing

7:48 EAL121 and COA15: Descended COA to 12,000 until I see where he will be in relation to EAL. Right now, they are at the same altitude.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has been determined
AND trailing inbound has not been vectored to the arrival route
AND separation has not been fully established

THEN assign altitude for separation
AND monitor spacing

8:13 AAL31: Need to coordinate with Tulsa since I forgot to give AAL his speed reduction.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND number 1 is at the gate
AND number 1 needs a speed reduction

THEN coordinate with approach sector
AND assign speed reduction

8:51 COA15: Looking at the arrival of COA in relation to the other aircraft. Deciding on the best sequence.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND separation has not been established

THEN reconsider
AND monitor to establish arrival sequencing

9:33 EAL121, AAL31, and COA15: Still trying to decide. I think AAL is going to be first, and EAL second, and I will have to vector COA behind. Does not look like it is going to work very well. Reducing COA speed should help.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND separation has not been established
AND sequencing has not been established

THEN reconsider
AND establish arrival sequence
AND monitor to vector trailing inbound for spacing
AND monitor to assign speed reduction to trailing inbound

Table 30.2B. Key Aircraft Status at 10 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	000	295	110	D-TUL
COA15	DC9	328	332	159	D-TUL
AAL31	MD80	067	405	110	D-TUL

Selective Notatic from 10 Minute Freeze

Wondering how the sequencing into Tulsa is going to work out. There may be enough room to squeeze COA between AAL and EAL. There is about 13 miles between the two. So I may try putting COA between the two. Will have to wait until they are a little closer to the fix.

FIRST: Probably observe the events happening.

Selective Notations from 10-15 Minute Sequence

10:27 COA15, EAL121, and AAL31: Waiting to see where EAL is going to end up. COA will go between EAL and AAL. I might take COA behind EAL. I have already vectored EAL quite a bit. He has done enough turns. Will have to wait and see how the situation develops.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND separation has not been established
AND sequencing has not been established
AND you have already vectored one of the inbounds

THEN reconsider
AND monitor to establish arrival sequence
AND consider multiple options
AND wait and see

11:16 COA15, EAL121, and AAL31: The speed, looks like AAL will be well in front of COA. But now COA and EAL are doing the same speed. Going to wait to see how it will work out.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND sequencing has not been established for numbers 2 and 3

THEN monitor to establish arrival sequence
AND wait and see

12:07 EAL121 and COA15: The more I look at it, EAL and COA will either be tied, or COA will be in front. So I plan to make COA number 2 into Tulsa. But I still have to wait and see.

PRODUCTION

IF there are three inbound air carriers to an approach controlled airport
AND sequencing has not been established for numbers 2 and 3

THEN consider multiple options
AND establish arrival sequence
AND wait and see

13:10 EAL121 and COA15: Looking at the same situation. Trying to make up my mind...I may have to vector EAL to get him behind COA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND sequencing has just been established
AND spacing has not been established

THEN reconsider
AND monitor to vector trailing inbound for spacing

14:07 EAL121 and COA15: Going to wait for the two aircraft to get closer. They are still quite a way from the fix.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND sequencing has been established
AND spacing has not been established

THEN monitor to vector trailing inbound for spacing
AND wait and see

14:29 TWA19: That routing was the only thing I had to do with TWA. So I am not worried about that.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there is a new inbound
AND new inbound needs routing

THEN vector for routing

14:42 TWA19, DAL143, and UAL59: Couple of more inbounds. Most likely the DAL will be first, the TWA will be behind him, and UAL will be last.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there are new inbounds
AND new inbound need need sequencing

THEN establish arrival sequence

Table 30.2C. Key Aircraft Status at 15 Minutes

Aircraft	Type	Heading	Speed	Alt.	Status
EAL121	L101	067	295	110	D-TUL
COA15	DC9	359	295	110	D-TUL
AAL31	MD80	067	405	110	D-TUL
TWA19	B727	022	410	230	D-TUL
DAL143	B767	068	410	377	D-TUL
UAL59	B727	334	410	194	D-TUL

Selective Notations from 15 Minute Freeze

Watching the first three inbouds develop, I did not do a good job or getting the three inbounds in. So I will probably let the DAL be first, TWA second, and UAL, last based on the fact that DAL is already on the route, and I should be able to slide UAL behind the other two.

FIRST: Flash COA to Tulsa, and hand him off. He is going to be number 2. That is definitely what I have decided there.

