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Identifying information for the Multi Sector Planner

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IDENTIFYING INFORMATION
FOR THE MULTI SECTOR PLANNER

A Thesis

Presented to

The Faculty of the Department of Industrial and Systems Engineering
San Jose State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by

Lisa Suyin Choo

May 2006

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ABSTRACT

IDENTIFYING INFORMATION FOR THE MULTI SECTOR PLANNER

by Lisa Suyin Choo

The FAA has conceptualized a new position, the Multi Sector Planner (MSP), for the US National Airspace System to resolve airspace capacity constraints and associated workforce issues among air traffic controllers. By conducting two simulation experiments, this research seeks to identify the types and timeliness of information that the MSP will require to perform efficiently. The pilot study reviews the current systems containing information available to the MSP. The card-sorting study identifies the information requirement of the MSP and the optimum time of its availability in different scenarios, to build the information architecture of the decision support tool for the MSP. The results indicate that the MSPs only need to look 30 minutes ahead beyond their sectors if they are responsible for three sectors and that air traffic controllers prefer to view information in distance rather than time based and categorized into five groups.

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INTRODUCTION

National Airspace System Operation Evolution Plan

The National Airspace System (NAS) Operational Evolution Plan is part of the National Aeronautics and Space Administration (NASA) and Federal Aviation Administration's (FAA) goal of revolutionizing aviation by safely accommodating increasing demand for flights through the US National Airspace System with less delay by 2010 (FAA, 2001). The mission focuses on operational solutions, and supports all phases of aircraft flights in the United States. The introduction of the Multi Sector Planner (MSP) is one of the plans to aid the growing capacity in airspace and the shortage of manpower in air traffic management. The MSP position has a different manpower structure from that currently used for air traffic control, being an evolution of today's controllers. In addition, several research groups have suggested that the FAA can make further improvements in the NAS through the introduction of the MSP. NASA, Booz Allen Hamilton, MITRE's Center for Advanced Aviation System Development (CAASD), Eurocontrol and Deutsche Flugsicherung have proposed different implementations and operational procedures for the MSP.

Capacity Constraint

There is an increasing demand in air travel, for both commercial and military use. It has been predicted that the volume of air traffic is expected to double by 2015 (Transport2000, 2004). A study at Berlin University of Technology (1999) projected that the air traffic controllers (ATCs) who are in charge of safe separation of aircraft and balancing expeditious flow may be overwhelmed with the increase in air travel, and this

might lead to their being overloaded with work. Based on the projection that air travel is expected to increase, traffic in the airspace is expected to increase as well (Baughcum et al., 1998).

Restructuring within organizations and adding new positions are presumed to be necessary to keep pace with the significant decrease in airspace capacity while concurrently trying to lighten the workload of the ATCs.

Workforce Issues

The air traffic control system is made up of a vast network of people and equipment, all working together to ensure the safe operation of commercial and private aircraft. ATCs coordinate the flow of air traffic to make sure that planes stay a safe distance apart. Their main concern is safety, but controllers also direct planes efficiently to minimize delays (Wickens, 1992).

There are five types of air traffic control facilities in the United States. The first is “Surface,” which is in charge of taxiways in the airport. The second is “Local Control,” which is in charge of the airspace from the ground to an altitude of 2500 feet. The third is “Terminal Area Control (TRACON),” which is in charge of the airspace from an altitude of 2500 feet to 15,000 feet. The fourth is “En-Route Center (ARTCC),” which is in charge of the airspace above the TRACON. The last is the “ATC Systems Command Center,” which is in charge of centralized planning for national flow control. This facility does not directly control flights. The En-Route Center is the main focus of the paper because the proposed position of the MSP will be in charge of high altitude airspace.

The current en route team consists of at most three controllers and is in charge of a sector in the airspace. The airspace is split into many irregular shapes called sectors. Each sector is controlled by a team of ATCs. En route controllers work in teams of up to three members, depending on traffic (CBASSE, 1997). The en route team consists of a radar controller, a data controller and when needed, a radar tracker.

There are a total of 15,000 ATCs in charge of all the facilities. The FAA estimated that nearly half of the nation's ATCs will be eligible for retirement before 2013 (U.S. General Accounting Office, 2002). Many of the potential retirees were hired in 1982 after President Ronald Reagan fired more than 11,000 striking members of the Professional Air Traffic Controllers Organization the year before. Hence, the new recruits for ATCs would suffer from a lack of mentors while learning the new trade. The FAA is trying to resolve the issues of airspace constraint and manpower shortage by introducing more advanced automation tools and restructuring within the air traffic management personnel.

ATCs' workload has been found to be the bottleneck in en route air traffic control. Hence, reducing their workload and reshuffling responsibilities by creating a new position could be one of the possible solutions to resolve this issue (Schaefer, Meckiff, Pirard & Aligne, 2001). The position of the MSP could evolve from the various roles of the ATCs today.

MSP Role

The MSP is a concept that several organizations have envisioned. These organizations have varying views on the roles that the MSP should encompass, but one thing they have in common is that the MSP will be in charge of more than one sector in today's airspace, and will also play the role of planning the routes of the aircraft. The concept of the MSP has been under development for several years, both in the United States and in Europe.

The role of the MSP given by the FAA (2004) is:

To provide radar controllers with manageable traffic flow. The MSP amends flights and issues nontactical clearances to reduce traffic complexity and resolve downstream conflicts. The MSP also coordinates with Area Supervisors and Traffic Management Units (TMUs) to formulate the local plan. The timeframe in which the MSP operates is approximately 15 to 60 minutes into the future (Page 42).

Goal of Study

Several studies have investigated alternative team configurations in ATC and decision support automation tools (e.g., McGregor et. al., 1997; Loudon et al 1999; Micro Analysis and Design, Inc & System Resources Corp. (SRC), 2000; Nicolaon, De Jonge et. al., 1997a, 1997b; Thompson et. al., 1999; Vivona et. al. , 1996). Most of the studies have not addressed the ATCs' needs regarding the type of information that would be made available to them. Furthermore, they have not addressed the differences in required information between a present and future ATC position. The goal of this study is to identify the information needed to support the proposed position, MSP, based on the Multi-D concept. The technique used to identify the information for this study is based on a human factors methodology called card-sorting. The investigation for this study

begins by building on the information architecture for the decision support tool that will aid the concept of the MSP.

BACKGROUND

Current Configuration

Full (100%) utilization of an average-sized sector involves 15 to 16 aircraft. Having 14 aircraft or fewer in a sector is considered “low traffic,” while having 18 aircraft or more in a sector would be considered “high traffic.” The number of controllers controlling a sector is dependant on the air traffic. Under normal circumstances (average traffic), the sector is managed by a team of two controllers: a radar position (R-side), whose primary responsibility is to monitor the radar display and ensure aircraft separation by communicating through a voice-radio to the aircraft and issuing maneuver instructions; and a data position (D-side), whose primary responsibility is to handle and coordinate data, strategic planning for the sector and support of the R-Side. The radar controller uses the information given by the data controller to communicate with the aircraft that is flying into or within the sector under their control. However, when there is low traffic in the sector, a single controller would be able to handle both responsibilities (CBASSE, 1997). During high traffic in the sector, a third controller may be required to be in the team as well. The third controller, a radar tracker, helps the radar controller to track the radar display.

In the Traffic Management Unit (TMU), the traffic management coordinator makes strategic decisions on the flow within the sectors. For example, traffic management coordinators use the projected weather and available runways at airports to inform TRACON about the possible arrival rates (aircraft/hour) of aircraft, and

coordinate flow parameters with adjacent facilities (Federal Aviation Administration, 1998).

The next section of this report goes into greater detail on how the controllers work as a team and the responsibilities of the two types of controllers, radar and data.

En Route Sector Teams

En route controllers work in teams of up to three members, depending on how heavy the traffic is. Each team is responsible for an airspace sector. A team, for instance, might be responsible for all planes that are between 30 to 100 miles north of an airport, flying at an altitude between 6,000 and 18,000 feet (CBASSE, 1997).

To prepare for an aircraft that is about to enter the team's airspace, the data controller organizes flight plans on paper strips coming from printing machines or on an electronic equivalent of that strip. If two planes are scheduled to enter the team's airspace at a same time, location, and altitude, this controller may arrange with the preceding control unit for one plane to change its flight plans. As an aircraft approaches a team's airspace, the radar controller takes on the responsibility for that aircraft from the previous controlling unit. The radar controller also hands over the responsibility for the aircraft to the next controlling unit when the aircraft leaves the team's airspace (FAA, 1998).

Air Traffic Controllers (ATCs)

The radar controller, who is considered the more senior team member, observes the aircraft in the team's airspace on radar and communicates with the pilots when necessary. Radar controllers inform pilots about nearby aircraft, bad weather conditions, and other possible hazards. Two aircraft on a collision course will be directed around

each other. If a pilot wants to change altitude in search of better flying conditions, the radar controller will check to determine that no other aircraft is along the proposed path. As the flight progresses to a sector boundary, the en route team responsible for that particular aircraft notifies the radar controller in charge of the sector that the aircraft is flying into. Through team coordination, the aircraft arrives safely at its destination.

The FAA air traffic control handbook, FAA Order 7110.65L CHG1 (FAA, 1998), provides a comprehensive description of controller responsibilities for en route terminal airspace. The handbook describes the necessary procedures that should be performed in any given situation. Below is a summary of the controllers' responsibilities presently.

Radar controller.

The R-side controller is in charge of ensuring that the aircraft are at least a five-mile radius apart from one another. The R-side controller makes sure that the computer entries (to an en route host computer) are completed before initiating control instruction to the aircraft within their sector or entering their sector. When the R-side controller is working in a team, they assist the data controller with nonautomation actions such as coordination, when needed. The R-side controller scans through the radar display to ensure that there is no conflict, and correlates the information on the radar display and the flight progress strip (FAA,1998).

Data controller.

The D-side controller is in charge of ensuring safe distances among aircraft. They also assist the R-side controllers by accepting and initiating nonautomated handoffs, and ensuring that the R-side controller is aware of the actions. The D-side controller

coordinates aircraft routes by scanning flight progress strips and correlating with the data from the radar display. The main task of the D-side controller is to ensure that all computer entries received by the R-side controllers are processed (FAA,1998).

Multi Sector Planner

This section of the report provides an overview of two alternative concepts of the MSP process. In order to give a better overview, concepts from various sources have been collected in order to reach a coherent description of this new position.

A primary goal of the MSP is to provide ATCs with manageable traffic flow within their area of responsibility. This could be achieved in two ways, depending on the main focus area: 1) providing flow with low complexity, 2) providing areas that are free of conflict within their area of responsibility.

Multidata Controller Concept.

Technology is advancing. This can be demonstrated from the gradual removal of the flight paper strips that the D-side controllers are currently using. As more of the manual responsibilities (e.g., preparing flight paper strips) of the D-side controllers are gradually being supported by automation, it is hypothesized that the D-side controllers will be able to take on a greater responsibility in terms of preplanning and coordinating, thus allowing the MSP to help out a few R-side controllers at a time. In this way, the MSP will still be carrying out the same role as a traditional D-side controller, but instead of assisting a single R-side controller, they would be assisting multiple R-side controllers. As this is a new and untried concept, the optimum number of R-side controllers that the MSP should be working with is still unknown.

Air Traffic Coordinator Concept.

The airspace traffic coordinator monitors several sectors for potential aircraft conflicts and more efficient traffic routes. They can put control actions into effect only by coordinating with the sector-based ATCs through the regular channels. The airspace traffic coordinator has no tactical control operations. They are concerned with strategic flow issues over multiple sectors, but at a level that is more local to the R-side controllers than the TMU. In certain aspects, they would provide a coordinating function between the TMU and R-side controllers.

Research

The following sections summarize the options taken into account in this report, extracted from these sources: FAA, Booz Allen Hamilton, Eurocontrol, and Deutsche Flugsicherung. (FAA, 2004; Booz Allen Hamilton, 2004; Eurocontrol, 2004; DFS, 2003) These descriptions are not intended to be exhaustive. They describe only the principles that govern the MSP role for each option, giving an overview of the scope of this new controller position.

Federal Aviation Administration.

The MSP position comprises some duties and responsibilities of today's planner and flow management positions. A primary goal of the MSP is to provide ATCs with manageable traffic flow. The MSP manages an airspace comprising several en route sectors configured to capture common traffic flow. The MSP coordinates closely with the ATCs to strategically manage traffic flow over the multi-sector area. The MSP amends flights and issues nontactical clearances to the pilot to reduce traffic complexity

and resolve conflicts. The MSP also coordinates with the area supervisors and TMU to formulate the local plan. The time frame in which the MSP operates is approximately 15 to 60 minutes into the future (FAA, 2004).

They have proposed a division of roles according to the airspace- low airspace and high airspace. There will be MSPs in charge of these two types of airspace. Both positions have similar job scopes, but different areas of responsibilities. The draft that contains this information is still under development. In this study, the MSP assumes the role of a MSP in charge of a high airspace.

Booz Allen Hamilton.

The definition and scope from the concept of en route modernization (Booz Allen Hamilton, 2004) proposed is similar to the FAA draft mentioned above, but the details seem to differ slightly.

The MSP coordinates closely with the tactical controllers in strategically managing traffic flow over several airspace sectors. Their primary goal is to reduce traffic complexity and balance traffic loads. The MSP manages an airspace comprising route sectors configured to capture common traffic flow. The timeframe in which the MSP operates is approximately 15 to 60 minutes into the future. Responsibilities include traffic complexity reduction, traffic load balancing, strategic separation assurance, response to strategic routing requests, strategic mitigation of airspace anomalies, strategic conformance to traffic flow manager initiatives, and formulation, execution, and feedback of the local traffic management plan.

Eurocontrol.

The MSP introduced by the Eurocontrol has the responsibility of monitoring a group of sectors in the airspace. In this role, the MSP will issue advisories and control instructions directly to aircraft via data link. The control instructions (e.g., speed, heading, and altitude changes) will become effective at the border of a sector. The MSP will focus on aircraft and their pending conflicts up to 10 minutes before they enter the MSP areas of responsibility (Eurocontrol, 2002).

Deutsche Flugsicherung (DFS).

The proposed MSP position is a replacement of a planner role in the European airspace that is similar to the data controller in North America today. This new position will be in charge of several airspace sectors. It describes the “traditional” planner role, but instead of a 1:1 ratio of data controller to radar controller, there will be one MSP (in a position similar to the data controller) coordinating with several tactical controllers. MSPs will focus mainly on solving conflicts through changes in entry or exit conditions at the tactical controller sector boundary (*Deutsche Flugsicherung*, 2003).

Summary of Concepts.

Figure 1 summarizes the four concepts introduced by FAA, Booz Allen Hamilton, Eurocontrol, and DFS. Each concept introduced by the different organizations mentioned how the roles would solve future issues such as shortage of manpower, and that an introduction of a new decision support tool would be needed. However, these concepts did not mention what information these new positions would need on the new decision support tools. Figure 1 illustrates that the FAA and Booz Allen Hamilton cover the widest range of responsibilities that the MSP should be handling.

Figure 1. Overview of the MSP options (adapted from Eurocontrol, 2002).

After mentioning the scope that the MSP has to cover, the reader should take note that this study did not measure which concepts were ideal for the position of the MSP, but rather the information required to aid the MSP for different scenarios. Further comparisons of the MSP options can be found in Appendix A.

METHOD

The study was done in two parts: the first was a pilot study and the second a “card-sorting” test (Tullis, 1985). The pilot study was conducted in order to understand the controllers’ information needs in their current working situation, and to build the design for the next study, card-sorting. The card-sorting test was used to identify the information and suggest when the information should be given to the controllers. Figure 2 shows the flow chart of this study, the information flow for the entire study, and the processes that led to the results.

Figure 2. Flow chart of study outline.

Pilot Study

FAA (2004) provided the roles and responsibilities for this study. The roles and responsibilities of the MSP are summarized as follows:

1. Traffic complexity reduction
2. Traffic load balancing
3. Separation assurance (strategic)
4. Response to strategic routing requests
5. Mitigation (strategic) of airspace anomalies
6. Conformance (strategic) to traffic flow management initiatives
7. Formulation, execution, and feedback of local traffic management plan
8. Airspace management support

One of the goals of this pilot study was to find out the source of the subject matter experts' information, while playing the role of the MSP. A pilot study was conducted at San Jose State University to identify the information requirements for the position of MSP in air traffic management.

There were three ATCs per session and a total of three sessions. Five scenarios (see Appendix B) were role-played for each session in order to understand how the controllers coordinated the different systems that were currently in use. Each ATC took turns to play the new position of the proposed MSP, and was asked to think out loud for each action that was undertaken. At the end of each session, the ATCs were asked to list out the systems that were currently in use for retrieval of information to fulfill the roles and responsibilities.

Participants

A total of 9 ATCs with at least 20 years of experience in air traffic control participated in the pilot study. These 9 ATCs had experience working in three positions: radar controller, data controller and area supervisor. Having worked in all three positions with at least 20 years of working experience made these ATCs the subject matter experts for the pilot study.

Results

There were two main results for this pilot study: the first result was two views on what the roles of the MSP should be, and the other result was the identification of the existing systems that store information to run the role of the MSP.

The general feedback from the subject matter experts comprised two polarized views of the MSP roles. The first view was the MSP as a support position for a few radar controller operations (Multi-D), and the second as an airspace traffic coordinator. The existing systems that have been identified for the new position of the MSP from the Cognitive task analysis can be seen in Appendix C.

Appendix C shows several systems that had been identified for each kind of information required by the MSP to run their responsibilities. The systems that had been identified are currently being used by different positions in the air traffic management, e.g., radar controller, data controller, area supervisor and traffic flow manager. These systems identified also indicate the level in which the MSP should be viewed from, e.g., a broad overview or specific viewpoint. For example, the radar controller's system showed the weather situation 1 hour ahead of current time for the sector they were in charge of.

This would be more appropriate for the MSP as the Multi-D concept. On the other hand, the traffic flow manager's system showed the weather situation across all sectors and up to 4 hours ahead of current time, hence it would be more appropriate for the MSP to undertake the role as an airspace traffic coordinator.

Card-sorting Test

The card-sorting methodology had previously been used to explore how items were grouped, in order to maximize the probability of users being able to find items. The card-sorting technique was modified for this study, it was to identify information from a stack of cards and categorize the information according to when it was needed.

Two sources of information were identified for this test. The first source came from the current systems identified from the pilot study. The second source was based on the reports mentioned in the literature review that had been compiled to form the cards for the card-sorting study (see Appendix D). In summary, the cards contained both present and future information that the future decision support system would be able to pursue.