Selective Notations from 15-20 Minute Sequence

15:25 Looking at the next aircraft coming in.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND there are new inbounds
AND arrival sequencing has been established

THEN monitor for spacing

15:41 EAL121 and COA15: Still looking at COA and EAL. Looks like EAL may be able to stay on the route, and I won't have to vector him. I have a J-Ball on him to check the distance.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND spacing has just been established

THEN monitor to vector trailing inbound for spacing
AND monitor spacing

16:34 DAL143: DAL checked on at the wrong altitude, so I had to verify.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds checked on the wrong altitude

THEN verify altitude

16:57 DAL143 and TWA19: Have to coordinate with R1 to get control for lower on DAL. He may not hit R1 airspace. But just to make sure, start his descent and get him down in front of TWA.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds needs to be cleared to descend
AND that inbound is in another sector

THEN reach out for control
AND monitor to clear to descend

17:47 EAL121 and COA15: The data block on EAL, I handed off too early, so he dropped off. Normally you can pull them back up. The situation looks like it should clean up between EAL and COA. EAL should fall in 5 miles behind.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds was handed off
AND the data block has dropped from the screen

THEN attempt to regain data block
AND monitor for spacing

18:49 UAL59: Started UAL down, not to his final (14,000), so he is in a better altitude.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND one of the inbounds needs to be cleared to descend
AND arrival sequence has not been established

THEN assign an intermediate altitude
AND monitor to clear to descend

19:23 DAL143 and TWA19: Right now the plan is to make DAL first. Should work the same as the last time. UAL will be second. Have reduced TWA's speed, so he will be last. I pointed TWA to R1 to start his descent since he is going into R1 airspace.

PRODUCTION

IF there are inbound air carriers to an approach controlled airport
AND arrival sequence has not been established
AND trailing aircraft has been assigned a speed reduction

THEN establish arrival sequence
AND monitor spacing
AND monitor to issue pointout

Systematic Grammar Network for A26, SPS 2A

Display Strategies

Planning strategies:

- 4 Reconsider
- 3 Lower-level plan
- 2 Short-term contingencies
- 1 Wait to see
- 1 Switching sequencing
- 1 Learning from errors
- 1 High-level, primary plan

Monitoring Strategies:

- 5 Observing routing
- 4 Observing separation
- 4 Observe to vector
- 2 Gather aircraft data
- 1 Reading vectors
- 1 Observing for sequencing

Control Strategies

- 3 Approach strategies (descend and slow)
- 1 Sequencing strategies (high-level between 3 or more aircraft)

Separation strategies (lower-level between 2 aircraft):

- 4 Vector for separation
- 2 Use speed for separation

- 2 Routing strategies

Handoff strategies:

- 3 Accepting handoff
- 2 Initiating handoff

Workload Reduction Strategies

- 1 Early control

Systematic Grammar Network for A27, SPS 2A

Display Strategies

Planning strategies:

- 5 Lower-level plan
- 2 Reconsider
- 2 High-level, primary plan
- 1 Wait to see
- 1 Switching sequencing
- 1 Short-term contingencies
- 1 Refine primary plan

Monitoring Strategies:

- 14 Observing separation
- 5 Observing routing
- 4 Gather aircraft data
- 3 Observe to vector
- 2 Observing for sequencing
- 1 Use of J-Ball

Control Strategies

8 Approach strategies (descend and slow)

1 Sequencing strategies (high-level between 3 or more aircraft)

Separation strategies (lower-level between 2 aircraft):

- 3 Vector for separation
- 3 Use speed for separation
- 1 Vertical separation

2 Routing strategies

Handoff strategies:

- 2 Accepting handoff
- 2 Initiating handoff

Workload Reduction Strategies

- 2 Early control
- 1 Eliminating a factor
- 1 Letting aircraft run at speed

Systematic Grammar Network for A28, SPS 2A

Display Strategies			
	Planning strategies:		
		6	Lower-level plan
		2	Considering multiple options
		1	Wait to see
		1	Short-term contingencies
		1	Refine primary plan
		1	Reconsider
	Monitoring Strategies:		
		7	Observing separation
		5	Observing routing
		3	Reading vectors
		2	Observe to vector
		2	Gather aircraft data
Control Strategies			
	4 Approach strategies (descend and slow)		
	Separation strategies (lower-level between 2 aircraft):		
		2	Vertical separation
		2	Use speed for separation
		1	Vector for separation
	2 Routing strategies		
	Handoff strategies:		
		2	Initiating handoff
Workload Reduction Strategies			
		1	Letting aircraft run at speed