Before the card-sorting test was conducted, the participants were given a brief overview of the concept of the MSP (see Appendix E) and guideline on the systems they were going to use during the simulation (see Appendix F). The participants role-played the position of the MSP to get a better understanding of how it would be like being a MSP. As the concept of the MSP is still currently undergoing refinement, the positions that the participants played varied from each other in order to observe how the MSP behaved and reacted. Each participant had a different seating arrangement. In the first simulation, the MSP sat beside the R-side controllers in the same room. The MSP sat between R-side controllers in charge of sectors 42 and 48. In the second simulation, the MSP sat in a separate room from the R-side controllers. The three R-side controllers sat side by side. The third simulation had two seating configurations: For the first run, the

MSP sat in a separate room from the R-side controllers. The R-side controllers sat side by side. For the second run, the MSP sat in between the R-side controllers in charge of Sectors 42 and 48. The fourth simulation also had two seating configurations: for the first run, the MSP sat in a separate room from the R-side controllers. The R-side controllers sat side by side. For the second run, the MSP sat in between the R-side controllers in charge of Sectors 42 and 48. Having a different seating arrangement for each simulation run facilitated observation to learn how the MSP interacted with the R-side controllers. An air traffic real time simulator from Airborne Observation Laboratory at NASA was used to create the adequate scenarios where participants were able to play the MSP role, hence recreating a real situation.

The scenarios were designed by Human Automation Integrated Laboratory (HAIL) from San Jose State University and created by AOL from NASA (see Figure 3). Wichita Falls (sector 47), Ardmore (sector 48) and Decod High (sector 42) are real-life high altitude sectors (FL240 and above) in Fort Worth Center. Fort Worth flows are organized on a “4 cornerpost” design, with arrivals coming in through fixes at the northwest, northeast, southeast and southwest corners, and departures heading out north, south, east and west. There was a ghost sector (sector 50) that had a confederate controller who worked the airspace surrounding the test sectors (sector 47, 48 and 42). The ghost sector fed traffic into the test sectors from all directions and accepted handoffs for aircraft leaving the test sector.

These scenarios were designed to recreate real life operations where there would be heavy traffic in the sectors that the MSP was in charge of. Figure 3 shows the three sectors, 42, 47 and 48 that the MSPs were in charge of.

Figure 3. Airspace used for this study.

There were a total of four simulations carried out over a period of 2 days. Each simulation had two runs, and each run lasted for 30 minutes; giving a total of eight runs (see Figure 4).

Figure 4. Seating configurations.

Each simulation involved four controllers at all times. Three of the controllers played the role of radar controllers in charge of the sectors that the MSP was in charge of, and the other played the role of a MSP. The purpose of having three radar controllers and a MSP was to simulate a real life scenario whereby the MSP had to interact with the other controllers. Figure 5 shows the MSP (man in the middle) during the simulation run. The MSP was seated in between two radar controllers. The participants interchanged roles for every simulation so that all the participants played the position of the MSP once, and only the participant playing the role of the MSP was involved in the card-sorting test that was held after each simulation run.

Figure 5. Picture of a simulation run.

Design

There were two types of cards in the card-sorting test. The first type of cards reflected the information the MSP needed, and the other type showed when the information was needed (See Figure 6).

Figure 6. Example of a card-sorting trial.

There were three trials per card-sorting session. The first trial required the participants to sort the cards according to the simulation they participated in as the MSP. The second trial required the participants to sort the cards according to a PowerPoint slide that showed a weather occurrence in sector 47 which was under the control of the participant. The weather occurrence was not part of the simulation run. The last trial required the participants to sort the cards according to a PowerPoint slide that showed two conflicts occurring in the sectors 42 and 48 which was under the control of a participant (see Appendix G). For each trial, the participant was asked to sort the first

pile of cards that contained the “What” information into two piles: information that was needed, and information that was not needed. After that the participants were asked to categorize the information according to when they needed it. This was repeated for all three trials.

Figure 7 shows the participant who role-played the MSP during the simulation run, taking part in the card-sorting test. In the image, the participant was in trial 2, where bad weather occurred in the sectors he was in charge of. Here, the MSP can be seen sorting the cards into categories according to when he needed the information.

Figure 7. Participant in a card-sorting trial.

At the end of the card-sorting test, the participants were given an Information Questionnaire (see Appendix H) that contained the same information as that on the cards from the trials. The participants were then asked to rank the importance of the information based on the three trials. The card-sorting test and the Information Questionnaire were two ways of identifying the information that the MSP may have needed on the interface of the decision support tool. This combination of both methods gave a comprehensive result to this study.

Participants

A total of 4 ATCs with at least 20 years of experience each in air traffic control participated in the card-sorting test. These 4 ATCs had experience working in three positions: radar controller, data controller and air traffic control manager. Having worked in all three positions with at least 20 years of experience made these ATCs the subject matter experts for the card-sorting test.

Apparatus

The apparatus used for this study were:

- 1) Real-time air traffic simulator provided by NASA's AOL
- 2) Real-time traffic display, where air traffic was shown
- 3) Two piles of cards, 2.5 in. by 4.8 in., with information written on them
- 4) Blank cards, where missing information was filled in
- 5) Microsoft PowerPoint, used to depict the storyboard for each scenario
- 6) Microsoft Excel, used to capture the data for each scenario

Procedure

The data for this study were collected during the card-sorting test, which was conducted after each simulation run. There were three trials in each card-sorting test, aimed at identifying information for the following areas:

- A) Overall scenarios based on the simulation run
- B) Weather impact in sector 48
- C) Two conflict occurrences in sectors 42 and 47

After each simulation, the participants who role-played the position of the MSP were asked to go to a separate room from the simulation, where they were given a low-risk consent form to sign (see Appendix F) to fill out. All participants were then given a set of general instructions explaining the card-sorting trial and how it was conducted (see Appendix J). Once the card-sorting trial was fully understood, the participants were left on their own to sort the first pile of cards into two piles: what was needed, and what was not. After the first pile had been sorted, the cards identified as information that was needed for the trial were categorized according to when they were needed. The participants were also given a pile of blank cards to fill in information that was missing from the cards. After going through all three trials for the card-sorting, the participants were given an Information Questionnaire to rank the importance of each information on a Likert scale of 1 (*least important*) to 5 (*most important*).

Data Analysis

To identify the information for the decision support tool, the data collected from each participant were analyzed. The data from each trial were split up, scrutinized, and categorized according to when the information was needed. The information from the information questionnaire had to have an average mean of 4 out of 5 on the likert scale or 3 out of 4 participants rated the information 4 out of 5 on the likert scale. In addition, the identified information from all the card-sorting trials was compared to the information from the questionnaire that the participants rated as important. The information from the card-sorting trials had to be selected by 3 out of 4 participants.

RESULTS

The results for this test are displayed in Tables 3 to 31. The legend for the abbreviations and the color coding is shown in Table 2. The numbers displayed in the results represent the card positions that contained the information on them. The initial categories given to the participants were in distance (miles) and time (minutes) before the boundary lines, but during the card-sorting session, 3 out of 4 participants categorized 80% of the information they needed according to distance entering the sector, instead of time entering the sector. The participants mentioned that this form of categorization was no different from the initial categorization. There were two new categories that 3 out of 4 participants added: constant information and information available as soon as possible. The categories displayed in time were removed and the categories displayed in distance remained. The participants made the assumption that an aircraft took 1 minute to travel five miles. Hence, there was a reduction in the number of categories of when the information was needed from 13 to 6. Table 1 shows the initial categories and levels given to the participants, and the modified categories and levels.

There were three trials in the card-sorting test. These three trials contained scenarios that controllers currently face in their everyday workflow. En route controllers today face two main issues: 1) aircraft conflicts and 2) bad weather. Trial A was the simulation run that the MSPs underwent. The simulation run had aircraft entering and leaving the sectors that the MSPs were in charge of. There were a total of 20 possible aircraft conflicts and no occurrence of bad weather. Trial B contained a scenario that displayed bad weather in one of the sectors that the MSPs were in charge of. Trial C

displayed two aircraft conflicts involving four aircraft in the sectors that the MSPs were in charge of.

There are a total of six result sections for this study. The first section is the information identified for all three trials using a card-sorting methodology. The second section contains the information identified from card-sorting versus Information Questionnaire. The third section contains the timing (in distance) of when the identified information should be presented to the MSP. The fourth section is the identified information for Trial A (scenarios from simulation run), categorized by distance. The fifth section is the identified information for Trial B (thunderstorm traveling east within the sectors), categorized by distance. The last section is the identified information for Trial C (four aircraft conflicting in two sectors), categorized by distance.