Systematic Grammar Network for A29, SPS 2A

Display Strategies

Planning strategies:

6 Lower-level plan
5 Reconsider
3 Wait to see
3 Switching sequencing
3 Consider multiple options
2 Short-term contingencies
2 Learning from errors
1 Backup plan

Monitoring Strategies:

15 Observing separation
5 Observing routing
4 Gather aircraft data
3 Reading vectors
3 Observe to vector
2 Observing for sequencing
1 Use of J-Ball

Control Strategies

4 Approach strategies (descend and slow)

Separation strategies (lower-level between 2 aircraft):

6 Use speed for separation
3 Vector for separation
1 Vertical separation

3 Routing strategies

Handoff strategies:

2 Accepting handoff
2 Initiating handoff

Workload Reduction Strategies

None

Systematic Grammar Network for A30, SPS 2A

Display Strategies			
	Planning strategies:		
		6	Lower-level plan
		4	Wait to see
		4	Reconsider
		2	High-level, primary plan
		1	Consider multiple options
	Monitoring Strategies:		
		9	Observing separation
		5	Observing for sequencing
		4	Observing routing
		3	Observe to vector
		1	Use of J-Ball
		1	Gather aircraft data
Control Strategies			
	5 Approach strategies (descend and slow)		
	Separation strategies (lower-level between 2 aircraft):		
		3	Use speed for separation
		2	Vertical separation
		1	Vector for separation
	1 Routing strategies		
	Handoff strategies:		
		2	Accepting handoff
Workload Reduction Strategies			
		1	Early control
		1	Letting aircraft run at speed

Combined Systematic Grammar Network for Novices on SPS 2A

Display Strategies

Planning strategies:

- 26 Lower-level plan
- 16 Reconsider
- 10 Wait to see
- 6 Short-term contingencies
- 6 Consider multiple options
- 5 Switching sequencing
- 5 High-level, primary plan
- 3 Learning from errors
- 2 Refine primary plan
- 1 Backup plan

Monitoring Strategies:

- 49 Observing separation
- 24 Observing routing
- 15 Observe to vector
- 13 Gather aircraft data
- 10 Observing for sequencing
- 7 Reading vectors
- 3 Use of J-Ball

Control Strategies

- 24 Approach strategies (descend and slow)
- 2 Sequencing strategies (high-level between 3 or more aircraft)

Separation strategies (lower-level between 2 aircraft):

- 16 Use speed for separation
- 13 Vector for separation
- 6 Vertical separation

- 10 Routing strategies

Handoff strategies:

- 9 Accepting handoff
- 8 Initiating handoff

Workload Reduction Strategies

- 4 Early control
- 1 Eliminating a factor
- 3 Letting aircraft run at speed

APPENDIX K:

STATISTICAL ANALYSES OF THE DATA FROM THE COGNITIVE STYLE ASSESSMENTS

RAW DATA

Group 1. Experts/Supervisors (N = 5)

SUBJ	AGE	YRS FPL	GEFT	TOTAL RT	ACCU-RACY	PROB 2A	PROB 5A	PROB AVG
1	46	19	4	511	10	100	85	92.5
2	52	22	17	1589	11	100	91	95.5
3	45	16	12	1231	9	78	94	86.0
4	44	15	13	510	9	100	94	97.0
5	49	22	13	637	11	93	98	95.5

Group 2. Experts/Nonsupervisors (N = 7)

SUBJ	AGE	YRS FPL	GEFT	TOTAL RT	ACCU-RACY	PROB 2A	PROB 5A	PROB AVG
1	41	8	11	1005	8	80	83	81.5
2	56	24	3	370	4	100	90	95.0
3	47	12	12	833	6	100	90	95.0
4	55	17	6	444	6	98	88	93.0
5	48	18	7	590	9	100	84	92.0
6	46	18	13	429	6	98	100	99.0
7	34	5	15	524	5	100	96	98.0

Group 3. Intermediates (N = 13)

SUBJ	AGE	YRS FPL	GEFT	TOTAL RT	ACCU-RACY	PROB 2A	PROB 5A	PROB AVG
1	30	0.67	16	827	11	100	98	99.0
2	28	0.83	12	491	9	100	89	94.5
3	31	0.50	12	611	7	90	94	92.0
4	26	0.83	4	892	5	100	100	100.0
5	28	0.83	12	602	11	100	100	100.0
6	34	0.83	18	654	11	98	100	99.0
7	28	0.83	11	465	5	*	*	*
8	32	0.58	18	597	9	*	*	*
9	29	0.92	16	839	9	*	*	*
10	33	1.17	9	672	7	*	*	*
11	27	0.83	18	600	8	*	*	*
12	32	0.47	14	348	8	*	*	*
13	28	*	4	1052	5	*	*	*

RAW DATA
(Continued)

Group 4. Novices (N = 11)

SUBJ	AGE	YRS RPL	GEFT	TOTAL RT	ACCU-RACY	PROB 2A	PROB 5A	PROB AVG
1	27	*	16	553	8	94	96	95.0
2	23	*	16	416	5	91	91	91.0
3	29	*	18	582	7	96	96	96.0
4	24	*	13	657	8	78	89	83.5
5	26	*	15	585	9	90	100	95.0
6	24	*	11	416	8	81	72	76.5
7	29	*	11	128	4	*	*	*
8	28	*	18	724	9	*	*	*
9	30	*	18	552	6	*	*	*
10	24	*	17	913	7	*	*	*
11	27	*	16	378	8	*	*	*

KEY:

YRS FPL	=	Number of years of experience as a full-performance-level controller.
GEFT	=	Number of items correct out of 18 on the Group Embedded Figures Test.
TOTAL RT	=	Total response time (time to first response) on the 12 items of the adult form of the Matching Familiar Figures Test.
ACCURACY	=	Number of items correct on the first try for the 12 items of the adult form of the Matching Familiar Figures Test.
PROB 2A	=	Performance rating (out of 100 possible points) on Problem 2A presented on the RTF simulator.
PROB 5A	=	Performance rating (out of 100 possible points) on Problem 5A presented on the RTF simulator.
PROB AVG	=	The arithmetic average of the two ratings received on problems 2A and 5A.

<u>STATISTICAL TESTS</u>

Analysis Of Variance: MFFT Speed (Total RT)

```
ANALYSIS OF VARIANCE
SOURCE     DF        SS        MS         F        P
FACTOR      3    462984    154328      2.30    0.096
ERROR      32   2149322     67166
TOTAL      35   2612305
                                INDIVIDUAL 95 PCT CI'S FOR MEAN
                                BASED ON POOLED STDEV
LEVEL       N      MEAN     STDEV  -----+---------+---------+---------+-
SUPERV      5     895.6     489.1              (---------*---------)
EXPERT      7     599.3     234.8   (-------*-------)
INTERM     13     665.4     192.5       (-----*----)
NOVICE     11     536.7     204.3  (-----*------)
                                   -----+---------+---------+---------+-
POOLED STDEV =    259.2               500       750      1000      1250
```

Analysis Of Variance: MFFT Accuracy (Number Correct On First Try)

```
ANALYSIS OF VARIANCE
SOURCE     DF        SS        MS         F        P
FACTOR      3     45.23     15.08      4.55    0.009
ERROR      32    105.99      3.31
TOTAL      35    151.22
                                INDIVIDUAL 95 PCT CI'S FOR MEAN
                                BASED ON POOLED STDEV
LEVEL       N      MEAN     STDEV  ------+---------+---------+---------+
SUPERV      5    10.000     1.000                 (-------*-------)
EXPERT      7     6.286     1.704  (------*------)
INTERM     13     8.077     2.216            (----*-----)
NOVICE     11     7.182     1.601       (-----*----)
                                   ------+---------+---------+---------+
POOLED STDEV =    1.820                 6.0       8.0      10.0      12.0
```

Multiple Comparison Tests: MFFT Accuracy (Number Correct On First Try)

Tukey HSD tests between all pairs of means indicated that each mean was significantly different from every other mean at the $p \leq .05$ level of significance.

STATISTICAL TESTS
(Continued)

Analysis Of Variance: GEFT Number Correct

```
ANALYSIS OF VARIANCE
SOURCE     DF        SS        MS         F        P
FACTOR      3     150.6      50.2      2.93    0.048
ERROR      32     548.1      17.1
TOTAL      35     698.7
                                 INDIVIDUAL 95 PCT CI'S FOR MEAN
                                 BASED ON POOLED STDEV
LEVEL       N      MEAN     STDEV  --+---------+---------+---------+----
SUPERV      5    11.800     4.764      (----------*---------)
EXPERT      7     9.571     4.315  (--------*--------)
INTERM     13    12.615     4.805              (------*------)
NOVICE     11    15.364     2.618                     (------*------)
                                   --+---------+---------+---------+----
POOLED STDEV =    4.139               7.0      10.5      14.0      17.5
```

Multiple Comparison Tests: GEFT Number Correct

Tukey HSD tests between all pairs of means indicated that only the difference between the Novices and the Nonsupervisor Experts was significant at the $p \leq .05$ level.