Table 1

Identified Categories: Proposed vs. Modified

Proposed Category	Levels	Modified Category	Levels
Distance	50 miles before the sector	Distance	50 miles before the sector
	100 miles before the sector		100 miles before the sector
	150 miles before the sector		150 miles before the sector
	200 miles before the sector		200 miles before the sector
Time	5 minutes	Constant Information	
	10 minutes	Information available as soon as possible	
	15 minutes		
	20 minutes		
	30 minutes		
	45 minutes		
	60 minutes		
	90 minutes		
	120 minutes		

Table 2

Legend

Trial:	Color Code:	Information Types:
A: Scenario from simulation	Black: Information occurring once	Qn: Information identified as important from Information Questionnaire
B: Weather	Red: Information occurring twice	CS: Information identified as important from Card-sorting Trial
C: Conflict	Blue: Information occurring thrice or more	

Table 3

Information on Cards

Card Position	Information for Card Sort
1	Aircraft hand-off status
2	Aircraft equip requirements
3	Aircraft type, Flight ID, SSR code, Current altitude & ground Speed
4	System proposes route at Controller's request
5	Current position
6	Current Flight plan
7	Current descent/ascent indication (as opposite to level-off)
8	Current vertical speed
9	Destination (Airport)
10	Evidence in support of deviation
11	Flight deviation information
12	Future position (Next Waypoint)
13	Alternative path for conflict resolution
14	Cleared flight level
15	Clearance Speed
16	Predicted distance between future position of aircraft and hazard
17	Requested route
18	Sector entry altitude at boundary NFL/XFL
19	Sector entry time
20	Time remaining before entry
21	Distance remaining to a point/between two aircraft
22	Identification of aircraft in conflict
23	Next sector the A/C is going to fly into
24	Identification of points of loss of separation
25	Identification of closest distance between two aircraft in conflict
26	Time to closest distance between two aircraft in conflict
27	Affected flow
28	Current traffic load (No. of A/C per sector)
29	Difference between predicted load and manageable load
30	Number of flights predicted to enter A/C sector
31	Predicted impact on traffic flow (Predicted > Manage)
32	Current restrictions
33	Current weather
34	Pilot reports of weather
35	SUA status
36	Available altitudes

37	Available routes
38	Available speeds
39	Current airport configuration runway
40	Letter or Agreements
41	Normal sector operations
42	Predicted change to operations
43	Winds aloft
44	Aeronautic Info
45	Current TFM initiatives
46	GPS status
47	Outages and closures
48	Feedback from other sector
49	Radio frequency of other sector
50	Receiving controller limitations/concerns

Table 5

Information Not Needed in All Trials

Card	Information on the card
2	Aircraft equipment requirements
8	Current vertical speed
10	Evidence in support of deviation
15	Clearance speed
18	Sector entry altitude at boundary NFL/XFL
19	Sector entry time
20	Time remaining before entry
21	Distance remaining to a point/between two aircraft
23	Next sector the aircraft is going to fly into
25	Identification of closest distance between two aircraft in conflict
29	Difference between predicted load and manageable load
38	Available speeds
42	Predicted change to operations
44	Aeronautic information
50	Receiving controller limitations/concerns

Table 6

Identified Information: Individual Trials

The information identified: Trial A	
Card	Information on the card
24	Identification of point of loss of separations
The information identified: Trial B	
Card	Information on the card
41	Normal sector operations
The information identified: Trial C	
Card	Information on the card
30	Number of flights predicted to enter aircraft sector
42	Predicted change to operations
46	GPS status

Table 7

Identified Information: Two Trials

The information identified: Trials A & C	
Card	Information on the card
11	Flight deviation information
16	Aircraft and hazard
26	Time to closest distance between two aircraft in conflict
37	Available routes
49	Receiving controller limitations/concerns
The information identified: Trials B & C	
Card	Information on the card
12	Future position (next waypoint)
13	Alternative path for conflict resolution
27	Affected flow
28	Current traffic load (No. of aircraft per sector)
27	Affected flow
28	Current traffic load (No. of aircraft per sector)
48	Feedback from other sectors

Table 8

Identified Information from Trials A, B, and C

Card	Information on the card
1	Aircraft hand-off status
3	Aircraft type, flight ID, SSR code, current altitude & current ground speed
4	System proposes alternative route at controller's request
5	Current position
6	Current flight plan
9	Destination (airport)
14	Cleared flight level
17	Requested route
22	Identification of aircraft in conflict
31	Predicted impacted on traffic flow (predicted > manage)
32	Current restrictions
33	Current weather
34	Pilot reports of weather
35	SUA status
39	Current airport configuration runway
43	Winds aloft
45	Current TFM initiatives
47	Outages and closures

Table 10

Identified Information: Card Details for Both Data Collection Techniques

Card	Information on the card
3	Aircraft type, Flight ID, SSR code, Current altitude & ground speed
4	Systems proposes alternative route at controller's request
5	Current position
6	Current flight plan
9	Destination (airport)
14	Clearance speed
17	Requested route
22	Identification of aircraft in conflict
31	Predicted impact on traffic flow (predicted > manage)
32	Current restrictions
33	Current weather
34	Pilot reports of weather
35	SUA status
39	Current airport configuration runway
43	Winds aloft
45	Aeronautic information
47	Outages and closures

There were a few cards that were identified by a single data collection technique.

Table 11 displays the information identified by the card-sorting test and the Information Questionnaire exclusively.

Table 11

Identified Information based on Data Collection Technique

<u>Card-sorting</u>	
Card	Information on the card
1	Aircraft hand-off status
<u>Information Questionnaire</u>	
Card	Information on the card
11	Flight deviation information
12	Future position (Next Waypoint)
13	Alternative path for conflict resolution
16	Predicted distance between future position of aircraft and hazard
24	Identification of points of loss of separation
26	Time to closes distance between two aircraft in conflict
27	Affected flow
28	Current traffic load (No. of aircraft per sector)
29	Difference between predicted load and manageable load
30	Number of flights predicted to enter sector (in charge)
37	Available routes
38	Available speeds
40	Letter of Agreements
41	Normal sector operations
48	Feedback from other sectors

information on card position 2 (aircraft equipment requirements) can be placed in Category CI (constant information) or Category 150M (information given 150 miles before the sector boundary line). This means that the information for this instance “aircraft equipment requirements” should be made available to the MSP while the aircraft is entering or in the airspace sector in which the MSP has responsibility of, or 150 miles before entering the sector boundary lines. The display of the information that can be placed in either category would be also dependent on when the information can be made available to the MSP. The results in this section help us understand which and when the information was needed. Table 13 displays the information that the participants needed constantly. Table 14 displays the information that can be placed in both two categories and the type of information. Table 15 displays the information that the participants needed as soon as possible, and Table 16 displays the information that the participants needed, based on distance.

Table 13

Identified Information Needed Constantly

Card	Information on the Card
3	Aircraft type, Flight ID, SSR Code, Current altitude & Ground Speed
5	Current position
32	Current restrictions
33	Current weather
34	Pilots report of weather
35	SUA status
39	Current airport configuration runway
45	Current TFM initiatives
47	Outages and closures

Table 14

Identified Information Type

Info Type	Information on Card	CI	ASAP	50M	100M	150M
Aircraft Information	Aircraft hand-off status					
	Aircraft type, Flight ID, SSR Code, Current Altitude & ground speed					
Flight Profile	System proposes route at Controllers' Request					
	Current flight plan					
	Destination (Airport)					
	Cleared flight level					
	Requested route					
	Identification of aircraft in conflict					
Traffic Info	Predicted impact on traffic flow					
Sector Constraints	Current restrictions					
	Current weather					
	Pilot reports of weather					
	SUA status					
Sector Management	Current airport configuration					
	Winds Aloft					
NAS Status	Current TFM initiatives					
	GPS status					
	Outages and closures					

Table 15

Identified Information Needed As Soon As Possible

Card	Information on the card
1	Aircraft hand-off status
4	System proposes route at Controller's request
14	Cleared flight level
31	Predicted impact on traffic flow (predicted > manage)

Table 16

Identified Information Categorized by Distance

50 miles before entering the sector boundary lines

Card	Information on the card
17	Requested route
34	Pilot reports of weather

100 miles before entering the sector boundary lines

Card	Information on the card
9	Destination (Airport)
17	Requested route
22	Identification of aircraft in conflict
31	Predicted impact on traffic flow (predicted > manage)
46	GPS status
47	Outages and closures

150 miles before entering the sector boundary lines

Card	Information on the card
3	Aircraft type, Flight ID, SSR Code, Current altitude & Ground Speed
5	Current position
6	Current flight plan

Identified Information Categorized by Need for Trial A

Table 17

Identified Information by Need for Trial A: Simulation Run

[illegible]

Table 17 shows the information that was identified specifically from Trial A. The simulation that each participant went through varied in terms of conditions under which they worked. Their working conditions were mentioned earlier in the Methods section. For this trial, the results take into account that the MSPs were in a different physical placement (either next to the R-side controllers in different placements or in a separate room from the R-side controllers). The information identified from this trial had been selected by at least 3 out of 4 participants. There were a total of four categories of when the information should be displayed to the MSP. The four categories were: constant information (CI), information available as soon as possible (ASAP), 50 miles before entering the sector boundary lines (50M), 100 miles before entering the sector boundary lines (100M). The color code in black indicates that the information on that card position belonged to that category exclusively. The color code in red indicates that the information could be placed in either two categories and the color code in blue indicates that the information could be placed in any of the three categories. For example, the information on card position 2 (aircraft equipment requirements) can be placed in category i(constant information) or category iv (information given 150 miles before the

sector boundary line). The results for this trial helped us to understand which information and when the information was needed for the simulation run. Table 18 displays the information that the participants did not need. Table 19 displays the information that the participants needed constantly, Table 20 displays the information that the participants needed as soon as possible, and Table 21 displays the information that the participants needed based on distance.