STATISTICAL TESTS
(Continued)

Analysis Of Covariance: MFFT Speed (Total RT)
(Influence of controller age removed)

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Covariates	24546.325	1	24546.325	.358	.554
AGE	24546.325	1	24546.325	.358	.554
Main Effects	405146.345	3	135048.782	1.970	.139
GROUP	405146.345	3	135048.782	1.970	.139
Explained	487530.077	4	121882.519	1.778	.158
Residual	2124775.562	31	68541.147		
Total	2612305.639	35	74637.304		

36 cases were processed.
0 cases (.0 pct) were missing.

Analysis Of Covariance: MFFT Accuracy (Number Correct On First Try)
(Influence of controller age removed)

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Covariates	.612	1	.612	.180	.674
AGE	.612	1	.612	.180	.674
Main Effects	44.583	3	14.861	4.372	.011
GROUP	44.583	3	14.861	4.372	.011
Explained	45.846	4	11.462	3.372	.021
Residual	105.376	31	3.399		
Total	151.222	35	4.321		

36 cases were processed.
0 cases (.0 pct) were missing.

Multiple Comparison Tests: MFFT Accuracy (Number Correct On First Try)

Post hoc comparisons between all pairs of means yielded the following three significant differences:

Group 1 > Group 2 ($t = 3.43$; $p < .01$)
Group 1 > Group 4 ($t = 2.14$; $p < .05$)
Group 3 > Group 2 ($t = 2.74$; $p < .05$)

Analysis Of Covariance: GEFT Number Correct
(Influence of controller age removed)

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Covariates	6.599	1	6.599	.378	.543
AGE	6.599	1	6.599	.378	.543
Main Effects	46.034	3	15.345	.878	.463
GROUP	46.034	3	15.345	.878	.463
Explained	157.213	4	39.303	2.250	.086
Residual	541.537	31	17.469		
Total	698.750	35	19.964		

36 cases were processed.
0 cases (.0 pct) were missing.

STATISTICAL TESTS
(Continued)

Analysis Of Variance: Problem 2A (Performance Ratings)

```
ANALYSIS OF VARIANCE
SOURCE     DF        SS        MS          F         P
FACTOR      3     331.8     110.6       2.14     0.127
ERROR      20    1031.8      51.6
TOTAL      23    1363.6
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL       N      MEAN     STDEV   ---+---------+---------+---------+---
SUPERV      5     94.20      9.55           (----------*----------)
EXPERT      7     96.57      7.37                 (--------*--------)
INTERM      6     98.00      4.00                  (---------*----------)
NOVICE      6     88.33      7.23   (---------*---------)
                                    ---+---------+---------+---------+---
POOLED STDEV =     7.18             84.0      90.0      96.0     102.0
```

Analysis Of Variance: Problem 5A (Performance Ratings)

```
ANALYSIS OF VARIANCE
SOURCE     DF        SS        MS          F         P
FACTOR      3     171.6      57.2       1.25     0.318
ERROR      20     914.2      45.7
TOTAL      23    1085.8
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL       N      MEAN     STDEV   -+---------+---------+---------+-----
SUPERV      5     92.40      4.83      (------------*-----------)
EXPERT      7     90.14      6.12    (---------*----------)
INTERM      6     96.83      4.49              (-----------*----------)
NOVICE      6     90.67      9.95    (----------*-----------)
                                    -+---------+---------+---------+-----
POOLED STDEV =     6.76            85.0      90.0      95.0     100.0
```

Analysis Of Variance: Problem Average Performance Rating

```
ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS         F         P
FACTOR       3     188.1      62.7      1.94     0.155
ERROR       20     644.9      32.2
TOTAL       23     833.0
                                INDIVIDUAL 95 PCT CI'S FOR MEAN
                                BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  -+---------+---------+---------+-----
SUPERV       5     93.30      4.40        (----------*---------)
EXPERT       7     93.36      5.79          (--------*--------)
INTERM       6     97.42      3.35                (---------*---------)
NOVICE       6     89.50      7.87  (----------*----------)
                                    -+---------+---------+---------+-----
POOLED STDEV =      5.68           85.0      90.0      95.0     100.0
```