Table 18

Information Not Needed in Trial A

Card	Information on the card
8	Current vertical speed
10	Evidence in support of deviation
13	Alternative path for conflict resolution
15	Clearance speed
18	Sector entry altitude at boundary NFL/XFL
19	Sector entry time
20	Time remaining before entry
21	Distance remaining to a point/between two aircraft
24	Identification of aircraft in conflict
25	Identification of points of loss of separation
29	Difference between predicted and manageable load
30	Number of flights predicted to enter aircraft sector
31	Predicted impact on traffic flow (Predicted > Manage)
36	Available altitudes
37	Available routes
38	Available speeds
40	Letter of Agreements
42	Predicted change to operations
48	Feedback from other sector
50	Receiving controller limitations/concerns

Table 19

Identified Information Needed Constantly: Trial A

Card	Information on the card
2	Aircraft equipment requirements
3	Aircraft type, Flight ID, SSR code, Current altitude and Ground Speed
5	Current position
7	Current descent/ascent indication (opposite to level-off)
27	Affected flow
28	Current traffic load (No. of A/C per sector)
32	Current restrictions
33	Current weather
34	Pilot reports of weather
35	SUA status
39	Current airport configuration runway
41	Normal sector operations
43	Winds aloft
44	Aeronautic information
45	Current TFM initiatives
46	GPS status

Table 20

Identified Information Needed As Soon As Possible: Trial A

Card	Information on the card
1	Aircraft hand-off status
4	System proposes route at controller's request
11	Flight deviation information
14	Cleared flight level
47	Outages and closures
49	Radio frequency of other sectors

Table 21

Identified Information Categorized by Distance: Trial A

50 miles before entering sector boundary lines

Card	Information on the card
23	Next sector the aircraft is going to fly into

100 miles before entering sector boundary lines

Card	Information on the card
2	Aircraft equipment requirements
6	Current flight plan
9	Destination (Airport)
12	Future position (Next Waypoint)
16	Predicted distance between future position of aircraft and hazard
17	Requested route
22	Identification of aircraft in conflict
26	Time to closest distance between two aircraft in conflict

Table 23

Information Not Needed in Trial B

Card	Information on the card
1	Aircraft hand-off status
2	Aircraft equip requirements
3	Aircraft type, Flight ID, SSR code, Current altitude & ground Speed
4	System proposes route at Controller's request
5	Current position
6	Current Flight plan
7	Current descent/ascent indication (as opposite to level-off)
8	Current vertical speed
9	Destination (Airport)
10	Evidence in support of deviation
11	Flight deviation information
13	Alternative path for conflict resolution
16	Predicted distance between future position of aircraft and hazard
18	Sector entry altitude at boundary NFL/XFL
19	Sector entry time
20	Time remaining before entry
21	Distance remaining to a point/between two aircraft
22	Identification of aircraft in conflict
23	Next sector the A/C is going to fly into
24	Identification of points of loss of separation
25	Identification of closest distance between two aircraft in conflict
26	Time to closest distance between two aircraft in conflict
28	Current traffic load (No. of A/C per sector)
29	Difference between predicted load and manageable load
30	Number of flights predicted to enter A/C sector
36	Available altitudes
37	Available routes
38	Available speeds
40	Letter or Agreements
42	Predicted change to operations
46	GPS status
48	Feedback from other sector
50	Receiving controller limitations/concerns

Table 24

Identified Information Needed Constantly: Trial B

Card	Information on the card
5	Current position
32	Current restrictions
33	Current weather
35	SUA status
39	Current airport configuration runway
41	Normal sector operations
43	Winds Aloft
44	Aeronautic Information
45	Current TFM initiatives
47	Outages and closures

Table 25

Identified Information Needed As Soon As Possible: Trial B

Card	Information on the card
14	Cleared flight level
31	Predicted impact on traffic flow (predicted > manage)

Table 26

Identified Information Needed 50 miles before Sector: Trial B

Card	Information on the card
12	Future position (next waypoint)
15	Clearance speed
17	Requested route
27	Affected flow
34	Pilots reports of weather
48	Feedback from other sector

Table 28

Information Not Needed in Trial C

Card	Information on the card
1	Aircraft hand-off status
2	Aircraft equip requirements
3	Aircraft type, Flight ID, SSR code, Current altitude & ground Speed
4	System proposes route at Controller's request
5	Current position
6	Current Flight plan
8	Current vertical speed
9	Destination (Airport)
12	Future position (Next Waypoint)
13	Alternative path for conflict resolution
14	Cleared flight level
15	Clearance Speed
16	Predicted distance between future position of aircraft and hazard
17	Requested route
18	Sector entry altitude at boundary NFL/XFL
19	Sector entry time
20	Time remaining before entry
21	Distance remaining to a point/between two aircraft
22	Identification of aircraft in conflict
23	Next sector the A/C is going to fly into
24	Identification of points of loss of separation
25	Identification of closest distance between two aircraft in conflict
26	Time to closest distance between two aircraft in conflict
14	Cleared flight level
15	Clearance Speed
16	Predicted distance between future position of aircraft and hazard
17	Requested route
18	Sector entry altitude at boundary NFL/XFL
19	Sector entry time
20	Time remaining before entry
21	Distance remaining to a point/between two aircraft
22	Identification of aircraft in conflict
23	Next sector the A/C is going to fly into
24	Identification of points of loss of separation
25	Identification of closest distance between two aircraft in conflict
26	Time to closest distance between two aircraft in conflict
27	Affected flow

28	Current traffic load (No. of A/C per sector)
29	Difference between predicted load and manageable load
30	Number of flights predicted to enter A/C sector
31	Predicted impact on traffic flow (Predicted > Manage)
35	SUA status
36	Available altitudes
37	Available routes
38	Available speeds
40	Letter or Agreements
42	Predicted change to operations
43	Winds aloft
44	Aeronautic Info
49	Radio frequency of other sector

Table 29

Identified Information Needed Constantly: Trial C

Card	Information on the card
7	Current descent/ascent indication (opposite to level-off)
32	Current restrictions
33	Current weather
34	Pilot reports of weather
39	Current airport configuration runway
41	Normal sector operations
45	Current TFM initiatives

Table 30

Identified Information Needed As Soon As Possible: Trial C

Card	Information on the card
46	GPS status
47	Outages and closures
50	Receiving controller limitations/concerns

Table 31

Identified Information Needed 50 miles before Sector: Trial C

Card	Information on the card
10	Evidence in support of deviation
11	Flight deviation information
48	Feedback from other sectors

DISCUSSION

Purpose of Study

Upon review and interpretation of the data, it was found that the results of the card-sorting test and information questionnaire give a preliminary assessment of the information for display on the decision support tool for the MSP.

The studies reviewed show concepts for the MSP and the need to restructure the current air traffic management. None of the prior studies indicate what the information will be, and when the information is to be displayed to the MSP. The information to be given to the MSP depends on the responsibilities that they have to undertake. In this study, the FAA has provided the role that the MSP has to undertake. The purpose of this study is to identify the information and decide on the optimum time for the information to be shown to the MSP.

The results from this study can be interpreted in many ways. One approach is to select the information that was most frequently chosen in all the scenarios. The rationale for choosing this approach is that there were only 4 participants in this study, whereas a conventional card-sorting test usually involves 20 to 30 participants (Tullis & Wood, 2004). Therefore, it would have been best to select the most frequently used information in all three trials of the card-sorting test. The information chosen would have been validated since it had been through a total of 12 card-sorting trials. The identified information from all three trials was categorized into when they would be needed (see Table 14). The rationale for categorizing the identified information is to decrease the cognitive workload that the MSP would have and increase situational awareness. Table

5, 18, 23 and 28 displays the information that will not be needed for all three trials.

Another approach is to select the information that is important to the participants, and also specific to the scenario. The rest of this section will be discussing the importance of information, and deciding the optimum time to provide it to the MSPs.

Reduction of Display Clutter

Previous Studies (e.g., Williams & Heiney; 2002; Scerbo, 1996) show that oversupply of information to controllers may bring about an adverse effect, resulting in information overload. The information is displayed to the MSPs in a sequence of importance, because it is not feasible to display it all at one time. The sequence of information display is important especially in situations where the users are facing crucial decision making. To prevent display clutter, information shown to the MSP needs to be shown in a sequence of importance and orderly timing. In table 14, the information identified has been split into the type of information the MSP would need, and when it is needed. Some of the identified information has been placed in 2 categories, e.g., Outages and closures under NAS Status have been identified as information needed constantly or 100 miles before entering the sector boundary. The importance of the information has been noted and should be placed on the display of the decision support tool for the MSP. However, placing the information constantly on the display can act as a distraction to the rest of the information that is considered important as well. Bearing this in mind, it would be best to alert the MSP at 100 miles before the sector boundary for outages and

closures by placing the information at that moment, so that it can be retrieved easily by the MSP without cluttering the display. A future study can be done to further categorize this identified information according to its availability.

Timeframe of Information

Identifying the information to aid the MSP is important, and so is the timing of the information to be displayed.

This study finds that controllers who role-played the position of the MSP prefer the information to be displayed in distance relative to the point of entries into the sectors.

The addition of two new categories has been introduced by 3 out of 4 participants. The two categories, “constant information” and “as soon as possible”, together with the other categories proposed, will reduce the amount of information that the MSP will have on their display.

The furthest distance that the MSPs will look ahead is 150 miles before the aircraft enters the sector boundaries. Thus, assuming that aircraft travel 5 miles per minute on average, it will be approximately 30 minutes before any aircraft enters the sector boundary lines. FAA (2004) stated that the timeframe in which the MSP operates is approximately 15 to 60 minutes into the future. This study finds that the timeline is consistent with FAA’s statement, except that the furthest time the MSP should be looking into the future is not more than 30 minutes.

Limitations

During post-experiment debrief sessions, 2 out of 4 participants pointed out a real-world problem that the study should incorporate as a scenario: Radar controller losing communication with the pilot due to a faulty microphone on the pilot's end. Having more scenarios can help identify information for the overall system for the MSP. An additional suggestion is to involve more participants for each scenario. This can help in validating each scenario in the card-sorting trial. All the participants also pointed out that the equipment in the simulation is different from those in the air traffic control center. In addition, the participants had to learn the usage of the equipment from scratch. This leads to a steeper learning curve when it comes to working in the actual simulation. An alternative suggestion made by 3 out of 4 participants is to have a longer training session and a more defined role for the MSP. The participants mentioned that they felt the position of the MSP was similar to a data controller, but with a wider scope of airspace to control.

Implications

The information identified can be further validated by running scenarios that currently occur in the air traffic control unit. The card-sorting test is at the beginning stage of the design life cycle for the decision support system. In order to build a strong foundation of the role of the MSP, a lower level of detail needs to be sorted out for the MSP before the concept can be validated. This can eventually lead us into finding out the timeframe in which the MSPs need information. Further investigation should be done to

validate the timeframe of the information identified from this study to get a more statistical result.

Further studies on information requirements for the MSP should include a more realistic simulation of the air traffic control displays and controls, and involve more participants.

CONCLUSION

This study was a preliminary assessment of the information that a MSP might need based on the responsibilities given by the FAA. The MSP is a new concept that is currently being explored. One major goal of this study is to identify the information to aid the role of the MSP. The results tell us that the MSP will need information on the aircraft only up to 150 miles beyond the controlled sectors. Data from the current study suggest that information should be given to the MSP primarily based on distance, and there should also be an option to allow them to view the information based on time.

Knowing when the identified information will be needed is important to this study. The identified information is classified into categories depending on the MSPs' needs while controlling air traffic. Further investigations would be needed to identify information for all possible scenarios for the MSP, and for validation of the information identified in this study. The results of this study are split into computational and noncomputational information. The identified noncomputational information will enable designers of the decision support system to include them during the development stage.

Overall, the usage of the card-sorting test helps to determine the information for the MSP and discover how the participants group information together. The noncomputational information needs further validation for the decision support tool in the future. Having this identified information provided to the MSPs allows them to run their roles and responsibilities smoothly. We are confident that the results of this study can bring the envisioned concept of the MSP one step closer to feasibility.

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Appendix A. Four Concepts of the Multi Sector Planner.

The following tables give an overall comparison of the responsibilities and tasks between the two concepts that are used for this study; Federal Aviation Authority and Booz Allen Hamilton.

✓	Compliant
✗	NOT Compliant
·	Partially Compliant
?	Not clearly stated

		MSP (FAA)	MSP (BAH)	MSP (DFS)	MSP (Eurocontrol)
Responsibilities	<ul style="list-style-type: none"> ▪ Traffic complexity reduction. (mitigating anticipated problems downstream sectors, moving aircraft to balance traffic flows/loads, changing the altitude of aircraft projected to cross an established flow) Forecast of traffic patterns is required.	✓	✓	To some extent	✓
	<ul style="list-style-type: none"> ▪ Traffic load balancing (monitors current and future traffic loads and manages traffic to maintain a steady and balanced flow across sectors, warning of demand peaks)	✓	✓	✗ To some extent	✓
	<ul style="list-style-type: none"> ▪ Separation assurance (strategic) (involving the resolution of traffic, airspace, and weather conflicts that are predicted to occur in a sector other than the one the aircraft currently occupies)	✓	✓	✓	✗ Not interested in individual a/c
	<ul style="list-style-type: none"> ▪ Response to strategic routing requests (reviewing requests from pilot and ETM trying to accommodate them based on current and expected traffic flows)	✓	✓	✗ No contact with pilot.	✓ Not direct contact with pilot
	<ul style="list-style-type: none"> ▪ Mitigation (strategic) of airspace anomalies (supporting the strategic mitigation of airspace anomalies: flight data management such as amending a flight plan, expediting a declared emergency, or strategic routing of “pop-ups” to ensure that traffic flows are not disrupted)	✓	✓	✗ No contact with pilot	✓

		MSP (FAA)	MSP (BAH)	MSP (DFS)	MSP (Eurocontrol)
	<ul style="list-style-type: none"> Conformance (strategic) to TFM initiatives (implementing TFM restrictions and does so by communicating and coordinating the strategy among TCs, e.g., off-loading aircraft in order to maintain the arrival spacing restriction, re-routing) 	✓	✓	To some extent	✓
	<ul style="list-style-type: none"> Execution, and feedback of local traffic management plan (providing sector-level knowledge and information and feedback about effectiveness of the implemented plan, suggesting where and when changes may be needed) 	✓	✓	✓	✓
	<ul style="list-style-type: none"> Airspace management support. (supports the AC by providing information about traffic load and TC workload, recommendations when staffing changes should be made and which sectors should be reconfigured) 	✓	✓	To some extent	✓
	<ul style="list-style-type: none"> Modification of local plan. ATFM initiative. (Generating new constraints that modified the initial local plan, e.g., turn on flow restrictions, to manage capacity, re-routing, level capping or negotiating an increase in sector capacity) 	Through his participation in coordinating local plan	Through his participation in coordinating local plan	✗	✓ Restricted to MSA

Appendix B. Scenarios Used in Pilot Study.

Scenario 1	Normal Traffic Scenario
<ul style="list-style-type: none"> • Traffic baseline scenario • Roles to be played: <ul style="list-style-type: none"> ○ R-side controller for Sector 18 ○ R-side controller for Sector 19 ○ MSP for three sectors (18, 19, 20) <p>It is 5 pm now, and traffic at different sectors is increasing steadily. There are 10 aircraft in sector 18, 19 aircraft in sector 19 and 22 aircraft in sector 20. There are a number of aircraft entering all 3 sectors. The MSP is in charge to assist the 3 R-side controllers of the sectors that he is in charge of.</p> <p>At this time, we would like for you to role play the different positions and observe the display that shows the aircraft in the sectors, as you act out the role.</p>	
Scenario 2	Convergence Scenario
<ul style="list-style-type: none"> • Traffic baseline scenario + aircraft conflict • Roles to be played: <ul style="list-style-type: none"> ○ R-side controller for Sector 18 ○ R-side controller for Sector 20 ○ MSP for three sectors (18, 19, 20) <p>It is 5 pm now, and traffic at different sectors is increasing steadily. There are 10 aircraft in sector 18, 19 aircraft in sector 19 and 22 aircraft in sector 20. There are a number of aircraft entering all 3 sectors. The MSP is in charge to assist the 3 R-side controllers of the sectors that he is in charge of. At a certain time, two aircraft are converging and they will loss the standard separation (5 NM, 1000 ft) if no action is taken.</p> <p>At this time, we would like for you to role play the different positions and observe the display that shows the aircraft in the sectors, as you act out the role. It is not required you to interact with aircraft, but to figure out when and how you would act.</p>	
Scenario 3	Saturated Scenario – Normal convergence
<ul style="list-style-type: none"> • Peak traffic scenario • Roles to be played: <ul style="list-style-type: none"> ○ R-side controller for Sector 19 ○ MSP for three sectors (18, 19, 20) ○ TFM <p>It is 6 pm now, and traffic at different sectors is increasing steadily. There are 10 aircraft in sector 18, 19 aircraft in sector 19 and 22 aircraft in sector 20. There are a number of aircraft entering all 3 sectors. The MSP is in charge to assist the R-side controller of the sectors that he/she is in charge of. The traffic flow manager will intervene in this scenario when the saturation of the sector gets out of hand. (E.g., TFM or MSP helps the tactical controller by</p>	

identifying the work overload and takes corrective measures, when he/she is unable to handle x number of aircraft.)

At this time, we would like for you to role play the different positions and observe the display that shows the aircraft in the sectors, as you act out the role. It is not required you to interact with aircraft, but to figure out when and how you would act.

Scenario 4	Communication failure
-------------------	------------------------------

- Traffic baseline scenario
- Roles to be played:
 - R-side controller for Sector 19
 - MSP for three sectors (18, 19, 20)
 - AS

It is 6 pm now, and traffic at different sectors is increasing steadily. There are 10 aircraft in sector 18, 19 aircraft in sector 19 and 22 aircraft in sector 20. There are a number of aircraft entering all 3 sectors. The MSP is in charge to assist the R-side controller of the sectors that he/she is in charge of. The Area supervisor is playing a role in this scenario. At a certain time, one of the aircraft losses the communication with the R-side controller.

At this time, we would like for you to role play the different positions and observe the display that shows the aircraft in the sectors, as you act out the role. It is not required you to interact with aircraft, but to figure out when and how you would act.

Scenario 5	Saturated sector due to National Flow intervention (e.g., weather conditions)
-------------------	--

- Peak traffic scenario
- Roles to be played:
 - R-side controller for Sector 19
 - MSP for three sectors (18, 19, 20)
 - TFM

It is 7 pm now, and traffic at different sectors is increasing steadily. There is a thunderstorm happening at this time in sector 18, this is indicated on the display with a circle. The role is to deviate traffic from the planned path to avoid the thunderstorm. There are 10 aircraft in sector 18, 19 aircraft in sector 19 and 22 aircraft in sector 20. There are a number of aircraft entering all 3 sectors. The MSP is in charge to assist the R-side controller of the sectors that he/she is in charge of. The traffic flow manager will intervene in this scenario when the saturation of the sector gets out of hand. (E.g., TFM or MSP helps the tactical controller by identifying the work overload and takes corrective measures, when he/she is unable to handle x number of aircraft.)

At this time, we would like for you to role play the different positions and observe the display that shows the aircraft in the sectors, as you act out the role. It is not required you to interact with aircraft, but to figure out when and how you would act.

Appendix C. Current Systems Identified from Pilot Study.

Users' Action	Information needed from System	Systems Identified
Monitor	Wind & Weather	WAM, HOST
Monitor	NAS Infrastructure Information	ERIDS, ESIS
Monitor	Sector-relevant Aerospace Information	ERIDS, DSR Display
Receive and Review	Flight in Progress Approaching flight	FIPS, URET, ETMS
Monitor	Flight specific Information	HOST, FIPS
Monitor	Flight Plan	HOST, URET
Monitor	Aircraft Status	HOST, DSR Display
Detect	Aircraft Conflicts	FIPS, DSR Display
Detect	Weather Conflicts	DSR Display, PIREPS
Evaluate	Alternative Trajectories	URET, DSR Display
Assess	Conflict Resolution Options	URET, DSR Display
Identify	Task requirement to implement Traffic Management initiatives	ETMS
Maintain awareness	Airspace Structure	HOST
Resolve	Conflict: Inter-sector Coordination	VSCS

Processes and data flow for the support of the Multi Sector Planner (MSP).

Appendix D. Information and Description of Cards.

What Type of Information		
Position	Information for Card-Sort	Description
Aircraft Information		
1	Aircraft hand-off status	Affected Aircraft hand-off status
2	Aircraft equip requirements	What the aircraft has for the route
3	Aircraft type, Flight ID, SSR code, Current altitude & ground Speed	Type of Aircraft , Secondary surveillance radar code, Altitude of specific aircraft, Speed of specific aircraft
Flight Profile		
4	System proposes route at Controller's request	Data that indicate a deviation from flight path
5	Current position	Position of specific aircraft
6	Current Flight plan	Route of specific aircraft
7	Current descent/ascent indication (as opposite to level-off)	
8	Current vertical speed	Sent by datalink
9	Destination (Airport)	Destination of specific aircraft
10	Evidence in support of deviation	Justification for a deviation from flight path
11	Flight deviation information	Data that indicate a deviation from the expected flight path
12	Future position (Next Waypoint)	Position that a controller expects an aircraft to occupy in the future
13	Alternative path for conflict resolution	Intent of aircraft involved in conflict (horizontal, vertical speed, FL)
14	Cleared flight level	Changes to the current route issued by controller
15	Clearance Speed	
16	Predicted distance between future position of aircraft and hazard	Distance between predicted position of aircraft and hazard
17	Requested route	Change to the current route requested by flight crew (datalink)
18	Sector entry altitude at boundary NFL/XFL	Altitude of aircraft entering the sector
19	Sector entry time	Time that an aircraft will enter the sector
20	Time remaining before entry	Amount of time remaining before an aircraft is expected to enter the sector
21	Distance remaining to a point/between two aircraft	
22	Identification of aircraft in conflict	
23	Next sector the A/C is going to fly into	
24	Identification of points of loss of separation	
25	Identification of closest distance between two aircraft in conflict	
26	Time to closest distance between two aircraft in conflict	Or maybe the time to loss of separation?

Card Position		Traffic Information
27	Affected flow	Traffic flow affected by restrictions
28	Current traffic load (No. of A/C per sector)	The traffic load currently in the sector
29	Difference between predicted load and manageable load	Difference between the traffic load predicted for a sector and the load that can be handled by the controller
30	Number of flights predicted to enter A/C sector	Number of flights predicted to enter sector
31	Predicted impact on traffic flow (Predicted > Manage)	Degree to which an aircraft action influences a traffic flow
Sector Constraints		
32	Current restrictions	Restrictions issued by traffic flow management specialists to control traffic flow and aircraft arrival rates.
33	Current weather	Location and presence of weather in sector, including precipitation, convection, turbulence, icing
34	Pilot reports of weather	Weather-related PIREPS in sector
35	SUA status	Current status (active, inactive, altitude range, duration)
Sector Management Information		
36	Available altitudes	Altitudes that can be issued to a specific aircraft
37	Available routes	Routes that can be issued to a specific aircraft
38	Available speeds	Speeds that can be issued to a specific aircraft
39	Current airport configuration runway	Current configuration of airport that affects sector traffic flow
40	Letter or Agreements	Required rules and procedures for moving aircraft beyond the sector boundary
41	Normal sector operations	Common rules and procedures for moving aircraft in a sector
42	Predicted change to operations	Anticipated changes to rules and procedures for moving aircraft in a sector
43	Winds aloft	Direction and speed of winds in sector
NAS Status		
44	Aeronautic Info	Information contained in aeronautical charts (e.g., approach plans)
45	Current TFM initiatives	TFM restrictions that are currently in effect
46	GPS status	Information on GPS status that includes anomalies and scheduled testing
47	Outages and closures	Equipment outages and closures relevant to sector operations
Communications		
48	Feedback from other sector	Information from other controllers that indicates current constraints, restrictions, or problems with traffic
49	Radio frequency of other sector	Radio frequency of other sector
50	Receiving controller limitations/concerns	Information from other controllers that indicates current constraints, restrictions, or problems with traffic

<u>When are the Information needed</u>
100 miles before the sector lines
150 miles before the sector lines
200 miles before the sector lines
5 mins
10 mins
15 mins
20 mins
25 mins
30 mins
60 mins
90 mins
120 mins

Appendix E. General Instructions for Simulation.

Purpose of Study

- To explore airspace performance, benefits and Safety along with human operator performance under an operational concept associated with “multi-sector” planner operations.
- To identify the information requirements associated with each operational concept and associated role(s) for the air traffic service provider.
- To make recommendations for an “optimal” operational configuration and design guidance based on cognitive engineering analyses of the human-system integration among operational concepts.

Operational Concept in this Walkthrough

- Strategic conflict search (time > 10 – 15 minutes) across multiple radar sectors
- “Planning Out” at aircraft transfer into sectors of responsibilities with MTDC and trial planning
- Management of electronic flight data strips
- Inter sector coordination with auto aiding
- Directed Assistance to one of the radar controllers

Assumed Automation & Communication Support

- Basic Controller Station DSR (or equivalent)
- Communications

- Data link communications available for transmitting clearances to the flight decks of air traffic (CPDLC)
- Data link communications among controller stations
- Voice Switching among controller and with Traffic Management Unit (VSCS or equivalent)
- Decision and Traffic Management Support
 - MTCD alert or equivalent
 - Route Evaluation Tool (URET or equivalent)
 - Electronic Flight Data Strips
 - Automated Handoff Function
 - Intelligent Information routing agents

3 Radar controllers serviced by a Single MSP serving the role of a Data-Side

Radar Controllers:

- Receive Handoff (accept, delay, or deny) (we are assuming an auto initiate and manual accept on the handoff by R-sides within sectors of the MSP control area).
Accomplished through digital (point and click) or voice communication to adjacent sector.
- Develop and revise sector control plan including plan contingency
- Overall Monitoring of Sector
- Conflict detection
- Conflict resolution (evaluate potential conflicts and implement means to avoid them) via voice or Data link
- Re-route aircraft (by aircraft request and within sector) other rerouting processes such as in trail or route change initiated by traffic management will be communicated to the MSP who will then communicate these to the appropriate R-side in that area of responsibilities.
- Issue advisory or safety related information. Via voice or Data link

MSP

- Receive Handoff (accept, delay or deny) hand off at entry to the MSP area of responsibility and initiate auto handoff to R controller within area of responsibility. Via voice or data link
- Receive or initiate point outs either with adjacent MSP or for each of the R-side controller in the MSP area of responsibility via voice
- Overall Monitoring of Sectors
- Indicate to R-sides potential conflicts and suggest resolution (assume a conflict detection and route evaluation support tool)
- Coordinate with Center Traffic Management Unit and accept modify traffic initiatives via voice

Appendix F. Hardware/Software Usage Instructions.

CPDLC Differences – AOL vs. CPDLC-1 Version

Miami Center..

... Airspace AOL

1: "DL Category Menu" on R-CRD [from CBI Lesson 1]

The screen snap was taken from a CBI (computer-based instruction) course developed for the CPDLC-1 service currently used at Miami Center. Miami Center's CPDLC (controller-pilot data link) implementation served as the model for our Airspace Operation Laboratory (AOL) CPDLC. However, many functions available in the full Miami Center CPDLC version are not supported by us. We have also added DAG-related datalink functions that are not part of the Miami Center system, including: support for

pilot request downlinks, RTA uplinks, and trial plan/ clearance/ advisory uplinks. These differences are indicated by ~~or RTA~~ or **highlighted text**.

CPDLC Terminology

CPDLC	Controller to pilot data link communication
Downlink	A message sent down from the pilot to the controller
Eligibility	Sector can communicate with aircraft via CPDLC. Only one sector at a time has eligibility.
Open/Closed Status	An “open” transaction is waiting for a reply from the flight crew to the controller or from the controller to the flight crew. SNT, TIM and SBY are open states. A “closed” transaction is completed; no further actions are expected or possible (NEG, UNA, AFF, WIL, ROG). Closed positive transactions (AFF, WIL, ROG) are removed from the status list after 6 seconds. Close nonpositive transactions must be deleted by the controller.
Positive/non-positive	“nonpositive” transactions (SBY, TIM, NEG, UNA) are grouped in a separate category on the status list.
Status list	A list of ongoing transaction. Includes (1) a “.” For selecting the transaction, (2) aircraft ID, (3) transaction specific information, (4) transaction’s current status. Can be turned on/off from the DC View.
Uplink	A message sent up from the controller to the pilot.

Transfer of Communications Procedure

Automation-assisted process of transferred both radio communications & data link eligibility from transferring to receiving sector after the handoff

- 1) Sector handoff is initiated by automation when aircraft approaches sector boundary. A handoff cannot be initiated while open or nonpositive transactions for the aircraft remain in the status list.
- 2) Handoff is accepted. When TOC mode is AUTO, a frequency uplink message is automatically sent to the aircraft.
- 3) The flight data block on both sectors has a lightning bolt -- "~" -- next to the call sign indicating a TOC in progress.
- 4) The pilot receives the message, tunes the new frequency, and responds via CPDLC to the uplink message ("WILCO").
- 5) CPDLC eligibility transfers to the next sector as soon as the "WILCO" is received.
- 6) The data link symbol in the data block reflects the transfer of eligibility: "◊" (hollow diamond) for transferring controller, "◼" (filled diamond) for receiving controller.
- 7) The flight crew will check in by voice if the message was "CONTACT...". They will NOT check in by voice if the uplink message told them to "MONITOR...".

Example: Trial plan on display

Trial Plan Actions

Open a trial plan route:	Click on "portal" (→) in flight data block
Add a trial plan waypoint:	(1) dwell and PICK [■□□] anywhere along the cyan route
	(2) move the trackball to relocate the waypoint
	(3) click ENTER [□■□] to input the new waypoint's location
Move existing waypoint on trial plan route:	Dwell and PICK [■□□] existing waypoint on the cyan route
Remove waypoint(s) from trial plan route:	Dwell and ENTER [□■□] an existing waypoint on the cyan route
Save trial plan as flight plan amendment:	QC [cid]
Uplink trial plan route as clearance:	UC [cid]
Cancel (single) trial plan:	Click on "portal" (→) in flight data block
Cancel all trial plans:	Type "TT ENTER"

CPDLC Actions

Uplink Frequency	UF [frequency] [cid]	Send specified frequency.
	UF [sector ID#] [cid]	Send default frequency for specified sector.
Transfer eligibility	SX [cid]	Transfers eligibility to sector with track control.
	SX /OK [cid]	Transfers eligibility to sector without track control.
Delete status list message:	DE [cid]	Delete <u>all</u> closed messages for specified aircraft.
	DE (slew & Enter on “.”)	Delete selected (closed) message.
	DE /OK	Over-ride for deleting open messages (must specify message or aircraft)
Uplink route clearance	UC [cid]	Uplink active <u>or</u> trial plan route to specified aircraft

Altitude Entry

Open altitude selection menu	PICK or ENTER on altitude field in FDB	Open menu for assigned, trial plan or interim altitudes
Altitude assignment	Enter [□■□] on selected altitude in menu	Enter new assigned altitude in FDB
Interim altitude assignment	Enter [□■□] on “T” adjacent to altitude	Enter new interim altitude in FDB
Remove interim altitude	Type “QQ[CID] ENTER”	Restore assigned altitude in FDB

Altitude Trial Planning

Open altitude selection menu	PICK or ENTER on altitude field in FDB	Open menu for assigned, trial plan or interim altitudes
Trial plan* altitude assignment	Picked [■□□] on selected altitude in menu	Put trial plan altitude in FDB. Conflict feedback provided.
Uplink trial plan altitude	UC [cid]	Uplinks trial plan route to specified aircraft

Appendix G. Screenshot Used for Card-sorting Trials B and C.

Trial B: Weather

Trial C: Conflict

Appendix H. Information Questionnaire.

Information Questionnaire

Instructions

The following questions ask you to consider the information that might be needed to assist the concept of the MSP, Multi-D. **Please circle** a number based upon the Importance Scale below for the Multi-D.

Not Important	1 2 3 4 5	Extremely Important
---------------	-------------------	---------------------

Aircraft Information	Multi-D Controller
Aircraft hand-off status	1 2 3 4 5
Aircraft equip requirements	1 2 3 4 5
Aircraft type	1 2 3 4 5
Flight ID	1 2 3 4 5
SSR code	1 2 3 4 5
Flight Profile	Multi-D Controller
System proposes route at Controller's request	1 2 3 4 5
Current altitude	1 2 3 4 5
Current position	1 2 3 4 5
Current Flight plan	1 2 3 4 5
Current Ground Speed	1 2 3 4 5
Current descent/ascent indication (as opposite to level-off)	1 2 3 4 5
Current vertical speed	1 2 3 4 5
Destination (Airport)	1 2 3 4 5
Evidence in support of deviation	1 2 3 4 5
Flight deviation information	1 2 3 4 5
Future position (Next Waypoint)	1 2 3 4 5
Alternative path for conflict resolution	1 2 3 4 5
Cleared flight level	1 2 3 4 5
Clearance Speed	1 2 3 4 5
Predicted distance between future position of aircraft and hazard	1 2 3 4 5

Requested route	1	2	3	4	5
Sector entry altitude at boundary NFL/XFL	1	2	3	4	5
Sector entry time	1	2	3	4	5
Time remaining before entry	1	2	3	4	5
Distance remaining to a point/between two aircraft	1	2	3	4	5
Identification of aircraft in conflict	1	2	3	4	5
Next sector the A/C is going to fly into	1	2	3	4	5
Identification of points of loss of separation	1	2	3	4	5
Identification of closest distance between two aircraft in conflict	1	2	3	4	5
Time to closest distance between two aircraft in conflict	1	2	3	4	5

Traffic Information	Multi-D Controller				
Affected flow	1	2	3	4	5
Current traffic load (No. of A/C per sector)	1	2	3	4	5
Difference between predicted load and manageable load	1	2	3	4	5
Number of flights predicted to enter A/C sector	1	2	3	4	5
Predicted impact on traffic flow (Predicted > Manage)	1	2	3	4	5
Sector Constraints	Multi-D Controller				
Current restrictions	1	2	3	4	5
Current weather	1	2	3	4	5
Pilot reports of weather	1	2	3	4	5
SUA status	1	2	3	4	5
Sector Management Information	Multi-D Controller				
Available altitudes	1	2	3	4	5
Available routes	1	2	3	4	5
Available speeds	1	2	3	4	5
Current airport configuration runway	1	2	3	4	5
Letter or Agreements	1	2	3	4	5
Normal sector operations	1	2	3	4	5
Predicted change to operations	1	2	3	4	5
Winds aloft	1	2	3	4	5
Aeronautic Info	1	2	3	4	5
Current TFM initiatives	1	2	3	4	5
GPS status	1	2	3	4	5
Outages and closures	1	2	3	4	5
Feedback from other sector	1	2	3	4	5
Radio frequency of other sector	1	2	3	4	5
Receiving controller limitations/concerns	1	2	3	4	5

Appendix I. Informed Consent Form.

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INFORMED CONSENT

INDIVIDUAL'S CONSENT TO PARTICIPATE IN RESEARCH IDENTIFYING INFORMATION FOR THE MULTI SECTOR PLANNER.

Federal Aviation Authority (FAA) sponsors the research in identify information for the Multi Sector Planner. The Federal Aviation Authority (FAA) under the direction of the principal investigator Dr. Kevin M. Corker will conduct the research. The research shall consist of laboratory tests in simulated air traffic management operation.

I _____, understand

"Identifying information for the Multi Sector Planner" is sponsored by the FAA and is being directed by FAA and Kevin M. Corker.

I have been assigned as a participant in the project named above. The purpose of this effort is to determine the information for the Multi Sector Planner. The research process will take approximately 45 minutes per session for 4 sessions in a day and all material, notes and opinions shall be confidential.

Through this effort, FAA expects to gain insight about the information that would be needed for the new position of the Multi Sector Planner.

I understand that my participation in this study is voluntary. I am participating because I want to. Dr. Kevin Corker has adequately answered all questions I have about this study, my participation, and the procedures

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involved. I understand that Dr. Corker will be available to answer any questions concerning procedures throughout this study. I understand that if new findings develop during the course of this research that may relate to my decision to continue participation I will be informed.

I understand that records of this study will be kept confidential, and that I will not be identifiable by name or description in any reports or publications about this study. All records and interviews shall be classified and confidential.

I understand that I may withdraw from this study at any time without penalty.

If I have questions about this study or need further information, I will contact Kevin M. Corker, the Principal Investigator, at (408) 924 3988 or via email at: kevin.corker@sjsu.edu

Questions about research, subjects' rights, or research-related injury may be presented to Pamela C. Stacks, Ph.D., Associate Vice President for Graduate Studies and Research at (408) 924-2477 or via email at: pstacks@sjsu.edu

I have read this consent document and freely consent to participate in this study under the conditions described. I have received a copy of this consent form.

Signature

Date

Investigator's signature

Date

Appendix J. Card-sorting Instructions

Introduction to Card-sorting Study

First of all, we'd like to thank you for coming. As you may be aware, we're in the initial stages of developing the decision support tool for the Multi Sector Planner. In order to make it as easy to use as possible, we'd like to get some input from the people who will be using it. And that's where you come in. We're going to ask you to perform a very simple trial that will give us some great insight into how we can make this decision support tool easier to use.

Here's how it works. In front of you is a stack of cards. Those cards represent the information for this decision support tool we are developing. You should try and sort the cards into groups according to the trial that occur in the scenario that make sense to you.

Once your groups are established, we'd like to have you give an appropriate time when you would need the information from the second stack of cards. You are allowed to make sub-groups if you feel that's appropriate. If you feel something is missing, you can use a blank index card to add it. Additionally, if a label is unclear, feel free to write a better label on the card.

Finally, if you think something doesn't belong, you can make an "outlier" pile. Oh, and one last thing. Feel free to ask questions during the trial if you feel the need. I can't guarantee that I can answer them during the trial, but I'll do my best to answer them when you're finished.

Appendix K. Acronyms

AS	Area Supervisor	LAF	Low Airspace
ACs	Area Controllers	MSP	Multi Sector Planner
ATCs	Air Traffic Controllers	Multi-D	Multi- Data Controller
ATM	Air Traffic Management	NAS	National Airspace System
BAH	Booz Allen Hamilton	NASA	National Aeronautics and Space Administration
CPDLC	Controller-Pilot Datalink Communication	R-side	Radar Controller
CTA	Cognitive Task Analysis	TCs	Tactical Controllers
DFS	Deutsche Flugsicherung	TFM	Traffic Flow Manager
D-side	Data Controller	TMU	Traffic Management Unit
FAA	Federal Aviation Administration	TRACON	Terminal Radar Approach Control
HAF	High Airspace	SME	Subject Matter Experts